FEX: Automatic Planimetric Feature Extraction

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Abstract

Availability of high resolution commercial satellite imagery coupled with advances in image interpretation technology render automated planimetric feature extraction distinctly feasible. This paper describes MacDonald Dettwiler's current work on automated and knowledge-based planimetric feature extraction. Results show significant time reductions over the traditional labour intensive photo interpretative methods.

1 Introduction

Topographical planimetric features include natural surfaces (rivers, lakes) and man-made surfaces (roads, railways, bridges). Conventional planimetric feature extraction involves a photointerpreter who manually interprets and extracts features by viewing imagery on a stereoplotter. Visual planimetric feature extraction is a very labour intensive operation. The photointerpreter uses various clues in order to determine what features are present in the imagery and where they are located. Traditionally, air photos were used for planimetric feature extraction. Some of the advantages of digital processing of satellite imagery over conventional photogrammetric methods include:

- Satellite imagery provides constant global coverage, and is readily available from image archives.
- Data acquisition and ground control costs are substantially less than those for equivalent aerial photography, due partly to decreased need for ground control.
- Satellite image data are already in the digital format necessary for computer processing. Computer processing reduces the labour intensity and , consequently, the costs of map compilation [9].

This paper deals with the extraction of planimetric features using satellite imagery. The technology of manually extracting planimetric features from satellite imagery can be extended to the capability of extracting features automatically. The advantages of automating feature extraction include: time and labour savings; accuracy improvements; and planimetric data consistency.

FEX (Feature EXtraction) is a system that extracts planimetric features from remotely sensed imagery for topographic mapping applications. The present system requires minimal user assistance. FEX involves a three stage process: training, extraction and verification. The extraction step is fully automatic. The training and verification steps require user interaction. Some manual verification stage will always be required. MacDonald Dettwiler is however researching the automation of the training stage while minimizing the verification stage.

2 What Can We See?

2.1 Imagery Input

Spatial and spectral resolution requirements determine the type of imagery used for planimetric feature extraction. The traditional approach involves air photos which offer a range of spatial resolution if the appropriate scales are available. If satellite data is used, the spatial resolution will be poorer than for many air photos but the spectral resolution will be more detailed. The spectral resolution is considered in terms of the identification of target signatures for establishing differences between surface cover types. The spectral aspect of satellite imagery is useful as it will also allow the production of true and false colour imagery without the additional image collection cost associated with air photo data. The spatial resolution is a factor in the recognition of patterns and shapes in the imagery and is usually limited by the resolution of the sensor system. The spatial aspect of imagery is enhanced by stereo viewing which allows the identification of features using the feature's three-dimensional properties.

Presently available systems do not offer good spatial and spectral resolutions in the same satellite. The best available spatial resolution is the SPOT PLA band which has a ground resolution of ten metres and can be collected as a stereo pair. The Landsat TM system has a high spectral resolution with seven bands covering a range from visible blue to thermal infrared.

2.2 Feature Identification

Features are identified by two primary spatial factors:

- **shape.** Linears are the most easily identified features in any image. Linearity can be identified even in an image at a small scale (i.e. 1:100000).
- **pattern.** (i.e. grid, dendritic) Patterns involve a more global overview of the imagery.

Other spatial factors (i.e. texture and size) are used mainly for enhancing the detail of the extraction based on the primary spatial features. The spectral characteristics of the feature are generally used for detail and not identification (e.g. dry river beds are more reflective than rivers). Likewise, the topology associated with the feature adds in detail definition (e.g. primary roads have a more direct route than secondary roads).

3 Planimetric Feature Extraction

Automation of planimetric feature extraction is a natural extension from manual extraction. The manual extraction process is described below, followed by the system's operational scenario.

3.1 Before: Manual Extraction Process

The manual extraction process involves image interpretation by an operator at several different scales. In the small scale process, the operator identifies the global feature pattern such as the grid pattern of a road network. The medium scale process is utilized to discriminate between the feature types. An example is the difference between roads and trails. The large scale stage is used to delineate the boundaries of the features.

The imagery is displayed at the appropriate scale for each of the interpretation processes. The results of the interpretation are then entered by digitizing the features in an image displayed on a Visual Display Processor (VDP) screen. The results of the digitization are stored in a GIS for later editing, analysis and display.

3.2 Present: Operational Scenario

Presently, human input remains essential to the process of extracting linear features from imagery. The role of image processing is to speed up, but not to replace, manual digitization. Present technology has not matured enough to fully automate the feature extraction process. For human assisted feature extraction to be effective, the operational scenario has to provide an efficient environment. Factors that influence the decision of the type of operational scenario to adapt include: total elapsed extraction time and minimization of extensive specialist knowledge.

At MacDonald Dettwiler, the extraction of linear features has been divided into three discrete steps, namely:

- Training.
- Extraction.
- Verification.

The training and verification steps are interactive. The extraction step is computer intensive and executed without operator input.

