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A Tool for Quantifying the Urban Gradient

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A Tool for Quantifying the Urban Gradient

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Abstract

There are several researches about the impact of the urbanization process with regard to the biota. These require standardized methods for broad measurement of landscape urbanization. The difficulty in finding a suitable method is the lack of uniformity and easily applied measurements of urbanization. This paper introduces a useful software tool based on a validated semi-automated method of measuring the degree of urbanization, which uses the worldwide accessible satellite imagery, image analysis and machine learning algorithms freely.
Using the tool needs only some manual work: giving the coordinates (longitude and latitude) of the centers of the examined locations, and selecting a few training points per location. The proposed system consists of a Windows Desktop Application for the whole process of calculation, a Windows Phone Client (WPC) for an easy way to collect locations, Web Services for WPC and a Website for crowdsourcing. Since the applied machine learning algorithm is supervised and the appearance of the structured elements and the surface are extremely diverse, the enlargement of the training set in an automatic way is essential. Using the desktop application the users can export their results and share them with others. Validating uploaded data is very time consuming, so it is available for crowdsourcing by soliciting contributions from the researchers.

Keywords: Crowdsourcing, semi-automated tool, supervised learning, urbanization index

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Introduction

Effect of Urbanization

Urbanization occurs at an accelerating rate worldwide. According to the United Nations[1] 52% of the inhabitants of the World lived in urban areas in 2011 and the average annual growth rate has been 1.97% between 2010 and 2015. The effect of urbanization can be observed by several natural phenomena. Liker et al. (2008) uses data records of more than 10 years to investigate the change of the weight, size, and condition of birds along the urbanization gradients. They observed house sparrows, but also other living beings or other natural or artificial phenomena can be the target of research of environmentalists or other researchers. In (Bókony et al., 2012) the birds from areas of different urbanizations are compared considering the relation between their condition and their competitive behavior. Vincze et al. (2015) gives an answer to how urbanization facilities individual recognition of humans by house sparrows.

Motivation

For these kinds of studies, it is necessary to quantify the intensity of landscape urbanization, which is often characterized by the proportion of areas covered by buildings, roads and vegetation (McDonnell and Hahs, 2008). A simple scoring method and its semi-automatic process has been validated by us (Seress et al., 2014) related to the quantification of the urban gradient. This paper introduces a useful software tool developed by us to help researchers measure urbanization in an inexpensive way.

Related Techniques

Scoring Method

The scoring method (Liker et al., 2008) uses satellite images of squared areas divided into 10 × 10 cells. The content of each cell is evaluated considering the type of the three major land-cover characteristics, namely vegetation (V, including agrarian areas and brownfields), and paved surfaces (R, mostly roads and parking lots), as follows:

$$V = \begin{cases} 0 & \text{if proportion of vegetation cover is } 0 \\ 1 & \text{if proportion of vegetation cover is between } 0\text{ - }50\% \\ 2 & \text{if proportion of vegetation cover is above } 50\,\% \end{cases}$$

[1] World urbanization prospects: The 2011 revision," United Nations Department of Economic and Social Affairs/Population Division, New York, Tech. Rep., April 2012. (http://bit.ly/1kC0wmW).

$$B = \begin{cases} 0 & \text{if proportion of building cover is } 0 \\ 1 & \text{if proportion of building cover is between } 0\text{-}50\,\% \\ 2 & \text{if proportion of building cover is above } 50\,\% \end{cases}$$

