

Role of Image Processing Techniques in Remote Sensing For Automatic Road Extraction

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Abstract— A massive remote sensing data plays irreplaceable role in the field of space technology. Road information is very important in remote sensing and geographic information system (GIS) , it has great importance in the application of traffic navigation, urban planning and military reconnaissance. Apart from the rapid development of space technology, road extraction has great significance in the earthquake relief and fire escape. Automatic extraction from aerial image is always an import problem in Photogrammetry, meanwhile has attracted more attention in the fields of Remote-Sensing Surveying and Mapping, Pattern Recognition, Computer Vision and Artificial Intelligence, etc. Many techniques have been proposed, and they are classified according to whether an approach requires human intervention. Road information is critical to the public when disaster comes, having a full knowledge of the road information may help reducing the casualties. As a result, road extraction is vital to the safety of our citizens as well as our government’s emergency warning, preparedness and planning. Therefore, strongly making use of the spectral properties of satellite imagery is a way to mitigate the geometric disadvantages comparable to those from aerial imagery.

Keywords—*Road Extraction, Remote Sensing Methods, Image processing Techniques*

Introduction

In remote sensing images, the general characteristics of the road are as follows: having a certain length, having relatively small width variation and direction changes, having relatively uniform internal gray scale but large contrast with its adjacent region, crossed with each other to form the road[1-2].Up to now, in the GIS (Geographic Information System)road data acquisition and update, the technology to real-time, all-weather, large area obtain high-resolution, high-precision, multi-temporal, multi-spectral digital image is already mature, highly against with the low development of the image processing theory and algorithm. Nowadays the airborne and satellite imagery is advancing to be high capacity and huge.Road extraction from digital imagery has been intensively studied in the computer vision and remote sensing fields. It is largely motivated by the rapidly increasing volume of collected imagery, which makes manual processes exceedingly time consuming. In semiautomatic approaches, a human operator provides information such as starting points or starting directions, which provide critical assistance in tracking roads[2],[16]. By contrast, automatic approaches attempt to achieve true operational autonomy. Although reliable performance is more difficult to achieve, automatic approaches still attract a great deal of research due to potential productivity gains [1], [4].

Digital road information is required for a variety of applications ranging from provision of basic topographic infrastructure over transportation planning, traffic and fleet management and optimization, car navigation systems, location-based services, tourism, to web-based emergency response applications and virtual environments [1]. To build a remote sensing application, a processing procedure must be developed to process the data and, therefore, generate the expected output. Before analyzing the images, they have to be geometrically and radiometrically corrected. This processing phase, called pre-processing, is essential mainly in applications where the images are acquired from different sensors and at different times. After this phase, the images are enhanced

to facilitate the information extraction. Finally, the images are segmented and classified to produce a digital thematic map.

Previous Work

Most of the previously developed road extraction methods could successfully recognize roads using different road features, which exhibit a homogeneous surface. However, in cases where surrounding objects like water, buildings, trees, grass and cars occlude the road or cast shadows, especially with influence of spatial structures such as overpass, the road extraction often fails, resulting in gaps and discontinuities in the detected road. [1]

Manvi et al., [2], proposed a Context Aware agent based Distributed Sensor Network (CADSN) to form an improved infrastructure for multi-sensor image fusion to monitor the militant activities. In [3], different method is used a region growing-based automatic network extraction method for SAR images with different resolutions and used for the generation of both road ratio and direction phenomenon.

The road seed selection approach fuses ratio and direction information, and the result shows high values in correctness and provides a guarantee for the next growing part. The proposed post processing method including road centerline smooth and road pruning makes the final road network more regularized. There is an increasing number of papers on road extraction from high resolution satellite imagery, particularly IKONOS. (Dial et al., 2001) gives an overview over the properties of the IKONOS sensor and presents a road extraction approach making use of the multispectral capabilities of the imagery. A system for road extraction from multispectral imagery based on fuzzy logic is proposed by (Amini et al., 2002). (Mena and Malpica, 2003) segment color images using the Dempster-Shafer theory of evidence for the fusion of texture, to extract linear features. (P'eteri and Ranchin, 2003) employ a multiresolution snake for the extraction of urban road networks given existing but imprecise GIS data. (Doucette et al., 2001) present a semi-automatic approach that uses a pre-classified imagery to detect roads using the so called "self-organising road map" (SORM). In (Zhang and Couloigner, 2004) a multi-resolution analysis approach based on wavelets, road junction detection, and grouping is proposed. (Mohammadzadeh et al., 2004) introduce an approach based on fuzzy logic and mathematical morphology.

