

Suburban informal building control

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Abstract

The problem of informal settlements is of significant importance worldwide and has similar causes whether in regions of Europe, Africa, Central and Latin America, or Asia. The type and quality of constructions vary, however. In Greece the majority of informal buildings are good constructions and do not resemble dense slums. Their number is estimated to be almost 1,000,000 all over the country. It can be said that it is actually a social and economic issue, that must be faced by a combination of measures. In this paper, a proposal to face this problem is developed, at technical and administrative level, taking into consideration the criteria of least possible cost and maximum benefit from usage of modern technology. Its basic idea is the development of a system for periodic automatic monitoring and detection of new buildings in large areas. With field control on specific locations, the immediate detection of informal construction becomes possible even before their completion, when measures against their development can be taken more easily. The suggested procedure is based technically on the use of high resolution image stereopairs and the application of automatic change detection, by computation and comparison of Digital Surface Models (DSMs), and building extraction techniques. Over the last twenty years research has been done in the field of automatically detecting and monitoring man made objects, mainly roads and buildings, with promising results and accuracies of 1 pixel or better. The proposed procedure is accompanied by a cost estimate for its application on eastern Attica, which is one of the Hellenic prefectures with a great number of existing but also emerging informal constructions.

1. INTRODUCTION

A combination of social, economic, legal, and administrative parameters leads, in several countries, to the stage of unplanned development and to the creation of a considerable number of informal buildings. In countries like Greece the majority of informal buildings do not resemble dense slums at the edges of big cities. On the contrary, informal buildings are of good constructions, in some cases 2-story buildings, or even luxurious constructions. Such type of buildings can be usually found scattered within agricultural land at the urban fringe of big cities or in areas close to the coast, mainly due to the increase of the population in the major urban centers, the new improvements in the road and railway network that reduced

commuting times, and to the high demand for urban land in areas with better environmental conditions. The lower prices of agricultural land parcels and the low profit from agricultural products, especially in comparison to the profits expected through the urbanization of land, are also significant factors. These informal constructions are used either for permanent residence, or in the coastal zone, for a second house for vacation. When increased in number, they may create various problems such as:

- decrease of state and local revenue since they are not fully taxed, as the informal buildings are not registered, but they also demand for additional infrastructure and services provision,
- serious social and economic impact on the owners and on the national economy and the real estate market. The owners may be charged with high penalties, also such properties cannot be transferred or mortgaged, while there is always a risk of creating an informal market, and
- in case of a massive scale they may have negative environmental effect.

Government has applied high penalties in case of detection of informal constructions but this alone cannot solve the problem. Sound update of land-use planning according to changing needs, and a series of other fiscal and social measures are also necessary. From a technical point of view, one common reason for the administration's inefficiency to control unplanned development is the difficulty to locate quickly, and in time, the under construction informal buildings in a cost-effective way and stop the construction at its beginning or apply a penalty within a short time after its completion. Classic administrative control procedures are proved inefficient, especially when public administration suffers from lack of employees, bureaucracy, and increased responsibilities. It is difficult to place inspectors at each area to stop illegal construction work and this will encourage corruption. The contribution of modern techniques and tools is necessary for the design of an automated and objective procedure for the detection of informal constructions. Such procedures are already tested in some countries, e.g., India has started pilot projects in a small area of 20 km² in Delhi; a project for monitoring construction activities using high resolution satellite imaging and a special multimedia

mapping to build a 3D Geographical Information System (GIS) with live cameras. This system has been developed jointly by the Indian Department of Science and Technology, the Russian Academy of Science and other private partners, at a nominal cost. Their optimistic time schedule includes full coverage of the capital city by next year, while it could be applied for crime surveillance and forecasting and even for activities like garbage collection (GISdevelopment, 2007).

In any case, in order to monitor urban and suburban environment for detecting illegal buildings, dense periodic measurements must be made, spread over large areas of interest. The automation of modern photogrammetric techniques can significantly increase the productivity and reduce the cost of detection. Over the last 20 years research has been done in the field of automatically detecting and monitoring man made objects, mainly roads and buildings, with promising results (Mayer, 1999). Of course the problem is complex and the technical matters that arise are difficult to overcome. International experience on the subject shows that achieving a global solution to the problem is yet to come. However, in many well defined cases there have been successful applications (Hurskainen & Pellikka, 2004; Karanja, 2002).

This paper makes a brief research about the problem of informal settlements in Greece, its current situation, and the available fundamental statistics and technical characteristics of such settlements. Also, it investigates the imagery data, currently available in the market, which can be used in automatic change detection and building extraction applications. Finally, an integrated approach is developed to support construction monitoring in areas where no formal urban plan exists. The fundamental criteria of this proposal are to maximize the benefits of appropriate modern technology and to minimize costs.

2. INFORMAL SETTLEMENTS IN GREECE

According to the existing legal framework, “informal construction” in Greece is characterized by any construction which (Potsiou & Ioannidis, 2006):

- exists without a building permit,
- has any kind of excess or violation to the building permit,
- is in violation of any valid urban and spatial regulation regardless of the existence of a building permit.

