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TOWARD AUTOMATIC UPDATING OF THE ISRAELI NATIONAL GIS - PHASE II

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ABSTRACT

Spatial Information revision and updating is the main concern and production effort of maintaining the ever-growing GIS systems and spatial data bases. Developing easily effected automatic updating methods of spatial information becomes the key to the successful maintenance of the large GIS data bases established by many mapping agencies all over the world. The paper presents the second phase in a multi-year research effort for the development of capabilities of automatic updating of the Israeli National Spatial Data Base. This ongoing research is funded by the Survey of Israel within the framework of maintaining the Israeli National GIS (was reported on the ISPRS' IC meeting in Haifa, September 1997).

Discussed are the experiments and the evaluation steps to define an efficient method for detection of change. Presented are the guidelines and results of the development of an autonomous process to define change thresholds as part of an automatic change detection step. Also discussed are methods for noise removal and gaps bridging, necessary for expediting execution time and the efficiency of the overall process. Presented are experiments with filtering methods, in the raster domain, and with buffering methods, in vector domain.

In addition, presented are the research efforts to develop capabilities of feature recognition and shape identification, as the basis for change identification (third phase in the research). Also discussed are the experiments and effort to develop GIS-Driven capabilities for a multi-source change detection process as part of an automatic GIS data base updating method.

1 INTRODUCTION

The National GIS in Israel have reached an advanced stage in terms of the remapping effort of the country. The remapping project is carried out according to a newly developed environment and methodology where topology and 3-Dimensional relationships are taken into consideration. On a parallel effort, the Survey of Israel is focusing on the establishment of procedures and algorithms for the GIS database updating. Methodologically, the updating effort was envisaged as a three level project. On the basic level, exeperiments are carried out for over three years to study the special needs and issues of 3-Dimensional photogrammetric updating [Raizman, 1997; Peled & Raizman, 1997]. On the Second level, based on the basic level exeperiments, a research, combined with a pilot project, is to be launched by the end of 1998, aiming to establish an updating system (methods, algorithms, technical specifications and software) “tailored” to the digital environment, special to the National Geographic Information System. This paper describes some of the issues that are dealt with on a third level research. This 3-year research, at the end of it’s second year, is aiming to define feasible tools for automatic (as much as possible) updating. A secondary goal of this research is to develop advanced tools for processing digital data from various sources and to establish the infrastructure for such processes, at the Survey of Israel. The research is carried out in a modular fashion in order to develop techniques and executables on every step of the project. Focus has been made to exploit the existing B\W frame airphotographs that are used for the mapping effort. The Rational of this approach is that these airphotographs are being scanned, anyhow, for the second level updating effort [Peled, 1997].

2 TESTING CHANGE DETECTION ALGORITHEMS

Much effort was invested on experiments carried out to define an efficient algorithm for detecting regions-of-changes. These regions could depict a single geographic element or covering a wide area. The Regions-of-Change are detected by comparison of two images from different dates. The images must be, of course, resampled to the same coordinate system, by implementing a geometric calibration algorithm, before executing the process of comparison. In this project, “orthophotos” were produced from both images, based on the external orientation parameters of each single image. The changes are detected by comparing the radiometric signatures (gray levels) of the two images. This comparison assumes that the differences between the radiometric signatures are due to the changes of

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object characters. Indeed, these differences could be a result of other factors, such: different atmospheric conditions, changes of sun light angle and intensity, general noises, rectification errors, etc as [Fisher & Pathirana, 1993]. To avoid the effects of these factors, a radiometric calibration must be implemented. This was be achieved by using a histogram-matching procedure. The gray levels, of the pixels, were changed to achieve the same histogram for each image. As a result of our experiments, it was concluded to "equalize" the histogram of the "old" image to the "new" one.

Many different types of change detection methods were developed and reported in the professional literature. Changes may be detected by comparing the gray levels for each pixel, in a local way. These methods are very simple and fast, but on the other hand, considering one pixel is susceptible to noise. To avoid noise interference, filtering techniques were tested, as well. These techniques perform a comparison between the pixel' neighborhoods, on both images. The output of the comparison methods is a new image, usually in a binary format. The output image contains values which indicate a 'change' or 'no-change' situation. In this research, six methods were be tested, as follows:

2.1 Change Detection by Simple Differencing

In this method, a simple differencing is computed between the gray level values, for each pixel. The difference may be positive, negative or equal to zero. Seemingly, a zero difference indicates no change. But, the objective here is to detect **significant** changes. Therefore, two thresholds were selected to define 'significant changes'. It is possible to define two types of change, by it's value: positive, negative or both. In this case the output image may contain two or three values which indicate: 'no-change', 'positive'-change or 'negative'-change. Separation into two types of changes, may be useful to identify the attribute of the change.

