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## LANDSCAPE DOMINANT ELEMENT – AN ATTEMPT TO PARAMETERIZE THE CONCEPT

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### DOMINANTA KRAJOBRAZOWA – PRÓBA PARAMETRYZACJI POJĘCIA

#### Abstract

A “landscape dominant element” – an object with the greatest range of visual impact on the surrounding space, of a strong form that integrates the entirety of a composition, distinguished by its height, dimensions, colour, material, texture or the variety of its details. The attempts to define the concept presented herein, and which is intuitively perceived as obvious, illustrate its ambiguity. They bring to mind a visual contrast between this subject and others that surround it. This article attempts to analyse views using the author’s computer program. The objects in the photos are characterized by their interference in a panorama silhouette or skyline, size, colour, height, and shape. This helped to identify those that clearly stand out from the other forms, with which they come into visual interaction. The purpose of these considerations is to create tools that allow for a partial objectification of the landscape composition assessment.

**Keywords:** landscape dominant element, landscape assessment, view analysis, shape descriptors, colour, size, skyline

#### Streszczenie

Dominanta krajobrazowa – obiekt o największym zakresie wizualnego oddziaływania w otaczającej go przestrzeni, o formie silnej, integrującej kompozycję, wyróżniający się wysokością, gabarytami, barwą, materiałem, fakturą czy bogactwem detalu. Te próby definicji pojęcia, które intuicyjnie odbierane jest jako oczywiste, obrazują jego niejednoznaczność. Wpisany jest w nie także wizualny kontrast pomiędzy tym przedmiotem a innymi, które go otaczają. W artykule podjęto próbę oceny widoków z wykorzystaniem autorskiego programu komputerowego. Obiekty widoczne na zdjęciach scharakteryzowano pod względem stopnia ingerencji w sylwetę panoramy lub „linię nieba”, rozmiaru, barwy, wysokości i kształtu. To pomogło wskazać te z nich, które wyraźnie odróżniają się od innych form, z którymi wchodzi w wizualną interakcję. Celem tych rozważań jest stworzenie narzędzi umożliwiających częściową obiektywizację ocen krajobrazowej kompozycji.

**Słowa kluczowe:** dominanta krajobrazowa, analiza widoku, ocena krajobrazu, współczynniki kształtu, kolor, gabaryt

## 1. Introduction

When analysing a landscape composition, scholars utilise a range of terms that define its constituent parts. Polish scholars use the following hierarchy: dominant elements, sub-dominant elements and accents, which, respectively, fulfil an increasingly weaker role in the organisation and structuring of the whole [2, 3, 6, 25]. In English literature the term “landmark” has a similar meaning [28]. Despite the fact that we understand these terms intuitively, numerous examples of diverging opinions expressed by different scholars have confirmed the fact that the line between a dominant and a sub-dominant element or that between a sub-dominant and an accent has so far not been precisely defined [5, 20, 34].

When evaluating the function of each building within a structure we co-consciously use multi-criteria analysis, the basis of which is the scale of the impact of an object. It depends on the qualities of the object being observed and the spatial relations that connect it with others that are a part of a composition.

One advantage of multi-criteria analysis is the fact that it can be performed using machines and programs in a fully algorithmic and parameterised manner, which makes the assessment more objective. However, it is necessary to formulate parameters thanks to which our machine will be capable of identifying objects and assigning them to a given definition. These tools can work with data from various sources, even photographs that are shared by users on the Internet.

Studies of the landscape structure using digital techniques are usually made using maps and aerial photographs. Analyses of eye-level views are few. Attempts to characterize the landscape components of the composition were made at work [24], juxtaposing the map and view, and then determining the angle that the individual components cover. Another numeric indicator that determines the percentage of the object in the view is the average brightness of the image. Due to the possibility of different image framing, it is useful when comparing different variants of land development [23]. Alternative parameter that characterizes the structure of objects, their granulation and placement is the box fractal dimension [19]. In terms of the analysis of solids and architectural forms, the shapes of objects were characterized by the number of angles and vertices [29] and some shape coefficients, such as compactness, convexity, rectangularity or centricity [18].

The method proposed by the author can aid experts in finding landscape landmarks [17] and point to objects that are potentially important within the landscape. Developing such tools can also be particularly helpful in the event of the necessity of analysing large areas when identifying priority landscapes.

In the article the author made an attempt at analysing the semantics of the notion of the dominant element. Specifying the qualities that make us prone to assign this role to a given form served as a starting point for determining criteria on the basis of which it can be possible to perform a more objective assessment. The discussion that was engaged in was meant to develop numerical indicators that could make it possible to automatically classify dominant elements on landscape photographs. This approach requires verification over the course of a discussion with experts, particularly in relation to the selection of specific indicators and threshold values. The method of the classification of dominant elements developed by the author will be possible to use in order to parameterise other constituent elements of the landscape.



## 2. Term definitions

When starting our search from dictionary definitions, we can come across the following descriptions:

- „1. a principal, dominant quality or element of something;
2. in statistics, the value of a quality that occurs the most often in a group;
3. the fifth sound on the major or minor scale; also: a chord based on this sound;
4. in psalms: the longest lasting sound” [26].

The description provided above confirms that this term is used in many fields, including in statistics and musicology. In studies concerning visual aspects only the first part of the definition will be useful. We find here a reference to the most important part, which defines the character of a given object.

In the foreign loanword dictionary we will read that a dominant element is:

- „1. a main characteristics, fundamental to anything; an overruling element, one that stands out;
2. *in statistics*: a) the value of the characteristic which is present the most often in a given test group; b) the most probable value of a random variable;
3. *biol.* a species that dominates over other species in a group of living organisms in terms of number;
4. *phys.* the dominant wavelength of a colour, defining its shade;
5. *mus.* a) in psalmic tones it is the longest sound on which a text is recited; b) in a modal system, the fifth sound of the fundamental scale or the fourth of the derivative scale” [27].

Here we have another reference to biology and physics. Similarly as in the previous definition, only the first part refers to broadly understood composition. The content is similar, as the dominant element is treated as a quality or the part of the object that is the most essential as well.

If we narrow the term down to architecture, then an architectural dominant element can be defined as:

- ▶ the main architectural element that stands out in the foreground, formally constituting the most important accent of a work of architecture, to which other elements are subordinate [31];
- ▶ the main accent of an architectural or urban composition [33];
- ▶ a building or architectural and urban complex that stands out within a given area thanks to particular qualities [10];
- ▶ a work of architecture with the greatest scope of impact that dominates the entire space that surrounds it [14];
- ▶ a work of architecture with a strong form that stands out in terms of form and height, one that fulfils the role of a distinct mark that accentuates a space [4];
- ▶ a symbol of spiritual or secular power, clearly standing out within the panorama of a city due to its large scale and exposed appearance; the sign of an important place within urban tissue, that stands out within a space thanks to its formal exceptionality [11].



These definitions can, overall, be assigned to one of two groups. In the first group their author refer to the form, the external appearance of an element or of an entire structure that is considered the most important in terms of composition, one that stands out in some way. The second also refers to the function of a dominant element, as a structure that provides a certain character to a composition.

The scope of the concept of a landscape dominant element is broader, because it covers both natural objects, as well as man-made ones. In this case there is also a reference to an element that identifies a space [16, 17], however, we can also find definitions through enumerating characteristics thanks to which landscape dominant elements (natural or architectural objects or architectural and urban complexes) stand out from their surroundings. These can be: size, height, colour, an original form or details [6, 34].

Examples of natural dominant elements are old plant specimens, particularly of trees, terrain forms – objects that are extraordinary, that set the character of their surroundings, ones that impact the space around them. However, in our current time this does not equate with their natural origin, as many of them, particularly plants, appeared in a given area because of man. It is human activity that has given dominant elements their significance. Their genesis was usually accompanied by a goal for said object to highlight the entirety of a composition [6]. A large or exotic tree could fulfil an aesthetic function, being a true ornament to a garden, while at the same time signifying the prestige and wealth of its owner.

The matter was similar with architectural dominant elements. Religious, administrative and representative buildings were intentionally given forms that set them apart from their surroundings in visual terms. Such structures fulfilled the role of orientation points, in addition to establishing the identity of a locality [15], playing, apart from a pragmatic function, also that of a mark [6].

We can currently question the intentionality of creating dominant elements with a retail-related or technical function [8]. It appears that these efforts do not have a conscious character [5]. It is difficult to suspect the author to have a religious motivation, the need to highlight the prestige of a structure or that of its owner, the establishment of a point that makes orientation within a space possible or improving its aesthetic. It is often economic or pragmatic conditions that are responsible for a form (the need to make the maximum possible use of a space). Due to this, it is residential tower blocks, as well as industrial or storage buildings that become dominant elements [10].