For the purposes of this research, interest is focused on the first category -constructions without a building permit- and on buildings at the urban fringe or generally in areas without urban plans, which gradually create unplanned settlements. The term “urban plan” refers to a formal set of rules and plans, which define the zoning and building regulations to be applied on both the private plots and the plots selected for common use and common benefit activities. In areas without urban plan construction is only permitted in land parcels bigger than 0.4ha and only for a building size up to 200m². Also, these land parcels must not have been characterized as archaeological sites, forest land, environmentally sensitive areas, and they should not be under any other protection restrictions, e.g., those for coastal zones.

Informal settlements in Greece do not have the characteristics of slums. The quality of construction and the living conditions in these areas are of a satisfactory or even high level (Figure 1). Also, illegal constructions have never created major conflict or violence with the state, mainly because they are built on legally owned land parcels. The lack of cadastre in Greece has a multidimensional impact on land management issues. It is the major factor that makes spatial planning procedure extremely time and cost consuming, and it allows the creation of informal

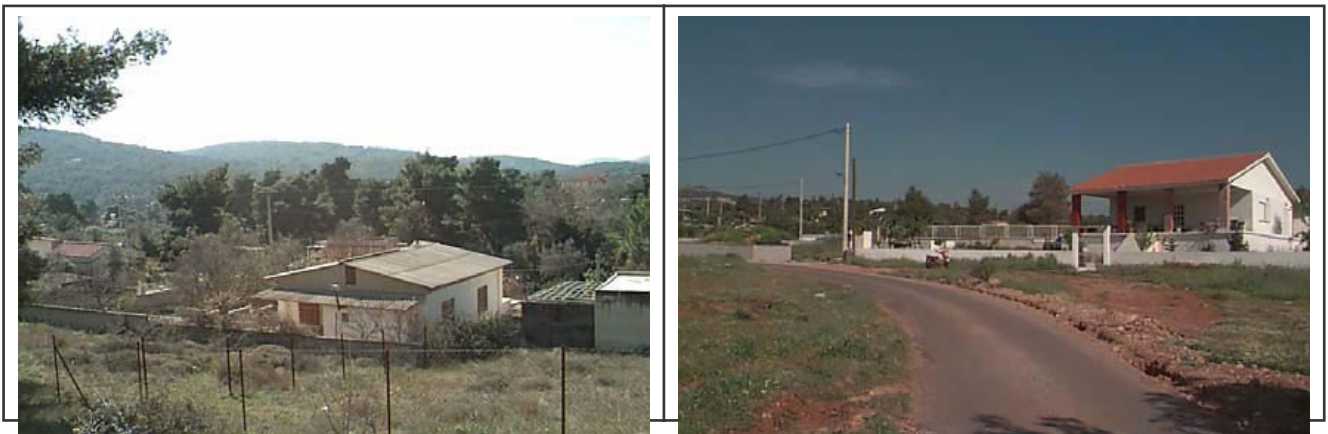


Figure 1. *Informal building constructions on legally-owned land parcels in Attica*

settlements, since there is no other tool available for environmental and development monitoring. Also, there is no other system for reliable statistical spatial data provision to support development of land, real estate market, and decision making for applying sound land use regulations and efficient land policy.

Illegal construction in Greece began soon after the enforcement, by Law, the requirement for a building permit prior to any kind of construction, at the beginning of the 1950s. The reasons are complicated and vary through the years, leading to the creation of informal settlements in several regions of the Hellenic jurisdiction, with different characteristics at each case. Starting with informal settlements within industrial zones (Figure 2), or at the urban fringe areas, today's current activity takes place in attractive vacation areas, or in areas close to or within coastal zones (not to mention numerous violations of building permits within formal urban areas, mainly related to increased building area

or to the permitted use). Several attempts have been made to minimize the problem either by applying procedures toward massive, nation-wide legalization of informal settlements with a parallel provision of urban planning improvements (Law of 1977 and 1983) or by applying tough penalties (Law of 2003), or locally through extensions of the existing urban plans. Nevertheless, none of the applied procedures has proved to be efficient; most of them have proved to be time and cost consuming due to the remaining lack of a modern tool (e.g., spatial information system) for applying coordinated and sound land policy.

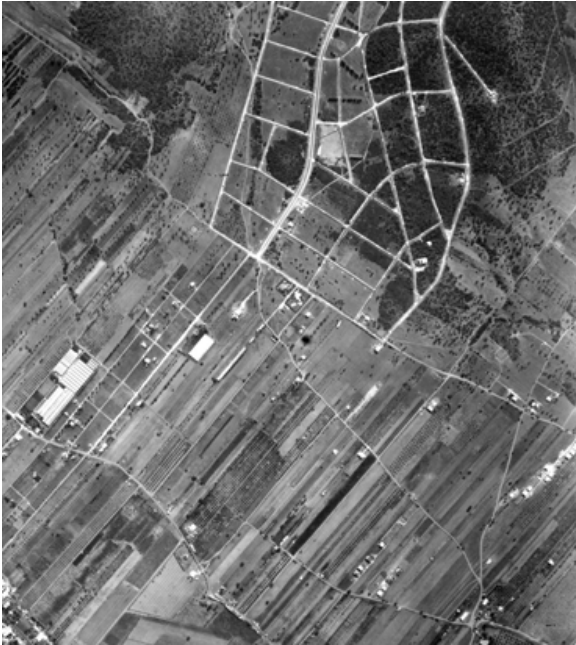
The real size of the problem has been difficult to estimate due to a lack of information until recently. In Greece there are approximately 6.9 million residences for a population of 11 million. It is roughly estimated that almost one quarter of the residences recently constructed were built without building licenses. A rough recent estimation by the general inspector of the Hellenic Ministry of Environment, Physical Planning



