Discrimination of Distance-dependent Zones in Landscape Views

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1 Introduction

A great variety of techniques, including written descriptions, plans, perspective views and panoramas, orthogonal projections or axonometric views and, at least, 3D models are used in order to represent the landscape. Apart from the latter (which have become more popular recently, due to the development of IT), scenic photographs are the most comprehensive for the general public, because they refer to human perception, imitating visual sensations of the observer (KAPLAN & KAPLAN 1989).

GeoDesign may be interpreted as the planning environment that puts the design into the context of its geographic location (FLAXMAN 2010, ERVIN 2011). It equips representatives of different disciplines with adequate tools to merge together their knowledge into a common collection (DANGERMOND 2009). Taking this fact into account, landscape images can be widely used in GeoDesign, as an informative layer, expanding the database related to the specific place.

In landscape analyses often some spatial metrics of image components are used to determine parameters of the analysed scene (SHAFER & MIETZ 1970). These numerical characteristics proved very useful in several tasks, like the studies of landscape preferences, specification of its visual resources, acceptation of landscape transformations, changes monitoring or prediction of future development scenarios (SMARDON et al. 1986, PALMER 1997, 2004). In the research mentioned above serious problems occur due to geometrical distortion, inseparably connected with the perspective projection. Therefore, a comparison between characteristics of objects can give biased results, if their depth in the scene differs. On the other hand, elements of a given view (buildings, trees, rocks) are comparable, regarding their dimensions, shapes or patterns, when they are positioned in the same distance-dependent zone.

The aim of this paper is to present some image processing techniques, appropriate to picture segmentation, for the purpose of automatic or semi-automatic detection of distance-dependent sectors (Fig. 1). In this process a photograph should be split into several sub-images, including adequate areas (e.g. a distant residential area or a forest). The surface of the

Fig. 1: A landscape photograph with the re-coloured distance-dependent zones

selected fragment can be used as a binary mask (MALINA & SMIATACZ 2005), in order to conduct further analyses affecting only this part of the picture (for the exemplary residential zone – to calculate the typical size or shape of buildings).

2 Task analysis

2.1 Distant-dependent zones

Shafer and Mietz distinguished eight zones that can be grouped with regard to distance: immediate (the foreground), intermediate and distant ones, as well as the background and the sky (SHAFER & MIETZ 1970). The taxonomy proposed focused on the analyses of the most beautiful wild landscapes. In everyday practice, particularly, in our European circumstances, landscape architects usually deal with semi-cultural or cultural landscapes (i.e. countryside or urban areas) (SMARDON et al. 1986). Therefore, this systematisation should be supplemented with zones embracing invested terrains, divided according to various types of developments (residential, commercial, industrial), their scale and density. In this case, distance-dependent fragmentation should be maintained, as well (BUHMANN et al. 2011).

From these image parts, two should be excluded from calculations in the initial phase of image analysis: the sky and the foreground. The sky is not objective of this research; moreover, its percentage in the image may depend on the position of the camera and on photographs framing (RIBE et al. 2002). The background includes objects that play no significant role at the landscape scale; however, if this part includes negative elements, the view is usually estimated low (BUHMANN et al. 2011). In addition, the foreground contains a huge number of details and much variation; it is therefore difficult to distinguish among the elements in support of scenic research.

2.2 Distant-dependent features of scenic photographs

We can point out distance-dependent features that are specific for landscape photographs (Fig. 2), the most important of which include:

- the blue haze,
- colour intensity,
- colour diversity,
- contrast between the adjacent pixels.

While the first of these variables increases proportionally with distance, the rest of them – decrease. The characteristics mentioned above will be exploited in a first attempt to conduct automatic or semi-automatic image segmentation.

Fig. 2: Distance-dependence features specific for the landscape photographs (haze, saturation, colour diversity, contrast)

3 Methods

From a whole range of scenic photographs, one was chosen for this illustration, which was taken in a cloudy day. The similarity in colour between distant mountains and the sky makes the distinction of these zones problematic (Fig. 2). In the research all the distance-dependent features have been employed.