2.2 Change Detection by Ratio

In this method, a simple ratio is computed between the gray level values, for each pixel. The ratio may be equal to 1.0, less than 1.0 or greater than 1.0. A ratio of 1.0, or close to 1.0, means no-change. Here, also, it is possible to define two types of change, by selecting two thresholds.

2.3 Change Detection by Normalized Index

In this method, the change indices are computed as a normalized ratio:

$$\mathrm{Ratio} = \frac{\mathrm{GL2} - \mathrm{GL1}}{\mathrm{GL2} + \mathrm{GL1}}$$

Where:

$\mathrm{GL}_1, \mathrm{GL}_2$ are the Gray Level values for the pixel, in both images.

A zero (or close to zero) normalized ratio indicates a 'no-change' situation. Again, by selecting two thresholds, it is possible to define two types of changes, as mentioned above.

2.4 Change Detection by Neighborhood Differencing

This method is similar to the first one. The only distinction here is expressed by computing the differences between the average of gray level values for the pixel' neighborhood, in both images, rather than the pixel itself.

2.5 Change Detection by Neighborhood Likelihood

By this method, a Likelihood parameter is computed for the neighborhoods of the pixel, in both images. The likelihood parameter indicates the similarity between the neighborhoods' gray level values. This parameter is computed by the equation [Skifstad & Jain, 1989]:

$$L = \frac{\left(\left(\frac{\sigma_1^2 + \sigma_2^2}{2} \right) + \left(\frac{\mu_1 - \mu_2}{2} \right)^2 \right)^2}{\sigma_1^2 \sigma_2^2}$$

where:

L the Likelihood parameter;

μ_1, σ_1^2 are the mean and variance of the neighborhood in the first image, respectively.

μ_2, σ_2^2 are the mean and variance of the neighborhood in the second image, respectively.

If the Likelihood parameter exceeds a given threshold, the two neighborhoods are defined as 'different'. By this technique, it is not possible to distinguish between the types of change. This method enables a clear detection of changes in large regions (in terms of area). On the other hand, it is not suitable for detecting thin linear elements.

2.6 Change Detection by Local Normalization Differencing

By this method, a local normalization is implemented between the pixel' neighborhoods. The purpose of the normalization is to convert the gray level values of the two neighborhoods, thus, to get the same mean and variance values, for each neighborhood, on both images. The normalized gray level values are computed by the equations:

$$GL_{n1} = \frac{\sigma_1}{\sigma_2}\left(GL_2 - \mu_2\right) + \mu_1$$

$$GL_{n2} = \frac{\sigma_2}{\sigma_1}\left(GL_1 - \mu_1\right) + \mu_2$$

Where:

$\mathrm{GL}_1, \mathrm{GL}_2$ are the Gray Level values for the pixel, on both images.

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GLn_1, GLn_2 are the Normalized Gray Level values for the pixel, on both images.

μ_1, σ_1^2 are the mean and variance of the neighborhood, on the first image, respectively.

μ_2, σ_2^2 are the mean and variance of the neighborhood, on the second image, respectively.

A simple differencing is computed between the normalized gray level values. A zero (or close to zero) difference value, indicates a 'no-change' situation. It is possible to define two types of changes, by selecting two thresholds. By this method, a local histogram-matching was processed for the each pixel. Thus, there is no need to implement a global radiometric calibration between the two images, when using this method.

2.7 Conclusions

Based on the above mentioned experiments, for detecting changes by several methods, three conclusions were made, as follows:

1. By comparing a single pixel, it is possible to detect linear and area-wide regions (of change). In contrast, by comparing the pixel' neighborhoods, it is possible to detect area-wide regions, more precisely, but it is difficult to detect linear elements.

2. The comparison of a single pixel procedures are very fast, as opposed to the comparison of the pixel' neighborhoods procedures (see table 1).

3. In most of the methods, that were tested, it was possible to distinguish between two types of changes (excluding the Likelihood method).

According to these conclusions, it was decided to chose the simplest method, comparison by simple differencing, for the change detection step.

3 DETERMINATION OF THRESHOLDS

The selection of suitable thresholds, to define a 'significant' change, is an important step of the comparison procedure. Especially, if one is aiming for the ambitious goal of developing automatic change detection procedures. In this project, several thresholds were tested, using a variety of images, with different gray level values histograms. It was observed that large thresholds values, produced low noise ratio, but the change regions were uncertain and not obvious. In contrast, small thresholds values, produced sharp and clear regions of change, but the noise ratio was high. The important observation of these experiments was the correlation that was found between the optimal thresholds and the variance of the gray level values histogram. It found that, the best thresholds values, for a simple differencing comparison, are close to the value of the SME (Squared Mean Error) of the histogram. This conclusion, opened the way for developing an automatic change detection process, where no guidance of a human operator is needed.

