Information Systems Architecture and Technology

System Analysis Approach to the Design, Control and Decision Support

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Wrocław University of Technology

Information Systems Architecture and Technology

System Analysis Approach to the Design, Control and Decision Support

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CONTENTS

PART 3. DATA MAINING, IMAGE PROCESSING AND PATTERN RECOGNITION

PART 4. COMPLEX OF OPERATION SYSTEMS CONTROL

INTRODUCTION

Systems approach to the computer aided design, control and decision requires model of the investigated process. All project, decisions and control algorithms are based on the knowledge about the plant under investigation. That's why models are so important in systems research. Investigation of object of the deferent nature (technical, economical, biomedical or computational) gives us many notifications about observed processes. Based on the collected knowledge, about investigated process the model of observed reality is proposed. The mathematical model gives precise description. Usually the relation between values characterizing process is given. The static properties are given by functional relations, equations and inequalities. The dynamics of investigated plants are given by differential equations and inequalities – for continuous or difference one for – discrete processes. The set of true sentences gives also mathematical description of the investigated process.

System analysis gives us the proper tools to create further decision about investigated plant based on the collected knowledge, and consequently based on the elaborated model. Base on the model the optimization, control and management task may be formulated. Base on the knowledge about the process the diagnosis may be proposed.

The above mentioned applications of different type tasks we can recognize in selected and revived chapters which have been divided into the following groups:

Part 1. *Knowledge Engineering, Mathematical Modeling and its Application in Project and Management Support*

Part 2. *Mathematical Model and its Application in Decision Support Systems*

Part 3. *Data Mining, Image Processing and Pattern Recognition*

Part 4. *Complex of Operation Systems Control*

The book provides an interesting representation of research in the area of system analysis in decision aided problems in proposed groups.

PART 1. KNOWLEDGE ENGINEERING, MATHEMATICAL MODELING AND ITS APLICATION IN PROJECT AND MANAGEMENT SUPPORT

Decision problems arise at different levels of healthcare systems, involving using scarce resources for the benefit of patients during diagnostic and treatment processes

throughout their stay in the system. The Chapter 1 focuses on modelling pathways of thoracic surgery and pulmonary oncology, primarily lung cancer patients in all phases of their hospital treatment as seen from patient-centred and system-wide perspectives. Assumptions for and initial results of applying a discrete event simulation model for analysing pathways are outlined. A case study for thoracic surgery/lung cancer patients treated in the period 2006–2011 in all hospitals in the Lower Silesia (Poland) is discussed.

Today's extremely competitive industrial environment is characterized by increasing load of information, novel technologies, and shorter product life cycles which emphasizes the importance of an integrated knowledge management system in industrial plants. The Chapter 2 describes an artificial system, an architecture that would support discovering, adding, storing, improving and sharing knowledge through experience, in a way similar to that which happens in nature. It is discussed an approach in which knowledge is represented by novel Set of Experience Knowledge Structure (SOEKS), and is brought into the future by SOEKS collection called Decisional DNA. The intention is to apply this unique concept in manufacturing plants to enhance industrial design .This chapter presents a conceptual background to the proposed approach to design an integrated manufacturing knowledge based structure by selection of processes, equipment, tooling, and sequencing of operations and the type of a manufacturing system.

The goal of the Chapter 3 is to propose an approach to employ set of experience knowledge structure and decisional DNA in an integrated design and planning environment. The aggregate product model provides the necessary abstraction of design data to facilitate the assessment of early designs. The main planning requirement was to apply the aggregate product model by developing process knowledge capturing and optimization techniques so that production cost and time can be calculated for complex fabrications requiring many setups and operations. It can result from employing a process knowledge base to create and evaluate process options from information in the product model and the factory layout. This knowledge must be linked to an up-to-date database and controlled by the process planning experts. The intention is to apply this unique concept in manufacturing plants to enhance industrial design.

In the Chapter 4 a dynamic version of the well-known goal programming approach is proposed. The classic goal programming approach allows to set various goals and control their achievement and relations between them. The dynamic approach allows to plan the achievement of goals over a longer period of time and choose the best paste. The goal programming approach to the environmental decisions planning in organizations is proposed. Two big organizations with a serious environmental politics are considered and it is propose how to find the best plan of putting the environmental politics into practice.

The webpages of local government are visited first of all in quest of information. Various types of visitors are looking for different information about: the government

office, the region, the investment or the land development plans. The visitors want also to have online possibility of dealing the official matters what is in conformity with European Commission resolution that presented a list of 20 basic public services that covers different interactions of the public sector with citizens and businesses. During last time several research on local government websites have been conducted. Most of them concerned the look and the content of communes' websites. Different criteria of evaluation were applied – they often based on Website Attribute Evaluation System. The Chapter 5 presents the results of research on 26 districts' websites of Lower Silesia. A methodology of the research was described. One stated four main areas, where 18 criteria were distinguished. Most of the criteria were rated in four point scale. The points obtained on each area were summed, the ranking of websites were compiled and the results were discussed.

Constraint Programming is an emergent software technology for declarative description and effective solving of large combinatorial problems. In that context, Constraint Programming can be considered as an appropriate framework for development of decision making software supporting scheduling of projects that are at risk of failure. The Chapter 6 deals with project prototyping problem for alternative completion of a failed project. The presented reference model contains the fields of a project management and an enterprise which implements projects. This chapter aims to describe the functionalities of both these fields in terms of constraint satisfaction problems and then to implement them in Constraint Programming languages. An example concerning information technology project implementation is used to illustrate the possibility of this approach.

PART 2. MATHEMATICAL MODEL AND ITS APPLICATIONS IN DECISION SUPPORT SYSTEMS

Business process management as a holistic management is one of the most promising approaches to management in general, it introduces business modeling for value chains and mapping all inputs and outputs those exist in an organization. The business process management model contains tasks, events, activities and gateways connected together to describe the business and provide insights how things are done. Modern information technology tools can support this process in various areas. The Chapter 7 focus on decision nodes how they are described and supported by business process management information technology tools and how the decision support could be enhanced using additional mechanism that will base on formal experience record.

Running and continuing a business is not possible without suitable information, especially in financial area. Hence appears a question: How to manage the company on a basis of filtered economic data? On this question try to answer Business Intelligence approach. It is important to consider the financial structure indicators and their influence on firms' market value. The right value of indicators allows to improve

company valuation. Such an approach becomes nowadays very essential, especially in the time of world economic crisis. The goal of research presented in the Chapter 8 was to build models, which will be useful as a tool in existing or new Business Intelligence systems. A group of Polish joint stock companies were analyzed. In research there was used a sophisticated statistical, simulating and uncertainty analysis software Decision Tools Suite (from Palisade company). Thanks to this tool it was possible to use a multidimensional approach to identified relations, which were analyzed with use of statistical and forecasting methods.

The Chapter 9 deals with the fast growing part of market: services in the Internet, basing on the example of the Polish Internet Mortgage Market. This market consists of 4 main stages starting from the top: banks are institutions that sell mortgage and offer the option to apply for it on their own web pages. The chapter presents the complete process of building and verifying sub-models for the internet mortgage market. The sub-models are described for three market situations, i.e. stable market, crisis, and boom.

The Chapter 10 proposes an approach to multicriteria ranking of universities. One of the various methods of linguistic multicriteria evaluation was selected and a set of criteria proposed. The chosen method and criteria were applied to rank three universities: one state university and two private ones. The results of the experiment are given. Basic information about linguistic multicriteria evaluation and fuzzy numbers are also presented.

The universities are like any organization. The problem is that the specificity of the activities performed at the university makes them extremely difficult to measure, especially the cost of research and course preparation activities is difficult to determine. In the Chapter 11 a method of approximate research/teaching activity cost measurement, taking into account subjective expert opinions of the research and teaching staff, is applied to university activities. The method is based on the Activity-Based Costing idea combined with the Analytical Hierarchy Process concept to the cost accounting of higher education institutions.

The Chapter 12 presents certain concept of information system called COURSERV, which supports business courier expenses work. To the creation of this system there has been used Internet service. Fundamental establishments of systems construction, structure and functional description are presented. Implementation of COURSERV system and implementation of the database of this system was accomplished.

PART 3. DATA MAINING, IMAGE PROCESSING AND PATTERN RECOGNITION

Computer driven medical image recognition support physicians in the diagnosis process, but it requires high dependability considering potential consequences of incorrect results. The Chapter 13 presents a system that improves dependability of medi-

cal image recognition by integration of results from redundant components. The components implement alternative recognition algorithms of diseases in the field of gastrointestinal endoscopy. In the presented solution, the authors consider both algorithms that detect a single disease and algorithms that detect many diseases, in which case results from different algorithms are partially overlapping. The information is processed using the N-version programming pattern to vote the final result. The solution adapts the standard N-version programming pattern to the specifics of the application area covering issues such as: managing diseases recognized by components, components reliability and data streaming. We maintain a catalog of known integrated components together with their reliability rating.

The Chapter 14 presents a prototype of system for recognizing different types of human physical activity. In the proposed system the recognition process is based on measurement data acquired by wearable sensors placed on user body. To this end, Shimmer units to gather accelerometer data were integrated with proposed system. From acquired data nine different features were extracted. The usefulness and importance of these features are demonstrated. Designed system was evaluated for different feature sets and classifiers. Obtained results indicated that system with wireless measurement units allows to recognize various physical activities with high accuracy.

The comparative studies and analysis of flying objects identification effectiveness are conducted with described algorithms and some results of their effectiveness evaluation are presented in the Chapter 15 algorithms are based on Hilbert–Foucault, Hilbert–Radon, Hilbert–Fourier and generalized amplitude-phase transforms hybrid methods of previous images processing. The ratings of algorithms and perspectives of future investigations are evaluated.

The Chapter 16 propose filter bank, which connects polyphase concept with idea of warping bandwidth of subbands by all-pass filter chain. Presented structure exploit the properties of multirate technique of polyphase and warped shifted version of prototype filter in sine and cosine modulated filter banks, delivering nonlinearly distributed bandwidths according to the auditory model of human perception of audio signals. Chapter reviewing the theoretical basics of fundamental ideas and discussing psychoacoustic scale approximation by the proposed structure.

An important issue in an area of human-computer interaction is a presentation of data to the user, especially to an external non-expert user of the system. The presented results are based on a setting where numerical data gathered by a multiagent system is assigned with Zadehian fuzzy-linguistic summaries, which – in case of incomplete observational data – are extended using auto epistemic operators of possibility, belief, and knowledge. Summaries are further aggregated and presented to the external user of the system. The focus of the Chapter 17 is set on the process of an aggregation itself and on interpretational is-sues related to the aggregation of fuzzy-linguistic statements with auto epistemic operators.

PART 4. COMPLEX OF OPERATION SYSTEMS CONTROL

The Chapter 18 presents the method of graphical design and simulation of control units for parallel digital sequential controllers. Presented approach allows for verification of controller design, represented by hierarchical graph, during simulation of parallel algorithms, step by step based on Petri Nets theory. Moreover, detailed analysis allows preventing deadlocks occurred in parallel system. As the result of hierarchical simulation, control words are generated which can be used for real digital device. Next, the paper presents an examples of appliance for real digital parallel system. The main advantage of proposed method is to develop the control unit by intuitive, fast and efficient way.

Many plant control systems involving control operations are presently implemented on programmable logic controllers (PLC). A significant part of control problems are similar for almost every application. Therefore, those typical control algorithms can be well documented, and, like framework models, they can be used for building programs in such applications. Due to the typical nature of plant architecture, a part of control algorithms for the equipment or overall PLC program structure can be even ready-made or generated automatically using the intermediate development interface (meta-program), which generates a frame structure of PLC code, expressed in a different language, i.e., XML. The Chapter 19 describes an approach for automated control program synthesis for a typical process plan that is developed in the production planning phase and is enhanced with PLC-specific information according to the IEC 61131-3 standard. The chapter presents the way to build control algorithms and automated generation of the PLC program according to quality criteria requirements.

Wireless networks on account of constant development gain ever greater possibilities of application in the industry. Popular wireless computer networks can be used not only for data transfer between computers, but also for remote control of electro-pneumatic servo drive based on the application running on the mobile computer. The Chapter 20 presents laboratory which allows to examine in practice the possibility applications for wireless control of the electro-pneumatic servo drive. For that purpose the microcomputer board was used, which task is to connect the wireless card, input output port and application for the operator. As the port of input/output for the controller was selected module for data acquisition equipped with analog inputs and outputs, however for wireless communication with the computer operator a wireless card is used. Servo drive was built based on the proportional pressure valve, pneumatic valve positioner, pneumatic actuator of double-sided action, convertor of linear transfers and measure of linear transfers.

Mobile robots equipped with arrays of tools are capable of performing various tasks over a wide area. In the Chapter 21 a case where in order to perform a task an executor – a mobile robot – has to move to the execution point – a workstation is discussed. Decision has to be made on how all available mobile robots should per-

form all the observation tasks. Movement times between workstations are not known exactly at the moment of decision making. They can vary due to movement parameters such as the need for collision avoidance. Their description is provided through type-C uncertain variables which certainty distributions are assumed known. In the scope of this chapter, formulated and solved is an uncertain decision making problem.

The Chapter 22 concerns Directed Acyclic Graph task scheduling on parallel executors. The problem is solved using own implementations of Tabu Search and genetic algorithms. There is also introduced a new approach to coding solution. Results given by the created algorithms are compared to those generated by greedy LPT algorithm. The analysis of the obtained results of multistage simulation experiments justifies the conclusion that the implemented, proposed algorithms seem to be promising.

The Chapter 23 concerns problem of routing school bus, that is treated as modification of Travelling Salesman Problem. Authors presents solution based on new approach – division of the problem into two stages. For first phase new algorithms have been proposed, for second heuristic algorithm were used. Series of tests aimed at determination of the best parameters for algorithms were performed. Properties of algorithms have been studied for evaluation and selection of the best method for solving the given problem.

Wrocław, September 2012

Jerzy Świątek

PART 1

KNOWLEDGE ENGINEERING, MATHEMATICAL MODELING AND ITS APLICATION IN PROJECT AND MANAGEMENT SUPPORT

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SIMULATION MODELLING OF
A REGIONAL HEALTHCARE SYSTEM
– PROBLEMS, FRAMEWORK,
IMPLEMENTATION IN ARENA

Decision problems arise at different levels of healthcare systems, involving using scarce resources for the benefit of patients during diagnostic and treatment processes throughout their stay in the system. This paper focuses on modelling pathways of thoracic surgery (TS) and pulmonary oncology, primarily Lung Cancer (LC) patients in all phases of their hospital treatment as seen from patient-centred and system-wide perspectives. Assumptions for and initial results of applying a discrete event simulation model for analysing pathways are outlined. A case study for TS/LC patients treated in the period 2006–2011 in all hospitals in the Lower Silesia (Poland) is discussed.

1. INTRODUCTION

Decision problems arise at different levels of healthcare systems, some of them being common (scheduling) and other – being specific to some clinical technologies (robotic surgery) or healthcare domains (cardiology). The decisions involve using scarce resources of healthcare systems for the benefit of patients during diagnostic and treatment processes in all phases of their stay in the system, starting typically from primary healthcare, through specific ambulatory care, followed by hospital and other types of care. Aiming at reducing variability in outcomes and costs various approaches were introduced to standardize treatment and care protocols for specific conditions as seen from patient-centred point of view [5]. One particular framework are Clinical Pathways (CPs), also called Pathways of Care or Clinical Profiles [3], defined as

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"health-care structured multidisciplinary plans that describe spatial and temporal sequences of activities to be performed to patients with a given pathology, based on the scientific and technical knowledge and the organizational, professional and technological available resources" [1]. In many cases, despite more general assumptions of modelling approaches, due to complexity of the problem, working models are developed focusing only on a specific part of system-wide patient pathway, e.g. hospital or ambulatory phase, or – on simplified clinical processes (single diagnosis-treatment-recovery sequence or homogeneous patients class). The ultimate goal of CPs to coordinate the patient journey through the entire care process is often not only considered for a limited part of the care process (typically the hospital phase), but also seen from classic (best care for the individual patient) and not from population (greatest good for the greatest number) point of view.

In this paper we focus our attention on modelling pathways of thoracic surgery (TS) and pulmonary oncology, primarily Lung Cancer (LC) patients in all phases of their hospital treatment. The pathways are considered from patient-centred and system-wide perspectives. The novelty of our proposal regards the following main issues: we aim at:

– developing a modelling framework enabling looking at healthcare pathways for complex, multi-optional pathways, which are typical for LC surgical patients,

– looking from regional, in addition to hospital and patient, point of view, taking into account available resources and their fair allocation from population perspective, and using routinely available regional empirical data (with all its imperfectness).

2. REGIONAL LEVELS OF DECISION MAKING

Multi-perspective analysis and modelling of decision problems, arising at particular levels of regional decision making, is recognized as complex and challenging healthcare domain [4], particularly because the consequences of delivering more and more care with limited resources result in decisions regarding "which patient class will be offered what type of care (...), the influence of these decisions on other patient classes, regarding accessibility and (...) care that will be offered to certain patient classes only" [6]. Hence assisting regional decision makers in rationalizing hospital funding allocation/relocation decisions, affecting all levels of healthcare system (Table 1) is undoubtedly of particular importance.

The region of Lower Silesia has around 3 million inhabitants, living in 29 districts, and being hospitalized in 120+ hospitals (and healthcare centres providing day or stationary care) around the region (extra-regional movements of patients are not considered in this paper). Healthcare public funding comes mainly (90+%) via regional branch of National Health Fund (NHF), which negotiate contracts with hospitals, stating yearly particular limits of spending per specialty and type of care. In addition

to the main regional decision maker, regional allocation decisions are also made by local government bodies (at regional and district levels), responsible for healthcare provision and – to some extent – for elements of regional health policy.

Table 1. Decision problems at different levels of regional decision making

Perspective	Decision problems	Data (for TS/LC only)	
		sources	scale
Clinical patient-based	surgical risk forecasting; operations scheduling; surgical resource allocation	fragmented PAS data some clinical data	main TS centre only: per year 8.000 persons 18.000 As/Ds
Hospital	admission planning; non-surgical workload; reimbursement strategy	limited PAS data	
Regional: NHF (financial)	allocating funds for services (90+% of total): contracts, payment, extra funds	claims financial & limited medical data	all hospitals: /y 10.000 persons 35.000 As/Ds. 100.000+ 'FCE'
Regional: LG/NHS (political)	allocating funds for upgrading resources; suggesting creating/merging/closing units/wards (10–% of total)	none available at present	

First phase of the research involved discussions with the decision makers at all levels to understand the system and specify goals of the modelling work. It resulted in formulating the following aims of studying the impact of organizational changes on patient pathways in relation to costs and clinical quality measures, in particular survival (TS/LC patients). The changes may include:

– Different reimbursement systems for particular services with the same estimated amount of the total within a specialty,

– Elimination of quotas or look at changes in expenditures on a specialty,

– Changes in the number of beds, operating room hours, elimination/creation/ mergers of departments / hospitals,

– Change in the allocation method, e.g. the total hospital budget, according to accepted resources and specialties.

Because of the scale of the problem domain we focused our analysis on a cohort of all TS/LC patients, observed as hospitalized in the period 01.2006–04.2011 in the region concerned. The group of 31.583 individuals had been tracked during 180.288 hospitalizations in all hospitals within the region, and with 448.303 FCEs being reimbursed by the NHF. The administrative data of NHF were the only databases enabling to track a person (recognizable individual) and to link different levels of care. It should be noted however that the observed events around the patients constituted only a subset of all activities which could have been performed in relation to them before or after the period of analysis, so the resulted patient pathways are precise subject to the period of analysis (it is one of the reasons why it is planned to extend the analysis with ambulatory care database, to include events prior to first hospitalization).

3. MODELLING FRAMEWORK: DISCRETE EVENT SIMULATION

Selecting modelling approach which would enable analysing the aspects of regional decision making, discrete event simulation (DES) seemed to be the approach of choice. Although DES has traditionally been used at a more operational or tactical level to answer specific questions, it was often used in the healthcare domain to solve resource allocation problems or to compare and evaluate interventions [2]. It is naturally predestined for problems characterized by complexity and variability (including stochastic nature). DES is well adapted to model complex multi-level patient pathways in a healthcare system, as the objects in the system may be modelled as distinct individuals, possessing characteristics (e.g. multiple diagnoses, each associated with a specific treatment pathway), that determine what happens to that individual. It enables to look at the processes from different perspectives, e.g. clinical, hospital and regional decision maker points of view, for which different output indicators as well as different time-scales may be used (for instance hour-by-hour, day-by-day, month-by-month for clinical, hospital, and regional/NHF level, respectively).

The modelling phase was preceded by an extensive data mining phase, concerned with retrospective analysis of available administrative (NHF), clinical (regional TS Centre), and epidemiological (Regional Cancer Centre) data. Time-consuming data collection, cleansing and statistical analysis were performed for the cohort of 31.583 individuals, mainly LC patients. The aim of this phase was to identify and statistically describe categories of patients passing through the regional healthcare system and how they move (treatment paths, evolution of diagnoses). A distinctive feature of our approach was the complex structure of a single patient pathway. Unlike in many publications, it was not possible to model the pathway as a single 'Arrival – Admission – Hospital Treatment – Discharge – Follow up – Exit' sequence. For most (2/3) patients tracked retrospectively during the analysis period, there were at least 2 (at most over 190) hospital stays in many hospitals, some of them constituting sub-sequences of stays (e.g. TS operation + several chemotherapy and/or radiotherapy shorter or longer stays). Some of these sub-sequences were related with an advancement of the main illness, which resulted in a change in patient status, for instance from 'primary cancer without metastases' to 'secondary cancer' or 'primary cancer with metastases'.

Due to great complexity of the problem it was decided that before the emulation of the whole process of individuals arrival in and transition through the system, which could enable tracking parallel processes (financing, health status of the subpopulation at clinic/hospital/region level) in different time scales, this second part of research work is limited to modelling 'first arrivals into the healthcare system' (i.e. first obser-

vation of a John Smith) and general structures of treatment processes once in the system.

4. APPLICATION TO TS/LC CASE STUDY: DATA MINING COMPONENT

Initial analysis of detailed data available for region-wide events for the period of analysis (2006-2011; TS/LC patients only) concerned:

– for 31.583 individuals: personal id; date of the first hospital admission during period of analysis; gender; dates of birth and (if available) date of death; district of residence; main ICD10 disease code, code for the first hospital ,

– for 180.288 hospitalizations of individuals: dates for hospital admission/ discharge; ICD10 codes (up to 10) of main diagnoses and specialty codes of wards visited during particular parts of hospital stay,

– for 448.303 reimbursed contract products (DRGs, operations, etc.): ICD9-CM procedure codes, ICD10 main disease codes, reimbursed amount.

Two stages of the dynamic process for patient pathways were defined, namely:

(i) 'first arrivals' – first observation of an individual in the system,

(ii) 'first pathway' – first admission to a hospital, assignment of a medical category, selecting and initiating first part of a treatment pathway, to be performed in this and in most cases other hospitals (admissions, discharges, processes).

Table 2. Average daily numbers of new observations (individuals)
by month and year

	1	2	3	4	5	6	7	8	9	10	11	12
2006	56,3	36,6	31,1	26,5	24,6	23,9	20,6	18,6	17,3	19,1	19,4	13,8
2007	18,6	18,6	18,3	15,5	16,8	16,8	14,3	14,7	16,0	14,8	16,6	14,0
2008	14,9	15,9	16,0	14,3	14,5	15,1	13,7	14,0	14,8	13,3	12,7	13,0
2009	14,7	14,5	14,3	14,0	13,5	14,5	13,2	12,8	13,9	11,1	12,3	10,4
2010	11,9	14,0	13,8	12,3	11,9	12,0	11,0	12,0	14,0	10,5	11,8	10,6
2011	10,8	13,7	13,7	11,7	10,3							

Table 3. Average daily numbers of new observations (individuals)
by day of the week and district

	1 1Sun	2Mon	3Tue	4Wdn	5Thu	6Fri	7Sat
1	0,19	1,34	1,03	0,96	0,92	0,69	0,20
0208	0,18	1,30	0,99	0,80	0,85	0,55	0,22
0219	0,20	1,24	0,82	0,91	0,88	0,71	0,14
0221	0,20	1,47	1,27	1,16	1,02	0,80	0,24
2	0,91	4,50	4,01	3,74	3,30	2,86	0,82
0264	0,91	4,50	4,01	3,74	3,30	2,86	0,82
3	0,10	0,53	0,47	0,46	0,42	0,32	0,09
0206	0,06	0,62	0,40	0,43	0,45	0,22	0,11
0214	0,16	0,50	0,38	0,44	0,36	0,37	0,10
0261	0,06	0,46	0,63	0,49	0,46	0,38	0,06

First look at the arrival data (Tables 2–3) suggests that main factors of variability are related to day of the week and district of residence (age group and gender are also pointed out by other data), and that early 2006 data should not be used when estimating input distributions as it includes large number of patients first observed in the system in previous years. Aiming at reducing the complexity of the arrival distributions to be estimated, cluster analysis based on k-NN was applied to group districts with similar arrival distributions by day of week (sample clusters in Table 3).

The hard part of the analysis phase was concerned with identifying multistage (Table 4), multi-hospital pathways of individual patients, and with generalizing observations for the whole cohort.

Table 4. Number of Stays during observed Pathways of 31583 Patients

Number of Hospital Stays	Number of Patients (id)	
1	11690	37,0%
2	4129	13,1%
3	2634	8,3%
4	1959	6,2%
5	1539	4,9%
6	1277	4,0%
7	1130	3,6%
8	927	2,9%
9	815	2,6%
10	662	2,1%

Table 5. Summary pathways for first 6 patients during first 10 hospitalizations according to: inter-arrival times (inta), cost of stay, treatment pattern (ther; 1 operation, 5 chemotherapy, 9 otherwise), hospital number (hosp), set of main diagnoses (km), length of stay (los); idos = personal id; interarrival times calculated to next admission if any

inta / lp

IDOS	1	2	3	4	5	6	7	8	9	10
1	255	0								
2	0									
3	0									
6	0	7	14	0	7	4	25	133	241	276
9	33	0								
11	68	292	182	29	203	0				

cost / lp

IDOS	1	2	3	4	5	6	7	8	9	10
1	88	44								
2	2162									
3	342									
6	57	240	57	73	240	52	362	1176	230	995
9	173	269								
11	121	132	0	388	1561	3176				

ther / lp

IDOS	1	2	3	4	5	6	7	8	9	10
1	9	9								
2	1									
3	9									
6	5	5	5	5	5	5	9	1	9	9
9	9	5								
11	9	9	9	5	1	1				

hosp / lp

IDOS	1	2	3	4	5	6	7	8	9	10
1	53	53								
2	71									
3	71									
6	71	71	71	71	71	71	81	71	81	81
9	71	81								
11	43	43	43	71	71	71				

km / lp

IDOS	1	2	3	4	5	6	7	8	9	10
1	1	0								
2	1									
3	6									
6	1	1	1	1	1	1	1	1	1	5
9	4	3								
11	0	0	0	1	1	1				

los / lp

IDOS	1	2	3	4	5	6	7	8	9	10
1	4	2								
2	8									
3	3									
6	0	8	0	0	8	0	10	14	6	11
9	18	8								
11	5	6	0	14	34	34				

A sample of preliminary results of this phase for 6 patients is presented in Table 5, where consecutive hospitalizations of the patients are illustrated with inter-arrivals times, length and cost of stay, number of hospital, diagnostic category and treatment pattern. The next step of this phase is to apply cluster analysis for grouping pathways of individual patients pathways, estimate discrete multi-dimensional distributions for resulting clusters and validate them as the next set of input distributions for the simulation model.

5. APPLICATION TO TS/LC CASE STUDY: MODEL DEVELOPMENT

Discrete event simulation model using simulation software Arena 13.9 (Rockwell Automation, Inc.) was developed to trace the life history of each patient. Figure 1 shows a draft structure of the overall model.
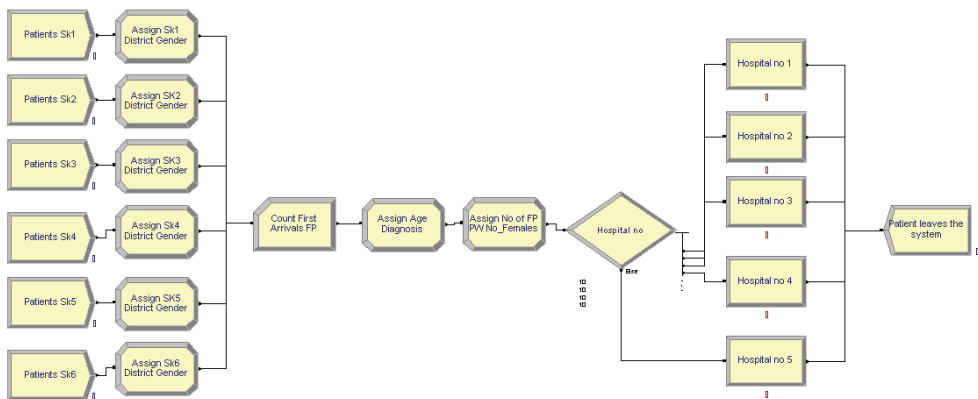
Fig. 1. Discrete event simulation model of 'first arrivals into the healthcare system'
by TS/LC patients in the Lower Silesia region – draft version (SK = Cluster)

The draft version of the baseline model starts with empty population of TS/LC patients (as mentioned before, the historical data concerns first observations of patients, who could have entered the system before the first year of analysis; consequently the final model would include a respective warm-up period to consider such patients). The new-comers (would-be TS/LC patients), arrive in the system classified by six clusters (Table 3) which correspond to 29 districts of Lower Silesia region (another extension, to include extra-regional TS/LC patients, which on average constitute around 1/3 of all TS/LC patients in the region, is also anticipated). The patient arrival processes are modelled as dynamic random Poisson processes, separately for each cluster, according to exponential distributions with time-varying parameters. The parameters are defined according to the results of the historical data analysis, and count for the day of the

week and year (the latter reflects general demographic tendencies). Note that Poisson-distributed daily arrivals generate new-comers throughout the day and we are able to space out the incoming patients rather than have them all occur at once. Next, a district number is generated according to particular intra-cluster distributions.

The arriving patients acquire basic attributes: Gender and Age Group (in 10-years intervals), which are sampled according to discrete distributions for each cluster, as well as First Diagnosis (diagnosis on arrival, an ICD-10 code), both of which are generated from the discrete distributions defined for the whole incident population. Finally the choice of a Hospital is sampled from a discrete probability distribution, based on First Diagnosis and a district number (in this case arrival clusters are re-defined taking into account locations of hospitals throughout the region instead of quantitative patterns of arrivals throughout a week).
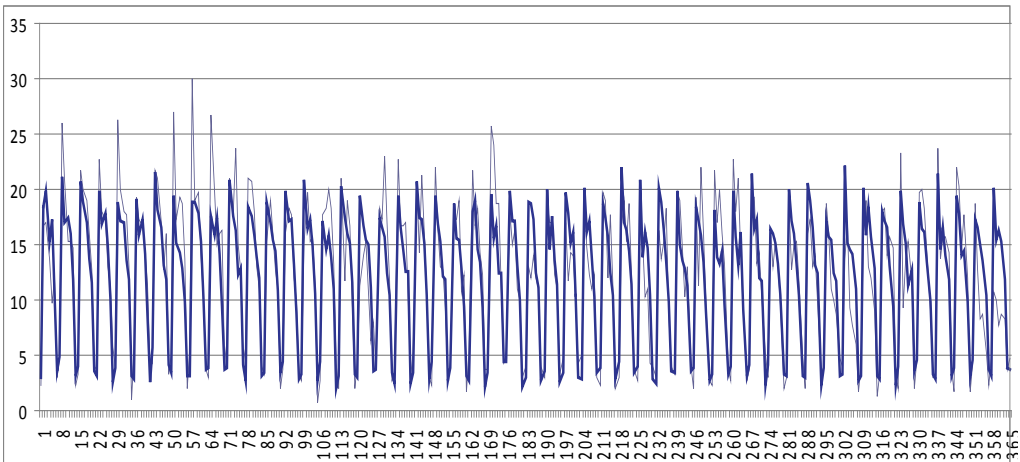
Fig. 2. Model validation: number of patients arriving in subsequent calendar days
(thin line – historical data, thick line – simulated data)

Table 6. Model validation: comparing average number of patients for the whole simulation period
with corresponding historical data

		Number of patients/day						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
Historical data	Average	1024.0	877.3	837.3	738.7	573.0	172.0	192.7
	Std. Dev	163.4	141.5	141.2	163.8	120.4	71.8	47.8
Simulation	Average	1014.7	868.9	835.4	719.2	562.6	162.2	191

The draft version of the model, reported in this paper, simulates events of first observations of TS/LC patients from January 1 until December 31 of a specific year. Simulation lasts for 365 days and is replicated to receive statistically valid outcomes.

Partial results of validation of the baseline model against the arrival schedules is shown in Figure 2, which compares daily number of new patients in the system according to historical data (thin line) and averaged results from 10 simulation replication. Replicating the simulation runs ensures the sample to be statistically valid but at the same time it smoothes out the output data. It explains the peaks on the graph (Figure 2).

The results are promising especially when considering high variability of the source data. Since uncertainty regarding demand is one of the key considerations in our analysis, in Table 6 we report a measure of the variability of overall demand for three years based on the empirical studies. We compare the overall number of new-comers with the overall number of patients arriving during one simulated year. The numbers averaged from 10 replications properly populate the model.

6. CONCLUSIONS AND RESEARCH DIRECTIONS

We report initial results of a research project aimed at developing a modelling framework enabling looking at healthcare pathways for complex, multi-optional diagnostic and treatment pathways. Such clinical pathways are typical for many oncological treatment processes, in particular for Lung Cancer patients, who may be treated, according to clinical recommendations, with surgery, chemotherapy, radiotherapy, or a mix of these procedures, in one or several hospitals, and – what is the greatest challenge for pathways modellers – in a single sequence of hospital stays, or in a number of sequences of hospital stays. The latter case may be due to an advancement of the main illness, development of metastases, pulmonary or cardiological complications, etc., which could result in decisions on more radical surgery or the opposite - implementing palliative treatment only. We currently continue studying the diversity of pathways in regional hospital database and design the next phase of the research project aimed at grouping pathways of individual patients pathways, estimate discrete multi-dimensional distributions for resulting clusters and validate them as the next set of input distributions for the simulation model.

The draft version of the simulation model is about to be extended in the 'first arrivals' module with introduction of year-to-year and month-by-month variability in arrival patterns. We have been faced with a number of additional problems in relation to input arrivals, for instance there is a strong correlation between the district of residence and the first diagnosis with the number of hospital which provides the first hospitalization for a new-comer. However, analysis of the regional databases revealed that there is a considerable variability within the structure of the hospital system in the region: from among 84 hospitals serving the analyzed group of patients in 2006, four years later 23 hospitals are not found in the databases, while there are 6 new hospital

units. Consequently, one should be cautious with averaging data for admission-to-hospital distributions, and their progress over time.

It is necessary to develop the model further – this paper provides the framework for future phases of our research.

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EMPLOYING SET OF EXPERIENCE KNOWLEDGE STRUCTURE AND DECISIONAL DNA TO ENHANCE INDUSTRIAL DESIGN: CONCEPTUAL APPROACH

Today's extremely competitive industrial environment is characterized by increasing load of information, novel technologies, and shorter product life cycles which emphasizes the importance of an integrated knowledge management system in industrial plants. We propose an artificial system, an architecture that would support discovering, adding, storing, improving and sharing knowledge through experience, in a way similar to that which happens in nature. We discuss an approach in which knowledge is represented by novel Set of Experience Knowledge Structure (SOEKS), and is brought into the future by SOEKS collection called Decisional DNA. Our intention is to apply this unique concept in manufacturing plants to enhance industrial design.This paper presents a conceptual background to the proposed approach to design an integrated manufacturing knowledge based structure by selection of processes, equipment, tooling, and sequencing of operations and the type of a manufacturing system.

1. BACKGROUND

The term Industrial Design (ID) for manufacturing is used in this paper to illustrate design and manufacturing areas efforts to recover the product-process, or, to enhance the grade to which the product and process are designed simultaneously [17].

ID Plays a vital and treasured role in today's manufacturing systems. Developing a more capable manufacturing system and carrying it to realization is the main role of industrial designers.

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Industrial designers usually utilize background knowledge and experience of current products to design new products and this kind of knowledge can be restrictive if it avoids the improvement of old methodologies and creates new approaches [9].

As functionality and complexity of the products is increasing, and companies need to withstand advantage in heavy competitive markets, it is not possible to make appropriate and effective decisions without the help and support of computer based manufacturing systems [9]. The importance of intelligent systems becomes more noticeable than ever before because of interrelation among activities in various manufacturing units and they can predict problems before they occur and provide respective solutions, intelligent manufacturing systems can be valuable in supporting the expected level of competitiveness.

In industrial companies the traditional systems do not have capacity for expansion in the technological achievements. Also, these companies are now facing challenging tasks such as the following:

• Re-engineering is not easily feasible,

• Learning Development in automation is difficult by limited decision-making capabilities of the machines,

• Decentralized management is hardly possible,

• Complexity in Reusability of systems (especially software components),

• Synchronization of material and information flows is always problematic.

Due to several factors including progress in technology and limited capability of traditional ID systems, the nature of ID systems has been changing from one form into another; manual systems to fully automated and autonomous systems [9]. Nowadays changes are occurring more frequently than ever before, so it requires knowing all details and possible plans towards the future.

This challenging environment requires introduction of new smart approaches and technologies as decision support tools. We plan to apply Set of Experience Knowledge Structure (SOEKS) and Decisional DNA (DDNA) as tools. Before discussing the conceptual structure of this application some overview of ID issues related to virtual engineering and semantics follows in Sections 1.1 and 1.2.

1.1. VIRTUAL ENGINEERING TOOL

To enhance manufacturing capability, computer assisted methods have been utilized to achieve revolutionized and high performance products and processes that can take advantages of an appropriate industrial design and continuing improvement. Total optimization and ID process must be started from a condition where subjects are simplified or idealized. In other words, to enhance ID we must exclude presumptions and include wider possibilities.

In this way Virtual Engineering (VE) is utilized for an integration of geometric models and related engineering tools for instance; analysis, simulation, optimization, and decision-making. It makes a computerized environment that facilitates multidisciplinary and collaborative product development allowing simplification and idealization of ID subjects [15]. VE accelerates problem solving without spending too much time gathering information, modeling information and then analyzing it. Virtual engineering is a user centered process that provides a collaborative framework to combine all of the design models, simulation results, test data, and other decision-support tools in a readily accessible environment [15]. Also, Virtual Engineering Tools (VET) as application of the VE concept is the most effective way to enhance product design and manufacturing. Such technologies include Computer-Aided Planning (CAP), Computer-Aided Manufacturing (CAM), Computer-Aided Design (CAD), Computer-Aided Process Planning (CAPP), Computer-Aided Testing (CAT) and Computer-Integrated Manufacturing (CIM) [17].

1.2. SEMANTICS IN ID

Semantic technologies compose some of the most motivating technologies resulted from the World Wide Web revolution that is frequently reviewed in different areas of knowledge engineering. Their greatest improvements in information technologies may still to be discovered. Semantics are used to enhance VEA by using different technologies that give power to the user, providing amongst other interesting issues a higher level of explicit conceptualization of the product life cycle processes and capturing knowledge [12]. Semantic Web is the new-generation Web that tries to represent information such that it can be used by machines not just for display purposes, but for automation, integration, and reuse across. [2] Enhancing the computer based VEA tools with semantic modeling and reasoning will give great benefits at the various stages of Product Life Cycle Management (PLC) which is defined as the flow of products; from creation, use, repair, reuse, recycling, and disposal; and the semantic enhancement of a VEA through its VET leads to an enhancement of the PLC stages where the VEA is utilized with the technical benefits that such improvement carries [15].

1.3. SET OF EXPERIENCE KNOWLEDGE STRUCTURE AND DECISIONAL DNA

Knowledge has been an important asset for individuals, organizations, and society throughout the ages. Decision makers, in general, base their current decisions on lessons learned from previous similar situations (Sanin and Szczerbicki 2005); however, much of the experience held by individuals is not properly capitalized on due to inappropriate knowledge representation or administration. This leads to decision reprocessing, insufficient response time and lack of flexibility to adjust when new

decisional conditions are found. In order to represent and reuse experience in an adequate form, Sanin and Szczerbicki (2005, 2008) proposed the concepts of the SOEKS and DDNA. SOEKS is a knowledge representation designed to store formal decision events in an explicit way and is based on four basic elements that are considered to be crucial in decision-making actions. These elements are variables (V), functions (F), constraints (C), and rules (R). Variables are used to represent knowledge in an attribute-value form, following the traditional approach for knowledge representation. Given that the set of F, C, and R of SOEKS are different ways of relating knowledge variables, it is safe to say that the latter are the central component of the entire knowledge structure. Functions define relations between a dependent variable and a set of input variables; therefore, SOEKS uses functions as a way to establish links among variables and to construct multi-objective goals (i.e., multiple functions). Similarly, constraints are functions that act as a way to limit possibilities, restrict the set of possible solutions, and control the performance of the system with respect to its goals. Finally, rules are used to represent inferences and correlate actions with the conditions under which they should be executed. Rules are relationships that operate in the universe of variables and express the connection between a condition and a consequence in the form if then else.

SOEKS is the basis for the creation of DDNA, which is a structure capable of capturing decisional fingerprints of an individual or organization. The name decisional DNA is an allegory to human DNA because of its structure and the ability that if offers to store experience within itself. Let us illustrate this metaphor: the four elements that comprise a SOEKS can be compared to the four basic nucleotides of human DNA, and they are also connected in a way that resembles a human gene. A gene guides hereditary responses in living organisms, and analogously a SOEKS guides responses in decision-making processes. A group of SOEKS of the same "type" (i.e., knowledge category) comprise a decisional chromosome, which stores decisional "strategies" for a specific category. Therefore, having several SOEKS chromosomes is equivalent to having a complete DDNA strand of an organization containing different inference strategies [12].

2. DISCUSSION AND CONCEPTUAL INTEGRATION

Decision-making has a key role in enhancing industry and the supporting technologies that we have mentioned before have been employed in ID to use various factors and details insightfully. Also the optimization techniques such as mathematical programming methods and genetic algorithms are being advanced for Product Manufacturing optimization. Although, the combination of these technologies being applied in ID, has improved decision making process slightly. Currently, as a result of the countless quantity of information, the process of decision-making in ID is compli-

cated. The ability of knowledge acquisition, throughout effective transformation of information, could determine the success and failure of an organization, so information and knowledge management is unavoidable [15].

To support decision-making systems and systemized organization of knowledge we must consider three associated issues:

1. Ascertaining the procedure to classify types of manufacturing knowledge.

2. Locating the knowledge structures to support manufacturing knowledge maintenance.

3. How to effectively utilize manufacturing knowledge models in process planning [6].

This process enables enhancement of ID as a result of intelligent and superior decision making. We must design a model and integrated structure, which necessitates logical framework for information flow, and allow cooperative decision making in industrial plants and manufacturing systems. This model comprises classes on the essential manufacturing information, such as artefact, manufacturing activities, manufacturing equipment, work-piece, estimated cost and time and manufacturing process sequences. In this structure, the main manufacturing activities comprise setup, work-piece handling, loading/unloading and processing [17] also, this structure contains the illustration of alternative activities, concurrent activities and parallel activities. To enhance decision the making process and ID we have to develop a manufacturing information structure that has been focused on manufacturing resource capability, process plan and manufacturing cost [1].

2.1. MANUFACTURING RESOURCE CAPABILITYMODELING

A manufacturing resource information model applies in process capability evaluation and resource selection. Also, this model illustrates the information on the characteristics and function of resources that utilize in manufacturing processes. For instance, a product and manufacturing capability model for CAD/CAM integration focuses on information about machinery processes, machine tools, operations and cutting tools [4] and model of manufacturing resource information illustrates on turning and milling machine tools, cutting tools suitable to the processes of drilling and milling [13].This object oriented manufacturing resource modeling for manufacturing process planning includes dimensions capability, shape capability, surface finish capability[18].

2.2. PROCESS PLAN MODELING

Process plan modeling includes a hierarchically structured process plan: generic plan, macro plan, micro plan and detailed plan .This model describes the process plan strategy of manufacturing process [13].

2.3. MANUFACTURING COST MODELING

The model is preliminary implemented in a software program to support Industrial Designers in estimating manufacturing costs from limited design information. Since the information tool provides an estimate of manufacturing costs at the design prototype stage, the development engineer can identify and eliminate expensive components and reduce the need for costly manufacturing processing [7].

3. FRAMEWORK OF PRELIMINARY PROCESS PLANNING AND PRELIMINARY DESIGN

The aforementioned models have not been integrated with each other completely, so we should develop an integrated manufacturing object model and framework which this framework includes preliminary design and preliminary process planning. Figure 1 shows a framework of preliminary process planning and preliminary design integration.
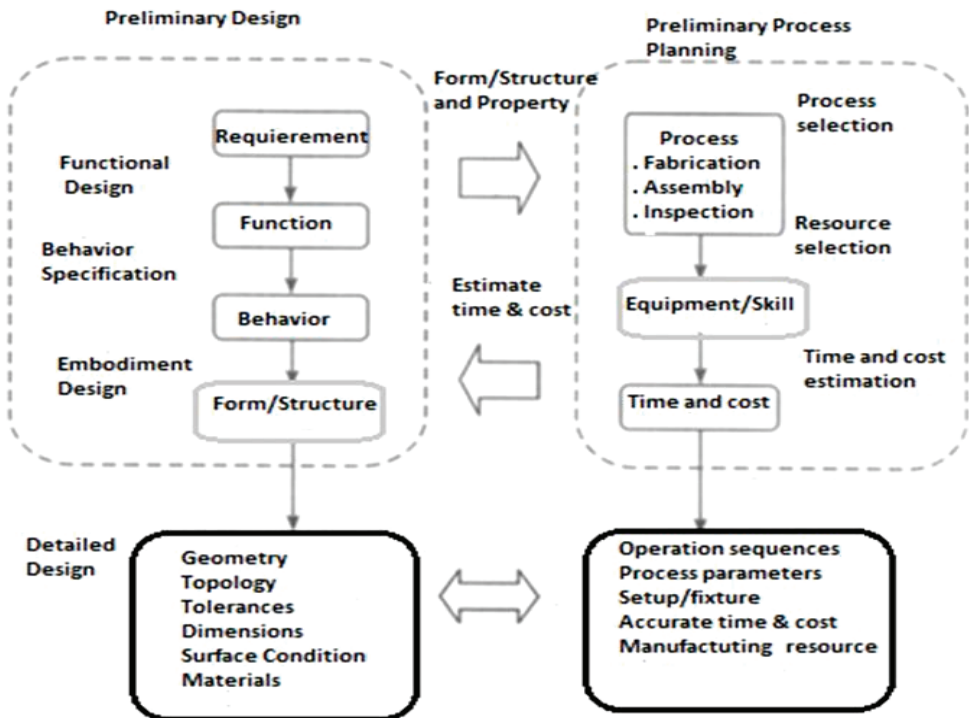
Fig. 1. Integration Framework of Preliminary Process Planning and Preliminary Design [13]

3.1. PRELIMINARY PROCESS PLANNING

Preliminary process planning supports the optimization of material selection, product design and resource selection to shrink manufacturing time and cost. It can be included three processes: select manufacturing resources, select manufacturing processes, and estimate manufacturing time and cost [3].

3.2. PRELIMINARY DESIGN

In decision making process, we can apply preliminary design to transform product functional requirements into abstract physical systems. Also, the information of a preliminary design is essential for design simulation, process planning and detailed design [13].

3.3. SHARING INFORMATION BETWEEN PRELIMINARY PROCESS PLANNING AND PRELIMINARY DESIGN

The design information, which includes the requirements, behavior, function, form and structure of an artefact, must be provided for product design based on the manufacturing process model, and to enhance design specification [3]. In order to acquire
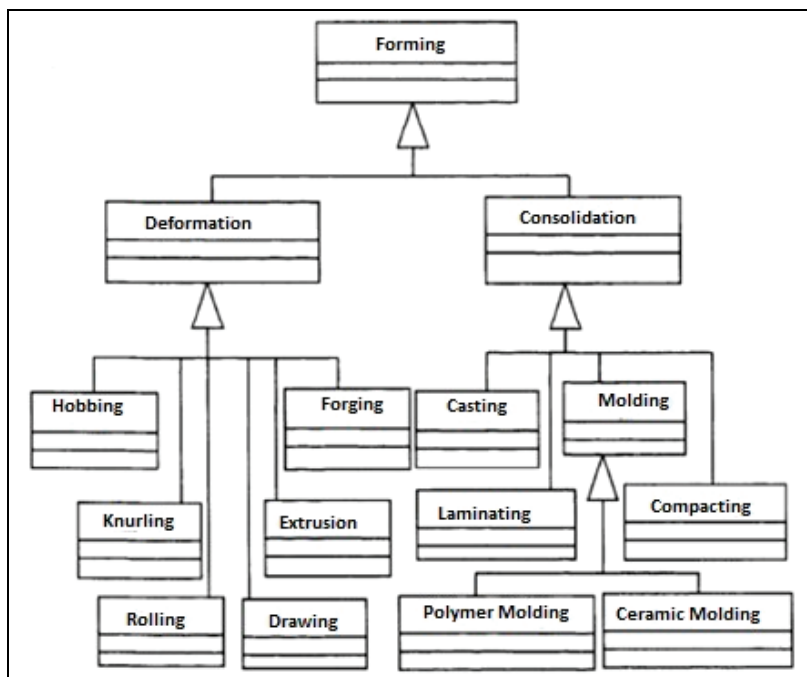
Fig. 2. Forming Class Diagram [13]

manufacturing information on preliminary process planning, such as Processes, Sequences, parameters, cost/time, we need several integrated information object models or diagrams such as Manufacturing activity class, Processing class, Assembly process class, Mechanical removing class, Manufacturing resource class, and Forming class. As an example, Figure 2 shows forming class diagram.

4. PURPOSE

How to automate experience based knowledge administration using intelligent techniques and software engineering methodology is still an unsolved research issue [10, 12]. The proposed approach to the solution of this issue is to systematically create, capture, reuse, and distribute experience in the work processes of an organization/system/institution, preventing important decisional steps from being forgotten in the daily operation or research tasks, and supporting a path towards appropriate automation for recurring tasks or findings. In this specific project, we focus on the adaptation and creation of new algorithms to perform good virtual experience analysis, based on the idea of introducing semantics into the data modeling and processing in industrial design and manufacturing system. ID User Knowledge gathering is still not addressed from a Semantic Point of view. SOEKS would able to model it. We need to accomplish four key tasks to enhance ID by utilizing SOEKS and Decisional DNA:

Task 1: Data Pre-processing and Semantic Representation. Knowledge is a combination of experiences expressed in terms of values, related information, and expert insight, which provides the framework for evaluating and incorporating new experiences and knowledge. Thus, there are four basic components that surround decisionmaking events: variables, functions, constraints, and rules. We need to propose new ways to pre-process and represent industrial design or manufacturing processes in the forms of Decisional DNA.

Task 2: Data Collection and Generalization. Establish techniques for collecting industrial design or manufacturing processes knowledge and transform it into Decisional DNA according to the models developed in Task 1. Afterwards, mixing of the collected knowledge and establishing a combination model for formal decision events is required.

Task 3: Evolving Knowledge base on industrial design. Combined models from Task 2 open possibilities for knowledge evolving techniques based on industrial design which lead to sub-solutions. The developed approach will reduce the gap between different proposed knowledge trying to solve similar problems and will look for a holistic encounter point of their solutions.

Task 4: Establishing techniques for manipulating, administrating and sharing of collected engineering design Decisional DNA. Decisional DNA as a knowledge rep-

resentation for formal decision events is recognized as the fundamental component of infrastructure for advanced approaches to intelligent knowledge management and knowledge engineering automation. The experience-based knowledge structure represented by Ontologies will facilitate the achievement of this aim while allowing for an easy sharing of Decisional DNA.

5. CONCLUSION AND FUTURE WORK

Existing conceptual approach have proposed to enhance ID and manufacturing system in industrial plants by supporting decision making system and systemize organization of knowledge. This knowledge management approach introduced knowledge based structure and architecture to enhance ID by utilizing SOEKS and Decisional DNA in manufacturing system.

The main contribution of our idea is the procedure to classify types of manufacturing design knowledge and knowledge structure to support manufacturing knowledge maintenance, also an appropriate methodology to utilize manufacturing knowledge models to industrial design by utilizing SOEKS and Decisional DNA. To carry out this concept we have to perform and combine data pre-processing and semantic representation, data collection and generalization, developing knowledge base on industrial design and establishing techniques for manipulating, administrating and sharing of collected engineering design Decisional D.

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SUPPORT INTERLINKING OF DESIGN AND PROCESS PLANNING BY SET OF EXPERIENCE KNOWLEDGE STRUCTURE AND DECISIONAL DNA: CONCEPTUAL APPROACH

The goal of this paper is to propose an approach to employ set of experience knowledge structure (SOEKS) and decisional DNA in an integrated design and planning environment. The aggregate product model provides the necessary abstraction of design data to facilitate the assessment of early designs. The main planning requirement was to apply the aggregate product model by developing process knowledge capturing and optimization techniques so that production cost and time can be calculated for complex fabrications requiring many setups and operations. It can result from employing a process knowledge base to create and evaluate process options from information in the product model and the factory layout. This knowledge must be linked to an up-to-date database and controlled by the process planning experts. Our intention is to apply this unique concept in manufacturing plants to enhance industrial design.

1. INTRODUCTION

In today's industrial competition industry, managers are forced to continuously make the best decisions in the shortest possible time and cost. The capability to provide concurrency among manufacturing functions is a critical need for modern organizations. Decision-making has a key role in enhancing industry and the supporting technologies that we have been employed in ID to use various factors and details insightfully.

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In order to accomplish this, we need an integrated knowledge structure that developed from design and process planning data. Through this approach geometry information is created from the design planning and the manufacturing information is focused on the production planning, process planning and plant operations [1]. The early stages of product design has a key role for life cycle cost control, manufacturability, product quality and process design should capture manufacturing information such as precision specifications and machining features including dimensional and geometric tolerances and surface roughness. In spite of several efforts done earlier to link the design and process planning, the sharing of information still has some limits.[1] This paper propose an conceptual approach to employ SOEKS and decisional DNA in an integrated design and planning environment. This conceptual approach aims to improve bottlenecking in sharing information between design and process planning stages.

1.1. INTERLINKING DESIGN AND PROCESS PLANNING

Interlinking design and process plays a key role in understanding Computer Integrated Manufacturing (CIM).From part geometry which has given from a CAD (computer-aided design), CAPP (computer-aided process planning) generates a sequenced set of commands to manufacture specified parts. However they have a tendency to acquire different product data descriptions. CAD is usually geometry-based, while CAPP is domain-dependent and feature-based, which usually results in unfitting practical implementation. Also it can be the predominant weakness of CAPP systems which causes exclusion from CAM (computer-aided manufacturing).

In order to solve this problem we have to develop a feature based CAD system to provide data directly to CAPP systems, but it enforces restrictions on product design and modeling [2, 3, 10].

1.2. SEMANTICS IN ID

Semantic technologies compose some of the most motivating technologies resulted from the World Wide Web revolution that is frequently reviewed in different areas of knowledge engineering. Their greatest improvements in information technologies may still to be discovered. Semantics are used to enhance VEA by using different technologies that give power to the user, providing amongst other inter-

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1.3. SET OF EXPERIENCE KNOWLEDGE STRUCTURE AND DECISIONAL DNA

Knowledge has been an important asset for individuals, organizations, and society throughout the ages. Decision makers, in general, base their current decisions on lessons learned from previous similar situations (Sanin and Szczerbicki 2005); however, much of the experience held by individuals is not properly capitalized on due to inappropriate knowledge representation or administration. This leads to decision reprocessing, insufficient response time and lack of flexibility to adjust when new decisional conditions are found. In order to represent and reuse experience in an adequate form, Sanin and Szczerbicki (2005, 2008) proposed the concepts of the SOEKS and DDNA. SOEKS is a knowledge representation designed to store formal decision events in an explicit way and is based on four basic elements that are considered to be crucial in decision-making actions. These elements are variables (V), functions (F), constraints (C), and rules (R). Variables are used to represent knowledge in an attribute-value form, following the traditional approach for knowledge representation. Given that the set of F, C, and R of SOEKS are different ways of relating knowledge variables, it is safe to say that the latter are the central component of the entire knowledge structure. Functions define relations between a dependent variable and a set of input variables; therefore, SOEKS uses functions as a way to establish links among variables and to construct multi-objective goals (i.e., multiple functions). Similarly, constraints are functions that act as a way to limit possibilities, restrict the set of possible solutions, and control the performance of the system with respect to its goals. Finally, rules are used to represent inferences and correlate actions with the conditions under which they

should be executed. Rules are relationships that operate in the universe of variables and express the connection between a condition and a consequence in the form if then else.

SOEKS is the basis for the creation of DDNA, which is a structure capable of capturing decisional fingerprints of an individual or organization. The name decisional DNA is an allegory to human DNA because of its structure and the ability that if offers to store experience within itself. Let us illustrate this metaphor: the four elements that comprise a SOEKS can be compared to the four basic nucleotides of human DNA, and they are also connected in a way that resembles a human gene. A gene guides hereditary responses in living organisms, and analogously a SOEKS guides responses in decision-making processes. A group of SOEKS of the same "type" (i.e., knowledge category) comprise a decisional chromosome, which stores decisional "strategies" for a specific category. Therefore, having several SOEKS chromosomes is equivalent to having a complete DDNA strand of an organization containing different inference strategies [6, 7, 8]

2. DISCUSSION

A successful design and suitable design decision infers lower manufacturing cost during the early design stages. Usually at the early stages of the design process is characterized by the continuing generation and addition of information to an incomplete model of the design. Generally, the key decisions related to quality and cost are being made during these stages. In the conceptual design for sheet metal fabrications, we need identification of feasible structures to meet the functional requirement, also in embodiment design we have to determine configuration of individual components which frame the overall geometry. This process needs the recognition of the position of joints between components, shapes and the methods of joining [4]. Also, calculation of production costs and times usually needs a process plan. In process planning all of these tasks require knowledge management system and we require accessible knowledge experts to allow evaluation of manufacturing issues which might arise during process and design planning stages.

In order to solve these issues, aggregate process planning is a method for evaluating different design and processing options at the early design stages in relation to manufacturing conditions. We aim to support the design and process assessment of complex fabrications, which typically need welding, cutting and bending proc

esses. This structure and modeling should be rule-based and object oriented, in addition, a knowledge base system has to be created to support the generation of methods for process suitability assessment on the basis of quality, cost and delivery. Furthermore, this system is able to support the generation of design options.

An object-oriented feature based product model can define the design of a fabrication, and this product model can be used in an aggregate process planning.

2.1. THE AGGREGATE PRODUCT MODEL

Manufacturing features have been regularly used in geometric modeling systems and CAPP systems to define basic shapes. The definition of manufacturing features usually depends on the application domain. An object-oriented, feature-based aggregate product model is able to capture necessary design information for aggregate process planning of fabrication. The purpose of an aggregate product model can be:

First, the aggregate product model representation must support for the transition of design data from conceptual stage through to the detailed design stage. For welded fabrications, the designer must examine with alternative combinations of components without completely detailing the design of those components [4].

Second, the aggregate product model should represent a suitable format of design that is appropriate for integration with aggregate process planning and with early design analysis systems. In order to reduce of processing times and data entry in aggregate process planning, the product model must only store the important information that effects the production. For a welded fabrication, combination of weld elements and joints can be identified as requirements for data confirmation [4].

2.2. STRUCTURE OF AGGREGATE PRODUCT MODEL

In manufacturing, component is a single part material with specific features made by processes such as milling, forging and casting. A component normally has machining features, such as steps, faces and shoulders. Figure 1 illustrates structure of the product model.

A mechanical part that has weld features same as seam tee weld joint, is called fabrication. These weld features are generally utilized to join two or more fabrica-

tions. weld feature, which includes two subclasses: a joint and a weld. Usually weld feature defines the dimensions and shape of weld joint. The Joint class finds the procedures to weld fabrications and weld class describe and the weld class describes the dimensions and shapes of the cross-sectional parts of different welds [4].