The training step enables the user to identify areas in the image which contain linear features of the kind to be extracted. The program analyzes the regional pixel data and derives values for a parameterized model of the linear feature. Values are derived for such properties as average feature width and along-track intensity.

The extraction step utilizes the feature model obtained in the training step. It searches for linear features in the image which match the feature model. The result of this step is a set of linear segments.

The verification step enables the user to delete segments which were incorrectly identified as linear features, and to connect unconnected segments which are judged to belong to the same linear feature. Verified results are stored as features in a Geographic Information System (GIS).

4 Accuracy

The feature identification process dictates that the image interpretation consist of direct pattern recognition based on spatial clues. Using spatial clues, linear features are the most readily identifiable features in any image. Even when linear features may be sub-resolution in width, such as a five meter wide cut line on a ten meter resolution SPOT image, the feature can still be identified by its shape. Given that the primary clues used to extract this class of features are well defined and relatively unambiguous the accuracy of extracting them will be high.

There are two types of feature extraction accuracy:

- Class identification accuracy. For linear features, there is a high class identification accuracy, for example in defining roads versus rivers based on spatial clues.
- Internal class distinction accuracy. There is limited internal class accuracy when determining, for example whether a road is paved or unpaved. A paved/unpaved classification will be determined by spectral clues which are not as rigorous as spatial clues.

The accuracies are relative measures within an image. The final absolute accuracy is scene dependent and a function of the experience of the interpreter.

4.1 Manual Extraction Accuracy

Positional accuracy is the accuracy with which the system locates a feature, when compared to a reference source. The reference source for manual extraction is ground truth data. The positional accuracy of manual extraction is a function of the image resolution and geocoding. The pointing accuracy in the image is usually subpixel as is the positional error resulting from the geocoding. Therefore, operator error is the largest source of positional inaccuracy. This is a serious problem as the digitization of large numbers of features is time consuming and tedious, resulting in operator fatigue and errors. The accuracy achieved should conform to certain standards.

4.2 Standards

The scale of most interest for satellite mapping is 1:50 000. The accuracy standards for NATO class A maps is that 90% of all well-defined points tested be accurate to within 0.5 mm. A similar level of accuracy has been adopted in the U.S. for the National Map Accuracy Standards and in Canada for class A maps. The accuracy standard as stated is a circular map accuracy standard (CMAS). The mean squared error (MSE) is a more common form of accuracy measurement [8].

4.3 Automated Extraction Accuracy

To determine how well the automated feature extraction algorithms perform, the results (e.g. extracted roads) have to be compared to some reference. This reference can be one of the following:

- Map of the area in question.
- Photointerpreter's manual feature extraction of the area from the same imagery.
- Untrained human observer manual feature extraction of the area from the same imagery [11].

The accuracy can be determined by comparing the system's results with one of the comparison references [11]. There are two types of accuracy considered:

- Positional Accuracy (Planimetric Accuracy). The system should be able to extract features with an accuracy of better than ± 1 pixel. The positional accuracy is based on the worst observable case.
- Feature Extraction Accuracy. There are two types of possible errors in feature extraction accuracy considered:
  - The system may find roads (features) that do not exist: *'false positives'*. A comission error percentage rate can be defined as *the number of pixels misclassified as road* divided by *the total number of pixels classified as road.*
  - The system may fail to find roads (features) that do exist: *'false negatives'*. An omission error percentage rate can be defined as the *number of road pixels missed in the road classification process* divided by *the number of road pixels as determined by manual extraction* [11].

5 Research

MacDonald Dettwiler is in the process of researching and developing a system that will have the capability to fully automate the planimetric linear feature extraction process [11]. The test imagery has been geocoded to a Universal Transverse Mercator projection by MacDonald Dettwiler's Geocoded Image Correction System (GICS). The resulting resolution of the geocoded imagery is 6.25 x 6.25 m pixels for the PLA imagery and 12.5 x 12.5 m pixels for the MLA imagery.

5.1 Research Prototype Results

The image test set was a scene from the area of Sherbrooke, Quebec Canada. Both urban and rural scenes were identified. The imagery had been geocoded by GICS before any extraction process was commenced.

The feature positional accuracy detected by the research prototype was subpixel, due to the subpixel accuracy achieved by the edge detection process. The parallel line structures detected in the scene resemble road-like features. The system was tested using different image sets and performed comparably in different circumstances.

By including additional knowledge and reasoning about what the information represents, the roads were detected automatically. Establishing connectivity of the road network can also assist in elimination of false positive detected road features.

The system was informed that road-like features with certain spatial and spectral properties were being sought. The system used this information to extract road-like features.

5.2 Research Prototype vs. Manual Results

The manual extraction results demonstrate the number of road features that can be identified. The automatically extracted results demonstrate the capability that the researched algorithms presently possess. The algorithms work well when there are well defined edges for the road boundaries. The manual results only display the road centerlines, whereas the automatic results show the two sides which define the road boundaries.

