A CONCEPT FOR AUTOMATIC CHANGE DETECTION IN REVISION OF TOPOGRAPHIC MAPS BY MEANS OF DIGITAL, IMAGE PROCESSING AND PATTERN RECOGNITION TECHNIQUES

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ABSTRACT

This paper presents a concept to automate the process of change detection for revision of topographic maps by using Digital Image Processing and Pattern Recognition techniques. The relevant changes are detected by comparing the features automatically extracted from a digitized new aerial photograph with those of the existing map. The fature extraction process is guided by general knowledge about the topographic objects, and by the existing map. A classified old photograph (the one used for compilation of the map) also plays an important role in the process. The comparison between the objects extracted the photo with the map objects is performed by matching the object descriptors (position, shape, size, etc.). Objects are finally classified as: "new object", "old object", or "object irrelevant for mapping". The implementation of such concepts, limited to detection of linear fatures (roads), is presented in details, followed by a practical experiment with real data.

1. INTRODUCTION

The world's demands for maps is a well known fact. The use of existing techniques requires plenty of decades to solve the problem. The situation is even worse in developing countries of large areas like Brazil. In these countries, the amount of work to be done contrasts with the country's little finantial and human resources.

In order to improve the situation, a lot of work has been done to speed up map production. For exemple: Computer Assisted Cartography, Global Positioning Systems (GPS), automatic production of DTM, etc.

Another field that needs to be speeded up is Map Revision, especially if we consider that the larger the number of maps published, the more the resources for mapping must be diverted from mapping to the revision of existing maps.

The next step foward seems to be the automation photo interpretation itself. During the last decades there have been many researchs, mainly conducted by scientists in fields other than photogrammetry, on automatic detection of topographic objects by digital image processing and patern recognition techniques |5|, |9|. Such technology might have a potential application in the field of map revision, since it can assist the human operator in detecting the changes by comparing the objects automatically extracted from a new photo with those in the existing digital map.

This paper describes a concept for such system, that incorporate digital image processing and pattern recognition to support the detection of changes for map revision. This research is the product of a M.Sc. thesis developed by the author at the Photogrammetry department at ITC (Holland), under supervision of Prof. N. J. Mulder and Dr. M. M. Radwan.

2. CONCEPTS

The system requires:

- The existing map to be available in digital form.
- The abailability of new photos to be used for upating the existing map.
The new photo is digitized and stored in raster format.
- Availability of the old photos from which the existing map was compiled.
The old photo is digitized and stored in raster format. Objects in the old photo have been identified in advance, and provided with a set of descriptors.

Starting with these data, the various objects in the new photo will be extracted and provided with descriptors (position, shape, size, orientation, etc.) during the feature extraction phase. Feature extraction involves Segmentation and Object Description. The objects are then classified with the guidance of the existing, the classified old photo and available specific Knowledge about objects. The result of this classification will indicate whether such objects are:

- "Old", and being mapped before
- "New", and needed to be mapped.
- "Irrelevant to mapping".

The new objects are the changes that, after being checked and edited by a human operator, must be transferred to the map.

Figure 1 ilustrates the whole process.

2.1. Feature Extraction

Feature extraction is the process of extracting from the digital images characteristic data about objects. These features are often represented by a list of descriptors |7|.

The spatial feature extraction process is outlined in figure 2.

2.1.1. Segmentation (Region Based)

Regions are defined as areas of uniform reflectance. The process starts by repeated application of an edge preserving smoothing filter until the process stabilizes, therefore

```
                    new photograph
                          |
                          v
         +--------------------------------------------+
         |                                            |
         |         SCANNING AND PRE-PROCESSING        |
         |         ===========================        |
         |                                            |
         +--------------------------------------------+
                          |
                          v
         +--------------------------------------------+
         |                                            |
         |             FEATURE EXTRACTION             |
+--->----|             ==================             |
|        |                                            |
|        +--------------------------------------------+
|                         |
^ feedback                v  objects with descriptors
|                         |
|        +--------------------------------------------+
|        |                                            |
|        |               CLASSIFICATION               |
|        |               ==============               |
|        |       +------------------------------+     |
|        |       |  CLASSIFICATION BASED ON     |     |
|        |       | SPECIFIC KNOWLEDGE ABOUT THE |     |
|        |       |         OBJECTS              |     |
|        |       +------------------------------+     |
|        |                                            |
|        |       +------------------------------+     |
+---<----|       |  MAP-GUIDED CLASSIFICATION   |     |
         |       |                              |     |
         |       |      +----------------+      |     |
         |       |      | COMPARISON WITH|      |     |
         |       |      |   OLD PHOTO    |      |     |
         |       |      +----------------+      |     |
         |       |                              |     |
         |       |      +----------------+      |     |
         |       |      | COMPARISON WITH|      |     |
         |       |      |   OLD MAP      |      |     |
         |       |      +----------------+      |     |
         |       |                              |     |
         |       +------------------------------+     |
         |                                            |
         +--------------------------------------------+
                          |
                          v
         classified objects  (including relevant changes)
```

