AUTOMATED VECTORIZATION OF URBAN AREAS BY USING VISIBLE AND INFRARED SPECTRUM IMAGES

De Cos Juez, F.J.

Prendes Gero, M.B.

García Fernández, R.

Universidad de Oviedo

Alonso, A.

Seresco S.A.

Abstract

A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship. The extension of their use is limited by the possibility to incorporate information. Most of the times it must be done manually through the digitalization of the images. Unfortunately this is a complex and tedious task and it represents the maximum contribution to the cost and source of mistakes. The present work shows a software application destined to be used as support for the soil uses planning in the concrete case of urban environments. Present application, throw the combined analysis of images in visible and infrared spectrum, is capable of providing vectorized information so much of the buildings and streets as of the location of green spaces without human intervention.

Keywords: *GIS; Urban design; Infrared imaging, automatic vectorisation*

1. Introduction

The constant evolution of technology based on capturing aerial or satellite images, as well as the more sophisticated computer resources, have managed to act as a substitute for fieldwork related to the extraction of geographic characteristics. This means a considerable cost-saving, resulting in a globalization of resources and systems a short time ago reserved only to a few organizations. Nevertheless, these processes are still far from being fully automated (Clapp 1997); therefore it is necessary to do some research on the development of intelligent software in order to deal with certain processes which, although they may be seen as simple for human understanding, they are far from being so for a machine (Pijanowski 2002).

This particular case is located into the digital cartography field. The purpose of this work is to automate as much as possible the making of a territory/ field map from high resolution images. It is proposed the development of an automated tool capable of providing information on street axes and borders displayed in those images, as well as green areas.

The starting point of every Geographic Information System is the capture of aerial images, either taken at low altitude or by satellite. In any case, prior to the beginning of the image acquisition process, it is advisable to establish the requirements of our system. The highest resolution is not always necessary, since a great amount of information could have the opposite effect if what is required is a roughly field analysis.

Generally speaking, it is convenient to take several exact images of the same position. If we capture images from a satellite, two pictures taken at two different times may be used to identify and discard shades and objects in motion which could be easily mistaken. Provided the images are captured at low altitude, they must be taken simultaneously and avoid re-takes.

In order to solve this problem, the best option considered is the combination of images with complimentary information, as the ones taken with thermographic and digital cameras. Thermographic cameras allow us to highlight vegetation areas where RGB images have colour values close to black; or else detecting objects at first glance hidden in shades, though its infrared radiation is enough to identify them in a second RGB image.

2. Methodology

To achieve the proposed aims and objectives, a series of characteristics must be fixed as to indicate whether something should be considered as green or urban area.

In connection with colours, all greyish areas should be considered as urban areas (streets). This is due to the fact that the asphalt colour varies depending on its type and age, being thus impossible to determine its exact tonality accurately. In addition, given the amount of shades shown in the images, black areas should also be taken into account. Generally speaking, colours with similar components are taken into consideration, except those closer to white. On the other hand, any green coloured area must be analysed in order to identify vegetation areas, as such areas vary their colour tone depending on their type, typology and preservation status.

In relation to form, different perspectives are used depending on the required typology. In the case of streets, their specific width limits are essential to leak those areas which do not meet those limits. Likewise, another key feature to be taken into account is the streets interconnection. Therefore, isolated segments are immediately discarded from filtering.

The following diagram represents the general process:

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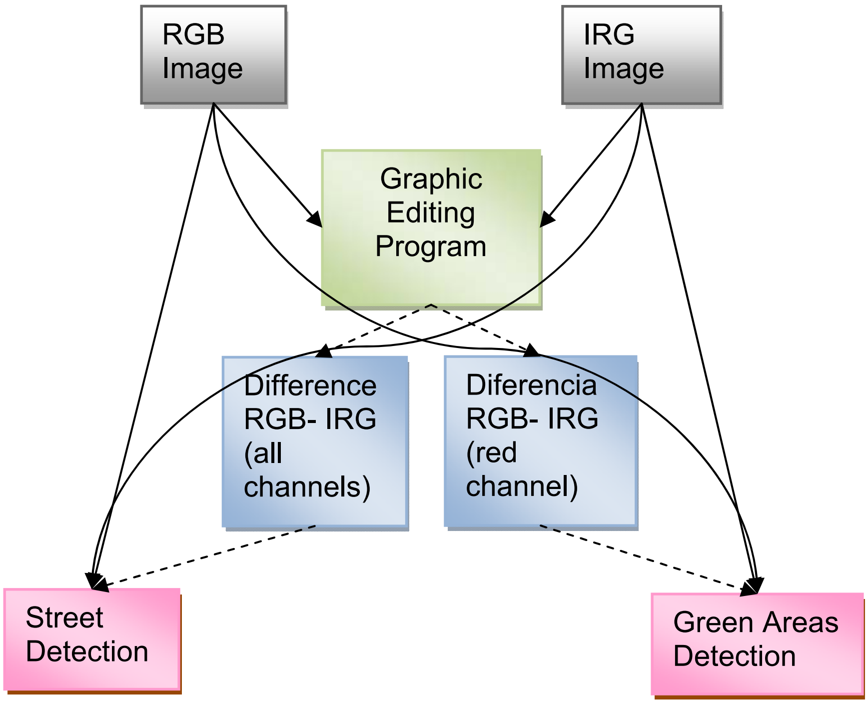
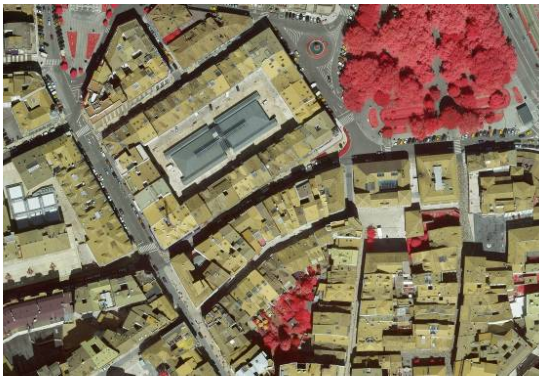
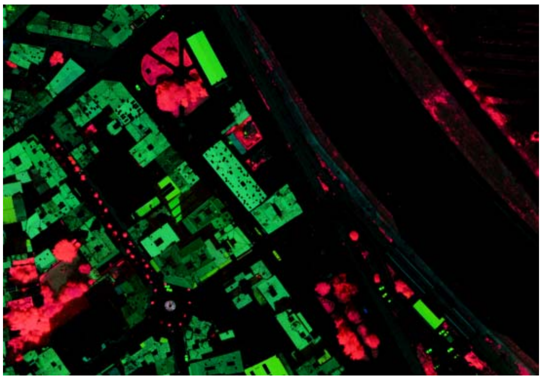


2.1 Previous steps.

Prior to the implementation of this process comes the combination of IRG and RGB images to create input images. Two different versions of the same image (IRG and RGB) are merged by a graphic editing program.

Applying the "minus" arithmetic operation between IRG and RGB images (in this particular order) and covering all colours (red, green and blue), we will get an image where green areas are displayed in red, while urban areas are highlighted in green. Unfortunately, grey areas cannot be accurately filtered. Streets and grey areas will remain in black. Illustration 2 displays the input images as well as the results of this training process.





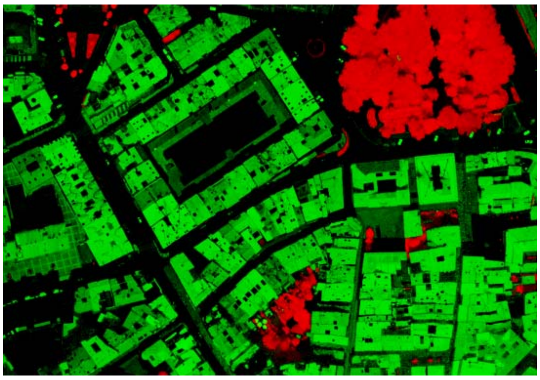


Illustration 1: Input and output images alter merging IRG and RGB images for the process of street detection.