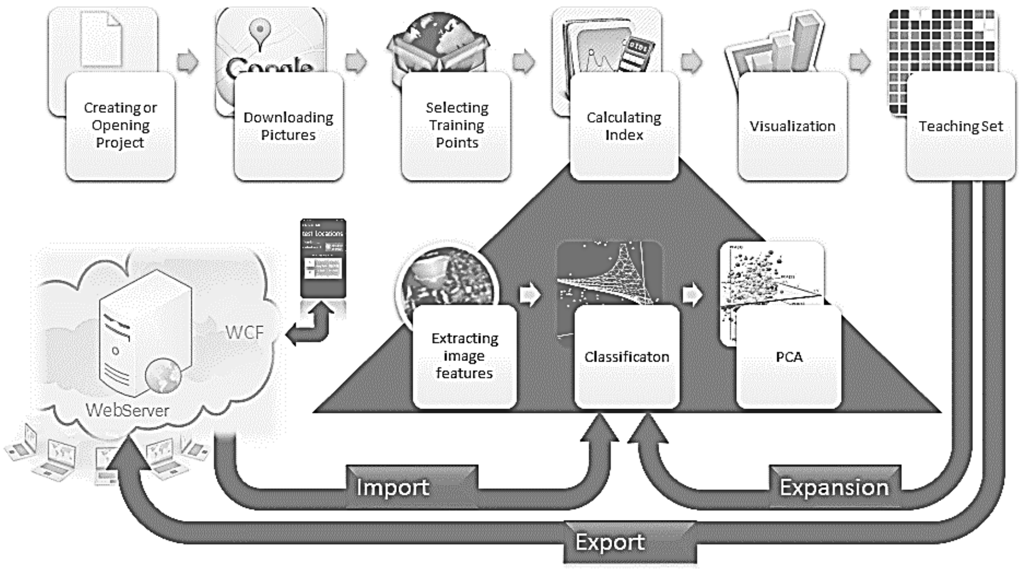
$$R = \begin{cases} 0 & \text{if no paved surface is present} \\ 1 & \text{if paved surface is present} \end{cases}$$

From these cell scores the following summary land-cover measures are calculated: mean building density score (potential range 0–2), number of cells with high building density (>50% cover; range 0–100), number of cells with paved surfaces (range 0–100), mean vegetation density score (range 0–2), and number of cells with high vegetation density (>50% cover; range 0–100). The 'urbanization score' is calculated using the PC1 score from a principal component analysis (PCA) of the five variables described above.

Semi-automated Process

The semi-automated process, based on the scoring, was developed by Czúni et al. (2012). This method is a trained classification method based on the analysis of several image features; its aims is to reduce the time required for scoring while retaining as much precision as possible. The whole process of the scoring method can be seen on Figure 1.

Figure 1. *Process of the Scoring Method Using the Tool*



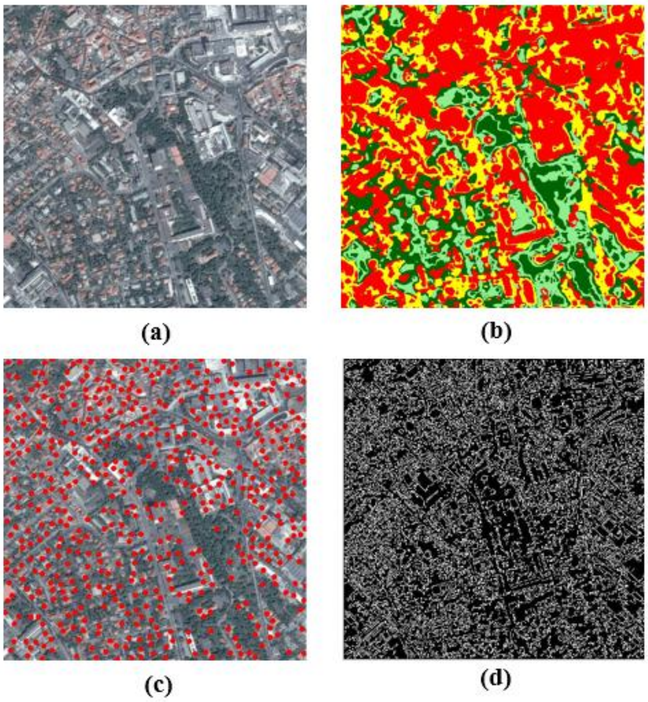
Used Data

This process uses freely and widely available satellite imagery from visual spectra downloadable by Google Maps API. Since this data is collected from several sensors and captured in different seasons and time of the day, its quality and visual appearances are diverse. For robust operation the usage of high amount of various image features is necessary.