In the product model, part is the super class of component, assembly and fabrication. Part has many subclasses such as weight, size, lead time and production cost and the associates of the assembly, component and fabrication can be attached to a subclass of the part class. A weld feature is able to attach a fabrication and a machining feature has an ability to be attached to a component or fabrication.
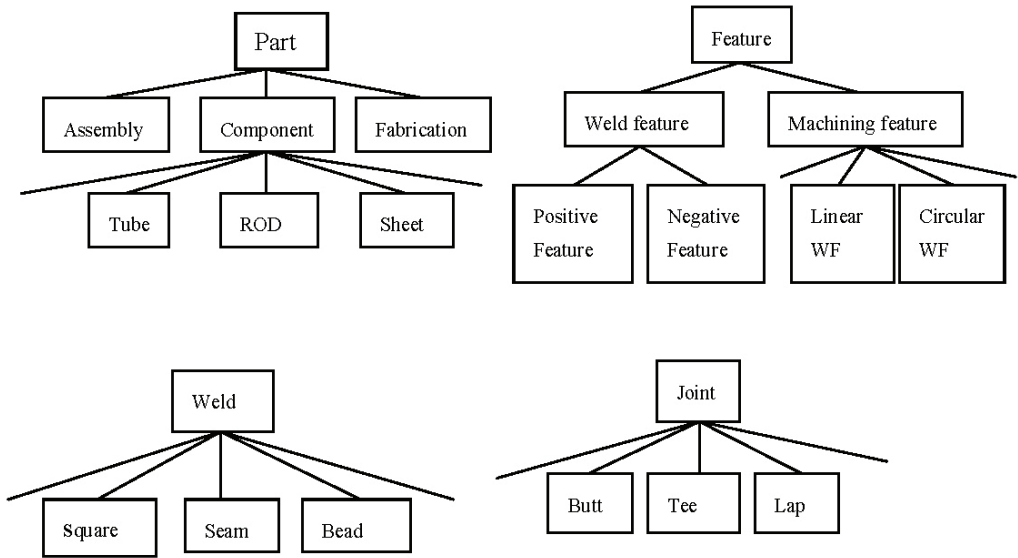
Fig. 1.The structure of the product model [4]

A product normally comprises of one or numerous fabrications, assemblies and components, Fig. 2, defines the structure of a product model which has started the main classes [4].
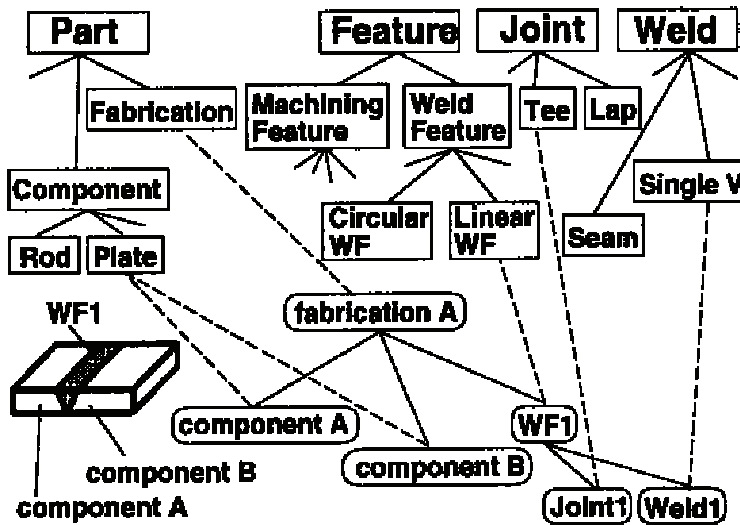
Fig. 2. The structure of an aggregate product model [4]

To create an aggregate product model, two procedures which are manual input and information abstraction, have been established. The manual input method is appropriate for the continuation addition of design information to the product model during the design process. The information abstraction method recovers the information from a geometric model. It can be used early during re-design to capture aggregate product information from current designs [4].

2.3. AGGREGATE PROCESS PLANNING METHOD

The aggregate process planning method can be used to calculate the manufacturability of complex fabrications at the early stages of design process. Generally this method is used directly by designers. Evaluation of production costs and time usually needs a process plan and it requires specialist knowledge during design process to allow evaluation of manufacturing issues. We have planned to support this requirement by providing a programmed analysis that does not require the involvement of a process expert for each design modification. This is achievable by applying a process knowledge base system to capture and evaluate process

decision making from information in the product model and factory layout [4, 5, 10].

2.4. TASKS OF AGGREGATE PROCESS PLANNING
FOR WELDING

Typically these tasks are being performed in a sequential system. Optimization methods apply in many of these tasks, such as equipment selection. The main aggregate process planning setups for welding are:

1. Raw aggregate plan creation.
2. Process selection.
3. Welding process orientation and set-up optimisation.
4. Equipment and consumable selection.
5. Process sequencing.
6. Manufacturing lead-time and cost calculation.

Totally an aggregate process planning method accelerates decision making in manufacturing. This method is capable of producing efficient and accurate results [5].

3. PURPOSE

The integration of CAD/CAPP causes an issue that CAPP relies on the product model data created by CAD, and CAD geometry-based, while CAPP is feature-based and domain-dependent which results in unacceptable implementation. Therefore, they usually do not have a proper linkage with each other. This problem would be solved by creating a feature-based CAD system to provide data directly to CAPP system [10].

We are attempting to solve this issue by providing an automatic knowledge-based system that does not require intervention by the process expert for each design modification. This knowledge must be controlled by the company process planning experts and linked to an up-to-date database. As a results we propose SOEKS to perform four duties:

Task 1: Data Pre-processing and Semantic Representation.
Task 2: Data Collection and Generalization.
Task 3: Evolving Knowledge base on industrial design.

Task 4: Establishing techniques for manipulating, administrating and sharing of collected engineering design Decisional DNA.

We believe SOEKS and Decisional DNA can support integration of design and process planning in manufacturing environment.

4. CONCLUSION AND FUTURE WORK

Current conceptual approach has proposed to improve interlinking design and process planning in ID and manufacturing system by classification of knowledge. This knowledge management approach introduced knowledge based model to enhance ID by utilizing SOEKS and Decisional DNA in manufacturing system. The main contribution of our idea is the procedure to develop a feature-based CAD system to provide data directly to CAPP systems and overcome to issues that might arise from interlinking between CAD and CAPP in ID. To carry out this method we have to create an aggregate product model which can be applied to capture and represent product information during the different stages of the design process and integrate this model with an aggregate process planning model. Following this integration, SOEKS and decisional DNA is able to support and enhance integration of CAD and CAPP.

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DYNAMIC GOAL PROGRAMMING APPROACH AND ITS APPLICATION TO ENVIRONMENTAL DECISIONS IN ORGANIZATIONS

In the paper we propose a dynamic version of the well-known goal programming approach. The classic goal programming approach allows to set various goals and control their achievement and relations between them. The dynamic approach we are proposing allows to plan the achievement of goals over a longer period of time and choose the best paste. We are applying the approach to planning environmental decisions in organizations. We consider two big organizations with a serious environmental politics and we propose how to find the best plan of putting the environmental politics into practice.

1. INTRODUCTION

The environmental decisions in companies are more and more important. The environment has to be taken into account – this is required partially by law, partially by the social pressure, and will be required to a greater and greater degree. Thus each company is forced to include the environmental decisions in the multitude of various managerial decisions that have to taken. Each managerial decision has to be evaluated according to numerous criteria (financial and non-financial ones, legal ones, ones related to the company image, ones related to the satisfaction of various parties etc.), in order to decide if, when and in which form it should be taken. As for environmental decision, they are rather difficult to be evaluated, there is thus a need for tools to help managers to take them.

Almost each environmental decision is a multicriteria and a multi-variant ones. This means that usually we can choose between several variants of the decision im-

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plementation, which differ in schedules, in equipment used etc., and we have to choose the optimal one, taking into account all the necessary constraints. In this paper we propose a new multicriteria decision making method which may help managers to choose optimal variants of environmental decisions. The new method is a extension of the well know goal programming method, which in its original form does not allow to take into account the criteria of the time when a decision is implemented. Our extension makes including such goals possible.

The outline of the paper is as follows: In Section 2 we present the notion of environmental policy and environmental program. In Section 3 we analyze the environmental program of two selected companies and choose three environmental decisions for further analysis. In Section 4 we propose the extension of the goal programming method. In Section 5 we apply the new approach to the decisions selected in Section 4.

2. ENVIRONMENTAL POLICY AND ENVIRONMENTAL PROGRAM

Environmental policy is company flagship[1]. It is a marketing document, because by showing it to the interested parties, the companies image is improved, resulting in more acceptance for its activities.

The environmental policy used by the companies should meet among others the following conditions:

- The environmental requirements should be compatible with the fundamental company goals with ,
- the environmental policy should be adopted to the nature of the business and its impact on environment,
- It should define the basic environmental values and goals of the company,
- It should ensure the transparency of the activities carried out to protect the environment,
- It should be made available to the public.

The environmental policy has usually the form of a short description, statements or bulleted intentions. According to ISO 14001, from the environmental policy there must follow one general, quantitatively defined goal (called strategic, major or primary), which company has to realize. This goal becomes the basis for the formulation of goals of the lower order (called functional, operational or instrumental), which constitute the environmental program. The task of management is, therefore, seeking to achieve the strategic goal through the implementation of the environmental program

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[1] Gajdzik B., Wyciślik A., *Wybrane aspekty ochrony środowiska i zarządzania środowiskowego*, Wydawnictwo Politechniki Śląskiej, Gliwice 2007, s. 115.

conducted as a result of a series of decision-making processes[2]. The achievement of goals is evaluated by comparing the actual results to the G values (called goal values).

3. ANALYSIS OF THE ENVIRONMENTAL POLICY AND ENVIRONMENTAL PROGRAM OF THE SELECTED COMPANIES

The study included two companies (P, D), which are members of one group located in two different countries, Poland and Germany. Their environmental policies and environmental programs were analysed.

Both companies have the same environmental policy. Its analysis indicates the strategic goal of a efficient use of natural resources by monitoring the consumption of water, electricity and heat.

This strategic goal is reflected in company's D environmental program. The environmental program is a development of the environmental policy, therefore it contains also lower level goals. In company D these goals are located in the following areas: emissions, waste, transport, environmental awareness, eco-friendly materials, in company P in the following ones: dangerous waste, emissions, awareness.

It was noted that, despite the same environmental policies, the studied companies have constructed their environmental programs in a different way. In the following we analyze a part of the environmental program of company P .

For this publication were analysed four pilot indicators, each of them is located in a different area (see Table 1). The detailed data are taken from company P. N ("now") stands for the present value of the corresponding indicator, G stands for its goal value. C stands for the cost of achieving goal G.

Table 1. Part of environmental program for company P

No.	Area	Goal	Indicator	N	Action	G
1	Energy	Using energy-efficient lighting	% energy-efficient lighting	0%	Change lamps on energy-efficient lighting	100%
2	Waste	Moving removable containers	% removable containers	59.72%	Change cartons packaging's on removable containers	100%
3	Water	Reducing water consumption	% armature: *time	0%	Change armature: *time-controlled armature	100%
			*photocells	0%	* photocells	100%

_____

[2] Nahotko S., *Podstawy ekologicznego zarządzania przedsiębiorstwem*, Biblioteka Menedżera i Służby Pracowniczej, zeszyt 219, Bydgoszcz 2002.

All the goals can be achieved in many ways: in different times and different costs. We can achieve all of them within one year if we have enough money. However, normally the achievement of the goals will be stepwise, and it may also happen that even within a period of several years some of the goals will not be achieved totally. We have to find a balance between environmental goals, environmental budget and the time. We have our desired values concerning all these aspects: we would like to achieve the indicator values G within e.g. one year, and without exceeding the environmental budget. On top of that we want to satisfy all the parties involved and improve our image. Thus, we are dealing with a multicriteria decision.

In this paper, let us abstract from the not easily measurable goal like satisfaction and image, and let us concentrate on the quantitative goals: the indicator value (Table 1) and the moment in time of achieving this goal. Let us assume the latter to be equal to one: we want to achieve the goal value of the indicator within one year. Each deviation from these goals will be considered as undesired, although maybe unavoidable. For solving multicriteria problems very often the goal programming is used[3]. However, the goal programming approach known in the literature does not allow to consider as one of the goals the moment of achieving the other goals. Thus, we propose to extend the goal programming approach to make such goals possible. This is done in Section 4.

4. DYNAMIC GOAL PROGRAMMING APPROACH

In the classical goal programming approach the decision maker gives the goal values of different objectives, thus the values he wants to achieve. Undesired deviations from the goal values usually cannot be avoided, but they are minimized.

Here we propose a dynamic goal programming approach, where one of the goals will be the time at which a certain value will be achieved. The other goal is the value of a certain indicator included in the environmental program of a company. We distinguish $m+1$ moments of time t_i, $i = 0, ..., m$ (the index 0 corresponding to the present moment) and $n + 1$ possible values v_j, $j = 0, ..., n$ of the indicator in question, where the index 0 corresponds to the present value of the indicator and the index n to the desired value and values v_j, $j = 0, ..., n$ are ordered from the worst one to the best one. The desired value of the time when the desired value of the indicator should be achieved is t_1, however, negative deviations both from t_1 (thus delays) and from v_n (thus smaller and greater values, depending on the nature of the corresponding indicator) may occur because of budgetary problems. Those deviations should be minimized.

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[3] Zanakis S.H., Gupta S.K., *A categorized bibliographic survey of goal programming Omega*, 13(3), 1985, s. 211–222.

We propose to solve the problem by means of the shortest path model in the following network (it is shown for $m = 4$ and $n = 2$):
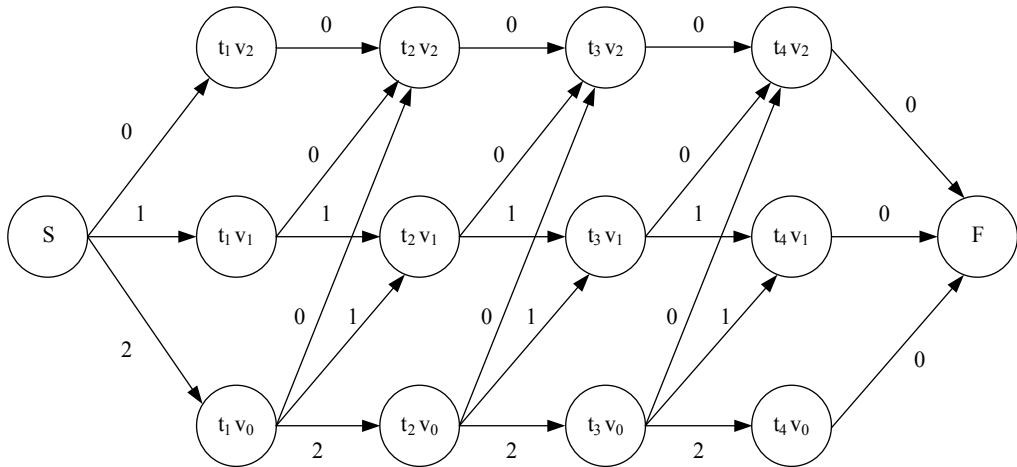
Fig. 1. Network structure of the problem

Nodes S and F are artificial nodes: S represents the present moment, when the value of the indicator in question is v_0 (N in Table 1). v_2 represents the goal value of the indicator (G in Table 1), and v_2 a value corresponding to the "half-way point" of G: e.g. if G is 100%, v_2 represents 50%. Node F is the artificial end node of the network. Nodes $t_1 v_2$, $t_1 v_2$ and $t_2 v_2$ represent the state where the desired value of the indicator has been fully achieved. If node $t_1 v_2$ is traversed by the selected path, the ideal state has occurred: the ideal value of the indicator has been achieved in the minimal possible time. If node $t_1 v_2$ is not traversed but node $t_1 v_2$ is traversed, the ideal value of the indicator has been achieved one period later. The latter situation means that either node $t_1 v_2$ or node $t_1 v_2$ precedes node $t_2 v_2$ on the path. For us the former is better than the latter, because the deviation from the desired indicator value is smaller already in the 1 period. The arc weights in Fig. 1 have been chosen in such a way that by seeking the shortest path from S to F we will find a strategy leading us as soon as possible to value G: the shortest path will tend to go as quickly as possible to the upper part of the network, which means minimising the deviations both from t_1 and v_2. Of course, with no additional constraints path $S - t_1 v_2 - t_2 v_2 - t_2 v_2 - t_4 v_2 - F$ would be selected as the shortest path, which would correspond the ideal situation. But this situation may be impossible because of budgetary problems.

Let us suppose we know the budget for the environmental action for each period of time $i = 1, ..., m$ and let us denote it by B_i, $1 = 0, ..., m$. Let us also link to each arc in the network from Fig. 1 the cost connected to the corresponding action (e.g. passing from indicator value v_0 to v_2 in the 2 period requires an investment (arc $t_1 v_0 - t_2 v_2$ will

be linked to a cost), maintaining the achieved value in the 2. period may cost nothing and sometimes even bring saving (arc $t_1v_2 - t_2v_2$ will be linked to zero or negative cost). If the cost of an arc is denoted as $C(\text{arc}_{start}, \text{arc}_{end})$, then we have to take into account budgetary constraints:

$$
\begin{aligned}
&C(S, t_1v_2) + C(S, t_1v_1) + C(S, t_1v_0) \le B_1 \\
&C(t_1v_2, t_2v_2) + C(t_1v_1, t_2v_2) + C(t_1v_0, t_2v_2) + \\
&C(t_1v_1, t_2v_1) + C(t_1v_0, t_2v_1) + C(t_1v_0, t_2v_2) \le B_2 \\
&C(t_2v_2, t_2v_2) + C(t_2v_1, t_2v_2) + C(t_2v_0, t_2v_2) + \\
&C(t_2v_1, t_2v_1) + C(t_1v_0, t_2v_1) + C(t_2v_0, t_2v_0) \le B_2 \\
&C(t_2v_2, t_4v_2) + C(t_2v_1, t_4v_2) + C(t_2v_0, t_4v_2) + \\
&C(t_2v_1, t_4v_1) + C(t_2v_0, t_4v_1) + C(t_2v_0, t_4v_0) \le B_4
\end{aligned}
\tag{1}
$$

If we look for the shortest path in network form Fig. 1 with the budgetary constraints (1), we will find a plan of achieving a most desirable situation possible with respect to the environmental indicator values and time. The corresponding model is an integer linear programming model: the model for the shortest path in Fig. 1[4, 5] completed by (1).

In the next section we will determine the arc weights for selected environmental indicators for the selected company. It is important to indicate that we understand here the notion of cost as a cash expenditure (and not as an expenditure on the memorial basis).

5. COST AND SAVINGS LINKED TO ENVIRONMENTAL ACTIONS IN THE SELECTED COMPANY

5.1. ENERGY

Using energy-efficient lighting can reduce energy consumption. The studied company does not use such lighting at the moment and the goal G is to use only such a lighting (Table 1). v_0 correspond to no use of energy-efficient lighting, v_1 to the 50% of energy-efficient lighting, v_2 to 100%. We consider a period of four years and try to find the optimal way of improving the energy usage.

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[4] Trzaskalik T., *Modelowanie optymalizacyjne*, Przedsiębiorstwo Specjalistyczne Absolwent Sp. z o.o., Łódź 2001.

[5] Trzaskalik T., *Wprowadzenie do badań operacyjnych z komputerem*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2003.

To calculate the cost of investment a survey was carried out in which we calculated the required number of bulbs in company. Taking into account the unit cost, we calculated the total cost of the passing from v_0 to v_2 (in any period): 128 336 zl. Passing from v_0 to v_1 or passing from v_1 to v_2 (in any period) would cost half of it: 64 168 zl. If v_1 has been attained, we save per year 2687,5 zl, if v_4 has been the yearly saving are 5 375 zl. On top of that, we may take into account the time value of money, let us assume that this value increases in one year per 10%. The corresponding values are shown in Table 2.

Table 2. Cost of lamps change ($i = 1, 2, 3$)

Arc	Cost (zl)
$S - t_1 v_0$	0
$S - t_1 v_1$	64 168
$S - t_1 v_2$	128 336
$t_i v_0 - t_{(i+1)} v_2$	$128\,336 \cdot \left(\dfrac{1}{1+0.1}\right)^i$
$t_i v_0 - t_{(i+1)} v_1$	$64\,168 \cdot \left(\dfrac{1}{1+0.1}\right)^i$
$t_i v_0 - t_{(i+1)} v_0$	0
$t_i v_1 - t_{(i+1)} v_2$	$64\,168 \cdot \left(\dfrac{1}{1+0.1}\right)^i - 2687.5 \cdot \left(\dfrac{1}{1+0.1}\right)^i$
$t_i v_1 - t_{(i+1)} v_1$	$-2687.5 \cdot \left(\dfrac{1}{1+0.1}\right)^i$
$t_i v_2 - t_{(i+1)} v_2$	$-5375 \cdot \left(\dfrac{1}{1+0.1}\right)^i$

5.2. WASTE

In the studied company finished products are delivered to customers by using two types of packaging: non-replaceable (cartons) and replaceable (fixed). To determine the ratio of the usage of both packaging a survey was carried out among a group of 8 logicians. In this way, it was found that 40.28% customers use cartons. As a result of the analysis the goal was formulated: a complete change from cartons to replaceable packaging.

To calculate the cost of investment a survey was carried out in which the annual cost of buying cartons was calculated. The company uses five types of cartons and each has a different purchase price. The information about the annual consumption volume of each types of cartons let us calculate the annual cost of their purchase, amounting to 340 508 zl. Then the cost of replaceable containers was calculated. The

most difficult task was calculating the number of necessary containers. In the calculation we used the information on the annual consumption of cartons and assumed 10% safety stock of containers. Therefore was calculated that the cost investment is 67 528 zl. However, we should take to account the cost of return transport of containers and the cost of packaging management. Analysing the transport costs of finished products to customers we found the average cost of return transport and packaging management as equal to 158 156 zl per year. For the value v_1 (half of the cartons replaced with fixed containers) the corresponding figures will be halved. Table 3 shows the corresponding cost.

Table 3. Costs of change of cartons to fixed containers ($i = 1, 2, 3$)

Arc	Cost (zl)
$S - t_1v_0$	0
$S - t_1v_1$	33 764
$S - t_1v_2$	67 528
$t_iv_0 - t_{(i+1)}v_2$	$67\,528 \cdot \left(\dfrac{1}{1+0.1}\right)^i$
$t_iv_0 - t_{(i+1)}v_1$	$33\,764 \cdot \left(\dfrac{1}{1+0.1}\right)^i$
$t_iv_0 - t_{(i+1)}v_0$	0
$t_iv_1 - t_{(i+1)}v_2$	$(-170\,254 + 33\,764 + 79\,078) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_iv_1 - t_{(i+1)}v_1$	$(-170\,254 + 79\,078) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_iv_2 - t_{(i+1)}v_2$	$(-340\,508 + 158\,156) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$

5.3. WATER

It was decided to achieve to goal of minimising the water usage in one of two ways: by replacing existing traditional armature by the time-controlled one or by introducing photocells.

At the beginning we obtained data on the water quantities consumed in a month and determined its cost taking into account: the price of water and the rates of license fees for water supply and sewage disposal. Then we determined the amount of installed armatures by type: taps, showers, toilets, urinals, and calculated the percentage of water consumption attributable to each of these device types.

Then we checked the prices of batteries: hand basin taps, urinals, showers and toilets. In this way it was possible to determine the cost of purchase of the new armature as equal to 9630 z and next was added the installation cost in the amount of 2889 zl. The total investment cost is thus 12 519 zl. We calculated also the savings due to the investment which amounts to 9175 zl per year. In Table 4 we can see the corresponding values for the case the company wants to achieve the goal of minimising the water

usage by introducing the time-controlled armature (again, if the goal v_2 is not fully attained, we halve the corresponding values):

Table 4. Costs of introducing time-controlled armature ($i = 1, 2, 3$)

Arc	Cost (zl)
$S - t_1 v_0$	0
$S - t_1 v_1$	$6\ 255.5 - 4587.5$
$S - t_1 v_2$	$12\ 519 - 9175$
$t_i v_0 - t_{(i+1)} v_2$	$(6255.5 - 4587.5) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_i v_0 - t_{(i+1)} v_1$	$(12\ 519 - 9175) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_i v_0 - t_{(i+1)} v_0$	0
$t_i v_1 - t_{(i+1)} v_2$	$(6\ 255.5 - 9175) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_i v_1 - t_{(i+1)} v_1$	$-4587.5 \cdot \left(\dfrac{1}{1 + 0.1}\right)^i$
$t_i v_2 - t_{(i+1)} v_2$	$-9175 \cdot \left(\dfrac{1}{1 + 0.1}\right)^i$

Investment which is based on the change of traditional armature to photocells costs 43 992 zl because of a higher purchase and installation price of such devices. However, the savings achieved by this solution are higher than in case of time-controlled armature and in this case are 13 046 zl per year. This solution may preferred because of higher water savings – which is beneficial for the environment – even if the purchase and installation cost is higher. The corresponding data is given in Table 5.

Table 5. Costs of introducing photo cells ($i = 1, 2, 3$)

Arc	Cost (zl)
$S - t_1 v_0$	0
$S - t_1 v_1$	$21\ 996 - 6523$
$S - t_1 v_2$	$43\ 992 - 13\ 046$
$t_i v_0 - t_{(i+1)} v_2$	$(21\ 996 - 6523) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_i v_0 - t_{(i+1)} v_1$	$(43\ 992 - 13\ 046) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_i v_0 - t_{(i+1)} v_0$	0
$t_i v_1 - t_{(i+1)} v_2$	$(21\ 996 - 13\ 046) \cdot (1/(1 + 0.1))_i^{\mathrm{T}}$
$t_i v_1 - t_{(i+1)} v_1$	$-6523 \cdot \left(\dfrac{1}{1 + 0.1}\right)^i$
$t_i v_2 - t_{(i+1)} v_2$	$-13\ 046 \cdot \left(\dfrac{1}{1 + 0.1}\right)^i$

6. APPLICATION OF THE DYNAMIC GOAL PROGRAMMING MODEL
TO THE ENVIRONMENTAL PROGRAM

We assume that a separate annual budget is given for each of the areas from Table 1: energy, waste and water.

If we apply the data from Table 1 to Fig. 1 and the model discussed in Section 2, with the annual budget of 100 000 zl in the 1. and 4. year and 50 000 zl in the 2. And 3. year, we get the following optimal path: $S - t_1v_1 - t_2v_1 - t_4v_2 - F$, which means that the desired value of the indicator can be achieved only in the fourth year. Thus a deviation of 3 years of the desired moment of fulfilling the goal concerning the energy will have to be accepted. During the first three years also a deviation of 50% from the desired indicator vale will have to be accepted. If the budget is increased to 100 000 zl in each year, the desired value of the goal can be achieved already in the 2. year – thus the deviation of time will be smaller.

An analogous procedure concerning Table 2, thus the waste, for budgets equal to 30 000 zl each year, would give us the following optimal path: $S - t_1v_0 - t_2v_1 - t_2v_2 - t_4v_2 - F$. Thus the time deviation will be 2 years, in the first year the indicator value deviation will be 100%, in the second year 50%.

We can also apply the model from Section 2 to the water use indicator. We will do it only for Table 5, representing the more environment friendly solution. We assume annual budgets equal to 10 000 zl in the first 3 years and the budget of 30 000 in the forth year. Then we gen the optimal solution : $S - t_1v_0 - t_2v_0 - t_2v_0 \ t_4v_2 - F$: the time deviation is 3 years and during the first 3 years there is a 100% deviation from the desired indicator value.

We might also introduce into the model budgetary deviations. We assumed in our calculations fixed budgets, but it we might make them flexible and optimize the undesired deviations from the budget limits, on top on the deviations from the goal value of the indicator and the goal moment in time when the goal should be achieve.

We would also get much more flexibility if we considered more steps in the goal achievement: v_j, $j = 0, ..., n$ for n greater than 2.

7. CONCLUSIONS

In this paper we introduced a new method of multicriteria decision making, based on the goal programming and shortest path models, which allows to consider time of decision implementation as one of the goals to be achieved, fully or partially. The new method was applied to the evaluation of three environmental decisions in two selected companies. It has turned out to be a useful tool for dynamic decision making for companies in creating and applying an environmental policy.

Further research is needed to integrate the proposed model in a system model, in which all the environmental decisions of a company are included and all the preferences, constraints and requirements, both of the quantitative and qualitative nature can be taken into account.

The proposed model can be also used in other types of decisions, so it might also be interesting to test it in other areas of company functioning.

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Ewa PRAŁAT*

WEBSITES OF LOWER SILESIAN DISTRICTS

The webpages of local government are visited first of all in quest of information. Various types of visitors are looking for different information about: the government office, the region, the investment or the land development plans. The visitors want also to have online possibility of dealing the official matters what is in conformity with European Commission resolution that presented a list of 20 basic public services that covers different interactions of the public sector with citizens and businesses.

During last time several research on local government websites have been conducted. Most of them concerned the look and the content of communes' websites. Different criteria of evaluation were applied – they often based on Website Attribute Evaluation System.

This paper presents the results of research on 26 districts' websites of Lower Silesia. A methodology of the research was described. One stated four main areas, where 18 criteria were distinguished. Most of the criteria were rated in four point scale. The points obtained on each area were summed, the ranking of websites were compiled and the results were discussed

"Accessibility and clarity" and "Content" areas were rated the highest – they got at least 50% of points. The area "New forms of activity and additional facilitations" obtained the lowest number of points. The best website got only 77% of maximal result and the average result hardly exceeded 50%

1. INTRODUCTION

Nowadays, the opinion that the Internet is the best source of information is widespread and no one is surprised by the fact that local governments have their own websites apart from the compulsory BIP (Public Information Bulletin) webpages.

The main objectives of these local government website are [3]: informing, realization of tasks, establishing relations, users' integration and creation of the positive image. The local government website is visited by different types of users who are looking for useful information; at the same time citizens are more and more often trying to

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use the Internet in dealing official matters (this issues will be discussed in greater detail on sections 2.1 and 2.2). Establishing relations consists in inducing visitors to keep up with the information presented on the local government website. Moreover it is very useful to integrate citizens around the website creating the community that eagerly comments on the texts and takes part in discussions or questionnaires. The website may also help to create a positive image not only of the local government office but also of the whole region.

There are no top-down guidelines concerning local government's website look and content. On the one hand, it is good that there is a latitude in designing these websites. On the other hand it results in diversity of websites, furthermore some local governments haven't manage this task. In consequence, besides very well designed websites with professional look and interesting content exist these with dull, rarely updated content and low functionality.

2. DISTRICT WEBSITES AND THEIR CONTENT

2.1. DISTRICT WEBSITES' USERS AND THEIR INFORMATION NEEDS

The websites of local governments are becoming more and more frequently visited. One can distinguish several groups of users taking into consideration the aim of visit. Each group has obviously different information needs [7]:

– Enquirers that have official matters to deal and want to learn how to do it. They want to find out the official hours, which forms they have to fulfil and which documents they have to enclose.

– Citizens that are looking for information that is useful in everyday life: the current cultural and sport events, the programme of the theatres and the cinemas, the offices' opening hours. They are interested in local authorities' decisions and their possible effects on their living standards. The local government investments and the municipal budget matter a lot to them. The citizens are also interested in the history of the town and the region.

– Businessmen and the local employees are interested in information that is presented in BIP. They are looking for financial information and investment plans.

– Potential investors often need information about land development plan. A detailed description of sites and possibility of their easy location on the map can be a strong incentive.

– Tourists are looking for information about tourist attractions, routes, accommodation and catering establishments. It is important to let them locate all these places on the map. The programmes of current and planned cultural and sport events as well as bus and train timetables are also very useful for them. The tourists will appreciate an easy to operate online map with streets and sites search engine.

2.2. E-GOVERNMENT

A term "e-Government" has a vast meaning that includes: the computerization designed to improve the information flow between central and local public administration, the computerization of services for citizens and companies and first of all the provision of public services and information access to final users. [2]

A list of 20 basic public services that cover different interactions of the public sector with citizens and businesses was presented by European Commission. Citizens are the recipient of twelve services, while companies are the target group of eight of them. All these services should be delivered through the Internet.

In Poland one can distinguish four stages of evolution of e-government [7]:

1. Presence – the authorities site is present in the Internet. It usually provides general information and it is sometimes described as "brochure ware".

2. Interaction – Internet site provides detailed information about procedures concerning questioning matter. Forms to download and links to other relevant sites are also available.

3. Two-way communication – allows communication between government officials and citizens via e-mail and interactive forms. It offers website search capabilities and often enables the access to information online, but requires a visit to a government office in order to complete the task.

4. Transaction – enables to conduct and complete entire tasks online. The user can send back filled forms signing them with the electronic signature. In Poland, realization of this stage is possible using electronic inbox (Elektroniczna Skrzynka Podawcza) or "e-interesant" system that requires however the visit to a government office. The full functionality of this stage includes online paying for taxes or fees.

Some authors present more advanced stages of e-government [2]:

– Integration – all government information and services, both local and national, are integrated on one website. Citizens can be assessed for tax through a single portal.

– Participation – website provides online services, such as online voting. The high level security and privacy have to be ensured.

2.3. PREVIOUS RESEARCH

Most of the recently conducted research on the local government websites have concerned communes' websites. Their methods of evaluation often adopted the Website Attribute Evaluation System (WAES) that use a set of criteria connected with websites' transparency and interactivity. Originally, the binary scale was applied because this method is checking whether the criteria are fulfilled, not to what extent.

In 2007 the research "Interactive commune" was conducted [4]. It involved 169 Lower Silesian communes' websites and was based on Nielsen's idea of usability. The ideal commune's website was worked out and serve as a model for comparison. Eight groups of criteria were analysed and most of the criteria were rated on a three-point scale. Investigated websites got good and very good notes in the areas: technical (loading time, way of presenting in most popular Web browsers), functional aspects (search engine optimization, clear and correct language), and web navigation. The worst notes were got by criteria like: presence of the information about website's author and interactivity of the website (online forms and forms for downloading). This research was repeated the next year and gave similar results.

In 2010 Marketing Agency "Wizerunek" conducted the research that involved 311 districts' websites. One took into consideration: transparency, accessibility and functionality of the webpage, its content, presentation of contact data and online marketing activity. Clearness of the domain name and presentation in popular browsers were the strong points of the websites. It was also easy to find contact data, but only general ones. Phone numbers and e-mail addresses of officials usually weren't available, as well as contact data to the website's administrator (this information appeared only on half of the websites). Moreover, on 80% of analysed websites there was no map that could show the route to the office. The lack of foreign-language versions of the districts' websites concerned half of the analysed websites. Moreover, only 6% of websites offered facilitations for people with bad eyesight. [1]

Basic functionality of the districts' websites were assessed as satisfactory – most of them made available the website search engine and links to related websites. However only a quarter of districts' websites had online forms that could facilitate the contact. The forms for downloading were accessible only on one third of websites. Marketing aspects weren't assessed high – slogans that could advertising tourists or investors were occasional, but what was worse, it was often difficult to find important information for these groups of users. [1]

According to the results of research, the best districts' websites came from Wielkopolskie, Warmińsko-mazurskie, Świętokrzyskie and Kujawsko-pomorskie voivodeships, however surprisingly the website of Milicki district won the title of the best website.

3. METHOD OF THE RESEARCH

The research took place in August 2011 and its subject were 26 websites of Lower Silesia district towns. In fact the voivodeship includes 29 districts but cities with county rights (Wrocław, Jelenia Góra, Legnica) weren't taken into consideration (see Fig. 1).

A modified WAES method was applied in the research. 18 criteria grouped into four areas (e-government, accessibility and clarity, content, new forms of activity and additional facilitations) were used. Most criteria were rated on a four point scale (from 0 to 3), only in some cases the extended scale was applied. The research areas and evaluation criteria are listed in Table 1.

Fig. 1. Districts of Lower Silesia [6]

Four stages of possible development of e-government were described on 2.2 section. In the area "Accessibility and clarity of website" the InternetSupervision.com tool was used for website speed evaluation. It enables to determine average loading time for each website. This time is calculated on the basis of the results taken from seven sites located all over the world. Validity of markup was tested using W3C Markup Validation Service. It checks the markup validity of Web documents in HTML, XHTML, etc. While analysing elements of website navigation one took into consideration the presence of the search engine for the website and the website map. The most subjective criterion was the website appearance where the colours, typography and menu layout were assessed.

In the "Content" area one took into account foreign-language versions of website (number of versions and their level of extensiveness). It was also important whether the website was updated regularly, contained the topical issues and presented information clearly. One examined not only information available to tourists, citizens and business but also the way and place of its featuring (searching is easier when they are gathered together).

Table 1. Research areas and evaluation criteria. Own study based on [5]

Research areas	Evaluation criteria
E-government	Stage I Stage II Stage III Stage IV
Accessibility and clarity	Search engine optimization Clearness of the domain name Loading time Markup validity Elements of navigation Appearance of website
Content	Foreign-language versions Presentation of text (topicality and clarity) Information for citizens Information for tourists Information for business
New forms of activity and additional facilitations	Presence on social networks Additional information channels Facilitations in text processing

The area "New forms of activity and additional facilitations" contained only three criteria. First of them concerned presence of the district on social networks (Facebook, Nasza Klasa, Twitter) that may attract many visitors. Electronic information bulletins, municipal sms services and rss channels gave their users opportunity of being kept up to date with the most important events. Facilitations in text processing were designed for users who weren't able to read standard size fonts (usually they could magnify the text or listen to it).

4. RESEARCH RESULTS

The points received by websites in each of the four analysed areas were summed. The highest results (77%) was achieved by the website of wrocławski district. Next places were taken by zgorzelecki and legnicki districts that achieved 66% and 64,5%

respectively. The last place in the ranking was taken by the website of lwówiecki district that got only 21% of points. The results of all analysed districts' websites are presented on the Figure 2.

The "e-government" area could give 14 point maximally, but only seven webpages exceeded threshold of 50%. The highest result was achieved by wrocławski district (86%). It is worth mentioning that the fourth stage of e-government was achieved by as many as 50% of analysed districts' websites.
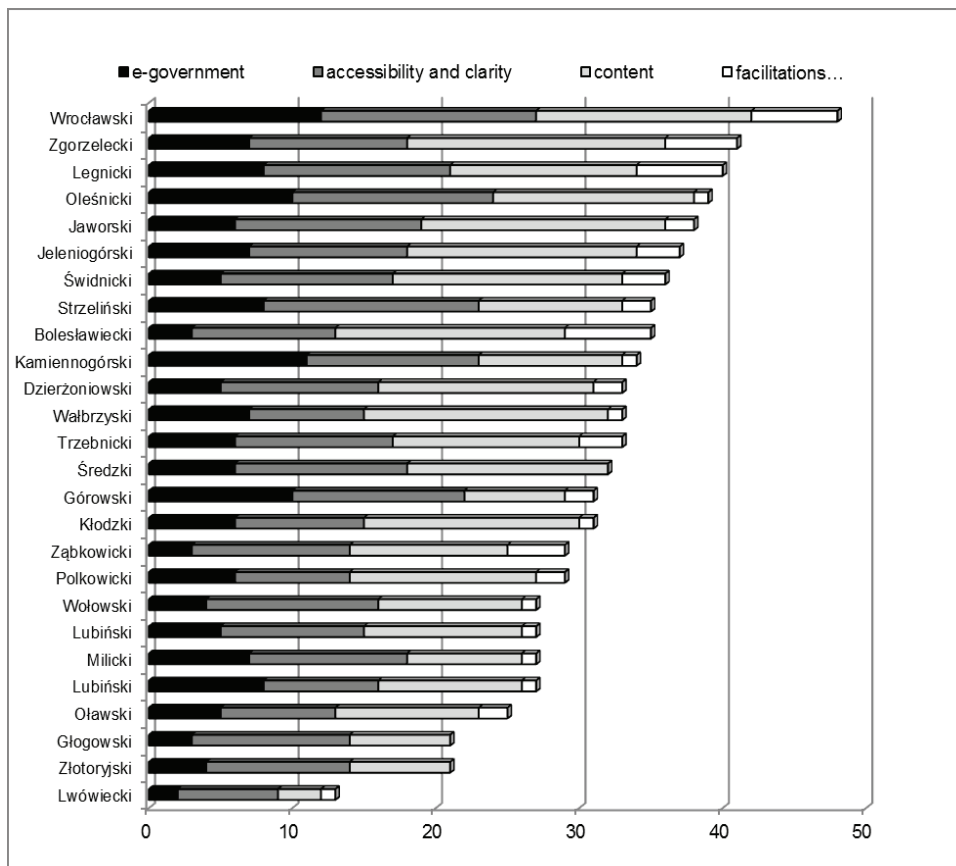
Fig. 2. Number of points received by each website in each analyzed area.
Own study based on [5]

In the area „Accessibility and clarity" no website achieved maximal number of points, but only one website (of lwówiecki district) got less than 50%. Moreover, four of the best websites (wrocławski, legnicki, oleśnicki and strzeliński districts) achieved 88 or more per cent of the maximal result.

The maximal note for area "Content" came to 24 points [5]. The best results were achieved by website of zgorzelecki district (18 points), jaworski and wałbrzyski districts (both 17 points). It should be remembered that it isn't enough to prepare interesting and often updated content. If the information weren't presented appropriately, the users may haven't possibility to find and read them.

In the case of „New forms of activity and additional facilitations" the highest result – 6 points that gave 67% of maximum result – was achieved by websites of wrocławski, legnicki and bolesławiecki districts. The authors of these websites took great care over the realization of all three elements that were assessed in this area.

On the Figure 3 the percentages of maximal results achieved by each website in each analyzed area are presented. As it can be seen the area "Accessibility and clarity" came out best – the average result exceeded 68% and in addition ten websites got at least 3/4 of maximum result. Second place was occupied by the area of "Content", however the average number of points hardly exceeded 50%. In addition only five websites got at least two thirds of maximal result. The average result in area of "e-government" reached 45%. It came out surprisingly well (in comparison with general notion on this subject), but in fact as much as 15 websites (58%) achieved less than half of points and six of them (23%) less than one third of points.
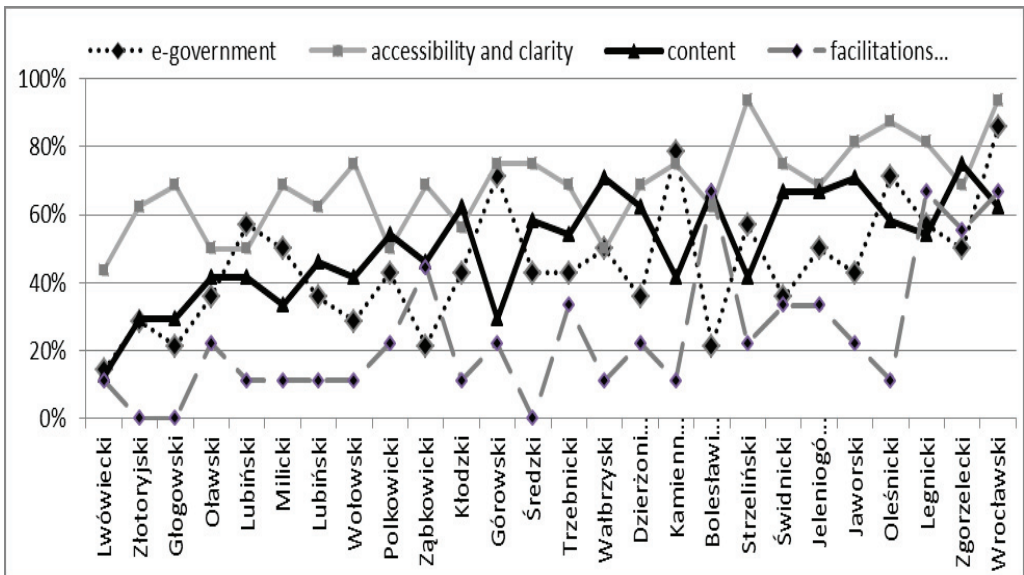
Fig. 3. Percentages of maximal results achieved by each website in each analyzed area.
Own study based on [5]

The lower results were achieved in the area "New forms of activity and additional facilitations" – the average result didn't even exceed 25% (it amounted to 24,5%). Three websites got no points and 19 subsequent didn't achieved half of points. On the Figure 4 the percentage of maximal number of points received by each criterion is presented. The only criterion that was completely fulfilled by all the websites was "Search engine optimization". Most of the analysed websites had also clear domains' names (86,6%) and met the standards of first stage of e-government development (76,6%). The criteria like information for tourists, citizens and business received only about half of points so it is still a lot to do on this subject. The most important element that should be taken into consideration are unquestionably the foreign-language versions of websites. As many as ten of them (38,5%) didn't contain any foreign-language information).
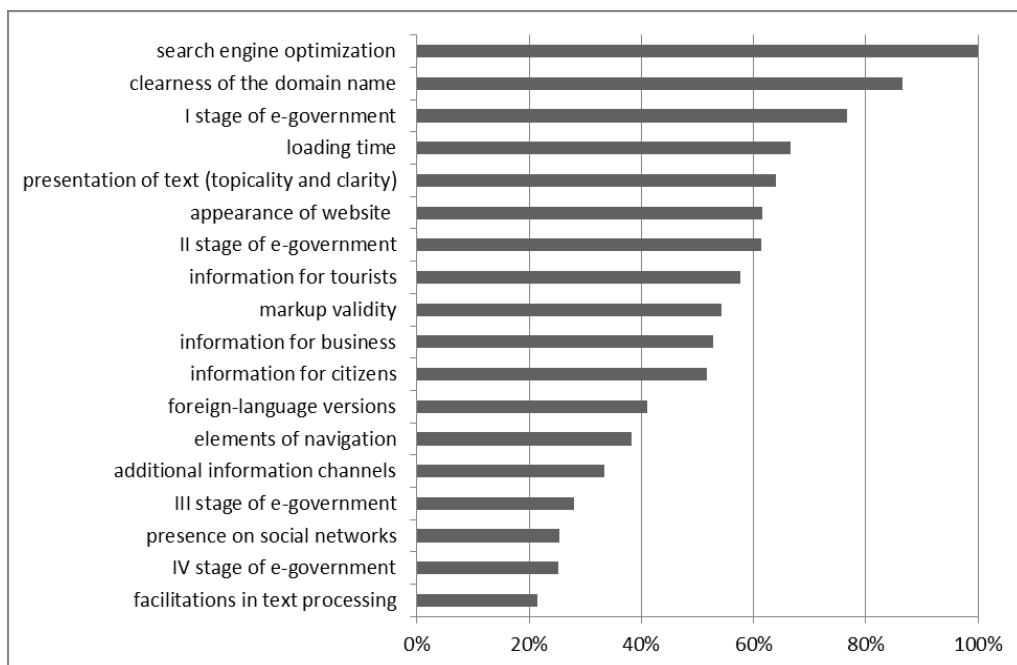
Fig. 4. Percentages of maximal results achieved by each criterion.
Own study based on [5]

Aside from two most advanced stages of e-government development the lowest results were achieved by all the criteria that were included in the last area "New forms of activity and additional facilitations". It may indicate that the responsible for the websites still underestimated new ways of promotion and staying in touch with users.

5. CONCLUSION

According to the results of the research the best website has obtained only ¾ of the maximal points. The results of four subsequent websites were visibly lower – they obtained between 66 and 61 per cent, moreover 38% of analysed websites has got less than half of points. These results indicate that it is still many to improve. The short-comings are particularly visible in the field of "New forms of activity and additional facilitations" and "e-government". However, the ranking of the districts' websites doesn't change significantly when these areas aren't taken into account. Only three websites go up at least five places.

The results of the research concerning Lower Silesia districts' websites are in accordance with the results of nationwide research that have been described on section 2.3 and other research concerning communes' websites. The worst notes have got the elements that could help the elderly people and these with bad eyesight to use a website.

The Lower Silesia districts' websites merit the moderate note. Not all the local governments know how to make good use of the chances given by the Internet. The most surprising is that they underestimate the power of social networks and aren't in a hurry of being present on them. Moreover the advantages of having the foreign-language versions of the website are neglected.

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Marcin RELICH*

FAILED PROJECT PROTOTYPING WITH THE APPLICATION OF CONSTRAINT PROGRAMMING

Constraint Programming (CP) is an emergent software technology for declarative description and effective solving of large combinatorial problems. In that context, CP can be considered as an appropriate framework for development of decision making software supporting scheduling of projects that are at risk of failure. The paper deals with project prototyping problem for alternative completion of a failed project. The presented reference model contains the fields of a project management and an enterprise which implements projects. This paper aims to describe the functionalities of both these fields in terms of constraint satisfaction problems and then to implement them in CP languages. An example concerning IT project implementation is used to illustrate the possibility of this approach.

1. INTRODUCTION

In spite of an incremental development of project management methods, the implementation of complex projects still remains a challenge for their managers. Many studies have found that project failures are still very common. For instance, the Independent Evaluation Group claimed that 39% of World Bank projects were unsuccessful in 2010 [3]. In turn, only 32% of information system projects succeed (delivered on time, on budget, with required features and functions) according to a Standish Group study [10]. It is estimated that around 44% of information system projects partially fail with time and/or cost overruns and/or other problems. Around 24% of information system projects are total failures and abandoned [1].

Every project and organization is unique. As a result, the work of a project is non-routine, and therefore risky [11]. The high rate of failure of projects can also be considered from this perspective. As projects are inherently uncertain, they are prone to

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unexpected events. Hence, there is a need to develop a tool that is able to rescue a failed project. If the project is in trouble, but not yet a disaster, the project manager can be supported by a task-oriented decision support system that seeks an alternative variant of project completion.

The results of research indicate very strongly that the version of project management depends on the characteristics of a company. For instance, small to medium enterprises require less bureaucratic forms of project management than those used by larger, traditional organizations [12]. This implies to consider project management in connection with the nature of the enterprise. Hence, there is a need to build a reference model that combines both these fields. Moreover, the single reference model results from limitations of project management software that among methods, methodologies, tools or techniques, was reported the highest number of times [14]. The most frequently described drawbacks of project management software indicate that it is inadequate for complex projects, as well as unable to model the 'real world' and holistic approach without difficulty. This is also a reason to build reference model that can be treated as a single knowledge base containing the fields of enterprise and project management. The considered model can be formulated in terms of a so-called constraint satisfaction problem that contains a set of variables, their domains, and constraints. This descriptive approach enables an effective implementation of the model in constraint programming languages, and a development of a task-oriented decision support system.

The paper is organised as follows. Section 2 presents a reference model that encompasses the characteristics of an enterprise and project management that then in terms of the constraint satisfaction problem is formulated. A method for obtaining alternative variants of projects is shown in section 3. An illustrative example of the approach, which presents a possibility of decision problem specification in a straight and in a reverse way, is presented in section 4. Finally conclusions and future research are presented in section 5.

2. PROBLEM STATEMENT OF PROJECT PROTOTYPING

The emergence of the systems approach to management has had a significant influence on organizational theory and management philosophies [4]. An organization considered as a system can be distinguished, among other things, as a subsystem connected with information, finance, as well as manufacturing, sales, marketing, procurement, human resources, accounting, etc. These subsystems can consist of other subsystems. For instance, the information subsystem can contain operating and decision-making information subsystems. The enterprise activity is also determined as its environment containing e.g. competitors, client, sub-contractors, and availability of resources.

The enterprise systems include such functions as resource control, decision making, sales and cost planning, employee motivating. These functions can be considered as a chain of processes, and are further called the functionalities. The execution of the functionalities depends on the enterprise characteristics and its environment. For instance, cost planning uses information about a number of client's orders, and price of required resources (in connection with their availability).

In the same way, it is also possible to consider project management that according to the Project Management Institute consists of nine areas of management: time, cost, quality, procurement, communications, risk, scope, human resource, and integration [7]. Also other classifications of project management occur in literature [11]. Nevertheless, each of the fields includes the successive elements that can be considered as the functionalities of project management. For instance, cost management consists of estimating costs, budgeting costs, controlling costs in a project [7].

The enterprise functionalities do not contain all functionalities of project management. For instance, the functionalities concerning project management include feasibility study and estimation of activity duration. In turn, enterprise management contains functionalities that do not occur in project management, e.g. sales planning and inventory controlling. The functionalities from both these fields can be described by a set of variables. In turn, the variables can be interrelated by occurring between their relationships, which link these variables and limit their domains. Some similar functionalities, such as cost planning, can occur in the enterprise as well as in project management, but they can be described by another set of variables. In the enterprise, cost planning takes into consideration costs which are not connected with the project e.g. advertising costs. In turn, cost planning for a project can contain monetary penalties that are usually imposed on projects when deadlines are exceeded.

The fields concerning an enterprise and project management can be combined by the constraints, e.g. the financial means in an enterprise should be greater than project budget. So, the reference model contains a set of variables and relationships that link and limit these variables. The relationships (constraints) combine the decision variables describing the capacity of an enterprise as well as these connected with project execution. For instance, the number of enterprise employees limits the time of project implementation. Consequently, the fulfilment of assumed constraints enables project execution within the enterprise according to the requirements.

The presented model can be described as a set of decision variables, their domains, and the constraints. Hence, it seems natural to classify some decision problems in terms of the constraint satisfaction problem (CSP). A considered approach is specified by constraints of reference model, and it enables a simplified description of an actuality. The description encompasses the assumptions of an enterprise, implementing therein projects, and a set of routine queries (the instances of decision

problems) that in framework of CSP are formulated [2]. The structure of constraint satisfaction problem may be described as follows [9]: CSP = $((V, D), C)$, where: $V = \{v_1, v_2, ..., v_n\}$ – a finite set of n variables, $D = \{d_1, d_2, ..., d_n\}$ – a finite set of n domains of variables, $C = \{c_1, c_2, ..., c_m\}$ – a finite set of m constraints limiting and linking variables.

The hierarchical structure of reference model implies a similar structure concerning the constraint satisfaction problem. The reference model can be described as single CSP that consists of CSP_1 and CSP_2 concerning a field of enterprise and project management, respectively. In turn, CSP_1 and CSP_2 contains successive elements describing the functionalities of different fields (CSP_{11}, ..., CSP_{1n} and CSP_{21}, ..., CSP_{2n}).

The hierarchical and open structure of declarative model combines both fields: functionalities containing management system of an enterprise and project that in the enterprise is executed. These separate fields as the constraint satisfaction problem are formulated, and then in single main CSP are unified. On the other hand, the problem can decompose into the subproblems concerning the functionalities of separate fields.

CSP according to the structure of the reference model is implemented, and as knowledge base can be also considered. The knowledge base is a platform for queries formulation as well as answers obtaining, and it comprises of facts and rules that specify the system's properties and relations between its different parts. As a consequence, single knowledge base facilitates an implementation of a decision support system.

A knowledge base can be considered in terms of a system. At the input of the system are the variables concerning basic characteristics of an object that are known and given by the user. For instance, the variables concerning available resources in the enterprise and an order of project activities. The output of the system is described by the characteristics of the object that are unknown or are only partially known. In the considered case, the variables can be connected with the cost and time of an activity as well as usage of resources. A distinction of decision variables, which are embedded in knowledge base, as an input-output variable is formed by arbitrary judgment, and it permits to formulate two classes of standard routine queries:

– in a straight way, i.e. corresponding to the question: what results from premises? (e.g. does a given allocation of resources ensure a schedule that does not exceed the given deadline?)

– in a reverse way, i.e. corresponding to the question: what implies conclusion? (e.g. what values of variables ensure a project completion by given constraints?)

The above categories encompass the different reasoning perspectives, i.e. deductive and abductive ones. The method concerning the determination of admissible solutions for the above-described problem is presented in next section.

3. METHOD FOR OBTAINING FEASIBLE VARIANTS
OF FAILED PROJECT

A method is dedicated for a class of problems, so it is formed according to an assumed model and question, which implies a type of problem. In case of a considered project prototyping problem, the method consists of following stages:

1) verification of a problem solution for assumed constraints, that is a seeking of project schedule (a straight way); if the constraints concerning a project (time, cost) are not fulfilled, then there is assumed that the project is at risk of failure and next stage is done;

2) seeking of values for decision variables (e.g. connected with resource reallocation in the enterprise) that fulfilled the assumed project constraints (a reverse way);

3) if there is a set of solutions, then a optimal variant of alternative project completion is chosen according to an assumed judgement criterion.

The planning issue and then the successive monitoring of the project, is one of the most important elements of project management that determines its success or failure [4]. If the planning indicates an overrun of constraint (e.g. target cost), and there are no possibilities to increase the constraint (e.g. by gaining the additional financial means, contract renegotiation), then to seek a set of feasible solution, a decision variable is chosen. This choice depends on a considered problem, so factors connected with the project (its size, density, life cycle, uniqueness of activities, urgency), and availability of resources. An assumed assessment criterion can concern e.g. time and/or cost minimisation as well as project quality maximisation (e.g. the quality can be considered as fulfilment of all project activities, obtaining assumed goals).

As an example illustrating the concept of the proposed approach, the functionality concerning cost and time planning is chosen. Analysis of differences between planned and actual value is known as earned value management, and it is a useful tool for cost management [6, 11]. In the proposed approach, monitoring costs and activity performance, as well as re-planning a project completion (with regards to schedule, resource usage) follows in time unit h (e.g. daily, weekly interval). The actual cost concerns a partial project performance (solid line), a trajectory of planned cost for current variant, and an exemplary alternative variant of project completion (dashed line) is presented in Fig. 1.

If planned total cost of project is greater than assumed financial constraint (current variant), then an alternative variant is sought that fulfils the assumed time and cost constraints. The alternative variant is one of feasible solutions, which according to an assumed criterion is chosen. The number of elements in a solution set depends on e.g. order of activities and time horizon, and in consequence on slack time as well as an availability of financial means for an alternative project completion.
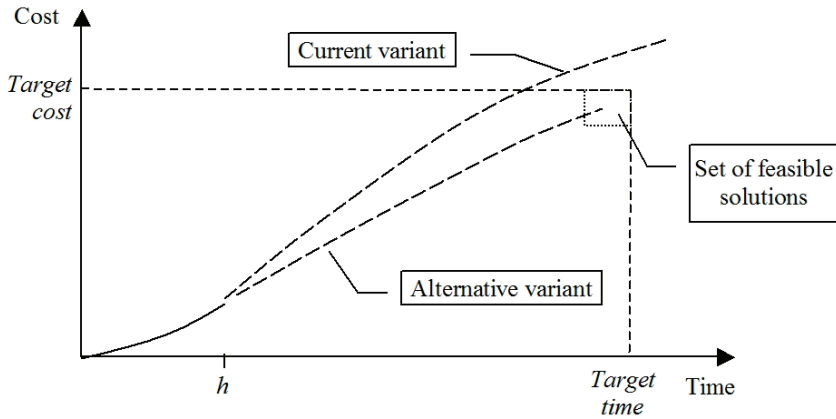
Fig. 1. Prototyping of project at risk of failure

The assumed model enables descriptive approach to the problem statement, encompasses constraint satisfaction problem structure and then it allows to implement the considered problem in the constraint programming (CP) environment. CP is an emergent software technology for declarative description CSP and can be considered as a pertinent framework for development of decision support system software aims. A CSP can always be solved with brute force search. All possible values of all variables are enumerated and each is checked to see whether it is a solution. However, for many intractable problems, the number of candidates is usually too large to enumerate them all. CP has developed some ways (constraint propagation and variable distribution) to solve CSPs that greatly reduce the amount of search needed. This is sufficient to solve many practical problems (e.g. further considered scheduling). CP is qualitatively different from the other programming paradigms, in terms of declarative, object-oriented, and concurrent programming. Compared to these paradigms, constraint programming is much closer to the ideal of declarative programming: to say what we want without saying how to achieve it [13].

The seeking of feasible solutions for a reverse way is connected with verification an available change for values of variables, constraints, and/or assessment criterion. For instance, they can contain a gaining of new resources for execution of critical project activities, and resource reallocation between a few of ongoing projects. In this case, the rescuing of failed project follows without any changes concerning a project management triangle (i.e. constraints contain time, cost and scope – sequence of activities). An example concerning the considered problem described in the constraint programming environment is presented in next section.

4. ILLUSTRATIVE EXAMPLES

The above presented reference model, as well as CSP has concerned a general case that allows describing any type of project in any enterprise. The general case is thereinafter limited to the medium service enterprises, which implement software projects. The example aims to illustrate a possibility of a formulation of project prototyping problem in term of CSP. In the next subsections, a decision problem in the straight and reverse way is formulated, using constraint programming techniques.