FIG. 1 - Scheme of Automatic Change Detection

```
          DIGITAL IMAGE
                |
                v
   +--------------------------+
   |       SEGMENTATION       |
   +--------------------------+
                |
                v
   +--------------------------+
   |    OBJECT DESCRIPTION    |
   +--------------------------+
                |
                v
       OBJECTS WITH DESCRIPTORS
```

FIG. 2 - Scheme of Spatial Feature Extraction

defining image segments of uniform reflection, followed by a process to trace the boundaries between these segments until each segment is enclosed by a polygon. Examples of such method can be found in |8| and |14|.

2.1.2. Object Description

In this process a set of descriptors is computed and assigned to each segment identified in the previous process. The descriptors are the basis for classification. Some examples of such descriptors are: chain coding |3|, polygon approximation |2|, perimeter, area minimum bounding rectangle, orientation, elongatedness, fit, skeleton, Fourier and Hardmard descriptors |11|,topologic relations |15|. Further details can be found in |7|, |10| and |12|.

2.2. Classification

The objects defined in the feature extraction phase are then classified according to its descriptors into the various classes specified for the topographic map. This classification will be partially done using our specific knowledge about the objects we want to extract, and partially done by comparing, at object level, the new photo with the old one, and the new photo with the map.

2.2.1. Classification based on "Specific Knowledge".

Examples of specific knowledge about objects are: Roads are elongated objects not wider than 30 metres, houses are small objects whose length to width ratio is around one, etc. There are also knowledge indicators concerning topology, for example: A road should be connected to a network, houses should be close to a road, and so on. Classification based on specific knowledge is best implemented using the concepts of production systems |9| and |5|.

2.2.2. Map-guided classification

The other source of information for classification is the existing map.
Map-guided classification could be performed simply by comparing each object extracted from the new photo with the objects of the map (after image and map have been registered to each other). This comparison is performed by matching the object descriptors. If the descriptors of the photo-object match with the descriptors of the map-object, then the objects are assumed to be the same and the same class is assigned from the map-object to the photo-object. This concept requires that the map gives for each of its objects the same set of descriptors used for matching. For example: Each photo-object is projected to the map via its positional attributes, like position of the center of gravity or the bounding rectangle. If there is a coincidence with th positional attributes of any map-object, then their other attributes, like orientation, shape, size, are compared. If they also match, then the

photo-object receives the same class of the map object (i.e. road, river, building, forest, field, etc.), otherwise it is classifield as a "new" object. When more than one photo-object match with the same map element, then these objects can be morged together (generalization).

However, when a map is too simplified/enhanced, the comparison of the photo with the map will produce many unmatched objects. Therefore some uncertainties will remain, for example it will be very difficult to distinguish between a change ("new") and an object irrelevant to mapping.
Further, it will be difficult to identify whether a mismatch was due to changes or due to Cartographic enhancements.

In order to eliminate part of these doubts, it is necessary to compare first the new photo with the classified old photo. If the old photo has not been classified before, it can be classified through the same process described for the classification of the new photo. The output of the classification of the old photo is a list of objects classified either as an "old map element" or as an "object irrelevant to the map legend".

The comparison of the new photo with the classified old photo is carried out by comparing each object of the new photo with those of the old photo. If a new-photo-object matches with any old-photo object, it receives the same class it has in the old photo ("old" or "irrelevant"), otherwise it is considered as a "modified" (or new) object. In this way it is possible to identify some of the new photo objects which are "irrelevant", assuming that there is no changes on the map specifications. When comparing the new photo with the map, only those objects classified as "modified" will be compared to the map objects. If the photo object matches with a map object, it receives the class from the map, otherwise it is classified as a new object.

3. IMPLEMENTATION (EXPERIMENTAL WORK)

An experiment was carried out using 1/20.000 aerial photographs, scanned with 200 microns pixel size (four metre on the ground), and a digitized topographic map at scale of 1/25.000. Figure 3 shows the outdated map, and Figure 4 shows an updated digitized aerial photography.

