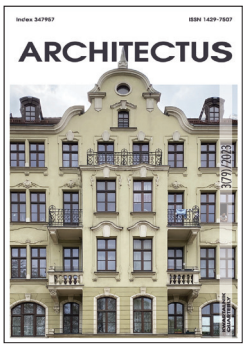

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Sky view factor method as an analytical tool in the analysis of compactness of an urban interior

Abstract

This article is aimed to present the results of the study on urban canyon compactness. The topic seems to be vital as physiognomic research on urban canyons has so far relied on visual assessment made by an observer intuitively. These types of studies comply with relevant standards which define elements of a visually sensed space and prescribe methods of recording such a sensual experience. Therefore, such studies are classified within descriptive research, and are sometimes charged with such drawbacks as the subjectivity and lack of comparativeness. To attain higher objectivity, the number of respondents is typically increased and results are calculated and presented in the statistical form. This article presents an analytical methods based on a normative approach, the application of which will render measurable and comparable results. The purpose of the studies consisted in testing one of the normative methods, i.e., the sky view factor (SVF) method, in the objective calculation of compactness of an urban interior.

Key words: sky view factor, analytical tool, normative approach, urban compactness

Introduction

Urban spatial transformation process can be controlled and shaped by legible and harmonious compositional arrangements. This, however, requires a definition of clear-cut compositional boundaries of an entire spatial arrangement, which further form composite urban structures. Depending on the urban tissue type – the built environment, greenery, infrastructure or a road – the outline and purpose of the boundary will vary and will have a different spatial representation. In terms of good composition, legibility of a spatial arrangement is very important because it can successfully pose a barrier to penetration of other, similar structures inside its interior. Clarity and compactness of delimited elements facilitates legibility of space. Christopher Alexander (2008) observed that boundaries of urban canyons needed to be visually defined. Aleksander Böhm, in his works (1981, 2004, 2006, 2007, 2012), highlighted the importance of ordered entities that protected urban landscape against spatial disharmony of uncontrolled and unlimited sprawl and ensured an aesthetic experience of a harmonious image of space[1]. According to Kevin Lynch (2011), legibility of rural and urban landscape derived from easy identification of its constituents, coherently organised into a pattern that is unique for the place. The feeling of inclusion inside an urban canyon depends on the degree of delimitation of space by urban walls and on the ratio of view obstructions to openings. The author hereof calls it "compactness"[2]. Andrzej Niezabitowski (1979, 43) called basic features of each spatial object "constitutive features" (i.e., features that are gradable). According to him such features included:

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[1] Referring to perception of space, these researchers defined constituent parts of a delimited landscape unit, which according to them included: walls, urban floors and ceilings and elements of fit-out, i.e., street furniture.

[2] The term compactness in urban planning typically does not refer to individual urban canyons but to entire urban structures such as particular complexes of buildings or permanent settlement units (villages and towns).

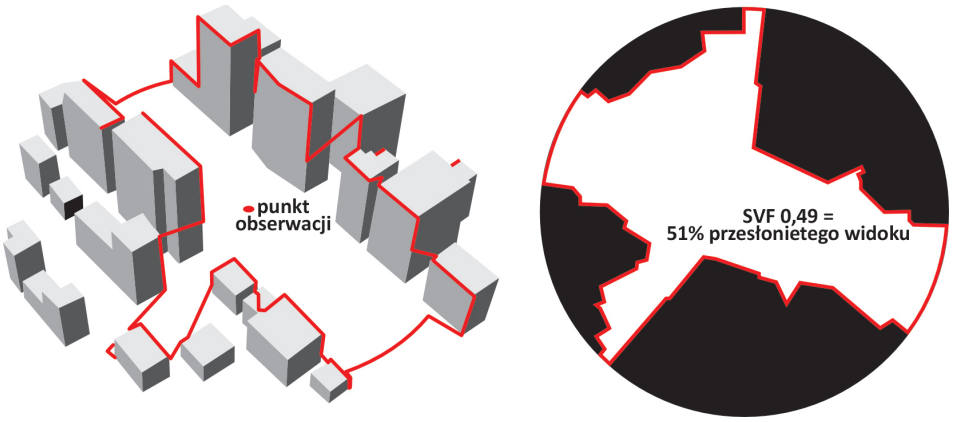

Fig. 1. Space representation principle via the sky view factor method (elaborated by B. Kaźmierczak on the basis of Park et al. 2017, 7)

Il. 1. Zasada odwzorowania przestrzeni metodą sky view factor (oprac. B. Kaźmierczak na podstawie Park et al. 2017, 7)

– complexity,
– differentiation,
– regularity and coordination,
– compactness or in other words cohesion.

