The update of middle scale topographic maps using high-resolution satellite images: a semi automatic method proposal. Results, critics, conclusions and perspectives from a bilateral research project

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SUMMARY

The analytical description of a semi automatic updating process of middle scales topographic maps using VHR satellite images, is the objective of this paper. The proposed method is a combination of manual and automatic procedures based to binary map algebra actions and applied in both, raster and vector types of data. This on going study started in the frame of a bilateral research project, which continues until now.

KEYWORDS: *Updating, topographic maps, VHR satellite images, map algebra*

INTRODUCTION - THE OBJECTIVE OF THE ARTICLE

In June 2001, a bilateral project started amongst the Surveying Department of the Technological Education Institute of Athens - Greece, the Information Department of the National Remote Sensing Center of China and the "Space Imaging Europe" and "Diastimiki Apikonisi" private companies under the aegis of the Hellenic Geographic Military Service. The project was co-financed by the European Union and the Ministries of Development, Research and Technology of Greece and China, and "Space Imaging Europe" and "Diastimiki Apikonisi" companies. The objective of this bilateral scientific collaboration which successfully completed on December 2003 has been the analytical study of the theoretical possibility of topographic maps updating using high resolution satellite images and the investigation of its practical applicability, clarifying at the same time its strong and week points. The positive results of the project allowed us to include the development of a specific methodology for such topographic map updating by the use of Geographic Information Systems (GIS), Global Position Systems (GPS) and Remote Sensing ("3S" project) advanced technology.

Four different updates process have been developed by the Greek and Chinese teams in collaboration. The analytical description of one of those four updating process of middle scales topographic maps using VHR satellite images, is the objective of this paper

BASIC STEPS FOR THE MIDDLE SCALE TOPOGRAPHIC MAPS UPDATING

From 1990, many proposals concerning the use of satellite images for map updating start to appear in the relative literature e.g. (Busch, 1998), (Dowman, 1998), (Jacobsen, 1997), (Ivica Skender, 1996), (Muller, 1994), (Ramirez, 1999), (Seager, 1998), (Holland, 2004), (ISPRS, 2001), (Armenakis, 2000).

In our case the basic steps (after the georeferenciation and orthorectification of maps and images) in the frame of a raster topographic map updating process using VHR satellite images could be summarized as following (those steps are used in all four developed updating processes):

a. Identification of the new cartographic objects
b. Identification of changes to the existing cartographic objects
c. Identification of the destruction of existing cartographic objects on the map
d. Identification of new cartographic objects that must appeared with a symbol on the map
e. Identification of existing cartographic objects on the map represented with a symbol that must be deleted.

The applied four different updating processes are the following:

1) Updating process 1 (figure 1): Overlay of all the raster map (all layers at the same time) to the satellite image (and non-layer by layer) and manually generation of the changes.

2) Updating process 2 (figures 1): Overlay of the satellite image to the map – manually generation of the changes of the polygons and lines (positives – new objects and negatives – deleted objects - combination) – overlay of the "changes" layer with the map's layers (separately for each layer) – creation of the new updated layer (using map algebra procedures).

3) Updating process 3 (figure 1): Overlay of the satellite image to each map layer (layer-by-layer – each layer separately) – manual process of updating, followed by integration of all map layers for the updated map production.

4) Updating process 4 (figure 1): Matching of each raster map layer with the image (using all the layers or only a part), realization of the update manually, georeferenciation of the updated layer or part of layer to the Greek geodetic system (EGSA 87).

TOWARDS A (SEMI) AUTOMATED TOPOGRAPHIC MAPS UPDATING PROCESS

Amongst the above four updating process the second one was the process offering the most chances to be full or partially computerized. Further research continues to this direction. This is the mean reason to be presented in more details this process.