Figure 2. *Informal settlements next to an industrial area in Attica*

and Public Works shows that, in total, the informal settlements in Greece are as many as 1,000,000 residences. The majority of them lie within 7-10 prefectures (out of a total of 13). The “new generation” of informal buildings are constructions of 1 or 2 stories of medium or large area size ($>50\text{m}^2$), which are estimated to lie on an average land parcel size of 1,000-1,500 m^2 . According to a statistical study (Karavassili, 2004)

for the period 1991-2001, approximately 93,000 legal and 31,000 informal residences were constructed each year; 40%, that is about 12,500 buildings, are in the area of Attica. This is equivalent to the size of a small town. Thus it can be concluded, that the biggest problem exists within the region of Attica, which in fact is the greater area of Athens, and mainly it's coastal zone.



(a) aerial photo taken at 1975



(b) aerial photo taken at 1980



(c) aerial photo taken at 1989



(d) satellite (IKONOS) image taken at 2001

Figure 3. Example showing the development in an agricultural area of Attica, which gradually has been turned into vacation area or even permanent residential area; it includes both a part within a formal urban plan and areas with informal settlements

Figure 3 shows a rather typical example of unplanned urban sprawl in an area of Southern Attica. This area is approx. 1.5 km from the sea and is characterized as agricultural land. Many land parcels though are small (most are under the minimum area size for a building permit) and gradually not cultivated. Until recently most construction there, was exclusively for vacation purposes. The construction development in the sample area is observed in four different time periods. Aerial photos of years 1975, 1980, 1989 and a satellite image of 2001 are shown. All construction made before 1974 was legal, since the government, for a short period, gave permits for vacation houses in smaller parcels. Later government changed these regulations, to require all new construction to be on parcels of 4,000m² or greater. The upper left area of the photos, with a dense road network, shows a part of the sample area which has a formal urban plan where development of land is permitted even in land parcels of an area size of 500m². All the remaining area is outside of the urban plan.

Observation of the above four images shows that:

- In 1975 all area was agricultural land with very few buildings used for agricultural purposes. Very few vacation houses appeared due to the temporary governmental decision to permit this type of construction.
- In 1980 more buildings appear: those legal within the urban plan, where construction is comparatively larger and denser, and those informal within the 'outside urban plan' area.
- In 1989 almost all area within the formal urban plan has been developed legally. There is significant development within the neighboring area where no urban plan exists; the majority of these buildings are informal, built without a building permit.
- In 2001 informal development in the area without urban plan becomes even denser. It is obvious that informal development was continued and it increased during the last decade and with even higher rates.

3. TECHNICAL ASPECTS

3.1 Available platforms and high resolution data

Today a wide variety of sensors and platforms is available, providing many choices of high resolution imagery suitable for digital detection of buildings and other manmade constructions or physical elements. The objective of this paper's research is the detection of illegal buildings, with a minimum area size of 30m² and planimetric accuracy of the final photogrammetric product (vector plot or orthophoto) of 1m. Sensors that meet these technical specifications basically can be divided in two broad categories: airborne and spaceborne.

Concerning airborne sensors, digital aerial cameras

are the standard choice for very high resolution imagery. There are two types of digital aerial cameras: array and CCD line cameras (Jacobsen, 2005). Large format digital array cameras include the DMC[®] and the UltraCam_p[®]. They both use multiple CCD arrays to synthesize an image of 8,000x14,000 and 7,500x11,500 pixels respectively. They employ electronic forward motion compensation and besides the usual R, G, B channels they also have a near infrared channel, with 4 to 5 times fewer pixels. At this point, the only commercial CCD line camera is the Leica ADS40[®]. It uses two linear CCD sensors with 12,000 pixels each, shifted by half a pixel against each other so that a little more detail can be seen in the image. It can record 3 panchromatic and 4 multi-spectral channels making it a valuable tool for both photogrammetry and remote sensing applications.

Spaceborne sensors are also a good source for high resolution image data. Satellite images may have lower ground resolution than aerial images, but each scene covers a larger area. Very high resolution spaceborne systems like IKONOS-2, QuickBird-2 and OrbView-3 provide panchromatic images with 0.82m, 0.62m and 1m ground resolution, for nadir view, respectively. The aforementioned satellites offer multi-spectral channels with four times less resolution than panchromatic ones and use a time delay and integration (TDI) sensor to cope with small exposure times (Jacobsen, 2006). The recently launched EROS-B offers a 0.7m ground resolution, it does not have a multi-spectral sensor and features TDI, while Kompsat-2 is one more satellite with 1m resolution, which was launched in July 2006. Very soon, new generation satellites like EROS-C, OrbView-5 and WorldView-1 will be launched providing higher ground resolution of about 0.4m-0.7m, and real time transmission of imagery, making spaceborne systems even more attractive.