Marshall McLuhan (1964) noted that perception was of dynamic nature and vision created a moving image of the surroundings, underlying the feeling of continuity and coordination. Similarly, John Ormsbee Simonds (1961) stressed that the observer felt discomfort if space did not feel inclusive[3]. Simonds also found out that a well-defined space evoked many positive feelings (curiosity, concentration, relaxation, etc.). He was of the opinion that images could be controlled and sequenced to ensure their best visual presentation and sensual perception of the surrounding landscape. Panoramic image series and sequences which formed systems of urban canyons could render the highest aesthetic and compositional values, and thus, were best suited for observation of a sensual experience that they underlay (Szolginia 1981). Christian Norberg-Schulz (2000) analysed urban space in view of three categories of constituents: streets, squares and districts characterised with a different purpose and importance of spatial, compositional and functional arrangements. According to him, streets and squares represented basic components crystallising the entire urban plan and created a system of interrelated public spaces. These findings initiated research on transport routes and perception of moving observers, they further underlay spatial separation of pedestrian zones and vehicle lanes (Appleyard, Jacobs 1987).

Theoretical bases

Urban analyses most often focus on such aspects as spatial and functional resources, terrain shape and architectural forms, including issues of physical structure (Bradecki 2021, 56) and visual appearance; landscape is aesthetically assessed through physiognomy as visual landscape (Wycichowska 2008). There are two different approaches adopted in the study of urban form, namely normative and descriptive analyses (van Nes, Yamu 2021, 4). Descriptive approach most often consists in subjective analyses of aesthetic quality of an arrangement of landscape and urban canyons. Survey is here a basic assessment tool, provided that an adequate representative group of respondents has agreed to participate in the study. Subjectiveness of their opinions shall be linked to a unique mental and emotional experience of physical space sensed by an individual. Though the assessments and ratings of individuals are subjective, the researchers have observed that – within the entire sample of respondents – there is a group of observers reacting similarly to selected images. (Mordwa 2009). Normative analyses are based on measurable and comparable parameters that define perception in the context of an adopted model. Development of new information technologies has brought about a number of ways of visual representation of landscape, such as photo collage, computer models, photorealistic 2D and 3D visualizations and virtual reality environment. They represent now basic tools of 3D presentation of the existing space. Among those tools we can name quantitative mapping methods that use algorithms and indices to get data on spatial and visual features of landscape, e.g. analyses that use GIS (Geographical Information System), *Space Syntax* or ISOVIST (Weitkamp 2010; Kocki, Kwiatkowski 2016; Wang, Huang 2019). These methods render quite objective results but they are time consuming and access to data or identification of proper delimitaton criteria may prove difficult.

Geometric bases of the Sky View Factor SVF method (Fig. 1) were defined by Douw G. Steyn in his report of 1980. In the report he saw an opportunity for the method to be applied in the calculation of horizon visibility or in visibility analyses of urban canyons (Steyn 1980; Johnson, Watson 1984). Léa C.L. Souza, Daniel S. Rodrigues i José F.G. and Mendes presented – in 2003 – a method for the application of GIS to generate hemispheric images of urban canyons and to calculate SVF (Souza et al. 2003). Unfortunately, in terms of technology at the time, this

[3] It's worth stressing that research in the field of neuroscience and cognitive science (Zeki 1999) confirmed that our brain rated visual stimuli (Ramachandran, Hirstein 2006) according to the beautiful-ugly dimension (Kawabata, Zeki 2004). Certain patterns of brain activity have been identified that correlate to declared intensity of highly aesthetic stimuli (Ishizu, Zeki 2014). Therefore, it may be stated that perception of beautiful images, regardless of their source of origin, may be defined through neuronal activity (Zeki 2019), thus, without doubt, it can be concluded objectively that human brain reacts to stimuli assessed as beautiful, though subjective perception of beauty may differ between individuals.