### **3. Model of assessing an object as a dominant element**

Every model is a sort of approximation of reality. In the community of landscape architects this term is understood as a physical element – a model or mock-up of an area, building or plant. The term has, however, a much broader meaning. We can, after all, model various types of processes and phenomena. A properly constructed model should take into consideration the most distinct qualities of an object (a static model) or, alternatively, the conditions that the course of a process or the occurrence of a phenomenon depend on (a functional model) [19].



To create a model of object evaluation as a dominant, a definition listing its characteristics that can be parameterized will be useful [21]. In table 1 the author presented a listing of the characteristics of objects and numerical indicators that can describe them. It should be highlighted that a dominant element always functions in the context of its surroundings, as the values that characterise it will always be read in the context of the parameters of neighbouring objects.

Table 1. A listing of the characteristics of an object and numerical indicators that can define them

Object characteristics	Numerical indicator
Considerable impact on the skyline	The highest point of the skyline
Considerable size	Surface area on a photograph
Significant height	Vertical dimension
Original form	Shape coefficients
Wealth of detail	Shape coefficients
Extraordinary colouration	Colour analysis

As the first of the factors that make it possible to define a form as a dominant element, the author took into consideration an object's impact on the skyline. This role can potentially be played by the tallest object, one that towers above the remaining ones. The author proposed an algorithm which searches for the highest-placed pixel of the highlighted objects.

The calculation of the next indicator is only seemingly without difficulty. Thanks to a raster image structure [13] we can highlight groups of pixels which correspond to individual objects visible on a digital photographic image. Their number will determine the size of a given element and will constitute a whole number. However, we should keep in mind the fact that due to perspective projection, objects located closer to the viewer appear larger, while those that are further away – appear smaller. This is why only comparisons between objects located on the same plane are conclusive [19, 22].

This also applies to the height of an object, which can be calculated as the maximum dimension on the vertical axis ( $y$ ) and the result will also be a whole number.

Considerable complications appear during the stage of segmenting an image, which is based on highlighting the fragments that correspond with each object. The result is dependent on the resolution of the image, the chosen file format and the associated compression method and the tool used to select the image fragment.

The 3D form of an object is represented on a photograph by its shape, understood as a contour visible in a given projection. In order to characterise it, we can use shape coefficients that describe the size of a shape, its elongation, compactness, the irregularity of its contour and its complexity. We can thus assume that the dissimilarity of an object, as well as a greater wealth of its detail – in comparison to other objects – will be reflected in the differences of these parameters.

Eleven factors were considered in the study, of which the first two are defined as circularity coefficients ( $W_1$  and  $W_2$ ). They are calculated using the following formulae:



$$W_1 = \sqrt{\frac{4 \cdot A}{\pi}} \quad W_2 = \frac{P}{\pi} \quad (1) \quad (2)$$

for which:

$A$  – is the surface area of an object, while  $P$  – is its perimeter.

$W_1$  is equal to the diameter of a disc with the same surface area as the object being analysed, while  $W_2$  – the diameter of a disc with the same circumference as the aforementioned shape. They primarily illustrate the size of an object, but can also be used to calculate the next coefficient.

$W_3$  (the Malinowska coefficient) can be calculated based on the proportions of the previous two indices. For elongated shapes it will take on high values, while for those with a shape similar to a circle – low values.

The following equation was used in the calculations:

$$W_3 = \frac{P}{\sqrt{4 \cdot \pi \cdot A}} - 1 \quad (3)$$

The following  $W_4$  coefficient (the Blair – Bliss coefficient) requires more complex calculations to be performed. In the formula:

$$W_4 = \frac{A}{\sqrt{2 \cdot \pi \cdot \sum_i r_i^2}} \quad (4)$$

$r_i$ , is the distance between each pixel and a shape's centre of mass (a centroid,  $i$  – signifies a pixel's number). What is being calculated here is the proportion between the surface area of an object and the sum of all the distances of the pixels from the centre. This means that for objects with a shape that is close to a surface and with smooth edges  $W_4$  will take on higher values. It is also defined as a measure of an object's hollowness, as forms with openings in them will have a higher surface area and the distances between pixels and the centre of a form can be relatively large, and, as a result – the value of the parameter will be low for them. In order to measure the regularity of an object, we can use  $W_5$  (the Danielsson coefficient):

$$W_5 = \frac{A^3}{\left(\sum_i l_i\right)^2} \quad (5)$$

The formula makes it possible to calculate the sum of minimum distances between each of the pixels belonging to a shape and its edge, marked as  $l_i$ .

The next coefficient –  $W_6$  (the Haralick coefficient) is calculated on the basis of the sum of the distances between a shape's centroid and the successive pixels that belong to its outline ( $d_i$ ) using the formula:

$$W_6 = \sqrt{\frac{\left(\sum_i d_i\right)^2}{n \cdot \sum_i d_i^2 - 1}} \quad (6)$$

for which  $n$  is the number of border pixels. If the form is heavily fragmented, it will increase.

The  $W_7$  coefficient is used to calculate the circularity of an object and is based on a very simple proportion:

$$W_7 = \frac{r_{\min}}{r_{\max}} \quad (7)$$

for which  $r_{\min}$  – is the minimum distance between the centre of mass of a given shape and its edge, while  $r_{\max}$  – is the maximum distance. Using it we can determine the elongation of an element, as well as the irregularity and fragmentation of a form, because with significant irregularities of the contour the value of the coefficient will be higher.

In order to determine irregularity we can use  $W_8$ , which is calculated as:

$$W_8 = \frac{D_{\max}}{P} \quad (8)$$

which is the relation between  $D_{\max}$  – the maximum size of an object and its circumference. It would be good to highlight that this index will reach a low value for shapes with a frayed edge that is relatively long. If we want to verify whether a shape resembles a circle, then we can use  $W_9$  (a modified Malinowska coefficient):

$$W_9 = \frac{\sqrt{4 \cdot \pi \cdot A}}{P} \quad (9)$$

signifies the circularity of an object and the closer it is to a circle, the closer its value is to that of 1. In this case it is the surface and circumference that are taken into account. The simplest in terms of calculation is the  $W_{10}$  coefficient, called the Feret diameter, which is the relation between a shape's highest horizontal ( $D_h$ ) and vertical ( $D_v$ ) dimension:

$$W_{10} = \frac{D_h}{D_v} \quad (10)$$

For horizontally elongated forms this will produce higher values, while for vertical ones – lower values.

The value of the last of the coefficients adopted by the author ( $W_{11}$ ) signifies the compactness of a shape, defined as the degree of the form filling a rectangle circumscribed upon it. It will thus take on values ranging between 0 and 1, however, in the case of more fragmented forms it will take on lower values [18, 21, 32].

Table 2 presents the results of an analysis of the usefulness of shape coefficients in order to assess an architectural and landscape form. The values of each parameter were assigned the characteristics of a form whose value is directly dependent on them.

As it can be seen, some of the coefficients reflect a pronouncement of the same characteristic, e.g. coefficients  $W_1$  and  $W_2$  reflect size, while  $W_3$  and  $W_9$  – elongation. Others oppose each other – e.g.  $W_5$  and  $W_7$ .

During the stage of comparing values the author encountered another difficulty that resulted from the different scale of the data. For example, the value of coefficient  $W_{11}$  ranges between 0 and 1, while the values of  $W_1$  and  $W_2$  reach up to several thousand units.

Table 2. roportional dependence between the value of a coefficient and the characteristic of a figure

$W_1$ and $W_2$	size
$W_3$	elongation
$W_4$	lack of openings, hollow spaces
$W_5$	regularity
$W_6$	fragmentation
$W_7$	irregularity, fragmentation
$W_8$	smoothness of the outline
$W_9$	circularity
$W_{10}$	horizontal elongation
$W_{11}$	compactness

A standard formula, presented below, was used during standardisation:

$$n'_i = \frac{n_i - n_{i\min}}{n_{i\max} - n_{i\min}} \quad (11)$$

for which:

$n'_i$  – is the standardised value,

$n_{i\max}$ ,  $n_{i\min}$  – are the highest and lowest values within a group of results, respectively [7].

This made it possible to bring all of the values to a range of between 0 and 1. Because we are interested in the distinctness of an object that fulfils the role of the dominant element within its surroundings, an average value for all objects (a median) was calculated for each coefficient. This was followed by an analysis of the differences between the values obtained for individual objects and this median. This made it possible to produce charts which clearly illustrated how much a given object differs from the others.