4 NOISE REMOVAL AND GAP CONNECTION

The output of change detection methods, contain, relatively, high ratio of noise. Noise may be depicted as isolated speckles (false regions), separated (true) regions of change and as gaps between regions. To remove these noise, bridge gaps and to connect nearby regions, four methods were tested, both in raster and vector environments, as follows:

1. **Majority filtering.** Setting the most frequently code, in the filter, to the middle pixel.

2. **Recommended majority filtering for a required code.** The objective is to avoid thinning linear elements, while removing noises and gaps by a regular majority filtering. By this method, the algorithm is searching for pixels with a 'no-change' code. Should a given number of pixels, in a predefined neighborhood, is detected to have the 'change' code, the algorithm will assign a 'change" code to the tested pixel. a recommended number of neighbors with. This, of course ma be processed for pixels that carry a 'change' code value or for both. The issue is that the algorithm may flip the code for these pixels the opposite value, at our discretion.

3. **Connecting gaps by directed filtering.** The goal of this method is the same as the previous one. The algorithm removes noises, which have an opposite code at two opposite directions of it. Also, it connects gaps, which have an opposite code at two opposite directions. The directions are defined by a predefined filter. There are optional 8 directions and 4 pairs of opposite directions.

4. **Buffering (vector environment).** The idea here was to use the ARC/INFO BUFFER routine, in order to combine adjacent regions of change. The algorithm comprises of three steps: (a) Converting the image to a vector format of a polygonal layer; (b) Implementing "out" Buffer process, by required distance which is correlated to the size of the original, raster domain, pixels; and (c) Implementing "in" Buffer process, in order to bring the regions size back to the "original" scale. By this method, it is possible to remove small regions (noise polygons), by defining an area threshold.

4.1 Conclusions

According to different experiments with noise removal and bridging gaps, it was concluded that a good noise removal operation causes more discontinuities in linear elements, and vice versa. It is optional to select a required size of the filters and a required distance for the buffers, in order to achieve better results. Also, it is possible to implement more than one method for the same output, image of change. Another factor that should be considered, is the performance time (see table 2).

5 CHANGE IDENTIFICATION

In general, there are two approaches for change identification, as follows:

1. Manual approach: Identifying the changes, interactively, by human operator.
2. Automatic approach: Identifying and extracting new features automatically, as much as possible, by the computer. Then, updating the database, interactively.

At this stage of this project, the tools and routines, that have been developed, enable identification of the changes, interactively. By viewing the orthophoto images as a background of the GIS coverages. Focusing on the regions of changes, the human operator may identify and digitize the new features, directly from the screen, and update the database.

To achieve automation, in this stage, the GIS-Driven change identification method was tested [Peled, 1993; Peled, 1994].

5.1 GIS-Driven Change Detection

The objective of a GIS-Driven Change detection algorithm, is to build a correlation system (geographic and radiometric) between the (any) digital images and the existing GIS database. The geographic correlation system was established, as the first step, when producing the “orthophoto”. The radiometric correlation system is defined by establishing training sets. A gray level histogram may be calculated, for each feature type (class), based upon he GIS coverages. Intersecting the “orthophoto” images with the coverages, will result with the definition of the features (in terms of geographic position, over the image, gray level matrix. These intersections are implemented, much faster, in the raster environment. Therefore, the vector coverages must be converted to a raster format. According to these histograms, it’s possible to define what are the specific signatures that define, uniquely, a required feature class.

5.2 Experimenting GIS-Driven Change Detection

At this stage, only two layers, of the Israeli National GIS, were tested: coverage #1 (Transportation) and coverage #7 (Buildings). These layers were selected due to a rapid changing for both, in contrast of the other layers.

(a) Buildings Coverage:
The majority of the buildings in coverage #7 are “regular” buildings. Therefore one class of buildings was tested. Figure no. 2 depict the histogram of gray level values for the pixels that fall in “regular” buildings category, in ‘unchanged’ regions. According to this histogram, it is not possible to define a unique interval of gray levels that characterize the class of buildings. Therefore, it was decided to check if there are any correlation between the gray level values and the position of the pixels within the polygon of the ‘building’. The motivation was to find whether the shadow, or other special partitions of the buildings (image), affect the histogram of gray level values. Another test, was to check for a correlation between the gray levels and the direction (by meaning of positive or negative change) of changed regions. As a result these test, it was found that the gray level values are distributed, arbitrary, over the buildings and the change region types.

(b) Transportation Coverage:
The transportation coverage includes seven different types of roads. Figure 3 illustrates the distribution of gray level values, for each road type, that falls in ‘unchanged’ regions. These histograms depict distinct peaks. Yet, it is still difficult to define gray level interval for each road class, uniquely.