4.1. ROUTINE QUERIES FORMULATED IN THE STRAIGHT WAY

The project concerns ERP (enterprise resource planning) system implementation in a commerce enterprise. In client's enterprise, some stand-alone systems work, but they have limited functionalities. Client has set the project completion at 9 weeks (360 working hours – time horizon $H = \{0, 1, .., 360\}$), by budget equals 100 monetary units (m.u.).

The project consists of seven activities: 1. analysis of business processes and information system in the client company; 2. analysis of IT systems, database structure in the client company; new software installing, initial configuration and testing; 3. customisation of standard software setting according to the business processes and client requirements; 4. customisation according to the untypical client requirements; 5. formulating a procedure of data migration, from previous software database to new one; 6. final configuration and testing software; 7. users training.

The activity network diagram for considered project $P = \{A_1, ..., A_7\}$ is presented in Fig. 2. Duration of project activities are determined by using past experiences as follows: $T = (50, 20, 40, 70, 20, 20, 120)$. The exemplary approaches concerning the estimation of the time of project tasks have been described e.g. in [5, 8]. The constraints according to the activity network of the project are following: C_1: $s_3 \geq s_1 + t_1$, C_2: $s_3 \geq s_2 + t_2$, C_3: $s_4 \geq s_1 + t_1$, C_4: $s_4 \geq s_2 + t_2$, C_5: $s_5 \geq s_3 + t_3$, C_6: $s_6 \geq s_4 + t_4$, C_7: $s_6 \geq s_5 + t_5$, C_8: $s_7 \geq s_6 + t_6$.
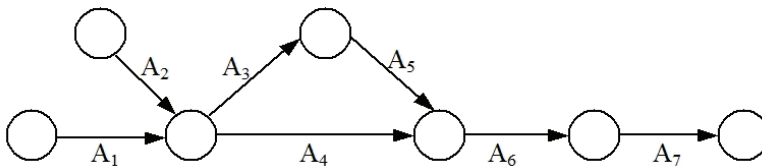

Fig. 2. Activity network of project

The implementation of considered activities requires a participation in project team, the members that are responsible for new software installing and its customisation according to the client requirements as well as users training. It is assumed that programmer can work by activities A_2–A_6, in turn consultant by activities A_1 and A_7. In this case, most activities are critical, and total time equals 320 working hours. Moreover, it is assumed that project members can work independently and parallel, and a number of employees, that can execute an activity, is known.

If the project has a slack time, then a variant of schedule is chosen according to a criterion concerning minimisation of team members and cost (their salaries). The planned time of project completion equals 320 working hours, so time constraint is fulfilled. The software company delegates to the project two employees: a programmer and consultant. Thus, a sequence concerning the number of employees (resource $dp_{1,j}$) for j-th activity is as follows: $Dp_1 = (1, 1, 1, 1, 1, 1, 1)$. Standard rate for consultant equals 0.2 m.u. per hour, in turn for programmer 0.3 m.u. per hour. In this case, the number of financial means (resource $dp_{2,j}$) allocated to j-th activity is following: $Dp_2 = (10, 6, 12, 21, 6, 6, 24)$. Total planned cost of the project equals 85 m.u., so cost constraint is also fulfilled.

The considered problem belongs to the class of "straight" ones, and it reduces to the following question: is there, and if so, what is a schedule that fulfils all constraints? An answer to the question is connected with determination of the starting time of the activity s_j, where $0 \leq s_j < 360$; $j = 1, 2, ..., 7$. The *CSP*-based reference model has been implemented in Oz Mozart. For considered constraints, a set of feasible solutions is searched that have fulfilled all constraints imposed by an enterprise capability and project requirements. A sequence of activity starting time for first admissible solution is following: $S = (0, 0, 50, 90, 160, 180, 200)$.

The project monitoring at the end of a fortnight of project execution indicates that activities A_1 and A_2 was completed in planned time. In turn, the activity A_3 after 80 hours is done in half. Re-estimating indicates that the duration of activity A_3 increases to 60 hours, and A_4 to 100 hours. As a result, the sequences of activity duration and its cost are following: $T = (50, 20, 60, 100, 20, 20, 120)$, $Dp_2 = (10, 6, 18, 30, 6, 6, 24)$. The rest of values of decision variables, their domains as well as the assumed constraints (e.g. sequence of activities, required total time of project) have not been changed. The planned time of project completion increases to 370 working hours, and it exceeds the deadline required by the client. In this case, the set of admissible solutions is empty, i.e. there is no schedule fulfils all assumed constraints. Thus, there is still a possibility to reformulate the considered problem by stating it in a reverse way, i.e. the way aimed at searching for decision variables (e.g. reallocation of resources) ensuring that the completion time of the considered project will not exceed the assumed deadline H. Such case is considered in next subsection.

4.2. ROUTINE QUERIES FORMULATED IN THE REVERSE WAY

In the straight way, the minimal number of employees assigned to the project is assumed as a criterion of an optimal variant choice. If for the straight way the time constraint is not fulfilled, then there is sought such allocation of enterprise resources that enables to complete the project in required time. It is assumed the same activity network, domains of decision variables, and the constraints as in previous subsection, for the straight way.

Taking into account above-mentioned assumptions, the considered problem can be reduced to the question: are the required resources in the enterprise, and if so, what their allocation ensures that completion time of the project does not exceed the deadline H and the cost? The response to this question is connected with setting of sequences concerning the number of assigned to the project employees (Dp_1), its cost (Dp_2), and starting time of activity (S).

The enterprise can additionally delegate at most one employee: consultant or programmer. The second programmer can work at the activities A_3 and A_5, the second consultant – activity A_7. The employees can independently and parallel implement an activity. The sequences of assigned to the project employees are as follows: $Dp_{1,1} = (1, 1, 2, 1, 1, 1, 1)$, $Dp_{1,2} = (1, 1, 2, 1, 2, 1, 1)$, $Dp_{1,3} = (1, 1, 1, 1, 2, 1, 1)$, $Dp_{1,4} = (1, 1, 1, 1, 1, 1, 2)$. Planned total time of project completion for these variants equals 355, 345, 360 and 330 working hours, respectively. The generated variants can be evaluated according to such criteria as, for example, time of project completion. In the case of different rate per hour among employees belong to the same group (e.g. programmers), the choice of optimal variant can also take into account the cost criterion.

5. CONCLUSIONS

Rapidly changing expectations related to supporting strategic decisions as well as aiming to reduce cost, result in the need to build a task-oriented decision support system. An efficient implementation, development, and updating of this system implies to formulate single knowledge base that results with a reference model of project prototyping. The proposed reference model encompasses the field of enterprise and project management. These fields, in terms of constraint satisfaction problems can be described that include the sets of decision variables, their domains, and constraints, which link and limit these variables. The hierarchical and open structure of model enables to solve the decision problems with different level of specificity. The decision problems can contain a query about the results of proposed decisions as well as the decisions ensuring the expected results.

Constraint satisfaction problem can be implemented in the constraint programming environment. Since a constraint can be treated as a logical relation among several variables, each one taking a value in a given (usually discrete) domain, the idea of constraint programming is to solve problems by stating the requirements (constraints) that specify a problem at hand, and then finding a solution satisfying all the constraints. Because of its declarative nature, it is particularly useful for applications where it is enough to state what has to be solved instead of how to solve it.

The advantage of the proposed approach is at least double. First, there is the description of enterprise and project management in terms of single knowledge base. This facilitates using of constraint programming to build a decision support system. Second, the decision support system seeks a set of feasible variants for project completion. This is especially attractive by lack of a possibility for continuing the project in its original form and it can support the managers for making a decision about a completion or abandonment of a project at risk of failure.

Further research focuses on the presentation of the reference model for the project prototyping problem, when some decision variables in an imprecise form are described. Moreover, further research can be aimed at developing task-oriented searching strategies, implementation of which could interface a decision maker with a user-friendly intelligent support system.

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PART 2

MATHEMATICAL MODEL
AND ITS APPLICATIONS
IN DECISION SUPPORT SYSTEMS

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EXPERIENCE BASED ENHANCED DECISION SUPPORT FOR BUSINESS PROCESSES

Business Process Management(BPM) as a holistic management is one of the most promising approaches to management in general, it introduces business modeling for value chains and mapping all inputs and outputs those exist in an organization. The Process model contains tasks, events, activities and gateways connected together to describe the business and provide insights how things are done. Modern information technology(IT) tools can support this process in various areas. This paper focus on decision nodes how they are described and supported by BPM IT tools and how the decision support could be enhanced using additional mechanism that will base on formal experience record.

1. INTRODUCTION

1.1. BUSINESS PROCESS MANAGEMENT

Business Process Management (BPM) has emerged as a comprehensive consolidation of disciplines sharing the belief that a process-centered approach leads to substantial improvements in both performance and compliance of a system. Apart from productivity gains, BPM has the power to innovate and continuously transform businesses and entire cross-organizational value chains. The paradigm of "process thinking" is by no means an invention of the last two decades but had already been postulated by early economists such as Adam Smith or engineers such as Frederick Taylor [1].

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The idea of "process thinking" is an old one and has been evaluated over time from work simplification paradigms such as Quality Control, Six Sigma, and Lean methodologies. Part of its origins is also related to Business Management and Information Technology (Figure 1).
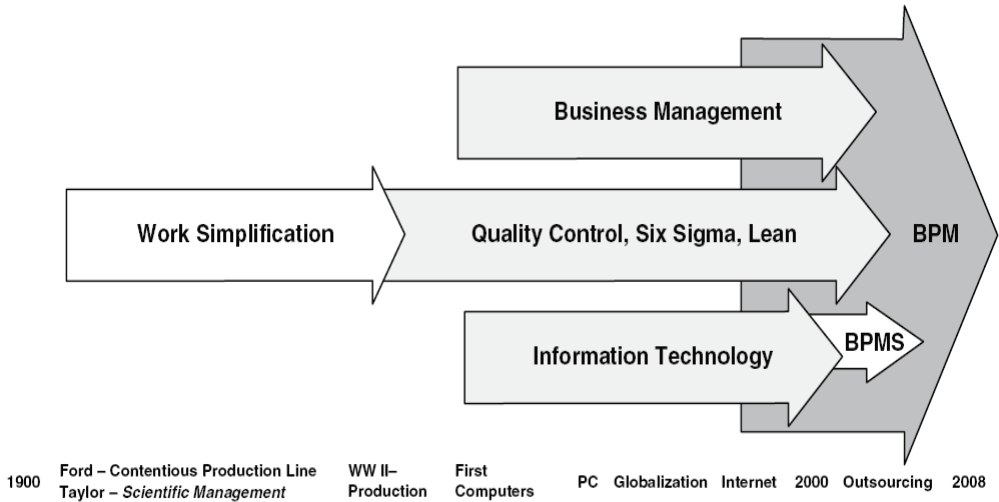
Fig. 1. The Evolution of "process thinking"[2]

The "process thinking" approach became very important in the following three main areas. First, in project management [3]. Second, in Total Quality Management (TQM), SixSigma and Lean approaches. And third, in Information Technology (IT) related areas such as Service Oriented Architecture, Enterprise Service Bus, and the Process Engine.

1.2. MAIN CONCEPTS OF BPM

The most important concept in BPM is a process. The main part of all process definitions in literature is that there is a chain of activities or transformations and it is about the dynamics of how things are done or happen. There is no commitment for that the process must be somehow defined. A business process corresponds to business domain, but depending on the approach the definitions vary.

Some popular process definitions can be provided as follows:
1. The business process or business method is a collection of related, structured activities or tasks that produce a specific service or product (serve a particular goal) for a particular customer or customers [4]

2. The business process is a series of steps designed to produce a product or service. Most processes are cross-functional, spanning the "white space" between the boxes on the organization chart. Some processes result in a product or service that is received by an organization's external customer. We call these primary processes. Other processes produce products that are invisible to the external customer but essential to the effective management of the business. We call these support processes [5].

3. The business process is a series of activities occurring within a company that lead to a specific end. Most often, the business process focuses on meeting the needs of the customer and delivering a good or service that will fulfill that need. In many cases, the business process is actually a collection of interrelated processes that function in a logical sequence to achieve the ultimate goal [6].

In other words, business processes refers to all processes in organization directly or indirectly, it crosses an organization in many ways, but still has some sequence of activities and interactions with other processes.

Business Process Modeling is a way of describing business processes. This approach assumes a formal notation for describing processes in such way that processes may be analyzed and improved. The history of modeling techniques is quite long starting from Gantt charts around 1899 through flow charts in the 1920s, Functional Flow Block Diagram and Program Evaluation and Review Technique (PERT) in 1957, Data Flow Diagrams and Integration Definition (IDEF) in the 1970s [7]. The modern methods are Unified Modeling Language(UML) and Business Process Modeling Notation (BPMN). The UML comes from software development domain, and BPMN is a notation for business analysts. The important differentiator is that UML can be used for process approach and that BPMN is dedicated to such approach.

Business process management is a field of management focused on aligning organizations with the needs of clients. It is a holistic management approach that promotes business effectiveness and efficiency while striving for innovation, flexibility and integration with technology [8]. In other words it is a business management approach that focuses on business process with information technologies matters paradigm. Integrated with IT tools and technologies, BPM is the enabler of implementation, measure, execution and simulation the business processes and could be considered as main differentiator from SixSigma and Lean approaches. The other perspectives are incorporated from former "process thinking" approaches.

1.3. BUSINESS DECISIONS IN BPM

A business decision is a fragment of business process and also can be modeled in business process notation. The mapping could vary; the simplest case is modeling

business decision as a gateway a node that controls the process flow accordingly to fulfilled conditions. There are many types of gateways (Table 1.)

Table 1. Basic gateways types for BPMN 2.0 [9]

◇	Exclusive Gateway – without Marker. Basic OR flow control, sufficient for YES/NO business decisions.
◈(X)	Exclusive Gateway – with Marker. Basic OR flow control, sufficient for YES/NO business decisions.
◈(O)	Inclusive Gateway. Executes all paths where condition is met. This gateway may map a business decision that performs multiple choices like M of N depending on conditions.
◈(+)	Parallel Gateway, always joins or forks in the flow, can be useful in modeling business decision process.
◈(*)	Complex Gateway, contains user defined behavior defined internally for complex synchronization, could be useful where any other type of gateway does not fit.
◈(◎)	Event-Based Gateway, is similar to exclusive gateway, but action is triggered by an event not the flow.
◈(⬠)	Event-Based Gateway to Start a Process, this can be useful for modeling decision that is a starting point in a process.
◈(⊕)	Parallel Event-Based Gateway to Start a Process, this can be useful for modeling decision that is a starting point in a process.

In fact modeling business decision as a single gateway is appropriate only if we want to treat decision as immediate automatic action executed by computer with more or less complicated logic. In this case there are ready to use solution that allows separating the logic from process model. The system class that is responsible for defining, managing and executing complex decision logic is called Business Rules Management System (BRMS) [10]. The integration between BPM tool and BRMS is already recommended by Service Oriented Architecture (SOA) design patterns i.e. "Rules centralization" pattern for reusing a specific logic in many services or processes[11]. From business process model perspective it is using a name for business rule instead of describing or implementing the logic. In BPRM the

logic is defined in a domain specific language, unfortunately there is no common standard for defining business logic. The crucial functionality is ability to implement decision trees, based on if-then conditions. Business logic can be refer both to internal and external databases, which is a standard for automated application scoring evaluation in banking. This evaluation will consider internal bank data about the customer as well as external information from organizations like Biuro Informacji Kredytowej S.A. which contains information about customer credit history in all polish banks [12]. BPMN 2.0 offers special activity task for lunching an evaluation of business rule called a rule task (Figure 2.)
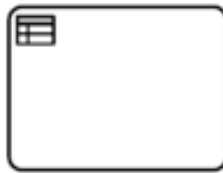
Fig. 2. Business rule task

Sometimes a decision is the main outcome of a process and model should contain all steps that are taken to achieve it, especially when the task related to decision are performed by different roles in an organization. In this case we model decisions task in the same way as other human related activates including subprocesses and gateways. In fact we treat the decision flow in the same way as any other work flow.
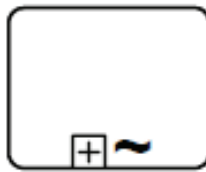
Fig. 3. Ad-Hoc subprocess

Some decision are made in hard to define way or there is no purpose for defining this stage, for example brain storming technique by definition is in free form and anybody can add his idea on the first stage, and then evaluated. In theory it can be also defined by BPMN 2.0 using an event for each new idea and then evaluating, but there is also another way for expressing such situation as ad-hoc subproc-

ess. It can be useful for decisions that are made in different ways especially including collective thinking and other factors hard to model like informal influences, intuition etc. By definition ad hoc subprocess is a collection of activities without a prescribed order or flow (Figure 3).

2. EXPERIENCE BASED DECISION SUPPORT

2.1. EXPERIENCE DECISION SUPPORT MECHANISM

The idea for experience based decision support system is to use formal decision event record for a decision support. A decision event is every instance of historical decision and with a help of formal notation like Set of experience knowledge structure (SOEKS) [13]. The notations allows catching main factors that are related to decision like constrains, variables, functions and rules. This knowledge structure is designed to externalize experience and make it explicate and shareable. The decision support system based on experience will be similar in assumptions to case base reasoning, both basis on decision repetitiveness. In other words the same case form past school has similar output to current one, but this assumption is critical to any experience applicability. For evaluating business logic the decision support system can not only measure distance between current and past situation, but also evaluate past rules and compare constrains.

2.2. KEY DIFFERENTIATORS

There are already decision support system used in BPM, but what is the difference between BRMS and this approach? We can extend this comparison by adding case based reasoning which is not a standard solution for decision support in BPM.

This comparison should be done multidimensional (Table 2).

Another aspect is how fast those decision support methods can be adjusted. In other words how fast can organization learn from current experience and how fast can introduce a change. The business rules will need an expert to define or change them, the change is may affect many processes that shares the same logic, so there must be some control and quality assurance mechanism in place, probably it must be approved by some organizational unit. In case based reasoning we can distinguish two mechanisms for adaptation, first one is fully automated when a case is processed it feeds the database and may be (accordingly to case selection mechanism) took in consideration in next decision event. The second change will include changes to distance function or changes to case selection mechanism and that will also require full change control mechanism. SOEKS based decision support has also

two nature, one related to routine adding a new experience record which can be automatic similar to case based reasoning and the second related to distance functions that matches previous experience with current decision events which probably requires change control mechanism. Single experience record besides values also contains rules, constrains and function that may require human verification on the second hand. So business rule change is the most ad hoc and manual in nature and case based reasoning is the most automatic approach to adopting the change. It will have impact on efficiency of change (Figure 4). In general the most digitized and automated process the fastest changes.

Table 2. Feature comparison between business rules,
case reasoning and SOEKS decision support

	Business rules	Case base reasoning	SOEKS decision support
Readability	Explicit "If then" constructions.	Sophisticated distance functions.	Explicit "If then" constructions, supported by distance functions for variables, decisions limited by explicit constrains
Source of knowledge/data	Provided by group of experts	Gathered from IT system audit logs	Provided by decision maker and gathered from IT system audit logs
Logic portability/ knowledge preservation	Well defined rules are portable not only between processes but also between enterprises	High tactic correlation to current process definition in an enterprises, even small changes in process definition could invalidate gathered case database	Decision events are grouped in larger chunks, that could be adjusted to changes in a processes or even shared with other enterprises
Business Process modeling integration	As decision node, gateway or subprocess. Approach supported by modeling tools	As custom logic in decision nodes, gateways or subprocesses. Not supported by modeling tools.	As custom logic in decision nodes, gateways or subprocesses. Not supported by modeling tools.

Finally those decision support mechanism vary in governance techniques and maturity level. Business rules can be stored in relatively small databases and governance mechanism will include versioning of changes, and could also provide some analysis tools enabling visualization, simulation etc. BRMS is an established and mature class of software commercial. Case based reasoning is not as popular as business rules or supported for general purposes, there are domain specific sys-

tems that use this kind of decision support. Case management basis on data-warehouse mechanisms, and in general particular cases are not modified, they are only marked with appropriate score or removed from repository. For data analysis there are used data mining techniques, but due to high tacit correlation to business process and excess amount of data it is hard to generalize decision logic for a single case. SOEKS based decision support has its first implementations and there is a tool for managing experience records called Decisional DNA Manager [15]. The governance techniques should contain both known form business rule decision support for SOEKS rules, constrains and functions and warehouse methods for large number of similar experience records. In fact rules, constrains and functions in experience record can be on the same general level as business rules with their application points in this case decision nodes or subprocesses in process model, but also can be unique specific for particular decision event. On another hand variables in SOEKS will contain only a subset of process audit data, which influences the decision.
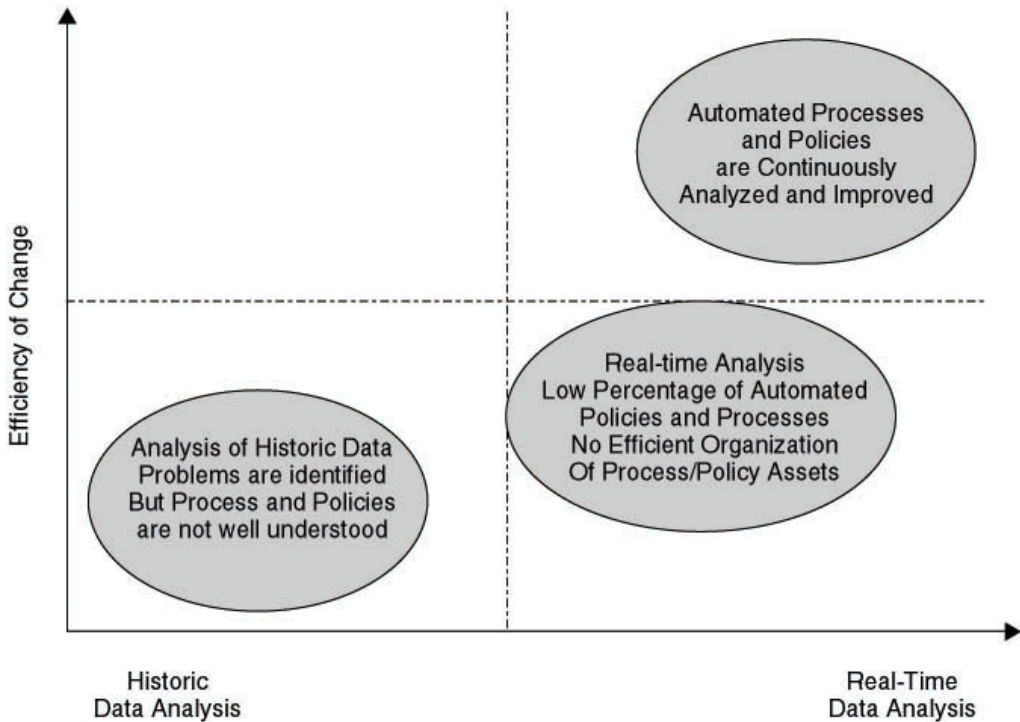
Fig. 4. Data analysis versus efficiency of change [14]

3. SUMMARY

SOEKS based decision support mechanism implemented with BPM could be an attractive alternative to business rules or case based reasoning. In fact it is somewhere between those two techniques. The similarities in data between SOEKS and case data, allow for faster adaptation to changes then expert driven business rules. It can be critical for fast changing environments where it is important to follow current trends. The ability of persisting rules, constrains and function that defines decision event in similar way to business rules deployed in a business process allow for further generalization and externalization for knowledge sharing. There are also drawbacks like lack of support for this kind of decision support in modeling tools, especially in term of process simulation where both SOEKS and case based reasoning must be limited to calculated values. The SOEKS decision support will also require special governance, which should be on regular basis as other operations, it introduces additional roles to an organization and cannot be fully automated. The choice of proper decision support will be always depended on the nature of particular decision point, but it is good to have another choice like SOEKS based decision support that potentially can mitigate the drawbacks of other decision support mechanisms.

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POLISH ENTERPRISES' FINANCIAL STRUCTURE MODELS AS A PART OF BUSINESS INTELLIGENCE SYSTEMS

Running and continuing a business is not possible without suitable information, especially in financial area. Hence appears here a question, how manage the company on a basis of filtered economic data. On this question try to answer Business Intelligence solutions. In this field we consider financial structure indicators and their influence on firms' market value. We adopted this approach because, if we choose the right value indicators we will be able to improve wisely our company valuation. We can say, that this issue becomes nowadays very essential, especially in time of world economic crisis. Because of mentioned argumentation, for this article we have performed analyses on a group of Polish joint stock companies. The goal of our research was to build models, which will be useful as a tool in existing or new Business Intelligence systems. In research there was used a sophisticated statistical, simulating and uncertainty analysis software Decision Tools Suite (from Palisade company). Thanks to this tool it was possible to use a multidimensional approach to identified relations, which were analyzed with use of statistical and forecasting methods.

1. INTRODUCTION

Commonly in theory as well as in practice of the area of firm's financial management, it is assumed that it is possible to increase the value of enterprises thanks to competent management of their capital structure (see more in [6], [9] and [12]).

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Here, most common is an approach, according to which optimization of the company's valuation is possible by rational creation of the debt level (at simultaneous usage of positive effects of the tax shield and avoidance of the negative influence of exaggerated costs of outranges debt) [4] and [12]). According to the described attempt, many models of financial structure management were formulated and they have been incorporated into various Business Intelligence systems. Most of mentioned models are planted in developed countries economies (mainly Great Britain, the USA and Japan) as well as in the environment of their capital markets. Although these models are marked by a great verifiability in market conditions of countries, in which they were created [14] and [4], it isn't possible to say, that they will be also verifiable in case of Polish enterprises (and, that they will be useful for Polish companies as part of complex Business Intelligence systems). This is connected with the completely different specificity of the domestic capital market, which history of functioning is relatively shorter, and the tradition of free market principles isn't so strengthened as in case of developed countries.

Because of mentioned issue there has been started analyses which are aiming at gaining a complex financial structure model, which will be useful for Polish enterprises as a part of existing or new Business Intelligence systems. It is assumed that such BI model should significantly help managers to make the right decisions (in area of choosing suitable financial resources for company). Moreover such model, implemented in BI system should give company new source of managerial knowledge, which will be effectively used and further managed (creating some kind of companies memory in field of financial management).

2. BUSINESS INTELLIGENCE MODELS IN ENTERPRISES

As we know from literature [see in: 2, p. 1] Business Intelligence (BI) term is not directly defined. In simple words we can say, that it describes and defines all data from company in a way of capturing, accessing, understanding and analyzing to bring it into action and to improve business performance.

In fact BI systems make it available to analyze huge amount of business information in order to support and improve decisions made by top enterprise's management. They transform the data from many different company's systems (e.g. ERP systems), and give managers systematized information (much further good BI systems crate repository of managerial knowledge about an organization).

BI systems provide managers analysis and reporting at various levels of the organization, which enable them to make better decisions [8]. And it is proved empirically that BI systems really have positive influence on firm's performance [see more

in 5]. Thanks to mainly complex approach to company's data, which is uniformly transformed, analyzed and reported.

On the basis of functionality and usability of BI systems there has been performed an economic research in a field of optimizing a value of companies with the decision of changing its financial structure. This study and built models (thanks to results of study) are a basis for creating or improving existing Business Intelligence Systems (of many manufactures such as: SAP, Microsoft, IBM, SAGE and others) , especially in the area of companies financial and strategic management.

3. THE SPECIFICITY OF POLISH CAPITAL MARKET

Capital markets, in which conditions models for western (developed) countries are being built, are characterized by an exceptional stability and strengthened principles of free market, which are dated at the 18th century. Here important is also a fact of the possibility of uninterrupted activity and capital accumulation by western enterprises over many decades. These factors determine the significant dissimilarity of conditions for the functioning of polish enterprises in global economy, in particular, when we will put it together with historic and economic background of Polish companies operation.

In Poland years from the 18th century till the end of the World War I, are practically a period of lack of the national autonomy [10, pp. 98–148, 176–179 and 214]. In turn the interwar period (1919–1939), is the time of only 20 years of the new formed statehood and rules of the free market. However an outbreak of the World War II is a time of another liquidation of the Polish statehood. Even recovering the independence in 1945 [Ibid., pp. 394–418, 434–440 and 483–448] is the beginning of the period, in which there wasn't space for private companies and rules of the free capital market. Only after 1989 we may speak of Polish free economy. This year it is said as the beginning of current Polish capitalism.

And so from the general analysis we can see clearly, that that so and not different term capital structure of Polish enterprises[1] in some way is a result of indicated above factors. Especially it is consequence of relatively shorter period of functioning of the free market economy in Poland and indirectly it is an outcome of the significant level

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[1] Most of Polish companies are using much more short term debt in their financial structure instead of long term debt. But as it is known (not only from literature) short term liabilities are rather more dangerous for enterprises, because of their radically quick chargeability, which even might be financed from fixed assets (and their sale can may a bankruptcy of certain company).

of historical economic backwardness's, which successively were made up by past 23 years. However it seems that the Polish economy in considerable degree is still in some kind of a phase preceding the level of developed states' economies, especially when we take into account Polish GDP level [19, p. 12–13] and domestic rate of innovation [11].

4. STATISTICAL AND ECONOMETRICAL MODELING OF POLISH COMPANIES FINANCIAL STRUCTURE MANAGEMENT

Only after describing the specific determinants of the Polish economy and after drawing its general position in relation to developed countries economies, it is possible to deal with detailed analysis of the chosen sample of Polish enterprises, in the context of creating for them specified BI models of managing their financial structure.

The aim of conducted analyses was to determine the BI models of relationship between the structure of financial resources and market value of analyzed firms. Such an approach results from universal in the financial literature point of view, according to which main objective of enterprise's operations should be the maximization of its market value in the long time horizon ([3, pp. 21–28] and [17, pp. 30–32]). Therefore in conducted analysis, was adopted an criterion, according to which the identification of the way of companies financing is their financial structure impact on their market evaluation. Such an approach is also consistent with the idea of BI systems, which on this basis could give managers synthesized information about companies' financial condition.

4.1. RESEARCH SAMPLE

For the examination were chosen 90 Polish nonfinancial stock companies, listed in the constant system on the Warsaw Stock Exchange at least from 2001. Years 2001–2010 were a period of conducted analysis. De facto 10 trade groups, from which individual companies were chosen for further analyses, were taken to the examination. Research sample determined in this way, is a group of practically over a half of nonfinancial companies, which are listed in the constant system on the Warsaw Stock Exchange from 2001 (at present it is almost one fourth of all companies of the basic Polish stock market). The conducted examination is based on data coming from financial statements of analyzed companies and from their stock exchange rating.

4.2. CHOSEN INDICATORS OF THE FINANCIAL STRUCTURE
AND THE MARKET VALUE OF ANALYZED COMPANIES

Based on gathered data was prepared a numerical representation of both the financial structure and the market value of analyzed companies. For the representation of firm's structure of financing, the following ratios were chosen [15, pp. 89–93]:

- ratio No. 1 (wsk.1): equity to assets ratio,
- ratio No. 2 (wsk.2): ratio of covering liabilities with cash flow,
- ratio No. 3 (wsk.3): debt to assets ratio,
- ratio No. 4 (wsk.4): long-term debt to equity ratio,
- ratio No. 5 (wsk.5): fixed assets to constant capitals ratio,
- ratio No. 6 (wsk.6): interest coverage ratio of foreign capital (TIE),
- ratio No. 7 (wsk.7): debt coverage ratio,
- ratio No. 8 (wsk.8): time structure of debt ratio,
- ratio No. 9 (wsk.9): debt to equity ratio.

However in order to describe the market value of analyzed companies a parametric measure, the *Q* Tobina ratio was used, define with the following pattern[2]:

$$q = \frac{V_M}{A_M} = \frac{MVA_E}{A} = \frac{MV_E - IE}{A} = \frac{pN - IE}{A} \tag{1}$$

where:
V_m – company's market value, A_M – market value of assets, MVA_E – Market Value Added (for shareholders), A – book value of assets, MV_E – Market Value of Equity, IE – value of equity invested in a company, p – current shares price, N – amount of shares.

4.3. THE DIVISION OF THE RESEARCH SAMPLE
INTO GROUPS OF COMPANIES

Because of received for all companies values of *Q* Tobina, the research sample was divided in 7 following groups:

- 1st group: which 6 companies registering mainly negative q Tobina values,
- 2nd group: 29 companies, which *q* Tobina values are in the range [0; 0.5],
- 3rd group: 13 companies, which *q* Tobina values are in the range [0.5; 0.7],
- 4th group: 17 companies, which *q* Tobina values are in the range [0.7; 1),
- 5th group: 9 companies, which *q* Tobina values are in the range [1; 1.2),

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[2] Own elaboration on the basis of the literature of the subject: [7, p. 6] and [20, p. 156].

- 6th group: 10 companies, which q Tobina values are in the range [1.2; 1.8),
- 7th group: 6 companies, which q Tobina values are in the range [1.8; $+\infty$).

Above described division results from considerable discrepancies in levels of the Q Tobina ratio for individual companies. These discrepancy constitute the crucial factor preventing the correct analysis of relation between rates of the financial structure and parametric representatives of the market value of studied firms. Separation of individual groups took place based on the changeability of the Q Tobina value.

4.4. MULTIFACTORIAL REGRESSION
AS CHOSEN RESEARCH METHOD

In the final analysis multifactorial regression (stepwise method) was used for verification of the connection between financial structure and market value of examined companies. In the purpose of assessing the influence of all structure indicators on the Q Tobina rate, there was performed estimation and the statistical verification of preliminary built models. At firs the regression models was built for all 9 indicators of the financial structure. Next by way of elimination, on the basis of received F-Snedecor and the t-Student statistics and on base of appropriate confidence intervals [1] a number of indicators was being reduced in (previous) preliminary model, to the moment in which received values of above statistics have indicated that should be rejected the hypothesis of the insignificance of coefficients of the model (both for individual coefficient of the financial structure indicators and for free term of model's equation). For every group analyses of the multifactorial regression were conducted, according to the presented above general outline, with use of statistical software StatTools belonging to the package of the Decision Tools Suite – version 5.7.

4.5. RESULTS OF CONDUCTED ANALYSES
OF THE REGRESSION

In this place only results of the regression for 1st, 2nd, 3rd, 5th and 6th group will be introduced. For 4th and 7th group there wasn't found statistical essential regression models and that's why the results for these two groups won't be presented.

For the 1st group of companies a Figure No. 1 is showing outcomes of conducted empirical analyses, computed with StatTools. It was possible to receive the statistically significant model for this group (all indicators of possible regression equation are essential according to statistics), but we couldn't say that it would be useful in practice, because of its huge level of standard error of the estimation.

StatTools Report

	Analysis:	Regression
	Performed By:	PWr
	Date:	14 april 2012
	Updating:	Static
	Variable:	Gr.1.śr.Q Tob.

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate		
	0,6546	0,4284	0,3570	4,075005317		

ANOVA Table	Degrees of Freedom	Sum of Squares	Mean of Squares	F-Ratio	p-Value	
Explained	1	99,58424154	99,58424154	5,9970	0,0400	
Unexplained	8	132,8453466	16,60566833			

Regression Table	Coefficient	Standard Error	t-Value	p-Value	Confidence Interval 90% Lower	Upper
Constant	3,475263165	1,391040424	2,4983	0,0370	0,888556674	6,061969656
Gr.1.śr.wsk.7	18,72274782	7,645439526	2,4489	0,0400	4,505685754	32,93980989

Fig. 1. Final report of the regression for the 1st group of companies (Source: own study)

StatTools Report

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate		
	0,9913	0,9826	0,9687	0,077846147		

ANOVA Table	Degrees of Freedom	Sum of Squares	Mean of Squares	F-Ratio	p-Value	
Explained	4	1,710208125	0,427552031	70,5529	0,0001	
Unexplained	5	0,030300113	0,006060023			

Regression Table	Coefficient	Standard Error	t-Value	p-Value	Confidence Interval 90% Lower	Upper
Constant	0,151625731	0,0419196	3,6171	0,0153	0,067155709	0,236095752
Śr.wsk.2	0,278126994	0,049100496	5,6644	0,0024	0,179187119	0,377066869
Śr.wsk.6	0,000833783	0,000627618	1,3285	0,2414	-0,000430897	0,002098463
Śr.wsk.7	1,772667779	0,456007527	3,8874	0,0116	0,853790554	2,691545004
Śr.wsk.8	0,130380408	0,011142973	11,7007	< 0.0001	0,107926779	0,152834038

Fig. 2. Final report of the regression for the 2nd group of companies (Source: own study)

In similar way was achieved results for the rest of groups. For the 2nd group a Figure No. 2 is showing received results. Received for this model standard error of the estimation is pointing at the good correctness of the result in the relation to the data structure.

For the 3rd, 5th and 6th group of companies the figures 3rd , 4th and 5th are showing received results of conducted analyses.

First we analyze the outcomes for the 3rd group. Standard error of the estimation at 0.04603, received for this group is pointing at the correctness of the achieved model, especially in the relation to the data structure.

StatTools Report

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate		
	0,9960	0,9919	0,9855	0,046032379		
ANOVA Table	Degrees of Freedom	Sum of Squares	Mean of Squares	F-Ratio	p-Value	
Explained	4	1,303081048	0,325770262	153,7392	< 0.0001	
Unexplained	5	0,010594899	0,00211898			
Regression Table	Coefficient	Standard Error	t-Value	p-Value	Confidence Interval 90% Lower	Upper
Constant	0,257377264	0,031034395	8,2933	0,0004	0,194841457	0,319913071
Gr.3.śr.wsk.2	0,195868747	0,019777254	9,9037	0,0002	0,156016623	0,235720871
Gr.3.śr.wsk.6	0,000819851	0,000361122	2,2703	0,0724	9,21722E-05	0,00154753
Gr.3.śr.wsk.7	0,820003012	0,272111113	3,0135	0,0296	0,271685957	1,368320067
Gr.3.śr.wsk.8	0,118971611	0,00681189	17,4653	< 0.0001	0,105245322	0,1326979

Fig. 3. Final report of the regression for the 3rd group of companies (Source: own study)

Next we analyze results for the 5th group. Standard error of the estimation at 0.35151 for this group model is also demonstrating the correctness of fitting to the data structure. That's why we should consider this model as useful in further analysis.

StatTools Report

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate		
	0,8437	0,7119	0,6759	0,315148971		
ANOVA Table	Degrees of Freedom	Sum of Squares	Mean of Squares	F-Ratio	p-Value	
Explained	1	1,96305496	1,96305496	19,7652	0,0022	
Unexplained	8	0,79455099	0,099318874			
Regression Table	Coefficient	Standard Error	t-Value	p-Value	Confidence Interval 90% Lower	Upper
Constant	0,370810815	0,173898088	2,1323	0,0656	0,047438967	0,694182663
Gr.5.śr.wsk.8	3,32111323	0,747021921	4,4458	0,0022	1,931990082	4,710236377

Fig. 4. Final report of the regression for the 5th group of companies (Source: own study)

And of course for the 6th group it should be said that achieved final model of linear regression is taking fitting to the data structure into account. Results for this group is showing Figure No. 5.

StatTools Report

Analysis: Regression				
Performed By: PWr				
Date: 14 april 2012				
Updating: Static				
Variable: Gr.6.śr.Q Tob.				

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate	
	0,7152	0,5116	0,3720	0,485767271	

ANOVA Table	Degrees of Freedom	Sum of Squares	Mean of Squares	F-Ratio	p-Value
Explained	2	1,730108545	0,865054273	3,6660	0,0814
Unexplained	7	1,65178889	0,235969841		

Regression Table	Coefficient	Standard Error	t-Value	p-Value	Confidence Interval 90% Lower	Upper
Constant	0,75802773	0,243968691	**3,1071**	**0,0172**	0,295809867	1,220245592
Gr.6.śr.wsk.2	0,15102544	0,100874876	**1,4972**	**0,1780**	-0,040089943	0,342140822
Gr.6.śr.wsk.7	2,872466842	1,328894794	**2,1615**	**0,0675**	0,354771197	5,390162487

Fig. 5. Final report of the regression for the 6th group of companies (Source: own study)

Received standard error of the estimation at the level 0.48577 for 6th group is showing, that also this model could be useful in further analysis.

4.6. CONCLUSION FROM CONDUCTED ANALYSES

As it can be seen from presented above StatTools reports, in all statistically significant models following ratios of the financial structure are appearing: ratio No. 2 (wsk.2) – ratio of covering liabilities with the cash flow, ratio No. 6 (wsk.6) – interest coverage ratio of foreign capital (TIE), ratio No. 7 (wsk.7) – debt coverage ratio, ratio No. 8 (wsk.8) – debt term structure ratio.

What is worth noticing, that in case of models for 2nd and 3rd group, there appears exactly all indicators mentioned above. In turn in models for 1st, 5th and 6th group at least one of ratios mentioned above of the financial structure appears.

Achieved results may indicate, that in case of above mentioned groups of companies (1st, 2nd, 3rd, 5th, 6th) the certain aspects of financial structure management are generally the most important. Firstly firms in these groups are aiming in securing the repayment of debts from the cash flow (this it is suggesting quite high rate of covering liabilities with the cash flow ratio in models). Secondly they aspire to current paying off interest on the debt (according to the appearance in the model of interest coverage from debt ratio). Thirdly they keep the sufficient level of the operating profit, essential

to cover installments and interests on the debt (the appearance of debt coverage ratio is pointing out this conclusion). And finally they monitor the timely repayment of the debt (this shows us the appearance of the debt term structure ratio).

Of course according to received results not all of above mentioned aspects of the financial structure are equally important in all groups of companies. In case of 5th group the most important seems to be monitoring of debt timely aspect, but for 6th group essential are aspiration to paying off interest on the debt and keeping the sufficient level of the operating profit (to cover debts and its interests).

Achieved results may finally point out, that in case of analyzed companies above indicators are one from the most important, used for rational financial structure management.

5. CONCLUSIONS

According to results of conducted regression analysis it should be stated that, they are pointing at multifactorial character of the influence of the financial structure on the market value of analyzed companies and this characteristic should be implemented into BI systems. Moreover achieved outcomes seem partly to confirm certain general assumptions of the contemporary approach to the financial structure management. Strictly, according to the group of models from dynamic area [4, pp. 235–261] the debt is often treated as the rare fund, which optimal utility is connected with having a so called free liallibities capacity, for future, big and sudden financial needs (related to specific process of conducted or planned investments). On the compliance of received results with this approach points out an appearance of debt coverage ratio in almost every computed models, while covering liabilities with the cash flow ratio and interest coverage ratio (of debt) in the rest of models. These financial indicators seem to confirm, that for analyzed companies aiming to repayment debts is important goal in financial structure management. In this way targeting to quick pay back of liabilities may be connected with need and intention to have free debt capacity.

Such a significant aspiration to debts repayment may be also associated with the policy of reducing financial risks of operations in Polish companies. It is noticed in sample both for ones too high levered, and those that want to avoid the sudden disorders of activity in relation to keeping too many short-term debts. Such an attempt to fast debt repayment may be very important, particularly in period of the global financial crisis [16, p. 1], in which might appear considerable problems with impelling contractors to "rolling" their trade credits, which were taken by companies.

We should finally underline, that received "preliminary" models, may be helpful in building comprehensive financial structure management BI model, which should be implemented into existing or new BI systems. Achieved solution will be directed for Polish companies, and it would be really helpful for Chief Financial Officers in efficient managing their companies' business.

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AN EXAMPLE OF
THE FUZZY INTERNET MORTGAGE
MARKET SUB-MODELS IMPLEMENTATION

The paper is the next step of research presented in the previous publications. showing the complete process of building and verifying sub-models for the internet mortgage market. The sub-models are described for three market situations, i.e. stable market, crisis, and boom. The paper presents the process of verification of sub-model no. 2 (crisis) as an example of the verification process that was applied. The paper concludes with directions for further research in this area leading to the ultimate application of the proposed model in a real life prognosis process.

1. INTRODUCTION

The paper deals with the fast growing part of market: services in the Internet, basing on the example of the Polish Internet Mortgage Market [8]. This market consists of 4 main stages starting from the top: banks are institutions that sell mortgage and offer the option to apply for it on their own web pages. Because the market is very substantial in size and is characterised by strong competition, banks allow their partners to sell their financial products on the partners' pages to generate more sold products. These companies are typical brokers that receive the commission for every product that they sell [10]. They promote and sell banks' products on their pages but they also create a network called "partner system" which allows the owners of small web pages to sell the products of the banks on their own pages. The owners of private web pages do not sell enough products to cooperate directly with banks, which is the reason for their association with brokers. For each product sold on a partner

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web page, its owner receives commission from the broker, who in turn gets his from the bank. [1].

Different participants of the market are represented on each level. On the first there are banks, the second – brokers, level 3 consists of Partner web pages. Customers make up the lowest level.

The main challenge of the strategic nature for this briefly described market is making accurate predictions about the number of sold mortgages, especially in the part of mortgages sold by web partners. Due to the fact that there are several variables of different nature (quantitative and qualitative) influencing the market, traditional statistical methods can't be used here because they don't work properly.

Variables in "hard" mathematics take numerical values, while in "soft" fuzzy logic applications the non-numeric linguistic variables are often used to facilitate the expression of rules and facts [2]. This is an important modelin aspect in this case where a number of variables such as for example "current market feelings" can't be expressed numerically. As stated in [3] the complete description of a real life system often would require far more detailed data than a human being could ever comprehend simultaneously, process, and understand. To address the above challenge a dedicated rule based fuzzy model for predicting the number of sold mortgages using web partners is proposed and developed. The proposed model is described in the sections that follow.

2. THE PROCESS OF MODEL DEVELOPMENT
AND MODEL'S STRUCTURE

To deal with the problem existing on the market a dedicated tool was supposed to be created. In the previous works several steps were made and the most important will be presented.

First the rule based model was created. The model, which was developed and embedded in times of fast growing period of market and economy, did not work properly in the times of financial crisis that came later, so it was necessary to introduce some changes to this model. This need triggered the idea of proposing sub-models that could account for different market situations.

2.1. THE FIRST MODELING GENERALIZATION: RULE BASED MODEL

The first version of rule based model was created in the year 2008, and was based on the Internet mortgage market experience of one of the authors encompassing the period of 2003–2008. As such it represented market conditions from that time period (fast growing market with highly positive prospects for the future).

The model consisted of 240 rules divided into two scenarios: the positive and the negative one. The general production rule in the model looked as below:

Production Rule:

IF variable_1 is value_1 **AND** variable_2 is value_2 **AND** variable_3 is value_3 **AND** variable_4 is value_4 **AND** variable_5 is value_5 **AND** variable_6 is value_6 **THEN** result will increase value_7   (1)

The rule consists of variables and its values presented below:
- Variable_1 = [Commission]
- Variable_2 = [Interest rates]
- Variable_3 = [Advertising]
- Variable_4 = [WIG]
- Variable_5 = [IbnGR]
- Variable_6 = [WNE]
- Result = [Selling mortgage in the Internet]
- Value_1 = [Small, medium, high]
- Value_2 = [Very small, small, medium, high]
- Value_3 = [Very small, small, medium, high, very high]
- Value_4 = [bad, average, good, very good]
- Value_5 = [bad, average, good, very good]
- Value_6 = [very bad, bad, average, good, very good]
- Value_7 = [Very small, small, medium, high, very high] [4]

After analyzing the model it was first decided that there might be problem with correlation of variables in the model. Generally, the pre-defined initial group of 6 variables had unnecessarily strong representation of very general economic indicators which were highly correlated with each other. The correlation was checked and variables in the model were optimized. After dealing with the correlation issue, the problem with market situation came together with the 2008 financial crisis. A worldwide economic situation has changed rapidly and the deep financial disturbance reached the mortgage market. The model, which was developed and embedded in times of fast growing period of market and economy did not work properly in the times of financial crisis that came later, so it was necessary to introduce changes to the developed model.

As the result of the introduced changes, the number of general economic variables was reduced and the final model includes 4 variables as listed below:

- Variable_1 = [Commission]
- Variable_2 = [Interest rates]

- Variable_3 = [Advertising]
- Variable_4 = [WIG – Warsaw Stock Exchange main indicator]

The above variables were represented a proper balance of general economical variables, market expectations, and the point of the view of the owners of partner web pages.

2.2. FUZZY MODEL

The redefined above rule based model did not work as well as expected. The main reason for this was that due to the specific character of the mortgage market there are several variables, which influence o the market, that can't be described by numbers using crisp values needed for hard mathematical modeling. It was necessary to try a different approach and that is why the fuzzy modeling was suggested [7]. The process of building fuzzy model was presented in three steps: fuzzification, fuzzy inference**,** and defuzzification [11].

In the process of fuzzy model development the production rule base, consisting of 81 production rules was used. The number of rules comes from the number of variables (four) in the model and values of these variables (three linguistic values for each variable): $3^4 = 81$ [2].

Each rule in the rule base is developed using the IF... THEN logical construct consisting of four variables as in the following example:

Production Rule:

IF Commission is *small* **AND** Interest rates are *small* **AND** Advertising is *small* **AND** WIG   is *small* **THEN** Selling mortgage in the Internet is   *small*

To develop and train the inference engine for our case the specification of values of output variables for the existing 81 production rules is necessary. As it was not possible to automatically generate the output values, the expert market knowledge was used for this purpose. For defuzzyfiaction the Height Method (also know as Max-membership principle) was used [6]. Finally the fully developed fuzzy model was created and basic tests were made.

2.3. SUB-MODELS

First, as presented in the previous chapter, one general fuzzy model was created; the model which was based on the original idea of developing a single model

to represent the marker reality described in Section 1. The first problems appeared during the process of selecting the variables for the model; it seemed impossible to find variables representing the whole market described by the data from different time periods. In each time period different variables represented the market conditions. Basing on the past results (data from years 2003–2010) one can conclude that that the creation of one comprehensive model does not give proper results, especially when the market changes. Due to this fact it was decided to divide the model into three single sub-models suitable for different market conditions.

Referring to the theory of economic cycles, it was decided to compose the general model of three sub-models representing three main market conditions: fast growing market (boom), recession, and moderate growth, which are the most distinct stages we usually go through in any one economic cycle. As it was important to keep the proper balance between the number of sub-models proposed and the level of differences influencing the market, the three sub-models seem a proper solution.

In the previous publication [9] the description of the three sub-models was presented. Later on the work on implementation and verification started. It took five months to prepare the final sub-models, two of which had to be changed.

Finally the sub-models described below were used:

Sub-model no. 1: Stable market (no changes according to [9])
1. Variable_1 = [Commission]
2. Variable_2 = [Interest rates]
3. Variable_3 = [Advertising]
4. Variable_4 = [WIG]

Sub-model no. 2: Recession
1. Variable_1 = [WIBOR6M]
2. Variable_2 = [Advertising]
3. Variable_4 = [WIG]
4. Variable_5 = [Commission]

Sub-model no. 3: Fast growing market
1. Variable_1 = [Advertising]
2. Variable_2 = [Commission]
3. Variable_3 = [WIG]
4. Variable_4 = [Average_Mortgage_Value]
5. Variable_5 = [Interest rate]

3. MODEL VERIFICATION

While the process of model development was presented in the previous chapter it was necessary to verify the model. The authors decided to divide the model verification into three parts as there were 3 sub-models created for three market situations. For example the process of verification will be presented on the sub-model nr 2 which was chosen because the market situation seems to be similar to current European market conditions. It's verification will be based on the data recorded in the market situation for which the sub-model was designed. Later proper weighting of variables and granulation levels will be added.

The model was verified using dedicated software interface developed in MS Excel (Figure 1). The interface allows for easy changes of the number of variables, weights, and granulation levels.
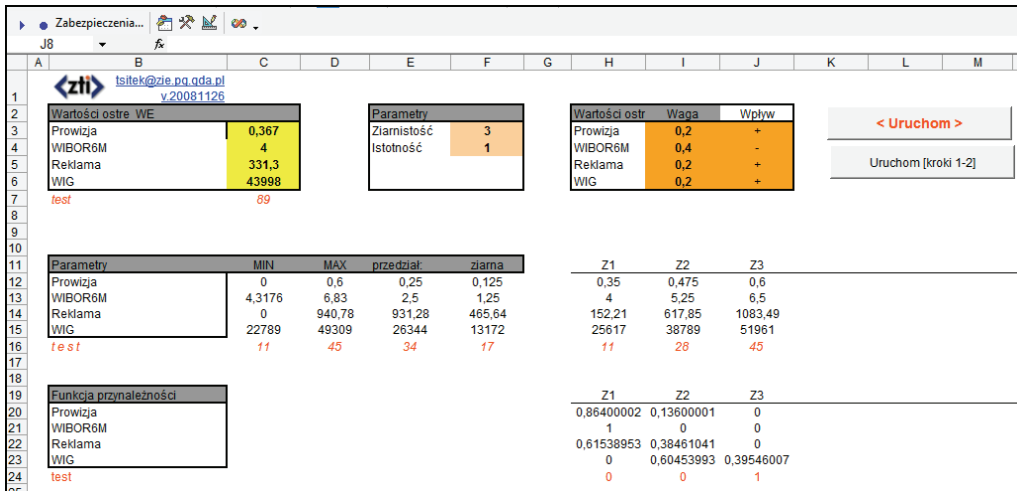
Fig. 1. Dedicated verification interface
for Polish Internet Mortgage Market model verification

Sub-model no. 2: Recession

Sub-model no. 2 is dedicated to the conditions of market in recession. The market situation called "recession" was observed on the Polish mortgage market in the period between the beginning of 2008 till the fourth quarter of 2009 and it will be verified based on the data recorded at that time.

Case 1

In the first case the data from March 2008 were selected (Table 1) to verify the sub-model.

Table 1. Case 1: input data from March 2008

Variable	Value
Commission	**0,55%**
WIBOR6M	**6,3**
Advertisement	**830 PLN**
WIG	**44900**

For the presented input values the three evaluations were made. For the first one, the granulation level was set at 3 and 81 rules were generated. The model produced the output variable (Selling Mortgage in the Internet) 1040,35 PLN, which was 38% lower than the real value recorded at that time (1704 PLN).

The second test was based on the same input variables but the granulation level was set at 4 and 256 rules were generated. The model generated the output variable 1306,29 PLN, which was 23% lower than the real value recorded in that time.

The third test was based on the same input variables but the granulation level was set at 5 and 625 rules were generated. The model gave the output variable 1154 PLN which was 32% lower than the real value.

It can be concluded that the difference on the level around 30% is high, with small differences on different granulation levels. For completeness verification should be also performed based on some other, different input data (Case 2).

Case 2

The data from December 2008 (presented in Table 2) was used in the second case. The methodology of verification was the same as presented in case 1.

Table 2. Case 2: input data from December 2008

Variable	Value
Commission	**0%**
WIBOR6M	**6,42**
Advertisement	**0 PLN**
WIG	**27725 pkt**

Three evaluations were made. For the first one, the granulation level was set at 3 and 81 rules were generated. The model gave the output variable (Selling Mortgage in the Internet) 0 PLN, which was the same as the real value recorded in that time.

The second test used the same input variables but the granulation level was set at 4 and 256 rules were generated. The model generated the output variable 0 PLN, which was the same as the real value recorded in that time.

The third test used the same input variables but the granulation level was set at 5 and 625 rules were generated. The model gave the output variable 0 LN, which was the same as the real value recorded in that time.

Case 2 was chosen for a specific data (real recorded value was 0 PLN) for the recession. Sub-model 2 produces proper results (output value produced by the model is the same as real value recorded in that period) for all granulation levels.

			Prowizja	WIBOR6M	Reklama	WIG		Wartość_Sprzedaży						iloczyn	
		1 | IF	0,864	1	0,61539	0	THEN	Z1						0	
		2 | IF	0,864	1	0,61539	0,60454	THEN	Z2						0,321431804	
		3 | IF	0,864	1	0,61539	0,39546	THEN	Z2						0,21026476	
		4 | IF	0,864	1	0,38461	0	THEN	Z2						0	
		5 | IF	0,864	1	0,38461	0,60454	THEN	Z2						0,200890679	
		6 | IF	0,864	1	0,38461	0,39546	THEN	Z2						0,131412728	
		7 | IF	0,864	1	0	0	THEN	Z2						0	
		8 | IF	0,864	1	0	0,60454	THEN	Z2						0	
		9 | IF	0,864	1	0	0,39546	THEN	Z2						0	
		10 | IF	0,864	0	0,61539	0	THEN	Z1						0	
		11 | IF	0,864	0	0,61539	0,60454	THEN	Z1						0	
		12 | IF	0,864	0	0,61539	0,39546	THEN	Z2						0	
		13 | IF	0,864	0	0,38461	0	THEN	Z1						0	
		14 | IF	0,864	0	0,38461	0,60454	THEN	Z2						0	
		15 | IF	0,864	0	0,38461	0,39546	THEN	Z2						0	
		16 | IF	0,864	0	0	0	THEN	Z2						0	
		17 | IF	0,864	0	0	0,60454	THEN	Z2						0	
		18 | IF	0,864	0	0	0,39546	THEN	Z2						0	
		19 | IF	0,864	0	0,61539	0	THEN	Z1						0	
		20 | IF	0,864	0	0,61539	0,60454	THEN	Z1						0	
		21 | IF	0,864	0	0,61539	0,39546	THEN	Z1						0	
		22 | IF	0,864	0	0,38461	0	THEN	Z1						0	
		23 | IF	0,864	0	0,38461	0,60454	THEN	Z1						0	
		24 | IF	0,864	0	0,38461	0,39546	THEN	Z2						0	
		25 | IF	0,864	0	0	0	THEN	Z1						0	
		26 | IF	0,864	0	0	0,60454	THEN	Z2						0	
		27 | IF	0,864	0	0	0,39546	THEN	Z2						0	
		28 | IF	0,136	1	0,61539	0	THEN	Z2						0	

Fig. 2. Rules generated for the presented data (case 2)

The results received in case 1 tend to be rather bad, especially when these results are compared with that ones that were received in cases 2 which perfectly fits the real results. It seems to be necessary to do the detailed research (including changes in the weights of variables) and add next cases with new data to verify the sub-model.

It should be also stated that in previous researches [12] the verification process of sub-model 3 (fast growing market) was presented. The complete process of verification and changes that were made in the sub-model 3 gave the result on average 9% the difference between prognosis generated by the sub-model and real results.

4. CONCLUSIONS AND FUTURE WORK

Polish Internet Mortgage Market is described in the first part of the paper. Then there are briefly presented the results of the previous works (which were also presented on the previous ISAT conferences) which include rule based model creation and its later fuzzyfication. Following, the idea of sub-models is presented together with the description of its implementation.

The verification process of the model is described with sub-model number 2 chosen for illustration. Basing on the real data the verification was done, one of verification gave proper results the other one was unacceptable. Further research with new cases seems to be necessary as it was done with sub-model 3 were after several works the results were very acceptable (average difference between model prognosis and real values on the level of 10%).

It seems that future research will need to focus on new cases in sub-model 2 and verification of sub-model 1. It is also necessary to create another additional tool that would automatically choose the proper sub-model based on the current market conditions.

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MULTICRITERIA EVALUATION
OF UNIVERSITIES

The paper proposes an approach to multicriteria ranking of universities. One of various methods of linguistic multicriteria evaluation was selected and a set of criteria proposed. The chosen method and criteria were applied to rank three universities: one state university and two private ones. The results of the experiment are given. Basic information about linguistic multicriteria evaluation and fuzzy numbers are also presented.

1. FUZZY NUMBERS AS MODELS OF LINGUISTIC TERMS

In many practical problems, in which non-mathematicians are involved, we face the problem of the need of some quantitative data and the inability of the persons asked to give them. What is worse, very often the data (e.g. scores in questionnaires) are given somehow, because they have to be given, but in fact they do no reflect the true opinions of the persons asked – because these persons find it difficult to express their opinions in numbers, and especially to do this coherently among each other. It is easier for them to use natural language expression. But automatic systems need numerical data for calculation and decision making support. That is why we need a quasi-natural language which will be offered to the persons asked and a translation system of expressing linguistic terms in a mathematical form, possible to be processed by computers.

Fuzzy numbers offer such a translation possibility. Fuzzy numbers [1] can be, to make it as simple as possible, defined as functions, so called membership functions, determined on a set $\mathbf{X}$, being a subset of the set of real numbers. A fuzzy number A is

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linked to a membership function $U(x)$ with the following properties and interpretation: $U(x) \in [0,1]$ for all $x \in \mathbf{X}$ and $U(x)$ expresses to which extent the adjective linked to A, let us denote it *ADJECTIVE(A)*, is true for x. For each A there will exist exactly one *ADJECTIVE(A)*.