The colour of every pixel of an image is recorded using the RGB system, which means that it utilises the basic constituent colours – red, green and blue, however, the higher the value of one of these constituents, the greater the saturation of a pixel with a given colour. Bright colours are usually characterised by higher values [9, 13]. An averaged colour was calculated for each object highlighted on a photograph, as an arithmetical mean of the value of the colour of all pixels belonging to said object. Afterwards, the average colour (a median) was calculated for all objects, with the deviation from the mean colour of the entire object or its part, e.g. in the case of a building – its walls or roof, while in the case o a tree – the crown and the trunk. However, we should be aware of various factors that affect the perception of colour, such as lighting, depending on the time of day and atmospheric conditions, or the transparency of air. Typically objects located on planes located further from the viewer lose their contrast and colour intensity. Due to this fact, the best course of action when performing colour analysis, similarly as in analysing the size of the objects, is to compare those that are located at a similar distance away from the observer [12, 20].



## 4. Materials

Assuming that the perception of the landscape is typically performed from the perspective of a standing person and photographs constitute an equivalent of visual experiences, four views of the Vistula River Boulevards in Krakow were subjected to an analysis. The author used digital photographs with a 3264 x 2448 pixel resolution obtained using a focal length of 35 mm, which were later combined into panoramas. With the presented settings we can record a view covering a horizontal angle of 54.43° and a vertical angle of 37.85°. A single pixel of the image thus corresponds to the vision of approximately one angular minute. This reflects the resolution of human sight, which means that a single pixel on a photograph reflects the smallest object that a human can see [1].

In order to perform an assessment of the shape, height and surface area of objects, the author used appropriately prepared images on which the analysed objects had been coloured white, and the background had been coloured black. Segmentation, which is a process based on highlighting objects (buildings, fragments of greenery) [9, 13] was performed by hand, attempting to outline the contours of each element with the greatest possible amount of fidelity. This precision can affect the results that are obtained, both in terms of surface area, maximum height, as well as shape [21, 22]. In three of the analysed cases these were works of architecture, while in one – a natural object. The individual buildings, plants and surfaces covered with greenery (lawns), were separated by lines with a width of 1 pixel, so that they could be treated as separate objects. When doing so, the contour of an object needs to be verified, as separated pixels and even ones that touch at the vertices could become identified as separate objects.

Colour analyses required that colours be applied to the objects, which was performed through multiplying the original photograph and a black and white image discussed above. As a result of this operation, the objects that were coloured white preserve their original colour (like when we multiply a value by 1) and the background, which we multiply by 0 (the colour black) becomes black [13].

## 5. Software interface

Due to a lack of free software that could perform all of the planned analyses, the author developed a program using the MATLAB environment with the use of the Image Processing Toolbox, an additional library of functions, the use of which simplifies coding. The graphical user interface of the program is very simple. It makes it possible to load an image from a selected folder and place tags on individual objects, which provides orientation in future results. The tagged image can be saved, thanks to which it is easier to interpret the calculation results. As characteristic parameters of objects, their size, height, shape coefficients and averaged colour (calculated as the arithmetic mean of the colours of all pixels) are calculated. In addition, the program also highlights the point located at the highest elevation, drawing a red, downward facing arrow above it. The possibility of saving an image with this marking has been introduced,





load an image

label areas

save the image with labels

calculate objects' areas

calculate objects' heights

calculate shape factors

calculate mean colours

save the image with the mean colour

indicate the highest point

save the image with the highest point

save the results and exit

Fig. 1. Program interface

as well as of the image with objects coloured using the averaged colour. The individual functions are initiated using buttons, which makes it possible to select any set of indicators (e.g. surfaces and shapes only). The results are exported into an Excel file in the form of a table, which enables their future processing and the generation of charts presenting the results in graphical form. The user can specify the location and name of the file with the results.

The functions of calculating the shape coefficients are highly complex and their calculation time is very long, which is why a progress bar was introduced, which shows the user that the program runs appropriately, as well as the level of progress of the calculation.

## 6. Research results

### 6.1. Case 1 – Hotel Forum

The first case is a view of Hotel Forum from Bulwar Inflancki. It is intuitively seen as a dominant element. The building has not been in use for many years and its owner draws profit from making its facade available as an immense advertisement surface. The colour of the building can be considered temporary, dependent on the graphic currently displayed on it. The image recorded in 2015 shows the building as a strong colour dissonance within its surroundings.



Fig. 2. View of Hotel Forum from Bulwar Inflancki

Fig. 3 shows that the highest point of the skyline (marked with a red arrow) is located at the top of the building. The surface of the white shape (tagged with the number 9) that corresponds to the hotel is larger than that of the neighbouring objects by over a dozen times, and its height – is almost twice as that of the highest object in its vicinity, which can be seen in the graphs shown on Fig. 4. The numeration of the horizontal axis corresponds to the successive objects, starting from left, while the values on the vertical axis correspond to the number of pixels.

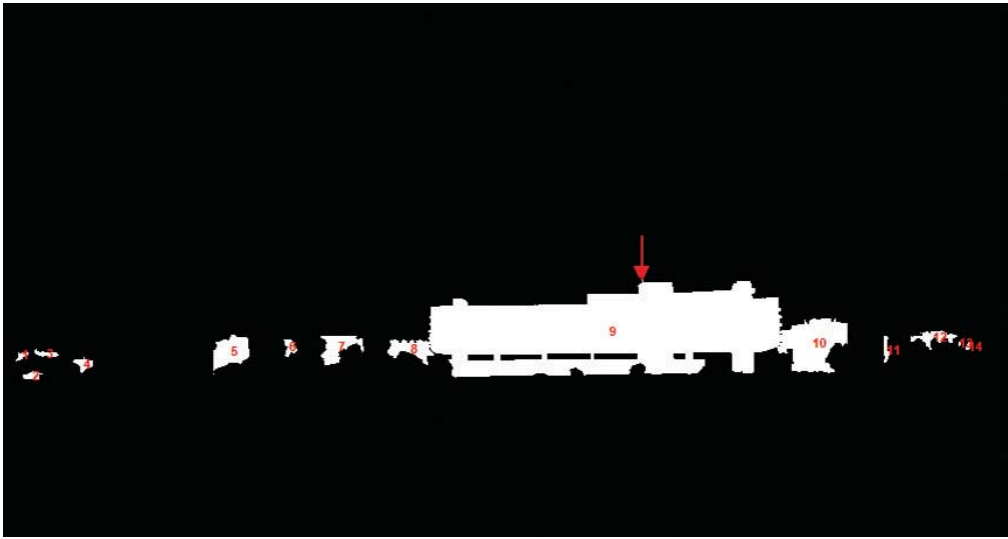


Fig. 3. View of Hotel Forum with a highlight of the visible fragments of buildings, tags for visible fragments of buildings and an indication of the highest point

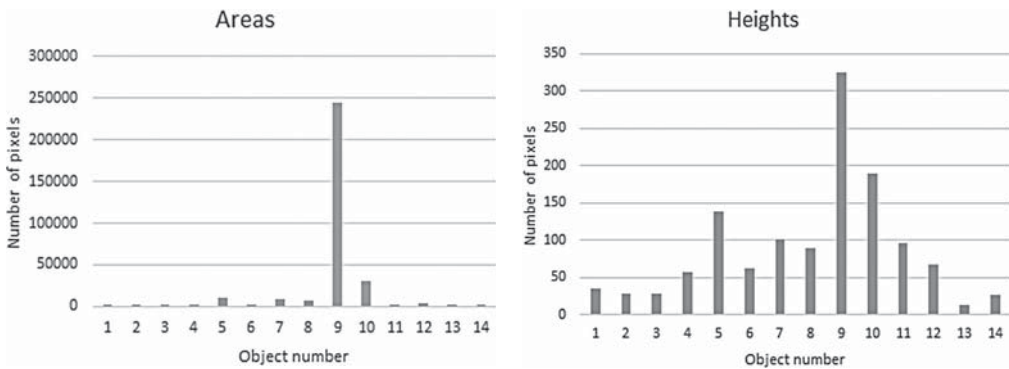


Fig. 4. Surface area and maximum height of the objects (in pixels)

Fig. 5 shows the differences between the values of shape coefficients ( $W_1-W_{11}$ ) calculated for the individual objects (numbered 1–14 according to Fig. 3) and the median value of the coefficient for all visible objects. The massing of the hotel differs from other objects in the analysed view primarily by its size, which is shown by high values for coefficients  $W_1$  and  $W_2$ . It is also horizontally elongated, which can be concluded from a high value of coefficient  $W_{10}$ . A low value for  $W_4$  and  $W_5$  indicate that the form features openings and is irregular. Coefficient  $W_6$ , in turn, is close to the median of the surroundings, as the outline of the objects is rather orthogonal and does not feature too much detail that would cause the contour to become fragmented. In this case, due to significant cover by plants, only the visible parts of the objects were analysed. It should be noted that apart from the obvious lowering of their surface area, this also causes their shape to become falsified. The massing of the building located to the

left of the hotel was divided into 4 separate fragments. A different approach, which has been presented in the following example, is possible as well.