Ancillary data, like a dense digital surface model (DSM), can be useful in a building extraction process. These data can be automatically derived from image stereopairs, but it is more efficient to produce them from a different sensor like a LIDAR or a SAR. The main problem with this kind of data is the increased cost. Spaceborne SAR sensors are the least expensive solution, but currently they do not offer the appropriate ground resolution. The ERS-1 & 2 and RADARSAT-1 satellites have a maximum 10m resolution. However, TerraSAR-X due to be launched at the beginning of 2007, is expected to cause a revolution in this field since it will have a 1m ground resolution; as a result future products of radargrammetry or interferometry methods will be available for high accuracy applications.

3.2 Change detection strategies

Monitoring the suburban environment for illegal buildings is, in fact, a change detection problem augmented

by some spatial information concerning land use zones and building regulations. The solutions proposed to the problem depend on the image scale. A schematic overview can be seen in Figure 4.

In small scales, e.g. cases of informal settlement monitoring, the problem is being addressed by various classification-segmentation techniques from the field of remote sensing. Such techniques can be categorized as low level, mid level and high level, in respect to the information used to address the problem.

Low level techniques consider information in pixel level to facilitate change. Image differencing, rationing and principal component analysis (PCA) were commonly used in the past (Pratt, 2001). Today they are still used in modern techniques, but only as part of a wider approach and in conjunction with each other (Moeller & Blaschke, 2006). Their main weakness is that they are unable to cope with variations in atmospheric conditions, ground conditions and illumination.

To overcome these problems, slightly evolved mid level techniques were introduced. Object oriented classification, feature and texture segmentation are some widely used examples (Blaschke et al., 2000; Busch, 1998; Walter, 2004). These techniques are more robust than the low level methods as they use higher level of information to detect change, but are still case dependent and difficult to extend.

The current trend is to use high level techniques. These methods are also known as knowledge based methods or expert systems. They incorporate cognitive functions to improve image-scene analysis and they make use of a wide variety of data. Their major advantage is that by using high level information and data fusion these systems are robust and effective, approaching the problem in a more holistic way. Examples show that they are capable in monitoring of small scale unplanned developments (Hofmann et al., 2006;

Hurskainen & Pellikka, 2004; Karanja, 2002).

In large scales, e.g. monitoring individual buildings, the problem is more complicated. A basic procedure can be seen in Figure 5. First, buildings are extracted and then they are back projected to the reference data where it is determined if there has been a change.

All of the above procedures can be automated, but with different levels of difficulty and success. Building extraction is by far the most difficult task to automate. The algorithm might miss certain objects or include some objects that are not buildings, e.g. trees. Due to the complexity of the problem, many different methods have been proposed, which will be discussed more thoroughly in the next chapter. Concerning back projection and assuming the data are georeferenced, the process is easily automated as it is just a matter of overlaying building-polygons from different time periods. Change determination is also relatively simple to automate. After overlaying the building-polygons, a similarity measurement is executed and a proper threshold value defines if actual change has taken place.

3.3 Building extraction

Building extraction is the most crucial step in applications like urban monitoring, 3D city modeling and automatic GIS revision. There has been research in the field and there have been many proposed algorithms to achieve it. Some of the most popular approaches are:

- mathematical morphology,
- DSM segmentation,
- active contours or snakes,
- neural networks and
- knowledge based systems.

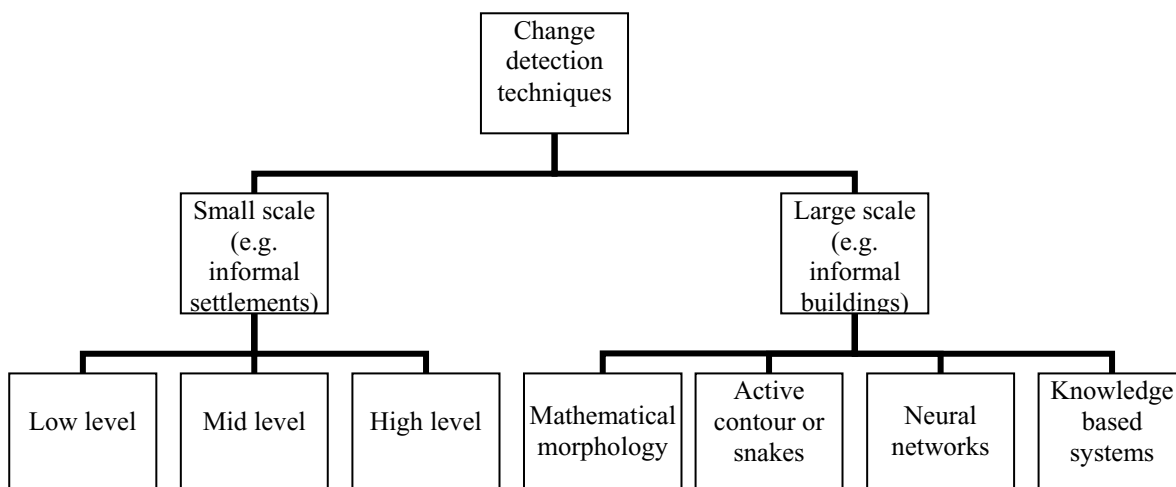


Figure 4. Change detection techniques categorized by scale

Mathematical morphology employs a set of image operators to extract image components based on the shape and size of quasi-homogeneous regions. The extraction can be multi-scale using the differential morphological profile (DMP), which keeps a variant size for the structuring element (Pesaresi & Benediktsson, 2001) and the only necessary data are imagery. Unfortunately the results lack completeness even in cases where additional data, like shadow footprints, are used (Jin & Davis, 2005; Shackelford et al., 2004).