The previous arithmetic operation was applied among images, in this case covering red colour only. In this particular case, the output is a black and white image with green and urban areas separated from the rest, as it can be seen in Illustration 3:

Illustration 2: Output image alter merging IRG and RGB images for the process of detection of green areas.

2.2 Street detection

The following diagram shows the street detection process (Illustration 4):

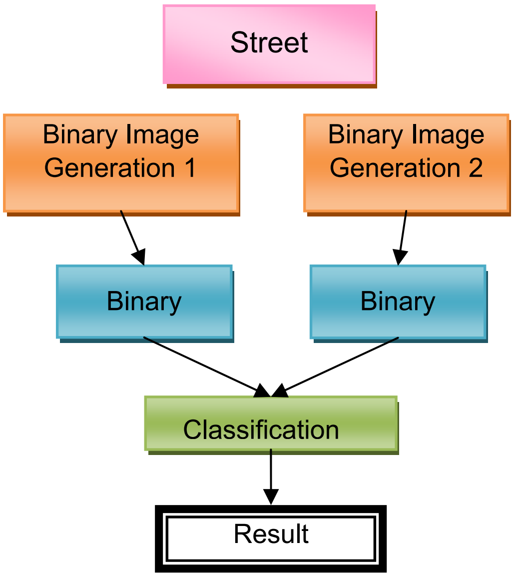


Illustration 3: Diagram for the street detection process.

2.3 Generating binary image 1

To generate the binary image from the input images, it was first covered the IRG image pixel by pixel, assigning a false value to every with RGB average components higher than 180; or else, when the difference between the maximum and minimum of their components is below a certain threshold, being 40 for this case. This method allows us, on the one hand, to discard most of the pedestrian areas as well as white areas, and on the other hand, it helps also to discard some set of pixels which cannot be properly evaluated by the generating binary image 2. Illustration 5 shows the results of the implementation of the aforementioned techniques on the input images.

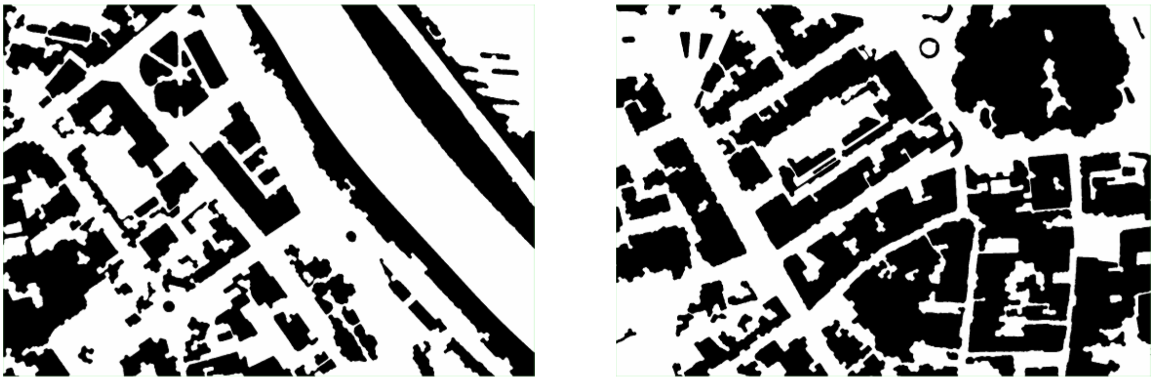


Illustration 4: Result of generating binary image 1.

2.4 Generating binary image 2

To generate the binary image 2, an algorithm is used to classify the pixels of the input image depending on the values of its R, G and B components. The resulting image is scanned pixel by pixel, separating those pixels with a difference between its red and green components is higher than a certain threshold of the rest.

When the algorithm is finished, it will show a binary image where green areas are represented by 1, and the rest of the image is represented by 0. A. A dilatation algorithm will be applied to the output image to reduce noise.