Fig. 6 depicts the buildings with their colours applied to them. Their analysis was based on calculating an averaged colour for every object (Fig. 7) and comparing their RGB constituents with the median values calculated for all fragments of buildings visible on the photograph.

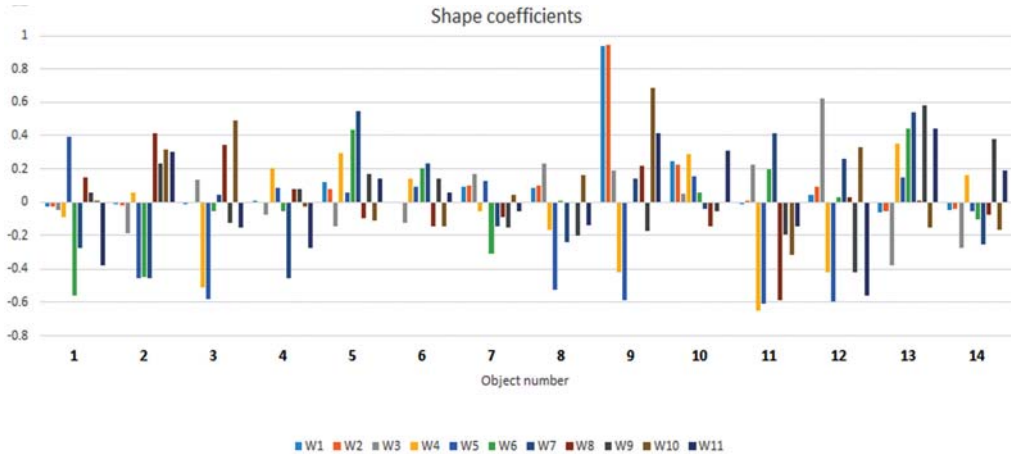


Fig. 5. The difference between values for shape coefficients for each object and the median values for all objects ( $y = 0$  is the median value for each coefficient)



Fig. 6. Buildings with their original colours (to the left – the entire building of the hotel, to the right – the advertisement surface)



Fig. 7. The median colours of the objects: to the left – taking into account the entire building of the hotel, to the right – taking into account the facade covered by the advertisement

In the case of subjecting the entire massing of the hotel to the analysis, it turned out that it is slightly less saturated with the colours blue and green. Bright residential blocks with a dominance of blue and green constituent colours located in the right part of the photograph (objects 10–14, according to Fig. 3) were proved to stand out. The fragments of the blocks to the left of the hotel were much darker (4–8). Most of the buildings sported significantly less of the red constituent. The exception was the object tagged with the number 3, which corresponded to a fragment of a roof visible amidst greenery. Despite the fact that the majority of the surface the object of the hotel (object 9) was its facade (around 59%), its median colour was also influenced by the lower storeys that remained in the shadow, as well as the pylons and the infrastructure located on the roof. Should we analyse solely the facade used as the advertisement surface, then the results will be much clearer. The colour red was clearly dominant within the area (object 9) (Fig. 8).

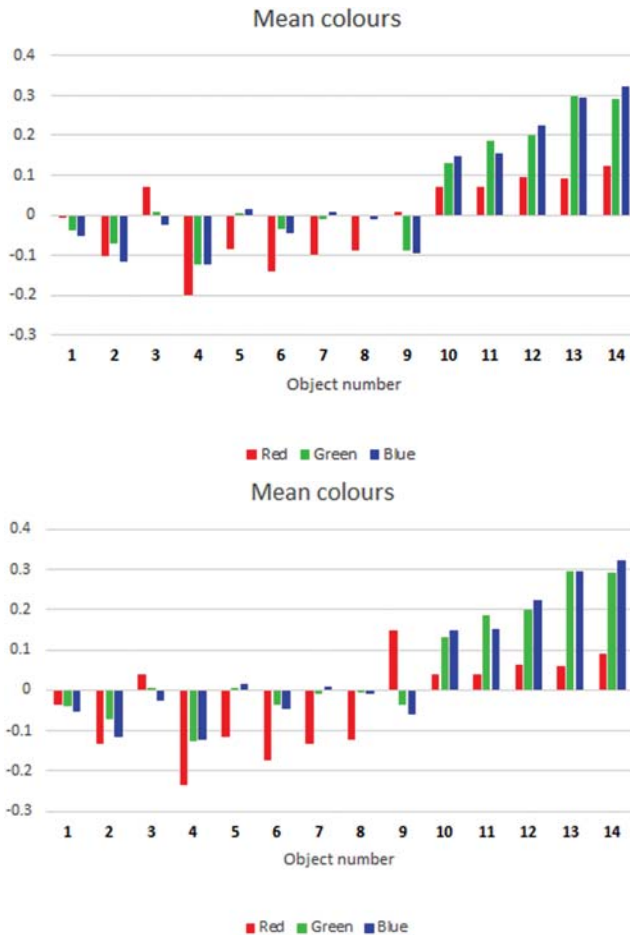


Fig. 8. The difference between the median colour of an object and the median for all objects: to the left – for the entire hotel building, to the right – for the facade covered by an advertisement (y = 0 is the median value for each colour channel)

## 6.2. Case 2 – the church and monastery of the Pauline Fathers at Skalka

The next case to be analysed by the author was a view of the Monastery of the Pauline Fathers at Skalka, observed from Bulwar Kurlandzki. The view is framed by groups of tall greenery which segment this fragment of the panorama. We can intuitively tell that the Monastery is the view's dominant element (Fig. 9).



Fig. 9. View of the Monastery of the Pauline Fathers from Bulwar Kurlandzki

This belief was confirmed by the results of the author's calculations. The highest point of the skyline was found at the top of the church bell tower (the object tagged with the number 9) (Fig. 10).

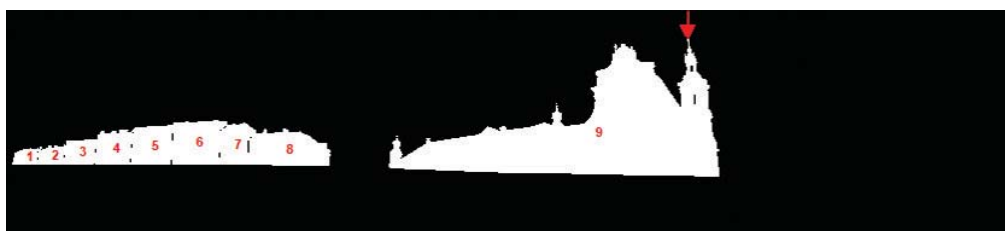


Fig. 10. View of the Monastery of the Pauline Fathers with the highlighted buildings, their tags and the highlight of the tallest point

The surface area of the shape that represents the outline of the monastery complex (9) exceeds the surface area of the neighbouring townhouses by around a dozen times, while the height of this shape – is almost three times as large (Fig. 11). In this example it was decided that, despite the see-through greenery blocking the buildings, in the picture with the original resolution we can identify their surface areas and highlight entire structures without making significant errors.

In this case the object had a shape that was clearly different than its surroundings, which was confirmed by shape coefficient values. Some of them reached high values, including  $W_1$  and  $W_2$  – which signified its above average size, while  $W_3$  and  $W_{10}$  – its horizontal elongation. The values for  $W_4$ , which were below average, were caused by the presence of openings, while  $W_5$  and  $W_{10}$  – the irregularity of the form and its lower compactness, respectively (Fig. 12).