Due to the complexity of the problem, our implemented system is limited to detection of changes in linear map features (particularly roads). The key steps in the process are: Feature extraction and Classification.

3.1. Feature Extraction

Because roads can be considered as linear objects in low resolution images, feature extraction consisted of: Line detection and Line description.

The selected line detection operator was the "Original-minusmedian" |8| and |13|. The detected lines are then defined as individual objects during the line description phase. This operation is basically a transformation from raster to vector and involves operation like: line thinning, line following and line weeding |1|. For each vector a set of descriptors is computed. They are:

- Bounding rectangle.
- Length.
- Direction.
- Straightness.
- Relational descriptors. This relation is expressed in terms of arcs and nodes where arcs are the individual lines, and nodes indicates which lines are connected to a particular one.

Figure 5 shows the results of Feature Extraction.

3.2. Classification

The first step in any classification process is the definition of classes. For our purpouse of change detection, limited to roads, these classes are:

- An "OLD ROAD". Being a road already mapped in the existing map.
- A "NEW ROAD". It could be a new road or a modified old road.
- An "IRRELEVANT LINE". This could be a noise, a road irrelevant to the map or any other linear feature which is not a road.

The process starts with the comparison between the new photo and the classified old photo. It is assumed that the old photo has been classified, and every line has been labelled either as:

- A "ROAD"
- An "IRRELEVANT LINE".

If this classification is not yet available, which is the case of our experiment, the old photo must first be classified by comparing their lines, extracted by the same automatic process described before, with the map lines. The comparison between the two sets of lines is obtained by matching each line of the first set with all the lines of the second. The objective is to classify the first set based on the classification of the second.

Two lines are matched by matching their descriptors. The first descriptor to be matched is the spatial location, expressed by the bounding rectangle. If there is enough overlap between the two bounding rectangles, the two lines are considered to have about the same spatial location and then the other descriptors are matched (direction and length).

When comparing the new photo with the classified old photo, if a new-photo line matches with an old-photo line, the same class