For road-constrained targets, the incorporation of road information into the dynamics models can greatly reduce the target motion uncertainty.^[4] The main approximation of the filter is the Gaussian assumption about the conditional target state distribution given a mode sequence and observations.

Another extracting method useful for high resolution remote sensing images is proposed in ^[5]. SOM network method has achieved a better extraction of the road network information especially in the extracted image detail information on the edge of road. The network is a fully connected array of neurons composed of unsupervised self-organizing, self-learning networks. Kohonen that in space, neurons in different regions have different division of labor, when a neural network to accept outside input mode, it will be divided into different reaction regions, all regions of the input mode with a different response characteristics.

Objects appear in natural scenes as groups of similar sensory features. Gestalt psychology reveals a set of principles to guide the grouping process based on local features. In particular, locally excitatory globally inhibitory oscillator networks (LEGION) proposed by Terman and Wang provide a framework to group object features and segment different objects through oscillatory correlation ^{[6],[7]}. A LEGION network consisting of relaxation oscillators can rapidly achieve synchronization within a locally coupled oscillator assembly and de synchronization between different assemblies.

road extraction methods

With the advent of research topic using very high resolution satellite images (VHRS) and aerial images that provide a more accurate location of the road as part of the surface and allow a particular recognition pathways detected (highway, street, road). This extraction accuracy is also beneficial

for various applications such as in the urban area and in the military (road safety). Extraction of roads from digital aerial/satellite imagery is not only scientifically challenging but also of major importance for data acquisition and update of geographic information system (GIS), databases or site models and thus can be a big help in car navigation systems or any emergency (rescue) system that needs instant maps.

In Road marking lines based on vehicle-based laserpoint cloud data by using intensity projection transforming the data of point clouds into images, extracting the lines from images by using Hough transform and then finding point around the road marking lines and fit straight line using least Square Method. This method is useful to build and update the road information in Cyber City automatically and solves the non-time-sensitive in surveying and mapping. It is undeniable that during projection data is reduced and loses some important information which a very long way to solve.

In Semi-automatic Method, A novel approach for semi-automatic extraction of road networks from remotely sensed imagery is presented. The spoke wheel operator is improved to acquire the start point, the width and the direction of the road to be extracted. And the road tracker makes use of template matching by thresholding differences of gray values rather than the least squares. Moreover, Euclidian distance transformation is employed to increase the reliability of template matching. From Figure- 1, Extensive experiments have proved that methodology can reliably and fast extract the ribbons roads in urban areas. Inevitably, the imitations are existed.

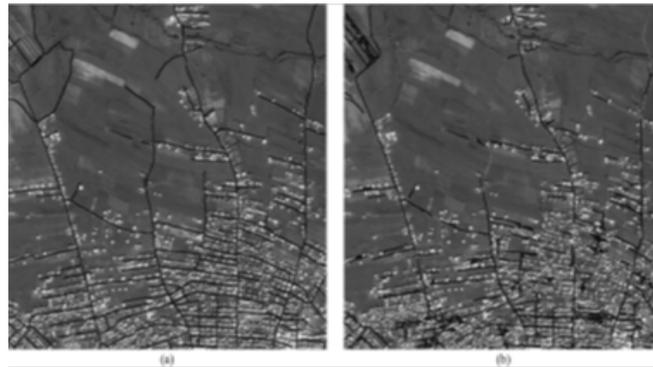


Figure 1 - Images obtained from sensors with different spatial resolutions.
(a) Landsat-TM5, 30 m.; (b) Alos-AVNIR, 10 m.

