The Study of Requirements for the System of Automatic Measurement of Vegetation Cover in River Catchments

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Abstract - In this paper we present an application of statistical pattern recognition methods to the analysis of air photographs in order to evaluate the vegetation cover in a Pilica River catchment (Central Poland). The analysis is a basis for using plants to improving water quality and increasing its availability. The task for the image processing and analysis system is to recognize in the air picture the regions of different vegetation forms and water containers, and evaluate their area. The most difficult problem from the point of image processing is segmentation due to altering the color of vegetation forms. An automatic image analysis is intended to replace geodetic measurements.

Keywords – Air picture, vegetation, image processing and quantitative analysis, river catchment.

I. INTRODUCTION

Pilica River (Central Poland) is a right side tributary of the Vistula River, its length is 342 km and catchment area of 9,258 km². In the catchment, agriculture which covers 64.2% of the area is the dominating land use. The forests comprise 30.7%, and other types of land cover 5.1%. The study site is the floodplain of the Pilica River valley, (51°18’58.46”N and 19°54’10.54”E), located in the middle reach of the river, upstream of the Sulejów Reservoir (Fig. 1). The experimental floodplain has a total area of 26.6 ± 2.7 ha.

II. GEODETIC MEASUREMENTS

A map of plant communities distribution of the Pilica River floodplain [3] was created based on the digital terrain model (DTM) in scale 1:2500. A DTM of the floodplain was developed by using geodetic measurements on the floodplain, which basis of trigonometric leveling from 815 points of the floodplain, with the aid of an electronic TOPCON GTS-211D tachymeter. The data was calculated using the geodetic WinCalc program for MS Windows™ V.3.5, and visualized with MicroMap for MS Windows™ V.4.0, and CorelDraw 9.0 applications. The map drawn in CorelDraw is presented in Fig. 2.

![Fig. 1. Location of the experimental Pilica River floodplain (Central Poland).](image1.png)

![Fig. 2. Distribution of plant communities on the Pilica River floodplain](image2.png)

The evaluated distribution of the area has been presented in Table 1.

<table>
<thead>
<tr>
<th>Community</th>
<th>Area [m²]</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole floodplain</td>
<td>266000.00</td>
<td>100.0%</td>
</tr>
<tr>
<td>Meadows</td>
<td>153281.25</td>
<td>57.6%</td>
</tr>
<tr>
<td>Rush with Carex</td>
<td>59793.75</td>
<td>22.5%</td>
</tr>
<tr>
<td>Rush with Phragmites</td>
<td>13262.50</td>
<td>5.0%</td>
</tr>
<tr>
<td>Old river bed</td>
<td>2000.00</td>
<td>0.8%</td>
</tr>
<tr>
<td>Willow bush</td>
<td>25000.00</td>
<td>9.4%</td>
</tr>
<tr>
<td>Forest</td>
<td>4000.00</td>
<td>1.5%</td>
</tr>
<tr>
<td>Other</td>
<td>8680.00</td>
<td>3.3%</td>
</tr>
</tbody>
</table>

III. IMAGE PROCESSING ALGORITHMS

Laborious geodesic measurements of the terrain may be replaced by color air picture analysis. The images may be taken with use of camera on a plane, balloon or a satellite. The aim of the image analysis is segmentation of the viewing area into regions that correspond to the individual plant communities and other objects: water, buildings, roads. We decided to extract 8 classes of objects: wet meadows, dry meadows, rushes with carex, rushes with pbrugmites, willow bushes, forests, water and remaining area. The images may be characterized by the following features: pictures are in color, but the saturation of the color is attenuated;

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Appendix

- the available resolution of the image is about 2 pixels per meter, but the exact scale is unknown and must be calibrated;
- the classes of objects may be distinguished with use of texture, color and intensity, but the results may be distorted by varying exposure conditions (weather, season of the year).

