Detecting Greenery in Near Infrared Images of Ground-level Scenes

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1 Introduction

An increasing demand for landscape digital analyses entails a rapid progress in the numerous fields of computer science, including image processing. A wide spectrum of problems was solved using remote sensing techniques, albeit applied algorithms operate on satellite or aerial views (ADAMS & GILLESPIE 2006). However, our environment is usually perceived by observers from the eye-level; therefore, ground-level views and panoramas seem to constitute landscape representation, which corresponds with the human visual sensations in the best way.

Scenic photographs, adequately transformed, provide important information about land cover. These images consist of components that can be divided into three groups: the natural or cultural substance and the background. An automatic identification of the sky in digital photographs can usually be accomplished on the basis of its colour. After reduction of this element, the view contains only natural (prevailing vegetal) and cultural objects. Effective image segmentation, aimed at their distinction is often hampered by similarities in the colours of vegetation and man-made objects, like house walls and roofs, café parasols or park benches. The further difficulties are caused by variations in the colour of vegetation with changes in season (particularly in the autumn) and lighting conditions (due to solar filtering, intensity, direction and orientation, in relation to the camera). Therefore, resulting images have to be controlled and corrected manually (OZIMEK & OZIMEK 2009).

In bi-level (black-and-white) images, with the distinction of cultural substance (Fig.1), quantitative and qualitative parameters of the view can be calculated. Basing on these data, research focused on landscape evaluation can be conducted (UNWIN 1975).

Application of vegetation indices (KRIEGLER et al. 1969, HUETE et al 2002) combined with thresholding operation (converting the image into a binary mode) potentially allows for automatic image pre-processing, with the object of greenery detection. The negative image would present only anthropogenic elements. It should be noticed, that this method does not take into account the other natural elements of view, such as water, rocks or bare soil.

Fig. 1: An example of bi-level image with buildings marked with white colour
This paper explores the effectiveness of vegetation indices (used in remote sensing) to automatic detection of plants using near-infrared photographs taken at ground-level. In particular, it examines the differences in various lighting conditions (sunny and cloudy days) and diverse leaves colours (green, yellow, red, brown).

## 2 Material and Methods

### 2.1 Vegetation indices

In remote sensing, NDVI (Normalized Difference Vegetation Index) is calculated basing on the equation:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where: NIR – means the near infrared channel, R – stands for the red channel (KRIEGLER et al. 1969).

As it can be seen from the graph of spectral characteristics of plants (Fig. 2), the algorithm can bring entirely correct results, as far as the distinction of verdure from the other “green” objects is concerned. Nevertheless, the problems related to the atmospheric effects (water vapour content) appear, especially in distant views.

In order to improve the results, EVI (Enhanced Vegetation Index) was put into practice, which is not only “chlorophyll sensitive”, but also takes into account the blue channel, responsible for atmospheric clutter (HUETE et al. 2002).

It is computed from the equation:

$$EVI = G \frac{NIR - R}{NIR + C_1R + C_2B + L}$$

where: NIR/R/B – colour channels: near infrared, red and blue, respectively, L – the canopy background, C_1 and C_2 – coefficients, considering aerosol resistance in the atmosphere, G – gain factor, L – soil adjusted factor. In the most popular MODIS EVI (Moderate Resolution Imaging Spectroradiometer) implementation they are: L = 1, C_1 = 6, C_2 = 7.5, and G = 2.5. The results are calibrated for the specialist equipment (ADAMS AND GILLESPIE 2006).

### 2.2 Input data

The equations show that both algorithms operate on non-spectral range, including near infrared. In this case, process of the image acquisition requires usage of the professional
devices. Nonetheless, the standard CCD matrix in a photo camera is sensitive for the electromagnetic wavelength between 350 and 1200 nm. This range is limited to the visible spectrum (380 – 760 nm) by means of filters. After their removing and using IR filter instead (> 850 nm), it is possible to register near infrared, crucial for the computations. These data have to be supplemented with colour channels (red: 600 – 760 nm, green: 500 – 600 nm, blue: 380 – 490 nm) from the second photograph of the same scene, made in the visible range. In the initial phase of the study, various techniques of image formation (JPG with “white balance” setting, or data from RAW format) have been checked, in the context of the results correctness.