Fig. 3: A blue channel of the image

The photograph usually registered in the RGB mode, can be easily split into colour channels (red, green, blue) in almost all graphical environments. In case of scenic views, image segmentation based on the blue channel is often effective, because of the light dispersion (a haze), which results in the increase of the values of blue component with distance (Fig. 3). An image histogram (the diagram showing the number of pixels at every level of intensity) may be analysed regarding local minima (Fig. 4). They usually indicate thresholds for image binarization (conversion into black-and-white mode) (GONZALES & WOODS 2002, JAYARAMAN et al. 2009).

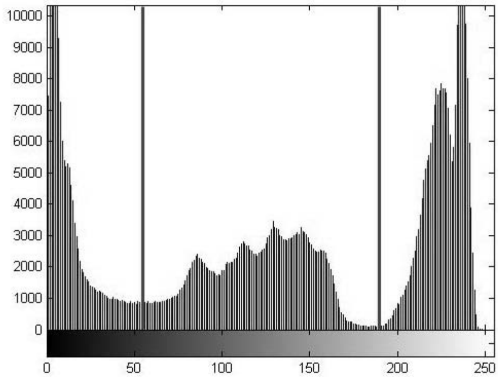

Fig. 4: A histogram of the blue channel with local minima (level 54 and 197)

An image representing colour intensity (Fig. 5) was obtained as a result of image conversion from RGB to HSV (hue, saturation, value) mode and the second channel separation (GONZALES & WOODS 2002, JAYARAMAN et al. 2009).

Colour diversity can be estimated by different indicators, like data variance, standard deviation or z-score method. Another approach consists in the calculation of the difference between pixels' values and the arithmetic mean or the median computed for the whole image. In the research the three variants were examined:

- the absolute difference between every pixel value and the image mean,
- the absolute difference between every pixel value and the image median,
- standard deviation calculated according to the equation:

$$\sigma = \sqrt{\frac{1}{N}\sum_{x=1}^{N}(x_i - \mu)^2}$$

where:

N – the number of pixels,
μ – the image mean.

In contrast calculation the formula was employed:

$$\Delta E^{*}_{abs} = \left[\left(\Delta L^{*}\right)^{2} + \left(\Delta a^{*}\right)^{2} + \left(\Delta b^{*}\right)^{2}\right]^{\frac{1}{2}}$$

where:

ΔE^{*}_{abs} – stands for the absolute colour difference,
ΔL^{*}, Δa^{*} and Δb^{*} – are differences in colour parameters in CIE L*a*b* colour models.

This colour difference equation was a subject of research, which confirmed that it is applicable not only for industrial purposes, but for analyses of scenic views, as well (BISHOP 1997). In this case a photograph was previously filtered with a high-pass filter, in order to enhance colour difference between the adjacent pixels.

Fig. 5: Image saturation (decreasing with distance)

With the aim of taking all four distance-dependent factors into consideration, three grayscale images were generated: the blue channel (Fig. 3), image saturation (Fig. 5) and contrast combined half and half with image colour diversity (Fig. 6). They were saved in grayscale mode (8-bit depth) and used as RGB channels of the new colour space, resembling “false colour compositions”. On the basis of the fact that there are three variables, six different allocations are possible. In the eye of beholder their usefulness may be different, since our sensitivity for colours is irregular. From the numerical point of view, they still represent the same content.

Fig. 6: Image contrast combined with the difference between pixels’ values and the image median

In order to check whether this new colour space is efficient and to obtain more objective results, Bayes naive classifier was applied for the specific zone detection (MALINA & SMIATACZ 2010).

After the manual indication of samples representing a given "class" (e.g. distant mountain range) in the landscape view, the parts of this image are classified as belonging to the same class, according to the rule of the maximum likelihood.

4 Results

In the analysed picture the separation of the foreground and the distant elements (mountains and sky) basing on the blue channel and its histogram characteristics brings positive results (Fig. 7). On the other hand, in case of the horizon line, the histogram of the blue channel is not useful, since they have similar characteristics, as far as colours are concerned (Fig. 2 and 3).