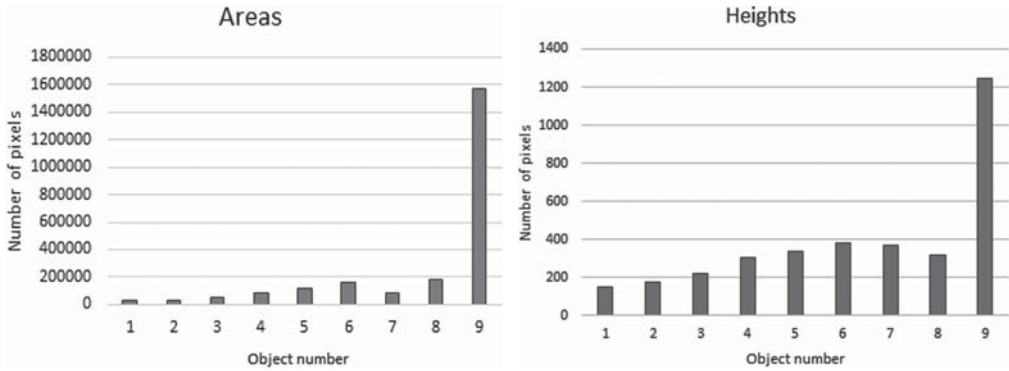


Fig. 11. The surface and maximum height of the objects (in pixels)

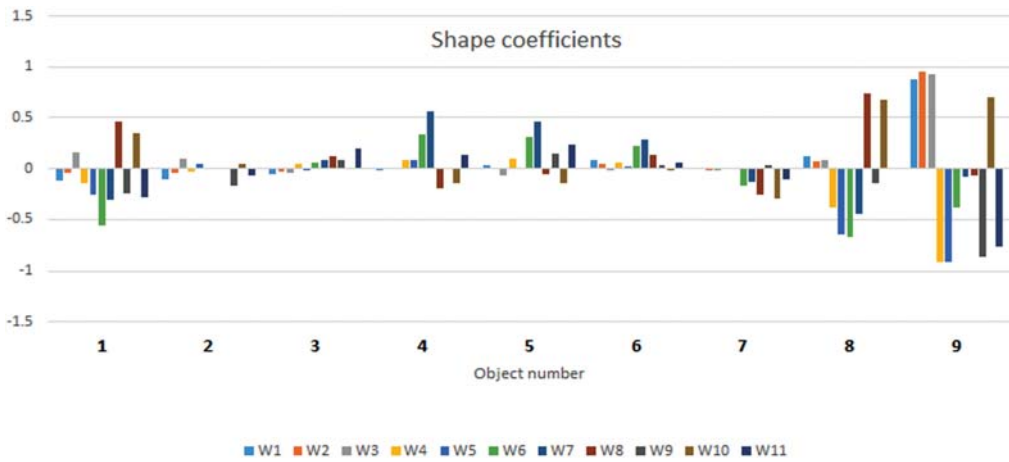


Fig. 12. The difference between the values of shape coefficients for each object and the median values for all objects ( $y = 0$  is the median value for each coefficient)

Highlighting the entire outlines of buildings causes green to constitute an admixture in the averaged colour of an object (Fig. 13 numbered according to Fig. 10). An approach was presented which appears to be justified in the situation when greenery can be seen through to some degree (e.g. in seasons when there are no leaves on trees). As a result of this approach,



Fig. 13. Buildings with their colours applied



however, the averaged colour of some townhouses (particularly those tagged with the numbers 1, 4–8) became relatively dark (Fig. 14).

The monastic complex was the brightest, but its colour was comparable to the pastel colour of the facade of a townhouse (Fig. 15).



Fig. 14. Averaged object colours

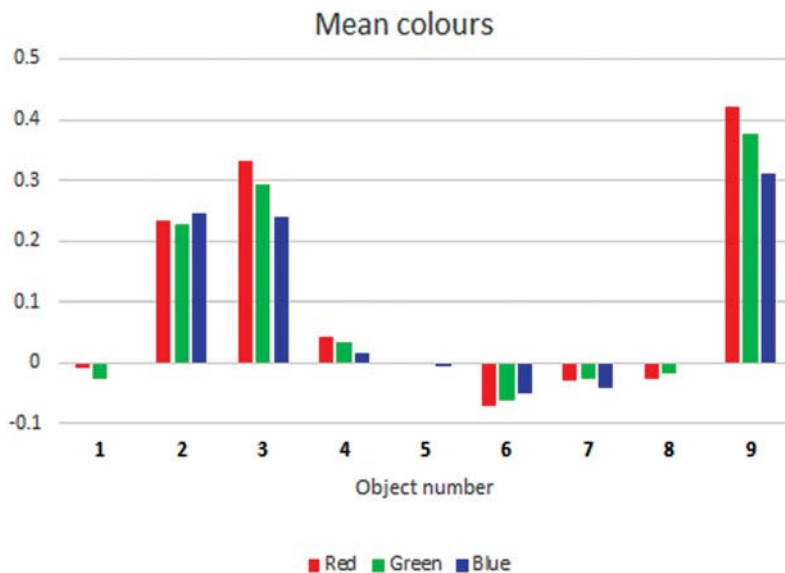


Fig. 15. The difference between the averaged colour of an object and the median for all objects ( $y = 0$  is the median value for each colour channel)

### 6.3. Case 3 – the Krakow Heat and Power Generation Plant (PGE)

The following analysis was performed for the case of a view in which the natural material is dominant (tall, medium-sized and low-lying greenery), however, we perceive the tall smokestack of the heat and power generation plant in Łęg as the dominant element.

Anthropogenic elements within the view belong to technical infrastructure and are relatively small (Fig. 16).

An analysis of the image indicated that the highest point had been located at the top of the heat and power plant's smokestack, marked with tag number 10 (Fig. 17).



Fig. 16. View of the Krakow Heat and Power Generation Plant from the Bouelwards in Dąbie

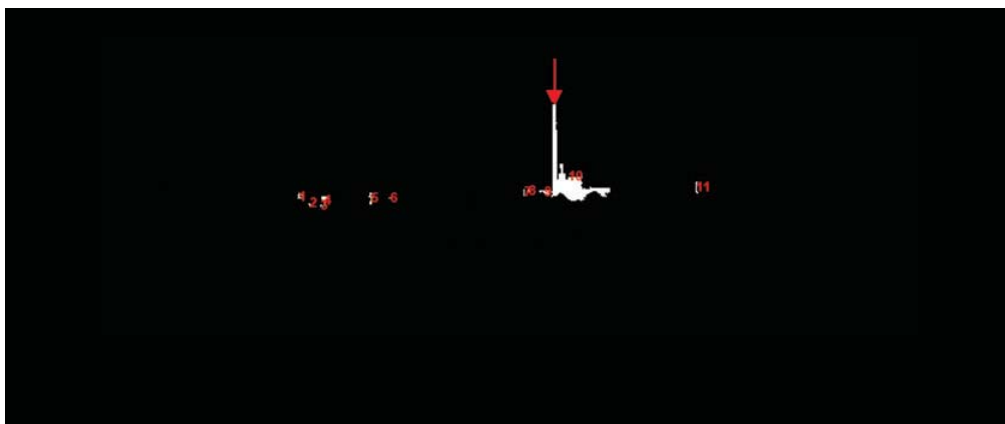


Fig. 17. The same view with a highlight of infrastructure objects, their tags and the highlight of the highest point

The surface area of this objects was nearly thirty times the size of the largest of the remaining visible fragments of buildings and its height – was almost eight times greater (Fig. 18).

The distinctness of the form of the heat and power generation plant from its surroundings was confirmed by high values for coefficients  $W_1$  and  $W_2$ , which were a result of its dominant size. The shape was elongated (vertically), which was shown by the  $W_3$  value, it was also irregular and fragmented to a greater degree than those of other objects ( $W_6$  and  $W_7$ ). The  $W_4$ ,  $W_9$  and  $W_{11}$  coefficients confirmed, in turn, that it did not feature openings or hollow spaces, while its shape was characterised by neither circularity nor compactness (Fig. 19).

Colour analysis did not indicate the heat and power generation plant, with its white and red smokestack and its overall massing featuring grey colour tones, to be significantly different in terms of colour from the other objects (Fig. 20 and 21). The most distinct in these terms was the yellow fragment of a silo marked with number 3 (numbered according to Fig. 17), which, unfortunately, was difficult to see on the scale used for printing (Fig. 22).