Using Hierarchical Grouping, Automatic Road Extraction From Satellite Imagery Using Hierarchical Grouping strategy to automatically extract main road centerlines from high-resolution satellite imagery. Hierarchical grouping means grouping all segments at once, selective segments are grouped gradually, and multiple clues are closely integrated into the procedure. By this means, the computational cost could be reduced significantly. Through the stepwise grouping, the detected fragmented line segments have eventually formed the long main road lines. It provides robustness and viability on extracting salient main road centerlines.

LEGION- locally excitatory globally inhibitory oscillator networks-Three stages are employed for road extraction: image segmentation, selection of candidate medial axis points, and road grouping. While some aspects of the first two stages have been developed in previous studies, a number of improvements have been introduced in these stages. These improvements, together with the newly introduced road Grouping stage, result in a novel automatic road extraction method. The fundamental idea of the proposed method is to group similar features and segregate dissimilar ones.

In the first stage, the gray level is used as a feature, which can be interpreted as similarity, and in the third stage, orientation is taken as a feature, which can be interpreted as good continuation. Both features are encoded in the LEGION model, which uses dynamics of oscillatory correlation to achieve grouping. The generality of the underlying idea implies that the method Fig -2 , could be used in a wide range of applications where region and boundary information need to be considered. While the proposed method is not very sensitive to particular choices of parameters, the experiments show that fine tuning of parameters could further improve extraction results. Future work needs to address the issue of automatically determining the optimal parameters for different types of images.



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Fig. 2. Road extraction from Ikonos1-Sub1. (a) Red band image of Ikonos1-Sub1 with reference road data marked. (b) Extraction result using the proposed method with the parameters $Wz = 60$, $\theta_p = 35$, $Np = 40$, and $Wzg = 0.85$.

SAR Images With Different Resolutions - The proposed improved line feature detector W-RLD has been used for the generation of both road ratio and direction information. Then, the road seed elements have been extracted with high correctness by a feature-fused procedure, providing a guaranteed road seeds for the road network growing. After fully considering the geometric and radiometric characteristics of road in SAR images.

Multi-Angled Template Matching Technique - It is a template-based approach for the extraction of the road network for high-resolution and medium-resolution images. Lines from four different directions are first extracted followed by the closure of small gaps in the network through the use of two specially designed rotating arms. Filters are used are different stages to remove noisy edges. The four sub-images are finally combined and overlaid on the original image to obtain the final output image. It is also fully automatic. There is no need to provide seed points like in semiautomatic approaches. Combining of template based process with a machine learning classifier may result in significant improvements in the performance measures especially in sub-urban areas .

A Wavelet Transform Based Method - A new technique is used to extract roads from high-resolution remote sensing images using wavelets. By choosing a proper wavelet, the modulus of the local extreme values of the wavelet transform of the undesirable thin lanes and small noises are apparently lowered, and hence they can be deleted by a properly chosen threshold. The new technique involves preprocessing the image such that the information of the roads are strengthened,

deleting undesirable information using wavelet transforms, and performing some further processing to get the final result.

Integration method of profile matching and template matching - An integration of profile matching and template matching leads to a news semiautomatic road tracer. Therefore, the two components may mutually complement, i.e., the profile may works when rectangular template fails, vice versa. It evolves into profile matching or rectangle template matching if the human operator adjusts the width of the rectangle or the profile. As a result, their cooperation leads robustness of the tracker for extracting road with much occlusion of vehicles and shadows of colonnade or surrounding buildings. This method is fast and reliably trace roads with continuous or discontinuous road marks or strip of vegetation and with much disturbing influence of occlusion of vehicles, shadows from trees or buildings, and radiometric change. The current limitations are that it can't automatically detect the width and direction of the road and it can't automatically update the road reference model.

Road Centerline Extraction Based on Shape Features and Multivariate Adaptive Regression Splines - To extract road centerline from high-resolution imagery accurately and smoothly, shape features are used. Edge filtering and thresholding were performed to separate potential road-segment interesting regions from background. Based on shape features and spectral feature, road segments were extracted. Road centerline extraction was converted to be a regression problem in which MARS was used to extract accurate and smooth road centerlines. The use of shape features leads to the detection of linear features effectively. The centerline extraction using MARS shows a good smoothness. Since this method is based on homogenous surface property, it is suitable for high-resolution imagery, and it is not suitable for low-resolution imagery. The main limitation of the proposed method is that the thresholds in the method have to be determined manually.