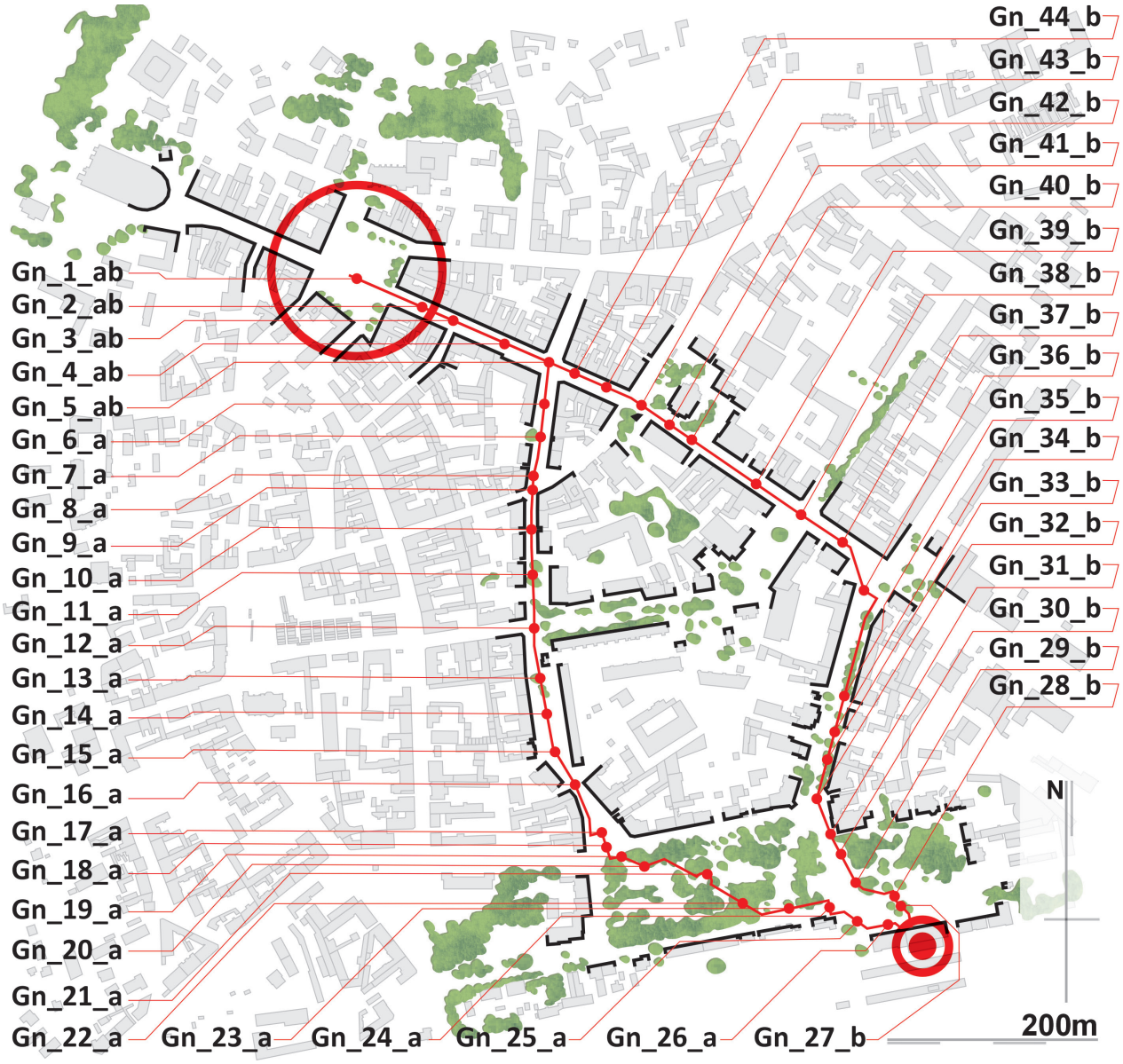

Fig. 2. Delimitation of view series and sampling points characteristic for respective panoramic image sequences in Gniezno (elaborated by B. Kaźmierczak)