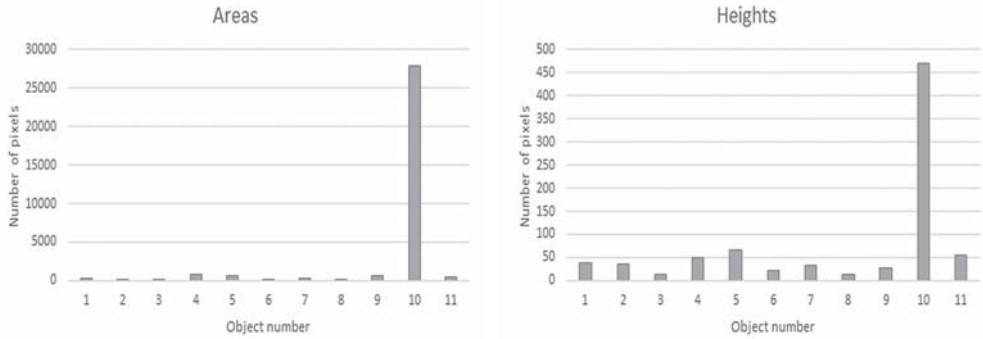


Fig. 18. Object surface area and maximum height (in pixels)

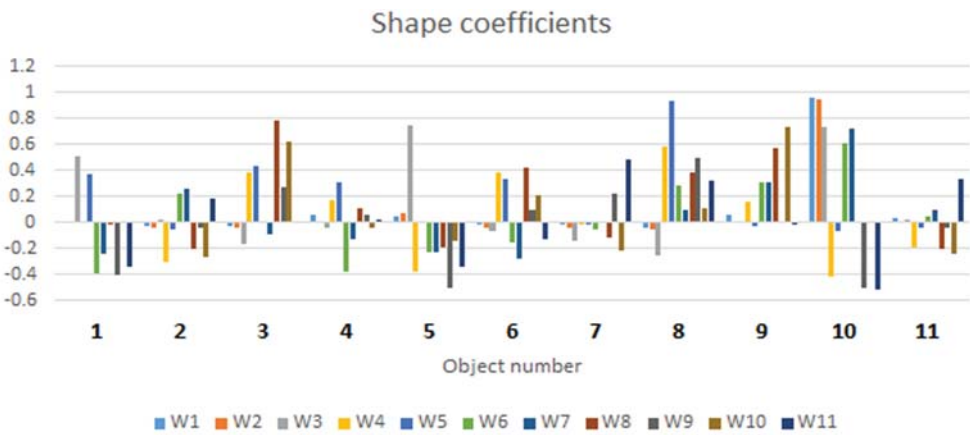


Fig. 19. The difference between the shape coefficients for visible fragments of objects and median values ( $y = 0$  is the median value for each coefficient)



Fig. 20. Coloured objects



Fig. 21. Averaged object colours

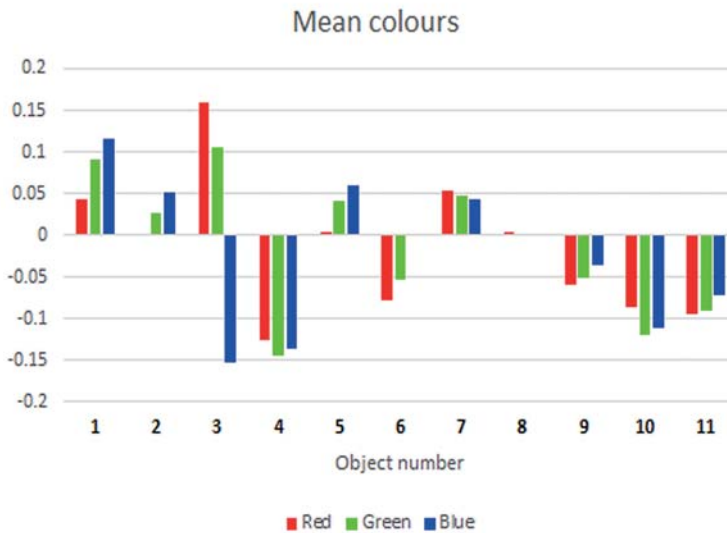


Fig. 22. The difference between the averaged colour of the object and the median for all objects ( $y = 0$  is the median value for each colour channel)

#### 6.4. Case 4 – A fragment of Bulwar Wołyński

The final case proves that program can be used to analyse both buildings and natural objects. In order to do so, a fragment of Bulwar Wołyński was selected, in which the crown of a tree is intuitively perceived as a dominant element (Fig. 23). At its top (object with tag number 23) was the highest point of the skyline (Fig. 24).

The tree was also the largest object in the view, especially when it was observed that the object with tag 7 corresponded to a lawn. It was around 10 times larger than the tree tagged with the number 27.



Fig. 23. View of a fragment of Bulwar Wolyński

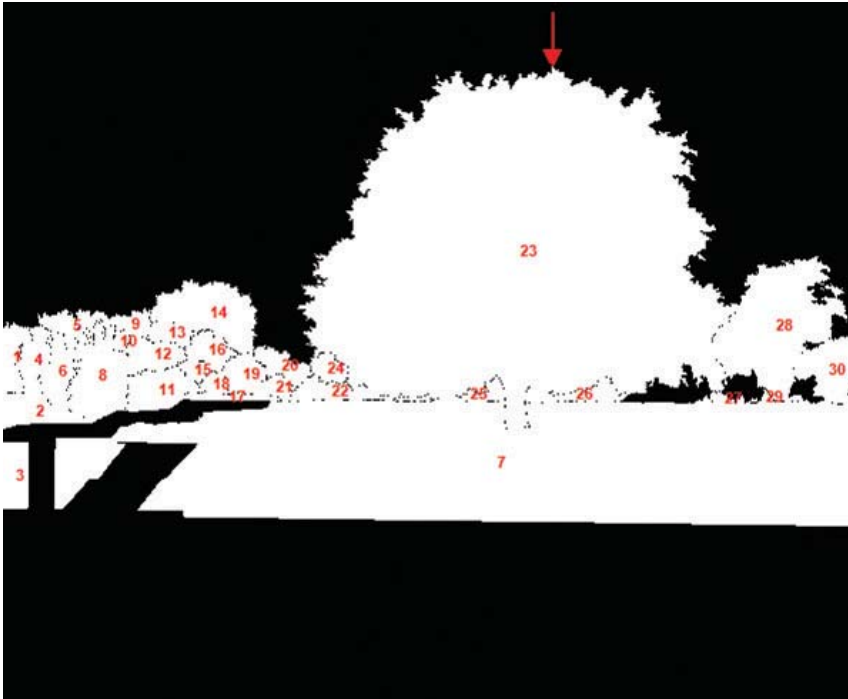


Fig. 24. The same view with a highlight of natural objects their tags and the arrowhead showing the highest point

Its maximum height was also two and a half times greater than that of the remaining objects (Fig. 26).

The chart showing the deviation of coefficient values from the mean was not legible on this scale due to the considerable number of objects (30) highlighted on the image (Fig. 27).

This is why the author decided to include an additional illustration (Fig. 28) showing that an object intuitively perceived as a dominant element stood out primarily through its size ( $W_1$  and  $W_2$ ), which significantly differed from the median. The  $W_{10}$  coefficient reached a very low value, which signified a lack of elongation. A low value of  $W_8$  was the result of fragmentation, the lack of smoothness of the contour, which had been caused by a greater precision when seeing an object on the first plane and the fact that its crown was viewed against the background of the sky, which made it possible to discern its outline with greater precision.  $W_9$  corresponded to a lower degree of the tree's circularity, which was understandable, because we could see its entire trunk, and in the case of the remaining trees and bushes – only the crowns.

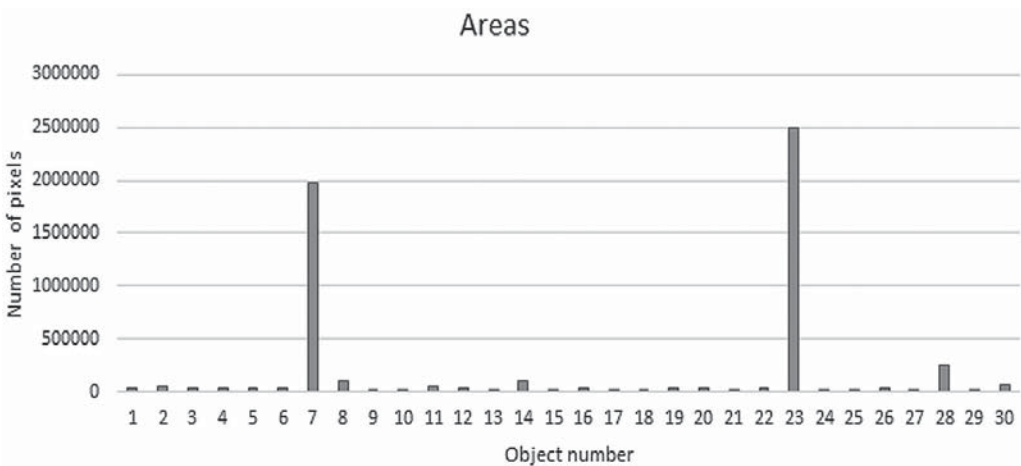


Fig. 25. Object surface area (in pixels)