Beyond question, the process of photography registration plays a crucial role in the final effects. It embraces, above all, sufficient image resolution (at least matching sight resolution) (BISHOP 2003), its correct sharpness, white balance and exposition. The calculations have been made for images 4302 × 2860 pixels with the equivalent focal length equal to 120 mm, redundant for human perception (the sufficient image size for this focus is 1600 × 1200 pixels). The photographs have been registered in the RAW format and converted into TIFF standard.

2.3 Modelling approach

The first step of the applied algorithms was a colour channel separation, which enables calculations on 2D matrices. NDVI and EVI indices have been computed, following the equations, cited in the section 2.1.

Afterwards, image binarization should be conducted, in order to obtain an image with the black background and plants marked with white colour. The value of threshold can be understood as the level, with which intensity of every pixel is compared, and points that are darker than the threshold take minimum value (black). The remaining pixels are converted into the maximum value (white). The main difficulty lies in the accurate choice of this threshold value. In other case, the result can be wrong.

The Otsu method has been chosen, since it guarantees comparatively correct results. In the initial phase of this technique, the histogram of image brightness is calculated. For every threshold, which divides image into two classes (objects and background), the between-class variance and the inner-class variance is calculated. As a result, the value of threshold is chosen, for which the inner-class variance is the smallest and, at the same time, the between-class variance is the biggest (RUSS 2002, PETROU & PETROU 2010, MALINA & SMIATACZ 2005). In the case, when the effect of this operation is negative, the manual choice of the threshold is possible, basing on the histogram features. Frequently, selection of the local histogram minimum brings about effective class separation (JAYARAMAN et al. 2009, MALINA & SMIATACZ 2005).

In the resulting images numerous errors appear, in particular, tiny spots that do not correspond to objects, but occur as the effect of insignificant differences in image local brightness. In order to remove them, morphological operations can be applied. Two basic operations, dilation and erosion, conducted successively, constitute the more complex transformation, known as closing (JAYARAMAN et al. 2009, MALINA & SMIATACZ 2005, NIENIEWSKI 1998). The outcome is more generalized; a picture loses in details, small holes are filled and the objects contours are smoother (Fig. 3).
Detecting Greenery in Near Infrared Images

Fig. 3: Algorithms of greenery distinction

NDVI calculation

- Reading an image in the visible light
  - Reading an image in infrared NIR
    - Red channel separation
      - Numerator calculation = difference NIR – R
      - Denominator calculation = sum NIR + R
      - Quotient calculation = numerator/denominator
        - Histogram calculation
          - Binarization using Otsu algorithm
            - Is the result satisfying?
              - Y: Image closing
                - Resultant image writing
              - N: Manual choice of threshold

Modis EVI calculation

- Reading an image in the visible light
  - Reading an image in infrared NIR
    - Red and blue channels separation
      - Numerator calculation = difference NIR – R
      - Denominator calculation = sum NIR + 6.5*R + 7*B + 1
      - Calculation of the equation: 2.5*(numerator/denominator)
        - Histogram calculation
          - Binarization using Otsu algorithm
            - Is the result satisfying?
              - Y: Image closing
                - Resultant image writing
              - N: Manual choice of threshold
3 Results

3.1 NDVI versus EVI

In the first experiment two vegetation indices (NDVI) have been compared. Fig. 4 shows the image in the visible spectrum and the next one (Fig. 5) – the same scene in near infrared (NIR) channel. The greenery is characterized by the high intensity, as well as the bright building seen in distance.