DSM segmentation is a very popular technique for extracting building, because it is simple and straightforward. The basic idea is to segment a DSM in two classes of objects, ground and above ground. There are two basic approaches to achieve this. The first is subtracting a DTM from a collected DSM resulting in a normalized DSM which includes only the above ground objects. The second is directly segmenting the DSM using simple algorithms, like multi-height bins (MHB), which is conducted by grouping homogeneous height regions (Baltasavias et al, 1995), or DSM filtering, similar to that done in point cloud data (Sithole & Vosselman, 2004; Tovari & Pfeifer, 2005). The problem with these methods is that the final above ground objects will include vegetation as well as buildings so the results might be complete but not correct. Because of this, DSM segmentation is mainly used to approximate the positions of buildings before the application of a more complicated and precise algorithm.

An active contour is a set of points which aims to enclose the target feature. The initial contour is placed outside the building and it evolves to match its shape. This approach can be seen as an energy minimization process. The final position of the snake around the building is the one that minimizes its energy definition (Nixon & Aguado, 2002). Snake applications show promising results (Oriot, 2003), but they also introduce some problems. First, there must be a way to automatically initialize the snake. Second, the algorithm has difficulty to distinguish between buildings and nearby trees of about the same height, degrading the extraction accuracy. However, these methods can be further enhanced with the use of multi-spectral data and height information (Guo & Yasuoka, 2002).

Neural networks are capable of scale and rotation invariant matching of predefined neuron graphs to images (Barsi, 2004; Bellman & Shortis, 2004). The whole operation is done in two steps. First the neurons are trained to detect specific building models in a selected training dataset and then they are ready to automatically detect the same models in other data.

Knowledge based systems are probably the most popular

method. They can be more flexible incorporating various kinds of methods and data in an intelligent way and thus they are more effective (Baltasavias, 2004; Mayer, 2004). The basic concept is to calculate the values of certain predefined criteria, referred to as cues (Hahn & Stötter, 1998), and from these to automatically decide if an object is a building and which are its exact properties, e.g. shape, size etc. The data used in these methods can be imagery, multi-spectral information, height data and even GIS information. In fact, the more diverse the base data are the easier it is to formulate robust cues. For example, if only a panchromatic image was available then it would be very difficult to automatically distinguish vegetation from buildings. Since buildings have a more structured geometric shape than vegetation, a possible way to do it is to measure the length and orientation of edges extracted by an operator like Canny and then decide which edges belong to buildings and which to vegetation. However, the use of a near infrared channel and the normalized difference vegetation index (NDVI) makes it more effective to accomplish the same task. The total number of cues used and the way the system makes its decisions depend on the complexity of the problem. For situations where a scene must be analyzed in a few classes, e.g. “buildings”, “water”, “vegetation”, a hierarchical approach is usually implemented. By gradually eliminating all the unwanted classes, finally the “buildings” class remains. The members of this class are then subjected to a refining stage where their exact geometric properties are defined. In cases where more detailed classes must be discerned and localized, then more cues are needed and a more complex decision system is necessary (Zimmermann, 2000; Straub et al, 2000).

In general, all the aforementioned methods involve problems concerning the completeness and correctness of their results, depending on the complexity of the scene. Reports show that about 5%-10% of the existing buildings are not extracted at all and almost 5%-10% of the final results are incorrect. Furthermore, the minimum size of the extracted buildings must be relatively large, depending however on the scale of the imagery and the density of ancillary data like DSMs.

4. PROPOSED PROCEDURE

Having first analyzed the problem of informal settlements in Greece today according to their basic legal, technical and administrative characteristics, and second investigated the modern tools, methods and techniques for building and

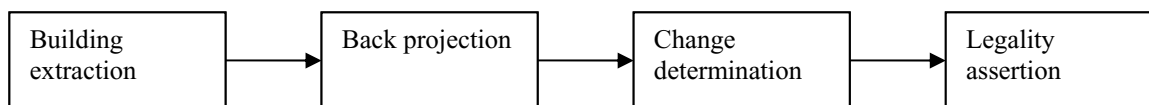


Figure 5. Phases of informal building monitoring

urban sprawl detection, an integrated proposal to monitor and control the problem is to be developed.