Il. 2. Wyznaczenie ciągów oraz punktów charakterystycznych dla poszczególnych sekwencji widokowych dla Gniezna (oprac. B. Kaźmierczak)

method could not have been fully used as greenery was not taken into account in the measurements which largely affected the results. Owing to development of digital technologies, this method is now commonly used in research on urban heat islands (UHIs) (Bärring et al. 1985), and from that data we can now derive insolation degree and heat absorption of urban canyons with account for greenery (White, Langenheim 2014). Bin Cong et al. (2018) describe in detail the origin and theoretical bases of the method, what's more, they use it in comparative studies of selected virtual development models generated based on different data. The SFV method has facilitated the improvement of tools necessary for more accurate and easier assessment of space. It has, furthermore, laid the foundations for a number of innovative applications.

Purpose and method of research

This research paper intends to find out how one of the methods of analysis, i.e., the SVF[4] method based on hemi-

[4] The analysis was originally planned to be made with the ISOVIST method. Digital area models containing terrain shape as well as built environment and land cover (trees and bushes), available in Geoportal (a central node of the Spatial Information Infrastructure with access to spatial data and related services) were planned to be used for that purpose. However, for the selected case study there were no accurate greenery models that could be used in detailed view analyses. A point cloud generated based on a LIDAR laser scan is relatively accurate, but only as regards the upper part of tree crowns. The tree bottom part is practically omitted. Models of greenery that reflect geometric forms of plants offer better options, yet they are too simplified for the analyses in question

Fig. 3. Set of equipment used in the research to measure visibility (photo by B. Kaźmierczak)

Il. 3. Aparatura badawcza użyta do pomiarów widoczności (fot. B. Kaźmierczak)

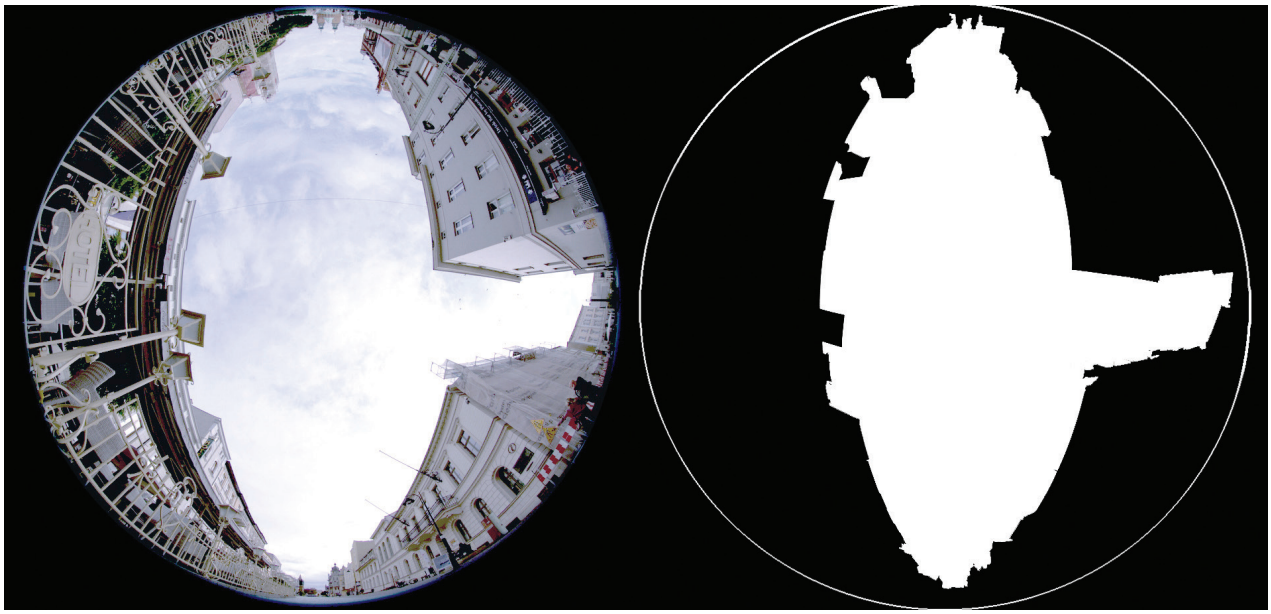

Fig. 4. Result of graphics editing intended for conversion of the image to the black and white representation (elaborated by B. Kaźmierczak)