Once green areas are apart, it was performed a similar process for buildings, which will be green coloured. It was necessary to scan the image once again pixel by pixel, classifying those pixels depending on the one hand on their different green and blue components, and on the other hand on their green and red ones.

At this point, a binary image is obtained where buildings are represented by 1 and the rest by 0. However, contrary to what occurs with green areas, it is not yet possible to reach a conclusive result. As one may see taking a closer look, it can be noticed not only backyards and roof windows, but also shades produced by the difference in height levels, as not belonging to the same domain. On the contrary, small street areas were classified as buildings - red coloured cars – Therefore, it was necessary to scan once again over those areas.

It is essential to pay further attention to those areas which are not considered as “buildings” due to their small size. In order to do that, a flood fill is applied to the image, so that different parts of the image are coloured differently, as can be seen in Illustration 6:

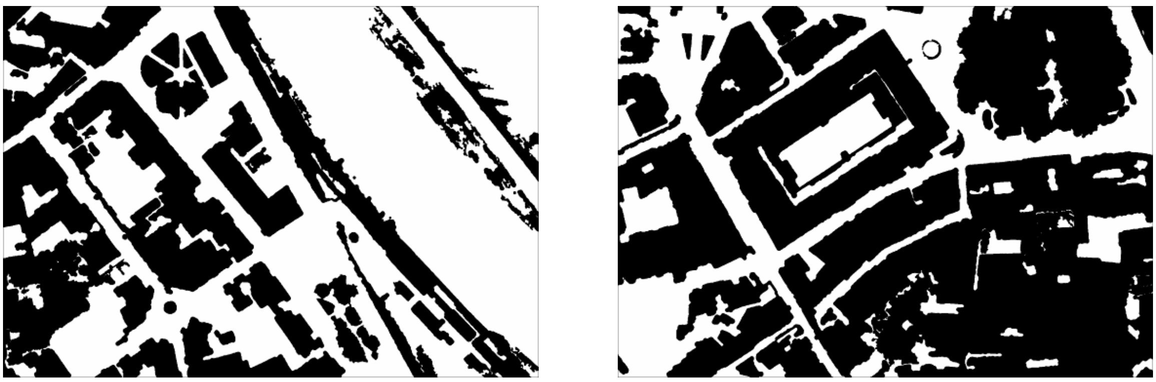


Illustration 5: Images resulting form binary image application.

2.5 Classification

It was first implemented on those areas with not enough width to be considered as streets.These areas are frequently found in parks with asphalted paths or areas with adjoined buildings at different heights, projecting shadows which lead to misleading classifications. The Chamfer Distance System (Echeverria 2008; Yeh 2002), is used to measure distances up to the edge of every pixel.

Finally, the line formed by pixels with a distance value higher than those corresponding to opposite pixels in any possible directions in window 3x3. It must be added those pixels whose distance value is equal or higher than that of their neighbours. Once the dividing borderline is calculated, its pixels are covered, searching for those with a distance value is lower than the minimum threshold considered for a street; then they are rejected.

Coming to this point, it is possible to yet consider certain areas as part of the domain (Calijuri 2002). These areas are not considered as streets, however they have not been erased in previous stages by the cleaning algorithm, sue to their size. The elimination of these areas was made according to width and continuity criteria. Given the interconnection among streets, those areas with no connection with borderlines must be rejected as discontinuous.

Using the condition of appearing in 2 of the 4 borderlines and not in all of them is made to reduce loss of information. Finally, the image is once again covered calculating the minimum width for each continuous border area (Choi 2000). If that width value is surpassed by a tolerance value determined by a percentage of the size image, it is then considered too wide to be a street and is rejected from the domain. This is used to eliminate rivers or asphalted areas, like courts or fields in corners.