In most cases, the difference between areas with informal settlements from the suburban areas with a formal urban plan lies in the pattern of development arrangement. Informal development usually has a dense pattern of medium or small sized buildings in an area with highly fragmented land parcels. So, the change detection and building extraction techniques selected for this project were those which could better fit to the specific geometric characteristics of unplanned development in Greece. The most important and critical factor of the proposed action plan though, is its innovative holistic approach, which makes it also appropriate to be successfully applied to the economic and administrative conditions in Greece; the proposed procedures combine technical and administrative aspects with a coordinated involvement of the public and private sectors. The current lack of an objective, reliable, and flexible system for a timely detection of the illegal buildings has allowed their growth in Greece, and hinders the efficient control of this phenomenon. The proposed system should operate independently from the will, negligence or inefficiency of the responsible agencies or the involved individuals; it should provide results before the final occupancy or operation of such buildings as residence or other use (store house, industry, etc), since occupancy and use may stabilize a situation and make its reverse almost impossible.

Obviously, this system can support but not substitute the legal, social, financial, and other initiatives that must be integrated into the state's land policy in order to minimize the problem and avoid the creation of new generations of informal settlements. The improvement of the national and regional spatial planning for sustainable development and the compilation of the Hellenic Cadastre Project are the main and necessary tools in order to achieve improvement in Greece.

4.1 Technical approach

First the technical part of the proposed system is developed. It is based on the periodic control at short epochs for the new construction detection, by using automated procedures, at areas of interest. The proposed approach for informal building monitoring is a knowledge based change detection method, employing high resolution aerial or satellite imagery, DSM and multi-spectral data. The main purpose is to devise a technique which is easy to use, cost efficient, robust and accurate. The results of the presented strategy will be automatically derived polygons on an orthophoto denoting possible informal buildings. A user will then assess the results and decide whether there has actually been a change in the area or not.

The main factors that influence the choice of the

imagery data used are the size of the area of interest, the image resolution and accuracy, the possibility of having stereoscopic images, and the existence of multi-spectral channels. By examining these factors, it can be said that:

- For cases where the area of interest is especially large, for spatial planning purposes at national or multi-prefecture level, or for cases where the area is comparatively small, of a size of 100 km² (which is the equivalent of a municipality), the use of satellite imagery is the most logical solution in terms of cost. In the first case due to the very large number of aerial images necessary for the coverage of such an area and to the huge volume of photogrammetric work these demand. In the second case due to the disproportionately high cost for aircraft flight expenses in comparison to the few necessary aerial images; one more factor that may increase the flight costs is the distance between the area of interest and the airport from which the aircraft has to start. At all intermediate cases the use of aerial images seems to give a more cost effective solution, taking into consideration the purchasing cost of the high resolution satellite stereoscopic scenes, which still remains very high.
- Considering that the minimum size of an informal building that might worth detection interest is 30m², a high resolution image is needed; aerial imagery, at medium photo-scale, is the best solution. An alternative choice would be high resolution satellite imagery, with pixel size 1m or smaller, like IKONOS, EROS-B, Quickbird or OrbView-3. It is worth mentioning that some space agencies have scheduled to launch satellites in 2007 with ability to acquire images with pixel size 0.4m.
- For the automated DSM extraction it is necessary to have the possibility of acquisition of image stereopairs by the air- or space-borne sensor, which will be used; such spaceborne sensors are the IKONOS or EROS-B. The best solution in terms of accuracy would be the use of an airborne LIDAR system, but the cost is too high.
- To augment the robustness of the method, ancillary data like multi-spectral images, with near infrared channel, must be used. Many high resolution spaceborne sensors offer this feature, like IKONOS or Quickbird; also the majority of the digital airborne cameras.

Consequently, in order to satisfy all the above factors, two options exist according to the characteristics of the area of interest: either the use of digital aerial camera (airborne solution) or of IKONOS imagery (spaceborne solution). It is predictable that in the near future there will be many more possible options related to satellite data.

A series of field and office works, whose products will be used for building monitoring and change detection, follow:

- Set up a network of ground control points, placed mainly at the periphery of the area of interest; measurement of their coordinates with GPS receivers. Considering the fact that these points will be useful in every epoch

of measurements it would be prudent to make, at least some of them, permanent on rooftops or other prominent spots.

- Bundle adjustment aerotriangulation and automatic DSM extraction in a Digital Photogrammetric Workstation (DPW). Considering that the smaller informal buildings to be detected are about 30m², this is approximately 5x6m, the DSM should be very dense, in a grid of 5m cell size, in order for at least one DSM point to be on top of each building.
- Finally, using the DSM, an orthophoto-mosaic for the area of interest can be produced. The two last steps are usual photogrammetric procedures and will be repeated in each measurement epoch.