Il. 4. Efekt obróbki graficznej mającej na celu doprowadzenie obrazu do formy czarno-białej (oprac. B. Kaźmierczak)

spherical images, can be used to assess geometry variation derived from researched urban canyons. The author has defined compactness of an urban canyon as a ratio of view obstructions to openings in selected sampling points in a given panoramic image sequence. Application of the SVF method allows us to define the fields of vision and also the degree of visual obstacles spotted from characteristic viewing (sampling) points within identified panoramic image sequences. The paper explains importance of proper identification of sampling points for the purpose of taking valid measurements. The available lit-

and would not render the expected results. 3D scans made with drone photogrammetry could offer a solution to the problem but would be too expensive and time-consuming.

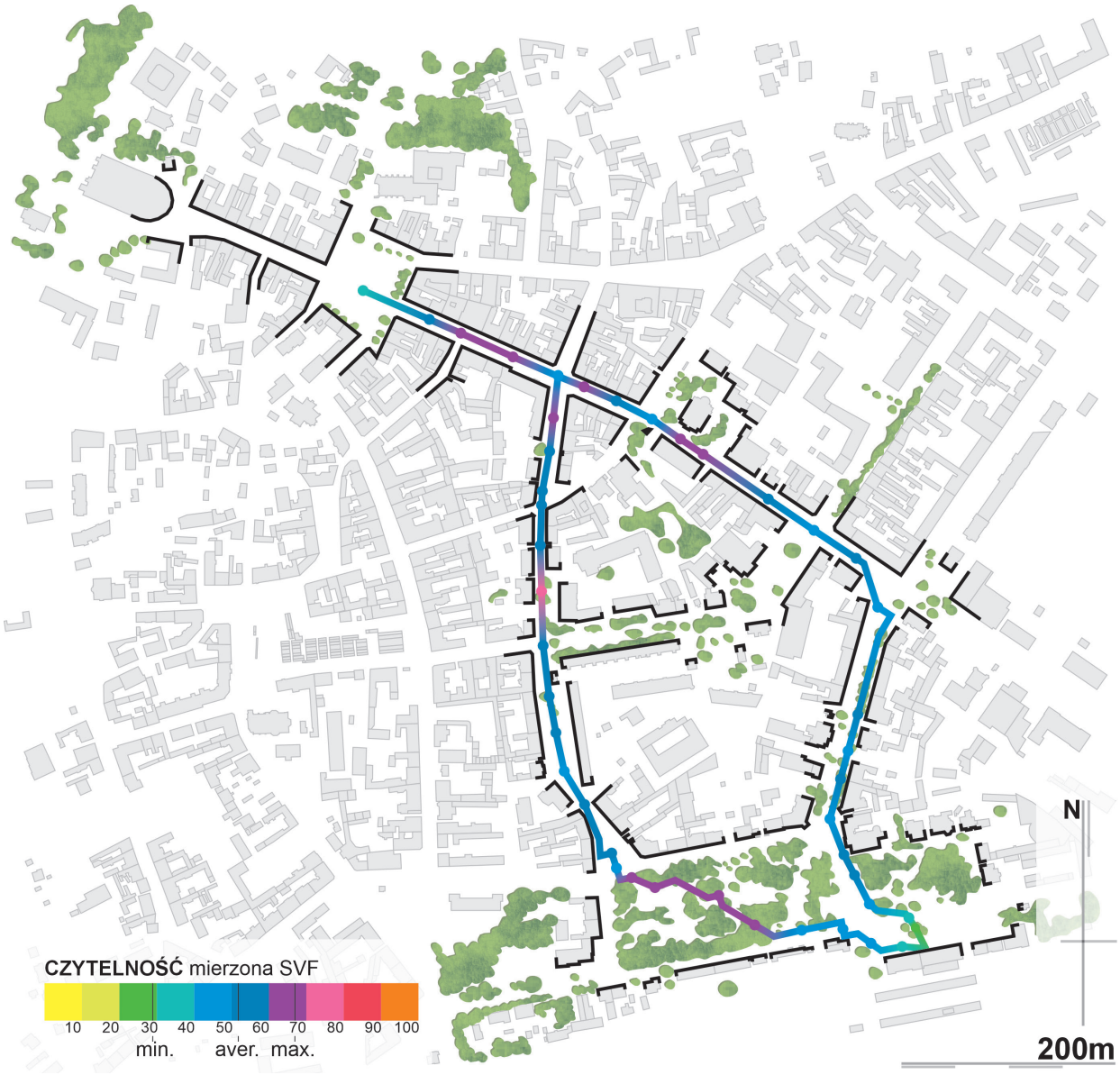

Fig. 5. Graphic representation of sequence distribution in the analysed series in view of assessment of compactness of urban canyons based on Gniezno example (elaborated by B. Kaźmierczak)

Il. 5. Graficzne przedstawienie rozmieszczenia sekwencji badanego ciągu w aspekcie oceny zwartości wnętrz urbanistycznych na przykładzie Gniezna (oprac. B. Kaźmierczak)

erary sources on methods of selecting relevant sampling points most often refer to a method that assumes equal distance between the points. However, the author hereof has come to the conclusion that such an approach is inadequate for panoramic image sequences. It has been, thus, decided that points – to take relevant photographs from – shall be identified in accordance with the following rule: each measurement point is to be located in the geometric centre of a canyon and is to represent one panoramic image sequence (wall-wall, wall-opening, opening-opening)