It is at this point when we get the definite image. The results must be highlighted to be finished, as pictured in illustration 7:

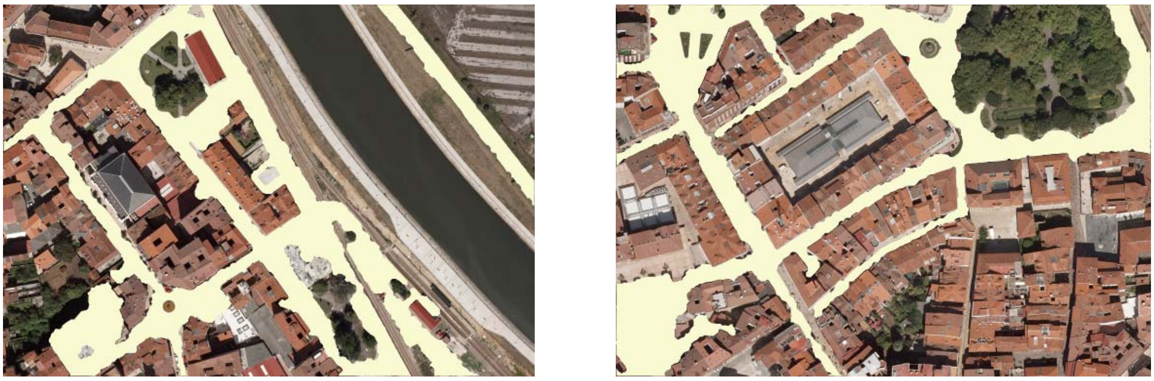


Illustration 6: Final result of automated identification algorithm for streets in urban areas. Plaza del Pilar.

2.6 Green areas detection

As with the previous case, to detect green areas a scheme as represented in Illustration 8 was followed:

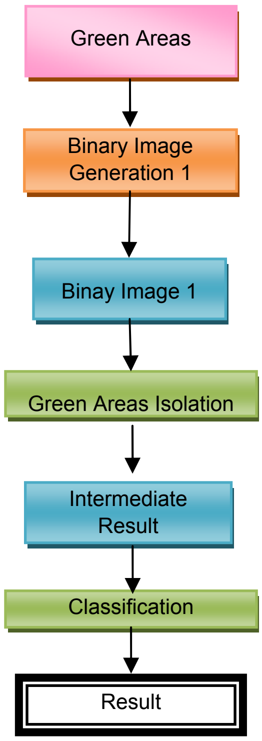


Illustration 7: Diagram of detection of green areas process.

2.7 Generating binary image 1

In this case, the image resulting from the previous stage is already a binary image. Therefore, it is applied an enhancement process similar to the one used in other binary images, in order to reduce the noise.

2.8 Green areas isolation

This is the process in charge of classifying elements within a green area. First, the grass area must be separated from the rest. One of the characteristics observed when working with grass areas is the high level of uniformity, compared to urban tree areas. Therefore, the green area is covered pixel by pixel, searching those whose colour dissimilarity is lower than a certain threshold (Phua 2005).

Although the homogeneity level is higher than in other areas, certain level of heterogeneity is also found in adjoined pixels. A low number of discordant elements is allowed among neighbouring pixels, adjusting thus the thresholds on the grounds of acquired experience when applying the algorithm.

In any case, windows wider than 3x3 should be used, as the number of pixels to be compared with each other must be wide enough to discard urban tree areas. The proper size of windows will be determined by image resolution.

The corresponding widening algorithm will be applied the same as in other processes. The orphan pixels will be cleaned before a conclusive result.

Illustration 9 shows the result of the application of the proposed algorithm to an image detail. It is also included the original infrared and RGB details.