The basic idea behind the proposed approach of monitoring informal buildings is that the construction of a new building will mean a change in a dense DSM at the spot it was constructed. Unfortunately errors in the automatic DSM, natural growth of plant life and changes in the ground elevation due to unpredicted factors, can all affect the procedure. To cope with these effects, each scene is considered to be a sum of four object classes: “water”, “trees”, “ground” and “buildings”. After a general detection of height change in the scene, each non-“buildings” class is eliminated hierarchically with the use of suitable cues. In general, this technique is a knowledge based method using DSM differentiation to facilitate change. In more detail and assuming a reference DSM (DSM_{REF}) and a recently collected new DSM (DSM_{NEW}), change detection is completed in six steps:

1. Near infrared (NIR) channel is used to eliminate “water” areas in DSM_{REF} and DSM_{NEW} . One may notice that since in many cases the area of interest is coastal and the DSM is produced automatically, many points will be erroneously placed in sea area. To filter out these points the NIR channel can be very useful. NIR light is absorbed by water and for that reason water appears almost black in the NIR channel. Setting a threshold on the NIR channel excluding very dark tones can eliminate the “water” class from an image and the corresponding points from the DSMs.
2. Initial assumption is made for candidate changed regions by DSM differentiation. Since now the DSMs do not include points in “water” areas, an initial assumption for change regions can be made through DSM differentiation:

$$CHANGE = DSM_{NEW} - DSM_{REF} \quad (1)$$

The two DSMs must cover exactly the same area and only positive values are accepted as change, because the purpose is to locate new buildings and not collapsed old buildings. The height values must refer to the same horizontal point, which is accomplished by interpolation.

3. Application is made of a change height threshold to

initial candidates. To further refine the candidate regions, the method takes into account the expected height of the new buildings. Informal buildings are one- or two-story houses. This means their height is 3-7m. These values can be used as a threshold to the change candidates.

4. “Trees” are excluded from the candidates by employing the normalized difference vegetation index (NDVI). At this point the candidate regions include “trees”, “ground” and “buildings” classes. The “trees” class can be excluded by the use of NDVI:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (2)$$

NDVI values between 0.5-0.8 mean the existence of “tree” whereas lower values mean the absence of it.

5. Exclusion is made of “ground” from the candidates by edge extraction. Buildings have long edges which usually form square, rectangular and triangular geometric shapes. On the other hand, edges on “ground” areas will be shorter and irregularly distributed. By setting a threshold for edge length and a model for edge orientation, the “ground” class can be distinguished from the “buildings” class.
6. Polygons are formed around the remaining “buildings” change candidates on the orthophoto.

Following the above technical procedure and based on a set of reference data, e.g., the situation at the area of interest as it stands today or at a particular time point of the near past, it is possible to detect changes in the class of “buildings” at various future epochs. If these changes are really related to buildings and, further, if these detected new buildings are indeed informal have to be determined by user made checks; these controls can be done either by using automated procedures such as comparisons with spatially defined land-use zones, or by on site visits, etc. In case of informal building detection, another automated checking is necessary. Combining the detected building overlay with cadastre GIS data with the land-use zones, or existing urban plans, it is easy to detect whether the building-polygon is within an urban plan or outside.

4.2 Administrative and financial issues

For an efficient informal building control system the technical procedure for building detection should be part of an integrated administrative procedure. This procedure should involve:

- The central administrative agency (Ministry for the Environment, Physical Planning, and Public Works), which will have the responsibility for the project, the necessary legal reforms, the decision making, the strategy and the regulations.
- The regional administration, Prefecture or County, which will have the responsibility for the commissioning and

supervision of the project and the validation of the measures and decisions. It is preferable this responsibility be at that level and not to the municipality level, since the areas of interest for control are usually greater (they belong to more than one municipality) and the problem can be faced technically and administratively better that way.

- The private sector which will have the responsibility for the compilation of the studies for the detection and the in-situ control of informal buildings.

According to the above administrative framework, the whole procedure includes the following stages:

1. Compilation of the technical specifications for the studies for the detection and control of informal buildings, by the Ministry; this includes the method and technical procedures, the products, the accuracies, etc. Also, development of the necessary specialized software, which will apply the proposed technical approach. The research made for this paper should be improved by statistical controls to check the efficiency of the proposed method at various specific areas of interest with various characteristics, and the levels of achieved success should be determined so that the system will be improved.
2. Creation of the responsible division at County or Prefecture level, which will manage and supervise each project and will apply the necessary final penalties. This division would require few employees, who will be specialized technicians, and should operate under a flexible administrative framework.
3. A study, which will provide the necessary reference data for each area of interest, should be commissioned, by the Prefecture or the County, to the private sector. Attention should be paid to evaluate all available relevant data, such as recent aerial photos at scales 1:25.000-1:40.000, DTM and orthophotos of acceptable accuracy. In-situ controls of the completeness and accuracy of the products should be included in the requirements of the study.
4. Contracts should be signed with the private sector for the compilation of the studies for informal buildings detection in a County or Prefecture. The contract should have long duration, e.g., 5 years, so that the private company will be able to apply the governmental policy efficiently without narrow time limits. The time schedule and the selection of application areas can be made in cooperation with the public administration. Two options can be followed: either to apply a periodic, e.g. annual, application of the procedure for informal buildings detection on the whole area of interest in a Prefecture or County, or alternatively to do a frequent sample control, that is an application of the procedure on random smaller parts, e.g. of a size of a satellite scene. The second choice has the advantage of "lower cost" and it will be completed within "less time", e.g., within 3 months.
5. Application of the study, using IKONOS satellite images or acquiring digital aerial images. The location

of new buildings that may be informal will be made automatically when the method is applied on areas where no urban plan exists. Then in-situ control should follow to prove the correctness of the results.