Two series (marked with *a* and *b* symbols) of urban canyons that link the Old Market Square in Gniezno and the railway station served as our research sample. The two series of urban canyons converged in the first five sampling points. Additionally, there were *n*+1 sampling points in the *b*-marked urban canyon series as compared to the *a*-marked canyon series. A photo was taken in each of the marked sampling point (Fig. 2) with the dedicated set of equipment. The set of equipment used for the studies contained Canon EOS 6D camera with Canon EF 8-15mm f/4L Fisheye USM Lens fixed on INDURO 75MM HI-HAT (LFB75) tripod set with Triopo NB ball-head (Fig. 3).

The photos taken were processed to obtain black and white images (Fig. 4). A relevant raster graphics editor was used for the purpose, the edited images were corrected up to maximum settings of light and shadow. An appropriate raster image processor, with an option of calculating white pixel percentage, was further used.

The SVF analysis method describes quantity of openings in an urban canyon concerned, whereas the assumed

Table 1. Breakdown of results, with sequences lengths where compactness is below the average value in the samples under our research (elaborated by B. Kaźmierczak)
Tabela 1. Zestawienie wyników z wyliczonymi długościami sekwencji o zwartości poniżej średniej dla badanych przykładów (oprac. B. Kaźmierczak)

Point symbol	View obstructions in percentage	(+/–) average
Gn_1_ab	35,18	(–)
Gn_2_ab	59,33	(+)
Gn_3_ab	60,35	(+)
Gn_4_ab	63,98	(+)
Gn_5_ab	49,29	(–)
Gn_6_a	64,12	(+)
Gn_7_a	59,68	(+)
Gn_8_a	55,71	(+)
Gn_9_a	53,22	(+)
Gn_10_a	54,4	(+)
Gn_11_a	**67,61**	(+)
Gn_12_a	50,01	(–)
Gn_13_a	55,51	(+)
Gn_14_a	58,02	(+)
Gn_15_a	43,74	(–)
Gn_16_a	58,42	(+)
Gn_17_a	57,29	(+)
Gn_18_a	48,03	(–)
Gn_19_a	61,12	(+)
Gn_20_a	64,27	(+)
Gn_21_a	61,23	(+)
Gn_22_a	60,31	(+)
Gn_23_a	44,02	(–)dł. 110,75
Gn_24_a	43,53	(–)
Gn_25_a	41,72	(–)
Gn_26_a	37,91	(–)
Gn_27_b	**29,17**	(–)dł. 188,68
Gn_28_b	38,44	(–)
Gn_29_b	45,97	(–)
Gn_30_b	51,65	(–)
Gn_31_b	52,25	(–)
Gn_32_b	41,95	(–)
Gn_33_b	53,75	(+)
Gn_34_b	45,99	(–)
Gn_35_b	56,03	(+)
Gn_36_b	41,65	(–)
Gn_37_b	53,27	(+)
Gn_38_b	40,76	(–)
Gn_39_b	59,15	(+)
Gn_40_b	60,65	(+)
Gn_41_b	64,92	(+)
Gn_42_b	49,54	(–)
Gn_43_b	57,74	(+)
Gn_44_b	65,98	(+)
Sum	2316,86	110,75/1010; 188,68/972
Average value SVF	52,66	10,96%/89,04%; 19,41%/80,59; średnia **84,81 %**