We will consider the following fuzzy numbers, defined in the domain [1, 9]:
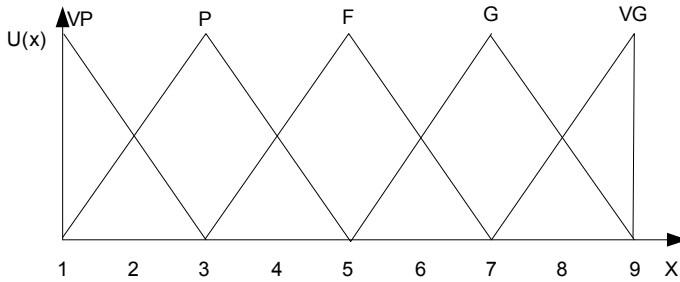
Fig. 1. Fuzzy numbers used in the paper together with their corresponding adjectives
(VP – very poor, P – poor, F – fair, G – good, VG – very good)
and their membership functions ([2])

Thus we will consider five fuzzy numbers: one linked to the adjective "very poor" (VP), with the membership function $U(x)$ such that

$$U(x) = \begin{cases} \dfrac{3-x}{2} & \text{for } x \in [1, 3], \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

Formula (1) means that if and only if an object gets, while being evaluated according to a selected criterion, a grade between 1 and 3, it is (according to the selected criterion) very poor to a certain positive extent. For example, if it gets grade 1, it is very poor to the highest possible degree, i.e. 1, if it gets grade 2, it is very poor to the degree 0.5, but if it gets a grade from interval [3, 9], it is very poor to the zero extent – thus, not at all. The idea is that if the questioned persons do not find it easy to give crisp grades, but prefer to use a natural language, they will be asked to say simply "this is, according to the selected criterion, very poor", and the corresponding algorithm will understand this expression according to (1). Of course, formula (1) is not "taken for heaven", but elaborated by experts in translation between natural language and fuzzy numbers (e.g. [3]) on the basis on a series of experiments. Formula (1) and the corresponding fuzzy number for the adjective "very poor" will be denoted in short as a triple of crisp numbers (1, 1, 3) – this is the usual notation for so called triangular fuzzy numbers.

In an analogous way we assume that the experts have determined the forms of fuzzy numbers, presented in Fig.1, corresponding to adjectives "poor" (P, (1, 3, 5)), "fair" (F, (3, 5, 7)), "good" (G, (5, 7, 9)) and "very good" (VG, (7, 9, 9)). It is easy to notice than an object may be at the same time e.g. poor and fair to some degrees (e.g. if it gets grade 4). That is what the fuzziness consists in: the boundaries between individual notions are not sharp, which is a feature of natural language.

If we have a fuzzy number $(a_1, a_2, a_3)(a_1 \leq a_2 \leq a_3)$, than its multiplication by a crisp number $t > 0$ gives by definition a fuzzy number (ta_1, ta_2, ta_3). The sum of two fuzzy numbers $(a_1, a_2, a_3)(a_1 \leq a_2 \leq a_3)$ and $(b_1, b_2, b_3)(b_1 \leq b_2 \leq b_3)$ gives a fuzzy numbers $(a_1 + b_1, a_2 + b_2, a_3 + b_3)$. The multiplication of fuzzy two numbers is defined analogously ([4]).

A big challenge while dealing with fuzzy numbers is their comparability. Contrary to the crisp numbers, it is not always unequivocal to say which of two fuzzy numbers is to be regarded as bigger. If we have several fuzzy numbers, it may be difficult to rank them. Figure 1 illustrates the problem: the membership functions presented there overlap each other and this overlapping may be even more "advanced", so that any ranking might be much less unequivocal than it is in Fig. 1, e.g. if we added in Fig. 1 a fuzzy number (1, 5, 9), it would be not at all obvious how to rank it with respect to the other fuzzy numbers. There are several ranking procedures proposed in the literature (e.g. [2, 4, 5, 6]). The ranking procedure should be adopted to the attitude and opinions of the decision maker. E.g. if the decision maker was a pessimist, the fuzzy number (2,5,7) would be higher in his eyes than the fuzzy number (1, 3, 9) – because he would rather take into account the pessimistic, lowest possible values where both membership functions are positive – thus the number 2 in case of the fuzzy number (2, 5, 7) and the number 1 in case of the fuzzy number (1, 3, 9). If he was an optimist, he would say the fuzzy number (1, 3, 9) is higher, because of the optimistic numbers 9 and 7. If he was neutral, a kind of average would be a criterion to him, e.g. the numbers 5 and 3, but averages of fuzzy numbers can be calculated in many other ways too ([4]). Here we will have to make a choice of a method of comparing fuzzy numbers and everyone using them to evaluate objects will be faced with this problem.

2. MULTICRITERIA CRISP EVALUATION

In many situations there is a necessity to rank a certain group of objects, but the criterion is not unique. This is e.g. the case of universities. In press many rankings of universities appear and many different criteria are selected. In each case when there are several evaluation criteria it is necessary to aggregate all the evaluations

into one number, taking into account the weights of individual criteria. What is more, quite often individual criteria have subcriteria, and the subcriteria evaluations have to aggregated to get the main criteria evaluations – it is only then that the final ranking can be determined. There may also be several levels of subriteria.

Abstracting for the moment from fuzzy numbers and linguistic expressions, let us suppose that the evaluations are made in crisp numbers. Let us suppose we have n_0 main criteria $C_{j_0}^0, j_0 = 1, ..., n_0$, with weights $w(C_{j_0}^0), j_0 = 1, ..., n_0$ summing up to one. Each main criterion may have $n_1(C_{j_0}^0)$ subcriteria $C_{j_0,j_1}^1, j_1 = 1, ..., n_1(C_{j_0}^0)$ with weights $w(C_{j_0,j_1}^1), j_1 = 1, ..., n_1(C_{j_0}^0)$, also summing up to 1. And so forth: each subcriterion C_{j_0,j_1}^1 may have $n_2(C_{j_0,j_1}^1)$ subcriteria $C_{j_0,j_1,j_2}^2, j_2 = 1, ..., n_2(C_{j_0,j_1}^1)$ with weights $w(C_{j_0,j_1,j_2}^2), j_2 = 1, ..., n_2(C_{j_0,j_1}^1)$ and each subcriterion C_{j_0,j_1,j_2}^2 may have further $n_3(C_{j_0,j_1,j_2}^2)$ subcriteria $C_{j_0,j_1,j_2,j_3}^3, j_3 = 1, ..., n_3(C_{j_0,j_1,j_2}^2)$ with weights $w(C_{j_0,j_1,j_2,j_3}^3), j_3 = 1, ..., n_3(C_{j_0,j_1,j_2}^2)$. This may of course continue, but in the application proposed in the present paper we will have just four levels of criteria. For all the criteria we will need the evaluations – from various groups of people, averaged somehow. Lets us suppose there are $i = 1, ..., M$ objects being evaluated. If a criterion $C_{j_0}^0, j_0 = 1, ..., n_0$ does have subcriteria, the corresponding evaluation (of the i-th object according to the criteria $C_{j_0}^0$), denoted as $E(i, C_{j_0}^0)$, are calculated from the following formula:

$$E(i, C_{j_0}^0) = \sum_{j_1=1}^{n_1(C_{j_0,j_1}^1)} w(C_{j_0,j_1}^1) E(i, C_{j_0,j_1}^1) \tag{2}$$

If a criterion $C_{j_0}^0, j_0 = 1, ..., n_0$ does not have subcriteria, the evaluations are give directly by the persons being questioned (we do not discuss here the problem of aggregating the evaluations given by various persons to one single evaluation, usually it will a simple average). Formula (2) is generalized to the other levels, to $E(i, C_{j_0,j_1}^1), j_1 = 1, ..., n_1(C_{j_0}^0)$, $E(i, C_{j_0,j_1,j_2}^2), j_2 = 1, ..., n_2(C_{j_0,j_1}^1)$, $E(i, C_{j_0,j_1,j_2,j_3}^3)$, $j_3 = 1, ..., n_3(C_{j_0,j_1,j_2}^2)$, $i = 1, ..., M$: if a criterion has subcriteria, the evaluation of the individual objects according to this criterion is calculated by a formula analogous to (2), if a criterion does not have subcriteria, the respective evaluations are given directly by the persons evaluating the objects.

Finally, we are in position to determine the final ranking of the M objects, it is given by the ranks

$$R(i) = \sum_{j_0=1}^{n_0} w\left(C_{j_0}^0\right) E\left(i, C_{j_0}^0\right) \qquad (3)$$

The higher the rank, the better.

3. MULTICRITERIA FUZZY (LINGUISTIC) EVALUATION

In case the persons evaluating various objects are not willing or able to give coherent crisp evaluations of the objects according to different criteria, they may be allowed to use linguistic expressions. Often those presented in Fig. 1 are used. These persons are not worried about the mathematical translation of their evaluation, they just use the expressions "poor", "fair" etc. But for the system these expressions correspond to membership functions, to fuzzy numbers. The fuzzy evaluations according to subcriteria are multiplied by weights. The weights may be fuzzy or crisp. In case they are fuzzy, a "language" to describe them me be chosen, similar to that for criteria (Fig. 1), composed of expressions like "high", "low", etc. In case they are crisp, they should be chosen in such a way that on each subcriteria level they add up to 1. The weighted evaluations are added up criteria level by criteria level and finally we get for each object $i = 1, ..., M$ n_0 weighted fuzzy evaluations $E\left(i, w\left(C_{j_0}^0\right) \cdot C_{j_0}^0\right)$ with membership functions $U\left(i, C_{j_0}^0\right)$, using fuzzy equivalents of formulae like (2).

As mentioned in Section 2, a ranking based on fuzzy numbers is usually not unequivocal. Here we adopt the ranking procedure used in [2]. Its general idea is as follows: For each criteria the following two crisp numbers are calculated:

$$MAX(j_0) = \sup_x \left\{ \exists i = 1, ..., M : U\left(i, C_{j_0}^0\right)(x) > 0 \right\} \qquad (4)$$

$$MIN(j_0) = \inf_x \left\{ \exists i = 1, ..., M : U\left(i, C_{j_0}^0\right)(x) > 0 \right\} \qquad (5)$$

$MAX(j_0)$ represents, for the criterion j_0, the highest crisp evaluation that was given for this criterion with a positive value of one of the membership functions from Fig. 1 – thus in a sense the ideal object according to this criterion. $MIN(j_0)$ represents the contrary: the lowest evaluation given with a positive value of one of the membership functions from Fig. 1, thus the worst object according to the considered criterion. Then for each object i a (crisp) distance between its evaluation according to each criterion main $E\left(i, C_{j_0}^0\right)$ and the values calculated in (5) and (6) is determined (details can be found in [2]): $DIST\left[i, MAX(j_0)\right]$ and $DIST\left[i, MIN(j_0)\right]$: the first one represents the distance of the object from the "positive ideal" and the second one the distance of the

object from the "negative ideal" . The final ranking of the objects is calculated on the basis of the sums $\sum_{j_0=1}^{n_0} DIST[i, MAX(j_0)]$ and $\sum_{j_0=1}^{n_0} DIST[i, MIN(j_0)]$, where the first one should be as small as possible and the second one as big as possible. An optimism level of the decision maker, $\alpha \in [0,1]$, is selected. The greater α, the greater is the weight of the criterion $\sum_{j_0=1}^{n_0} DIST[i, MAX(j_0)] \to \min$, the smaller α, the greater is the weight of the criterion $\sum_{j_0=1}^{n_0} DIST[i, MIN(j_0)] \to \max$. It is so, because an optimist sets optimistic goals and wants to be as close as possible to the best solution, and a pessimist only wishes to be as far as possible from the worst solution. Details again can be found in [2].

4. CRITERIA FOR UNIVERSITY EVALUATION

We propose to use the criteria for university evaluation listed below. These criteria have been chosen on the basis of a pilot questionnaire performed in two Polish universities. We have $n_0 = 3$ main criteria (student satisfaction, university teacher satisfaction, university management satisfaction), which are composed of several subcriteria. Each criterion should be given a weight.

- C_1^0: student satisfaction
    - $C_{1,1}^1$: teaching process
        - $C_{1,1,1}^2$: teaching staff
        - $C_{1,1,2}^2$: teaching methods
        - $C_{1,1,3}^2$: teaching infrastructure
        - $C_{1,1,4}^2$: organisational aspect of the teaching process
    - $C_{1,2}^1$: administration functioning
        - $C_{1,2,1}^2$: dean office
        - $C_{1,2,2}^2$: recruitment process
        - $C_{1,2,3}^2$: financing system
    - $C_{1,3}^1$: university infrastructure
        - $C_{1,3,1}^2$: university library

- $C_{1,3,2}^2$: free computer access
- $C_{1,3,3}^2$: campus
- $C_{1,3,4}^2$: possibility of developing own interests
- $C_{1,4}^1$:university prestige
- $C_{1,5}^1$: professional perspectives
- C_2^0 : teacher satisfaction
  - $C_{2,1}^1$: remuneration policy
    - $C_{2,1,1}^2$: wages height
    - $C_{2,1,2}^2$: bonuses
    - $C_{2,1,3}^2$: social and fringe benefits
  - $C_{2,2}^1$: working conditions
    - $C_{2,2,1}^2$: safety at the work place
    - $C_{2,2,2}^2$: work organisation
      - $C_{2,2,2,1}^3$: holiday length
      - $C_{2,2,2,2}^3$: information access
      - $C_{2,2,2,3}^3$: working hours
    - $C_{2,2,3}^2$: possibility of professional development
      - $C_{2,2,3,1}^3$: possibility of conference participation
      - $C_{2,2,3,2}^3$: possibility of acquiring scientific degrees
      - $C_{2,2,3,3}^3$: number and quality of scientific seminars
    - $C_{2,2,4}^2$: atmosphere at the work place
  - $C_{2,3}^1$: university infrastructure
    - $C_{2,3,1}^2$: equipment of the offices
    - $C_{2,3,2}^2$: equipment of the laboratories
    - $C_{2,3,3}^2$: university building standards
  - $C_{2,4}^1$: university prestige
- C_3^0 : university management satisfaction
  - $C_{3,1}^1$: university scientific influence

- $C_{3,1,1}^2$: right to confer scientific titles
- $C_{3,1,2}^2$: number of scientific titles conferred
- $C_{3,1,3}^2$: staff potential
  - $C_{3,1,3,1}^3$: reliability
  - $C_{3,1,3,2}^3$: ethical attitude
  - $C_{3,1,3,3}^3$: expert knowledge
  - $C_{3,1,3,4}^3$: languages knowledge
  - $C_{3,1,3,5}^3$: own development, continuous learning
  - $C_{3,1,3,6}^3$: ability to use technical equipment
  - $C_{3,1,3,7}^3$: ability to work and solve problems by themselves
  - $C_{3,1,3,8}^3$: ability to generate initiatives
  - $C_{3,1,3,9}^3$: creativity
- $C_{3,1,4}^2$: number of citations
- $C_{3,1,5}^2$: number of PhD students
- $C_{3,1,6}^2$: number of publications
- $C_{3,1,7}^2$: number of accreditations passed successfully
- $C_{3,2}^1$: university development
  - $C_{3,2,1}^2$: university infrastructure
  - $C_{3,2,2}^2$: number of faculties
  - $C_{3,2,3}^2$: internationalisation of the studies
    - $C_{3,2,3,1}^3$: number of programmes taught entirely in a foreign language
    - $C_{3,2,3,2}^3$: number of students studying in a foreign language
    - $C_{3,2,3,3}^3$: international exchange of students
    - $C_{3,2,3,4}^3$: multi-culturality of the students
    - $C_{3,2,3,5}^3$: number of foreign teachers
    - $C_{3,2,3,6}^3$: number of open lectures in foreign languages
    - $C_{3,2,3,7}^3$: number of summer schools
  - $C_{3,2,4}^2$: number of students

- $C_{3,2,5}^2$: number of branches in other towns
- $C_{3,3}^1$: economic effectiveness
  - $C_{3,3,1}^2$: cost level
  - $C_{3,3,2}^2$: use of European funds
  - $C_{3,3,3}^2$: use of industrial funds
- $C_{3,4}^1$: university prestige
  - $C_{3,4,1}^2$: cooperation with the industry
    - $C_{3,4,1,1}^3$: number of common projects
    - $C_{3,4,1,2}^3$: number of orders from the industry
    - $C_{3,4,1,3}^3$: will of the industry to employ the university graduates
  - $C_{3,4,2}^2$: cooperation with other universities
    - $C_{3,4,2,1}^3$: students exchange
    - $C_{3,4,2,2}^3$: number of common projects

In the questionnaire each criterion should be accompanied by an explanation what exactly the person asked should understand under it. As we can see, the main criteria divide the persons to be asked into three groups: students, university teachers and members of the university management. Thus, the universities are evaluated from three different perspectives.

5. REAL WORLD UNIVERSITIES COMPARISON – RESULTS

We used the criteria presented in section 4 in a real word experiment. We asked a selected group of students, teachers and managers of three Polish universities (one state university (U1) and two private university: U2 and U3) to evaluate their university according to the criteria proposed above, using the language from Fig.1 (thus only the expressions: very poor, poor, fair, good, very good – the answers were averaged according to one of the methods described in [4]). For simplicity reasons we assumed that the criteria weights are crisp and equal on each criteria level. We chose three optimism levels: 0 (the decision maker is a complete pessimist), 0,5 (the decision maker is neither a pessimist nor an optimist) and 1 (the decision maker is a complete optimist). The persons participating in the questioning were asked to give evaluations only on the lowest criteria levels, which were then aggregated to the higher levels and finally to the final ranking of the three universities.

The following evaluations were given.

D. Kuchta, R. Ryńca

Table 1. Evaluations given by the students representatives of three universities (main criterion C_1^0)

University	U1	U2	U3
$C_{1,1,1}^2$	Good	Fair	Fair
$C_{1,1,2}^2$	Fair	Good	Poor
$C_{1,1,3}^2$	Fair	Poor	Poor
$C_{1,1,4}^2$	Fair	Good	Fair
$C_{1,2,1}^2$	Poor	Poor	Poor
$C_{1,2,2}^2$	Fair	Fair	Fair
$C_{1,2,3}^2$	Poor	Poor	Poor
$C_{1,3,1}^2$	Fair	Fair	Fair
$C_{1,3,2}^2$	Fair	Fair	Fair
$C_{1,3,3}^2$	Fair	Fair	Fair
$C_{1,3,4}^2$	Fair	Poor	Poor
$C_{1,4}^1$	Good	Fair	Fair
$C_{1,5}^1$	Good	Fair	Fair

Table 2. Evaluations given by the teaching staff representatives of three universities (main criterion C_2^0)

University	U1	U2	U3
$C_{2,1,1}^2$	Fair	Fair	Fair
$C_{2,1,2}^2$	Fair	Fair	Poor
$C_{2,1,3}^2$	Good	Fair	Fair
$C_{2,2,1}^2$	Fair	Fair	Fair
$C_{2,2,2,1}^3$	Good	Fair	Fair
$C_{2,2,2,2}^3$	Fair	Fair	Fair
$C_{2,2,2,3}^3$	Fair	Fair	Fair
$C_{2,2,3,1}^3$	Fair	Fair	Poor
$C_{2,2,3,2}^3$	Good	Fair	Fair
$C_{2,2,3,3}^3$	Fair	Fair	Fair
$C_{2,2,4}^2$	Fair	Fair	Fair
$C_{2,3,1}^2$	Fair	Poor	Poor
$C_{2,3,2}^2$	Fair	Fair	Fair
$C_{2,3,3}^2$	Fair	Poor	Fair
$C_{2,4}^1$	Fair	Fair	Fair

Table 3. Evaluations given by the management representatives of three universities (main criterion C_3^0)

University	U1	U2	U3
$C_{3,1,1}^2$	Good	Fair	Fair
$C_{3,1,2}^2$	Good	Fair	Fair
$C_{3,1,3,1}^3$	Good	Good	Good
$C_{3,1,3,2}^3$	Very good	Very good	Good
$C_{3,1,3,3}^3$	Very good	Very good	Very good
$C_{3,1,3,4}^3$	Good	Fair	Fair
$C_{3,1,3,5}^3$	Good	Good	Fair
$C_{3,1,3,6}^3$	Fair	Fair	Fair
$C_{3,1,3,7}^3$	Good	Good	Good
$C_{3,1,3,8}^3$	Fair	Fair	Fair
$C_{3,1,3,9}^3$	Good	Good	Good
$C_{3,1,4}^2$	Fair	Poor	Poor
$C_{3,1,5}^2$	Good	Very poor	Very poor
$C_{3,1,6}^2$	Good	Fair	Fair
$C_{3,1,7}^2$	Fair	Poor	Poor
$C_{3,2,1}^2$	Fair	Fair	Fair
$C_{3,2,2}^2$	Fair	Fair	Poor
$C_{3,2,3,1}^3$	Fair	Poor	Poor
$C_{3,2,3,2}^3$	Fair	Poor	Poor
$C_{3,2,3,3}^3$	Fair	Poor	Poor
$C_{3,2,3,4}^3$	Fair	Fair	Fair
$C_{3,2,3,5}^3$	Good	Fair	Fair
$C_{3,2,3,6}^3$	Good	Fair	Fair
$C_{3,2,3,7}^3$	Fair	Poor	Poor
$C_{3,2,4}^2$	Fair	Good	Good
$C_{3,2,5}^2$	Fair	Very good	Fair
$C_{3,3,1}^2$	Fair	Fair	Fair
$C_{3,3,2}^2$	Good	Poor	Fair
$C_{3,3,3}^2$	Poor	Poor	Fair
$C_{3,4,1,1}^3$	Good	Poor	Fair
$C_{3,4,1,2}^3$	Fair	Poor	Fair
$C_{3,4,1,3}^3$	Good	Fair	Fair
$C_{3,4,2,1}^3$	Good	Fair	Fair
$C_{3,4,2,2}^3$	Good	Fair	Fair

Independently of the optimism level chosen, we got each time the same overall ranking, which corresponded to the numbering given to the universities before the experiment: the state university turned out to be the best one, the second was university U2 and the third – university U3. It is easy to notice that private universities U2 and U3 are according to some criteria better than the state university U1. However, in the overall ranking the state university turned out to be better. Of course, other criteria weights might change the situation. However, in the experiment performed we did not ask the participants to give criteria weights and assumed them to be equal on each criteria level, because the questionnaire presented to them was already quite long and demanded plenty of time and attention. In the future a reduction of the number of the criteria (the subcriteria levels) might be taken into consideration, in order to reduce the effort linked to the questionnaires.

6. CONCLUSIONS

The paper contains a proposal of how to rank universities according to multiple criteria. The proposition comprises first of all the criteria themselves and secondly a choice of a ranking method, in which the user can use linguistic expressions, which are then automatically "translated" into quantitative expressions and aggregated into a ranking of universities. The possibility to use a quasi human language assured on one hand a certain ease for the participants of the research, representing various backgrounds and mathematical preparation levels, and on the other hand a coherence in their answers.

Multicriteria ranking can always be questioned, because it has the drawback of aggregating different points of views and different perspectives into one number, and this aggregation depends heavily in the criteria and methods chosen. However, it seems to be difficult to avoid ranking of universities. It is performed by many institutions, published in the press and discussed by the public. It is thus desirable to understand the mechanisms of such rankings and to be able to influence them, so that they reflect the real quality of universities and really help various customers of universities as well as the management of the latter to make right decisions.

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MEASURING THE COST OF ACTIVITIES PERFORMED AT THE UNIVERSITY

The universities are, like any organization, more and more drastically faced with the question "how much cost the our products (students, courses etc.)?" and "Are these cost justified?". In order to answer this question, more or more often the activity based costing method is used, where an intermediate step – measuring the cost of university activities – is necessary. The problem is that the specificity of the activities performed at the university makes them extremely difficult to measure, especially the cost of research and course preparation activities is difficult to determine. In the paper a method of approximate research/teaching activity cost measurement, taking into account subjective expert opinions of the research and teaching staff, is applied to university activities. The method is based on the well known AHP method and will help to answer the questions about the cost of university activities and products.

1. INTRODUCTION

The turn of the 20th and 21st centuries has brought a wide range of changes in the economic, technological and social environment. In the course of the above changes a crucial part was played by the higher education system, which is also nowadays considered a priority, as its goal is to prepare people to perform specific functions in the economy and in the society.

Activities pursued by institutions of higher education require involvement of various resources, including human labour, materials and fixed assets, financial outlays, and others. An effective use of these resources is one of the conditions of successful management. As the demands of the education market grow, managers need increasingly more accurate information in order to take both strategic and operational decisions. Basic information, necessary for the management purposes, should include the amount of the incurred expenses and description of the process during which the expenses arose. Information based

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on traditional cost models, i.e. the total cost accounting and the variable cost accounting are not always suitable for the decision-making purposes. The managers, aware of that fact, are deeply convinced of the necessity to implement such cost models that would provide them with full and reliable information.

The purpose of this paper is to propose application of the Activity-Based Costing concept combined with the Analytical Hierarchy Process concept to the cost accounting of higher education institutions. Assuming that a proper presentation of the models will allow one to understand their essence and distinctness from the traditional solutions, the models have been supported by a practical example.

2. ANALYTIC HIERARCHY PROCESS METHOD

Analytic Hierarchy Process method is mainly applied to support selection of variants of decision. It was developed in the mid 1970s by American scientist Thomas Saaty. Numerous applications of the method, among others in economy, logistics, management and marketing prove its effectiveness [1]. The AHP method combines certain mathematical and psychological concepts. It employs a multi-criteria approach, which allows for aggregation of multiple criteria in order to solve problems, simultaneously taking into account assessor's preferences, treating them as a natural phenomenon.

The basis of AHP method is a hierarchical goal structure, presented as a tree, at the top of which there is a superior goal with subordinate goals below and partial goals at the bottom. Execution of a superior goal by each alternative results from execution of intermediate goals (main and partial) expressed by corresponding criteria. In graphic form, it may be presented by means of a simple diagram (fig. 1).
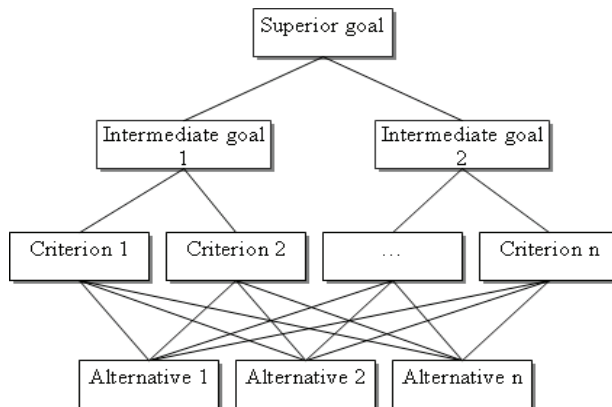

Fig. 1. Diagram of the hierarchical structure.
Source: Yao J., *Feature AHP Method Used for Excellent Students Evaluation*,
International Conference on Optics, Photonics and Energy Engineering, China, 2010, p. 422

Upon developing the hierarchical task model in AHP, all criteria (factors) are pairwise compared to establish their mutual relations. Thus, evaluation matrix is created, which illustrates the level of meeting relevant criteria by a given alternative. The scope of acceptable values, in accordance with a scale introduced by the method creator ranges from 1 to 9 points. The evaluator may express their preferences for each pair of criteria (factors), verbally at first: equal importance, moderate importance, strong importance, very strong importance, extreme importance. The preferences are written in form of figures as 1, 3, 5, 7, 9. Intermediate numbers are also introduced, i.e. 2, 4, 6, 8, applied when it is difficult to express an opinion. They are presented in table 1.

Evaluation of each pair made by experts is entered in the square matrix with dimension $n \times n$, where n denotes a number of elements on a given level. The constructed matrix has the following properties: expressions on diagonal a_{ii} equal 1, expressions above diagonal a_{ij} are expert evaluations and expressions below the diagonal are their reciprocals, i.e. $a_{ji} = 1/a_{ij}$.

Table 1. Scale comparisons by Saaty's

Indicator	Definition	Clarification
1	Equal importance	Two compared factors are equally important
3	Moderate importance	Slight advantage of one factor over the other
5	Strong importance	Significant advantage of one factor over the other
7	Very strong importance	Very significant advantage of one factor over the other
9	Extreme importance	Extremely higher significance of one factor over the other
2, 4, 6, 8	Intermediate values	Applied only if necessary

Source: Yao J., *Feature AHP Method Used for Excellent Students Evaluation*,
International Conference on Optics, Photonics and Energy Engineering, China, 2010, p. 423.

Upon constructing the matrix, the priorities (weighs) are established. To this end, the highest eigenvalue λmax of the matrix and related eigenvector are appointed. Eigenvalue is applied to evaluation of committed errors, and eigenvector is a vector of priorities (weighs). For each matrix, consistency of evaluations is checked, i.e. if $a > b$ and $b > c$ then $a > c$. In order to examine the matrix consistency, Saaty proposed appointing two coefficients CI (Consistency Index) and CR (Consistency Ratio).

$C..I. = \dfrac{\lambda_{max} - n}{n - 1}$, where n is matrix dimension,

$C.R. = \dfrac{C.I.}{R.I.}$, where *R.I.* is a value from charts for a relevant *n*.

If Consistency Index (CI) and Consistency Ratio (CR) are lower than 0.10, one may be satisfied with the decision makers' evaluation, but when they assume too high values, the decision makers must be asked to give their evaluations again [1].

Application of AHP is purposeful and justified when there is a hierarchy of evaluation criteria in the study, representing various levels of detail, related to hier-

archy of goals or anticipated benefits, where data for analysis are not of quantitative, but rather qualitative nature, evaluations are burdened with subjectivity of an analysing person, and alternatives, due to their comparability, must belong to the same class [7].

3. ACTIVITY BASED COSTING METHOD

In the late 1980s, in the United States, two American professors Robin Cooper and Robert Kaplan developed a concept of Activity Based Costing (ABC). The concept is based on the assumption that the direct cause of cost occurrence is actions undertaken by an entity, which cause exploitation of resources and thus cost creation [7]. In the literary references, many examples of cost calculations based on ABC model are found. In most of them, a two-stage cost allocation model is applied, on which analytic hierarchy process model is based, which is graphically presented in figure 2 [6].

In the first stage of cost allocation according to ABC method, the costs are attributed to actions by means of allocation keys of the first type. In the second stage, costs of individual actions are allocated to cost objects with allocation keys of the second type. It should be explained here what a cost object is, it is defined as an object for which costs are accumulated and calculated. For universities, a student, a doctoral student or individual forms of education, i.e. lectures, classes, seminars, labs etc. may constitute cost objects.

In the ABC model, cost allocation at individual stages is not an easy task. It is difficult to specify such a cost driver for each identified action which will ideally express the relation between costs of a given action and a cost object. Furthermore, not all the costs may be referred to cost objects via cost drivers, reflecting the reason for cost occurrence and demand of a given cost object for a given action. Some imperfections of the ABC method are the reason for continuous search for new solutions. Analytic Hierarchy Process method is supposed to be a response to certain weaknesses of the ABC method. Below, a detailed description of items on all levels of analytic hierarchy process model with indication of similarities to the ABC method.

In the activity based costing model, costs of used resources are at the top, in the further stage allocated to actions. Application of the AHP model will be the reason for a general goal to be located on top. In the presented example, it is a division of overhead costs into individual cost objects.

On the second level there are cost drivers, with activities located on the third level. Cost drivers serve as an allocation key, on this level they enable allocation of overhead cost to individual activities. The activity identification stage is very important, when specifying the activities one must assume such a level of detail which should enable presentation of cause and effect relations between a cost and a product and moreover would not lead to excessive complexity and excessive system

operation costs [5]. Dividing and combining activities requires analysis of relevant issues; firstly, during combining activities, one should consider aggregation of the activities with insignificant cost with other activities. Application of this solution shall significantly decrease the identification time for cost drivers. Secondly, combining cost representing activities with activities which do not represent costs should be avoided [4].

On the fourth level of hierarchy, costs of individual activities are allocated to products by means of cost drivers, newly defined for this level. Number of associations between the isolated activities and products may be random, and for each level it is possible to specify a set of its cost drivers [6]. In case of the ABC model, only one cost driver may be specified for each activity.

At the final, lowest level of the presented model, there are cost objects. Cost of individual cost objects is established by means of previously defined cost drivers indicating the demand of cost objects for specific activities. Degree of activity consumption by cost objects is expressed in percent, similarly to the contribution of costs of individual activities in overhead costs.
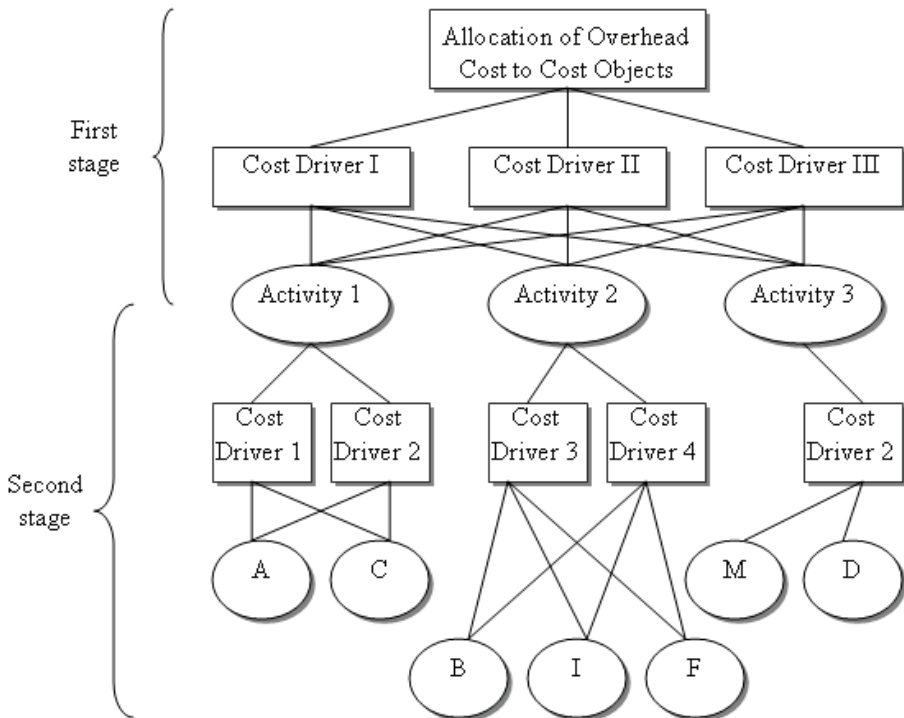
Fig. 2. Proposed hierarchy of overhead allocation to cost objects.
Source: Partovi F., *An analytic hierarchy approach to activity-based costing*, International Journal of Production Economics, Elsevier Science Publishers B.V., 1991, p. 155

Upon definition of activities, cost drivers, isolation of cost objects and creation of the decision tree on their basis, one may proceed to the next stage of cost calculation. In the traditional activity based costing model, overhead costs are allocated to isolated activities by means of cost drivers. Executing the AHP method, evaluations are made by pairwise comparisons, and for this stage, a proper question is: "What is the significance of activity A in comparison to activity B with regard to the cost driver 1". As a result of evaluation performed for individual items, one obtains a preference matrix, and ultimately – a set of weighs attributed to isolated activities. The presented stage of cost calculation corresponds to the first stage of ABC method [6].

Application of the AHP method is greatly facilitated when using proper software, such as Expery Choice [6], or a spreadsheet.

At the moment when overhead costs are divided into individual activities, with application of the AHP method it is possible to create a set of pairwise comparisons of various cost objects with cost drivers appropriate for this level. Thus, answer to the question: "What is the contribution of cost object A compared to object cost B with reference to individual actions?" becomes possible. It should be emphasised here that performance by an evaluator, decision maker of a series of pairwise comparisons of individual items on each level of the AHP model is only required when quantitative measurements are not available [6]. Ultimately, we obtain contribution of costs of individual products in overhead costs, expressed in percentage.

Application of the analytic hierarchy process method for division of overhead costs into individual cost objects contributes, among others, to a decrease in data collection and analysis costs. Furthermore, the model allows the management staff to develop new models for strategic goals. Decision makers may apply the AHP model for analysis of sensitivity of various cost drivers, for observation how they affect activities, cost objects and for making decisions on this basis, concerning selection of proper cost drivers.

4. COST ALLOCATION MODEL FOR A TECHNICAL UNIVERSITY BASED ON AHP AND ABC

The following assumptions are made in the structure of cost accounting concept for a technical university:
− The concept is based on methodology applied in activity based costing and analytic hierarchy process method, which are based on a functional structure of a technical university,
− The concept presents a uniform cost accounting designed for making management decisions, it means that it only serves internal goals of the unit. The accounting cannot be applied for external reporting purposes, as it is not compliant with provisions of law. It may only operate beside the obligatory account of cost accounting,

− Input data for the cost accounting are based on grouping the costs applied in the reported cost accounting and other published sources,
− Output data are categorized by clients (students).
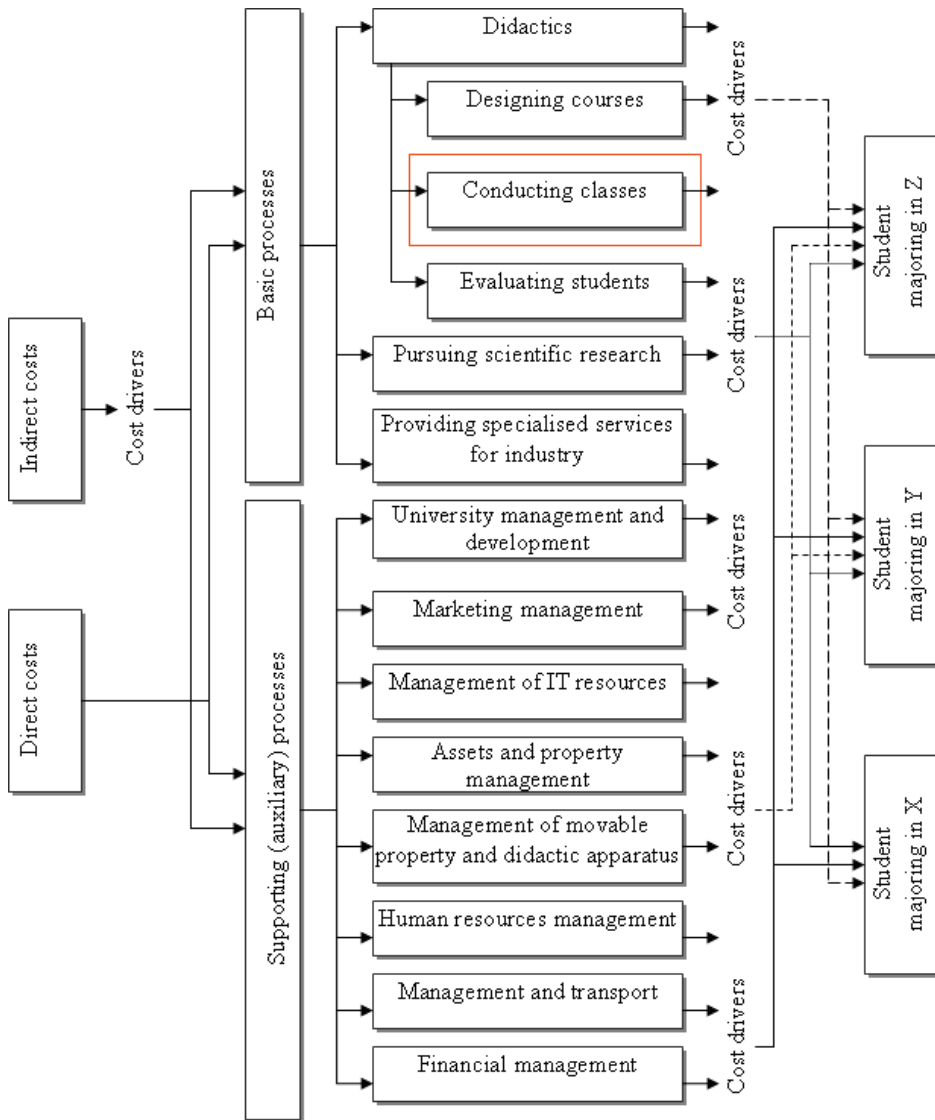
Fig. 3. Cost allocation model for a technical university.
Source: Study based on Kuchta D., Bojnowska A., Parkitna A., *Application of activity based costing at a Polish university* (in Polish), Konferencja z cyklu rachunkowość a kontroling, Systemy zarządzania kosztami i dokonaniami, 2010

At the very beginning of works on constructing an cost accounting of costs for a technical university, the direct and indirect costs incurred in the school should be isolated. Subsequently, activities executed by the school should be identified. The activities may be grouped. Activity groups are called primary economic processes. The basic process and their constituent actions identified at a technical university are presented in figure 3 [3]. According to the division proposed by M. E. Porter, all processes executed by economic entities are divided into basic and auxiliary processes [8].

At the next stage, allocation of direct and indirect costs to isolated activities takes place. When it is possible, reference of costs to activities should take place directly, with necessary analysis of source documents of an entity. However, in a situation in which it would be unjustified, one must apply proper cost drivers of the first type. By means of weighs they reflect diverse cost absorption of the isolated activities. Subsequently, cost objects should be specified. In the proposed concept, the authors suggest recognising students as cost objects. However, it is also possible to indicate differences in costs of individual teaching forms, i.e. lectures, classes, seminars, labs and others.

The next stage should establish relations between cost objects and activities. To this end, establishing cost drivers of the second type is necessary, reflecting a number of activities executed for individual cost objects – students. Ultimately, after allocation of activity costs to cost objects, individual cost of student education is obtained. In the further section of the study, the presented model of cost allocation for a technical university based on AHP and ABC methods shall be supported with a practical example.

5. EXAMPLE

Theoretical assumptions presented above shall be illustrated with a practical example. When analysing processes and activities performed at a technical university, the authors of this study focused their attention on the process – Conducting classes – in terms of which the following activities were distinguished – course execution in form of a lecture (LT), course execution in form of a project (P), course execution in form of classes (C), course execution in form of lab classes (LC) and course execution in form of a seminar (S).

Cost calculation procedure, constituting an illustration of detailed considerations of the described model shall be presented on the basis of a selected activity, namely course execution in form of a project. Figure 4 presents a decision problem in hierarchical form, the highest level is occupied by a general goal, i.e. allocation of project execution costs. The lower level displays three attributes, i.e. a number of students in

classes, cost absorption of the speaker and other used resources, forming allocation keys in cost calculation. The lowest level specifies cost objects, assumed to be students of departments selected as an example: IT and Management Department, Chemistry Department and Architecture Department.
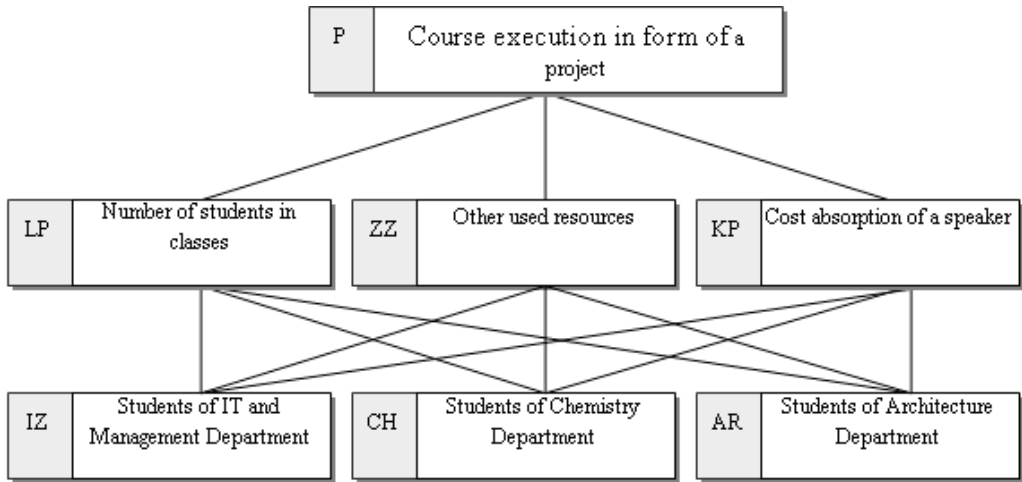
Fig. 4. Hierarchical structure of course execution in form of a project.
Source: Study based own

For mutual reference of previously isolated activities, a pairwise comparison matrix is created. The developed matrix can be found below (1).

$$
\begin{array}{c}
 \begin{array}{ccccc} LT & P & C & LC & S \end{array} \\
\begin{array}{c} LT \\ P \\ C \\ LC \\ S \end{array}
\begin{bmatrix}
1/1 & 3/1 & 3/1 & 3/1 & 2/1 \\
1/3 & 1/1 & 3/1 & 2/1 & 2/1 \\
1/3 & 1/3 & 1/1 & 4/1 & 1/1 \\
1/3 & 1/2 & 1/4 & 1/1 & 1/1 \\
1/2 & 1/2 & 1/1 & 1/1 & 1/1
\end{bmatrix}
\end{array}
\quad W =
\begin{bmatrix}
0.38 \\
0.22 \\
0.14 \\
0.09 \\
0.17
\end{bmatrix}
\qquad (1)
$$

The matrix above shows that course execution in form of a project (P) constitutes 22% of costs attributed to the process – Conducting classes. On the basis of the matrix, it may also be stated that for a decision maker, a lecture is three times more important than a lab class. At the next stage, a pairwise comparison matrix is created for attributes with regard to a general goal (2).

$$
\begin{array}{ccc}
 & \text{LS} \quad \text{ZZ} \quad \text{KP} \\
\begin{array}{c} \text{LS} \\ \text{ZZ} \\ \text{KP} \end{array} &
\begin{bmatrix} 1/1 & 2/1 & 1/3 \\ 1/2 & 1/1 & 1/1 \\ 3/1 & 1/1 & 1/1 \end{bmatrix} \quad
W = \begin{bmatrix} 0.28 \\ 0.26 \\ 0.46 \end{bmatrix}
\end{array}
\tag{2}
$$

At the next stage, a pairwise comparison matrix is created in order to compare each cost object due to its attributes. Since the analysed problem distinguishes three attributes, three matrices must be created. Below, an exemplary matrix for number of students in classes is presented (3).

$$
\begin{array}{ccc}
 & \text{IZ} \quad \text{CH} \quad \text{AR} \\
\begin{array}{c} \text{IZ} \\ \text{CH} \\ \text{AR} \end{array} &
\begin{bmatrix} 1/1 & 1/7 & 1/5 \\ 7/1 & 1/1 & 7/1 \\ 5/1 & 1/7 & 1/1 \end{bmatrix} \quad
W = \begin{bmatrix} 0.07 \\ 0.78 \\ 0.15 \end{bmatrix}
\end{array}
\tag{3}
$$

It results from the matrix above that due to a number of students, Chemistry Department is the most cost-consuming. In an analogous manner, two more matrices for remaining attributes should be created. The results should be collected in one matrix (4).

$$
\begin{array}{cccc}
 & \text{LS} \quad\; \text{ZZ} \quad\; \text{KP} \\
\begin{array}{c} \text{IZ} \\ \text{CH} \\ \text{AR} \end{array} &
\begin{bmatrix} 0.07 & 0.07 & 0.14 \\ 0.78 & 0.77 & 0.72 \\ 0.15 & 0.16 & 0.14 \end{bmatrix}
\end{array}
\tag{4}
$$

At the last stage of calculation, global priorities are indicated, in other words: a sum of products of priorities in each branch of hierarchy tree is calculated. Manner of establishing global priorities is presented below (5).

$$
\begin{bmatrix} \text{IZ} \\ \text{CH} \\ \text{AR} \end{bmatrix} = (0.28) \times \begin{bmatrix} 0.07 \\ 0.78 \\ 0.15 \end{bmatrix} + (0.26) \times \begin{bmatrix} 0.07 \\ 0.77 \\ 0.16 \end{bmatrix} + (0.46) \times \begin{bmatrix} 0.14 \\ 0.72 \\ 0.14 \end{bmatrix} = \begin{bmatrix} 0.10 \\ 0.75 \\ 0.15 \end{bmatrix}
\tag{5}
$$

The end value of the matrix indicates cost absorption of individual cost objects. The results of performed calculation were presented in graphic form, figure 5.

In the presented example, the students of the faculty of chemistry turned out to be the most cost consuming group, whose share in the total costs involved in the completion of a course in the form of a project, amounted to 75%. On the other hand, the total

cost of the students of the faculty of management and computer science amounted only to 10%.
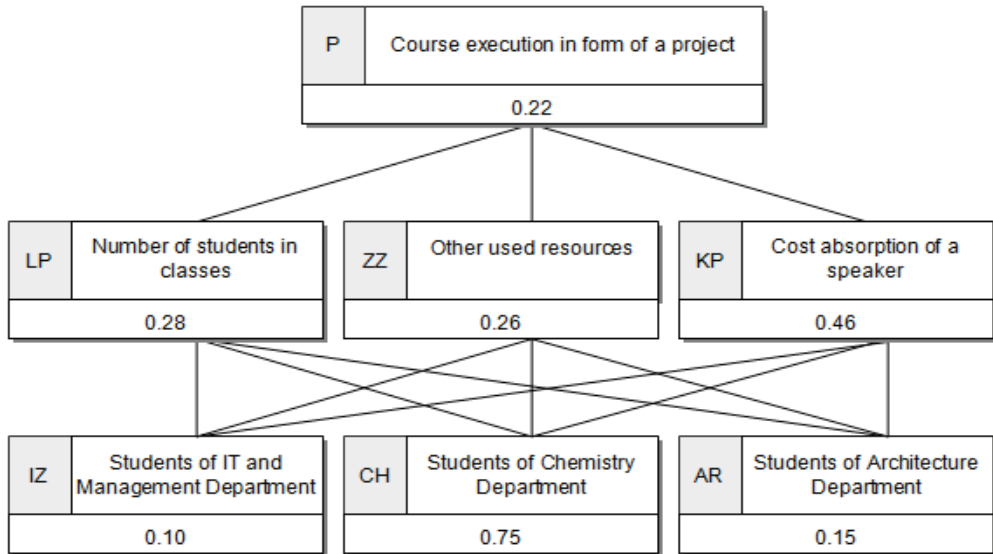
Fig. 5. Division of costs of course execution in form of a project.
Source: Study based own

6. SUMMARY

In face of growing competition on the educational service market and increasing expectations of the customers, the education institutions are forced to look for new effective management and cost reduction methods on a permanent basis.

Activity based costing presented by the authors of this paper, illustrates the structure of the costs incurred by entities to a larger extent than the traditional models.

It is not only a source of information about the type and amount of used resources, but it also enables one to analyse factors affecting these resources. Activity based costing allows one to assess the costs of the provided services in a more precise way. Improvement of the activity based costing with the implementation of the analytical hierarchy process method in the calculation of settlement keys, deserves attention, too, as it eliminates some faults of the standard approach to the activity based costing method, and difficulties in the process of selection of appropriate cost carriers. Both the activity-based costing and the analytical hierarchy process methods are effective instruments supporting the management and cost estimation. This paper indicates possibilities of applying them by higher education institutions.

Legitimacy of applying these methods and benefits from their implementation depend, among others, on the quality of their implementation, ability to use the obtained information, and ability to view the activity of higher education institutions from the point of view from the processes occurring inside them.

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Zbigniew BUCHALSKI*

IT DECISION SYSTEM
FOR THE COURIER SERVICES SUPPORT

This paper presents certain concept of IT system called COURSERV, which supports business courier expenses work. To the creation of this system there has been used Internet service. Fundamental establishments of systems construction, structure and functional description are presented. Implementation of COURSERV system and implementation of the database of this system was accomplished.

1. INTRODUCTION

The Internet is an ideal solution for companies to appear on the market through the website and through its functionality, without having to invest substantial sums of money in expensive, not always effective, advertising campaigns on radio, newspapers or television.

The purpose of this paper is to present the concept, design and computer implementation of user-friendly IT system for the courier services support named COURSERV system. To the creation of this system there has been used Internet service. Designing Internet service is defined as the arrangement and creation of individual web pages that in turn interconnected links form a whole - Internet service. Each party contains the information the transfer of which to the user is the main objective of the site.

A typical Internet service consists mainly of text and images. The first page of the site is called a homepage. Some sites use the one that is commonly called Splash. This is the page on which the user gets when entering the URL address and

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usually contains a welcome message, select the language in which information is to be provided or select region from which the user came from. Splash task is to obtain certain information from you in order to better personalize the information displayed or purely aesthetic grounds, to create a visual atmosphere associated with the subject site.

After creating all the pages of the service they must be published on the Internet. All files must be uploaded to the server using software called an FTP client. After uploading the files to the server, users from outside have access to it. After the publication of the site, the author may use a variety of techniques to increase the number of visits and the number of clicks.

2. ASSUMPTIONS AND OBJECTIVES OF BUILDING COURSERV SYSTEM

COURSERV system performs basic operations carried out from the customer's account, such as logging, reporting shipments, invoicing and notification of order status change as well as a number of management functions from the administrator account. The presented system simplifies the management of a courier company, with the aim of improving communication with customers by providing them with a number of tools for self-use of courier services.

Aims and objectives of the COURSERV system construction can be divided into two groups. The first group are the assumptions related to the design and implementation of the system. COURSERV system should have the following elements:
- friendly and easy to use interface,
- easy to use surveillance by the administrator,
- to facilitate contact between the employee and the customer.

The second group of assumptions of the COURSERV system concerns all matters relating to security courier service, such as:
- data verification,
- data access,
- method of data storing.

For the computer implementation of the COURSERV system there has been used the following technologies:
- markup language HTML/XHTML,
- PHP programming language,
- MySQL query language,
- database management application phpMyAdmin.

The website that serves as a support system of work organization of a courier company must use technology to connect it to a dynamic relational database MySQL. For this purpose there has been used multitier architecture which includes among others: a database server (MySQL), application part (web server with preinstalled PHP interpreter) and the client part (web browser).

At the beginning there should be explained the differences that occur when using a static web page with respect to the dynamic page that uses a multilayered architecture. Both these cases use the three-step way from the computer to the server. The first is the position of the client (user), access to any network connecting us directly or indirectly to the web server and server itself that hosts the data we are interested in.

Both the site static and dynamic query mechanism looks exactly the same. The user can use a computer using TCP (Transmission Control Protocol) and HTTP (Hypertext Transfer Protocol) connects to the server containing the content with his interests. At this point, three-layer application goes to the second stage – to the network. Using the standard port 80 or http port, and DHCP (Dynamic Host Control Protocol) network is trying to find a web site server and go to him giving us access to the content of our interests.

Different is the thing in the case of dynamically generated pages. After connecting to the server it will automatically check the availability of location, and therefore check whether the file (with the difference that this time the content is dynamically generated) is in the storage server (eg. if there is a file called index. php). If the file is missing we have a situation like in the case of the static, and thus is given an error message. However, if the file is there website will be executed according to the submitted parameters. PHP interpreter processes the query by needs of the user connects to a MySQL database and the entire application is executed.

Thus, a fundamental difference between the parties performed static and dynamic is visible on the server side. The dynamics of web pages can be given to their construction using one of several areas of scripting languages. In our case it will be PHP.

3. COMPUTER IMPLEMENTATION
OF THE COURSERV SYSTEM

For the implementation of the COURSERV system there has been used IT tools available for free. Webs editor with the possibility of writing in PHP has become the Adobe Dreamweaver CS5 available for free 30-day version. There has also been used VertrigoServ integrating the tools such as MySQL, PHP and Apache. Layout of the

website (otherwise known as graphic design) is an integral part of the COURSERV [1, 2, 3, 4, 5, 6, 7].

Website implementation began with registration on the free hosting service www.yoyo.pl, then a domain has been registered as a domain used while creating internet system. Choosing hosting service was extremely important because of the need to ensure proper operation of the software that had to be preinstalled on the reserved ser-ver. The most important for the server was to have the prein-stalled system for the database phpmyadmin operation and the MySQL database system.

The next step towards creation of the COURSERV system was to develop graphic design referring to the subject system. To achieve this step there has been used Adobe Photoshop CS5 tool to create graphics, and then there was the imple-mentation using HTML and Cascading Style Sheets CSS. Subsequently proceeded the determination of the database structure that was used to operate the service. Starting to create the graphic design had to be taken into account features that will meet the COURSERV system to create the necessary at a later time, control buttons to navigate the web site.

It was easy to observe that first iron feature in all these sites is that the courier can be ordered through the courier website. Designing the portal there could not be forgotten the button telling us the login. Another element, without which the system supporting the work of the courier company is not entitled to work properly is the possibility of tracking the consignment number generated by the system. It was therefore necessary not to forget about it designing a the system layout.

The forms used on the web at the stage of writing them in HTML has been adapted for later use in PHP and use MySQL relational database. All references in the forms relate to later peaks PHP already created, so that at the design stage the service was designed to handle PHP scripts. Designing the interface and the form of order itself there should have been taken care of every detail to assist in obtaining the detailed information needed for the smooth delivery of the downloaded package without any problems and obstacles. Helpful to this purpose, the system forms pre-sented below:

- Text box

Type "text" is the basic type of text field. It has a height of one line of text and the specified length. You can type text into it, which later will be sent along with the form, as an answer to your question.

- Drop-down list

If we want the form to send different values than the content markup <option> ... </ option>, you can enter tags for these additional attributes value = "value". Their

content may vary from the text entered after the tag <option> ... </ option>. Attributes value = "..." are mandatory if you intend to use in script form.

- Text area

This command displays multiline text box (text area) on the screen. It allows to enter a long comment by the user who fills out a form. You can also specify the marker <textarea> a </ textarea> default content that appears in this field (it is not excluded, of course, its subsequent rejection by the user).

- The check box

This command will display the square fields (box), which you can select and "uncheck" the mouse. Using it you can enter a question, where you can choose several ready-made answers from those given.

HTML code creates on the screen simple, but containing all the necessary to complete the order data. The form provides basic information about our customers, we input the approximate weight of the packages and enter comments on the delivery, if any.

Another extremely important for the system and its functionality is the whole process of logging on to the service and the authentication process. In aim to do this there is a form login.php prepared on the designing stage.

- The password

It introduces a field where you can enter a password. It differs from a simple text box only in that when you type text into it characters given are not visible, but only the asterisk ("*"). There can also be used exactly the same attributes, though the default password could not be a good idea. The login form has an additional two hidden functions called by clicking on the word "here" located below the login button.

If you do not have an account click here – this function leads us to form an account on our site. It allows to identify the user through a detailed form with required fields to create an account. These data include: name, address, city, zip code, e-mail, cell phone number. These data make it possible to fairly reliably verify the identity of a user of our service, and compiled in our system administration functions additionally certify the true data input by the user.

The forgotten password feature, under which we are able to log on to our system is another element forming part of the COURSERV system. Calling this function by e-mail address given when registering a new user is additionally supported by a potential user safety and does not allow a password to any unauthorized third parties by us.

Inherent mechanism for supporting the work of the courier tracking system is available from the user interface. In the COURSERV system we do so using the form set to track the status of the consignment.

4. THE DATABASE OF THE COURSERV SYSTEM

The Internet service collects customer data, collecting it for further use in the system, and is built in a way that the website where it is located was a dynamic site it requires implementation of a database. The best for this purpose is to used database system MySQL and PHP programming language. However, the construction of a robust system with a database requires considerable commitment at the stage of creating architecture of the service. Database system that came with your COURSERV database is one consisting of three tables. These tables are made of many cells filled with data at the stage of creating an account on the site or via assistance data from the site.

To properly build the database there should be carefully planned its layout of tables and structure so that each record in the database was carefully located by row and column of the table. Designing graphic layout we should be aware of what function will complement what line and from which line data will be collected. Each of the tables in a database stores separate data and is supplied with information from another source within the COURSERV system. The following tables present the whole system with explanations of their construction and a description of each row.

The table "customers" consists of eleven lines which form the core COURSERV application. Each of these eleven lines, except for the first (which is replenished automatically) and the latter is supplemented by a web browser directly by the customer asking him to provide accurate data for further cooperation. The first line that is the only box klientid replenished automatically without human intervention. It includes the ID numbers assigned to customers, according to which the user is identified in the system. It is the primary key table (sql – primary key) as indicated in the section Key symbol of the PRI. Autosum option of consecutive numbers is due to the parameter ID auto_increment. The last row in the table having two values changing without human intervention is "active", after which the system identifies the user account activity – it takes the value 0 or 1. A detailed picture of the table customers including building components concrete line is shown in Fig. 1.

As shown in the table above, each of the rows of the table customers is also centrally fixed length string and the top-set type, which will be located in the cell.