Road Detection by Directional Morphological Enhancement and Segmentation Techniques - There are many civilian, commercial, and military applications for this problem including the determination of existence of roads after a natural or man-made disaster. The approach exploits both the spectral and spatial properties of roads using a multi-step approach. The main steps in our algorithm are: road enhancement t, road segmentation, hole filling, small region filtering, length based region filtering, small branch removal method and road segment linking. The proposed algorithm was evaluated using IKONOS, CARTOSAT-2A, QuickBird and Arial panchromatic images. The results demonstrate that the algorithm is highly accurate.

Object-Oriented Approach of Information Extraction from Panchromatic Satellite Images based on Fuzzy logic-With the newly arisen fuzzy based object oriented approach, the classification precision has been improved significantly. A fuzzy inference system for object oriented classification is presented to increase the classification accuracy for other projects in future, the presented method is feasible to provide ancillary data. In conclusion, it is demonstrated that the fuzzy rule based object oriented approach provided by eCognition software is a breakthrough in elucidation of remotely sensed data/images and is an efficient and practical approach for information extraction. From the experimental results it can be realized that the object oriented information extraction approach based on fuzzy thresholding will become the trend for the analysis of high resolution satellite imagery.

Representing Techniques

For each remote sensing application a specific processing methodology must be developed. Fig. 3 illustrates the main steps of digital image processing which define the operations sequence, in general, adopted for building a methodology. Preprocessing phase consists of those operations that prepare data for subsequent analysis that attempts to correct or compensate for systematic errors. Common preprocessing techniques include atmospheric correction, noise filtering, detector

calibration, geometric correction, and image registration [8], [9]. After preprocessing is complete, the analyst may use enhancement techniques to enhance the objects of interest as well as feature extraction techniques to reduce the data dimensionality. Here, it is named as enhancement.

