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Determining bioclimatic indicators using very high resolution colour air photography in a mixed urban environment

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ABSTRACT: A major challenge for civil engineers using remote sensing over an urban environment is information extraction. This is because the urban environment presents particular characteristics, contrary to agriculture or forestry. Moreover, in the context of energy saving and the protection of natural resources, bioclimatic building design is being developed. Bioclimatic design has to do with those construction techniques that allow the heating, air conditioning and lighting of buildings using natural energy sources. It takes into consideration properties of buildings, such as the construction material and the size and the orientation of buildings for the maximum utilisation of sunlight. The aim of this research was to investigate whether the techniques of remote sensing combined with Geographical Information Systems (GIS) are able to extract reliable spatial based information from remotely sensed images in an urban area in order to be used to calculate bioclimatic indices and, thus, saving time and allowing a better environmental urban problem determination and management.

INTRODUCTION

An important challenge for the science of remote sensing is the extraction of features of the urban environment. This is due to the fact that the urban environment is a mixed- and multiple-use environment the pattern of which is rapidly changing due mainly to human activities [1]. Additionally, in the context of the protection of natural resources and energy saving, the bioclimatic design of buildings is being developed, with the goal of allowing the maintenance of comfortable climatic conditions inside buildings with the use of natural sources of energy. To produce such a result, the attributes of the buildings should be taken into consideration, such as the materials from which the buildings are constructed, the size of the buildings (their area and volume) and the interaction of those factors with solar radiation.

Bioclimatic indicators were invented as a means of quantifying the feeling of heat or cold. Since humans live inside a space, called the environment - rural or urban - the attributes of this environment play a significant role in the shaping of climatic conditions and those conditions are quantified by means of bioclimatic indices. Of all the attributes of the environment, geometry is among the most important, provided that the geometry of buildings affect the flux of wind and the amount of solar energy that reaches the soil or other buildings in their neighbourhood.

A number of bioclimatic indicators are affected by the geometry factor, such as Tmrt (Mean Radiation Temperature), which is a prerequisite to the determination of the Physiological Equivalent Temperature (PET), Predicted Mean Vote (PMV) and Standard Effective Temperature (SET). Consequently, the determination of bioclimatic indicators must be preceded by the extraction of data regarding the geometry of the environment, such as perimeter, area, slope and aspect, as well as the size and the of the land uses.

This project provides a methodology for the rapid extraction of data used in the calculation of bioclimatic indices and, it aspires to shift the focus of architects, bioclimatic engineers, civil and surveying engineers and environmental engineers from the standard, time consuming methods that met the needs of yesterday to a modern approach in urban environment management. This modern approach takes into consideration the integration of man-made structures with environmental variables that affect well-being, in the context of energy saving and protection of natural resources.

AREA OF INTEREST

The area of interest was based in the campus of the Agricultural University of Athens, located in the Votanikos area. The Agricultural University covers an area of 247,000 m^2 and consists of 24 independent buildings that house teaching facilities, offices and laboratories. Moreover, there are vineyards, flower gardens, stables for farm animals, experimental crop fields and sports facilities.

GEOSPATIAL DATA USED

For this article, the dataset used consists of:

1. A colour digital air photograpy, pixel size 0.25 m taken from an altitude of 5,000 ft, with the airborne camera Zeiss RMK Top15.
2. The Digital Elevation Model (DEM) (resolution 20 m) of the area with additional break lines and elevation points.

For the collection of ground control points (GCP), a handheld GPS receiver, Garmin Dakota 10 was used. For the classification of the airphoto and the accuracy check the PCI Geomatica software was used and for the digitalisation, the processing of the DEM and the production of thematic maps, as ArcGIS 9.3 was also used.

Figure 1: The area of interest is shaded.

THE METHODOLOGY

The first step in this research was the collection of GCPs in order to be used for the geo reference process of the aerial photo. Thirty-nine GCPs were collected and from each GCP position a panoramic photo was taken. Using those GCPs, the airphoto was geometrically corrected, achieving RMS error of 1.02 pixels. The geo referenced aerial image was used for heads up digitisation of the land uses and for supervised classification. Field work was done to assist the photointerpretation of the aerial photo. Eight land-uses have been identified and those land-uses or classes were also tested for extraction using computer based classification methods.

Several methods, such as maximum likelihood, minimum distance and the parallelepiped classificators were deployed and compared regarding the accuracy of the classification [2]. The land-use classes identified were concrete buildings with a concrete roof, tiled buildings, buildings with a tiled roof, fallow lands, low vegetation areas, trees, playgrounds, roads and parking, and shadows. The accuracy of the classifications was assessed, by means of the Kappa coefficient, omission and commission error measures and the classificator that performed best was selected [3]. The performance of each classificator is displayed in the following tables.

Table 1: Parallelepiped classificator accuracy measures.