☐	**klientid**	int(5)		UNSIGNED	Nie	*Brak*	AUTO_INCREMENT
☐	**imie**	char(15)	utf8_polish_ci		Nie	*Brak*	
☐	**nazwisko**	char(30)	utf8_polish_ci		Nie	*Brak*	
☐	**adres**	char(50)	utf8_polish_ci		Nie	*Brak*	
☐	**miasto**	char(50)	utf8_polish_ci		Nie	*Brak*	
☐	**kod_pocztowy**	char(6)	utf8_polish_ci		Nie	*Brak*	
☐	**email**	char(50)	utf8_polish_ci		Nie	*Brak*	
☐	**gsm**	int(12)			Nie	*Brak*	
☐	**login**	varchar(20)	utf8_polish_ci		Nie	*Brak*	
☐	**password**	varchar(64)	utf8_polish_ci		Nie	*Brak*	
☐	**active**	smallint(2)			Nie	*Brak*	

Fig. 1. Skeleton table clients including the table component

For example:
- klientid – is a cell consisting of a maximum of five characters, of which they can only be a number, which tells us indicating an int meaning integer,
- lines starting from the application name and e-mail ending with a standard text differed among themselves only the length of an array of characters ranging a minimum of 6 in the zip code and up to 50 cases for entering the address or city.

Another component of the database forming an integral whole is a table that stores opinions on the services made by our system. This is an extremely important option of the COURSERV system having as its goal the continuous improvement of quality services to clients of the system. It allows you to keep track of the state of satisfaction or dissatisfaction with the service. The mechanism of action is extremely simple, and its function is to inform the owner of the company sent in real-time e-mail of satisfaction with the service. Feedback is recorded simultaneously via the website of our company to the database in order to later editing.

The structure of opinion base is constructed analogously to the customer database of the various difference that there is also the record date, which is populated automatically by the and Apache which tells the system of nothing but the date and time of receipt of the opinion on the server.

The most important element of the COURSERV system is obviously possibility to place orders through the website. This is the mechanism that has been designed to improve the operation of the shipping company and it is expected to contribute to the ease of customer service. As in the case of log system, which is registering new customers and the system of issuing opinions on services, the mechanism is equipped

with its own separate database, which stores all the information we need. All data contained in the form are passed to the appropriate database created for the purpose of this form. Its structure as a whole is presented in Fig. 2.

	Pole	Typ	Metoda porównywania napisów	Atrybuty	Null	Domyślnie	Dodatkowo
☐	zamowienieid	int(3)			Nie		auto_increment
☐	klientid	int(3)			Nie		
☐	wartosc	float(6,2)			Nie		
☐	wielkosc	varchar(64)	utf8_polish_ci		Nie		
☐	imie	varchar(255)	utf8_polish_ci		Nie		
☐	nazwisko	varchar(255)	utf8_polish_ci		Nie		
☐	firma	varchar(255)	utf8_polish_ci		Nie		
☐	adres	varchar(255)	utf8_polish_ci		Nie		
☐	telefon	varchar(255)	utf8_polish_ci		Nie		
☐	uwagi	varchar(255)	utf8_polish_ci		Nie		
☐	data	datetime			Nie		
☐	status	varchar(255)	utf8_polish_ci		Nie		

Fig. 2. The structure of the orders table

Description of the subsequent rows of the table orders is as follows:
- zamowienieid – a record that stores the serial numbers of orders, commonly called numbers slips. Auto_increment attribute ensures numbering continuity without any human intervention,
- klientid (clientid) – a record that keeps the customer number obtained when registering a new client in the courier system. Because of having to log into the COURSERV system to order a courier, it is the only attribute needed to identify the customer,
- value – the shipping cost determined on the basis of a predefined price list of carriage,
- size – a record which stores the approximate weight of the package,
- name, company, address, phone – these records store customer data items,
- date – a record that holds the date of the contract,
- status – this option shows you the current status of his shipment.

Adopted by system order is saved in the structure of the database shown above and it is presented as shown in Fig. 3.

Package was successfully shipped, we get a tracking number assigned to the package and the screen of our computers automatically generates a message containing a number of our packages. The package was correctly shipped and we got our unique tracking number shown by the system.

zamowienieid	klientid	wartosc	wielkosc	imie	nazwisko	firma
4	1	0.00	Paleta	Marcin	Waworek	Nifco Poland Sp. z.o.o.

adres	telefon	uwagi	data	status
Fabryczna 1-3	509800580	Paczke dostarczyc do kontroli jakosci.	2011-06-11 16:49:00	PrzyjÄ™to zamÃ³wienie, oczekuje na odebranie przez...

Fig. 3. Cell of the orders table filled with data

5. SUMMARY

Presented in this paper a system called COURSERV supporting the work of the courier company completed targets and goals set at the beginning of construction of the system and can successfully be recommended to use in practical applications. Designed website, which was based on this system has been properly compiled, tested in all possible ways, works flawlessly and is fully functional. Thanks to the universality of the technologies used, the system can be upgraded at any time for more modules activities, such as loyalty program, the ability to view archived orders, generating paper consignment notes in pdf format.

Graphic design is transparent, and the user interface intuitive and easy to use. The use of MD5 encryption system guarantees the anonymity of the content of user passwords, which even in case of breach of system security will not allow a hacker to know the contents of a password. The system is completely safe and the element ensuring the security is to force the user to activate your account via e-mail message sent to an address specified by the user.

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PART 3

DATA MAINING, IMAGE PROCESSING AND PATTERN RECOGNITION

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DEPENDABLE INTEGRATION
OF MEDICAL IMAGE RECOGNITION COMPONENTS

Computer driven medical image recognition may support medical doctors in the diagnosis process, but requires high dependability considering potential consequences of incorrect results. The paper presents a system that improves dependability of medical image recognition by integration of results from redundant components. The components implement alternative recognition algorithms of diseases in the field of gastrointestinal endoscopy. In our solution, we consider both algorithms that detect a single disease and algorithms that detect many diseases, in which case results from different algorithms are partially overlapping. The information is processed using the N-version programming (NVP) pattern to vote the final result. The solution adapts the standard NVP pattern to the specifics of the application area covering issues such as: managing diseases recognized by components, components reliability and data streaming. We maintain a catalog of known integrated components together with their reliability rating. The solution is a part of a complex service deployed and run in the KASKADA environment that is a framework for processing of computational intensive data in the streaming model. The KASKADA environment leverages the clustering architecture of supercomputer centers to allocate computational tasks to available computing nodes. Tests and results of exemplary disease recognition performed in the environment are presented.

1. INTRODUCTION

Computer driven medical image and video recognition may support medical doctors in their diagnosis process by automating image analysis and giving adequate recommendations. The great responsibility laying in guiding doctors in medical examinations result in strong expectation for algorithms' quality and precision. It is strongly expected that algorithms outputs are reliable and lack misleading data. At the same time video frames captured by medical imaging examinations comprise scenes difficult to analyze and de-

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tect objects within. For those reasons, most of the current commercial applications of medical imaging supporting systems are limited to simple and relatively safe tasks, e.g., data visualization, image synthesis, enhancement or compression.

In our work, we focus on gastrointestinal endoscopy image and video recognition of results. There exist many algorithms that cover a wide range of devices and recognized disease types[9] [5] [7]. The algorithms, however, does not guarantee absolute correctness and reliability, which introduces uncertainty.

Considering the difficulties, we propose a solution that intends to improve the correctness of image recognition by aggregation of results from many alternative recognition algorithms. We propose to apply the N-version programming (NVP) approach to vote results from alternative algorithms and return a summary result to a medical doctor. The NVP approach conforms well to this application area because there exist many alternative algorithms (modules) that supply overlapping functionality.

We adjusted NVP to the specific requirements encountered in this application area. The proposed solution may operate both on images and video streams depending on the diagnosis technique used by a medical doctor. In the solution, we use weighted voting of recognized diseases considering algorithm credibility, certainty of returned result, the range of recognized diseases and other factors. The proposed solution is implemented as an NVP Voter. Representative algorithms have been integrated in the environment.

2. BACKGROUND AND RELATED WORK

The problem addressed in the work covers both medical image recognition, dependability improvement by redundancy and management of computational intensive tasks.

2.1. MEDICAL IMAGE PROCESSING AND RECOGNITION

In response to a great demand for more intelligent systems also complex modules performing image analysis and classification are constructed and utilized [2], as well as future advancement is anticipated. Thus, in the scientific area many complex systems are being evaluated. Many of them are designed to perform highly complicated tasks and examples of such systems can be shown in the field of gastrointestinal endoscopy. Multiple algorithms capable of detecting specific diseases in endoscopic videos were developed [9] [5], similar methods for detecting general disease occurrence [7][11] and many other complex image analysis systems [6].

However, because of multiple difficulties in medical image analysis, most of complicated tasks as well as many simple tasks require utilization of advanced image analysis methods. This is a great challenge in area of reliable image processing and performance efficiency. Processing complexity often implies high demand for computational power. As the authors show in previous work [1], disease detection complexity exceeds the power of single PCs. Therefore, execution of algorithms can be highly parallelized using KASKADA platform developed within the MAYADAY 2012 project [8].

2.2. REDUNDANCY-BASED DEPENDABILITY ASSURANCE

Development of dependable software systems requires application of adequate means that typically require additional effort and resources [14]. Redundancy is a key element of dependability improvement. In our solution, we focus on redundancy in software components using the N-version programming (NVP) technique as a method to increase dependability.

NVP assumes that there exist many modules (programs) that are functionally equivalent and should return the same results for the same input values. In NVP, results generated by the modules are gathered by a decision mechanism that, typically, performs a kind of voting and calculates the final result [13], [4]. However, the technique increases application development-time and operation-time costs.

Despite the costs, NVP is well suited for development approaches, in which software is composed from existing components. The work [3] analyzes development of dependable systems out of undependable components. Focusing on the Web services technology, the authors propose a model of composite Web service that is composed from component Web services. The work [10] proposes to apply voting and redundancy to increase Web services dependability. Authors describe a dedicated voting module, called Web Services Fault Tolerance Mechanism (WS-FTM). Our work differs in that we propose a solution addressed for NVP in medical image recognition rather than a general model for Web services.

2.3. THE KASKADA DATA PROCESSING ENVIRONMENT

KASKADA [8] platform is a novel approach in the field of high performance computing. It is a universal runtime platform for algorithms processing multimedia streams, e.g. videos and sound recordings. Except being a powerful execution environment for time-consuming algorithms, KASKADA also provides a universal external interface in the form of automatically created Web services, enabling launching algorithms from remote locations, e.g. from doctor's office. KASKADA is also a framework facilitating the construction of stream algorithms. Also, extensive communication mechanisms are provided by the platform, enabling construction of highly parallelized, distributed algorithms in the form of computational services.

2.4. GASTROENTEROLOGY IMAGE RECOGNITION

One of the most common tasks in the field of image analysis of endoscopic videos is the detection of diseases. Designed algorithms are often aimed at detecting specific diseases, while another typical case is detection of abnormal tissues differing from normal, healthy state and therefore indicating occurrence of a disease without speci-fying it's type. Large group of algorithms is also based on a common processing pat-tern assuming utilization of artificial intelligence classifying methods, where the analysis is divided into 3 main steps as presented in Fig. 1.
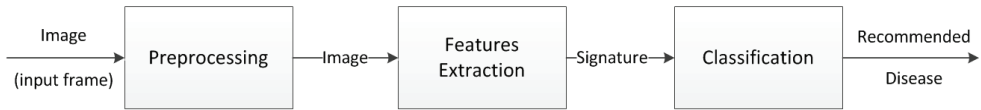
Fig. 1. A typical scheme of endoscopic disease detection algorithms

First, the input image is preprocessed in order to enhance it's quality and facilitate disease recognition. Next, features are extracted from the image by computing a set of measures using various image analysis methods, which are merged into an image signa-ture. Signatures are finally assigned to disease or non-disease group using artificial intel-ligence classifiers. The algorithm scheme presented above is remarkably flexible, the findings being detected are in fact determined by the provided training data set.

3. SYSTEM STRUCTURE AND OPERATION

In order to increase recognition accuracy, we propose to extend traditional image recognition approach with N-version programming (NVP) Voter. Figure 2 shows a general overview of image acquisition, processing and returning result to the user.
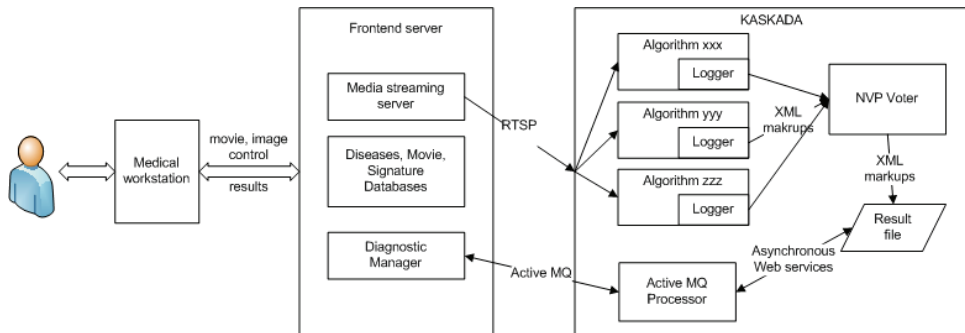
Fig. 2. A general model for medical image processing using NVP-Voter

3.1. INTER-COMPONENT INTERFACES

NVP Voter needs to interoperate with interfaces used in the system in order to avoid any changes in existing components. The interoperability is required on all layers of software integration. In the system, the following communication protocols are used:

- Real Time Streaming Protocol (RTSP) - the protocol is used for video file transfer between Medical workstation, the Kaskada Platform and services with recognition algorithms.
- ActiveMQ messaging - the mechanism is used for transmitting user requests to the system and results to the user frontend application.
- KASKADA service integration - the interface is used to transfer data between services hosted in the environment.

NVP Voter operates on results returned by the Log complex service. The Log service uses the KASKADA communication interface to transfer XML data with markup of detected diseases. The markup contains disease classification codes and timestamps of detected anomalies in the scope of elapsed time of the video stream.

NVP Voter does not modify the format of processed data, but rather adjusts timestamp and disease information in the considered file. Therefore, it may be transparently integrated with the existing system without the necessity to modify either simple services or frontend application.

3.2. ALGORITHMS CATALOG AND QOS ATTRIBUTES

The voting considers both the information about recognized diseases, result certainty and credibility of integrated modules. Result certainty is supplied by the module that supplies the simple service of disease recognition. Module credibility, in turn, results from assessment of each module.

The assessment procedure is initially applied during the training phase. The training was performed in a dedicated testing environment, which allows to automatic adjustment of parameters and carry out the tests on real medical pictures. The built testing environment takes 3 inputs: a set of algorithms to be tested, a set of their parameters with assigned values' ranges, and sets of medical images, on which classifiers are trained and tested with crossvalidation.

Cross-validation was found necessary, when overfitting of the algorithms was observed in the tests. It allows for better use of training data. The algorithms were trained and tested k times, every time on a different subset of input data. We used $k = 4$ to balance computational requirements and accuracy. Data subsets was constructed in a way, in which each subset proportion of diseases was preserved, and

all images from one examination belonged to the same subset. After choosing best algorithms' parameters' values, classifiers were trained on all of the subsets together.

For each algorithm, we define the efficiency score ($W_{A,d}$) as a value indicating the number of correct answers for a disease. Efficiency below 0,6 means random answers.

$$W_{A,d} = \begin{cases} Efficiency(A,d) & for\ Efficiency(A,d) \geq 0.6 \\ 0 & for\ Efficiency(A,d) < 0.6 \end{cases} \tag{1}$$

Each algorithm returns probability ($P_{A,d}(F)$) as a metric of disease detection.

$$P_{A,d}(F) = Output\ for\ frame\ \boldsymbol{F}\ of\ algorithm\ \boldsymbol{A}\ trained\ for\ disease\ \boldsymbol{d} \tag{2}$$

3.3. VOTING SCHEMAS

NVP Voter anticipates two modes: single frame mode and video streaming mode. Video stream processing leverages algorithms used for single frame processing, applying it to each recognized concept.

For a single image/frame, NVP Voter receives information about recognized diseases and confidence levels from each of integrated modules. NVP Voter calculates the final result using the following rules:
1. An initial list of diseases is created by union of diseases recognized by any of integrated module. An unspecified disease is also considered.
2. Each disease receives a rating calculated as a normalized weighted sum of rates multiplied by module credibility and result confidence level.

$$P_d(F) = \frac{\sum_A W_{A,d} P_{A,d}(F)}{\sum_A W_{A,d}} \tag{3}$$

The rate of unspecified disease (healthiness) is calculated as sum of rates for specific diseases

$$P_{healthy}(F) = 1 - \frac{\sum_{A,d} W_{A,d} P_{A,d}(F)}{\sum_{A,d} W_{A,d}} \tag{4}$$

3. Information about calculated diseases is returned to the user.

Video stream processing applies single image processing rules to region time-stamps in the video stream. The timestamps of the result returned by NVP Voter is a join of timestamps from integrated modules. Each starting and ending tag establishes timestamp start or end in the final result. If a tag from one module is located within a timestamp region returned from another module, the timestamp region is split. The result specifies timestamp with detected diseases and confidence level.

4. IMPLEMENTATION AND EVALUATION

As a part of the research we performed NVP-Voting for selected algorithms and exemplary test data. We used five algorithms and approximately 1500 images with different diseases (polyp, cancer, ulcer, colitis, crohn).

4.1. CONSIDERED ALGORITHMS

The investigated disease detection components were constructed by implementation and training of 5 disease detection algorithms. Four of the algorithms are based on chosen methods from the literature, while the remaining one is a simple algorithm focused on color features of the image. The algorithms were trained towards detection of general disease state against the normal, healthy tissues. Used algorithms are as follows:

- Kodogiannis1– algorithm designed for detecting disease tissues proposed by Kodogiannis et. al. [7]. The method is based on RGB and HSV color spaces. Texture information is extracted using unique NTU transformation.
- Magoulas1 – disease detection algorithm developed by Magoulas et. al. [11]. The method performs texture analysis by using Gray Level Coocurrence Matrices, reflecting spatial dependencies between image pixels.
- Magoulas2 – a more complex version of the previous algorithm [12]. The author extended the method by utilizing 2D discrete wavelet transforms. Image is decomposed into LH, HL and HH bands, GLCM texture analysis is performed and statistics are computed.
- BaoupuLi1 – cancer detection algorithm proposed by Li and Meng [9], utilizing RGB and HSI color spaces. Each channel is processed using two level 2D-DWT trans-formations, from which HL, LH and HH bands are considered. Resulted images are subject to LBP transformations.

Finally, a trivial Test generator based on color features of picture is used. The generator consists in pointing average pixel value for R, G, B and H, S, V canals. The purpose of this generator is to be a representation of a low quality algorithm.

4.2. TESTING PROCEDURE AND RESULTS

The testing was performed on a dedicated image set, independent from the training image set. The images presented both healthy tissue and disease tissue, covering different diseases without specifying disease type. All algorithms were tested using the set independently from the disease type recognized by each of them.

Classification of data set gives 4 raw components of result: True Positive, True Negative, False Positive and False Negative. However, those measures give few information about efficiency of recognition. In order to present more readable results, compound measures are used, such as: sensitivity, specificity and F-score. F-score, often used in document classification, takes recall and precision into consideration. The value of $F = 0$ denotes the worst result. The measure is appropriate for rating of medical image recognition to give a general overview of efficiency:

$$F_\beta = (1 + \beta^2) * \frac{specificity * sensitivity}{\beta^2 * specificity + sensitivity} \qquad (5)$$

where β is comparison coefficient meaning how many times sensitivity is more important than specificity. Figure 3 shows results for the tested modules.
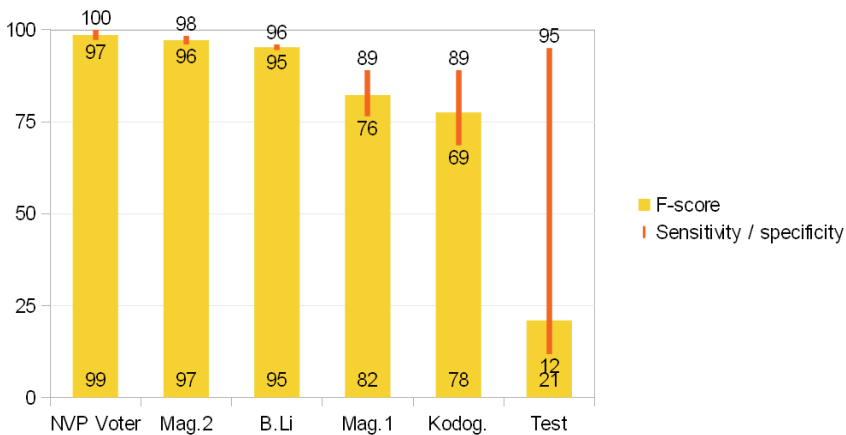
Fig. 3. Results for NVP Voter, four literature algorithms and a Test generator

As can be seen, NVP Voter increases the correctness of recognized diseases as compared to any of the algorithm.

5. CONCLUSIONS AND FUTURE WORK

The paper presented a method that applies N-version programming to increase accuracy of medical image recognition algorithms. In the method, we focused on processing of gastroenterology images. The presented method was implemented as a prototypical NVP Voter module that is hosted in the KASKADA environment. Experimental studies show that NVP Voter results are more accurate than any of integrated algorithms.

Implementation of detailed configuration capabilities and a user friendly interface are the main areas of future work. Currently, the system needs to be configured by a software developer, which limits its application area. We plan to enable a medical doctor with means to configure the voting algorithm: the number of recommended diseases and granularity of disease timestamps. Additionally, we plan to supply a feedback mechanism that would enable algorithm rating during system operation.

ACKNOWLEDGMENTS

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RECOGNITION OF PHYSICAL ACTIVITY
BASED ON DATA ACQUIRED BY WEARABLE SENSORS

Abstract: This paper presents a prototype of system for recognizing different types of human physical activity. In this system the recognition process is based on measurement data acquired by wearable sensors placed on user body. To this end, Shimmer units to gather accelerometer data were integrated with proposed system. From acquired data nine different features were extracted. The usefulness and importance of these features are demonstrated. Designed system was evaluated for different feature sets and classifiers. Obtained results indicated that system with wireless measurement units allows to recognize various physical activities with high accuracy.

1. INTRODUCTION

Rapid development of wireless sensor networks (WSN) opens new possibilities for various areas such as industry, healthcare, sport, emergency management or entertainment. Moreover, combining such technologies with system analysis techniques gives engineers and researchers powerful tool to solve practical problems in mentioned areas. In these solutions WSN are used to acquire measurements and transfer them to the computation units. On the computational unit the system analysis techniques such as optimization, machine learning and mathematical modelling are implemented in order to solve the problem of decision making. In general we can distinguish two kind of computational units: remote and local. The first one usually operates in distributed environments which are composed of huge amount of sensing nodes with wireless transceivers and one or more computation units. The second group is characterized by one (usually) computational unit which is connected with several wireless devices. Wireless devices are used to build wireless

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networks called Body Area Networks (BAN) to acquire and transfer measurement data. Then the transferred data are processed on local computational units (called *personal server*).

According to WHO (World Health Organisation) chronic diseases such as diabetes, cardiovascular diseases are the leading cause of death. Cardiovascular disease was cause of death for 17.1 million people in 2004. It was 29% of all global deaths. Risk factors for chronic disease such as cardiovascular disease are e.g. unhealthy diet and low level of physical activity. They affect people, decreasing their health and usually lead to increasing costs of healthcare. Some of these costs can be reduced by delivering tools which are able to promote healthy lifestyle and supporting healthy diet habits.

In this paper results of research project on an application to acquire data from a wearable sensor and to recognize the types of physical activity the user engages in is presented. The task has to be solved in real time. The problem can be approached from various directions. The method of determining the user's movements had to be taken into consideration. Ideally, the application would be versatile enough to be easily adapted to numerous types of sensors and execution environments. This is essential in making it mobile and actually useful in real-life conditions. Thus, the techniques of detecting and interpreting motion had to be able to be performed on varying equipment.

It is worth stressing that nowadays, most cell phones utilize various built-in sensors, such as accelerometers and gyroscopes. Because a cell phone is a device that is usually carried around, it is possible to use our application as a personal trainer. The main functionality of this application is to monitor user's daily activities (e.g. strolls) and based on its results calculates burnt calories. Additional functionality of proposed solution is related to implementation of motivation mechanisms in order to improve user's commitment with sports training.

In order to recognize the types of physical activity, a series of recognition-related problems had to be solved. The choice of algorithms, techniques and features influences not only the program's execution time, but the percentage of correct answers as well. The goal of our work was to create an application that would be fast and correct in the majority of cases. In the following sections, we describe our data collection methodology and our approach to recognize physical activity types from accelerometer data, followed by results.

2. STATE OF THE ART

The most and successful and exhaustive work in regard to activity recognition is that of Bao and Intille [2]. In their experiments, subject wore five biaxial accelerometers on different body parts as they performed a variety of activities like walk-

ing, sitting, standing still, watching TV, running, bicycling, eating, reading etc. Data generated by the accelerometers was used to train a set of classifiers, which included decision trees, decision tables, naive Bayes and nearest-neighbor classifiers. Using five accelerometers provide good classify accuracy however it could be uncomfortable for the user, so we attempted to recognize several types of activates using a single triaxial accelerometer. Worth mentioning is MOPET, a context-aware and user-adaptive wearable system for fitness training presented by Buttussi and Chittaro [4]. They described system that supervises a physical fitness activity based on alternating jogging and fitness exercises in outdoor environments. Such system could improve user's health, in terms of cardiovascular benefits, loss of weight or muscle strength, by providing motivation as well as safety and health advice adapted to the user. Active research is being carried out in exploiting different sensors embedded in mobile devices. Provisioning services to the user based on his location and/or activity is a new way of user-application interaction. Apple's iLife Fall Detection sensor which embeds an accelerometer and a microcomputer to detect falls, shocks or jerky movements is a good example. Making device aware of the activity of the user fits into the framework of user context awareness. Detected user context can be utilized for ambulatory monitoring like presented above or for entertaining purposes. A lot of games and applications available on Android Market store utilize smartphones build-in sensors to make them user-friendly. Hand and body motions are usually very intuitive ways of influencing a game's behavior, while complex button-based controls may produce unnecessary confusion. Applications like Edomondo Sports Tracker which use GPS to monitor user location or Lane Splitter which use build-in gyroscope to interact with user. Following this trend we would like to replace accelerometer Shimmer sensor with embedded in smartphone one which would help us to make our application become more user-friendly.

3. METHODS

3.1. EXPERIMENTAL SETUP

Before any recognition can take place, the user is required to put a wearable sensor in his right pocket, and connect it to the computer via Bluetooth connection. The point is to locate the sensor close to the user's center of mass, as it is the best indicator of what movements the user's body is involved in at any given moment. This location may also come in handy in case of substituting the sensor with a cell phone. The right pocket is a common place to store one's cell phone in, so the application does not force the user to change his/her habits.

3.2. PATTERN RECOGNITION – METHODOLOGY

Pattern recognition in general is a task which consists of several stages, namely: feature extraction, feature selection, and classification which are presented in Fig. 1. Feature extraction is a step in which input data is processed in order to bring out the values we intend to process. These values may not be visible explicitly in the input data, so they need to be extracted in some way. For example, the mean value of a series must be calculated and cannot be derived immediately. In the feature selection step, the extracted features are examined, and those that are found obsolete are discarded. While it could be possible to conduct computations on all of the extracted features, it often turns out that they can be simplified and accelerated by disposing of the unnecessary features, thus speeding up the whole process. The last step is the classification. Using a classifier, or a set of them, an n-dimensional space is created (where n is the number of selected features). The chosen set of classifiers must be first trained in order to correctly recognize patterns. This is achieved through any kind of machine learning techniques. After the process is finished, the classifier is ready to perform its task.

To recognize a particular activity type, a recognition algorithm is presented. In general, the algorithm has to acquire the necessary data, extract and select the features vital to recognition process, then, according to a separate classification algorithm, use this data to identify the observation and assign a specific class to it.
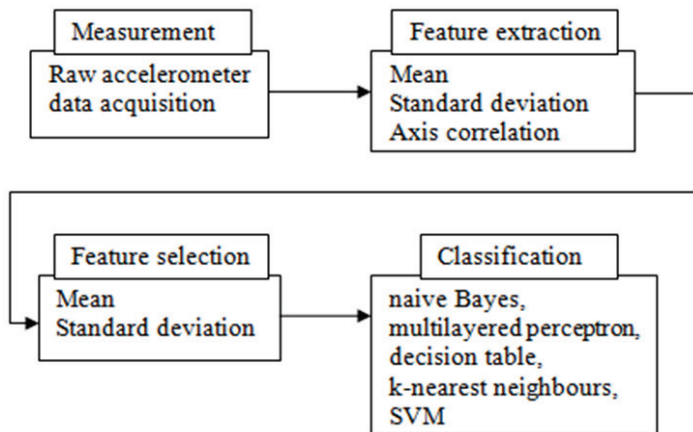
Fig. 1. Pattern recognition stages

3.3. DATA ACQUISITION

To collect all necessary data for recognizing chosen psychical activities we used a single sensor. An accelerometer, which is the most essential part of the sensor, is

a device that measures proper acceleration. The one that was used could measure the acceleration in all three spatial dimensions, which means it could provide a complete data of its movements. The sensor connected to a computer periodically sends the values it measures on each of the axes. The units in which the data is expressed are of no importance. Collected data are then processed by the application. The physical activity types we selected for the application to distinguish are as follows: standing, walking, running, push-ups, jumping in place, sitting, crouching and long jumps. Figure 2 shows gathered data for different activities. We can see that triaxial accelerometer data provide good distinction between chosen activities.

Fig. 2. Triaxial readings for different activities

3.4. DATA EXTRACTION

The application utilizes the accelerometer module of Shimmer sensor. The only data it acquires, are the values of acceleration on all three axes. Then, it calculates mean value and standard deviation of the respective axes. Next, the correlation factor between every axes pair. Correlation is calculated between each pair of axes as the ratio of the covariance and the product of the standard deviation.

$$corr(x, y) = \frac{\text{cov}(x, y)}{\sigma_x \sigma_y} \qquad (1)$$

Correlation is especially useful for differentiating among activities that involve translation in just one dimension. In summary, it gives us nine different features to identify physical activity types. The number of features could be problematic in a performance point of view, so it could be useful to check whether all of them are necessary to properly recognize chosen activities.

3.5. DATA SELECTION

The usefulness of chosen features has been demonstrated in prior work [2]. However from the performance point of view it could be necessary to recheck the influence of each feature on the accuracy of classification, because not all of them could be equal important in process of classification. Accurate tests was performed using Weka Machine Learning Toolkit. Results of those tests are presents in Table 1.

The symbol *X* in a field means that this particular feature has been dropped in this setting. We did a 10-fold cross-validation for each of the classifiers in each of the mentioned settings. In a 10-fold cross-validation, the data is randomly divided into ten equal-sized pieces. Each piece is used as the test set with training done on remaining 90% of the data. The test results are then averaged over the ten cases. It could be quite surprising that chosen psychical activities could be properly recognized while using only 3 features. These selected features are: mean of *x*-axis, mean of *z*-axis and standard deviation of *x*-axis. Those results will become important when we move our framework to the Android platform which is more performance sensitive than a personal computer. However after switching to setting 9 we can observe noticeable improvement in application performance even on the PC.

Table 1. Effect of dropping an attribute on classification accuracy

Setting	1	2	3	4	5	6	7	8	9
Mean X		X							
Mean Y		X							X
Mean Z		X						X	
Standard Deviation X			X		X				
Standard Deviation Y			X			X	X	X	X
Standard Deviation Z			X				X	X	X
Correlation XY				X	X	X	X	X	X
Correlation XZ				X	X	X	X	X	X
Correlation YZ				X	X	X	X	X	X
Average no. of correctly classified instances [%]	100	95	97.5	98.75	93.75	98.75	97.5	96.25	97.5

3.6. CLASSIFICATION ALOGIRTHMS

In order to successfully recognize, sample teaching inputs had to be acquired. The teaching inputs are basis on which all the recognition is performed. Each teaching input is already recognized, and set to be an example of a particular movement. Then them can be used for testing purposes. Five different classifiers are used to distinguish between the chosen psychical activity types, namely: naive Bayes algorithm, multilayered perceptron, decision table, k-nearest neighbours and support vector machine all available in Weka toolkit. Each mentioned classifier

was tested using Weka's experimenter module. In 10 repeated iterations using 10-fold cross validation classifier accuracy was estimated. The results are presented in table 2.

Table 2. Accuracy of classifiers

Classifier	Accuracy [%]
Naive Bayes	97,5
Multilayered perceptron	92,5
Decision table	68,75
K-nearest neighbours	96,25
SVM	88,75

Three from five tested algorithms reached more than 90% accuracy on selected data set. However multilayered perceptron and *k*-nearest neighbours took a lot more CPU time to build model than naive Bayes. When the accuracy is the same, performance value should be the second attribute that help us chose best algorithm for our application.

Table 3. Representative Confusion Matrix

Activity	Classified as							
	Running	Walking	Push ups	Jumping	Sitting	Standing	Crouching	Long jumps
Running	10	0	0	0	0	0	0	0
Walking	0	9	0	1	0	0	0	0
Push ups	0	0	10	0	0	0	0	0
Jumping	0	0	0	10	0	0	0	0
Sitting	0	0	0	0	10	0	0	0
Standing	0	0	0	0	0	10	0	0
Crouching	0	0	0	0	0	0	10	0
Long jumps	0	0	0	1	0	0	0	9

4. RESULTS AND DISCUSSION

To achieve acceptable classification accuracy and performance speed, we tested different settings of attributes and classifiers. Table 1 shows that setting 9 let us choose only necessary features which improved our application performance in a noticeable way, and at the same time barely affected classification accuracy. Table 2 shows that almost all tested classifiers gave good classification results. Naive Bayes, multilayered perceptron and *k*-nearest neighbours stand out in a positive way. How-

ever, the first one took less CPU time to build model, so in our application we used naive Bayes. Results of classification of chosen 8 types of psychical activities are presented in table 3. We did a 10-fold cross-validation and presented results are average of these ten cases. As we can see only 2 misclassifications were made. However, choosing more complex activities could make us add more sensors to properly recognize them.

5. PATTERN RECOGNITION SYSTEM

The general structure of the application is presented in Fig. 3. At the beginning, user must put Shimmer sensor in hit right pocket. In the first stage of pattern recognition, data are collected from the wearable sensor, in intervals spanning one second. The inherent sensor sampling frequency is 50Hz, which means that a sequence of 50 readings on each axis is sent for further processing every second. The application receives the sequence and conducts the necessary calculations. As was previously proven, the only features that need to be extracted are *Mean Y*, *Mean Z* and *Standard Deviation Z*. These are used in the actual recognition process, with the help of the previously mentioned classifiers, taught by previously created archetype sequences for each type of physical activity. Those stereotypes could be replaced by user to adjust the application to his needs. The final output is determined by using naive Bayes algorithm . The application displays the recognized activity type and number of burned calories in the GUI layer, with which user directly interacts.
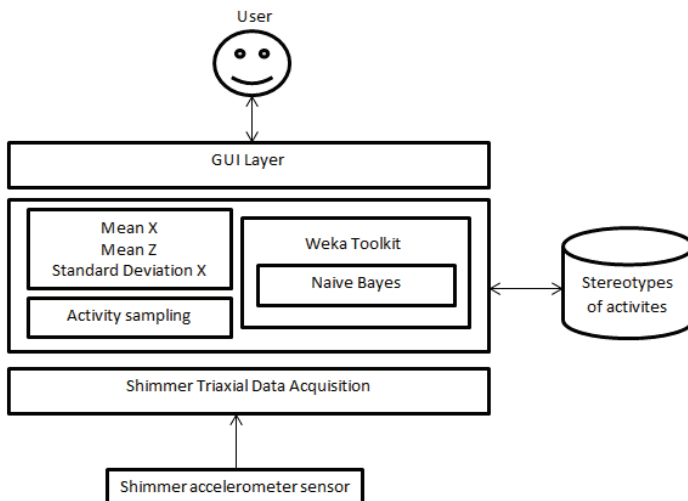
Fig. 3. Pattern recognition stages

Section presents system requirements and specifications which refer to the capabilities of the final system. Presented specification is a result of user needs analysis and complies with technical limitations. We divide it on functional and non-functional requirements.

Functional requirements for desktop application

− Application must get data from Shimmer accelerometer via Bluetooth;
− Application must properly recognize specified types of user activities;
− User could provide stereotypes of activities to personalise application;
− User could generate charts for the last 30 measurements;
− User could generate chart from present daily/weekly activity. It helps to evaluate number of burnt calories;
− User could fix number of calories to be burnt each day, and when he exceed his limit, he should be informed by beep;
− User could save and get data to/from database.

Non-functional requirements for desktop application

− User must pair the Shimmer sensor with computer;
− User must put Shimmer sensor in his right pocket while perform activities;
− Results of recognition should be presented in simple and easy to understand way;
− System must be comfortable to use and not bothersome.

Especially non-functional requirement could be fulfilled better if we replace Shimmer accelerometer with smartphone which has built-in sensors. Then our system would be a lot more comfortable to use and do not require any additional equipment.

6. CONCLUSIONS AND FUTURE WORK

We found that the chosen types of activities can be recognized with high accuracy using a single triaxial accelerometer. We tested different settings of combinations of features and found that mean of x-axis, mean of z-axis and standard deviation of x-axis fulfill all requirements. Using naive Bayes as a classification algorithm let us sustain good classification accuracy and performance speed. An interesting extension would be to use accelerometer embedded into a smartphone replacing utilized Shimmer sensor. Then, all smartphone users could use our application without any additional equipment. Furthermore we found that the best place for accelerometer is near user's center of mass so we choose user right pocket. This location may also come in handy

in case of substituting Shimmer with a smartphone. The right pocket is a common place to store one's cell phone in, so the application does not force the user to change his/her habits.

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THE EVALUATION OF FLYING OBJECTS
IMAGES IDENTIFICATION ALGORITHMS
BASED ON GENERALIZED DIGITAL
HILBERT OPTICS HYBRID METHODS

The comparative studies and analysis of flying objects identification effectiveness are conducted with described algorithms and some results of their effectiveness evaluation are presented. Algorithms are based on Hilbert–Foucault, Hilbert–Radon, Hilbert–Fourier and generalized amplitude-phase (GAP-) transforms hybrid methods of previous images processing and correlation comparison of tested object spectra with sets of template model spectra of images synthesized with 3-D graphic software application and stored at data base (warehouse). The bases of comparison are the spectra of identity (non-)transformed, the Radon-, Fourier- and GAP-transformed images of synthesized and rotated at 3-D space flying objects. The histograms of intra- and inter-class comparison correlation coefficients with statistic moments and discriminant analysis parameters are presented as base of evaluation. The ratings of algorithms and perspectives of future investigations are evaluated.

1. INTRODUCTION

Correct and fast identification of moving – especially flying objects as basic procedure of dynamic scenes (DS) analysis is very important practical problem on computer vision and image processing deals with many different branches of science, technology, military targeting, guidance and security monitoring, education, human health and handicaps medical care, drivers and pilots training, etc. [1, 2, etc.] Applica-

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tion of generalized complex analysis algorithms based on digital Hilbert optics methods (MDHO) can improve effectiveness of such kind identification methodology. The main stages of this methodology consist of algorithms elaborating and effectiveness evaluating. The identification realized with hybrid optical-electronic systems (HOES) is based on identification information technology (IIT) of moving objects detecting, shape describing and identification (modeling) as structural elements of DS. During several last decades the methods of Hilbert optics have begun to be applied for solving of such image processing problems. The term ''identification'' here is used in meaning the spatial shape and dynamic characteristics modeling as sets of pattern features and object recognition based on different types discrimination and separation algorithms. The improvement of identification abilities needs leads to the elaboration of more sophisticated procedure with higher sensitivity on interclass objects' shapes changes and more protecting (high-stability) on image dynamic changes (caused by relative movements of objects inside DS) forming their intraclass peculiarities. These demands set up such kind of "trade-off" situation and therefore needs the further design and properties investigations of prefiltering and features extraction methods arise. The improving of interclass discrimination abilities and intraclass stabilities, as authors' theoretic and experimental researches and simulations proof, could be achieved with MDHO applications [3–5, etc.]. Especially, the applications of generalized two-dimension phase images of identified objects determined with separable and no separable digital Hilbert transforms (DHT) present the high interest as the means for moving (flying) complex shape objects (CSO) identification. The state of art analysis shows the insufficiency of this class algorithms investigation in context of formulated above problem.

The main goal of this article is to present the results of comparative study and evaluation of effectiveness of correlative algorithms used for CSO identification based on hybrid digital isotropic and anisotropic linear and nonlinear Hilbert-optics methods.

2. THE DESCRIPTION OF MDHO IIT INVESTIGATION METHODOLOGY

The presented below results show the possibilities of preserving or even increasing the discrimination abilities of the correlative algorithms applied at MDHO-transformed amplitude-phase images obtained via isotropic and anisotropic DHT (or their hybrids with referent transforms). As theoretic basis of investigated algorithms the convenient identity (non-)transformed, Radon-, low spatial frequency domain filtered Fourier (separable algorithms FFT_LSF) and the generalized amplitude-phase (GAP-) transforms (complex analysis) based on Hahn's algorithms [2] as reference to comparative study are used. The experimental investigations has been realized with the use of 20 modeling 3-D aircrafts' images as the source of more than 20.000 of 2-D

plane images (plane projections) distorted via the rotations, translations, additive noises and rendering with controlled random illumination conditions. The range of rotations was $(0..10)^o$ or $(0..90)^o$ at each direction – course, bank and slope – with $1,0..5,0^o$ steps. On next, these distorted binary and gray-scaled (rendered) images have been processed with different types of DHT algorithms for generalized two-dimension amplitude and phase images recovering. Linear algorithms remain the signs of Hilbert transforms but nonlinear ones use the adaptive amplitude normalization (AAN) of Hilbert transforms dynamic range or use the absolute values (AVN) of these transforms to estimate the AP-fields. The isotropic two-dimension DHT algorithms calculate the transforms as logic (or arithmetic) sums of parallel one-dimension transforms but anisotropic – as result of stage (cascade) transposed images transforms. Some examples of origin images and their transforms are presented in Figs. 1, 2 below.

2325 – BW	2364 – BW	2368 – BW
2325 – BW PLAN	2364 – BW PLAN	2368 – BW PLAN
2325 – GR	2364 – GR	2368 – GR

Fig. 1. Some original images of investigated objects

The originalIIT system realized on Matlab 7.5 basis has been used to provide the statistical experimental researches of correlative discrimination properties of two-dimension MDHO-transformed images. As the results the estimations of probability distributions and their statistic moments of inter(IrCC)- and intraclass correlation coefficients (IaCC) has been obtained. For analysis of discrimination (interclass sensitivity

2325 – NTR	2325 – FFT	2325 – HTA
2325 – HTI	2325 – FCA	2325 – FCI
2325 – RD_NTR	2325 – RD_HTA	**Legend** NTR – Non-Transformed image FFT – Modified FFTShift transform HTA – Hilbert anisotropic transform HTI – Hilbert isotropic transform FCA – Foucault anisotropic transform FCI – Foucault isotropic transform RD_NTR – Modified Radon transform on original image RD_HTA – Modified Radon transform on HTA-ed image

Fig. 2. Samples of transformed images of '2325' original image

and separation) and stability (intraclass clustering and grouping) properties the matrices of statistic measures of class distances have been calculated. These measures are obtained as ratios of differences of Ia- and IrCCs means values and sums of standard deviations of Ia- and CCs. As measure of probable recognition (identification) error (method of minimal average risk) estimation the intersection of IaCC- and IrCC-distributions are calculated. Results of experiments show the difference between influence of linear and nonlinear algorithms on character of distributions. As the representative sets of CSO images elaborated the nearest form objects are chosen.

The two main projections – side and upper (bottom) views of these CSO non-transformed images (in BW- (Binarized Black-White) and GR- (Gray) formats) are used as base image templates identified with tags ('2325' etc.).The rotation of CSO model in 3-D space causes the angular noise distortions which generate the fuzzy clusters of patterns represent the classes of images. This pattern are: spectra of transformed images or signatures like AP-fields, differential AP-fields, vector signature descriptions (VSD) correlation coefficients or statistical parameters histograms or diagrams. The identification procedure sets up the signature of image classification patterns and makes the decision which type of CSO (CSO-class) the tested image is represented. This decision is based on threshold comparison algorithms with adaptive threshold level setting.

3. ANALYSIS OF CSO IIT MODELING EXPERIMENTAL RESULTS

The experimental investigation of proposed IIT consists of stages numerical modeling and statistical analysis of tested and template CSO images coefficients of correlation (*CoC*) obtained in the transforms' domains. For such analysis additionally to common descriptive measures of statistic moments specially proposed measures are used:

- *classes* (*cluster*) *compactingeffectiveness* (*CCE*) - ratio of mean value to mean-square deviation of correlation coefficients (intra- and interclass correlation) of tested and template object transformed images for each class. The next step is the averaging of local measures over all classes;
- *classes* (*clusters*) *discriminationeffectiveness* (*CDE*) - ratio of classes mean values differences to sums of mean-square deviations of these classes (clusters);
- *previous data transforming effectiveness* (*PDTE*) – ratio of correlation coefficients means values differences inside previously transformed data classes (clusters) to such kind differences of reference classes (mostly – non-transformed (identity transformed) data);
- *average and minimal peak-factors (A&MPF)* – ratios of maximal coefficient of intra-(inter-) class correlation value to average or nearest (sub-) maximal correlation value;

– *average relative classification decisionrisk* (*ARCDR*) could be chosen as thein-
dicator of data discrimination and effectiveness of classification at stage of
identification procedure (incorrect decision rate – *ICDR*) and has to be calcu-
lated as ratio of average value of CSO transformed image misidentification
probability to the same one calculated for identity (or Fourier-) transformed im-
ages.

Table 1 presents the relative average values of *PDTE* and *CCE* (to identity trans-
formed data (*NTR*) classifier – a) and Fourier transformed and filtered data (*FFT*)
based classifier – b) as reference), Table 2 – relative average CCE values. These
measures are calculated in conditions of side view (side projection) – *SV* and plane
view (upper or bottom projection) – *PV*, CSO image BW format. The abbreviations
used at the tables mean: *NTR* – identity transform (Non-TRansformed data), *HTA* –
anisotropic adaptive normalized Hilbert transform, *HTI* – isotropic adaptive normal-
ized Hilbert transform, *HTA_A* – anisotropic absolute values normalized Hilbert trans-
form, *RD_NTR* – Radon-identity transform, *RD_HTA* hybridHilbert anisotropic –
Radon transform, *FCA* – Foucault anisotropic transform, *FCI* - Foucault isotropic
transform,, *FFT* – Fast Fourier Transform (hybrid with low spatial frequency filtering
(*LSF*) algorithm), *MoM* – mean of mean (general average).

Table 1. Relative average values of PDTE and CDE measures of CSO classification

MDHO algo-rithm type		NTR	RD_NTR	RD_HTA	HTI	HTA	FCI	FCA	HTA_A	FFT
a) NTR_Ref										
PDTE	SV	1,00	2,47	0,42	0,59	0,90	1,11	0,98	0,65	1,51
	PV	1,00	2,50	3,60	0,98	0,88	0,86	0,77	-	0,37
CDE	SV	1,00	0,00	1,09	0,84	1,19	1,86	1,41	0,89	0,67
	PV	1,00	0,00	1,39	1,09	1,12	1,20	0,96	-	0,31
b) FFT_Ref										
PDTE	SV	0,66	1,64	0,28	0,39	0,60	0,73	0,65	0,43	1,00
	PV	2,69	6,71	9,67	2,65	2,35	2,32	2,06	-	1,00
CDE	SV	1,50	0,00	1,64	1,25	1,79	2,79	2,12	1,33	1,00
	PV	3,18	0,00	4,43	3,48	3,57	3,82	3,07	-	1,00

(Shadowed blocks here and below – non-existed or low representative eliminated data)

The analysis of results presented at Table 2 shows that MDHO-based hybrid Ra-
don-Hilbert anisotropic transform based algorithms of classification (*RD_HTA*) obtain
parameters *CDE* and *PDTE* increased relatively to *NTR* in *PV* CSO images recogni-
tion conditions – 1,09..3,6, *HTI*-and *HTA*-based algorithms – in such conditions
– 1,09..1,20. In *SV* CSO images recognition conditions some of these algorithms as-
sure the increasing of effectiveness – 1,09..1,86.

Table 2. Relative average values of CCE measures of CSO classification

CSO class	2325	2364	2368	2369	2372	2386	MoM
a) CCE_SV							
FCA	0,51	0,45	0,34	0,40	0,47	0,55	0,45
FCI	0,38	0,41	0,18	0,08	0,31	0,36	0,29
HTA	0,68	0,62	0,63	0,64	0,70	0,65	0,65
HTI	0,63	0,65	0,75	0,55	0,68	0,61	0,65
NTR	1,00	1,00	1,00	1,00	1,00	1,00	1,00
HTA_A	0,66	0,69	0,80	0,66	0,83	0,69	0,72
RD_HTA	0,79	0,31	–	0,31	0,65	0,52	0,52
b) CCE_PV							
FCA	0,60	0,56	0,42	0,51	0,54	0,61	0,54
FCI	0,55	0,33	0,39	0,43	0,45	0,51	0,44
HTA	0,60	0,61	0,58	0,63	0,67	0,68	0,63
HTI	0,73	0,61	0,50	0,57	0,68	0,60	0,61
NTR	1,00	1,00	1,00	1,00	1,00	1,00	1,00
RD_HTA	1,62	1,8	–	0,58	1,35	1,58	1,39

The comparison of MHDO-based algorithms effectiveness with *FFT_LSF* as reference shows the increasing in the range 1,2..9,7 – in *PV* CSO images recognition but decreasing of *PDTE* parameters – 0,3..0,7 in *SV* CSO images recognition conditions. Good performances are presented by *RD_HTA* based on anisotropic Hilbert transforms.

The analysis of relative average *CCE* parameters presented at Table 2 shows their mostly decreasing in range 0,3..0,7 with exception of algorithm *RD_HTA* which presents the *CCE_PV* increasing up to value 1,4.

Table 3. *MPF* parameter of intra-class (diagonal blocks)
and inter-class *CSO* correlation matrices estimations

ToT	NTR_SV_GR							NTR_SV_BW						
	CSO	2325	2364	2368	2369	2372	2386	CSO	2325	2364	2368	2369	2372	2386
HTA_SV		1,00	1,51	1,55	2,34	1,60	1,26	2325	1,00	1,54	1,29	2,03	1,25	1,12
	2325	1,00	1,00	2,24	1,68	1,82	1,43	2364	1,00	1,00	1,73	1,29	1,45	1,34
	2364	1,70	1,00	1,00	3,31	1,80	1,56	2368	1,79	1,00	1,00	2,77	1,31	1,30
	2368	1,82	3,08	1,00	1,00	2,46	1,93	2369	1,46	2,13	1,00	1,00	2,12	1,79
	2369	2,95	1,99	3,85	1,00	1,00	1,31	2372	2,34	1,42	2,86	1,00	1,00	1,17
	2372	1,81	2,27	2,18	2,94	1,00	1,00	2386	1,34	1,63	1,42	2,47	1,00	1,00
	2386	1,32	1,59	1,90	2,17	1,38	1,00		1,17	1,55	1,48	2,07	1,23	1,00
	RD_HTA_SV_GR (RD-HTA_...)							RD_HTA_SV_BW (RD-HTA_...)						
	CSO	2325	2364	2368	2369	2372	2386	CSO	2325	2364	2368	2369	2372	2386

HTI_SV		1,00	1,28	1,75	1,47	1,09	1,05	2325	1,00	1,35	1,35	1,26	1,08	1,03
	2325	1,00	1,00	1,16	1,32	1,05	1,21	2364	1,00	1,00	1,29	1,09	1,07	1,06
	2364	1,62	1,00	1,00	1,27			2368	1,55	1,00	1,00	1,05	1,79	1,28
	2368	1,38	1,76	1,00	1,00	1,21	1,27	2369	1,22	1,34	1,00	1,00	1,27	1,17
	2369	1,66	1,59	1,70	1,00	1,00	1,05	2372	1,56	1,28	1,52	1,00	1,00	1,04
	2372	1,50	1,80	1,44	1,66	1,00	1,00	2386	1,21	1,51	1,15	1,52	1,00	1,00
	2386	1,26	1,36	1,38	1,60	1,28	1,00		1,13	1,32	1,15	1,44	1,17	1,00
		FCA _SV_GR							FCA _SV_BW					
FCI_SV		1,00	1,93	1,70	2,93	1,75	1,35	2325	1,00	2,24	1,47	4,76	1,43	1,28
	2325	1,00	1,00	2,14	1,75	1,91	1,61	2364	1,00	1,00	2,63	1,42	1,78	1,62
	2364	2,34	1,00	1,00	3,47	1,80	1,62	2368	3,28	1,00	1,00	-	1,65	1,64
	2368	2,46	2,66	1,00	1,00	2,71	2,37	2369	1,81	-	1,00	1,00	3,67	2,35
	2369	3,89	2,32	6,71	1,00	1,00	1,41	2372	-	1,75	-	1,00	1,00	1,29
	2372	2,15	2,38	2,25	4,52	1,00	1,00	2386	1,58	2,71	1,92	-	1,00	1,00
	2386	1,69	1,96	2,64	3,62	1,59	1,00		1,28	2,02	1,97	-	1,39	1,00
		FFT_LSF_SV_GR							FFT_LSF_SV_BW					
NTR_SV		1,00	1,43	1,40	1,41	1,37	1,38	2325	1,00	1,45	1,35	1,34	1,33	1,32
	2325	1,00	1,00	1,34	1,40	1,47	1,39	2364	1,00	1,00	1,51	1,44	1,44	1,42
	2364	1,51	1,00	1,00	1,35	1,41	1,30	2368	1,51	1,00	1,00	1,34	1,33	1,28
	2368	1,55	2,24	1,00	1,00	1,38	1,35	2369	1,55	2,24	1,00	1,00	1,28	1,34
	2369	2,34	1,68	3,31	1,00	1,00	1,39	2372	2,34	1,68	3,31	1,00	1,00	1,29
	2372	1,60	1,82	1,80	2,46	1,00	1,00	2386	1,60	1,82	1,80	2,46	1,00	1,00
	2386	1,26	1,43	1,56	1,93	1,31	1,00		1,26	1,43	1,56	1,93	1,31	1,00
	CSO	2325	2364	2368	2369	2372	2386	CSO	2325	2364	2368	2369	2372	2386

The analysis of *average and minimal peak-factors* (*A&MPF*) dependences on type of transform used for previous image processing over the whole set of identified CSO classes is based on procedures of global maximal *CoC* values (*GMV*) searching (diagonal elements equal 1 in intra-class CSO correlation matrix and less than 1 – in inter-class correlation matrix) and calculation of average value of no-diagonal elements (for average peak-factor – *APF* calculation) and (or) finding the next nearest (by value) to global maxima value – *NNV* (for minimal peak-factor *MPF* calculation). The maps of *PF* are built as tables of *GMV* to each *CoC*-matrix component ratios and could be used for setting the strategy of templates (as data base components) turn choosing priority in sequential correlative identification. The *A&MPF* parameters also are used for estimation of correlation comparing threshold levels and studies of potential asymptotic discriminative properties of investigated algorithms of identification. The *A&MPF* estimated values are presented at Tables 3, 4 in accordance to types of transform based algorithms and observation conditions.

Table 4. Comparative analysis of average *A&MPF* parameters
(*_SV_GR&_SV_BW* observation conditions)

a) Estimations of mean APF and MPF values vs. Type of Transform (ToT) and CSO Class – in observation conditions:														
Condition	APF_SV_GR							APF_SV_BW						
ToT\CSO	2325	2364	2368	2369	2372	2386	MoM2	2325	2364	2368	2369	2372	2386	MoM2
NTR	1,31	1,19	1,29	1,21	1,36	1,21	1,93	1,11	1,11	1,11	1,11	1,16	1,13	1,52
HTA	1,39	1,27	1,46	1,32	1,45	1,28	2,41	1,15	1,18	1,18	1,20	1,23	1,19	1,76
RD_HTA	1,03	1,06	1,13	1,10	1,04	1,03	1,27	1,02	-	1,29	1,12	1,03	1,05	1,22
HTI	1,26	1,16	1,36	1,19	1,24	1,20	1,64	1,15	1,14	1,13	1,16	1,21	1,19	1,41
FCA	1,46	1,25	1,41	1,36	1,48	1,37	2,31	1,24	1,27	1,26	1,25	1,39	1,30	2,31
FCI	1,72	1,40	1,74	1,57	1,88	1,52	2,81	1,26	1,28	1,28	1,29	1,42	1,30	2,04
FFT	1,15	1,40	1,26	1,29	1,26	1,29	1,43	1,24	-	1,39	1,25	1,25	1,28	1,40
MoM1	1,33	1,25	1,38	1,29	1,39	1,27	1,97	1,17	1,20	1,23	1,20	1,24	1,21	1,67
b) Relative measure of effectiveness: APF_CoC(DHOTransfData)/APF_CoC(NTRData) – NTR_Ref														
Condition	APF_SV_GR							APF_SV_BW						
NTR	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
HTA	1,06	1,07	1,13	1,09	1,07	1,06	1,22	1,04	1,06	1,07	1,07	1,06	1,06	1,15
RD_HTA	0,78	0,90	0,87	0,91	0,77	0,85	0,71	0,92	-	1,16	1,01	0,89	0,93	0,83
HTI	0,96	0,98	1,05	0,98	0,92	0,99	0,90	1,04	1,02	1,02	1,04	1,04	1,05	0,97
FCA	1,11	1,06	1,09	1,12	1,09	1,13	1,18	1,12	1,14	1,14	1,12	1,19	1,16	1,42
FCI	1,31	1,18	1,35	1,30	1,39	1,26	1,61	1,13	1,15	1,16	1,16	1,22	1,16	1,44
FFT	0,88	1,18	0,97	1,07	0,93	1,07	0,81	1,12	-	1,26	1,12	1,08	1,14	0,97
c) Relative measure of effectiveness: APF_CoC(DHOTransfData)/APF_CoC(FFTData) – FFT-Ref														
Condition	APF_SV_GR							APF_SV_BW						
NTR	1,14	0,84	1,03	1,32	1,08	0,94	1,34	0,89		0,80	0,89	0,93	0,88	1,10
HTA	1,20	0,91	1,16	1,02	1,15	0,99	1,67	0,93		0,85	0,96	0,98	0,93	1,27
RD_HTA	0,89	-	0,90	0,85	0,83	0,80	0,90	0,82		0,92	0,90	0,82	0,82	0,69
HTI	1,09	0,82	1,08	0,92	0,99	0,93	1,14	0,92		0,81	0,93	0,96	0,92	1,01
FCA	1,27	0,89	1,12	1,05	1,18	1,06	1,60	1,00		0,91	1,00	1,11	1,01	1,59
FCI	1,49	1,00	1,38	1,22	1,50	1,18	1,83	1,01		0,92	1,03	1,13	1,01	1,23
FFT	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00		1,00	1,00	1,00	1,00	1,00

A. Sudoł et al.

Table 5. Estimations of interclass misidentification probabilities
(average decision risk method)

ToT		NTR_SV_GR						NTR_SV_BW					
	CSO	2325	2364	2368	2369	2372	2386	CSO	2325	2364	2368	2369	2372	2386
HTA_SV	2325	–	0,306	0,259	0,005	0,249	0,599	2325	–	0,000	0,178	0,000	0,231	0,458
	2364	0,258	–	0,000	0,019	0,001	0,139	2364	0,001	–	0,000	0,186	0,045	0,119
	2368	0,141	0,000	–	0,000	0,160	0,241	2368	0,131	0,001	–	0,000	0,170	0,175
	2369	0,002	0,036	0,011	–	0,000	0,022	2369	0,000	0,237	0,000	–	0,000	0,000
	2372	0,182	0,003	0,255	0,003	–	0,551	2372	0,247	0,086	0,267	0,000	–	0,522
	2386	0,580	0,171	0,287	0,062	0,557	–	2386	0,491	0,136	0,198	0,017	0,530	–
		RD_HTA_SV_GR (RD-HTA_...)						RD_HTA_SV_BW (RD-HTA_...)					
HTI_SV	2325	–	0,001	0,000	0,000	0,080	0,115	2325	–	0,011	0,000	0,000	0,085	0,317
	2364	0,182	–	0,000	0,039	0,205	0,457	2364	0,094	–	0,145	0,529	0,580	0,553
	2368	0,373	0,003	–	0,218	0,048	0,002	2368	0,424	0,150	–	0,446	0,342	0,422
HTI_SV	2369	0,143	0,021	0,323	–	0,299	0,221	2369	0,099	0,267	0,084	–	0,315	0,283
	2372	0,225	0,002	0,462	0,142	–	0,390	2372	0,410	0,052	0,522	0,154	–	0,456
	2386	0,488	0,127	0,391	0,144	0,469	–	2386	0,585	0,183	0,448	0,201	0,567	–
		FCA_SV_GR						FCA_SV_BW					
FCI_SV	2325	–	0,205	0,379	0,004	0,369	0,613	2325	–	0,000	0,274	0,000	0,336	0,498
	2364	0,000	–	0,005	0,076	0,033	0,148	2364	0,000	–	0,000	0,370	0,119	0,220
	2368	0,170	0,000	–	0,003	0,336	0,349	2368	0,170	0,000	–	0,000	0,240	0,245
	2369	0,000	0,220	0,000	–	0,043	0,083	2369	0,000	0,220	0,000	–	0,000	0,029
	2372	0,286	0,028	0,198	0,000	–	0,557	2372	0,286	0,028	0,198	0,000	–	0,554
	2386	0,511	0,134	0,171	0,000	0,542	–	2386	0,511	0,134	0,171	0,000	0,542	–
		FFT_LSF_SV_GR						FFT_LSF_SV_BW					
NTR_SV	2325	–	0,216	0,489	0,477	0,607	0,493	2325	–	0,088	0,401	0,459	0,484	0,550
	2364	0,306	–	0,647	0,764	0,567	0,727	2364	0,000	–	0,139	0,387	0,308	0,429
	2368	0,259	0,000	–	0,114	0,020	0,235	2368	0,178	0,000	–	0,321	0,342	0,471
	2369	0,005	0,019	0,000	–	0,315	0,323	2369	0,000	0,186	0,000	–	0,440	0,293
	2372	0,249	0,001	0,160	0,000	–	0,108	2372	0,231	0,045	0,170	0,000	–	0,525
	2386	0,599	0,139	0,241	0,022	0,551	–	2386	0,458	0,119	0,175	0,000	0,522	–

(Shadowed blocks here and below– non-existed or low representative eliminated data)

Parameter *ARCDR* is evaluated as the ratio of probability estimations of incorrect classification decisions(misidentification) rates (*ICDR*) made with previously transformed (with investigated algorithms using) data to the same kind estimation made with using of reference processing algorithm. The results of statistical modeling and analysis of this parameter are presented at Tables 5, 6, 7. Table 5 contains the mean values of estimated probabilities of misidentification (inter-class discrimination) CSO in side projection (_SV_GR&_SV_BW) observation conditions. Table 5 consists of the means of *ICDR* estimations – a) and relative measures of CSO class discrimination effectiveness

with *NTR* – b) and *FFT* – c) reference algorithms respectively. These results show the approximate equivalence of the recognition (CSO identification)effectiveness assured by using of previously identity (*NTR*) and Hilbert transformed (*HTA*) images as tested and template patterns. The analysis of data shows the advantages of Hilbert transforms based algorithms over Fourier transforms based algorithms – c) and relative close commensurability with identity transform based ones – b).