Moreover, some classes of objects are very similar to each other, for instance water (especially from old river bed) has similar color that rushes with Carex, and wet meadows are similar to rushes with Phragmites. The meadow may be partially dry and wet and some plants appear together. The observation leads to the conclusion that the supervised method of image recognition must be applied. We decided to use the well-known \( k \) nearest neighbor rule \([2]\), which has been successfully applied for many other classes of images \([1]\). The feature vector is calculated for each pixel of the image. The coordinates are: hue, saturation, intensity, and intensity gradient and variance obtained for the pixel neighborhood. To calculate the color coordinates an RGB to HSI conversion must be applied \([5]\). For the neighborhood of the pixel \( p \) (Fig. 3),

\[
\begin{align*}
    p_1 & = p_x \\
    p_2 & = p_y \\
    p_3 & = p_z \\
    p_5 & = p_s \\
    p_6 & = p_h \\
    p_7 & = p_i \\
\end{align*}
\]

Fig. 3. The notation for pixel neighborhood the gradient magnitude is obtained as shown in the Eq. 1

\[
\begin{align*}
    \nabla p_i &= \frac{1}{3\sqrt{2}} \sqrt{\text{grad}X^2 + \text{grad}Y^2} \\
    \text{grad}X &= p_i + p_+ + p_- - p_+ - p_- \\
    \text{grad}Y &= p_i + p_+ + p_- - p_+ - p_- \\
\end{align*}
\]  \hspace{1cm} (1)

The variance is calculated as shown in the Eq. 2

\[
\begin{align*}
    \sigma^2 &= \frac{0.0045}{m} \sum_{i=1}^{m} (p_i - m)^2 \\
    m &= \frac{1}{9} \sum_{i=1}^{m} p_i \\
\end{align*}
\]  \hspace{1cm} (2)

The distance function for the feature space is defined as:

\[
\begin{align*}
    \rho(c, c_i) &= \rho_n \left( \left( H_i - H \right) + |S - S| \right) \\
    &\quad + |I - I| + \left| \nabla c - \nabla c_i \right| + \left( \sigma^2 - \sigma_i^2 \right) \\
\end{align*}
\]  \hspace{1cm} (3)

where

\[
\rho_n \left( H_i - H \right) = \frac{1}{1.8} \left[ \begin{array}{c} \left| H_i - H \right| \left| H - H_i \right| < 180 \\
                          \left( 360 - \left| H_i - H \right| \left| H - H_i \right| \right) \left| H_i - H \right| \geq 180 \end{array} \right. \\
\]  \hspace{1cm} (4)

The coefficients in Eqs. 1-4 are intended for feature standardization.

The training set is obtained manually for the picture. The user of the program has to point a few pixels belonging to each type of object. Nevertheless, the number of samples in training set may be too large, because the user may “click” new points without any limitation. Before the classification the training set is reduced to 50 samples using Skalak procedure \([4]\). As the number of samples (image pixels) reaches a few millions, the reduction is very helpful.

The number of found samples for each class is proportional to the area of each community. To obtain the appropriate scale the user must find the known distance in the image (for example a road length), mark its extreme points and enter the distance value.

IV. RESULTS AND CONCLUSIONS

The results of the recognition are presented in Table 2.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
Community & Area [m²] & Fraction \\
\hline
Whole floodplain & 306698 & 100.0\% \\
Wet meadows & 133359 & 43.5\% \\
Dry meadows & 34345 & 11.2\% \\
Rush with Carex & 91823 & 29.9\% \\
Rush with Phragmites & 23231 & 7.6\% \\
Old river bed & 1541 & 0.5\% \\
Willow bush and forest & 22399 & 7.3\% \\
\hline
\end{tabular}
\end{table}

The area, that has been analyzed appeared slightly greater than obtained from geodetic measurements. The meadows change their wetness and of coarse color, so the areas of wet and dry meadows should be added. The total meadow area is 167704 m² (54.7\%), which is a value comparable to the geodetic examination. Rushes are the communities, which is more difficult for optical recognition. The color of the rush with Carex is very similar to water, and this is the reason, why the optical area analyses differ from the geodetic measurements (rushes with Carex 29.9\% instead of 22.5\%, rushes with Phragmites 7.5\% instead of 5\%). The area obtained for old river is a bit less than real area (0.5\% instead of 0.8\%). The water is hardly visible, because the plants cover the water surface. The area of willow bush and forest appeared underestimated (7.3\% instead of 11\%). The recognition of the area with trees is more difficult, the area has a specific texture. In the future we intend to employ some texture oriented image segmentation algorithms to deal with the problem.

ACKNOWLEDGMENTS

The research was supported by the Polish Ministry of Education and Science, project: 2 PO4F 053 28.

We particularly thank dr eng. G. Kowalski, the staff and students of the Technical University of Lodz for collaboration on the development of the DTM of the floodplain.

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