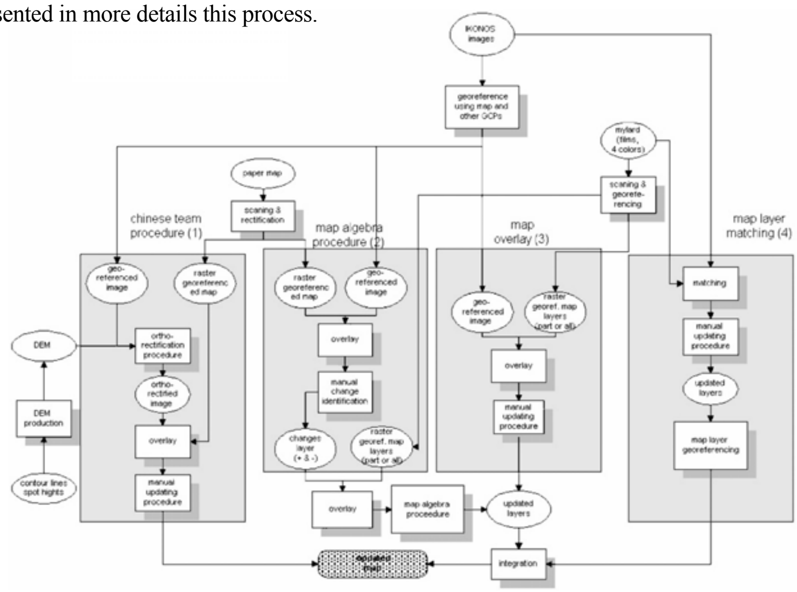


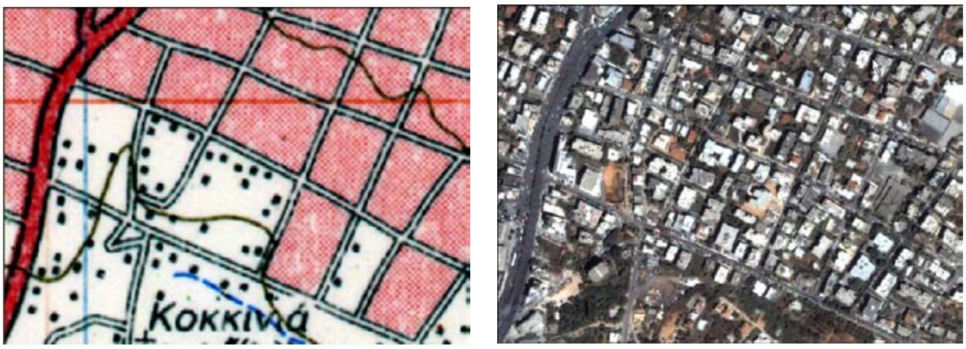
Figure 1: Four different map-updating approaches.

The basic concepts of the proposed process – presented in details in the following paragraph – was to manually identify the changes in each cartographic layer (also in the raster map, composed of all the layers) and at the next step to develop a procedure for their automatic incorporation in each map layer. Of course we had to face up of some basic problems and difficulties in the updating process such as lack of accuracy of the analogue topographic map (scanned at 300 dpi), errors in the cartographic objects identification process, accuracy and precision deficit during the overlay process (between the satellite image and the raster map, that is the scanned analogue topographic map) – matching errors, difficulty on the identification, development and application of clearly specified criteria and rules for different cartographic objects categories, etc.

TOPOGRAPHIC MAP UPDATING UNDER THE TERMS OF MAP ALGEBRA

Map algebra was to found to describe quite adequately the procedure used to update the topographic maps. The concept of map algebra has been coined for quite a while now (Tomlin 1990). It is only recently thought, that leading GIS software vendors provide actual tools that enable us to state an ill-structured problem such as the updating to topographic maps with map algebra terms.

The two inputs are the scanned at 300 dpi topographic map (fig. 2a) and the high-resolution satellite images (fig. 2b). Five analogue layers (films / mylard) compose the topographic map: black, red, green, blue and brawn. One example of the black mylard is given in figure 5a. Those films are used here because they are the actual source of conventional maps. The originals are in hard-copy form. They scanned (300 dpi analysis) to be digitally processed. On the other side the satellite image is inherently digital and thus is directly input to our process.

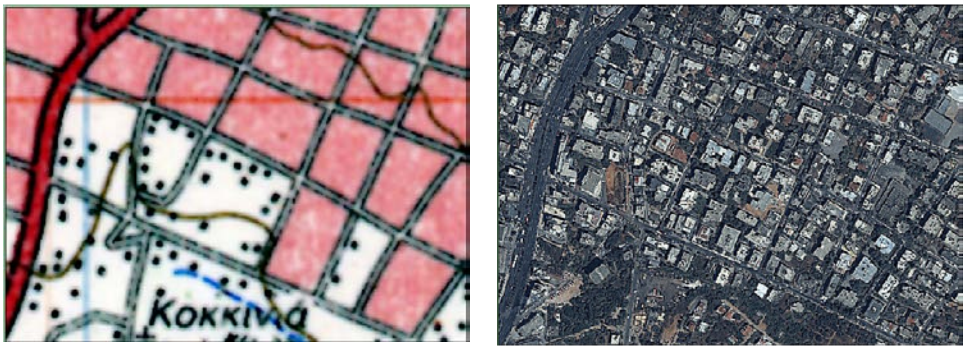


(a) (b)

Figure 2: The original portions of the input images to the tested updating procedure 2.
Also an example of urban blocks expansion.

A noise reduction method is applied on the analogue maps and layers (fig. 3a). The films are enhanced mainly in terms of speckle removal. This process is automated. During this step, both scanned topographic map and the raster / mylard films (layers) are georeferenced to the Greek geodetic system (EGSA 87), using an affine transformation. In those layers, the transformation is based on only four ground control points (GCPs) -the four corners of each layer-, since the content of the layers do not permit the identification of additional points. The transformation is very accurate though, since those four points are common in all layers and known with high accuracy.

At the same time the satellite image is enhanced using a high pass kernel to make edges more sharp (fig. 3b). The satellite image is then classified (fig. 4a) so that information content is reduced to only what is relevant to the topographic updating. This processed image is then projected to the Greek grid using sixteen GCPs with a 2^{nd} order polynomial transformation. The coordinates for the GCPs are taken from larger scale maps (1/5k). At the moment no need for additional GPS recordings has emerged.