Table 6. Comparative analysis of *ARCDR* parameters
(*_SV_GR&_SV_BW* observation conditions)

a) Estimations of mean ICDR values vs. Type of Transform (ToT) and CSO Class – in observation conditions:														
Condition			_SV_GR							_SV_BW				
ToT\ CSO	2325	2364	2368	2369	2372	2386	MoM	2325	2364	2368	2369	2372	2386	MoM
NTR	0,284	0,093	0,132		0,192	0,310	0,170	0,173	0,070	0,105		0,194	0,255	0,139
HTA	0,233	0,094	0,139	0,023	0,200	0,331	0,170	0,174	0,092	0,119	0,051	0,226	0,274	0,156
RD_HTA	0,039	0,140	0,054	0,155	0,204	0,237	0,138	0,083	0,364	0,271	0,315	0,356	0,406	0,299
HTI	0,282	0,067	0,310	0,155	0,260	0,324	0,233	0,322	0,149	0,326	0,161	0,341	0,397	0,283
FCA	0,314	0,093	0,214	0,042	0,268	0,350	0,214	0,222	0,142	0,152	0,080	0,250	0,309	0,192
FCI	0,193	0,077	0,108	0,044	0,211	0,271	0,151	0,193	0,077	0,108	0,044	0,211	0,271	0,151
FFT	0,457	0,584	0,301	0,399	0,324	0,377	0,407	0,396	0,270	0,335	0,380	0,420	0,454	0,376
MoM	0,257	0,164	0,180	0,136	0,237	0,315	0,215	0,223	0,166	0,202	0,172	0,285	0,338	0,231
b) Relative measure of effectiveness: PrbICD(DHOTransfData)/PrbICD(NTRData) – NTR_Ref														
NTR	1,00	1,00	1,00		1,00	1,00	1,00	1,00	1,00	1,00		1,00	1,00	1,00
HTA	0,82	1,01	1,05		1,04	1,07	1,00	1,00	1,32	1,14		1,17	1,08	1,14
RD_HTA	0,14	1,51	0,41		1,06	0,76	0,78	0,48	5,19	2,59		1,84	1,59	2,34
HTI	0,99	0,72	2,35		1,35	1,04	1,29	1,86	2,13	3,11		1,76	1,56	2,08
FCA	1,11	1,00	1,62		1,39	1,13	1,25	1,28	2,03	1,45		1,29	1,21	1,45
FCI	0,68	0,82	0,82		1,10	0,87	0,86	1,12	1,09	1,03		1,09	1,06	1,08
FFT	1,61	6,27	2,28		1,68	1,22	2,61	2,28	3,86	3,20		2,17	1,78	2,66
c) Relative measure of effectiveness: PrbICDR(DHOTransfData)/PrbICDR(FFTData) – FFT-Ref														
NTR	0,62	0,16	0,44	0,00	0,59	0,82	0,44	0,44	0,26	0,31	0,00	0,46	0,56	0,34
HTA	0,51	0,16	0,46	0,06	0,62	0,88	0,45	0,44	0,34	0,36	0,13	0,54	0,60	0,40
RD_HTA	0,09	0,24	0,18	0,39	0,63	0,63	0,36	0,21	1,35	0,81	0,83	0,85	0,89	0,82
HTI	0,62	0,11	1,03	0,39	0,80	0,86	0,64	0,81	0,55	0,97	0,42	0,81	0,87	0,74
FCA	0,69	0,16	0,71	0,11	0,83	0,93	0,57	0,56	0,52	0,45	0,21	0,59	0,68	0,50
FCI	0,42	0,13	0,36	0,11	0,65	0,72	0,40	0,49	0,28	0,32	0,12	0,50	0,60	0,38
FFT	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Table 7. Comparative analysis of *ARCDR* mean parameters

ToT\ CSO	2325	2364	2368	2369	2372	2386	MoM
a) Estimations of mean ICDR values vs. Type of Transform and CSO Class in _PV_BW observation conditions							
NTR	0,053	0,003	0,003		0,070	0,038	0,034
HTA	0,071	0,004	0,004	0,019	0,086	0,050	0,039
RD_HTA	0,057	0,034	0,000	0,076	0,136	0,068	0,062
HTI	0,058	0,001	0,002	0,002	0,082	0,055	0,033
FCA	0,103	0,031	0,022	0,050	0,135	0,099	0,073
FCI	0,106	0,010	0,003	0,005	0,122	0,078	0,054
FFT	0,040		0,187	0,186	0,148	0,134	0,139
MoM	0,070	0,014	0,032	0,056	0,111	0,075	0,060
NTR-Ref_PV_BW							
NTR	1,00	1,00	1,00		1,00	1,00	1
HTA	1,33	1,32	1,32		1,22	1,31	1,3
RD_HTA	1,08		0,00		1,93	1,78	1,2
HTI	1,10	0,36	0,49		1,16	1,42	0,91
FCA	1,94	9,34	6,56		1,92	2,59	3,25
FCI	2,00	3,04	1,02		1,74	2,04	1,97
FFT	0,75	0,00			2,11	3,48	1,58
FFT-Ref_PV_BW							
NTR	1,34		0,02	0,00	0,47	0,29	0,42
HTA	1,79		0,02	0,10	0,58	0,38	0,57
RD_HTA	1,45		0,00	0,41	0,92	0,51	0,66
HTI	1,47		0,01	0,01	0,55	0,41	0,49
FCA	2,60		0,12	0,27	0,91	0,74	0,93
FCI	2,69		0,02	0,03	0,83	0,59	0,83
FFT	1,00		1,00	1,00	1,00	1,00	1,00

Table 8 presents the comparative analysis *CDE* and *PDTE* parameters of shape discriminators of gray images based on MDHO algorithms in plane projection (_PV_GR observation conditions). Additionally to above evaluated algorithms the several new ones are considered – generalized amplitude-phase analysis (*GAPA*) and differential-phase analysis (*DPAphi*) where variable *phi* presents the angle shift of *GAP*-images planes. This analysis shows the moderate advantages of *GAPA, HTA* and *HTI*-based algorithms over the identity transform based algorithms and much more – over FFT-based ones as references. Otherwise, the DPA-based algorithms assure less effectiveness comparatively to references.

Table 8. Comparative analysis of general phase and MDHO-based identification algorithms

CSO\ToT	NTR	GAPA	FFT	HTI	HTA	DPA1	DPA3	DPA5	DPA8
a) CDE_PV; NTR_Ref									
2325	1,00	0,92	0,18	1,10	1,29	0,65	0,23	0,08	0,07
b) PDTE_PV; NTR_Ref									
2325	1,00	1,02	0,76	4,69	4,84	0,23	0,53	0,50	0,69
c) CDE_PV; FFT_Ref									
2325	5,56	5,10	1,00	6,12	7,15	3,62	1,26	0,44	0,42
d) PDTE_PV; FFT_Ref									
2325	1,32	1,34	1,00	6,20	6,41	0,30	0,70	0,65	0,91

4. CONCLUSION

The comparative effectiveness analysis of complex shape objects identification based on correlation of preliminary transformed to digital Hilbert-transform spectral domain 3D model rotated images is presented. The results of analysis point the commensurability of Hilbert transform based identification algorithms to the identity transform based ones and some advantages these algorithms over the FFT-based algorithms. The DHO-based algorithms and technologies characteristics' analysis show the some directions to future investigations of MDHO hybrid optic-information systems properties.

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POLYPHASE CONCEPT AND ALL-PASS TRANSFORMATION AS A VALUABLE SOLUTION FOR PSYCHOACOUSTICALLY MOTIVATED FILTER BANK

This chapter propose filter bank, which connects polyphase concept with idea of warping bandwidth of subbands by all-pass filter chain. Presented structure exploit the properties of multirate technique of polyphase and warped shifted version of prototype filter in sine and cosine modulated filter banks, delivering nonlinearly distributed bandwidths according to the auditory model of human perception of audio signals. Chapter reviewing the theoretical basics of fundamental ideas and discussing psychoacoustic scale approximation by the proposed structure.

1. POLYPHASE CONCEPT OF FILTER BANKS

1.1. INTRODUCTION

Properties of human auditory system are the basis for contemporary acoustic signal processing. Boundaries of human's hearing mechanism allow to significantly improve both the efficiency and the performance of such methods as transmission, enhancement and compression of audio signals. The main approach reviled in this field is critical-bands phenomenon, which emphasis nonlinear sensitivity of human's ear over distributed frequency. Because the low tones are separated more precisely then high ones, it is possible to compose such audio processing system, which approximate that model and emphasis features more significant to the auditor ears in order to ignore negligible components. The most common approach uses filter bank or summarize boundless of DFT, which bands approximating critical-bands.

However, there are many ways o achieve the non-uniform filter banks which approximating humans auditory system in the way, how analyzing of sound is done by the ears. Evident approach, achieves the unequal bandwidths connecting the outputs of uniform filter bank [1]. Besides of simplicity of implementation and variety of hardware implementation, it is obvious that such mechanism introduce bandwidths distribution constrained to regular grid fixed by underlying uniform subband decomposition. More sophisticated distributions requires high density of this grid, which highly increase complexity of this method. Moreover, even slight change to the bandwidths requires reconstruction of such a filter bank. Other approach utilize the tree structured filter band constructed with used of pyramidal stacking of two channels systems [2]. Another different ideas are using the transforms such as welvelet packet transform [3] or warped DFT [4], which are closer to model of human's auditory system, but may fail, due to numerical instability, especially in case of second of mentioned methods.

This chapter discuses the warping technique introduce to the well-know construction of uniform polyphase filter bank [5]. To achieve the critical-band spread over the analyzed frequency bands the bilinear mapping by all-pass filter was used. The design is applicable to both uniform DFT and DCT based polyphase filter banks. This solution allow to get relatively simple and robust nonuniform filter banks, with ability to tune to the specific auditor's needs. However, even this solution can distinguish merits of sine and cosine modulation by the fact, that channel signals are complex in case of DFT modulation, which emphasis structural and computational complexity grow. If you assumed that cosine modulated filter bank, as a base for all-pass transform is devoid of of negative aspects by real channel signals and more less in-band processing load, you must notice that this came with the cost of higher complexity of the bank. In this chapter concept of both approach have been shown.

1.2. FILTER BANK STRUCTURE

The well known expression for the impulse response of an *M*-channel uniform filter bank valid for both paraunitary systems, which have the perfect reconstruction property and those that only approximate it, are following:
DFT modulated polyphase filter bank:

$$H_k(z) = H\left(zW_M^k\right) \leftrightarrow h_k(n) = h\left(nW_M^{-kn}\right), \tag{1}$$

$$F_k(z) = F\left(zW_M^k\right) \leftrightarrow f_k(n) = f\left(nW_M^{-kn}\right) \tag{2}$$

where $k = 0, ..., M-1$ is the channel number, $h(n), f(n), n = 0, ..., L-1$ denotes the *n*th of *L* coefficients of the analysis and synthesis FIR prototype filter.

DCT modulated polyphase filter bank:

$$h_k(n) = 2h(n)\cos\left(\frac{\pi}{M}\left(k+\frac{1}{2}\right)n + \xi_k\right), \tag{3}$$

$$f_k(n) = 2f(n)\cos\left(\frac{\pi}{M}\left(k+\frac{1}{2}\right)n + \gamma_k\right), \tag{4}$$

where $k = 0, ..., M-1$ is the channel number, $h(n), f(n), n = 0, ..., L-1$ denotes the nth of L coefficients of the analysis and synthesis FIR filter. In case of paraunitary filter banks with the same prototype filter $h(n) = f(n)$ of length $L = 2Mm$ there are common the following equation [6]:

$$h_k(n) = 2h(n)\cos\left(\frac{\pi}{M}\left(k+\frac{1}{2}\right)\left(n-\frac{L-1}{2}\right) + (-1)^k\frac{\pi}{4}\right), \tag{5}$$

$$f_k(n) = 2h(n)\cos\left(\frac{\pi}{M}\left(k+\frac{1}{2}\right)\left(n-\frac{L-1}{2}\right) - (-1)^k\frac{\pi}{4}\right). \tag{6}$$

However still the FFT algorithm is used to efficient implementation of cosine modulation. The z-transform domain representation of eq. (5) and (6), where the real coefficient prototype filter is treated as combination of two filters with complex coefficient, and where factor $e^{-j\frac{k\pi}{2M}}$ is similar to DTF can be computer by Fourier transform of double size M [6].

$$H_k(z) = e^{j(-1)\frac{k\pi}{4}}W_{2M}^{-\left(k+\frac{1}{2}\right)\left(\frac{L-1}{2}\right)}H\left(zW_{2M}^{-\left(k+\frac{1}{2}\right)}\right) + e^{-j(-1)\frac{k\pi}{4}}W_{2M}^{\left(k+\frac{1}{2}\right)\left(\frac{L-1}{2}\right)}H\left(zW_{2M}^{-\left(k+\frac{1}{2}\right)}\right) \tag{7}$$

$$F_k(z) = e^{-j(-1)\frac{k\pi}{4}}W_{2M}^{-\left(k+\frac{1}{2}\right)\left(\frac{L-1}{2}\right)}H\left(zW_{2M}^{\left(k+\frac{1}{2}\right)}\right) + e^{j(-1)\frac{k\pi}{4}}W_{2M}^{\left(k+\frac{1}{2}\right)\left(\frac{L-1}{2}\right)}H\left(zW_{2M}^{-\left(k+\frac{1}{2}\right)}\right) \tag{8}$$

Function is directly related with DFT transform and can be processed by it's fast algorithm. The scheme of such a structure is depicted in fig. 1 with the additional components add in place of delay, which is an all-pass filter $A(z)$:

$$z^{-1} \rightarrow A(z) = \frac{a + z^{-1}}{1 + az^{-1}} \tag{9}$$

and multirate decimation factor R, which can reach M in critical sampling case.
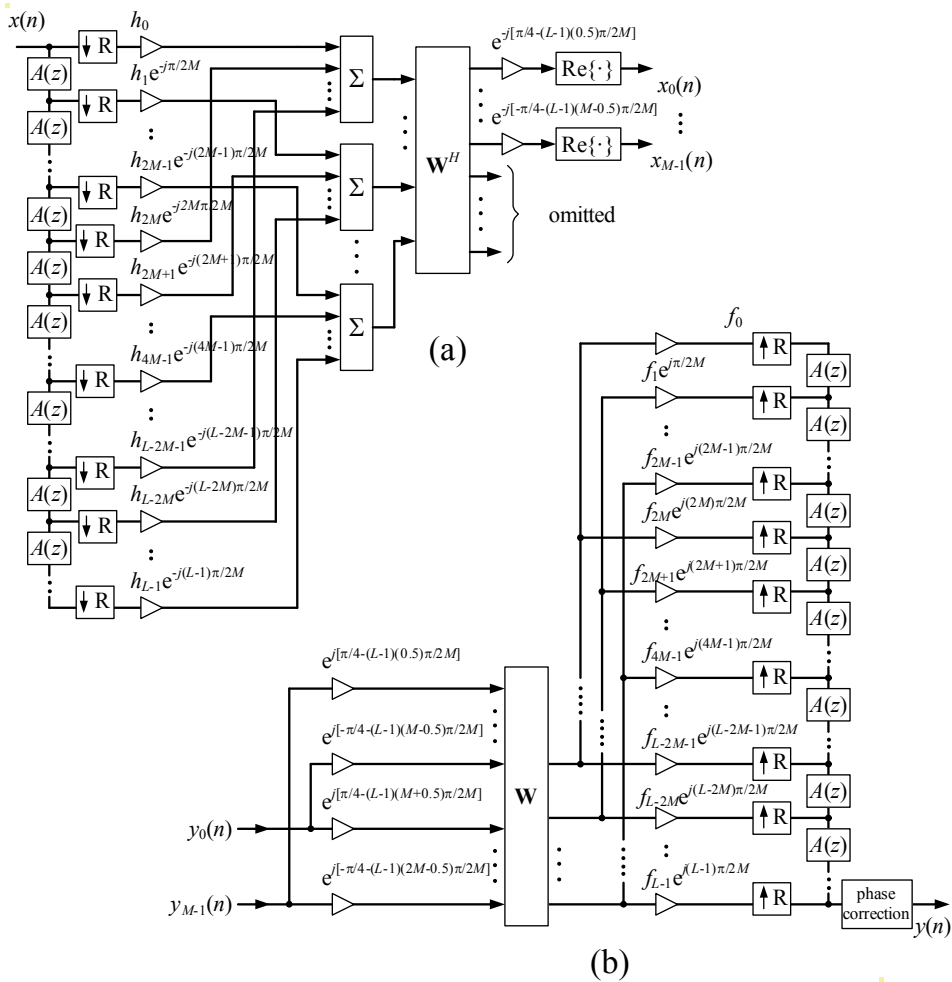
Fig. 1. Structure of the analysis (a) and synthesis (b) warped DCT filter bank

Schemes of the filter bank in case of warped DFT filter bank are related to this representing the warped DCT filter bank. However, there is lack of the inband FFT output - input modulation by complex constant

2. ALL-PASS TRANSFORM IDEA

Warped filter bank illustrated in fig. 1 is implemented with use of the all-pass filter chain introduced in place of the all delay elements. Equation (9) is realized by the first

order casual and stable filter, where coefficient $-1 < a < 1$ define the freedom of mapping frequency. That way a bilinear conformal mapping of the unit circle onto itself is done with deformation of the system responses, which become nonuniform in a manner defined by the all-pass filter phase function:

$$\varphi(\omega) = 2 \tan^{-1} \left(\frac{1-a}{1+a} \tan \frac{\omega}{2} \right),$$ (10)

which is illustrated at fig. 2.

Moreover first order all-pass filter is a good to obtain a very close approximation of psychoacoustic scales [7]. Figure 3. depict the accuracy of such mapping.

2.1. DESIGN OF BARK SCALE FILTER BANK

The mentioned filter bank must be designed in pragmatic way to find the compromise between the overall filter bank performance and non uniform spreading band usage (see fig. 4) . However, such constructed filter bank can achieve only the nearly perfect reconstruction property, resulting in non-audible distortion, not crucial in case of the speech enhancement system. Moreover, careful selection of subsampling ratios
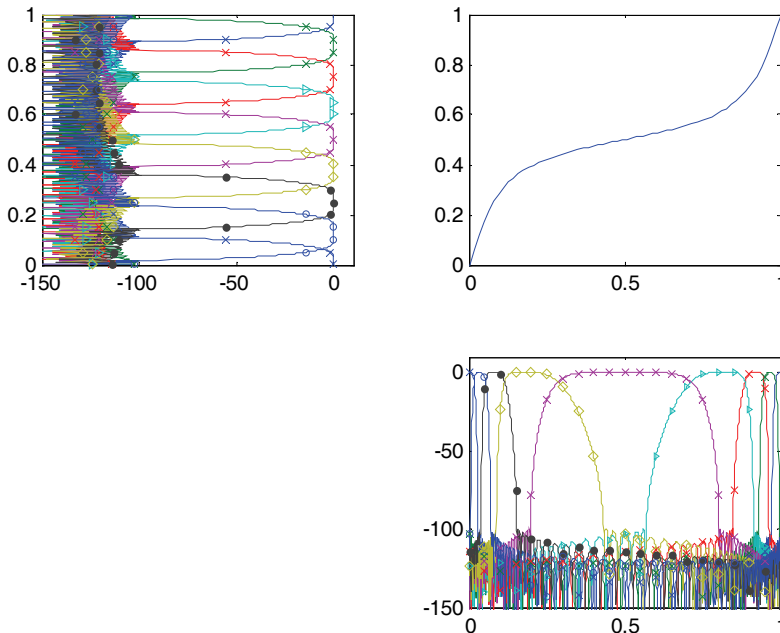
Fig. 2. All-pass transformation of filter bank $a = 0.6$
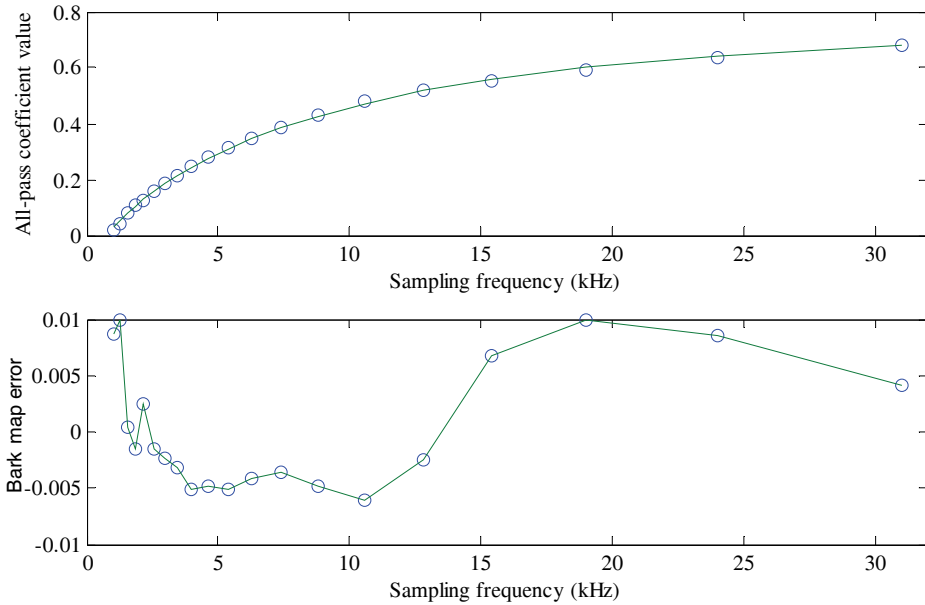
Fig. 3. Bark scale approximation error for a given mapping coefficient of the all-pass filter

for avoiding and minimizing the redundancy of subbands must be perform, because such bank has higher aliasing risk caused by phase distortion and changes of band-widths with regard to uniform filter bank design. Experiment shows that optimal results can be achieved for $R \leq \dfrac{M}{4}$, which of course degrade profits given by decima-tion. Nonetheless, when in band signal processing method are invasive even the critical sampling can be used and the additional filtering must be applied into synthesis filter bank for phase correction processing. In this case the phase distortion are compensated using postfiltering [7, 8].

2.2. TUNING UP OF THE BANDS

The other interesting properties arise when the deep experiments has been done in order to exploit the individual reception of speech enhancement system constructed on such a bank [9, 10], demanding tuning of the bandwidths distribution, because of the individual psychoacoustic properties of the auditor. The tuning allows to adjust filter bank characteristic and overall signal processing system to user's personal preferences giving benefits in quality and it is done only by the

simple change of the all-pass filter coefficient. Moreover, this change can be done in real time according to the users interaction motivated by his audio fillings. Such modification of up to half shift of the band center frequencies do not require the changes in the well design structure of filter bank and also in processing schema. Figure 5 illustrate the tuning properties.

The construction of filter bank presented earlier have been used in few works as a decomposition tool in audio processing algorithm [9, 10]. The results achieved in author's work [10] has been presented at figure 6, The spectral minima tracking in subband method has been used to improve over all speech quality based on nonuniform filter bank decomposition. Even strong relation between noise tracking of noise and rough masking threshold estimated on noise suppression preprocessing of degraded subband signals gave the very good result. It's due the cochlear model spaced bandwidths according to the Bark scale and method, which do not completely attenuate the noise but lower its level below the roughly estimated masking threshold. According to the informal listening test conducted in order to evaluate this method the approach with use of nonuniform all-pass warped filter bank offers a performance superior to the same method based on other frequency decomposition algorithms, delivering very good speech intelligibility and natural environmental response of processed signal.
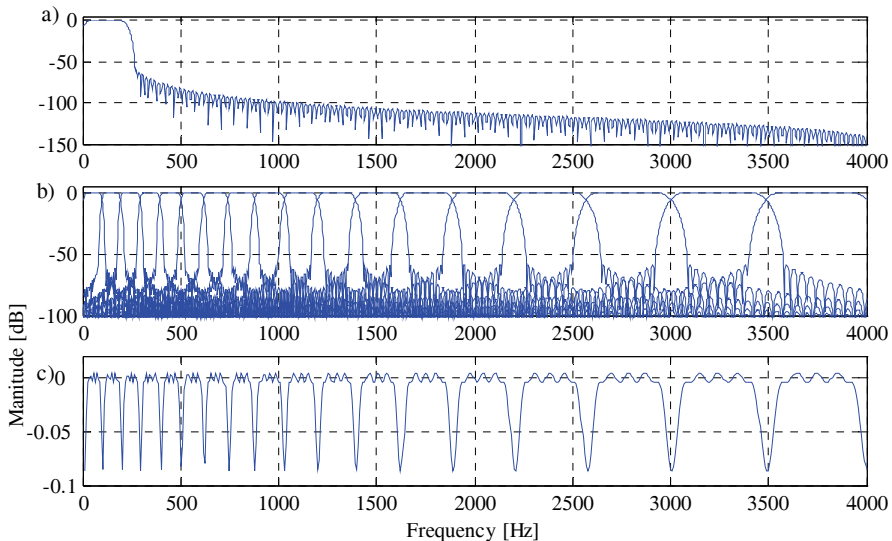
Fig. 4. Carefully designed nonuniform filter bank which approximates the Bark scale
for 8 kHz sampling frequency in speech processing system; a) prototype filter,
b) magnitude response of the filter bank, c) magnitude response of the distortion function
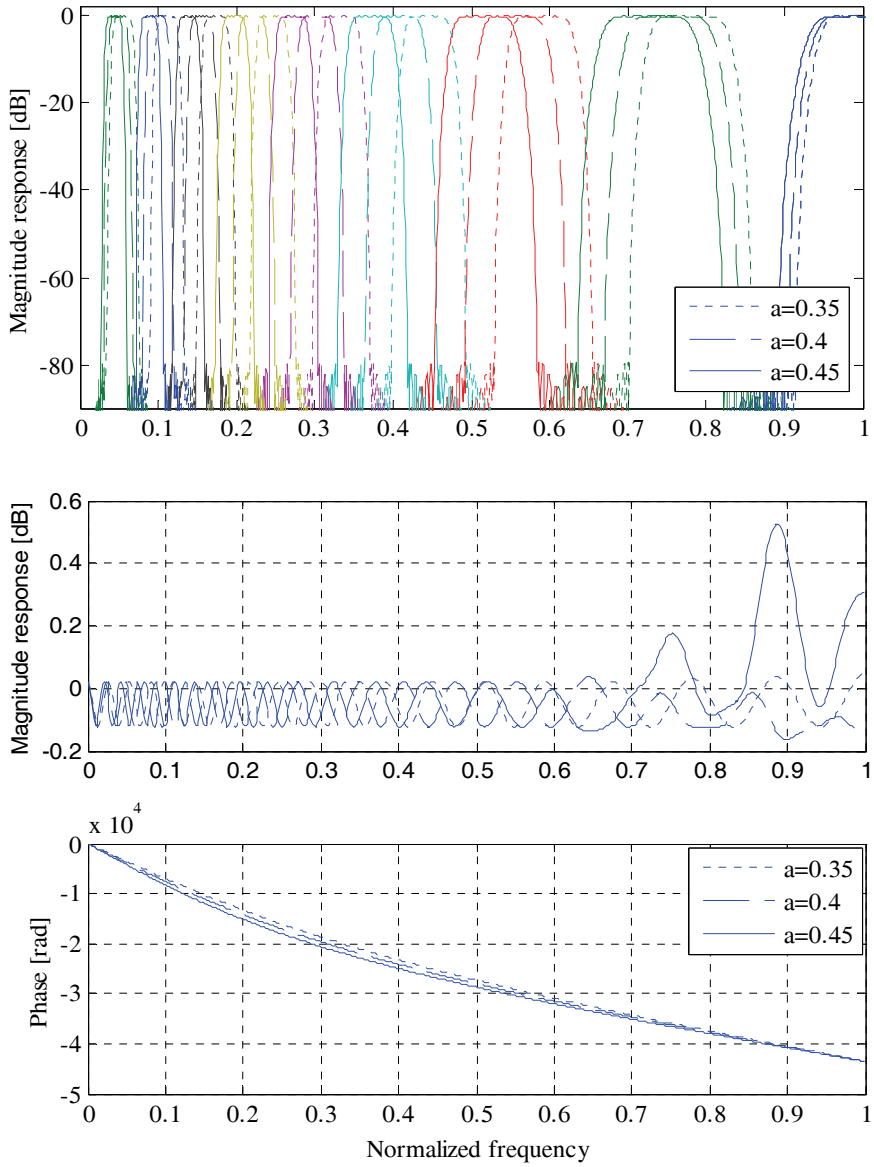of the filter bank

Fig. 5. Bark scale approximation error
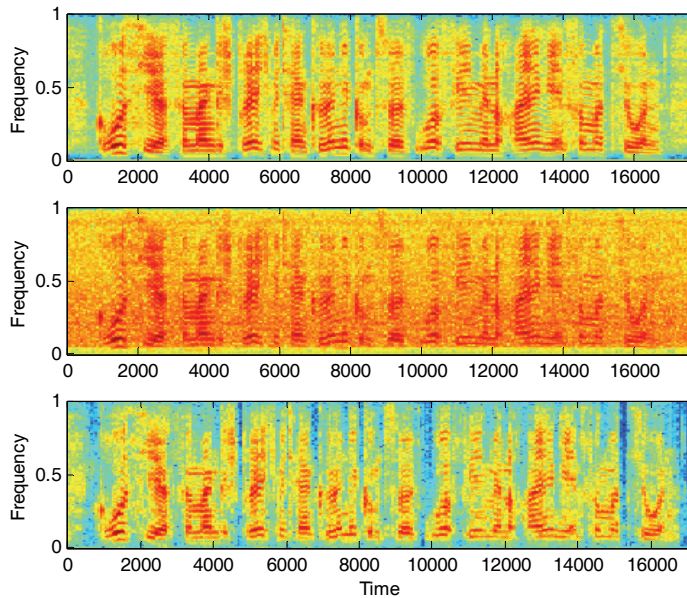for a given mapping coefficient of the all-pass filter

Fig. 6. Speech enhancement by minimal spectral tracking method incorporated
in nonuniform all-pass warped filter bank

4. CONCLUSION

This chapter do not deplete the subject of nonuniform filter bank construction. However, it discusses the availability of incorporate the all-pass transformation and polyphase concept for constructing the tunable psychoacusticaly motivated filter bank with very close approximation of auditory models. The ability for tuning of such frequency decomposition in reasonable scope, without redesigning the filter bank is a additional pros of presented idea. Comparison of using such filter bank in methods of speech enhancement and adaptive filtering made with used of known methods, shows that presented warped filter bank deliver superior performance and natural sound of preprocessed acoustic signal.

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AGGREGATION OF MODALLY-EXTENDED FUZZY-LINGUISTIC STATEMENTS

An important issue in an area of human-computer interaction is a presentation of data to the user, especially to an external non-expert user of the system. The paper is based on a setting where numerical data gathered by a multiagent system is assigned with zadehian fuzzy-linguistic summaries, which – in case of incomplete observational data – are extended using autoepistemic operators of possibility, belief, and knowledge. Summaries are further aggregated and presented to the external user of the system. The focus of this paper is set on the process of an aggregation itself and on interpretational issues related to the aggregation of fuzzy-linguistic statements with autoepistemic operators.

1. INTRODUCTION

Systems constructed for casual users cannot be overly complicated in their everyday usage. An approach which aims at enabling easier communication between humans and computers is to use natural language statements both as an input and as an output of the system. In this paper we concentrate on a system which processes raw data acquired by a distributed net of sensors and provides an external user of the system with a textual summary using natural language statements.

An assumed multiagent system [12] provides natural language textual messages to the user. Messages contain a semantic summary of numerical data acquired locally by a distributed group of independent agents. Existing solutions in an area of Natural Language Generation [3, 5, 15] focus mostly on a precision, short length, and lack of ambiguity of the summary in situations in which data is complete. The focus of an assumed system is set to handling situations in which data is partially missing. Instead of discarding such data or using imputation procedures [9], the

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information about the original incompleteness is conveyed to the user. It is accomplished by building textual summaries including autoepistemic operators of possibility, belief, and knowledge.

The analyzed approach [12, 13] presents an example of a city traffic and a way in which traffic-summaries generated by local agents can be aggregated in order to obtain a summary of a region or a route. It shows a simple approach to an aggregation of local summaries without analyzing commonsense properties of the approach. It bases on the theory of grounding [4, 6, 7] of modal statements and uses fuzzy-linguistic concepts originating from Zadeh [16–18].

A big advantage of a fuzzy-linguistic approach is that from a basic set of concepts other concepts can be derived – not only by combining multiple concepts but also through direct operations on membership functions – with an application of Zadeh's linguistic hedges (operators which modify the meaning of their operands in a specified, context-independent fashion [18]).

Niewiadomski [11] claims that *"Popular summarization methods are based on statistical values (e.g., mean, median, variance). On the other hand, too precise results may look unfamiliar, e.g., in press reports, mass-media news, in a colloquial communication, and in all the situations in which a bit rough but quickly generated and easily understandable textual message is necessary, rather than the detailed results of terse analysis. People prefer to use and exchange natural language information, even if it is less precise than figures."*

An analysis conveyed by this paper directly extends the approach presented in [12]. We show alternative methods for an aggregation of local summaries and discuss their properties in detail.

Section 2 outlines an application scenario and an existing solution. Section 3 presents the basic aggregation mechanism and discusses its properties. In Section 4 we propose alternative aggregation mechanisms and elaborate on possibilities of their usage. The paper concludes with Section 5 which contains a summary and potential topics for further investigation.

2. GENERAL SETTING

A general setting consists of a network of agents monitoring locally city-traffic. Agents are capable of fulfilling two main tasks:
- – a task of a generation of local traffic descriptions in a textual form,
- – a task of an aggregation of local traffic descriptions obtained from other agents.

In this part we will briefly introduce a traffic scenario and we will outline a way in which agents generate local messages. It is needed as it constitutes a base for our further discussion.

2.1. TRAFFIC SCENARIO

Each single agent (see Figure 1) is equipped with a set of sensors monitoring a number of links of a road-network. Data obtained from sensors is aggregated over time-intervals consisting of 15 minutes each. It results in a situation in which an agent observes the environment in discrete-like time. Further, if the agent obtained a relevant information about the current state of traffic within the link, it can assign a fitting linguistic concepts and in result, generate textual summary using a simple traffic description pattern "There is a [*traffic*] [*object_text*]", where *traffic* is a linguistic concept describing a state of property traffic and *object_text* is a textual description assigned to the object (e.g., *"Camberwell Junction moving east into Riversdale Road"*).
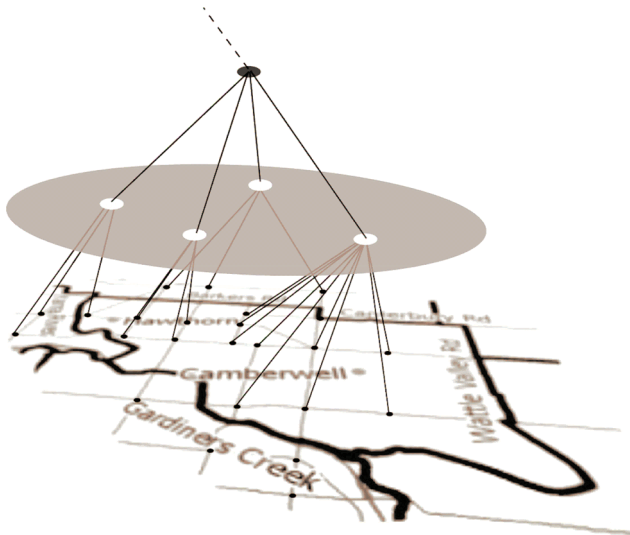
Fig. 1. Processing of summaries within a hierarchical architecture (after [8, 9])

In a situation where a respective piece of data is missing (e.g., because of a measurement failure) the agent cannot directly assign a summary. However, in an assumed approach [6,7] the agent in presence of missing data reduces its lack of knowledge using its previous experiences. The agent performs a reasoning based on a historical data in order to assign a modal summary including one of autoepistemic model operators of possibility, belief, and knowledge. The final textual summary is generated in an analogical way using the following pattern "[*belief*] there is a [*traffic*] [*object_text*]", where the *belief* is one out of the following three: "It is possible that", "I believe that", "I know that".

2.2. STRUCTURE OF THE AGENT

An agent is located in a relational environment consisting of objects $o \in O$. Objects exhibit discrete properties changing over discrete time. The agent observes the environment and stores results of its observations in its private database. In particular, an agent is assumed to perceive discrete values $u \in U$ of a single conceptual dimension of each object.

An external language – assumed to use language concepts $f \in F$ – is represented within an agent with a set of respective fuzzy mappings

$$\mu_f: U \rightarrow [0, 1]. \tag{1}$$

A certain language concept f becomes activated within an agent if and only if an agent perceives a value u of an observed conceptual dimension in an object o and if $\mu_f(u)$ is not lower than an assumed cognitive threshold for an activation of concepts μ_{min}. We do not discuss here properties which need to be fulfilled by a set of fuzzy mappings in order to guarantee a rational language-behaviour of an agent as they are an object of our different work (for the time being still in review).

As it has already been mentioned, an agent in presence of missing data reduces its lack of knowledge using its previous experiences. The agent is equipped with a mechanism which allows it to extract a set of possibilities (potential states of an unobserved property within a given object) based on its own experiences. The approach follows works of Johnson–Laird [1] addressing a possibility of use of a model theory to deal with modal reasoning. Dennett [2] states that *"exposure to x – that is, sensory confrontation with x over suitable period of time – is the normally sufficient condition for knowing (or having true beliefs) about x"*.

Moreover, an agent is capable to assign each of those possibilities – represented using a notion of a mental model [1, 6, 8] – with a numerical value described as a grounding strength inducing a corresponding mental model.

An interplay of grounding strengths leads to a notion of a relative grounding strength. The relative grounding strength represents a relation between an amount of experience supporting a certain model in relation to the amount of experience opposing the model.

Based on a value λ_f of the relative grounding strength evaluated for a given mental model (representing an exhibition of a certain concept within a given object) an agent can ground modal statements [12] using a relevant relation of epistemic satisfaction. To avoid sending our reader to read other papers let us simplify it greatly and state that an agent is equipped with a system of modality thresholds

$$\langle \lambda_{minPos}, \lambda_{maxPos}, \lambda_{minBel}, \lambda_{maxBel} \rangle \tag{2}$$

and that a formula "*Know f(o)*" is grounded iff. $\lambda_f = 1$, a formula "*Bel f(o)*" is grounded iff. $\lambda_{minPos} \leq \lambda_f \leq \lambda_{maxPos}$ and a formula "*Know f(o)*" is grounded iff. $\lambda_{minBel} \leq \lambda_f \leq \lambda_{maxBel}$.

A set of following constraints (compare [4, ISKE]) guarantees the rational behaviour of the whole system:

$$0 < \lambda_{minPos} < 0.5 \leq \lambda_{maxPos} \leq \lambda_{minBel} < \lambda_{maxBel} \leq 1. \qquad (3)$$

3. AGGREGATION OF LOCAL SUMMARIES

Summaries in [12,13] are aggregated based on predefined patterns. A pattern is a set of objects with an assigned distinct name. For example, one can introduce a pattern called Hawthorn consisting of all traffic nodes (objects) located within Hawthorn district of Melbourne. We will omit the naming of patterns for the sake of readability of our model. Therefore, all subsets of a set of object *O* will be treated as potential patterns *P*.

Take a note that although in Figure 1 we presented a strictly hierarchical approach to a process of an aggregation of summaries, it can be naturally implemented in fully unstructured architecture, where agents are uttering statements (which can be treated as a local broadcasting) and each individual agent aggregates statements obtained from nearby agents. Modifying the method for messages coming from overlapping areas is also not an issue and can be obtained with a simple weighting.

A textual description for a given pattern *P* is evaluated based on local descriptions generated for objects constituting this pattern. Also, each object *o* in a pattern *P* is assigned with a numerical value – a non-negative weight – describing its importance.

An aggregation evaluated with a fuzzy concept is not a straightforward task as an output is not supposed to be one out of many non-related values. On a contrary, fuzzy-linguistic concepts can have an overlapping meaning. It is also possible to derive a set of semantic relations between concepts and autonomously build a personal thesaurus [14].

Unlike as in [13], a setting presented here (following [12]) results with a multiple fitting summaries at the same time. A choice of a single final summary is not a trivial task and is left aside for now, but such measures as precision of concepts, relation between concepts and other methods from the NLG (natural language generation) literature can be adopted to deal with the the problem.

For now we focus on evaluating a set of fitting summaries. For each concept *f* we evaluate a strength with which it is induced by local summaries. After [13], the basis for an aggregation is an evaluation of a strength $w(P, f)$ with which a particular concept *f* is induced by a set of local summaries describing objects within a pattern *P*. It uses a notion of σ representing a not-discussed here function of a cognitive similarity of fuzzy-linguistic concepts.

Definition 1. *An Induced Strength of the Concept.* For a given set S of local summaries s related to a pattern P, weights of objects $o \in P$, fuzzy mappings μ_f, a system of modality thresholds (2), and the similarity function σ, an induced strength of a concept f is given as

$$w(P,f) = \sum_{s \in S} \left(\hat{w}(o_s) \cdot \sigma(f, f_s) \right) \tag{4}$$

where $\hat{w}(o_s)$ is a modified weight.

The modification of the base weight $w(o_s)$ is related to the re-interpretation of autoepistemic operators used by agents building local summaries. Modified weights reflect a reduction of importance of these summaries which are based on incomplete knowledge (hence they contain modal operators). The main intuition stating that the weaker the operator, the lower the value of the modified weight becomes, holds.

Finally, if:
- $w(P, f) = 1$ then "*f(o)*" and "*Know f(o)*" are added to aggregated summaries;
- $\lambda_{\text{minBel}} \leq w(P, f) < \lambda_{\text{maxBel}}$ then "*Bel f(o)*" is added to aggregated summaries;
- $\lambda_{\text{minPos}} \leq w(P, f) < \lambda_{\text{maxPos}}$ then "*Pos f(o)*" is added to aggregated summaries.

An example of an aggregated summary would be "*I believe that there is a heavy traffic from Hawthorn Bridge to Eastern Fwy via Church St, High St, Doncaster Rd*".

4. METHODS OF AGGREGATION

One of the most important issues which needs to be dealt with is an re-interpretation of a modal operator used in a local summary. An agent cannot know the values of modality thresholds (2) implemented in an agent generating the summary. The crucial point of exchanging messages of a semantic language of communication is that the meaning of semantic concepts is assumed to be shared within the population of communicating agents.

In particular, the relation of epistemic satisfaction should be consistent within the population, as discrepancies can lead to a misunderstanding between agents. In a situation where the relation of epistemic satisfaction cannot be predefined, method for an autonomic development of the relation using common context can be used [10].

Different approaches to the process of aggregation are reflected in a way in which modified weights are calculated. Two main sources of these modifications are:
- a reinterpretation of autoepistemic operators,
- a trust rating of a given agent.

4.1. REINTERPRETATION OF AUTOEPISTEMIC OPERATORS

An agent receiving a statement with an autoepistemic operator can reinterpret it based on its own mechanism of grounding and generating of such statements. The natural frame for this reinterpretation is a system of modality thresholds (2) which dictates the borderlines for the meaning.

As it has been mentioned before, the main intuition is to dampen these information sources which are based on incomplete observations. The lower the belief of the agent uttering the statement, the lower should be the impact of this very uttering on an aggregated summary.

An approach rewarding the real data the most would be to weight each modal statement related to an object o with the lowest possible weight of a modality threshold for a given operator, namely:

- $\hat{w}(o) = w(o)$ if an operator *Know* is present in the statement,
- $\hat{w}(o) = \lambda_{\min Bel} \cdot w(o)$ if an operator *Bel* is present in the statement,
- $\hat{w}(o) = \lambda_{\min Pos} \cdot w(o)$ if an operator *Pos* is present in the statement.

The second possibility lies in assuming the most optimistic interpretation for each statement with a modal operator. It should be pointed out, that when interpreting, humans often relate to the most representative values for a given concept. This results in a following approach:

- $\hat{w}(o) = w(o)$ if an operator *Know* is present in the statement,
- $\hat{w}(o) = \lambda_{\max Bel} \cdot w(o)$ if an operator *Bel* is present in the statement,
- $\hat{w}(o) = \lambda_{\max Pos} \cdot w(o)$ if an operator *Pos* is present in the statement.

Naturally, all the potential lies in between. We can introduce an attitude factor for a given agent. Let us put a parameter $a \in [0, 1]$ and let a value 0 of a represent a completely pessimistic (or secure) agent and let a value 1 represent an optimist. Values in between represent different attitudes – the more optimistic as the value gets higher and closer to 1 and more pessimistic as the value gets lower and closer to 0.

In such a case we obtain a following set of modifications:

- $\hat{w}(o) = w(o)$ if an operator *Know* is present in the statement,
- $\hat{w}(o) = \left(\lambda_{\min Bel} + a \cdot \left(\lambda_{\max Bel} - \lambda_{\min Bel} \right) \right) \cdot w(o)$ if an operator *Bel* is present in the statement,
- $\hat{w}(o) = \left(\lambda_{\min Pos} + a \cdot \left(\lambda_{\max Pos} - \lambda_{\min Pos} \right) \right) \cdot w(o)$ if an operator *Pos* is present in the statement.

Please take into consideration, that while the above formulas may take a form of the first two formulations, they bear different interpretations.

4.2. RELIABILITY FACTOR

Now, assume that an agent is placed in a certain feedback loop and that users of the system can return a feedback in a simple binary form, simply stating, whether they have found the summary right or wrong.

Assume also, that an agent assigns other agents with a reliability factor r ranging from 0 to 1. As in our example new summaries are generated every 15 minutes (because of data obtained by VicRoads, see [12, 13]), an agent can wait up to three more cycles (45 minutes) for a feedback. In case of a positive feedback it modifies the weight r by assigning it with a new value

$$\min\{1, r + 0.1\} \tag{5}$$

and in a case of a negative feedback it modifies the weight by assigning it with a value

$$\max\{0, r - 0.1\}. \tag{6}$$

Only one change of value can occur for each generated summary and the one with more feedback is chosen. Of course, an amount of feedback needed for the change itself should be tuned based on a particular area of application. The same should be stated for a parameter 0.1 used in equations (5) and (6).

There are two possible ways of applying a parameter r. The first one is to influence a reinterpretation of autoepistemic operators, thus replacing a parameter a with a parameter r.

The second one is to include it in a fully multiplicative way – by replacing $\hat{w}(o)$ with $r \cdot \hat{w}(o)$ – leading to a situation in which some always-wrong agents can be fully ignored.

5. SUMMARY AND FUTURE RESEARCH

In the paper we assume a multiagent system [12] which provides natural language textual messages to the user. Messages contain a semantic textual summary of numerical data acquired locally by a distributed group of independent agents. The main task discussed with the paper is a process of an aggregation of local traffic descriptions obtained from other agents into a complete summary.

We describe a method for evaluating fitting candidates for a final summary. As we deal with an area of fuzzy-linguistic concepts, there are concepts overlapping in terms of their meaning – and therefore – in some situations there are multiple fitting summaries. It is not a problem as known methods – especially from the area of NLP – can be applied in order to deal with this task.

The main improvement over an already existing approach [12, 13] is an extension performed in an area of an evaluation of a weight of a particular summary during the process of an aggregation.

We propose two main approaches to the modification of weights. The first one is a modification related directly to the reinterpretation of used autoepistemic operators of possibility, belief, and knowledge. The second one is based on an autonomous assignment of reliability factors to other agents based on a feedback obtained from external users of the system.

An interesting extension to this system would be an incorporation of a mechanism for concept learning. The language assumed in this paper – left a bit underdiscussed, we admit – is predetermined and models of concepts do not evolve over time. Autonomous development of concepts' meaning is an interesting task related to the problem of language grounding itself [4] and is the main target of our further research.

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PART 4

COMPLEX OF
OPERATION SYSTEMS CONTROL

Grzegorz RUBIN*
Krzysztof BIELAWSKI**

EFFICIENT SIMULATION METHOD FOR PARALLEL DIGITAL SYSTEMS CONTROL UNITS DEVELOPMENT

This paper presents the method of graphical design and simulation of control units for parallel digital sequential controllers. Presented approach allows for verification of controller design, represented by hierarchical graph, during simulation of parallel algorithms, step by step based on Petri Nets theory. Moreover, detailed analysis allows preventing deadlocks occurred in parallel system. As the result of hierarchical simulation, control words are generated which can be used for real digital device. Next, the paper presents an examples of appliance for real digital parallel system. The main advantage of proposed method is to develop the control unit by intuitive, fast and efficient way.

1. INTORDUCTION

In the recent years, increased interest in building and using parallel digital systems has been noticeable. The main problem of that approach is proper control of scheduled tasks for specified system. Synchronization of parallel processors elements inside projected system should be done correctly and as fast as possible. Considered of definitions, modeling and simulation of discrete devices should be done by Petri nets [2]–[4], because describing parallel steps of control unit is much easier than the other way. Additionally using extended mathematical theory of them and sets of analysis methods, we can do formal verification [9]. Usage and modifications of Petri nets were known since 70's. Nowadays device implementation of discrete

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parallel computational elements and its control units is made by hardware description language (HDL).

2. CONTROL UNITS FOR PARALLEL DIGITAL SYSTEMS

Every digital system approach requires time scheduling of parallel processes which can be done based on Petri Nets theory. There are few know examples of that approach [4]–[7]. For proposed approach based on shared memory architecture an application was design. Presented environment allows on graphical designing and simulation of algorithms step by step. Possibility of hierarchical designing and simulation are allowed too. That is useful for error correction by simulation of each part of designed algorithms. As the result of simulation, for presented graph on Figure 6 corresponding to small part of projected system for bit serial operations, we have control vectors for FPGA device.

Parallel processors in shared memory architecture [8] are presented in Figure 1, each processor requires an appropriate control. Achieve the effective control of the individual elements is possible using a suitable tool, which creates a model system (Fig. 2). Modeling and simulation systems based on Petri net theory allows for optimal scheduling of the proposed system.

Modeling of real digital systems is usually done in hardware description language (HDL). There are many groups from different manufacturers to design and implement systems in a programmable FPGA devices. Designed in this way the programmable systems require appropriate performance testing. Unfortunately, the preparation of appropriate error free vectors of testing is time consuming and in the case of parallel systems is often not possible. Therefore, the use of tools in preparation of test vectors appear to be appropriate. Result of such actions are presented in the next chapter.
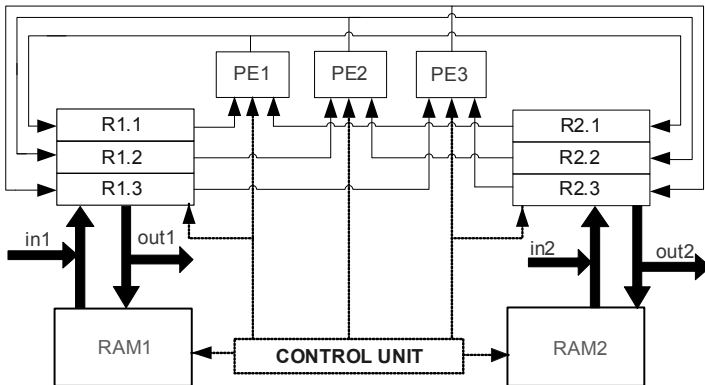

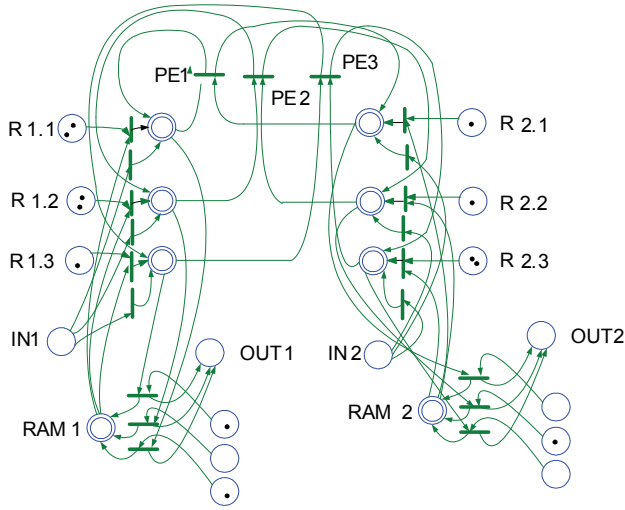Fig. 1. System of balanced bit-serial shared memory architecture

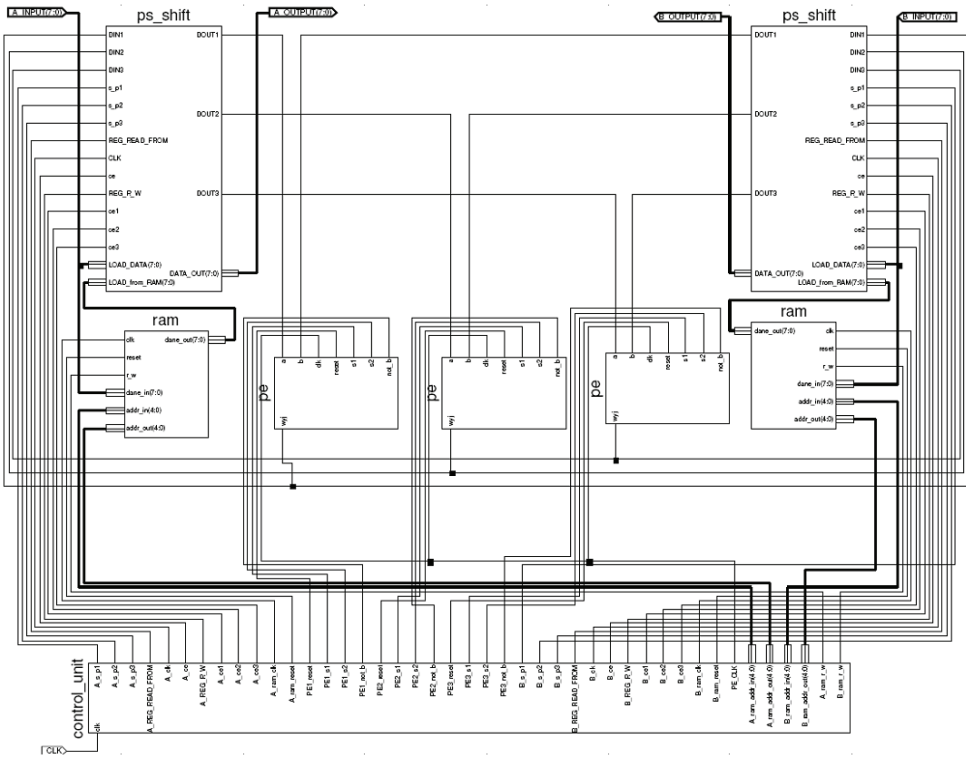Fig. 2. Petri nets model of system of balanced bit-serial shared memory architecture

Fig. 3. Schematic model of hardware implementation of balanced bit-serial shared memory architecture

Pe1	Pe2	Pe3	Left Register	Right Register	Left RAM	Right RAM
55 54 53 52	51 50 49 48	47 46 45 44	43 42 41 40 39 38 37 36 35 34 33 32	31 30 29 28 27 26 25 24 23 22 21 20	19 18 17 16 15 14 13 12 11 10	9 8 7 6 5 4 3 2 1 0

Fig. 4. Control vector for projected system on fig. 3

Digital systems to properly execute the tasks they need a control unit. One possible approach is to build a Mealy machine, or use the memory of microprogramm. In an environment for the design of programmable devices in the simulation it is possible to prepare a text file with the prepared set of input data. An example of such a control unit, written in VHDL code is presented below:

```
architecture Behavioral of control_unit is
  file plik : TEXT open READ_MODE is "input.txt";
  signal inset : std_logic_vector(0 to 58) :=
"00000000000000000000000000000000000000000000000000000000000";

begin
    process(clk)
            variable linia : LINE;
            variable instr : bit_vector(0 to 58) :=
            "00000000000000000000000000000000000000000000000000000000000";
    begin
            if((rising_edge(clk)) and ( not endfile(plik))) then
                    readline(plik,linia);
                    read(linia,instr);
                    inset <= to_stdlogicvector(instr);
            end if;
    end process;

            A_s_p1 <= inset(0);
            A_s_p2 <= inset(1);
            A_s_p3 <= inset(2);
            A_REG_READ_FROM <= inset(3);
            A_clk <= inset(4);
            A_ce <= inset(5);
            A_REG_R_W <= inset(6);
            A_ce1 <= inset(7);
            A_ce2 <= inset(8);
            A_ce3 <= inset(9);
            A_ram_clk <= inset(10);
            A_ram_reset <= inset(11);
            A_ram_r_w <= inset(12);
            A_ram_addr_in <= inset(13 to 17);
            A_ram_addr_out <= inset(18 to 22);
            PE1_reset <= inset(23);
            PE1_s1 <= inset(24);
            PE1_s2 <= inset(25);
            PE1_not_b <= inset(26);
            PE2_reset <= inset(27);
            PE2_s1 <= inset(28);
            PE2_s2 <= inset(29);
            PE2_not_b <= inset(30);
            PE3_reset <= inset(31);
            PE3_s1 <= inset(32);
            PE3_s2 <= inset(33);
            PE3_not_b <= inset(34);
            B_s_p1 <= inset(35);
            B_s_p2 <= inset(36);
```

```
        B_s_p3 <= inset(37);
        B_REG_READ_FROM <= inset(38);
        B_clk <= inset(39);
        B_ce <= inset(40);
        B_REG_R_W <= inset(41);
        B_ce1 <= inset(42);
        B_ce2 <= inset(43);
        B_ce3 <= inset(44);
        B_ram_clk <= inset(45);
        B_ram_reset <= inset(46);
        B_ram_r_w <= inset(47);
        B_ram_addr_in <= inset(48 to 52);
        B_ram_addr_out <= inset(53 to 57);
        PE_CLK <= inset(58);
end Behavioral;
```

Each part of the vector corresponds to a different element of the system architecture (Fig. 3). Preparation of an appropriate sequence of control bits allow on the rapid testing of programmed physical device in the logical structure. In the case of incorrect performance of the task finding errors is very difficult and time consuming. Therefore, you should re-use modeling tools using modified Petri nets in order to generate new test control vectors.