6. The responsible administrative agency should administer a judgment, such as penalties, an injunction against continuing construction, removal of the construction, or other actions which should be decided by the central administration and applied consistently in the whole jurisdiction.
7. Frequent repetition of the whole procedure is required so that the target to control and eliminate massive informal urban development (new illegal buildings or informal large extensions to the existing buildings), will be achieved. The challenge is to achieve the detection of each illegal building before its completion. So, it is important to make periodic controls within short periods. If this becomes too costly, the alternative is to apply sudden sample controls.

An additional benefit of the procedure is the derived byproducts, like orthophotos and dense DSMs, necessary for a variety of other applications, such as applying spatial planning, real estate market monitoring, environmental protection studies, coastal zone management, risk assessment and disaster management for floods or fires.

The most appropriate area to check the applicability of the proposed procedure is the eastern part of Attica (Figure 6). As can be detected from available statistics about informal settlements, this area is one of those most afflicted; in addition, it is close to the city of Athens and land values are especially high. A coastal zone of 3 km width, which is attractive for permanent residence or for vacation housing (it is marked on Figure 6 with a cyan color line) and where the biggest percentage of illegal buildings exists, is of special interest. The area includes 43,500 ha, with a coastal line of a 160 km length; administratively it includes 22 municipalities, all of which are in the County of Eastern Attica. Consequently the County is the most appropriate agency for the proposed procedure.

Regarding the cost necessary to run this project, it is noted that for areas with similar size, acquisition of digital aerial images is the least costly approach. The analysis of the alternative possibilities gives:

- In order to have full coverage of the area with IKONOS stereo-pairs, with an overlap of 10% so that an aerotriangulation adjustment can be applied, eight full and four smaller size IKONOS scenes are necessary (the footprints of these images are marked in red color in Figure 6); these cover land of a size of a total approx. 900 km². The cost for acquiring these images is approximately 60,000 €, which is especially high. In order to achieve the desired accuracies it is enough to measure the coordinates of approximately 20-30 control points, located on the corners of the scenes.
- In order to use stereoscopic aerial images, it is necessary

to acquire images with a pixel size of 60-80cm on the ground (equivalent to photos of a scale of 1:30,000). Approximately 80 images are needed for the full coverage of the area, which create approx. 70 stereo-models. Twenty to twenty-five control points, measured by GPS, and scattered at the periphery of the block, are enough for the aerialtriangulation adjustment, when measurements using differential kinematic GPS made during the aircrafts flight are available. The total cost of the procedure, from the acquisition of digital images by airplane up to the orthophotos production, is of the size of 50,000 €.

5. CONCLUSIONS

Unplanned urban development is still an issue in Greece, as it is in other countries around the world. According to this research and to the authors' experience, the creation and extent of informal settlements is not always directly dependent on the country's GDP or the level of prosperity. The phenomenon of good quality illegal construction is due to several other social, fiscal, cultural and legal parameters which influence the development of land in the area. The solution is complicated and it demands a series of combined actions at several levels.



Figure 6. Attica peninsula with the municipalities' boundaries and the footprints of IKONOS images covering the eastern coastal zone

On a long term approach the solution might be the development and validation of a spatial planning and zoning system, which would define with accuracy and consistency sound land-use regulations and permit systems, and in parallel, the operation of a modern land administration system at the national level, which will secure tenure, and will record any construction and development of the land parcels. The combination of the two systems will provide the state with a tool useful not only to secure and protect the tenure but also the value of the property, and will serve the economic growth. They will also provide for a fair and equitable land taxation system. Tax revenue received from previously unrecognized improvements will help to pay for the proposed systems.

On an interim term approach the necessary solution might be a governmental decision for a legal reform to unregulated land in order to unblock the housing needs of the people and the national economy as well, as needs develop and change through the years. Very strict, almost unrealistic restrictions and/or the use of police measures only in order to control and supervise the situation have proved in practice to be inefficient. Speed and flexibility in planning and applying urban plans in order to meet the demand for developable land is of significant importance. Also, the availability of reliable economic, market and environmental data for a cost effect analysis of the applied land-use regulations will better support the sustainable development with respect to the rights of the individual citizen and to the principles for nature and environmental protection.

In the short run the solution may be the control and systematic monitoring of informal constructions, by an objective and reliable method. This will also gain public acceptance, and will create the necessary culture, by increasing awareness, that there is a technical way available, and the political will, to detect illegality and apply the Law. The proposed procedure can contribute to that end. It is intended to control unplanned urban development and to eliminate the creation of new informal settlements, until the planning and application of the long- or interim- term actions will be achieved.

From a technical perspective, it is an automated procedure which is easy to use, robust and accurate enough, to meet the needs of the specific purposes. It benefits from the modern "know how" in monitoring of changes and in automatic building extraction using high resolution images. No special investment on specific and expensive hardware is needed, only GPS receivers and Digital Photogrammetric Workstations. All the rest processing is done by software.

Administratively, the proposed system may be easily applied at a regional level, without significant requirements for state acts, e.g., new legal framework. It is cost efficient taking into consideration the benefits of solving the problem of loss of state revenue and the impact on the national economy such informalities bring, until the necessary reforms will be in place.

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