Image Processing

The image processing module extracts 52 different features based on color, texture, and local contrast (edges and corners) information, as described in detail by Czúni et al. (2012). The following features are calculated: the number of edge points detected by the Canny edge detector (Canny, 1986) applied in 19 different settings (19 values); number of points belonging to each of the 5 specified segment classes: grass, tree/bush, building, paved surface, others, with 4 different window size settings of the Laws classifier (20 values; Laws, 1980); number of corner points detected by the Harris corner detector (Harris and Stephens, 1988) applied in 6 different settings (6 values); average value of Red, Green and Blue channels within a block (3 values), average and modus of Hue (of the HVS color space), and the corresponding variance of Hue (4 values). Some examples of the results of these algorithms are shown on Figure 2. Among these methods only the Laws classifier requires some manual work with the selection of some training points, the others run automatically.

Figure 2. *Results of the Image Processing Algorithms (a) the Original Satellite Image, (b) the Output of the Laws Classifier, (c) the Output of the Harris Detector, (4) the Output of the Canny Edge Detector*



Machine Learning

For the application of the scoring method the labels of the surface proportion should be estimated. The Support Vector Machine (SVM) with a Radial Basis Function is used for this (Cortes and Vapnik, 1997). As with any supervised algorithm, it needs a teaching set for training and cross validating the classifier. Manually scoring values have been used for this by a single observer (G.S.) who has extensive practice with manual scoring. Table 1 shows the parameters of the three SVM models.

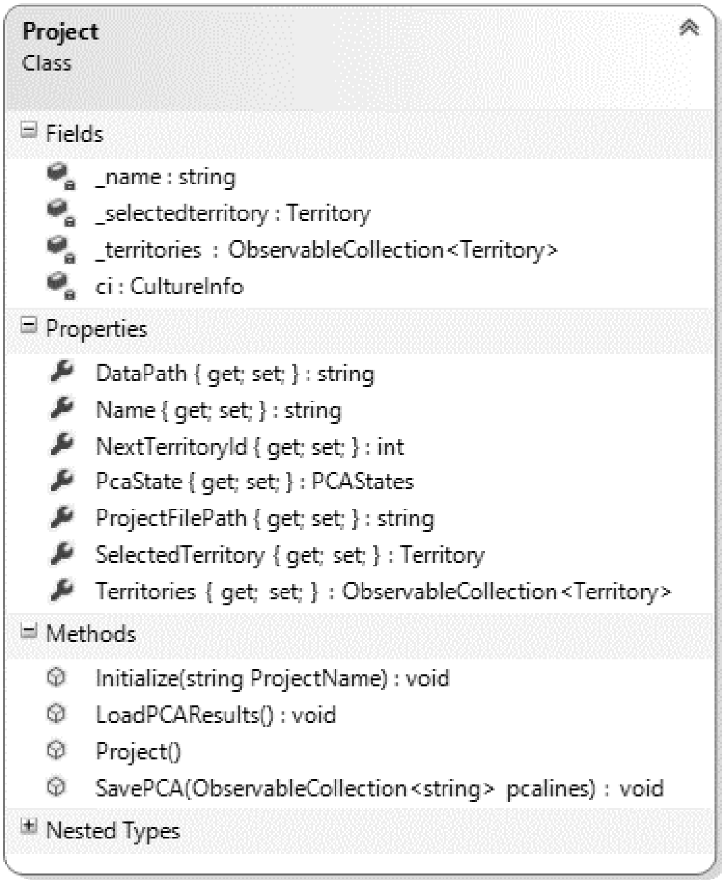
Table 1. *Parameters of the Three SVM Models*

Parameter	Building	Vegetation	Road
C	2	2,00E-15	2000
Gamma	2,00E-09	2,00E-06	2,00E-12
Epsilon	1.19209e-007	1.19209e-007	1.19209e-007

Dimension Reduction

The aim is to get only one value for each site, therefore a Principal Component Analysis (PCA) has been applied, and the first component is named the "Urbanization Index".