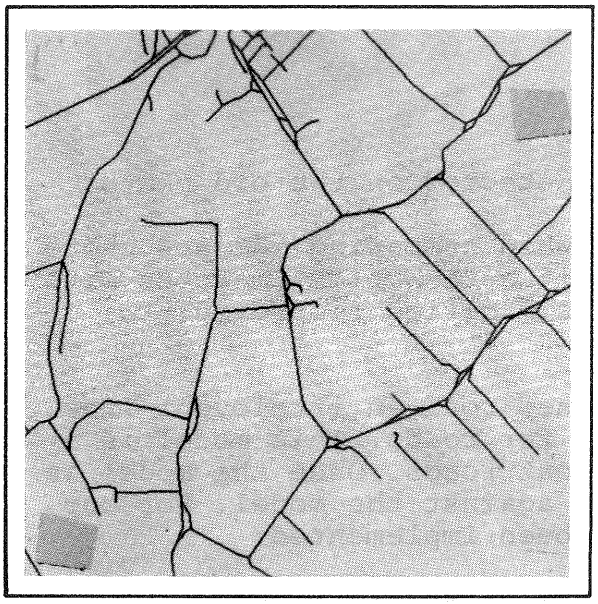

FIG. 3 - Outdated map

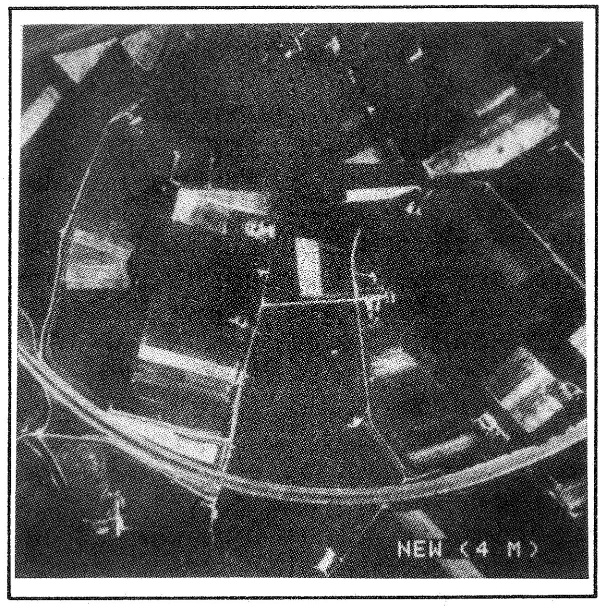

FIG. 4 - Updated photograph

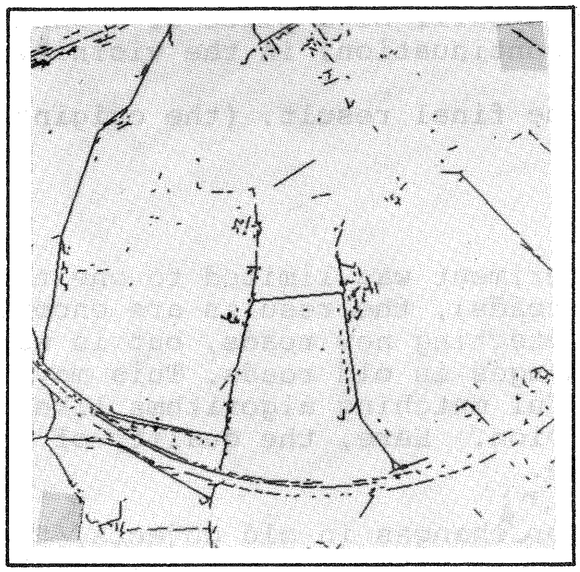

FIG. 5 - After Feature Extraction

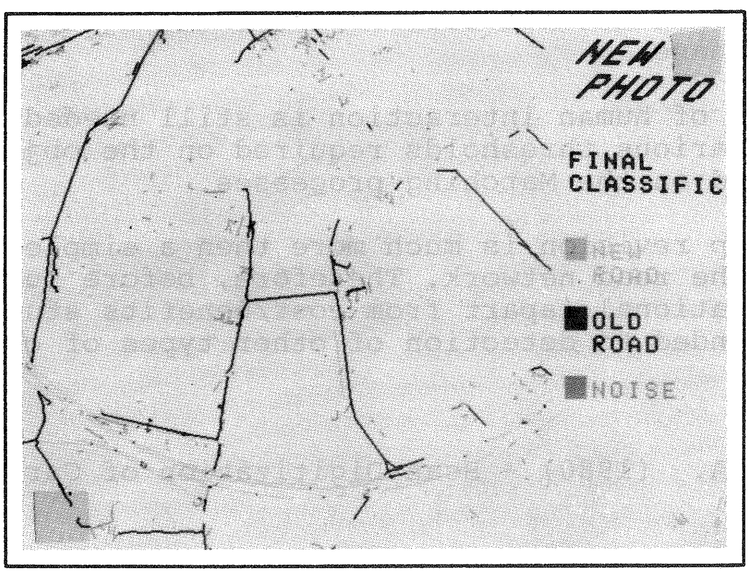

FIG. 6 - Final Classification

is assigned from the old-photo line to the new-photo line. Otherwise it is classified as a "NEW LINE".

Still, this 'new line' can be:

- A "NEW ROAD".
- An "IRRELEVANT LINE".
- An "OLD ROAD" that has not been detected on the old photo.

The third possibility is detected when comparing the new photo with the map. During this process,if a "NEW LINE" matches with any map line, its classification is modified (improved) to "OLD ROAD".

In order to distinguish between a new road an irrelevant line, it is necessary to defined a model for roads. This model is a representation of our knowledge about roads. Once the model is defined, each "NEW LINE" is tested against the model. For our experiment, three hypothesis have been implemented:

- A new road must have a high degree of straightness.
- A new road must be a long line.
- A small line can still be a piece of a road if there is another line (a continuation) in the vicinity.

Figure 6 shows the final result. (the original picture is in colours)

4. CONCLUSIONS

Although the experiment was limited to one test area and to one type of object (roads), the results are encouraging. The method is powerful in detecting new roads, but is was not able to detect little changes in old roads. This may be achieved by using more powerful matching algorithms like: Chain coding or Polygon Aproximation. Here, the quality of the map also plays an important role.

When searching for changes in old objects, the method can not perfectly distinguish between a map element that has been destroyed, and therefore must be deleted from the map, and a map element that has not been detected during the feature, extraction phase.

A great deal of human interaction is still needed in order to adjust the various thresholds required on the object Detection and on the Matching processes.

Moreover, map revision is much more then a simple detection of changes in the road network. Therefore, before such method becomes operational (apart from cost/benefits studies), it must be extended to detection of other types of objects.

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