In comparing the manual versus automatic results, the following factors are considered:

- **Time.** The manual digitization and extraction took 2.5 hours, while the automatic extraction took 50 minutes for the same scene.
- **Labour.** Both the manual and automatic processes have the three stages of training, extraction and verification. The only difference is in labour. The automatic extraction stage takes up no manpower, while the manual process requires 2 man-hours.
- **Omission & Comission Errors.** The manual extraction produced results that had less than 5% comission errors and less than 10% omission errors with respect

to a ground truth point of reference. The reference source for the automatic results were the manual extraction results. The equivalent automatic extraction errors were less than 37% and less than 21% with respect to the manual results.

- **Data Consistency**. Different photointerpreters will obtain different results on the same scene. The automatic extraction algorithm will always obtain the same results on the same scene.

6 Summary

MacDonald Dettwiler has demonstrated the capability of doing planimetric feature extraction from satellite imagery.

The FEX system has demonstrated the possibility of automating the extraction of road features to facilitate automatic mapping from remotely sensed imagery.

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Figure 1: Sherbrooke scene.

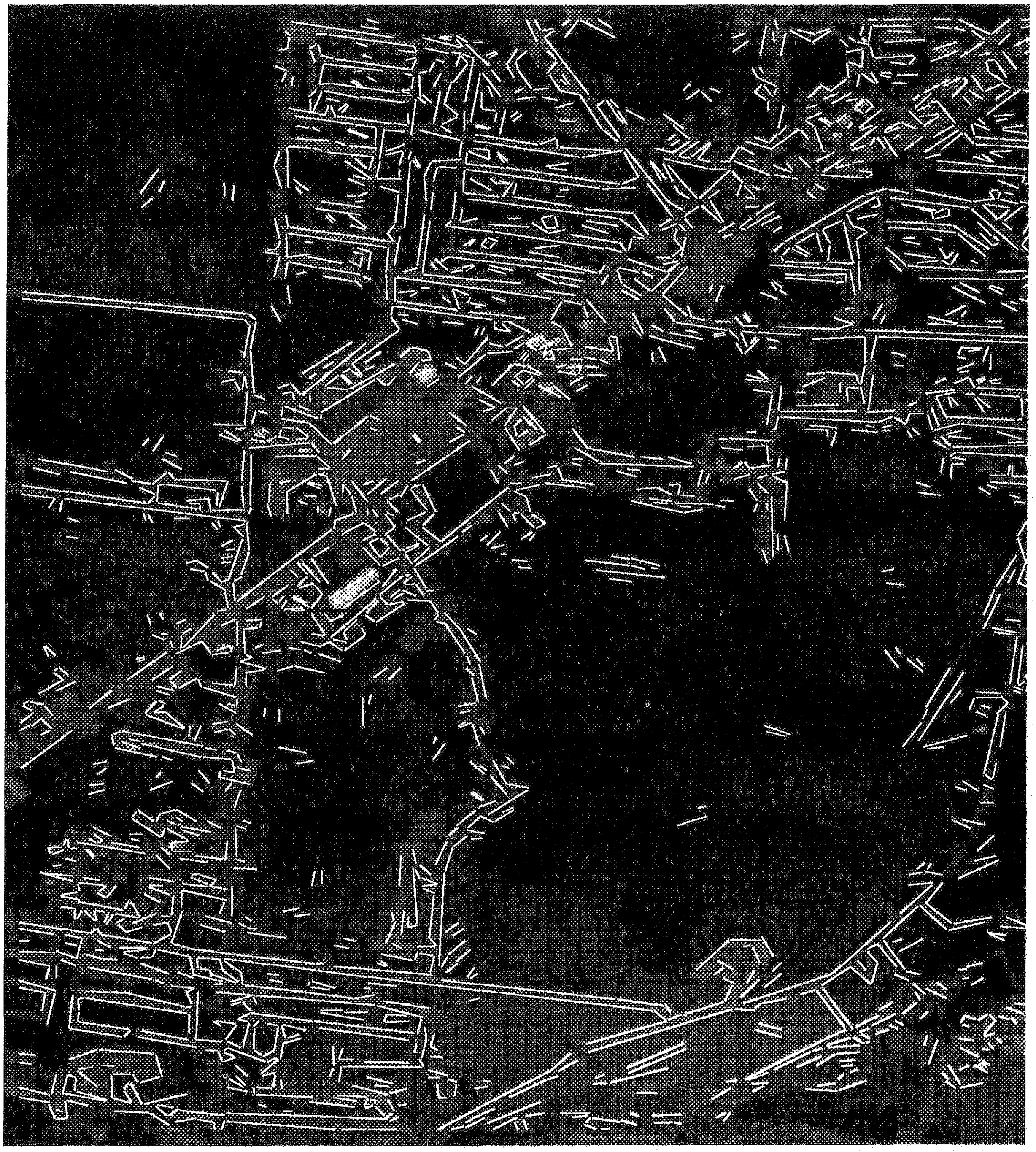

Figure 2: Sherbrooke scene: Automatic Extraction of Road Features (sides of road).