3. WALIDATION TOOL BASED ON MODIFIED PETRI NETS

3.1. MULTILEVEL PETRI NETS

The extension of Petri nets (Hardware Petri nets – HPN) is a bipartite directed graph $HPN = (P,T,K,Z)$, consisting two non-empty and non-crossing sets of places $P = \{P_\varepsilon, S_v\}$, and set of transitions $T = \{t_j, \tau_i\}$, connected between themselves with arcs K, with rules Z. Places in HPN describe execution of separated elementary parts of algorithm and activate two types of transitions: simple t_j and controlled (macro transitions) τ_i. Macro transitions $\tau_i = \{\tau_i^1, \tau_i^2, \tau_i^3\}$ contain control τ_i^1, vector τ_i^2 and interrupt τ_i^3. Thick line represents simple transitions t_j in arc line, and macro transitions τ_i – two thick lines. The set of places P_ε includes tops with standard rules of creation. The tops of cumulated places may consist tokens $m(S_v) > 0$ or not $m(S_v) = 0$. Specific functionality S_v shows that, during synchronization the tops of one or few simple transitions $t_j \in T$ don't change $(m(S_v) = \text{const})$. Macro-places are presented as double circle. Set of arcs $K = \{K_1, K_2\}$ consists set of simple arcs K_1, and set of arc with changing value K_2. Either given sets consist arcs necessary conditions, having the same properties as arcs in the Petri nets, and arcs in other cases, which shows synchronisation conditions of transitions. For the models to identify a set of pass T network is defined as a collection of model elements. Then

the arrangement of elements is defined by a set of *P*, *K* arcs, and the principles of functional *S*.
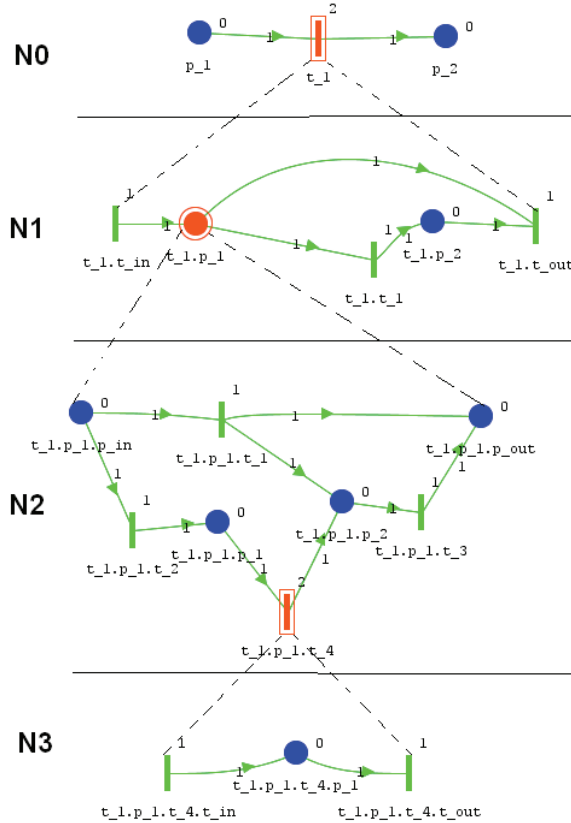
Fig. 5. Multilevel modified Petri Net

In a complex scheme by building computational models of hierarchical structure, hierarchical systems can be distinguished levels. Connection with each of the subsystems can represent several levels of the structure. Each level is a single hierarchical block points to group on the lower level (Fig. 5).

3.2. GRAPHICAL MODELING OF DESIGNED SYSTEMS

Validation of the prototype can be done by formal methods or simulation applying graphical tool. During simulation every event which occurs step by step will be placed in the time graph. Every fired transition corresponds to hi logical level (digital one)

and no fire, low logical level (digital zero). The result of simulation shows step by step of behavior of modeled system based on Petri Net theory. Tracking simulation process allows to check in which moment given tasks are running and there are no problems with its execution. Displayed time graph are exactly control vectors of modeled system architecture, which can be applied to simulation process using tools for designing programmable devices eg. ISE WebPack [10].
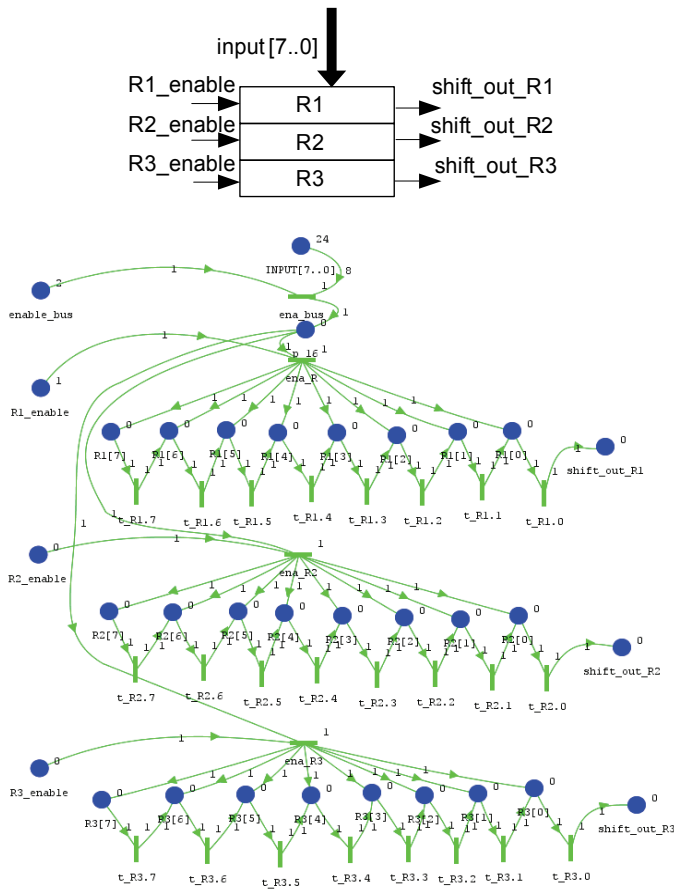
Fig. 6. Three 8 – bit shift registers block and Petri Nets based model

An example of system (Fig. 1) with three parallel connected bit-serial processor elements, connected to shared memories was presented in previous chapter. For transparent presentation of detailed modeling and how it works only small part of system architecture and its Petri nets model was modeled and simulated. Block of three shift registers model and its Petri nets model presents figure 6.

3.3. SIMULATION OF PETRI NETS BASED MODEL

Figure 7 shows five steps of the simulation. The result is shown on the screen and the timing of individual action of transitions allow the assessment of simulated model. During the simulation, it is possible to edit the content of all places on every testing stage.
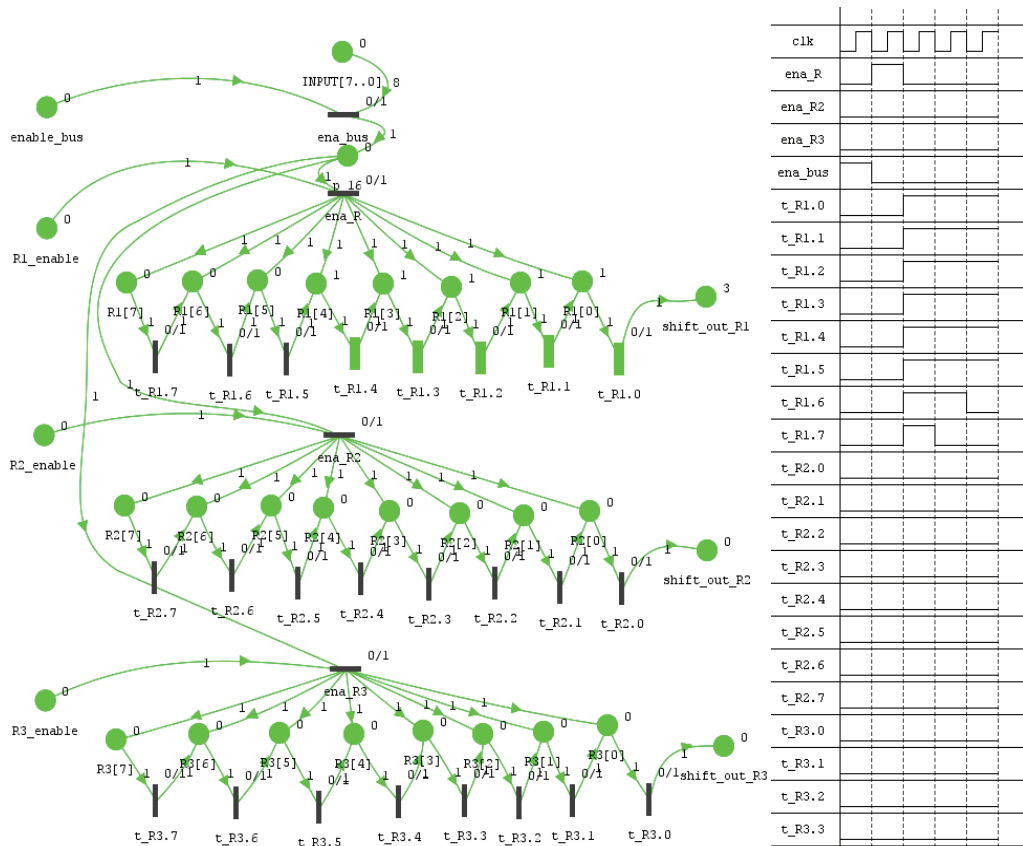
Fig. 7. Simulation five steps of block of shift registers

After twelve steps we get a full time of load operation activities 8 data bits in the register R1, and then move towards the exit all the vector information. As a result, the place shift_out_R1 get 8 tokens. The simulation result can be saved to a text file and used to test the systems implemented in programmable FPGA for example.

Table 1. The result of designed digital system simulation

Set of controls vector	Saved to file set of control vectors – ready for prototype testing tools
ena_R1 : 010000000000	000100000000000000000000000000
ena_R2 : 000000000000	100100000000000000000000000000
ena_R3 : 000000000000	000011111111000000000000000000
ena_bus: 110000000000	000011111110000000000000000000
t_R1.0 : 001111111100	000011111100000000000000000000
t_R1.1 : 001111111000	000011111000000000000000000000
t_R1.2 : 001111110000	000011110000000000000000000000
t_R1.3 : 001111100000	000011100000000000000000000000
t_R1.4 : 001111000000	000011000000000000000000000000
t_R1.5 : 001110000000	000010000000000000000000000000
t_R1.6 : 001100000000	000000000000000000000000000000
t_R1.7 : 001000000000	000000000000000000000000000000
t_R2.0 : 000000000000	
t_R2.1 : 000000000000	
t_R2.2 : 000000000000	
t_R2.3 : 000000000000	
t_R2.4 : 000000000000	
t_R2.5 : 000000000000	
t_R2.6 : 000000000000	
t_R2.7 : 000000000000	
t_R3.0 : 000000000000	
t_R3.1 : 000000000000	
t_R3.2 : 000000000000	
t_R3.3 : 000000000000	
t_R3.4 : 000000000000	
t_R3.5 : 000000000000	
t_R3.6 : 000000000000	
t_R3.7 : 000000000000	
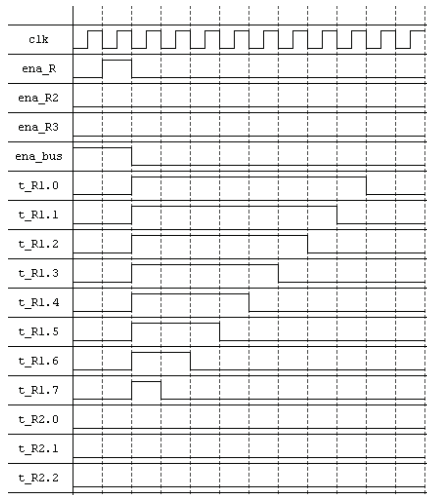
Fig. 8. Simulation time graph

The developed environment is under evaluation and may have shortcomings.

4. CONLUSION

Modified Petri Nets allow for effective parallel digital system modeling. Applying of graphical tool for algorithm mapping and behavioral simulation of projected system, allows for early sense of errors on the stage of elements implementation. Generated control vectors could be used as a control words for simulation in programmable devices environment or as a microprogram for control unit of physical digital circuit.

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ANALYSIS OF THE QUALITY CRITERIA FOR AUTOMATED DESIGN OF PLC PROGRAM MODELS AND ALGORITHMS

Many plant control systems involving control operations are presently implemented on programmable logic controllers (PLC). A significant part of control problems are similar for almost every application. Therefore, those typical control algorithms can be well documented, and, like framework models, they can be used for building programs in such applications. Due to the typical nature of plant architecture, a part of control algorithms for the equipment or overall PLC program structure can be even ready–made or generated automatically using the intermediate development interface (meta-program), which generates a frame structure of PLC code, expressed in a different language, i.e., XML. Nevertheless, there is still a strong need to validate the considered application, as to whether it is correct and compliant with the quality criteria requirements, such as those described in the ISO/IEC 9126 standard.

This paper suggests an approach for automated control program synthesis for a typical process plan that is developed in the production planning phase and is enhanced with PLC-specific information according to the IEC 61131-3 standard. However, the reliability of generated PLC code depends on the correctness of the plant control model and meta-program, i.e., whether they really generate code that correctly implements the model. This paper presents the way to build those control algorithms and automated generation of the PLC program according to quality criteria requirements.

1. INTRODUCTION

An automated control system can be described as a system which uses sensors to collect data, which is then processed by the control algorithm and operates as a proc-

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ess, running within the PLC. The continually increasing complexity of technological processes causes a corresponding growth in the complexity of control algorithms. Similarly, the structure of controlled technological objects and process control requirements is affecting the control of the system and its software architecture and system–wide quality requirements.

As it pertains to ensuring system software security and reliability, this can be accomplished by choosing a compliant and certified PLC. Internal system software is provided by choosing the PLC and can only be configured and parameterized.

A control program implements an automated control task. For each process or mechanism, it is always unique. As already mentioned, this process can be complex – quality and security of developed control programs may depend on many factors, such as 0 0:

- PLC type;
- programming software package;
- program development methodology;
- organization of program creation factors and other.

It is important to note that even in cases where different control processes are used, the same automated control solutions can be applied. Similarly, unique tasks for the algorithms can be applied repeatedly. Using this approach, one can is very likely to develop programs with higher quality and safety standards. There is a high probability to increase the quality and safety of developing program by using an already proven program fragments. To avoid copying errors automated software synthesis techniques are used increasingly.

There are many different approaches for automated PLC program generation. Most of them focused on data exchange between different models and applications. However there are some similarities and common requirements for these approaches.

Prior to the automated PLC program generation process it is necessary to use a model which describes or otherwise defines the technological objectives and requirement for process and design of the plant equipment. Process models can be established in three ways:

- using a modeling language represented with formal or semi-formal meta-model (e.g., Unified Modeling Language (UML) [3], Signal Interpreted Petri Nets (SIPN) [4]);
- projecting the interactive graphical cell model [5];
- or constructing the plant model using a library of standardized elements of process [6].

In many cases of automated PLC program generation with digital planning information, the open interfaces between planning and the PLC programming software packages are required as shown in Figure 1. This is where a data transformation takes place and the generated data is imported in the respective target application 0.
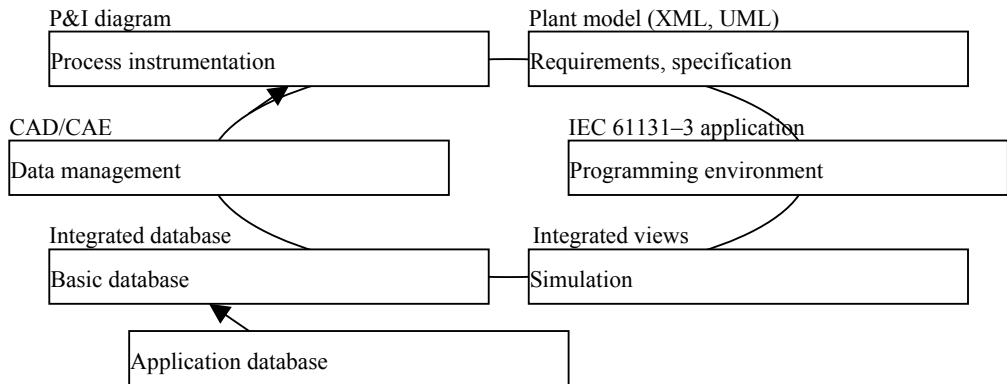
Fig. 1. Automated PLC Applications Development Process

The Base Model is a process plan that is developed in the production planning phase and is enhanced with PLC-specific information, according to the IEC 61131-3 standard 0. This model should be exported to a special developed interface (meta-program), transformed with the aid of the reference model and finally imported in the target system in the form of IEC 61131-3 code. With the aid of the Extensible Markup Language (XML) format interface, all PLC programming languages and variable lists can be imported and exported.

2. PLC PROGRAMMING INTERFACES

The programming system (called "the application package") is used for the construction of PLC programs, uploading to the PLC and its monitoring activities (programs launch and alignment). These software packages have the following properties (in terms of safety and reliability) [9]:

- Most programming packages are unique and designed specifically for a particular PLC family or a group of families, so there is a high variety of these packages.
- The programming software package has program editors, the sets of the standard function libraries and the tools to start and modify the program. The architecture of all of these software package components, its operating philosophy, as well as the structure and function libraries is all non-standardized.

The PLC software model is not united, and, in many cases, it is determined by the individual producers, traditions and interests. The IEC 61131-3 standard is governed by the software model, but even such a common software model is not widespread and is only carried by a limited number of PLCs.

A control program can be complex. Many program language and structure varieties are used, depending on the package possibilities and the developer's qualifications and experience. With the exception of the IEC 61131 and IEC 64199 standards, there are no other regulations as to how the doses control program must be written. Program structure, style and algorithms are all a part of the creative process. All of these components can be defined by automated software process models.

A process model contains the necessary information for describing a system which filters out the non-essential details. This filtering facilitates the compression of the information contained in one model. The human knowledge in any area is based on the abstract representation of information. In this sense, a model includes the necessary elements with great influence to an abstraction layer and omits those elements which are not essential.

There are two types of models: structural and development models 0. The first type of model highlights the system organization and the second – its behavior. The model concept allows one to achieve the visualization of the system, its structure or behavior specification, the templates that guide the system performance and, finally, the documentation containing the information taken into account during the system design.

Modern systems allow the programming of control devices in one or more of the standard IEC 61131-3 programming languages or ones similar to them. The standard does not cover neither the program's project, nor its applications and file formats, so it remains the responsibility of each individual vendor to resolve these incomplete areas. Only a few programming packages allow the indirect transfer of one system's program set to another system. These solutions typically use a single medium for data exchange.

Since the release of the IEC 61131-3 programming standard, users want to be able to exchange their programs, libraries and projects between development environments 0. TC6 (Technical Committee for XML) of PLCopen[1] suggests using an open interface not only as the export/import tool from one development environment to another. Actually, it is not important where this XML code is coming from, as long as it is recognizable and usable. It could be generated by other tools like simulation and modeling tools, and consumed by verification, documentation, and version control tools.

Most PLC packages allow you to use symbolic variable names. Variables can be of elementary as well as composite and derived data types. Most software packages allow the declaration of variables in the program regulated by the standard IEC 61131-3 data types. However, there are compatibility issues which may result from this.

Function and function block library elements perform various functions (e.g., mathematical, control, fuzzy, systemic, and communication). The IEC 61131–3 standard standardizes only the most critical functions and functional blocks. Control

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[1] http://www.plcopen.org/

equipment manufacturer offers a wider set of libraries, which are specialized and do not meet the standard.

In principle, all the information for variables, functions and function blocks is available in the exported XML file. The inner workings are in the importing function. One exception is the generation of the coordinate system information in freestyle graphical editors – this is generated via the export functionality. Vendor-specific information and attributes can be included in the export file and possible deleted during the importing process, if applicable. The supplier-specific information should not deal with any of the logic part of the program. This means that filtering is done during the importing process – suppliers have to make sure that the extensions of the XML schemes for internal purposes are done in such a way that the deletion of information does not affect the functionality of the project. This could be done via an additional, supplier specific XML scheme, besides the PLCopen defined version, linked via an URL or file to the source.

Applications are analyzed before being sent to the control device. Text programs are compiled (rarely interpreted), so the syntax is checked by compiler. Meanwhile, graphical programs are usually checked for certain errors by the development graphical programming language editor, so they're already syntactically correct at the time of program creation. It's important to highlight that code editor usually only check for syntax correctness, rather than control algorithm correctness.

The ability to use data types, libraries functions, structuring opportunities of programs and certain programming techniques might reduce the errors incidence in the program. By taking advantage of important recommendations, many errors can be prevented, but the authors of the programs are still not protected against errors in algorithms.

3. AUTOMATED PLC PROGRAM DESIGN PROCESS

Depending on the project phase, different tools and methods are used. In the worst case, the corresponding data has to be re-entered during the transition from one phase to the next, because there is a lack of appropriate interfaces between the individual tools. To reduce complexity of interfaces between different models and tools, modules may be one appropriate solution. The modules integrate the different models and their tool representation for themselves.

An agile software development approach for embedded systems has been transferred to automation and process control. Using XML, an approach was developed, which allows the automatic generation IEC 61131–3 code from an XML model and the importing to the PLC programming tool.

The different models or tools offer one view on the module as shown in Figure 2. The challenge is to integrate the views of different project phases and disciplines.
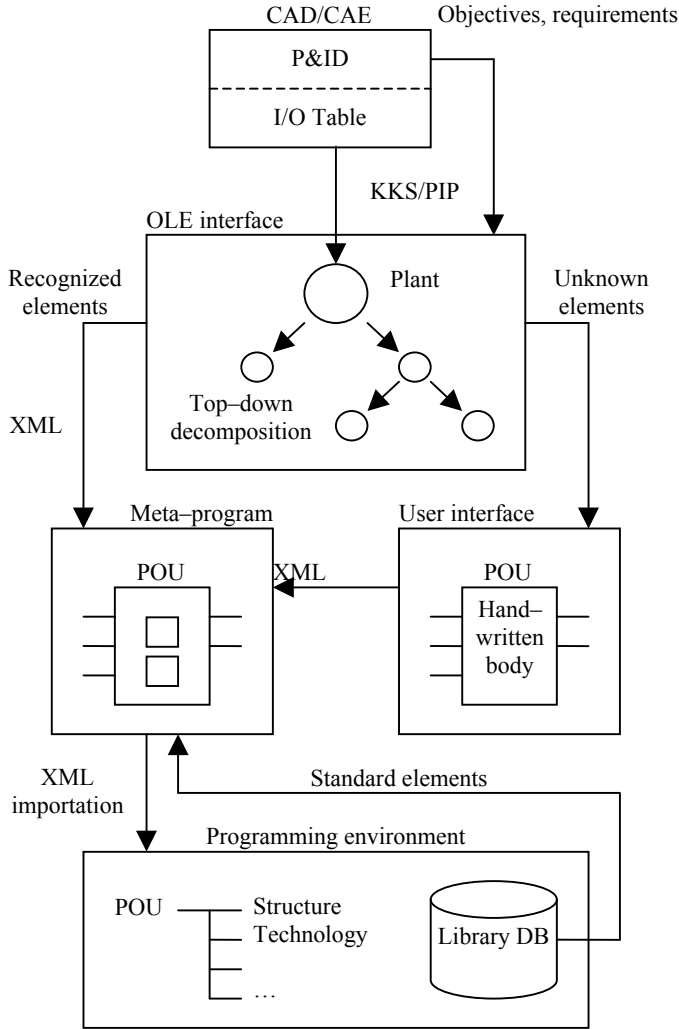

Fig. 2. Automated PLC Applications Development Process

A module with these views is an aggregation of information. The ideal to strive for would be a higher-level modeling notation and strategy supported by a tool that consistently provides all system information in one model or provides powerful and clearly specified interfaces to models of other disciplines or project phases.

The first phase of the process automation is the basic and detail engineering design. In this phase, the objectives and requirements for a plant are discussed. Most

engineers in this phase are using some kind of CAD/CED (Computer Aided Engineering/Computer Aided Design) tools. P&ID (Piping and Instrumentation Diagrams) and I/O (Input/Output) tables should be used in the next phase of automation.

Main idea of program synthesis algorithms is to identify signals at the detailed design phase, to which technological branch they belong and order them to corresponding function block inputs and outputs.

The main restrictive condition is a formal technical description of the equipment in the process plan. This means that the design of equipment must be described according to certain rules. The issue: the real object signals must be unambiguously encoded because the meta-program could respectively attribute them to the objects groups. Such a decision should be known to the plant industry engineers.

The energy industry is often subject to the Power Plant Classification System (KKS). All of the plant equipment may be specified based on this system 0.

From work project at the basic design stage, the information will be exported into an XML format to analysis program that generates instances of typical function blocks and assigns corresponding I/O channels to them. As a result, a program code for PLC programming software is generated.

Then, the input–output data from the detailed design project is uploaded into the meta-program using project I/O export list. In order to identify I/O signals, the exported data must have the certain restrictive conditions to provide complete information on the work project.

The model is drawn up automatically using XML technologies and displayed graphically using a user interface open source tool. It requires a program that identifies the individual elements of the process and by creating templates for model elements (motors, valves, etc.). It also uses the XML scheme, which will be grouped into data elements and a data mapping tool.

The design software EPLAN[2] has the capability to export the work project I/O signal list with the controller's physical addresses, along with other necessary information (e.g., KKS code). The exported file contains the information elements which are separated into an XML structure. Useful information is deemed to be that which will require automation of the sub-creation. Without this information, the next automated creation is impossible 0. It is noted that each signal functional text also has a strict form, which must have the signal KKS code and the signal function as a commentary or other adequate form. Exported data describes the control model of the process.

The I/O signal list is designed using the following rules:

- type (DI, DO, AI, AO);
- number (01, 02, ..., 10, 11, ...);

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[2] http://www.eplan.us/products/eplan-electric-p8/

- name (KKS functional text);
- physical address (for example: „AT% IX62.0“);
- type of variable (BOOL, INT, WORD, ...);
- comments (functional text).

After the signals are described with unique names and addresses, sub-programs can be designed. Sub-programs consist of blocks of typical control algorithms, such as the motor, valve etc. control block which is described in the user library 0.

In this case, during the automation process of control sub-programs, it's possible to transfer the block inputs and outputs to options, and assign them to the block input and output.

The user imports the data from the design tool. User interface elements of a program are displayed graphically and placed on a template (P&ID Framework). The user can choose different layout templates. It also provides information for the selected template for which there isn't enough data. In addition, the proposed layout templates contain information about the different technological models.

Since the data is grouped into elements and the selected layout of the scheme remains the only choice for the conversion of the XML programming tool that is able to use the XML format. Each programming tool has a different XML format (defined in XML scheme) which can also be described in the template. The template shape depends not only on the selected programming tool, but also with the programming language (e.g. ST language of IEC 61131-3). Finally, the meta-program generates an import/export file as an XML data file. This file combines the physical process control model, the technological model and the standard (or user derived and standardized) function block library.

The effort to evaluate reliability, safety, and other program quality criteria requires a more detailed analysis of how program quality criteria, safety standards, and known program methodologies are established and how one might ensure that the criteria is met. These subjects will be discussed in the subsequent sections.

4. ANALYSIS OF THE PROGRAM QUALITY CRITERIA

The quality of a product is not quite easy to describe, because this concept signifies differently for different people. If for example the readability of a program is considered to be important for someone, for others the compactness of a software program could be of higher importance. With the help of this example another problem is quite apparent, namely the mutual influence and the distinctive existence of the characteristics. To make a program understandable, many explanations may exist in this program, but in consequence the volume of the software increases.

The ISO/IEC 9126 standard is governed by the software quality model and the guidelines for the software quality analysis. The software quality model consists of six key quality criteria, which also have additional quality features that characterize the aspects of quality in more detail as it is shown in Figure 3.
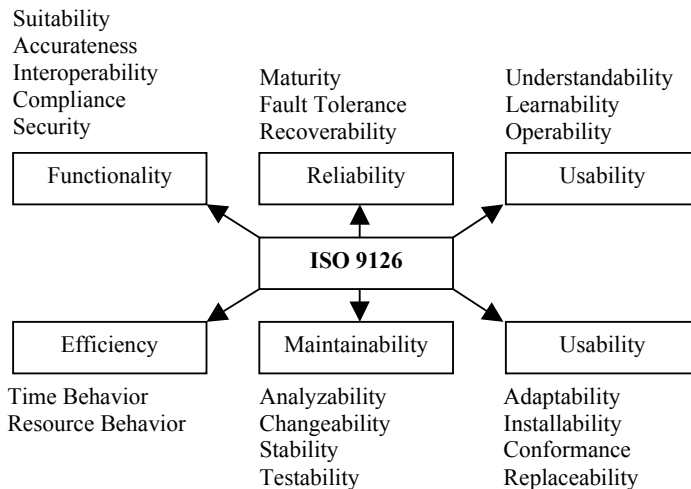
Suitability
Accurateness
Interoperability
Compliance
Security

Maturity
Fault Tolerance
Recoverability

Understandability
Learnability
Operability

| Functionality | Reliability | Usability |

ISO 9126

| Efficiency | Maintainability | Usability |

Time Behavior
Resource Behavior

Analyzability
Changeability
Stability
Testability

Adaptability
Installability
Conformance
Replaceability

Fig. 3. Software Quality Model of ISO/IEC 9126

The external measures of quality criteria are characterized by the software in regard to the user and his environment. These measures must:
- quantify the external quality of the software that is used;
- measure or probabilistically determine the quality of the software during its testing process;
- measure the quality criteria in use of the software.

The following measurements of external quality should be made:
- the measurement of the software behavior (testing, working with the software, its interactions with other software and hardware equipment);
- the measurements of ergonomics and user behavior with the software;
- the measurements of events (damaging of the equipment or human damage, harm to the environment, destruction or distortion of information, breach of security, narrowing the services or profit reduction).

The internal measures of quality criteria define the quality of the software or already automatically generated PLC application due to the point of view of the software developer. The purpose of these measurements is to describe the quality of the software regardless of its environment.

The above mentioned quality parameter measurements are regulated by the standard only in the abstract. Therefore the experts that analyze the software are able to assess the quality features. The standard gives only four grades of quality measures: Excellent, Good, Fair and Poor. The first three assessments stand for satisfactory grades, the fourth stands for refused.

Often as not, in the analysis of selected cases the usual ten-point grading scale or a logical TRUE/FALSE rating system is used. It is also available while comparing the two programs, which is enough to determine which program is better or worse with certain quality criteria.

4.2. SOFTWARE EVALUATION STANDARD ISO 14598

The IEC 9126 standard is governed by the program quality criteria, whereas IEC 14598 standard is governed by the model of how to achieve the following quality criteria and evaluate them. This standard consists of 6 parts:
1. ISO 14598-1 General overview.
2. ISO 14598-2 Planning and management.
3. ISO 14598-3 Process for Developers.
4. ISO 14598-4 Process for Acquirers.
5. ISO 14598-5 Software evaluators.
6. ISO 14598-6 Documentation for evaluation modules.

The standard defines three approaches of quality evaluation: software *developer,* the *user* and the *evaluator* of the quality. For each of these approaches there is a part of the standard as specified in Figure 4.
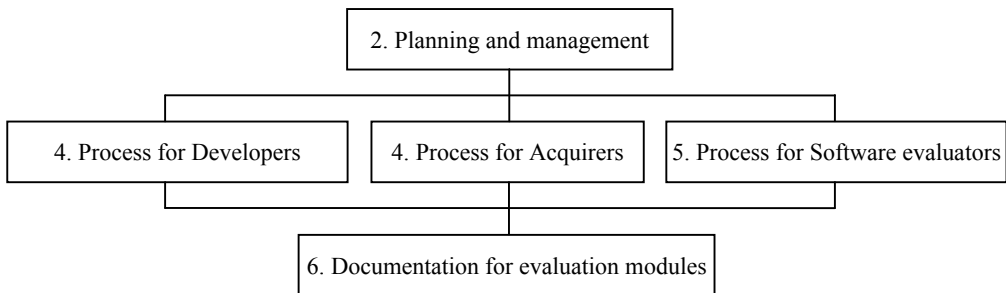
Fig. 4. Architecture of IEC 14598 Standard

While IEC 14598 is based on the IEC 9126 standard definitions of quality criteria, these standards are not as closely linked as well as developed and elaborated independently of one another. It also does not take those standards into the software life-cycle characteristics. Therefore, in 2003, the steering group was created to bring together and update these standards to a new generation standard of ISO/IEC 2500

SQUARE (Software Product Quality Requirements and Evaluation) 0. The architecture of the standard is created, also as the main parts of the standard, however the standard specifications are not yet well-established and widely publicized.

IEC 9126 standard safety criteria apply only to data and unauthorized use of function. IEC 14598 standards recommend the analysis of the software according to the SCOPE[3] project that adapted classification of analysis levels. In the automated management systems the definition of security is much more defined. The automated management software is the E/E/PES (Electrical/Electronics/Programmable Electronics System) system; therefore it is covered by such schemes applicable safety standards, which are discussed in further section.

4.3. FUNCTIONAL CRITERIA AND ITS EVALUATION

Functional criteria for software are those that can clearly measure or calculate the probability of certain indicators. One of these kinds of criteria for IEC 9126 standard is efficiency. Both time and resource receptivity of a particular software environment can be measured and on-demand, compared with another software.

During the operation of the software, information about software maturity can be collected. So called *Defect density* is this type of measure. It is a value that describes how many errors have been found in 1000 lines of a program text in a particular program life-cycle point. It depends on the chosen point of the program's existence 0, because at the beginning of the program life-cycle the number of errors is the highest, while after start-up and tune-up the same number significantly reduces.

The probabilistic reliability program measures as Mean Time Between Failures (MTBF) or probability of failure on demand are also possible 0.

Analyzability (the additional criteria for convenient maintaining) can also be expressed in formal measures. The number of certain quantitative parameters of the software has to be counted. Several types of measures are used:

1. The counting of software modules, routines, the hierarchy levels of routines for each module, interfaces between modules, functions, user interfaces, etc.
2. The counting of the function size of the software in accordance with IEC 1971 standard (also known as the Cosmic FFP method[4]). The principle of the method is to declare the so called "functional needs of the user" (such as writing data to the disc, database maintenance, needs for the information output, needs for the adjustment of the data, etc.

The extent of the program and the resources need to analyze the program are evaluated in accordance to one of these measures.

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[3] http://www.cse.dcu.ie/essiscope/
[4] http://www.cosmicon.com/

Other kind of criteria can be expressed partway only. The following section describes the methodology of how to formalize the criteria for the specific case of automated generation software development process.

4.4. NON-FUNCTIONAL QUALITY CRITERIA

The so called non-functional quality criteria are no less important for the program life-cycle, because they might determine the functional criteria of the program. In example, such criteria in accordance with IEC 9126 are: re-usability, volatility, immunity from disorders, testability, etc.

Table 1. Analyzed Quality Criteria and Their Influence on Weight

Parameter	Add. criteria	Influence	Evaluation	Method
Functionality	Expediency	c_{fun_1}	k_{fun_1}	Comparison with the terms of refer.
	Exactness	c_{fun_2}	k_{fun_2}	Comparison with the terms of refer.
	Interoperability	c_{fun_3}	k_{fun_3}	Expert rating
	Compliance	c_{fun_4}	k_{fun_4}	Measurements
	Security	c_{fun_5}	k_{fun_5}	Expert rating
Reliability	Maturity	c_{rel_1}	k_{rel_1}	Expert rating
	Fastness	c_{rel_2}	k_{rel_2}	Expert rating
	Reproducibility	c_{rel_3}	k_{rel_3}	Expert rating
	Service feasibility	c_{rel_4}	k_{rel_4}	Expert rating
Practicality	Perspicuity	c_{pra_1}	k_{pra_1}	Expert rating
	Availability	c_{pra_2}	k_{pra_2}	Expert rating
	Operationality	c_{pra_3}	k_{pra_3}	Expert rating
Efficiency	Time receptivity	c_{eff_1}	k_{eff_1}	Measurements
	Recouce receptivity	c_{eff_2}	k_{eff_2}	Measurements
Convenience	Analyzability	c_{con_1}	k_{con_1}	Cosmic FFP
	Convertibility	c_{con_2}	k_{con_2}	Expert rating
	Stability	c_{con_3}	k_{con_3}	Expert rating
	Testability	c_{con_4}	k_{con_4}	Expert rating
Operability	Adaptability	c_{ope_1}	k_{ope_1}	Expert rating
	Installability	c_{ope_2}	k_{ope_2}	Expert rating
	Coexistence	c_{ope_3}	k_{ope_3}	Expert rating
	Compliance	c_{ope_4}	k_{ope_4}	Certification
	Interchangeability	c_{ope_5}	k_{ope_5}	Expert rating

In this case, the criteria can be evaluated based on the methodology of the SCOPE project:
1. Most importantly, the optional quality criteria (essential to the analyzed software) have to be chosen, as it is shown in Table 1.
2. The following table indicated the impact of the criterion on overall quality criterion, i.e., the normalized criterion. Then the measures of the criteria are chosen.

3. Finally, the evaluation of the criteria and the calculations of the overall criterion/vector of the criteria are done.

The overall vector of the criteria is calculated using this formula:

$$K_{PI} = C_{fun} \sum_{i=1}^{5} c_{fun\_i} k_{fun\_i} + C_{rel} \sum_{i=1}^{4} c_{rel\_i} k_{rel\_i} + C_{pra} \sum_{i=1}^{3} c_{pra\_i} k_{pra\_i} +$$
$$+ C_{eff} \sum_{i=1}^{2} c_{eff\_i} k_{eff\_i} + C_{con} \sum_{i=1}^{4} c_{con\_i} k_{con\_i} + C_{ope} \sum_{i=1}^{5} c_{ope\_i} k_{ope\_i} \tag{1}$$

K_{PI} – program quality evaluation, $C_{fun, rel, pra, eff, con, ope}$ – overall quality criterion values. Other parameters have the same values as it is shown in Table 1.
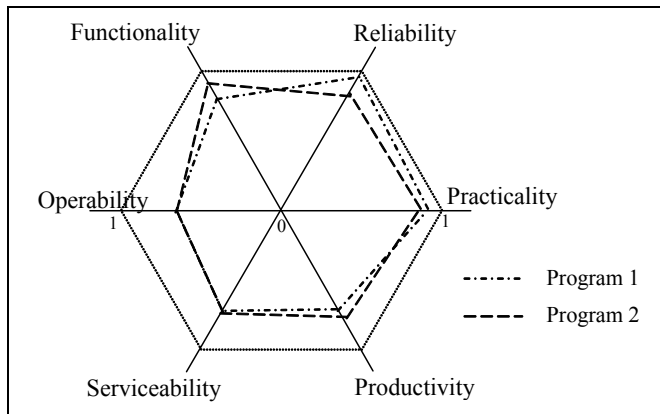
Fig. 5. Two Programs Quality Criteria Comparison Chart

The graphical depiction of the quality criteria is used for the comparison of the software, as it is shown in Figure 5. This is the way to illustrate the differences of program quality criteria. For example, Figure 5 illustrates that Program No.2 has lower reliability, although its functionality is higher.

5. CONCLUSIONS

Practice and analysis of the software show that more or less all fields of equipment software error rate are roughly comparable 0. To reduce the impact of errors in the user program integrity, the program aims to write as much as possible to formalize the process and make use of methodologies and tools that enable software to avoid mistakes. Using program writing guidelines like hardware and system software security, software development process and programming techniques for automated application development process the outstanding quality results could be achieved.

Automated application development enables to eliminate some of the criteria (e.g., reliability, practicality) or make it stable equal to constants.

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WIRELESS CONTROL OF
THE ELECTRO-PNEUMATIC SERVO DRIVE

Wireless networks on account of constant development gain ever greater possibilities of application in the industry. Popular wireless computer networks (WLAN) can be used not only for data transfer between computers, but also for remote control of electro-pneumatic servo drive based on the application running on the mobile computer. In order to examine in practice the possibility of use such application the laboratory position was built for wireless control of the electro-pneumatic servo drive. For that purpose the microcomputer board was used, which task is to connect the wireless card, input output port and application for the operator. As the port of input/output for the controller was selected module for data acquisition equipped with analog inputs and outputs, however for wireless communication with the computer operator a wireless card is used. Servo drive was built based on the proportional pressure valve, pneumatic valve positioner, pneumatic actuator of double-sided action, convertor of linear transfers and measure of linear transfers.

1. INTRODUCTION

Wireless networks at the end of few last years gain more popularity [2]. Constant development of this technology causes that they become ever faster, safer and reliable. The wireless communication on account of easiness installation is very common in the domestic consumption as well as becomes more popular in the industry [2]. The aim of this work is to present the possible use of WiFi wireless network in the servomechanism electro-pneumatic control. For that purpose was built laboratory position and written application for the communication between operator and servomechanism.

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2. COMMUNICATION IN NETWORKS

The communication between devices via network must be held according to strictly defined principles so-called protocols, which are specific for applied communication of every type. The task is to define such features as the format and structure of sent message, ways of message exchange between network devices, methods of the system information exchange and mistakes between network devices as well as to establish and finish connections. Protocols don't usually describe how to carry determined function out, so the implementation of given protocol is independent from specific technology.

Successful communication in the network requires sharing of many different protocols. Such connected group of protocols is called the protocol suite, which is often presented as the stack [7]. There are two basic models of the network. Model TCP/IP (protocol model) and OSI model (reference model) [8]. The reference model and protocol model along with their layers presented on Fig. 1.

OSI model	**TCP/IP model**
7. Application	Application
6. Presentation	
5. Session	
4. Transport	Transport
3. Network	Internetwork
2. Data link	Network interface
1. Physical	
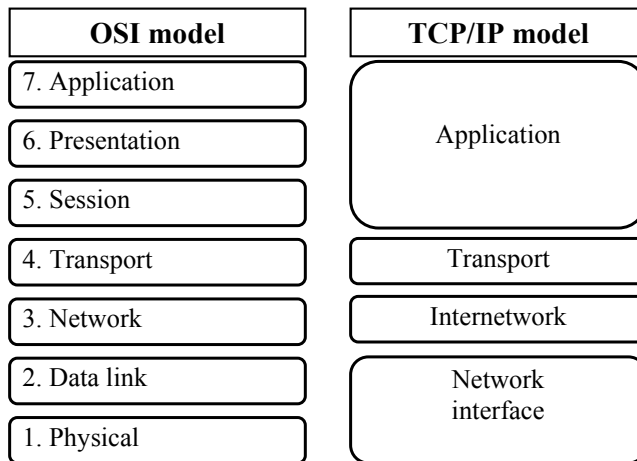
Fig. 1. OSI model and TCP/IP model

Model TCP/IP is regarded as the model of Internet network. It defines four layers, which are responsible for correct communication network. Layer access to the network is responsible for control of physical devices and media forming the network. Next layers are responsible for determining the best route of packages in the network, communication between different devices in different networks and reading data from the user. Sending data they go from the upper layer to lowest, however the receipt of data is a reverse process.

OSI model consisting of seven layers provides a list of functions and services, which may occur in every layer, by what has a significant participation in the development of other protocols [7], [8], [1].

In the first layer of the TCP/IP model it is possible to distinguish three types of media transmission, connecting devices and providing data transmission: metal cables, fibre-optic and wireless communication.

To advantages of the cable networks it is possible to rank providing adequate signal power on the entire cable length, protection against external signals effects as well as lack of local regulations and standards with the use of frequency band. For wireless networks the advantages of cable networks will be their defects, because without additional legal standards it is possible to use only some frequency bands, the useful signal is susceptible to external interferences as well as it is hard to ensure the appropriate quality of signal along with recede from its source. Advantages of wireless networks are undoubtedly easy access to the medium transmission as well as easiness of the structure and expansions of such networks [7], [11].

One of popular access wireless methods to the computer network is WLAN (Wireless Local Area Network). These networks are in accordance with the 802.11 group of standards, which describes rules for the first and second layer OSI model. Frequency range of the radio waves used by the standard doesn't require the concession; therefore it is possible to use this standard without special licenses.

Standard 802.11 determines the outline of division bands into channels for the frequency range between 2.4 GHz and 2.483 GHz, where distance between individual channels are 5 MHz and width of channel are 22 MHz. This band isn't a subject to licensing and is divided into 11 channels for North America and 13 channels for Europe [3]–[6].
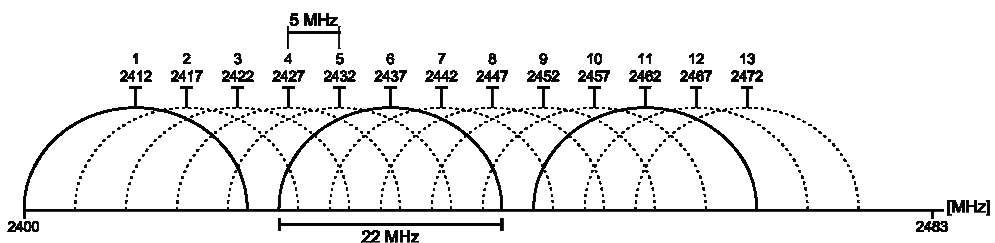

Fig. 2. Channels in the band 2.4 GHz

2.2. NETWORK PROTOCOLS – INTERNET LAYER

Network layer is responsible for the exchange of data fragments via network be-tween determined terminal devices. This layer is responsible for addressing, encapsu-lation, routing and decapsilacion of transmitted data. The most popular protocol used in the network layer is IP protocol (Internet Protocol). Currently is used in version 4 as well as successively version 6 is being implemented of this protocol. Moreover, in the network layer implement are protocols such as: IPX (Internetwork Packet Exchange), Apple Talk or connectionless service CLNS/DECNet network.

IP protocol is a connectionless protocol, by which communication with its use is faster and flexible, but all at the same time can be unreliable. Setting the reliability transmission therefore is dependent on layers of the high level in network model. In the IP protocol in version 4 addressing is hierarchical. In 32 bit part intended to the destination and source address are distinguished network part and host part. The entire pool of addresses (2^{32} = 4 294 967 296) is divided into classes A, B, C, D, E where classes from A to C are addresses of the unicast type with allocating for the addressing network devices [7].

2.3. TRANSPORT PROTOCOLS – TRANSPORT LAYER

Transferring large and constant data bands could make impossible to make other transmission in the same time because of seizing the entire transmission channel. An-other problem would be rectifying transmission errors and retransmit damaged data. Therefore, data are divided into smaller fragments (segmentation), which are trans-mitted between devices in the network. Such process also allows many different appli-cations for simultaneous work in the network by placing in one transmission channel the part of messages coming from different applications (multiplecsation). The task of segmentation, merging data and multiplexing communication lie on the transport layer side [7].

Depending on requirements which are put to transmit data, two basic transmission protocols are distinguished: TCP and UDP. The TCP Protocol is a protocol which guar-antees reliable provision of data to the recipient by tracking transmitted data, receipt confirmation of data and repetition of lost data. It is interconnection protocol, what means that before transmitted data by the network, connection is established between the communicating devices. Second protocol which is simpler under construction is UDP Protocol. It is a protocol faster than TCP, doesn't require confirmations as well as doesn't provide lost data for the retransmission, by which doesn't ensure reliability. As for applying mentioned protocols, where reliability of the data transmission is required the TCP protocol is applied (database applications, electronic mail, websites). In case of less sensitive data, where applications are tolerant to loss of small amounts data the UDP protocol is applied (video or voice transmission) [7], [9], [10].

2.4. APPLICATION – APPLICATION LAYER

The task of protocols layer is to provide an interface between the user of the network device and network data. In this layer it is possible to distinguish two types of the software: applications and services. Services of the application layer are usually transparent for the user and are responsible for connecting the application with network as well as sending data. However, the application provides interface for the user as well as initiates the process of data transmission by the network. In application layer as in remaining layers of the network model implement are protocols of different type defined by standards and data formats. FTP can be an example of the application, service and protocol, which are the interface for user (application), supporting program connections for transmission files (service) and interchange standard of network communications (protocol).

Protocols of the application layer define the way of data exchange between applications and services, which are started on devices participating in the communication. They carry it out by determining the type and format of exchanged message as well as by determining the way of sending and receiving message [7].

3. CONTROLLER OF THE ELECTRO-PNEUMATIC SERVO DRIVE

The controller of servomechanism was built based on the ALIX.1D microcomputer board (Fig. 3). This board is equipped with AMD Geode 500 MHz processor and 256 MB memory RAM. Powered with tension 12 V and characterized by small conscription of the electricity, row of 0.4 to 0.5 A. The task of board is to connect wireless card, input output port and application for the controller. For that purpose on the memory card was installed operating system Windows XP. This system was chosen, because equipping board meets the minimal requirements for system as well as in this system doesn't have more considerable problems with detection installed additional devices and with drivers to it.

As input/output port for the driver was chosen module for the data acquisition MicroDAQ USB-1208FS (Fig. 3). This system has 4 analog inputs in the symmetrical system (differential) and 8 inputs in the asymmetrical system. Inputs have resolution of 12 bits in the symmetrical system or 11 bits in the asymmetrical system. In the asymmetrical system is a possibility of tension measurement ±10 V, while in the differential system ±20 V. Module is characterized by sample frequency to 50 kS/s using hardware scanning. For generation output signals are available 2 analog outputs about resolutions of 12 bits. Output tensions range amounts to 0–4.096 V at maximum load capacity 15 mA. Analog data are sent with the frequency to 10 kS/s for one channel or 5 kS/s for two channels using the hardware method. This module is connected to the driver board by USB interface.

For the communication with operator computer is used Ubiquiti XR2 card (Fig. 3). The card is equipped with connector MMCX, which provides better connection card – pigtail than popular in miniPCI cards UFL connectors. Advantages of this card are 802.11b and 802.11g standards, large output power (26 dB) and sensitivity of the receiver to –95 dB. Card is recommended in applications, where is required the highest reliability and quality of transmission. Depending on used aerial inside the premises it is possible to obtain up to 200 m, however on the open area about 50 km.
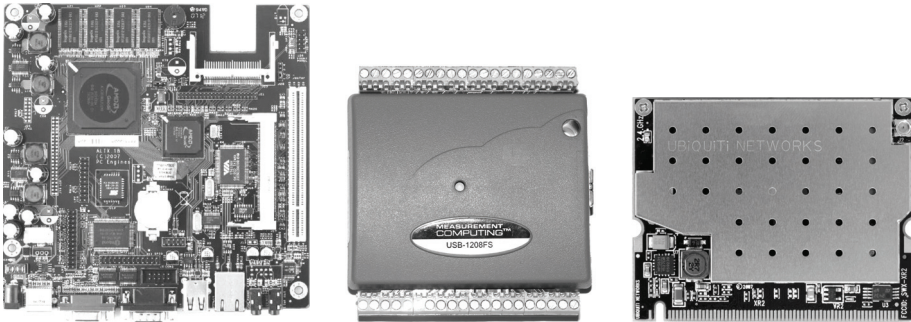
Fig. 3. Elements used for construction of the controller. From left: ALIX 1D microcomputer board, module of the acquisition data MicroDAQ USB-1208FS, wireless card Ubiquiti XR2

According to the TCP/IP model for proper operation of the devices in network should assign them unique network addresses. For that purpose the pool of addresses IPv4 from class B was divided into subnet consisting of two hosts. The division into smaller subnet was achieved by change of the mask this way so that only 2 least significant bits were used for appointing addresses of devices. The output address was network address 172.16.0.0/16. After distinguishing the subnet address 172.16.2.0/30 was chosen as the address of network. The address of driver is 172.16.2.1 and the address of operator (computer) is 172.16.2.2. Remaining address in the subnet (172.16.2.3) is a reserved broadcast address. Such addressing increases the safety before connecting to the network of "strange device", since next address 172.16.2.4/30 is already an address of other subnet, by what devices will not be able to directly communicate with. In order to provide the reliability of transmission and due to small amounts of data which are sent by the network as the transport protocol TCP was chosen.

For the driver communication with operator were written two applications. One for controller and second for operator. The application of controller performs role of the service. Its task is to listen closely and wait for the connection on chosen port from the operator. In case of connection detection the service starts to collect and send data. When operator finishes the connection, the application again turns into the state of listening and waiting.

Both programs were written using LabVIEW software (Fig. 4) which allows to write program with the use protocols such as TCP, UDP, Bluetooth or IrDA. So that applications could sent data via protocol TCP must use blocks to open and close connection for determined IP address and port, block to listen for incoming connections as well as recording and reading blocks of data from the TCP connection. On the picture bellow is presented an example of the client application and server created with the use LabVIEW.
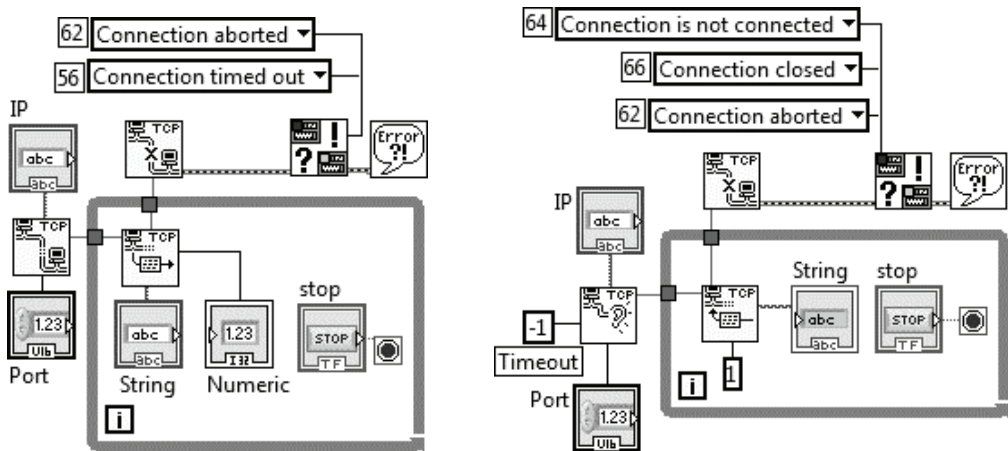

Fig. 4. From left: client application, application of the server

Laboratory position view of the wireless control electro-pneumatic servo drive as well as panel controller view of the wireless communication is presented on Fig. 5.
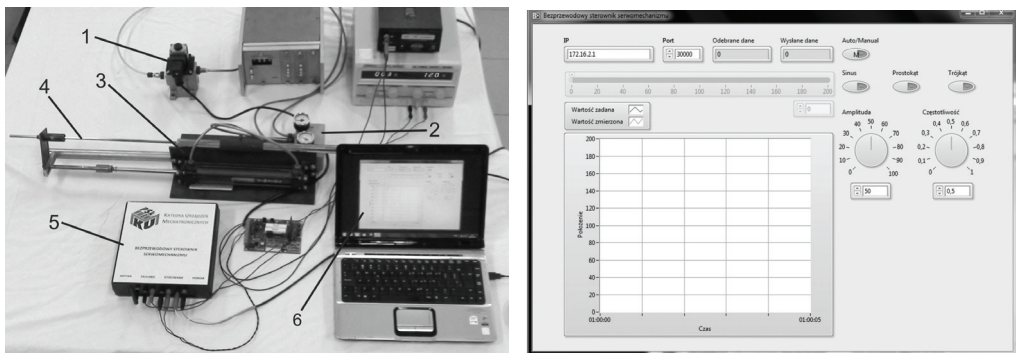
Fig. 5. On the left: Laboratory position view of the wireless control electro-pneumatic servo drive: 1 – proportional pressure valve SMC VEP3141, 2 – valve positioner A705, 3 – pneumatic actuator, 4 – convertor of linear transfers PT×200, 5 – measure of linear transfers MPL102, 6 – driver of the wireless communication, 7 – computer panel of the controller. On the right: panel controller view

The task of proportional valve pressure is to ensure on its output set pressure proportional to the value of control tension. Valve it is possible to steer out in order to obtain on it output pressure between 0.005 MPa and 0.15 MPa at maximum working pressure 1 MPa. It is characterized by flow control of pressure and response time 0.05 s. Valve is connected to the pneumatic positioner valve, which is responsible for establishing appropriate actuator position on the pressure base controlled by the valve. It is designed to work with the piston pneumatic actuators. Its mechanism of maneuverable tensing ensures fast and accurate setting the piston actuator proportionally to the value of control signal. Valve can be controlled by the signal about values 20–100 kPa, at the power pressure 0.25–1 MPa.

For measurement of the transferring actuator was used transformer sensor of linear transfers PTX200 and measure of linear transfers MPL102. The sensor is built based on differential transformer, which is located in the casing of sensor. In the transformer inductor is placed movable magnetic core, however in the casing is spring guaranteeing pressure of the tang to measured object. This sensor requirements power of variable voltage with carrier wave about frequencies 5 kHz, which is provided from the measure of linear transfers. This device is equipped with two-channel measuring amplifier, built in stabilized of power supply and digital voltmeter of the direct current. On the output of device is obtained voltage ±10 V.

The controller role is to proxy in the communication between operator and pressure valve as well as convertor of transfers. Controller (5) after getting signal of actuator from the operator processes this value and generates the appropriate tension on its output in order to control proportional pressure valve (1). On the output of valve (1) appears pressure proportional to its control tension, which is given on positioner valve (2). The task of valve is proportional actuator hanging (3) to set position dependent pressure values. Convertor of linear transfers (4) measures the value of displacement, which is read out by the controller (5) and sent to the operator. In this way the operator has feedback information whether the actuator achieved the set value.

4. RESULTS

As a result of conducted experiment in the laboratory position obtained characterizations of the servomechanism electro-pneumatic work, which were presented in Fig. 6 and 7.

From analysis of above graphs it results that there is a delay between the value of set signal and actuator position. By virtue that driver performs the role only as control system of the delay isn't significant in the process of regulation. For the regulation process responsible is pneumatic positioner valve. Small values of delay occur in the process of manual control, however larger delays appears at automatic control, where changes of the control signal are faster. The reason of such delays may be applied transport protocol, which on account of the quality transmission assurance imposes delays.
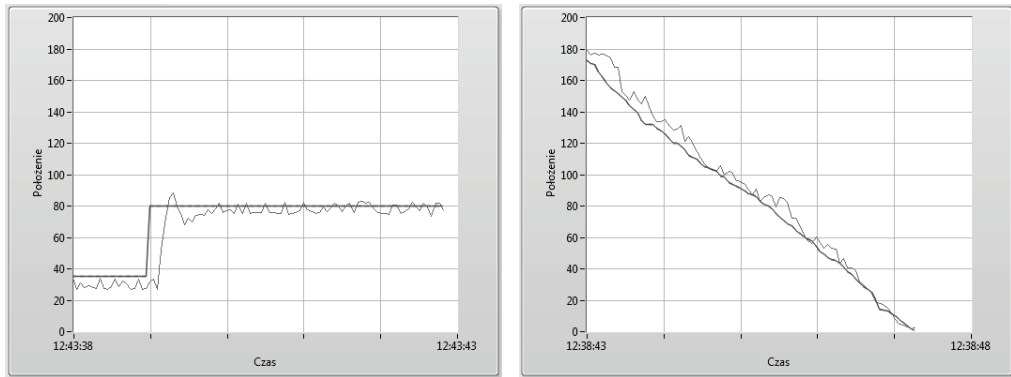
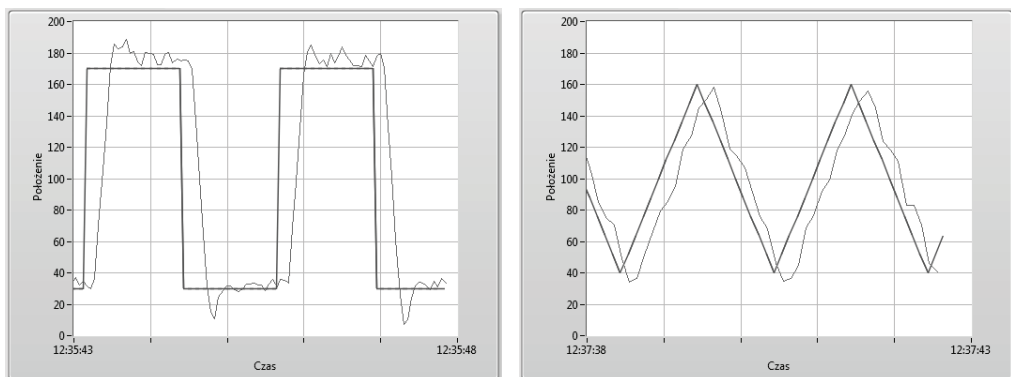Fig. 6. Manual control of the electro-pneumatic servo drive

Fig. 7. Automatic control of the electro-pneumatic servo drive

Next stage of works associated with examining wireless transmission in control of the pneumatic servomechanism will be change TCP protocol to UDP in order to check, whether the simpler transports will also impose delays in the data transmission.