The results of three approaches towards estimation of colour diversity are presented in Fig. 8 and 9. The difference between pixels' values and the image median was chosen, as it returns the results with the most profound visual discernment between the fragments located at different depths (Fig. 8).

In this new colour space the visual distinction between distance-dependent zones is facilitated. This subjective feeling was verified by means of the program that exploits the naive Bayes classifier. The fragments classified as belonging to the indicated class are coloured in saturated yellow, which was absent in the original image (Fig. 10 – 14).

Fig. 7: Separation of the foreground – a threshold in the blue colour channel (a binary mask).

Fig. 8: A new colour space (R = image saturation, G = contrast + the absolute difference between pixels values and the median, B = blue channel)

Fig. 9: A new colour space (R = image saturation, G = contrast + standard deviation of pixels values, B = blue channel)

The attempt of distant rocks selection in the original image brought unsatisfactory effects. It was impossible to choose adequate parameters in order to distinguish the mountain range (Fig. 10). As a result of distance-dependent factors adoption, detection of a given fragment became more precise (Fig. 11). Some errors appearing in the top left hand corner (misclassified fragments of the sky) may be eliminated after supplementing the algorithm with the rule of adjacency. Starting from the area indicated as the sample, the program checks the neighbouring pixels and removes detached areas (Fig. 12).

Figures 13 and 14 show the results of this algorithm application for different landscape views. In the first of them an attempt was made to distinguish the spruce groves in front of the lake. In the second image the sky was chosen to be classified as the most differentiated area (clouds and colour gradient).

5 Conclusions and Outlook

Thanks to the idea of using grayscale images, which represent distance-dependent features, as the RGB colour channels, the quality of the photograph can be improved in such a way that detection of the foreground, the intermediate and distant zones, as well as background and the sky, is facilitated. Differences in the values of the blue channel, image saturation, its

Fig. 10: An attempt to detect the distant mountain range in the original image

Fig. 11: Detection of distant mountains in the image displayed in the new colour space

Fig. 12: The result of misclassified fragments elimination

contrast and colour variation, help to expose individual characteristics of areas that look similar in the original photograph. However, it should be kept in mind that this transformation does not introduce new information into the picture, but only depicts it in the more useful way.

Fig. 13: Distinction of groves located in front of the lake (with checking adjacency)

Accordingly, in some photographs automatic distinction of sub-images is impossible, due to the identical colours of different objects. In these cases the algorithm should be supplemented with the module that checks the pixels neighbourhood and removes remote areas. However, in numerous views, detached fragments belong to the same object. In Fig. 11 elements from the foreground cut through the forests and meadows located in the intermediate distance. The groups of trees and residential buildings are dispersed in the Fig. 13. As a consequence of the adjacency rule application, the program did not mark the rows of trees at the lakeside. Taking this fact into consideration, the decision on remote fragments removal should be left to the user.

Fig. 14: Detection of the sky

Fig. 14 depicts unsolvable problem of pixels' values identity. The colours of the distant hill and the sky are so similar that even after image conversion into the new colour space they are numbered among the same class.

The tolerance factor makes the class definition fuzzier, which guarantees more precise results. When the class is more homogeneous, the value of the tolerance factor should be low. On the contrary, while the data are diverse, it should be higher. At present, this calibration must be made manually, basing on the user's judgement. The excelled effects are achieved when the samples of the class are pointed at image fragments that have extreme features, in respect of colours.

The detection of the zones containing dispersed objects with the high colour variety meets cardinal difficulties. The types of areas mentioned above appear not only in the foreground, but also in the more distant zones, like for instance dispersed development, fragmented fields and meadows. The question still remains, how to precise fuzzy boundaries of zones containing these kinds of objects. It is worth to notice, that this decision may influence the results, e.g. calculating the intensity of residential area.

Another approach toward distance zones estimation may consist in the application of 3D cameras. The distance between the objects and the camera can be calculated, based on the geometrical dependencies. Due to its complexity, this problem should be a subject of the individual research.

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