Fig. 6 and 7 present automatically binarized images obtained as the products of NDVI and MODIS EVI calculation. They seem to suggest that the NDVI (Fig. 6) promises better outcome; however, it should be taken into consideration that MODIS EVI (Fig. 7) is scaled for specific equipment (spectroradiometers). After elimination of calibrating coefficients (Fig. 8) both indices provide similar results. Fig. 9 confirms this fact, showing insignificant difference between the resultant images. The final effect (after closing operation – Fig. 10) presented in the Fig. 11 has been obtained by the operation of the logical negation and the background elimination.
3.2 Different lighting conditions

In order to examine the effects of automatic greenery detection in different lighting conditions, photographs were taken during the sunny and cloudy days (Fig.12 and 13). In addition, the same scene was photographed in a moment, when the sun was temporarily
obscured by clouds. The autumn season was chosen, because in this case, plants distinction was the most problematic. There are numerous obstacles, when the photographs are taken against the light and the branches are only partially covered with leaves. Like in the previous example, the calculations of NDVI and EVI (without calibrating coefficients) for a specific image gave almost identical results (Fig. 14 and 15). The difference in automatic greenery distinction in various lighting condition is noticeable (Fig.16).

3.3 Various leaves colours

When leaves change the colour in the autumn, their reflection in near infrared remains at the high level, thanks to the fact they still contain some chlorophyll. Simultaneously, the content of carotenoids is increasing. These substances are responsible for red, orange and yellow hues appearing in this season (Fig. 18). They reach high values in the red channel, which has the negative impact on vegetation indices calculations (Fig. 19). Like in the former experiments, in the last image (Fig. 20) an attempt was made to distinguish man-made objects in the analysed view, but results are burden with errors. In this photograph, beside the problems concerning greenery, some faults occur as a result of reflections in windows and other glossy surfaces (Fig. 20).
4 Conclusions and Outlook

In this paper an effort was made to evaluate the usefulness of NDVI and EVI for automatic greenery detection in the eye-level views. This determines the initial step for cultural substance distinction, which is crucial for landscape parameters calculation and would help in its evaluation. As it was proved by the experiments, both indices (NDVI and EVI without calibrating values) provide similar results.

In the resultant images some errors occurred, in particular:

- The absence of chlorophyll in trees trunks and branches, as well as in dry grass or fruits cause that they are not indicated as parts of plants. In particular, it is visible in the foreground (Fig. 4, 11, 12, 13, 17).
- As a result of seasonal colour changes (yellow leaves), the level of reflectance in the red channel rises; thus, the values of vegetation indices become low (Fig. 20).
- Some inaccuracy occurs in the objects contours, prevailingly, as the consequence of pixels values interpolation (antialiasing) (Fig. 11).
- Glossy surfaces (glass, water) reflect waves, not only in the visible spectrum, entailing their resemblance to the source objects (Fig. 20).
The applied algorithms are dedicated to the “green parts” of plants, therefore the other natural elements (soil, rocks, water) are not detected (Fig. 12, 17).

The problems with plants indication appear, while photographs are taken against the light; particularly, when the branches are not fully covered with leaves.

On the other hand, the algorithm proposed in the part 2.3 brings several advantages:

- Distinction between the verdure and green man-made objects is effective (Fig. 3, 5, 7, 9).
- Fragments of plants located in the shade are characterized with the high level of reflectance in near infrared, and low in the red channel; therefore, they are properly distinguished by the vegetation indices (Fig. 11, 13, 17, 18).
- The algorithm brings correct results in distant parts of the view (Fig. 6, 8).
- The Otsu method provides positive outcomes. Seldom, was the manual correction of the threshold level necessary (Fig. 9, 11, 14, 16).

The aim of the research has been realised to some extend. While the distinction between anthropogenic objects and distant areas covered with trees or grass is effective and can automate the phase of image processing, a considerable number of faults appear in the foreground.

What was to be expected, only fragments of plants that contain chlorophyll (leaves) can be indicated using the algorithm proposed. Therefore, the method does not guarantee correct results in the separation of the other natural landscape components (trees branches and trunks, water, soil, rocks).

The further difficulties are due the reflections in glossy objects. Spectral similarity between the mirror images and real objects has the negative effect on the outcomes.

Some errors are integrally connected with the raster image structure. Antialiasing, accomplished in order to smooth objects contours, causes inaccuracies that appear at the edges, in particular, when the local gradient is high.

References


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