	Parallelepiped	
K = 0,458		
Overall accuracy % = 53,176		
Classes	Omission Error%	Commission Error%
Class-00	100	100
Concrete buildings	71,42857143	47,05882353
Tile buildings	5	11,62790698
Fallow lands	47,58064516	9,722222222
Low vegetation	45,45454545	72,30769231
Trees	52	43,75
Playgrounds	99	97,36842105
Roads and parkings	62,79069767	70,37037037
Shadows	26,08695652	38,18181818

Table 2: Minimum distance clasificator accuracy measures.

	Minimum Distance	
K = 0,402		
Overall accuracy% = 48.235		
Classes	Omission Error%	Commission Error%
Class-00	100	100
Concrete buildings	33,76623377	12,06896552
Tile buildings	41,17647059	13,04347826
Fallow lands	62,3853211	38,80597015
Low vegetation	56,25	72,72727273
Trees	60,46511628	42,37288136
Playgrounds	100	100
Roads and parking	59,09090909	51,35135135
Shadows	20	57,44680851

Table 3: Maximum likelihood accuracy measures.

	Maximum Likelihood	
K = 0,461		
Overall accuracy% = 53.176		
Classes	Omission Error%	Commission Error%
Class-00	100	100
Concrete buildings	51,47058824	13,15789474
Tile buildings	20	9,090909091
Fallow lands	52,5862069	15,38461538
Low vegetation	56,41025641	77,33333333
Trees	51,76470588	29,31034483
Playgrounds	99	92,85714286
Roads and parkings	60	74,07407407
Shadows	100	52,08333333

Provided that the parallelepiped clasificator had the lowest omission and commission error in most classes, it was selected as the best performing clasificator.

The slope and the aspect of the area were extracted from the DEM and the digitised land uses were overlaid on the slope and aspect map of the area respectively. Finally, the classification method and the GIS method were compared, in order to find out which method was best for the extraction of data used in the determination of bioclimatic indices.

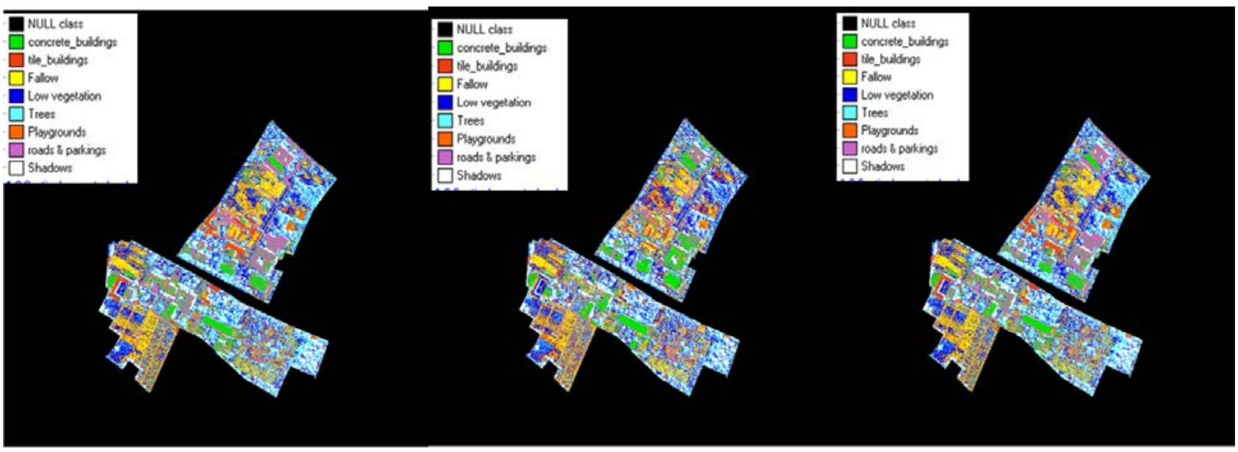

Figure 2: From left to right, maximum likelihood classification, minimum distance classification and parallelepiped classification.

DISCUSSION AND CONCLUSIONS

This research proved that the classification techniques applied were not sufficiently precise. This happened because there was confusion between the classes of concrete buildings and roads-parking, mainly because of the almost identical spectral signature of the materials. The same applies to the classes of trees and low vegetation. Fallow lands were very efficiently classified with the user's accuracy index amounting up to 90%.