compactness parameter refers to the number of view obstructions. Black pixels were computed and their number was compared to the total number of all pixels. Thus, the SVF result (range from 0 to 1) was subtracted from 1 and multiplied by 100. This way, a percentage of view obstructions in the entire recorded image could be calculated.

Results

On the basis of computations of a percentage share of view obstructions in respective sampling points, lengths of sequences have been defined in reference to the number of view obstructions as "over" or "under" a mean value calculated for the entire selected series of the urban canyon. As a result, it was possible to find out which sequences of series scored the lowest value of view obstructions and at which length (Fig. 5). In the row titled "total", all percentage shares of view obstructions were totalled in order to calculate an arithmetic mean of the ratio and to find out the maximum length of a sequence characterised with the value of view obstructions below the arithmetic mean in reference to the entire length of the series (a, b). Table 1 presents the graphic representation of the analysis results.

Conclusions

Compactness of urban canyons understood as a ratio of visual obstacles to openings is one of the most important parameters defining physionomic quality of urban space. Owing to the application of the SVF method, the compactness factor can be easily calculated with objectively good results. The presented herein method of carrying out research does not require high financial outlay or knowledge of advanced tools. This method can be automated with the use of mobile 360° cameras and ready to use photoprocessing algorithms that calculate pixels of the same colour. The author has applied the said method for the assessment of a component of space physiognomy, which – when compared to the methods typically used in descriptive analysis based on a subjective sensual experience of the observer – was of innovative nature. In the light of the presented studies, it seems vital to search for similar normative methods of calculating physionomic features of urban canyons, such as for example those listed by Niezabitowski: complexity, differentiation or regularity. Thus, the Sky view factor method may prove a useful analytical tool in the work of an architect/urban planner, which can, furthermore, successfully supplement the descriptive methods of space valuation used so far.

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Streszczenie

Metoda sky view factor jako narzędzie analityczne w badaniu zwartości wnętrza urbanistycznego

Tematem artykułu jest badanie dotyczące analizy zwartości wnętrza urbanistycznego. Temat ten może być interesujący, gdyż badania fizjonomiczne wnętrz urbanistycznych zwykle polegają na analizie widokowej wykonywanej przez obserwatora w sposób intuicyjny. Istnieją oczywiście standardy dotyczące tego typu badań, które określają rodzaje elementów widzianej przestrzeni czy sposób ich zapisu. Analizy takie mieszczą się w nurcie badań opisowych, co często spotyka się z zarzutem dotyczącym ich subiektywności i braku porównywalności. Dla zwiększenia obiektywizmu takich badań zwiększa się liczbę obserwatorów a wyniki obliczane są i prezentowane w formie statystycznej. W niniejszym artykule opisane jest zastosowanie metodyanalitycznej bazującej na podejściu normatywnym dającym możliwość uzyskania policzalnych i porównywalnych wyników. Celem badania było przetestowanie jednej z takich metod – sky view factor (SVF), której użycie może posłużyć do określenia stopnia zwartości wnętrza urbanistycznego w sposób obiektywny.

Słowa kluczowe: sky view factor, narzędzie analityczne, podejście normatywne, zwartość wnętrza urbanistycznego