Figure 3. *Class Diagram of the Project Class*



Tool Introduction

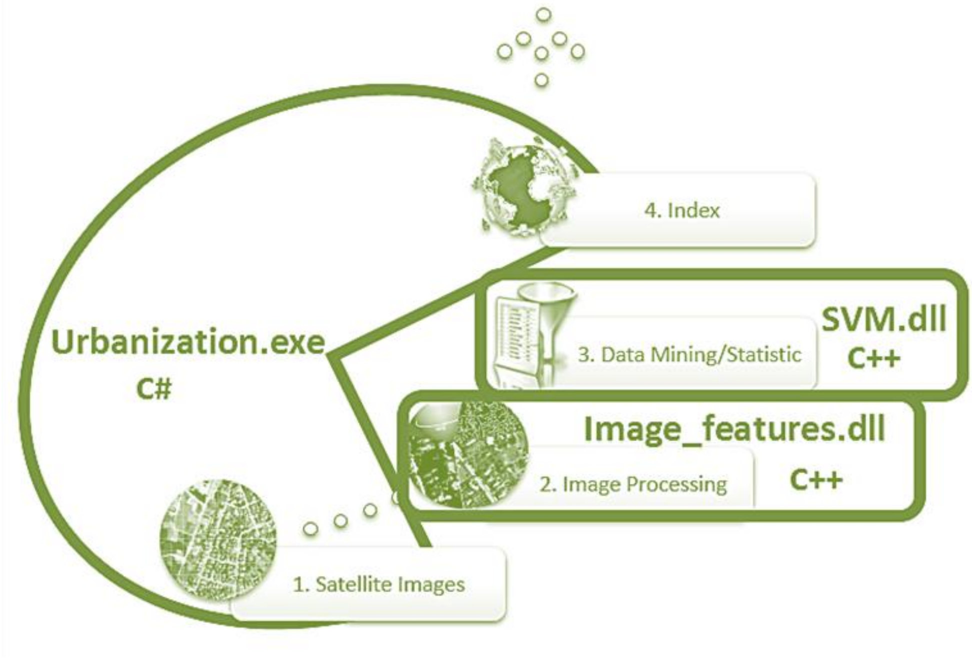
Architecture

The application consists of three parts (desktop application, mobile client and server) and all of them are included into a projects structure (Figure 3). A project needs to consist of at least two territories in order to calculate the urbanization score.

Desktop Application

The desktop application is written in C# because of its good visualizing (Figure 5 left) and quick developing possibilities. The computation intensive parts (image processing, data mining and PCA) are implemented in C++ on separated dynamic language libraries (Figure 4). The application uses the Google Maps API service library for obtaining images, and the opencv library for image processing and machine learning algorithms (Bradski, 2000).

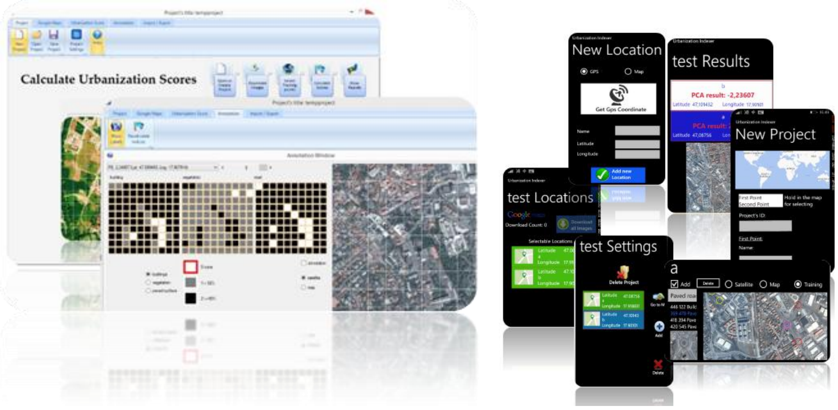
Figure 4. *Components of the Desktop Application*



Mobile Client - Web Service

For fieldwork researchers a mobile client implementation has been made where calculations run on the server side while information is displayed on the mobile device. Figure 5 (right) shows the user interfaces of the managing projects and the visualizing results.

Figure 5. *User Interfaces of the Desktop Application (left) and the Mobile Client (Right)*



Import & Export Functions

The users of the software can improve the accuracy of the classification results by sharing their checked output using crowdsourcing. For this reason import and export functions are applied and a website is provided.

Conclusion and Future Work

According to thorough tests (Seress et al., 2014) the classification accuracy of the semi-automatic process is more than 80% on the average depending on the examined area. Presently the teaching set consists of 3700 records, the contributions of the users can be raised significantly. The introduced software tool has already been used by some research groups, and it seems to be a practical tool for the calculation of the urbanization index.

The software tool can be downloaded from http://keplap.mik.uni-pannon.hu/en/urbanization_index.

We plan to involve new image features to improve accuracy and to extend the scale of application in the future.

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