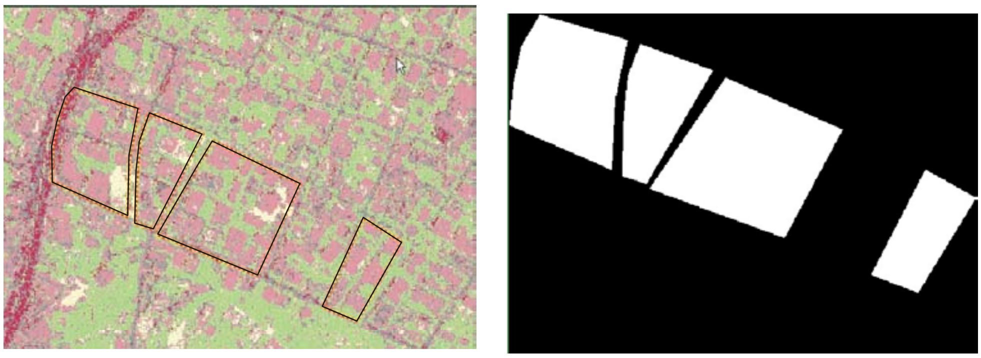


(a) (b)

Figure 3: Image processing steps of the original samples images.

The next step was to overlay the two data sources (satellite image and black layer). The fact that some changes have occurred is visible now. In some cases for example the city has expanded, in other cases there are evident alterations on the urban web (fig. 4a). Since they are easily detected we are able to proceed with the on screen digitization of the changes (fig. 5a).

The role of map algebra concerns the manipulation of "image's pixels changes". There are two categories of changes. Negative (-) changes which refer to features that have been removed and Positive (+) changes meaning that features have been added. A removal is not only when a building has been demolished for example but also in case land has changed use (fig. 2a,b). In this case, an area is removed from one class, which results in a negative change, add added in another class, positive change. This is to say that positive and negative changes are closely linked.



(a) (b)

Figure 4: (a) New urban blocks recorded in classified satellite image. (b) The raster format of the new blocks, after map algebra procedures.

Positive and negative changes are recorded into positive and negative polygons subsequently. The polygon information is then merged to the original films in a map algebra fashion: To apply the positive changes, we construct a mask that has zero for no change areas and the value of one for changed areas (fig. 4b). After that we add this mask to the original film, adding in essence the new areas in this class (fig. 5b). This example helps to clarify the practical result of the method (fig. 4, 5).

In a similar manner, to remove negative changes form the initial film, we first make a mask that contains the value of one for no change areas and zero value for changed (removed) areas. We then multiply this mask with the corresponding film (another map algebra procedure: matrix multiplication).

For refining further the process, priority order is set between the films to be updated. The black film (fig 5a) is of priority one, meaning that changes will have to be applied to this film first. It contains rigid features such as roads, buildings, that we want to stay intact.

(a) (b)

Figure 5: Final steps: (a) the analogue layer (black film), (b) the updated analogue layer, with the new urban blocks.

The new objects and changes that have been manually identified in the previous phase were been automatically integrated to each layer without problems in a significant percentage using the proposed updating process based to the map algebra (degree of automation >80% in area features - polygons). Effectiveness, rapidity, use of the existing data, without necessary creation of vector databases, and low cost are the obvious advantages of the proposed process.

The first part of the process still manual operation (identification of cartographic object's changes). The incorporation of the cartographic objects changes influence in many cases the different map's objects such as places-names, numbers etc. Nevertheless the updating of each layer can solve in a certain degree this problem which in any case will re-appear when the map names (the map lettering) layer will be superimposed to the others updated layers.

CONCLUSIONS AND PERSPECTIVES

On this article a new structured and independent from any software and hardware process for semi automatic analogue topographic maps updating has been summarily presented. The originality of this work primary consists on a new process of topographic map updating, part of which (the integration of the changes) is automatic. This approach could be characterized "pragmatic" but also original and innovated since in our knowledge is based in new ideas and concerns raster cartographic databases. The key contribution of this method is the high degree of automation since the updated objects are defined manually in a preliminary phase.

Concrete results confirmed the effectiveness of our proposal that could be used with any kind of high resolution and accuracy satellite images. In fact, in the frame of the proposed methodology it is possible to effectively incorporate automated and manual procedures at the same time, such as supervised classification and satellite images interpretation respectively. Nevertheless an overall assessment for the evaluation of the proposed process is not finished yet.

The positive results have already enabled both teams to ensure the continuation of their collaboration in the frame of a new bilateral two – years research project (2004 – 2006), financed from the EU, the Ministries of Development, Research and Technology of Greece and China and the Greek private company "Diastimiki Apikonisi". The new project concerns the accuracy improvement of the topographic maps with the use of satellite images of high-resolution high accuracy without reconstruction from scratch taking into consideration the matching problems between the satellite images and the topographic maps.

At the same time further investigation is going on, to automate the process as much as possible (the manual changes identification part) formulating specific rules and constraints for the topographic maps updating process (automated change detection using VHR satellite images). In addition current software developments are examined to apply the presented procedure in practice.

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