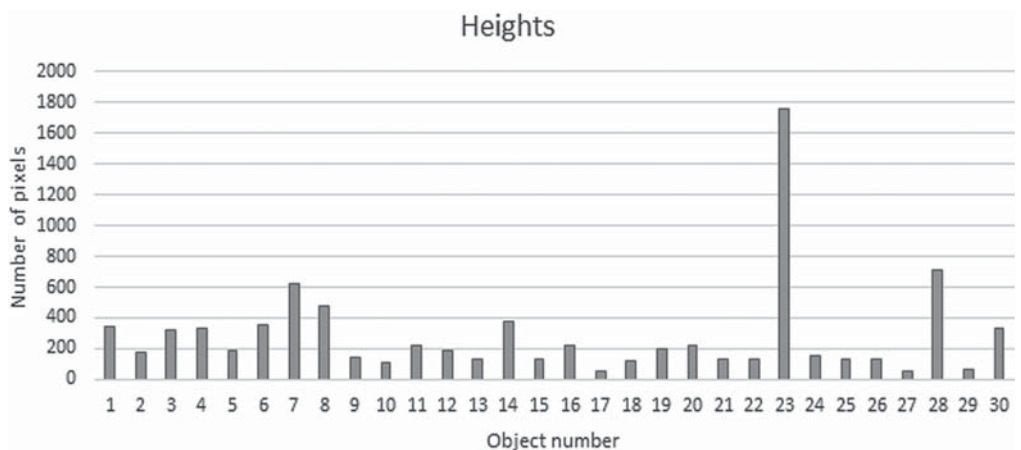


Fig. 26. Maximum object height (in pixels)

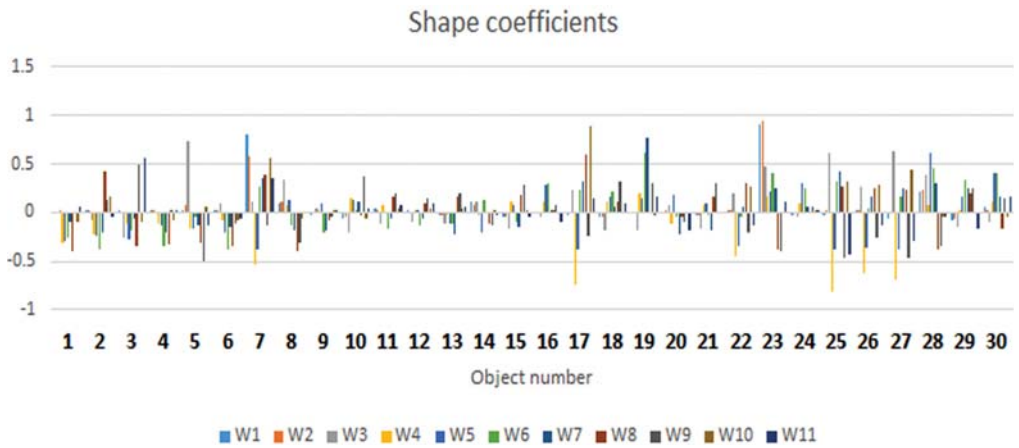


Fig. 27. The difference between the shape coefficients for objects and median values ( $y = 0$  is the median value for each coefficient)

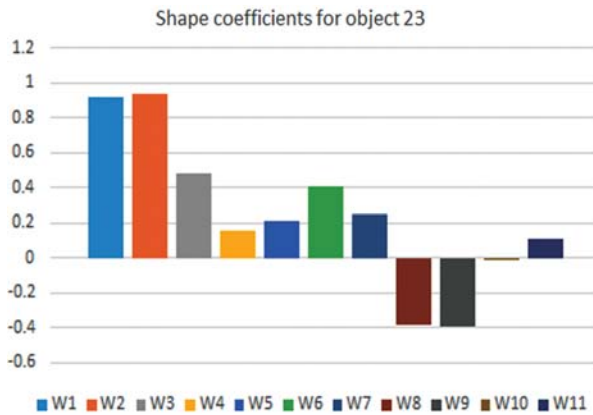


Fig. 28. The distinctness of the shape of the largest tree from the surrounding natural objects



Fig. 29. Plants with colour enabled



Fig. 30. Averaged colours of the objects

The colour analysis also produced predictable results. The dominant object did not stand out from its surroundings in terms of colour (Fig. 29–31). Both the illustration showing the averaged colours of the objects and the chart presenting the results of the calculations indicated that the object tagged with the number 12 stood out the most from the background. This was the result of the fact that a white billboard was located within the outline of the crown of this small tree.

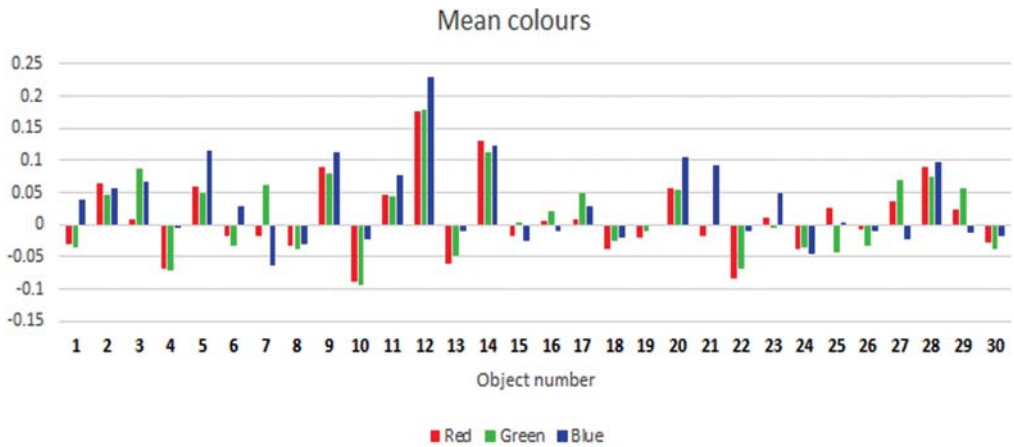


Fig. 31. The difference between the averaged colour of an object and the median colour of the surroundings ( $y = 0$  is the median value for each colour channel)

## 7. Conclusion and summary

The research method developed by the author was meant to parameterise the concept of the dominant element of the landscape. Characteristic qualities of dominant elements of the landscape were listed, such as: a distinct size and height, alteration of the panorama of the city or the skyline, a shape and colour that are different from the surroundings. The results of the calculations performed with the use of an original computer program and presented in Table 3 have shown that objects intuitively assessed to be dominant elements do indeed possess either some or all of these qualities.

It appears that the size and height of an object and its impact on the outline of a panorama or a skyline play a deciding role in our judgement. In the case of architectural forms, their form was also parameterized by means of 11 coefficients. Their values clearly differed from the average and showed the original form of the dominant. The historical object was also characterized by a rich detail, which was indicated by the high values of W5 and W10 coefficients. In the last example, the tree in the foreground was evaluated similarly. This resulted from the greater detail of its contour, which in turn depends on the distance from the observer. The analysed objects, however, did not stand out from other colours, except for the facade of Forum Hotel, which was obscured by a blatant advertising in red.



Table 3. Characteristics of objects signifying that an object fulfils the role of a dominant element

Object characteristics	Case 1 Hotel Forum	Case 2 Monastery of the Pauline Fathers at Skalka	Case 3 Krakow Heat and Power Generation Plant (PGE)	Case 4 A Tree
Significant impact on the skyline	+	+	+	+
Significant size	+	+	+	+
Significant height	+	+	+	+
An original form	+	+	+	-
A wealth of detail	-	+	-	+
Extraordinary colour	+	-	-	-

The research, however, was performed on only four cases, which does not make it possible to prepare full statistical documentation. Due to the complexity of the problem and the variety of spatial situations it should be expanded to include a greater number of different cases.

The results presented by the author show that the method has a universal character and can be applied both in the case of buildings and natural elements. The results that were obtained were similar to intuition. The analysis of the objects in terms of their size, shape, height or colour can constitute an objective tool which can help to precisely determine their role in a composition. Numerical indicators can be helpful in the assessment of existing landscapes, as well as in the monitoring of changes that take place in views or in the making of design decisions.