6 SUMMARY

According to the above mentioned experiments, the conclusion was that using, only, radiometric data (from black and white aerial photographs), is not enough to enable automatic change identification processes. Therefore, it was decided continue the research by using colored photographs and multi-spectral remotely sensed images. In addition, a geometric identification approach was envisaged for the third phase of this research. Just recently, work has begun with experimenting with edge detection algorithms, in order to describe the geometric parameters of the elements in the detected regions of change.

In light of the results of the first and second phases of this research, it is most likely, now, that the Survey of Israel will adopt other digital sources of spatial information. These are either space photographs or remotely sensed satellite images. The foundation that was established by this research will serve any of the potential sources and will be the basis of the second generation model for the GIS database updating .

7 REFERENCES

1. **Fisher, P.F. & Pathirana, S. (1993).** The ordering of Multitemporal Fuzzy Land-Cover Information derived from Landsat MSS data. *Geocarto International, (3).* pp. 5-14.

2. **Peled, A. (1993).** Change Detection: First step toward automatic Updating. 1993 ACSM-ASPRS Annual Convention & Exposition Technical Papers, New Orleans, LA., USA , Vol. 3. pp. 281-286.

3. **Peled, A. (1994).** Revision of Digital Maps and GIS Databases. ISPRS, Proceedings Symposium, Mapping and Geographic Information Systems, Athens, Georgia, USA, Vol. 30, Part 4, pp. 268-272.

4. **Peled, A. (1997).** On the Updating of the National geographic Informatiopn System. Proceedings,

ILSPRS Annual Conference, May, 22. Tel-Aviv, Israel. pp. 54-66. (Hebrew)

5. **Peled, A. & Raizman, Y. (1997)**. Toward Automatic Updating of the Israeli National GIS. Proceedings, ISPRS WG III/2, III/3 and II\8 Joint Workshop on Theoretical and Practical Aspects of Surface reconstruction and 3-D Object Extraction, Haifa, ISRAEL, September 9-11, 1977. pp. 114-119.

6. **Raizman, Y. (1997).** The National Topographic GIS - Progress and Updating Processes. Proceedings, ILSPRS Annual Conference, May, 22. Tel-Aviv, Israel. pp. 50-53. (Hebrew)

7. **Skifstad, K. & Jain, R. (1989).** Illumination Independent Change Detection for Real World Image Sequences. *Computer Vision, Graphics and Image Processing, 46(3).* pp. 387-399.

Table 1: Performance times of change detection methods. For an image of 4000x4000 pixels, 2x2 km. Executed in SUN SPARC Station 5.

Performance time (Appr.)	Filter size	Method of Comparison
40 sec.	-	Simple differencing
40 sec.	-	Ratio
40 sec.	-	NDVI
8.5 min. 15.5 min.	5x5 7x7	Differencing between the average of neighborhoods
30 min. 58 min.	5x5 7x7	Likelihood parameter
58 min.	7x7	Local Normalization

Table 2: Performance times of noise removal and gap connection operations. For an image of 4000x4000 pixels, 2x2km. Executed in SUN SPARC Station 5.

Performance time (Appr.)	Filter size	Algorithm
3 min. 6 min	7x7 15x15	Majority filtering
100 sec.	7x7	Recommended majority filtering for a required code
12.5 min. 23 min.	7x7 11x11	Connecting gaps by directed filtering
"out"- 50 min. "in" - 15 min.	-	Buffering at the vector environment (Depends on the number of polygons)
7 min.	-	Converting image to vector coverage

Figure 1: Gray levels distribution of the "orthophoto" of the "new" image.

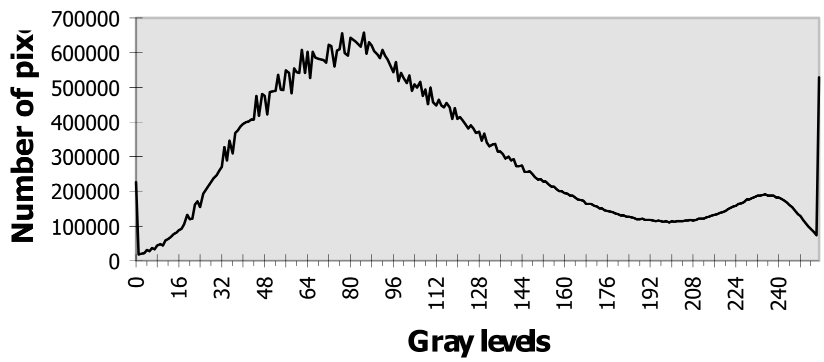

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Figure 2: Gray level distribution of pixels that fall on buildings in unchanged regions.

Figure 3: Gray levels distribution of pixels that fall on roads in unchanged regions.