In spite of the fact that defect in the studied controller is impose of delays between the control and read signal, what disqualifies it as the adjuster, it is possible to use it for simple control of the servo drive in systems not-requiring big precision and in places dangerous to very operator of the servomechanism.

5. SUMMARY

The development of computer networks, particularly wireless networks causes that they are more efficient and safe, by what can be often used in the industry. Wireless communication in spite of its limitations, such as susceptibility to disruptions or de-

lays in transmission gives us great possibilities of use where it isn't possible to apply cable networks. Wireless control can significantly improve security of the operator as well as reduce structure costs of the network infrastructure. Conducted simulations in the laboratory position confirm that it is possible to use the wireless computer network WiFi without obstacles to communication of the operator with the remote device. Moreover, must note that after exchange of the software it is possible relatively easily to adopt the controller of other tasks.

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Maciej HOJDA*

UNCERTAIN APPROACH TO
MULTI-ROBOT TASK ALLOCATION

Mobile robots equipped with arrays of tools are capable of performing various tasks over a wide area. Considered is a case where in order to perform a task an executor – a mobile robot – has to move to the execution point – a workstation. Decision has to be made on how all available mobile robots should perform all the observation tasks. Movement times between workstations are not known exactly at the moment of decision making. They can vary due to movement parameters such as the need for collision avoidance. Their description is provided through type-C uncertain variables which certainty distributions are assumed known. In the scope of this work, formulated and solved is an uncertain decision making problem.

1. INTRODUCTION

Multi-robot systems are usually required to provide efficient planning and execution methods of tasks they are required to perform. Specific conditions depend on real-life scenarios amongst which some of rapidly rising in popularity and coverage include search and rescue applications [18], production in flexible manufacturing systems [7, 4, 14], inspection and surveillance [11, 13, 17]. Various specific problems with such applications are considered within the framework of so-called multi-robot task allocation, or MRTA.

Drawing from domains such as mechanical modeling, operational research or control theory, MRTA conforms to the problems of every underlying domain. As mentioned in [3] formal requirements of scientific pursuit have been largely overlooked in the domain of MRTA to the benefit of a more pragmatic approach – construction of working, applicable multi-robot systems [1, 18]. Nevertheless, in the

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last decade more works focus on formulating and solving proper optimization problems, some of which are strictly related to known problems from underlying domains. Such an approach has been undertaken in this chapter where considered is a problem of time-optimal task allocation on mobile robots with unknown movement times.

In earlier works of the author [6, 7, 9] cases where execution times were obtained with the use of a decision making procedure have been presented. It was then assumed that workstations spread over a flat working space had tasks assigned to them. To perform the task, mobile robots – executors – had to drive-up to workstations. Both, the task assignment and robot movement were a part of the decision making process. Controllability of the executors changes the classical problem of task scheduling into task scheduling (or allocation, as used in MRTA) on moving executors or the routing-scheduling problem. Tasks were complex actions consisting of two phases: movement to the workstation and performance of an activity at that workstation.

For this chapter it is assumed that the movement times are not known and there is no readily available procedure to obtain them. Instead it is expected of an expert to provide the required information. Movement times are modeled with the use of type-C uncertain variable formalism [2]. Activity performance time is assumed to be known.

Related uncertain problem formulations have also been considered in earlier works of the author. In [8] an uncertain task scheduling problem was solved for the case of basic uncertain variables. In [10] problems of certainty index maximization with a fixed approximate execution time were undertaken. This chapter is a follow-up of earlier research conducted in aforementioned papers.

Out of five sections the first one is this short introduction to problems of task allocation in multi-robot systems. Second section provides formulation of deterministic version of the problem with uncertain version formulated in the third section. Fourth section presents the solution algorithm and fifth closes the chapter with conclusions.

2. TASK ALLOCATION PROBLEM IN MULTI-ROBOT SYSTEMS

Given are sets of executors $\mathbf{R} = \{1, 2, ..., R\}$ and workstations $\overline{\mathbf{H}} = \{1, 2, ..., \overline{H}\}$. Workstation $\overline{H}$, called the depot, is where all executors start and end their movement. By $\tau_{r,g,h} = \hat{\tau}_{r,g,h} + \overline{\tau}_{r,h}$ denoted is the sum of the drive up time $\hat{\tau}_{r,g,h}$ and the execution time $\overline{\tau}_{r,h}$ of the task h by the executor r driving-up from workstation g. Binary decision variables $\gamma_{r,g,h}$ take value $\gamma_{r,g,h} = 1$ if executor r executes the task h after

driving-up from the workstation g. Value $\gamma_{r,g,h} = 0$ is given otherwise. Execution times and the schedule are further denoted by $\tau = [\tau_{r,g,h}]_{r \in \mathbf{R}; g, h \in \overline{\mathbf{H}}}$ and $\gamma = [\gamma_{r,g,h}]_{r \in \mathbf{R}; g, h \in \overline{\mathbf{H}}}$. Feasible schedule is given by the following conditions

$$\gamma_{r,g,h} \in \{0,1\}, r \in \mathbf{R}, h \in \overline{\mathbf{H}} \tag{1}$$

$$\gamma_{r,h,h} = 0, r \in \mathbf{R}, h \in \overline{\mathbf{H}} \tag{2}$$

$$\sum_{r=1}^{R} \sum_{g=1}^{\overline{H}} \gamma_{r,g,h} = 1, h \in \mathbf{H} \tag{3}$$

$$\sum_{g=1}^{\overline{H}} \gamma_{r,g,p} = \sum_{h=1}^{\overline{H}} \gamma_{r,p,h}, r \in \mathbf{R}, p \in \overline{\mathbf{H}} \tag{4}$$

$$\gamma \in S \text{ where } S = \{\gamma : \sum_{g \in \overline{\mathbf{H}}_S} \sum_{h \in \overline{\mathbf{H}}_S} \gamma_{r,g,h} \leq \overline{H}_S - 1, \overline{\mathbf{H}}_S \subseteq \overline{\mathbf{H}}, \overline{\mathbf{H}}_S \neq \varnothing, r \in \mathbf{R}\}, \tag{5}$$

$$\sum_{h=1}^{\overline{H}-1} \gamma_{r,H+1,h} = 1, r \in \mathbf{R} \tag{6}$$

where $\overline{H}_S$ is the cardinality of $\overline{\mathbf{H}}_S$. They ensure that all tasks are executed exactly once, that executor routes form cycles with no subcycles, and that each executor starts and ends its route in the depot. Set of all feasible schedules for which constraints (1)–(6) hold is denoted as Γ. In the deterministic case, the problem is to find the schedule γ minimizing the total execution time given as

$$T(\gamma) = \max_{r \in \mathbf{R}} \sum_{g \in \overline{\mathbf{H}}} \sum_{h \in \overline{\mathbf{H}}} \gamma_{r,g,h} \tau_{r,g,h} \tag{7}$$

under constraints $\gamma \in \Gamma$. Solutions to the problem are proposed in [7, 12]. Formally, the problem is defined as follows.

Problem A. Task allocation in multi-robot systems.
Given execution times τ find $\gamma \in \Gamma$ maximizing (7).

3. UNCERTAIN TASK ALLOCATION IN MULTI-ROBOT SYSTEMS

3.1. UNCERTAIN VARIABLES

Use of uncertain variables for modeling and solving non-deterministic problems is well founded in the literature of uncertain systems [2, 5, 8, 10, 15, 16]. Their primary use is to represent values which are not strictly known but can be described by an expert. This description uses the notion of a so-called soft property. For an uncertain variable $\bar{x}$ a soft property with intuitive meaning that "$\bar{x}$ is approximately equal to x" is denoted by $\bar{x} \cong x$. More generally, property $\bar{x} \,\widetilde{\in}\, D_x$ is understood as "$\bar{x}$ approximately belongs to D_x". Expert describes the variable by providing a certainty index for every possible value of $\bar{x}$. The higher the index the more certain is the value to occur. Formal definition is as follows.

Definition 1. Uncertain variable.

For a given set of possible values X, a certainty distribution $h(x) \overset{\Delta}{=} v(\bar{x} \cong x)$ is given by a certainty index $v(.)$ defined as follows:

$$v(\bar{x} \,\widetilde{\in}\, D_x) = \begin{cases} \max\limits_{x \in D_x} h(x) & D_x \neq \varnothing \\ 0 & D_x = \varnothing \end{cases},$$

$$v(\bar{x} \,\widetilde{\notin}\, D_x) = 1 - v(\bar{x} \,\widetilde{\in}\, D_x) = v(\bar{x} \,\widetilde{\in}\, X \setminus D_x)$$

$$v(\bar{x} \,\widetilde{\in}\, D_{x_1} \vee \bar{x} \,\widetilde{\in}\, D_{x_2}) = \max\{v(\bar{x} \,\widetilde{\in}\, D_{x_1}), v(\bar{x} \,\widetilde{\in}\, D_{x_2})\},$$

$$v(\bar{x} \,\widetilde{\in}\, D_{x_1} \wedge \bar{x} \,\widetilde{\in}\, D_{x_2}) = \min\{v(\bar{x} \,\widetilde{\in}\, D_{x_1}), v(\bar{x} \,\widetilde{\in}\, D_{x_2})\}$$

where $D_x, D_{x_1}, D_{x_2} \in X$.

Usually considered are certainty distributions with specific "shapes" (Fig. 1), from the most common triangular distribution [2, 16], followed by polynomial functions of variables with the triangular distributions (parabolic, hyperbolic) [2] and other. Values x^* are the most certain to occur while $\underline{d}, \overline{d}$ determine the spread of possible values.
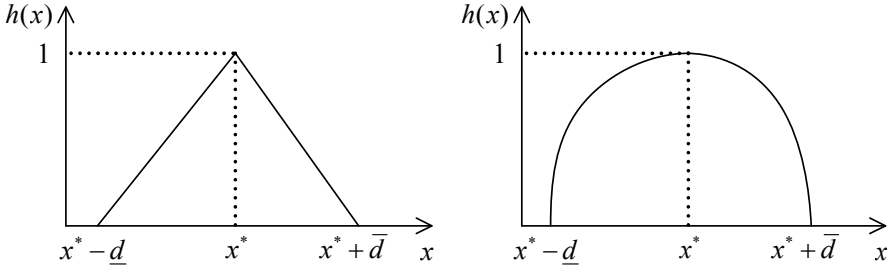
Fig. 1. (a) Triangular certainty distribution, (b) Parabolic certainty distribution

The triangular certainty distribution, which is the one considered in this work, is given by the following function

$$
h(x) = \begin{cases}
0 & x \leq x^* - d, \\[2mm]
\dfrac{1}{d}x + 1 - \dfrac{x^*}{d} & x^* - d < x \leq x^*, \\[2mm]
1 & x = x^*, \\[2mm]
\dfrac{-1}{d}x + 1 + \dfrac{x^*}{d} & x^* < x \leq x^* + d, \\[2mm]
0 & x > x^* + d /
\end{cases} \qquad (8)
$$

Presented basic uncertain variable is but one of the many types available. As argued in the literature [2], expert's knowledge can be better utilized with the use of type-C uncertain variable which is defined as follows.

Definition 2. Type-C uncertain variable.

For a given set of possible values X, a certainty distribution $h(x) \triangleq v(\bar{x} \cong x)$ is given by a certainty index $v_c(.)$ defined as follows:

$$
v_c(\bar{x} \widetilde{\in} D_x) = \frac{1}{2}[v(\bar{x} \widetilde{\in} D_x) + 1 - v(\bar{x} \widetilde{\in} X \setminus D_x)],
$$
$$
v_c(\bar{x} \widetilde{\notin} D_x) = 1 - v_c(\bar{x} \widetilde{\in} D_x) = v_c(\bar{x} \widetilde{\in} X \setminus D_x)
$$

$$
v_c(\bar{x} \widetilde{\in} D_{x_1} \vee \bar{x} \widetilde{\in} D_{x_2}) = v_c(\bar{x} \widetilde{\in} D_{x_1} \cup D_{x_2}),
$$
$$
v_c(\bar{x} \widetilde{\in} D_{x_1} \wedge \bar{x} \widetilde{\in} D_{x_2}) = v_c(\bar{x} \widetilde{\in} D_{x_1} \cap D_{x_2})
$$

where $D_x, D_{x_1}, D_{x_2} \in X$.

It is worth noting, that the same intuitive certainty distributions $h(x)$ are used in both the basic uncertain variable and type-C uncertain variable, no additional knowledge is required from the expert in either case. Type-C uncertain variable processes that knowledge in a different way [2], by using both, the $v(\bar{x} \in D_x)$ and the $v(\bar{x} \notin D_x)$ to evaluate the soft property $\bar{x} \in D_x$.

3.2. UNCERTAIN PROBLEM FORMULATION

Let us now consider the uncertain version of the formerly presented problem of multi-robot task scheduling. Property that the total execution time is approximately no greater than a given value is given by $T(\gamma) \stackrel{\sim}{\leq} \alpha$. Provided a fixed certainty level of $\bar{v}$ one has to find a schedule minimizing the approximate total execution time α, i.e.

$$\hat{\gamma} = \underset{\gamma \in \Gamma}{\arg\min} \, \underset{\alpha \in D_\alpha(\gamma)}{\min} \, \alpha, \tag{9}$$

where:

$$D_\alpha = \{\alpha > 0 : v[T(\gamma) \stackrel{\sim}{\leq} \alpha] \geq \bar{v}\} \tag{10}$$

while total execution time T is given as (7) with movement times $\hat{\tau}_{r,g,h}$ no longer known directly but given as type-C independent uncertain variables with certainty distributions $h_{r,g,h}$ where the most likely value will be denoted as $\hat{\tau}^*_{r,g,h}$ and spread of possible values is given by $\underline{d}_{r,g,h}, \overline{d}_{r,g,h}$. Concisely, the problem is formulated as follows.

Problem B. Uncertain task allocation in multi-robot systems.
Given certainty distributions $h_{r,g,h}$ and a certainty index $\bar{v}$ solve (9).

4. SOLUTION ALGORITHM

Every feasible solution satisfies the inequality that follows from (10):

$$v[T(\gamma; \tau) \stackrel{\sim}{\leq} \alpha] \geq \bar{v} . \tag{11}$$

Substitution of (7) into (11) gives

$$v[\max_{r \in \mathbf{R}} \sum_{g \in \mathbf{H}} \sum_{h \in \mathbf{H}} \gamma_{r,g,h}(\hat{\tau}_{r,g,h} + \overline{\tau}_{r,h}) \stackrel{<}{\sim} \alpha] \geq \overline{v} . \tag{12}$$

Due to independency of variables $\hat{\tau}_{r,g,h}$ the left hand side of the above inequality transforms into

$$v[\max_{r \in \mathbf{R}} \sum_{g \in \mathbf{H}} \sum_{h \in \mathbf{H}} \gamma_{r,g,h}(\hat{\tau}_{r,g,h} + \overline{\tau}_{r,h}) \stackrel{<}{\sim} \alpha] =$$
$$= \min_{r \in \mathbf{R}} v[\sum_{g \in \mathbf{H}} \sum_{h \in \mathbf{H}} \gamma_{r,g,h}(\hat{\tau}_{r,g,h} + \overline{\tau}_{r,h}) \stackrel{<}{\sim} \alpha]. \tag{13}$$

Let us consider indexes

$$v_r \stackrel{\Delta}{=} v[\sum_{g \in \mathbf{H}} \sum_{h \in \mathbf{H}} \gamma_{r,g,h}(\hat{\tau}_{r,g,h} + \overline{\tau}_{r,h}) \stackrel{<}{\sim} \alpha_r], \tag{14}$$

which have the interpretation of certainty that the total execution time of the *r*-th executor satisfies the constraint (11). Solving (9) is equivalent to solving (14) with regards to α_r under the condition

$$\alpha = \max_{r \in \mathbf{R}} \alpha_r , \tag{15}$$

Furthermore, under the assumption

$$\alpha_r = \sum_{g \in \mathbf{H}} \sum_{h \in \mathbf{H}} \alpha_{r,g,h} , \tag{16}$$

expression (14) can be rewritten into

$$v_r \stackrel{\Delta}{=} v[\gamma_{r,1,1}(\hat{\tau}_{r,1,1} + \overline{\tau}_{r,1}) \stackrel{<}{\sim} \alpha_{r,1,1} \wedge \gamma_{r,1,2}(\hat{\tau}_{r,1,2} + \overline{\tau}_{r,2}) \stackrel{<}{\sim} \alpha_{r,1,2} \wedge ...$$
$$... \wedge \gamma_{r,\overline{H},\overline{H}}(\hat{\tau}_{r,\overline{H},\overline{H}} + \overline{\tau}_{r,\overline{H}}) \stackrel{<}{\sim} \alpha_{r,\overline{H},\overline{H}}] =$$
$$= \min_{g \in \overline{\mathbf{H}}, h \in \overline{\mathbf{H}}} v[\gamma_{r,g,h}(\hat{\tau}_{r,g,h} + \overline{\tau}_{r,h}) \stackrel{<}{\sim} \alpha_{r,g,h}]. \tag{17}$$

Considering partial certainty indexes $v_{r,g,h} \stackrel{\Delta}{=} v[\gamma_{r,g,h}(\hat{\tau}_{r,g,h} + \overline{\tau}_{r,h}) \stackrel{<}{\sim} \alpha_{r,g,h}]$, from definition of the Type-C uncertain variable and from the triangular distribution (8) we obtain the following certainty distribution

$$v_{r,g,h} = \begin{cases} 0 & \alpha_{r,g,h} \le \hat{\tau}^*_{r,g,h} - \underline{d}_{r,g,h}, \\ \dfrac{1}{2}[\dfrac{\alpha_{r,g,h} - \overline{\tau}_{r,h}}{\underline{d}_{r,g,h}} + 1 - \dfrac{\hat{\tau}^*_{r,g,h}}{\underline{d}_{r,g,h}}] & \hat{\tau}^*_{r,g,h} - \underline{d}_{r,g,h} < \alpha_{r,g,h} < \hat{\tau}^*_{r,g,h}, \\ 1/2 & \hat{\tau}^*_{r,g,h} = \alpha_{r,g,h}, \\ 1 - \dfrac{1}{2}[-\dfrac{\alpha_{r,g,h} - \overline{\tau}_{r,h}}{\overline{d}_{r,g,h}} + 1 + \dfrac{\hat{\tau}^*_{r,g,h}}{\overline{d}_{r,g,h}}] & \hat{\tau}^*_{r,g,h} < \alpha_{r,g,h} < \hat{\tau}^*_{r,g,h} + \overline{d}_{r,g,h}, \\ 1 & \hat{\tau}^*_{r,g,h} + \overline{d}_{r,g,h} \le \alpha_{r,g,h}. \end{cases} \quad (18)$$

The above holds for $\gamma_{r,g,h} = 1$. For $\gamma_{r,g,h} = 0$ it always holds that $v_{r,g,h} = 1$ which does not influence (17). Furthermore, from (13) and (17) it holds that (12) is equivalent to $\forall r \in R, g \in \overline{H}, h \in \overline{H} \quad v_{r,g,h} \ge \overline{v}$. Additionally, for the nontrivial interval $\hat{\tau}^*_{r,g,h} - \underline{d}_{r,g,h} < \alpha_{r,g,h} < \hat{\tau}^*_{r,g,h} + \overline{d}_{r,g,h}$, function (18) is strictly growing with respect to $\alpha_{r,g,h}$, therefore (12) is equivalent to

$$\forall r \in R, g \in \overline{H}, h \in \overline{H} \quad v_{r,g,h} = \overline{v}, \quad (19)$$

We can consider two nontrivial cases. Substituting (18) into (19) we obtain:

a. $0 \le \overline{v} \le \dfrac{1}{2}$. $\alpha_{r,g,h} = 2\overline{v}\underline{d}_{r,g,h} + \hat{\tau}^*_{r,g,h} - \underline{d}_{r,g,h} + \overline{\tau}_{r,h}$,

b. $\dfrac{1}{2} < \overline{v} \le 1$. $\alpha_{r,g,h} = 2(\overline{v} - 1)\overline{d}_{r,g,h} + \hat{\tau}^*_{r,g,h} + \overline{d}_{r,g,h} + \overline{\tau}_{r,h}$.

Substituting the above into (16) then into (15) and into (9) while including cases where $\gamma_{r,g,h} = 0$ we obtain

$$\hat{\gamma} = \arg\min_{\gamma \in \Gamma} \max_{r \in R} \sum_{g \in \overline{H}} \sum_{h \in \overline{H}} \gamma_{r,g,h}(2\overline{v}\underline{d}_{r,g,h} + \hat{\tau}^*_{r,g,h} - \underline{d}_{r,g,h} + \overline{\tau}_{r,h}) \text{ for the case a,}$$

$$\hat{\gamma} = \arg\min_{\gamma \in \Gamma} \max_{r \in R} \sum_{g \in \overline{H}} \sum_{h \in \overline{H}} \gamma_{r,g,h}[2(\overline{v} - 1)\overline{d}_{r,g,h} + \hat{\tau}^*_{r,g,h} + \overline{d}_{r,g,h} + \overline{\tau}_{r,h}] \text{ for the case b,}$$

Therefore, we have reduced the uncertain problem B into two deterministic versions of the original problem A.

5. CONCLUSIONS AND FUTURE WORK

Formulated and solved was a decision making problem in a multi-robot task allocation system. Provided solution has the form of a lossless determinisation which reduces the uncertain formulation of the problem to a special case of its original, deterministic version.

Future work worth consideration includes comparison of the approach with type-C uncertain variables considered in this work, to earlier approaches using basic type of the uncertain variable. Especially valuable will be the analysis of influence of the quality of expert's knowledge on the solution obtained with both types of variables. Exploration of different types of certainty distributions, aside from triangular ones, is also in the works.

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COMPARISON OF ALGORITHMS
FOR TASK SCHEDULING ON PARALLEL EXECUTORS

This paper concerns Directed Acyclic Graph task scheduling on parallel executors. The problem is solved using own implementations of Tabu Search and genetic algorithms. There is also introduced a new approach to coding solution. Results given by the created algorithms are compared to those generated by greedy LPT algorithm. The analysis of the obtained results of multistage simulation experiments justifies the conclusion that the implemented, proposed algorithms seem to be promising.

1. INTRODUCTION

The problem of scheduling is one of the oldest and very frequent in the real world issue. The problem is connected with efficient allocation of tasks to executors. Effectiveness of scheduling is measured with a specified evaluation function [1, 6], and [12]. Task scheduling is very time-consuming and very demanding of computing resource problem, especially when it is solved by a complete review approach. Even high effective computers are not able to find optimal solution in finite time [1, 11]. Scheduling problem has been classified as a NP-complete problem. It became necessary to develop algorithms that allow find solution which is close to optimum [10].

Good solution can be obtained by using one of the approximate greedy algorithms. Examples of these algorithms are LPT [12] or Best Fit. Common feature of these algorithms is the way in which tasks are assigned to the executors. All of these algorithms tries to keep maximal time as close to the specified time as possible [1, 12]. Such a value can be the averaged time of completing all of the tasks or time that is needed

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to complete all assigned tasks by executors. Main disadvantage of these algorithms is that they can obtain optimal solution only for certain examples of problem. Recently meta-heuristic and genetic algorithms become very popular methods to solve this problem [2, 3], and [9]. This paper focuses on the efficiency of our own implementations of algorithms based on ideas of genetic algorithms and Tabu Search. The considered problem, called Directed Acyclic Graph (DAG) consists in task scheduling on parallel and identical executors Tasks are independent and there are no time restrictions in which tasks have to be completed.

The rest of the paper is composed as follows. In Section 2, the mathematical model of problem is presented. Section 3 contains brief description of the considered algorithms. Section 4 contains a design of experiment. In Section 5, the results of investigations are presented, followed by discussion. Section 6 contains final remarks.

2. PROBLEM STATEMENT

The mathematical model of the considered task scheduling problem is given in three-field notation as $P|precc|C_{\max}$ [11, 12]. System P consists of p parallel and identical executors. It is assumed that processors are connected with each other, but the time needed for communication between them is negligibly small and is therefore omitted. Tired effect and experience gathering effect are not considered [2, 3]. The tasks to be scheduled are given as Directed Acyclic Graph (DAG). Graph is described by tuple $G = (T, E, L)$, where $T = \{t_1, t_2, ..., t_n\}$ is set of tasks, $E = \{e_{ij}|t_i, t_j\ T\}$ is set of edges that represent order limitations between tasks, $L = \{l_1, l_2, ..., l_n\}$ is set of tasks time duration [2, 3]. Task given by ti cannot be executed until all of its predecessors are not completed. All tasks are indivisible. There are no other order limitations despite given set E. All tasks have the same arrival time which is equal to 0. For none of tasks there are given the deadline.

For the evaluation of solutions there is used schedule length criterion that is also called makespan criterion. Makespan specifies the time after which all tasks will be completed. Time after which task will be completed is affected by both task duration and time of completion of all of its predecessors. Set $F = \{f_1, f_2, ..., f_n\}$ contains moments in which execution of each task has been started. The evaluation function [11] taken into consideration is expressed by the equation (1).

$$C_{\max} = \max(f_1 + l_1, f_2 + l_2, ..., f_n + l_n) \tag{1}$$

The problem consists in minimization of the function $C_{\max}$. Solution of the problem is given by schedule $H = (F, P)$, where F is a set of start moments of tasks, and $P = \{p_1, p_2, ..., p_n\}$ is a set of executors to which tasks are assigned. The schedule is con-

sidered to be feasible if all tasks from a given set of tasks are scheduled and all order limitations are satisfied.

3. ALGORITHMS

3.1. SOLUTION CODING

One of the important and also difficult problems in designing heuristic algorithms is the selection of coding method. Coding method has to take into account not only which executor is processing task but also when this processing is starting. In addition coding method has to be aware of order dependences between tasks. For this reason heuristic algorithm cannot be used without modification to solve any different problem. To simplify coding and enable the use of heuristic algorithms to solve similar problems a new way of notation has been created. In the proposed approach, the solution S is given by a tuple $S = (V, A)$, where V is a one-dimensional array of numbers, and A is an algorithm that translates the array V to a human-readable and possible to assess form. The proposed translation algorithm.is presented as below.

Algorithm 1: Translation algorithm	
Step 1	**For** i=1 **to** n
Step 2	Create set *FT* that contains tasks feasible to execute
Step 3	Select form *FT* task *t* with the highest priority
Step 4	Create set *PT* that contains predecessors of task *t*
Step 5	Determine the earliest moment s_t that task *t* can be started; s_t is equal to the latest moment of completion of all tasks from *PT*
Step 6	Select executor *e* that moment of the processing completion p_e is earlier that s_t and difference between s_t and p_e is minimal
Step 7	**If** executor *e* was found **Then**
Step 5	Assign task *t* to executor *e*
Step 6	Set moment of processing completion $p_e = s_t + l_t$
	Else
Step 7	Select executor *e* with the earliest moment of processing completion
Step 8	Assign task *t* to executor *e*
Step 9	Set task *t* execution start moment $s_t = p_e$
	End If
	End For

We assume that an array V consists of n elements that represent the tasks. Value of each element is unique and indicates a priority. Priority indicates the translation algorithm order in which tasks should be scheduled. In each iteration algorithm A selects the feasible tasks with the highest priority and then assigns them to the executor. Example 1 illustrates the translation algorithm.

Example 1

The dual-processor system and a set of DAG (see Figure 1) tasks are described by parameters defined in Table 1. The step by step performance of the algorithm is described below.

Table 1. Parameters of exemplary scheduling problem

Task	t_1	t_2	t_3	t_4
Duration	5	4	2	4
Priority	1	2	4	3

The step by step performance of the algorithm is described below.
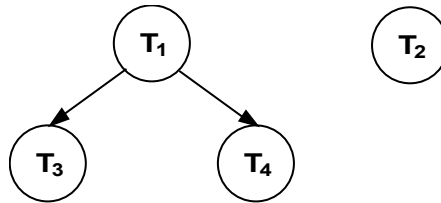
Fig. 1. Simple example of DAG

Step 1. The feasible tasks are t_1 and t_2. Because the task t_1 has higher priority than t_2 it will be scheduled as first. Task t_1 has no predecessors, so the earliest moment of execution is equal to 0. Processing times of the two executors are equal to 0, so the task t_1 will be assigned to p_1.

Step 2. The feasible tasks are t_2, t_3 and t_4. Task with the highest priority is the task t_2. The earliest moment of execution is 0. Processing time of p_1 is 0, so the task t_2 will be assigned to p_1.

Step 3. There are task t_3 and task t_4 left. Task t_4 should be scheduled as first because of higher priority. The earliest task start time is equal to the moment of completion all of his predecessors which is 5. The task t_1 will be assigned to p_1 because:

- Processing time e_1 is smaller than start time of t_1,
- The difference between e_1 and start time of t_1 is smaller than difference between e_2 and start time of t_{1P}.

Step 4. The last task is t_3. The earliest task start time is equal to the moment of completion all of his predecessors which is 5. Task will be assigned to p_2 because this is only executor which processing time is smaller than start time of t_3. Because the task t_3 cannot begin until all predecessors are not completed the processor p_2 will have to wait idly for 1.
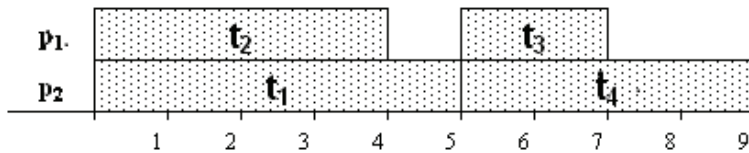
The resulting schedule is presented in Figure 2.

Fig. 2. The final schedule

3.2. SCHEDULING TABU SEARCH (STS)

Tabu Search method is classified to the meta-heuristics local search class. The basis of the algorithm is searching for a local optimal solution. Search area is created by all neighbors of the current solution, which is the result of previous iteration, or has been imposed from the start of the algorithm [4, 7], and [8]. In order to escape from local optima algorithm use short term memory called tabu list.

In the paper, the created algorithm based on Tabu Search is considered. The name of this algorithm is STS (Scheduling Tabu Search) and our implementation specifies the idea of Tabu Search as follows:

- Solution is represented by notation presented in 3.1.
- Basic solution is generated random.
- Neighbors are generated by swap method.
- All neighbors are examined in each step of iteration.
- Short term memory is implemented as tabu list.
- Tabu list size is given as a parameter.
- To reduce resource requirements tabu list stores moves instead of solutions.
- Long term memory is implemented as frequent list.
- After 50 iterations without improvement the least used move is performed on current global solution.

3.3. SCHEDULED GENETIC ALGORITHM (SGA)

The idea of using evolution to the search for optimal or close to optimal solutions is described in many works, e.g. [5, 7], and [8]. It assumes that a solution is treated as part of a population. An individual is composed of chromosomes. Steps of an algorithm are very similar to the natural process of evolution.

The algorithm called SGA (Scheduled Genetic Algorithm) was created and implemented for the purposes of this paper. The algorithm has the following features:

- Solution is represented by notation presented in 3.1.
- Parameters of the algorithm are size of the population, mutation probability; size of the ranking can be set before running the algorithm and number of elite solutions that are added to new population.

- Basic population is generated by random algorithm.
- A modified roulette-selection method is applied. Ranking of solutions is created. Solution on *i*-th position has $n - i + 1$ points, where n is number of solutions in ranking. Probability that solution will be selected is proportional to the number of points.
- The elite solution mechanism is used.
- Solution is given as a permutation, hence, Partially Mapped Crossover method is used for crossover operator and swap method is used for mutation operator.

4. DESIGN OF EXPERIMENT

The goal of the research conducted in this paper is to confirm or rebut the thesis that if the tasks have similar duration, the solutions generated by heuristic algorithms are not better than the solutions obtained by the greedy algorithm LPT. The thesis originates from properties of greedy algorithms that make the best local decision every step. In case of LPT algorithm greedy strategy allows to obtain optimal solutions if all tasks have the same duration and set *E* is empty. An additional objective is to compare the efficiency of heuristic algorithms. For this purpose the same problem instance will be solved by SGA and STS algorithms for which stop criterion is given the same time horizon.

Before taking the investigations it is necessary to adjust the parameters of heuristic algorithms for the considered problem. For this purpose for three randomly generated instances of the problem, the effect of changing parameter values on the derived results was investigated. On this basis, parameters, for which algorithms achieved the best results, have been selected.

The main part of the research was divided into two parts:
- Experiment 1: Problem without tasks order limitations.
- Experiment 2: Problem with tasks related to each other with order relation.

Two multiprocessor systems have been considered. The first system consisted of 5 processors, and the second one consists of 10 processors. In Experiment 1, the number of 9 problem instances was investigated. Three combinations of tasks sets of size 20, 40 or 60 tasks with duration generated at random were investigated. Moreover, three cases of randomness were taken into consideration:

(i)   Uniform distribution from the range 1 to 10,
(ii) The Gaussian distribution N(5, 1),
(iii) The Gaussian distribution N(5, 2).

In Experiment 2, similar instances were tested. The only difference was that order limitations were considered in the second experiment. In both experiments the density of relations between tasks was equal to 20%.

In order to compare effectiveness of algorithms – for any designed instance, task scheduling was being solved by three: algorithms LPT, algorithm SGA, and algorithm STS. For any instance three time horizons were established: 2 min, 10 min, and 30 min.

5. INVESTIGATION

Preliminary research has shown that for this research the best results were obtained by STS when tabu list size was equal to 50. For SGA, the best results were obtained when population contained 270 individuals, 20% of population took a part in selection, 25% of population was build from elite individuals and mutation probability was equal to 3%.

Experiment 1. The results obtained in Experiment 1 are presented in Table 2.

Table 2. Experiment 1 – results

Problem	LPT	SGA (2 min)	SGA (10 min)	SGA (30 min)	STS (2 min)	STS (10 min)	STS (30 min)
5×20×Gauss(5;1)	20	20	20	20	21	20	20
5×20×Gauss(5;2)	21	20	20	20	22	20	20
5×20×Random(1;10)	26	26	26	26	26	26	26
5×40×Gauss(5;1)	40	40	40	40	40	40	40
5×40×Gauss(5;2)	41	38	38	38	39	38	38
5×40×Random(1;10)	44	44	44	44	44	44	44
5×60×Gauss(5;1)	60	60	60	60	61	60	60
5×60×Gauss(5;2)	63	63	63	63	63	63	63
5×60×Random(1;10)	67	67	67	67	67	67	67
10×20×Gauss(5;1)	11	11	11	11	11	11	11
10×20×Gauss(5;2)	11	11	10	11	10	12	11
10×20×Random(1;10)	14	14	14	14	14	14	14
10×40×Gauss(5;1)	20	20	20	20	21	21	20
10×40×Gauss(5;2)	22	19	20	20	21	19	20
10×40×Random(1;10)	22	22	23	22	22	22	23
10×60×Gauss(5;1)	30	31	31	31	32	32	31
10×60×Gauss(5;2)	32	32	32	32	32	32	32
10×60×Random(1;10)	34	34	34	34	34	35	35

The obtained results show high efficiency of heuristic algorithms. It may be observed, that results obtained after 2 minutes were comparable or even as good as the results obtained after 30 minutes. This property is observed for both the STS algorithm and SGA. It is worth to mention that the translation algorithm is responsible for obtaining the best result based on the values in table V.

The results in Table 3 seem to confirm the thesis. Heuristic algorithms found solution better than LPT only for 4 instances. For other instances, SGA and STS gave results equal to or worse than those obtained by the LPT.

Experiment 2. The results obtained in Experiment 2 are presented in Table 3. These results, may confirm the effectiveness of heuristic algorithms. Again, the results obtained after 2 min are comparable with the results received after 30 minutes.

Table 3. Experiment 2 – results

Problem	LPT	SGA (2 min)	SGA (10 min)	SGA (30 min)	STS (2 min)	STS (10 min)	STS (30 min)
5×20×Gauss(5;1)	35	33	33	33	33	33	33
5×20×Gauss(5;2)	32	30	30	30	30	30	30
5×20×Random(1;10)	41	41	41	41	41	41	41
5×40×Gauss(5;1)	65	59	59	59	59	59	59
5×40×Gauss(5;2)	60	58	58	58	58	58	58
5×40×Random(1;10)	85	81	81	81	81	81	81
5×60×Gauss(5;1)	93	94	92	92	92	92	92
5×60×Gauss(5;2)	112	111	111	111	112	111	111
5×60×Random(1;10)	114	108	108	108	108	108	108
10×20×Gauss(5;1)	32	32	32	32	32	32	32
10×20×Gauss(5;2)	31	31	31	31	31	31	31
10×20×Random(1;10)	51	49	49	49	49	49	49
10×40×Gauss(5;1)	81	81	81	81	81	81	81
10×40×Gauss(5;2)	56	56	56	56	56	56	56
10×40×Random(1;10)	70	68	68	68	68	68	68
10×60×Gauss(5;1)	118	116	116	116	116	116	116
10×60×Gauss(5;2)	108	108	108	108	108	108	108
10×60×Random(1;10)	114	114	113	113	114	114	113

The results, as in Experiment 1, confirm the effectiveness of heuristic algorithms. Again, the results obtained after 2 min are comparable with the results received after 30 minutes.

For problem with order dependences between tasks, the greedy algorithm LPT has not achieved such good results. For more than half of instances heuristic algorithms

have reached a better solution than the LPT. In other cases, the results were just as good. It is worth to notice, that in Experiment 2 there was no situation in which LPT algorithm have obtained better solution than STS and SGA.

6. CONCLUSION AND FINAL REMARKS

The results of Experiment 1 have confirmed the hypothesis formulated in Section 3. If the number of tasks with similar or identical execution times is much larger than number of other tasks, the SGA and STS algorithm give results close to the result of the initial algorithms. Moreover, a similar relationship also appeared for problems where tasks duration was generated randomly. Therefore, it can be concluded that for problem without order limitations greedy algorithms achieve satisfactory results. Profits from the usage of genetic algorithms and meta-heuristics for this kind of problems are then negligible and if the unit of time is not day or hour, the use of such time-consuming algorithms are pointless.

The results of Experiment 2 allow reaching different conclusion. If tasks are order-dependent then greedy algorithm LPT is much less efficient than the heuristic algorithms. STS and SGA algorithms for more than half of the instances set a better solution than the greedy algorithms and for the remaining instances the results were the same. This observation allows concluding that if problem is given by the graph with non-empty set of edges then better results can be achieved by the heuristic algorithms.

Comparing the results obtained using SGA and STS, which were performing the same time period it, can be concluded that both algorithms are comparably effective. It is worth to notice that even for short execution time, the results were very good and in most cases the same as results for greater execution time. Main reason on high effectiveness of algorithms was usage of proposed approach. The created translation algorithm seems to be a source of very efficient performance of algorithms which use it.

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SCHOOL BUS ROUTE PROBLEM:
PROBLEM FORMULATION AND NEW SOLVING APPROACH

People has always sought to cut costs, everyone is looking for savings – this applies to people as individuals and to companies as well. Rapid development of new technologies in industry often leads to significant decrease in costs. Increasingly, however, the money is sought through the use of optimization tools to improve technologies in use. Such tools have long been used in transportation, and, concerning the subject of transport, Travelling Salesman Problem (TSP). This papers concerns problem of routing school bus, that is treated as modification of TSP. Authors presents solution based on new approach - division of the problem into two stages. For first phase new algorithms have been proposed, for second heuristic algorithm were used. Series of tests aimed at determination of the best parameters for algorithms were performed. Properties of algorithms have been studied for evaluation and selection of the best method for solving the given problem.

1. INTRODUCTION

Travelling Salesman Problem (TSP) [1]–[5], formulated in 1800s by Irish mathematician William Rowan Hamilton, is one of most intensively studied optimization problem. The main idea of TSP is to find the shortest path between set of cities. This problem belongs to the class of NP-hard (non-deterministic polynomial-time hard) problems and it is solved using heuristic algorithms. Many modifications of TSP have been created. The most popular is Vehicle Routing Problem (VRP) introduced by G. B. Dantzig and J. H. Ramser in [6]. There are many variants of VBR, and over the years many solution approaches have been studied, like in [7]–[9]. All those problems are very complex and to solve them complex (thus expensive) tools needs to be used. That's why only enterprises can afford to purchase

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products that enables optimization in that field. Smaller companies are forced to create route by trial and error or by using very simple tools, resulting in small savings. In this paper new simple algorithms, that can be easily adjusted for transportation problems of small companies, have been developed and tested. Motivation to work on this topic was formulated in [10], which concerns planning route for school bus (in this paper this problem was called School Bus Route problem – SBR). It might seem that this is not a good field for application of optimization methods, because of small amounts of money spent on transportation for one school. But important is to remember, that there is about 4500 schools in Lower Silesia only. So it is a potential source of huge savings for the State.

2. TRANSPORTATION ISSUES

2.1. PROBLEM DESCRIPTION

Problem, the solution of which is subject of this paper, concerns the school bus. The basis of the problem is very similar to TSP – given is set of bus stops (vertices) and distances between them (edges with weights). What differs SBR from TSP is introduction of two modifications. The first is to add weights to vertices – it is assumed that at each bus stop a certain number of children is waiting for the school bus. Second is that some of bus stops, the ones that are making loses, may be disregarded in a bus route. Objective also changes – in TSP goal is to find the shortest route, in SBR objective is to find the most profitable route (or the one, that produces the smallest loss). These small modifications significantly widens already huge solution space.

2.2. NEW SOLUTION APPROACH

Because of its similarity, method of solution of SBR refers to TSP. To solve TSP most commonly used are heuristic algorithms, such as Simulated Annealing [4], [11], [12] or Tabu Search [4], [13], [14] and it gives good results. Those algorithms searches the solution space checking out surrounding solutions. During its operation, structure of neighbourhood is fixed. Thus it cannot be used to solve SBR. Solutions proposed in literature suggest use of heuristic methods that can modify the structure of neighbourhood during its operation. In [10] authors have attempted to create new heuristic algorithm. It was complex method, which did not give expected results. In this paper, new simpler approach is presented. Division of the problem into two stages has been proposed. First phase is to determine which bus stops should be part of the route and which are redundant, which simultaneously determines the number of bus stops in the route (figure 2). The second one comes

down to finding the shortest route for a designated set of bus stops (figure 3). Whole solution should take into account such factor as route length, fuel price, number of served students and ticket price. Also it needs to be remembered that problem considers school bus, so there should be restriction on the number of skipped bus stops.
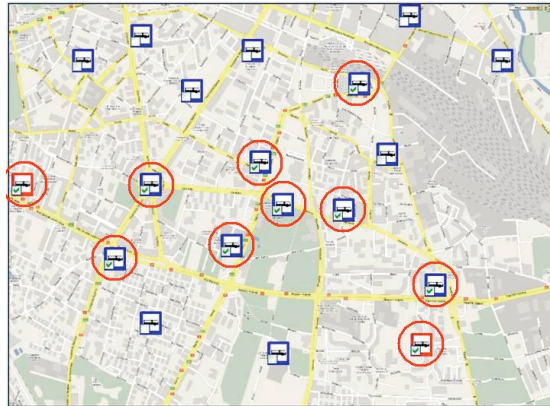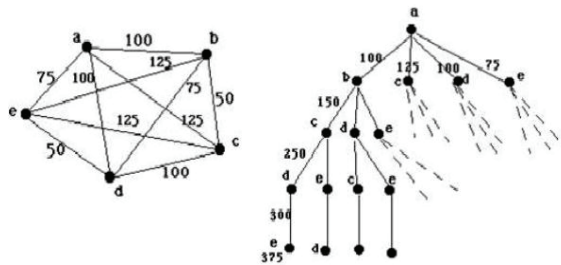

Fig. 1. First stage of solution

Fig. 2. Stage two of solution

2.3. MATHEMATICAL MODEL

To create reasonable solution, it is worth to create mathematical model first. Reference to graph theory [15] seems necessary. Given is undirected weighted graph, where vertices represents bus stops (2.1) and edges represents links between them (2.2). In the graph weights have both edges and vertices. Exemplary graph is shown in the figure 3. Graph consists of vertices (yellow dots) with weight (number of students) beside and edges – there is also a weight (distance between bus stops) beside.
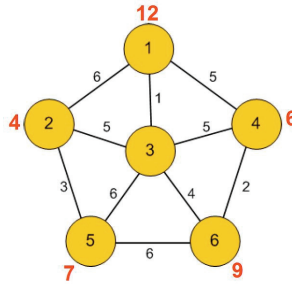
Fig. 3. Sample undirected weighted graph

The above statements, assuming that the bus stops are located in two-dimensional space, and its location is described by Cartesian coordinates, can expressed mathematically as follows (description of used symbols is contained in table 1).

Table 1. Description of used symbols

Symbol	Meaning
BS	Set of vertices (bus stops)
n	Number of vertices in graph (BS)
(x_i, y_i)	Vertices coordinates
$s_{n,h}$	Weight of vertex (number of students at the bus stop at specific hour)
h	Time of transit
$L(i, j)$	Matrix of edges (links between BS)
$l_{i,j}$	Weight of edge (distance between BS)
$S(n, h)$	Bus stops occupation statistics
GI	Gain from route r
r	Specific solution (route)
r_i	i-th bus stop in solution r
P_t	Ticket price
Z	Size of solution r
$C(1\ m)$	Cost of passing 1 meter
MPSS	Minimum percentage of served students

$$BS(n) = \begin{bmatrix} bs_1 \\ \vdots \\ bs_n \end{bmatrix} = \begin{bmatrix} x_1 & y_1 & s_{1,h} \\ \vdots & \ddots & \vdots \\ x_n & y_n & s_{n,h} \end{bmatrix} \tag{2.1}$$

$$L(i, j) = \begin{bmatrix} l_{1,1} & \cdots & l_{1,j} \\ \vdots & \ddots & \vdots \\ l_{i,1} & \cdots & l_{i,j} \end{bmatrix} \quad S(n, h) = \begin{bmatrix} s_{1,1} & \cdots & l_{1,h} \\ \vdots & \ddots & \vdots \\ s_{n,1} & \cdots & l_{n,h} \end{bmatrix} \tag{2.2}$$

$$G(r) = P_T \times \sum_{i=1}^{Z} s_{r_{i,h}} - C(1\,m) \times \sum_{i=1}^{Z-1} L(r_i, r_{i+1}) \tag{2.3}$$

It should be remembered, that the school bus is considered and some constraints need to be introduced – unacceptable is situation, when most of bus stops are omitted. New parameter, that provides proper constraint, is MPSS – minimum percentage of served students, and its specifies minimum percentage of children that bus must transport to school. Therefore, each route should satisfy the following inequality:

$$\frac{100 \times \sum_{i=1}^{Z} s_{r_{i,h}}}{\sum_{i=1}^{n} s_{i,h}} \geq MPSS \,[\%] \tag{2.4}$$

2.4. FORMULATION OF OPTIMIZATION MODEL

Putting all previously defined issues together, along with developed equations, general algebraic model of problem was obtained (figure 4).

Given	BS, set of bus stops L, links between bus stops S, number children at bus stops
and	(x_i, y_i), coordinates i-th of bus stop n, number of all bus stops (size of the instance of the problem)
Parameters	P_T, price of a ticket C(1m), cost of passing one meter MPSS, minimum percentage of served students
Define	r, profitable bus stops and sequence of its passage Z, numbers of bus stops to visit (size of solution)
Maximize	$G(r) = P_T \times \sum_{i=1}^{z} s_{r_i,h} - C(1m) \times \sum_{i=1}^{Z-1} L(r_i, r_{i+1})$
Subject to	$\dfrac{100 \times \sum_{i=1}^{Z} s_{r_i,h}}{\sum_{i=1}^{n} s_{i,h}} \geq MPSS\,[\%]$

Fig. 4. Optimization model for SBR problem

3. USED METHODS

Approach used to solve SBR problem is to divide problem into two stages. Algorithms used in each stage, its input and output data are described below:

3.1. STAGE ONE – BUS STOPS CHOOSING ALGORITHMS

Selecting right set of BS is first stage of finding optimal solution and results received at this point will be considered as input data for TSP algorithms. For this purpose three bus stops choosing algorithms were invented: Most Occupied (MO), Cut the Worst (CTW) and High Gain Neighbour (HGN). All of them selects most profitable BS with limiting condition, which is minimum percentage of served students (MPSS). Both parameters was defined above and they guarantee that too many BS (therefore number of students) cannot be skipped – assurance of enforced quality of service. Algorithms uses all data on profits from ticket and bus transit costs (e.g. number of students at the bus stops, distances between stops, fuel cost). The result is a set of bus stops, which becomes an input data for heuristic algorithms (second phase). In first stage three algorithms are used:

a) Most Occupied

First of algorithms – Most Occupied – is the simplest one. It is considered as a control algorithm. Comparison of results for control algorithm, self-invented algorithms and results without using of Bus Stops Choosing algorithms will allow to decide if use of new algorithms is reasonable. MO starts with two points – first BS and school. Then it seeks for the BS with the biggest number of students waiting there and it ads most occupied BS to set of points. Algorithm ends its working when percentage of served students is bigger than MPSS. MO refers only to number of students, it does not refer to gain function, therefore it is expected to give poor results.

b) Cut the worst

First important Bus Stops Choosing algorithm is Cut the Worst. In contradiction to rest of algorithms, it references to length of whole route and its working is based on cutting bus stops from route (MO and HGN starts with two points and they adding another to the route). First step of CTW is to find shortest route containing all of the BS. For this purpose CTW uses one of heuristic algorithms. After finding the best route, algorithm is sequentially cutting of the least occupied BS. After every cut of action, algorithm is checking obtain gain (or cost) for route with and without appointed BS. If excluding BS is profitable, change is saved and algorithm inspects next BS. Otherwise change is rejected and algorithm continue its working. Algorithm terminates its action when cutting of the BS makes percentage of served students smaller

than MPSS (cut-off BS is attached to the route, so required quality of serviced of school bus was maintained) or after analyzing all of the stops.

c) High Gain Nieghbour

Last of algorithms is High Gain Neighbour. It also uses gain function. At the beginning route consist of two points (first BS and school). In first step starting point is analyzed. Algorithm selects three closes to starting point bus stops (called further the neighbourhood) and choosing from them the one, that is most profitable (provides the most gain or smallest cost). The chosen BS is becoming analyzed point. After every step algorithm checks whether analyzed point is part of neighbourhood of school (the last point). If it is, algorithm terminates its action. If after all above steps percentage of served students is smaller than MPSS, most occupied of remained bus stops are included to route until required quality of service is reached.

All of described algorithms designates set of bus stops along with certain order. So results of its working can be treated as input data to TSP algorithms. Interesting fact is that even if MPSS is 100%, results of algorithms will be different and it may have affect the performance of TSP algorithms.

3.2. STAGE TWO – TRAVELLING SALESMAN PROBLEM

After selecting the proper set of BS, the shortest route between them should be found. Basically it is Travelling Salesman Problem. To solve this problem heuristic algorithms are used. Three algorithms have been chosen – Simulated Annealing, Tabu Search and Random Search. As a way of generating neighbours, swap function was selected. The evaluating function used in second stage to determine which route is better is based on the distances between bus stops and is the sum for whole route.

4. EXPERIMENTATION ENVIRONMENT

To test usefulness of described approach special application has been created. First version was developed in C# and second in C++, both in Visual Studio 2008. Main window of the application is shown in Figure 2. How the application works is shown in the figure 3. Given is set of bus stops along with pairwise distances between them and number of students at each bus stop. Each parameter seen in the figure 5 can be set individually. Additionally parameter hour can be seen in the figure 6 – number of students at bus stops may differ depending on the hour, therefore in application three times of bus transit are available and route is determined separately for each one. As a result, route and gain is designated. Also information about exact percentage of served students is available.
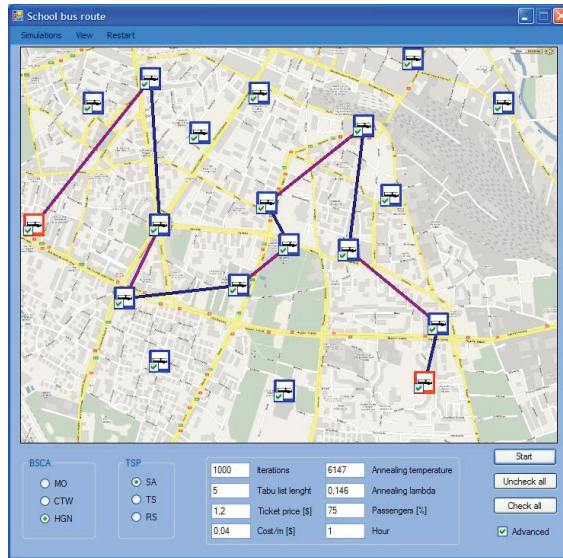
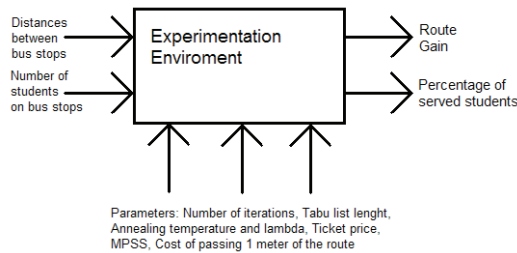Fig. 5. Main window of application

Fig. 6. Diagram of application functioning

5. RESEARCH

Before the main part of research, parameters for heuristic algorithms were determined. For Simulated Annealing examined values of parameters ranged: lambda parameter from 0.05 to 1 with step 0.05; temperature from 2500 to 100000 with step 2500. For Tabu Search values of parameters ranged: tabu list length from 0 to 10 (19 bus stops), 13 (27 bus stops), 17 (34 bus stops) with step 1; neighbourhood size from 2 to 16 with step 2. Number of iterations for both algorithms ranged from 500 to 3000

with step 500, and from 5000 to 15000 with step 2500. As the best, following values were selected: temperature = 10000, lambda = 0.1, tabu list length = 7, neighbour size = 10. Initial research were performed on two instances (Ins19 and Ins35) created randomly by author in a way that reflects real cases (19 and 25 bus stops, respectively with 62 and 114 children distributed randomly).

Key point of research was to examine properties of algorithms designed for the selection of bus stops and their combination with heuristic algorithms. Initial tests have been performed on Ins19, but with total number of children equal to 87. Its results are shown in figure 7. As expected MO and Random Search are the worst.
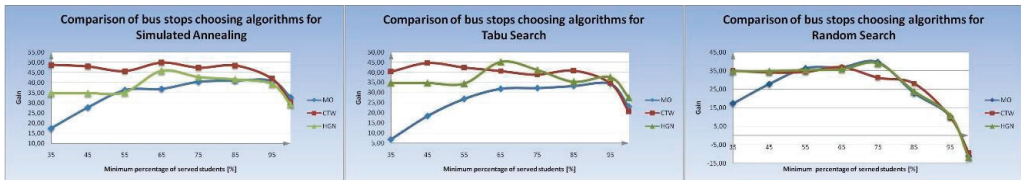
Fig. 7. Results of initial test

Further research concerned CTW and HGN, with use of all heuristic algorithms. Results are shown in figures 8 and 9.
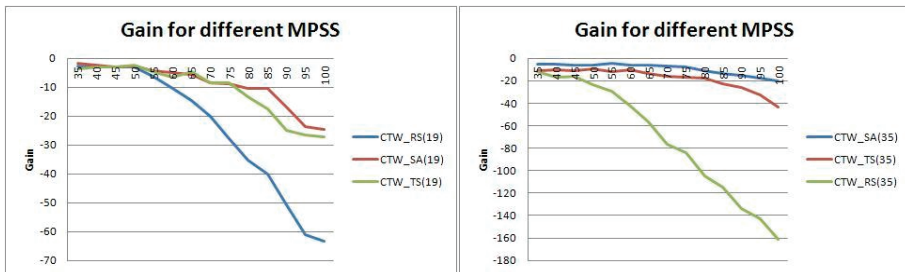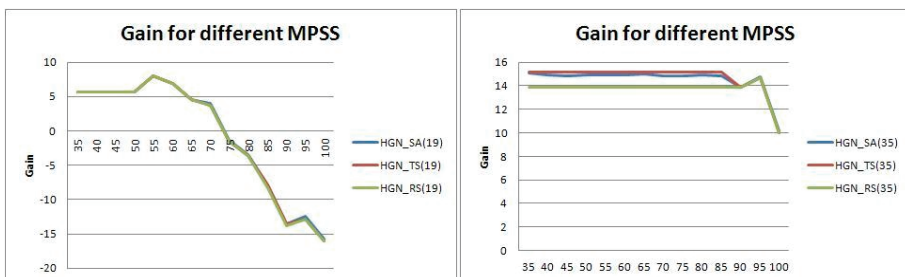

Fig. 8. Gain from Isn19 and Isn35 for CTW

Fig. 9. Gain from Isn19 and Isn35 for CTW

Some unexpected fact can be easily seen. For smaller instance, the results are identical for all heuristic algorithms. Path determined by HGN is so good, that heuristics are not able to improve it. For bigger instance improvement is relatively all. Additionally, in second case HGN determines probably the same root for almost every value of MPSS, but in both cases it gives better results than the CTW. At the end, combinations of algorithms were tested on random instances of the problem. Sizes of instances were chosen randomly from the range of 20 to 40.
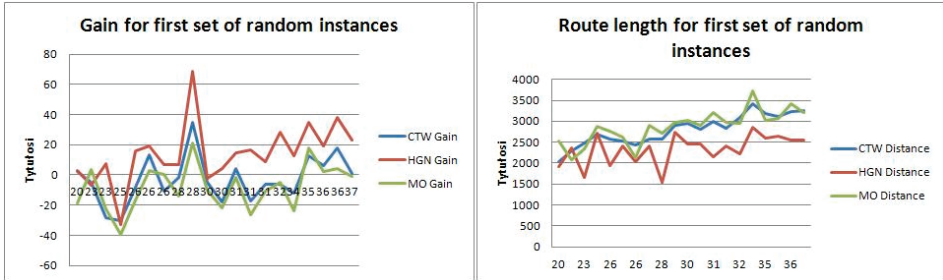

Fig. 10. Gain and route length depending on the size of random instances

6. CONCLUSIONS

Analysis of the results leads to several conclusions. First of all, the difference in gain between results for TSP (when MPSS = 100) and SBR implies, that use of solutions for *TSP* in SBR is irrational – there are significant savings from the use of new solution approach. Algorithms works fast, are not externally difficult to implement, therefore they could be a good solution for small and medium business. Looking at the results for random instances, expected regularity in route length can be seen (more bus stops, longer route). But looking at gain, no dependency of gain on size of instance can be seen. What can be deduced is that greater impact on gain than number of bus stops have their distribution and the distribution of students at the bus stops.

The best of bus stops choosing turn out to be HGN, both for case based on real life conditions and random. Sometimes route determined by HGN only is very good (heuristic algorithms cannot improve it or improves marginally). Thus can be concluded, that the best is to built new solution from the ground, rather than trying to improve solution obtained by the method for a similar problem.

For further consideration, it would be worth to propose a solution for children from skipped bus stops, e.g., suggest such ticket price that omitting the bus stop would be unprofitable or just suggest the nearest bus stop. A premium for transporting surplus number of children could be introduced. Finally introducing time limitations and bus capacity restrictions could generalize problem presented in this paper.

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