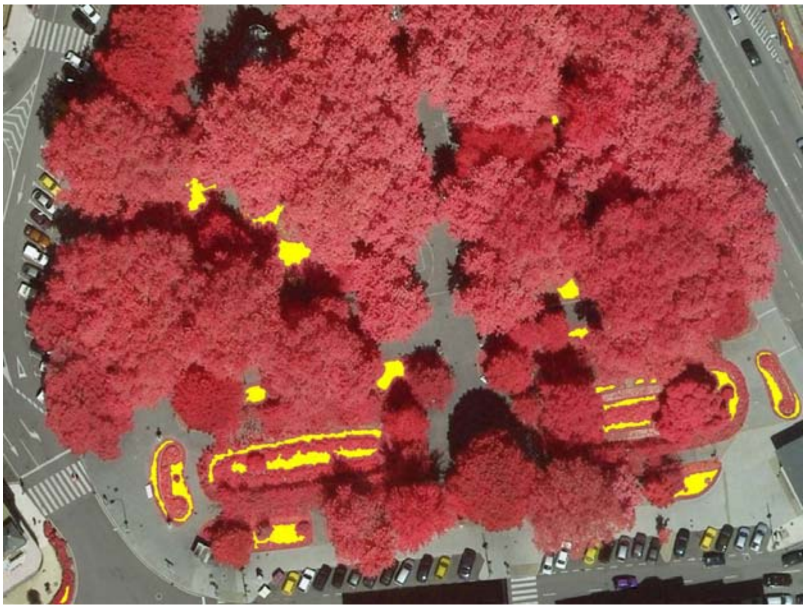


Illustration 9: Results of application of grass detection algorithm.

The last stage of the 3 process consists in separating different species within the same urban trees area. For this purpose, we concentrate on their different colour tones in the RGB as well as infrared images. In this particular case, the attention is paid mainly on tress with dark green foliage. When it comes to classifying, the heterogeneity level of adjoining pixels must be taken into account, as it is higher in urban tree areas (Mathey 2008). As a consequence, although it may be seen as uniformity from the distance, it may not be quite so. This makes us allow more pixels which do not meet the colour requirements, widening thus the conditions and tolerance of the set. Therefore, the algorithm to be used would be similar to the one used for separating trees from grass, allowing for RGB values more than for the uniformity of the set.

As the presence of little shades is constant in all areas throughout urban trees, it must be taken into account the frequency of darker pixels we are bound to find. When a slightly darker pixel from those around is found, it will be checked if any of its “neighbours” belong to the seeking set (Wong 2008). Supposing these pixels are not yet scanned, it must be then calculated which set they belong to, t is then incorporated to the domain if a significant number of their neighbours belong to the same set. The same will be applied to pixels with some shades around it, which will be included in the domain along with their adjoining neighbours.

The process finally finishes with the application of the above mentioned clean and enhancement algorithms, proceeding afterwards with the merging of the input and output images for the final result, as can be seen in Illustration 10:

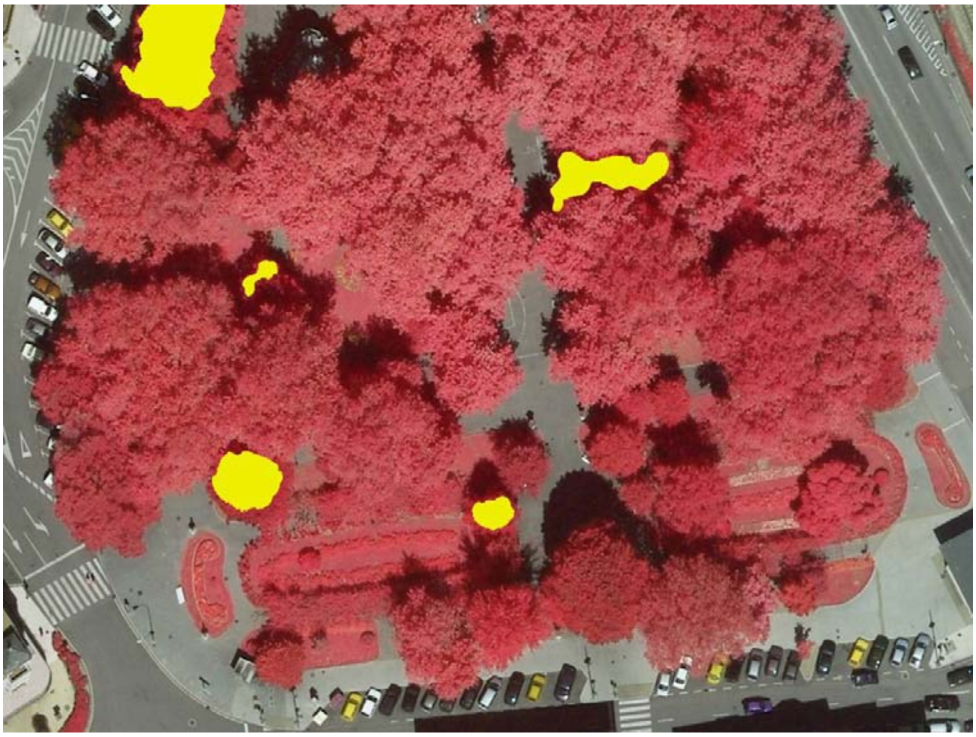


Illustration 10: Result of the application of tree classifying algorithm.

3. Conclusions

As a conclusion, a code implementation allows for a 75% automatic street detection and 85% green area detection within an urban area. This represents an important step forward in what such type of tools are capable to perform.

The generated tool enables to store new content in the geographic information systems for the Local Administration, thus improving their own management and making them more efficient in customer service.

Finally, regarding future steps on this project, it is expected to maintain and update the generated code with new generated data (input images from new locations). This will not only enhance its usefulness, but also serve of great hep to contrast and filter the algorithms expressly designed for this application.

Likewise, it lays the foundations for future species classification for the defined green areas.

References

Bhering, E.; Calijuri, M.L., Marques, E., Meira, E. and Maia, F., 2000. Digital land-use cartography—the example of Viçosa, Brazil, *Engineering Geology*, Volume 63, Issues 1-2, pp1-16

Brown, G.; Manik; G.; Pijanowski, B. Shellito, B., 2002. Using neural networks and GIS to forecast land use changes: a Land Transformation Model, *Computers, Environment and Urban Systems*, Volume 26, Issue 6, pp. 553-575

Clapp, J.M., Rodriguez, M. and Thrall, G.; 1997.How GIS Can Put Urban Economic Analysis on the Map; *Journal of Housing Economics*, Volume 6, Issue 4, pp. 368-386

Coomes, D., Echeverria C.; Hall, M. and Newton A.C. Spatially explicit models to analyze forest loss and fragmentation between 1976 and 2020 in southern Chile; *Ecological Modelling*, Volume 212, Issues 3-4, 10, pp 439-449

Keechoo Choi and Wonjae Jang, 2000. Development of a transit network from a street map database with spatial analysis and dynamic segmentation. *Transportation Research Part C: Emerging Technologies*, Volume 8, Issues 1-6, February-December 2000, Pages 129-146

Krcmar, E.; Mathey, A.; Dragicevic, S. and Vertinsky, I.; 2008. An object-oriented cellular automata model for forest planning problems, *Ecological Modelling*, Volume 212, Issues 3-4, pp. 359-371

Minowa, M. and Phua, M.; 2005. A GIS-based multi-criteria decision making approach to forest conservation planning at a landscape scale: a case study in the Kinabalu Area, Sabah, Malaysia, *Landscape and Urban Planning*, Volume 71, Issues 2-4

Sumić, Z., Venkata, S. and Yeh, E., 2002 Intelligent Tools and Their Applications in Geographic Information Systems, *Expert Systems*, pp 489-551

Wong, N. and Jusuf, S.; 2008, GIS-based greenery evaluation on campus master plan. *Landscape and Urban Planning*, Volume 84, Issue 2, 6, pp. 166-182

Correspondence (for further information, please contact):

Francisco Javier De Cos Juez.

Área de Proyectos de Ingeniería Universidad de Oviedo.

C/ Independencia 13, 33002 Oviedo (España).

Phone: +34 985 10 42 72

Fax: + 34 985 10 42 56

E-mail: decos@api.uniovi.es

URL: http://www.api.uniovi.es