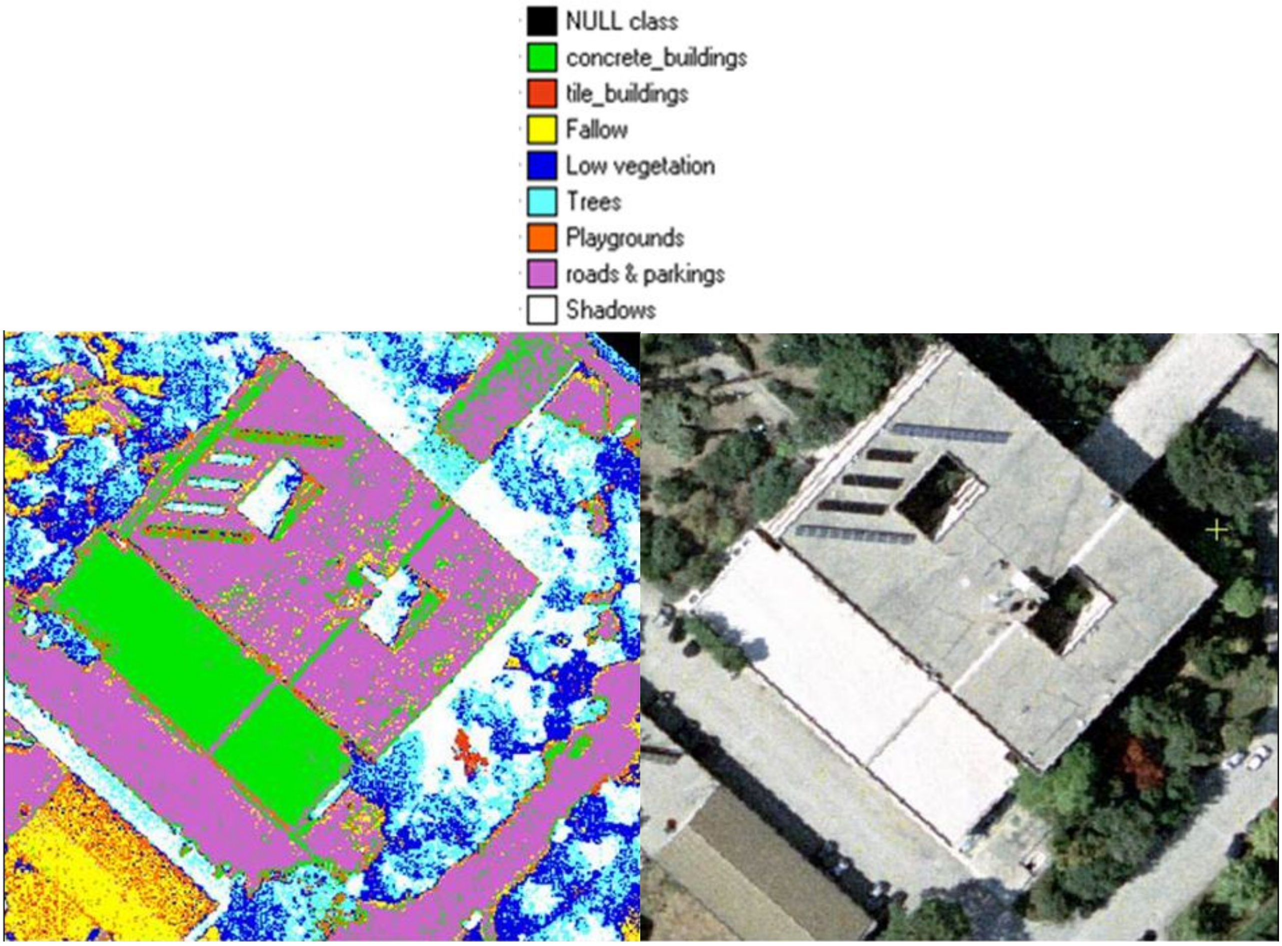

Figure 3: Example of classification confusion - the roads class is confused with the concrete buildings.

On the other hand, GIS heads up digitising proved to be a safer method, due to the fact that the *human classifier* cannot be misled by similar spectral signatures. Instead, the recognition of features is based on their geometric attributes, such as shape and their texture [4]. Moreover, the GIS approach had the added benefit of automatic calculation of the area and the perimeter of the digitised features. The downside of this approach is the insertion of the *human error* factor.

To address the issue of feature extraction for the purpose of extracting bioclimatic indices, a more efficient approach would be object-oriented classification.

IMPACT ON ENGINEERING AND TECHNOLOGY EDUCATION

This article demonstrates how geospatial datasets, such as digital colour aerial photography and image processing techniques can be used by engineers (civil, surveying, bioclimatic and environmental) coping with impact assessment and decision-making for the urban environment. They can reduce the amount of time-consuming field work and support the extraction of quick spatial based information which allows for better problem determination and management.

Extracting data relating to mixed urban environments from remotely sensed images is a significant part of engineers' training, especially those who utilise remote sensing for decision making and planning [5]. Educational workshops could be set up as a way to train undergraduate or postgraduate students, in order to perform data extraction under real circumstances. In that way, all engineers who utilise remote sensing for analysis and decision making will be familiar with a complete and flexible method for taking all the advantages from this modern technology and using it in problem-solving, according to the specifications of each appointed task they need to carry out.

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