Due to there being a lack of software on the market that could precisely meet the requirements that were specified, while software with comparable functionality that does exist is expensive, the author decided to develop an original application. Image segmentation, based on highlighting objects of interest, was performed manually using the freeware GIMP program, which is an image editor, and is very labour-intensive and can cause imprecise selection that can produce small errors in the results. Previous attempts at automatic view and panorama segmentation, however, had not produced the desired results [19, 22]. The author encountered numerous dilemmas when performing colour analysis. Some wall fragments of buildings were covered by trees. Two approaches to the solving of this problem were presented. In the first, the greenery was compact – only the visible fragments of buildings were selected, which entailed a change in their surface area, height and shape. In the second, where greenery had the appearance of being see-through – entire objects were highlighted, and thus their geometric parameters were not being changed, but the admixture of the colour of the trees distorted their averaged colours. The method allows for a significant degree of freedom in this regard. We can subject maximally large fragments of the walls of individual buildings that are not covered by trees, to a colour analysis. The next decision concerning the decision as to whether the colours would be analysed for walls along with window openings

and other details or would they be ignored, or would only the colours of roofs be analysed. Another problem appears when a building features the use of materials of a different colour in different parts of it.

The decisions presented above were not free of subjectivity, however, it is most essential to adhere to a consistent approach throughout the analysis of a specific image in relation to all of the objects that are visible in it.

The method is far from fully automatic and from being a machine classification of dominant elements. It constitutes a tool that must be supervised by an expert, but thanks to precise indicators it equips them with objective premises for decision-making, both during the stage of surveying the landscape, as well as during the design process.

*Carrying out research involving the calculation of numerical indicators characterizing the objects was possible thanks to the program created in MATLAB by Piotr Łabędź. I would like to thank him for cooperation.*

## References

- [1] Bishop I.D., *Testing perceived landscape colour difference using the Internet*, „Landscape and Urban Planning”, No. 37, 1997, 187–196.
- [2] Bogdanowski J., *Kompozycja i planowanie w architekturze krajobrazu*, Ossolineum, PAN, Wrocław 1976.
- [3] Böhm A., *Architektura krajobrazu*, Wydawnictwo Politechniki Krakowskiej, Kraków 1994.
- [4] Czarnecki W., *Planowanie miast i osiedli*, PWN, Warszawa 1960.
- [5] Czyńska K., Rubinowicz P., Zwoliński A., *Analizy zabudowy wysokiej w krajobrazie miasta/Analyses of tall buildings in the cityscape*, „Teka Komisji Urbanistyki i Architektury o. PAN w Krakowie”, Tom XLV, 2017, 319–341.
- [6] Dąbrowska-Budziło K., *Wśród panoram Krakowa. O przemianach widoków i o tym, jak je ocalić*, Wydawnictwo Literackie, Kraków 1990.
- [7] Funkcje normalizacji, [http://sztuczna-inteligencja.eprace.edu.pl/1001,Funkcje\\_normalizacji.html](http://sztuczna-inteligencja.eprace.edu.pl/1001,Funkcje_normalizacji.html) (access: 19.07.2018).
- [8] Gadomska W., Marks E., *Contemporary structures dominant due to height in the landscape of the great masurian lake district/Współczesne dominanty wysokościowe w krajobrazie krainy wielkich jezior mazurskich*, „Space&Form = Przestrzeń i Forma”, Nr 33, 2018, 207–224.
- [9] Gonzales R.C., Woods R.E., *Digital Image Processing*, Prentice Hall, New Jersey 2002.
- [10] Graczyk R., *Identyfikacyjna funkcja dominanty architektonicznej w strukturze małego miasta*, Politechnika Poznańska, Poznań 2005.
- [11] Gyurkovich J., *Znaczenie form charakterystycznych dla kształtowania i percepcji przestrzeni*, Monografia PK, No. 258. Architektura, Wydawnictwo Politechniki Krakowskiej, Kraków 1999.

- [12] Łabędź P., Ozimek A., *Detecting greenery in near infrared images of ground-level scenes*, [In:] *Peer reviewed proceedings of Digital Landscape Architecture 2012 at Anhalt University of Applied Sciences*, eds. E. Buhmann, M. Pietsch, M. Heins, Wichmann, Berlin 2012.
- [13] Malina W., Smiatacz M., *Metody cyfrowego przetwarzania obrazów /Methods of Digital Image Processing*, EXIT, Warszawa 2002.
- [14] Małachowicz E., *Ochrona środowiska kulturowego*, PWN, Warszawa 1988
- [15] Myczkowski Z., *Krajobraz wyrazem tożsamości w wybranych obszarach chronionych w Polsce*, Wydawnictwo Politechniki Krakowskiej, Kraków 2003.
- [16] Niedźwiecka-Filipiak I., Borc Z., *Dominants of a Farmer and Modern Village in South-West Poland/Dominanty dawnej i współczesnej wsi południowo-zachodniej Polski*, „Architektura Krajobrazu”, No. 1–2, 2006, Vol. 12.
- [17] Niedźwiecka-Filipiak I., *Wyróżniki krajobrazu i architektury wsi Polski południowo-zachodniej*, Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu, Wrocław 2009.
- [18] Niezabitowski A., *O strukturze przestrzennej obiektów architektonicznych. Podstawy ogólnej morfologii przestrzeni architektonicznej*, Wydawnictwo „Śląsk”, Katowice 2017.
- [19] Ozimek P., Böhm A., Ozimek A., Wańkowicz W., *Planowanie przestrzeni o wysokich walorach krajobrazowych przy użyciu cyfrowych analiz terenu wraz z oceną ekonomiczną/ Planning spaces with high scenic values by means of digital terrain analyses and economic evaluation*, Wydawnictwo Politechniki Krakowskiej, Kraków 2013.
- [20] Ozimek A., *Cyfrowa analiza dopasowania kolorystycznego nowych obiektów do istniejącego otoczenia = Digital analysis of new objects colour matching to the existing environment*, „Space & Form = Przestrzeń i Forma”, Nr 26, 2016, 271–283.
- [21] Ozimek A., Łabędź P., *Quantitative and qualitative analyses of landscape views*, [In:] *Peer reviewed proceedings of Digital Landscape Architecture 2013 at Anhalt University of Applied Sciences*, eds. Buhmann, E., Ervin, S. M., Pietsch, M., Wichmann, Berlin 2013, 93–100.
- [22] Ozimek A., Ozimek P., *Algorytmy przetwarzania obrazu w wyróżnianiu tworzywa kulturowego i przyrodniczego na fotografiach krajobrazowych/Image processing algorithms in cultural and natural substance distinction in landscape photographs*, Nauka Przyroda Technologie 2009, T. 3, z. 1, 12, Poznań 2009.
- [23] Ozimek P., *Zastosowanie algorytmów światła lokalnego w wyznaczaniu wykresów widoczności* (PhD Thesis, promotor: Böhm, A) Politechnika Krakowska, Kraków 2003 .
- [24] Pardo-García S., Mérida-Rodríguez M., *Measurement of visual parameters of landscape using projections of photographs in GIS*, *Computers, Environment and Urban Systems* 61, 2017, 56–65.
- [25] Siewniak M., Mitkowska A., *Tezaurusz sztuki ogrodowej*, Wydawnictwo „Rytm”, Warszawa 1998.
- [26] *Słownik języka polskiego PWN*, <https://sjp.pwn.pl> (access: 19.07.2018).
- [27] *Słownik wyrazów obcych*, PWN, Warszawa 1995.
- [28] Swardon R., Palmer J., Felleman J., *Foundations for Visual Project Analysis*, A Wiley Interscience Publications, New York 1986.
- [29] Stamps III A.E., *Psychology and the aesthetics of the built environment*, Springer, Boston 2000.

- [30] Steinitz C., *Toward a Sustainable Landscape with High Visual Preference and High Ecological Integrity: the Loop Road in Acadia National Park, U.S.A.*, „Landscape and Urban Planning”, 54(2001), Elsevier.
- [31] Szolginia W., *Architektura*, Sigma NOT, Warszawa 1992.
- [32] Tadeusiewicz R., Korohoda P., *Komputerowa analiza i przetwarzanie obrazów/Computer image analysis and processing*, Wydawnictwo Fundacji Postępu Telekomunikacji, Kraków 1997.
- [33] *Terminy architektoniczne i urbanistyczne*, [http://www.dolana.pl/sloownik\\_wyrazow\\_architektonicznych.php](http://www.dolana.pl/sloownik_wyrazow_architektonicznych.php) (access: 19.07.2018).
- [34] Vogt B., Nassery F., *Geometryczne przesłanki zaistnienia dominanty w przestrzeni współczesnego miasta/Geometrical premises of becoming the architectural landmarks in the space of the contemporary city*, „Czasopismo Techniczne”, 6-A/2008, 561–573.