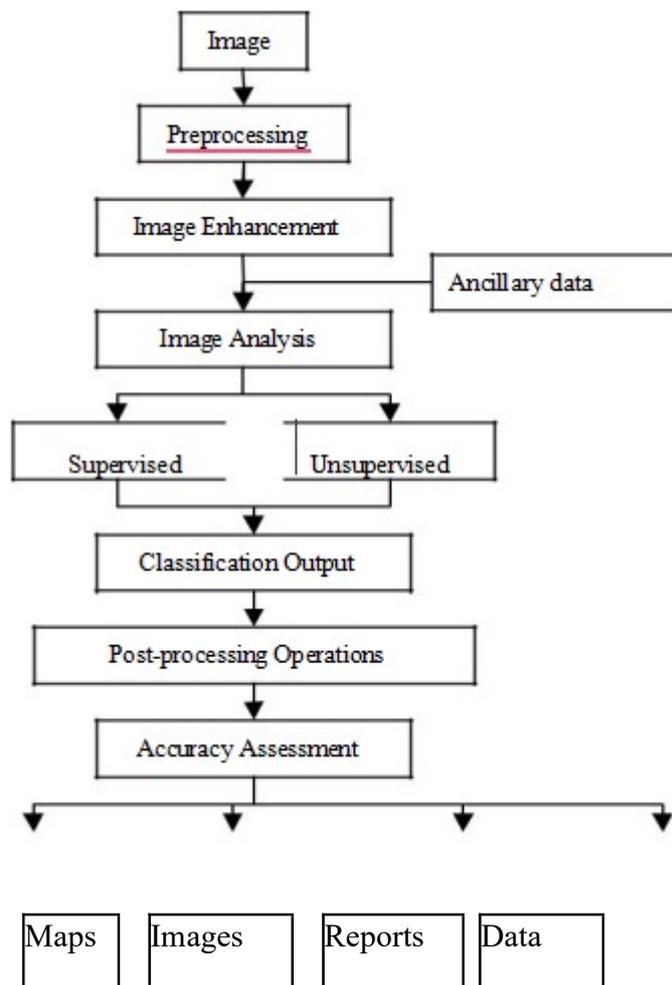


Figure 3 - Fundamental steps in remote sensing image processing

Feature extraction attempts to extract the most useful information of the data for further study. This phase reduces the number of variables that must be examined, thereby saving time and resources. Enhancement operations are carried out to improve the interpretability of the image by increasing apparent contrast among various features of interest to facilitate the information extraction task. Common enhancement and feature extraction techniques include contrast adjustments, band rationing, spatial filtering, image fusion, linear mixture model, principal component analysis and color enhancement [8], [10]. In general, the enhancement techniques are empirical because they depend on the imaging characteristics of data and application. After preprocessing and enhancement steps, the remotely sensed data are subjected to quantitative analysis to assign individual pixels to specific ground cover types or classes. The class identifies the type of ground cover (water, vegetation, soils, for example). The pixels are identified based upon their numerical properties or attributes. This phase can be performed by analyzing the properties of individual pixel (per pixel) or group of pixels (region). In latter, the image is firstly segmented into a set of regions that can be described by a set of attributes (area, perimeter, texture, color, statistical information). This set of

attributes is used to characterize and identify each object in the image. This operation of recognizing objects in the image is called image classification and it results in thematic maps as output. After classification, it is necessary to evaluate its accuracy by comparing the classes on the thematic map with the areas of known identity on the ground (reference map). A reference map is created using information acquired by the user in the field work. Indexes to measure the classification accuracy such as Kappa [9] are often used. The index values ranges from 0 to 1, and values greater than 0.6 indicates a good overall result. Post-classification is an optional processing step.

Step 1: Pre-Processing

The preprocessing techniques are designed to enhance selected features and eliminate irrelevant data. The feature extraction techniques are designed to extract specified, application-dependent information from a digitalized radiographic image. Feature extraction consists of the extraction of significant features from a background of irrelevant detail. The techniques consisted of gray level, distribution linearization, spatial digital filtering, contrast enhancement, and image subtraction. For practical applications this pre-processing is well-defined.

Step 2: Image Enhancement

Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further image analysis. For example, you can remove noise, sharpen, or brighten an image, making it easier to identify key features. Image Enhancement alters the visual impact that the image has on the interpreter in a fashion that improves the information content. a. Contrast enhancement b. Intensity, hue, and saturation transformations c. Density slicing d. Edge enhancement e. Making digital mosaics f. Producing synthetic stereo images. These data may be obtained from maps (e.g. geological units, soil classifications, political boundaries) or may be continuous variables (e.g. digital elevation models, aeromagnetic surveys, and regional economic indicators).

Step 3: Image Analysis

Image analysis is the extraction of meaningful information from images; mainly from digital images by means of digital image processing techniques. Image analysis tasks can be as simple as reading bar coded tags or as sophisticated as identifying a person from their face.

Step 4: Image Classification(Un/Supervised)

Different land cover types in an image can be discriminated using some image classification algorithms using spectral features, i.e. the brightness and "colour" information contained in each pixel. The classification procedures can be "supervised" or "unsupervised". In *supervised classification*, the spectral features of some areas of known land cover types are extracted from the image. These areas are known as the "training areas". Every pixel in the whole image is then classified as belonging to one of the classes depending on how close its spectral features are to the spectral features of the training areas. In *unsupervised classification*, the computer program automatically groups the pixels in the image into separate clusters, depending on their spectral features. Each cluster will then be assigned a land cover type by the analyst.

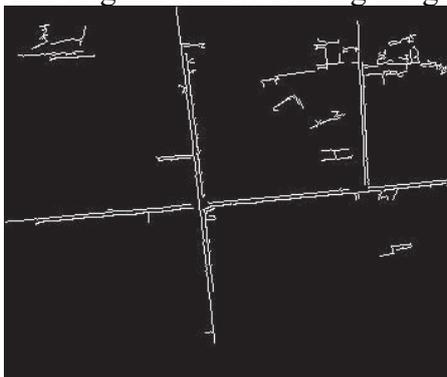
Step 5: Accuracy Assessment

A vital step in the classification process, whether supervised or unsupervised, is the assessment of the accuracy of the final images produced. This involves identifying a set of sample locations (such as with the SAMPLE module) that are visited in the field. The land cover found in the field is then

compared to that which was mapped in the image for the same location. Statistical assessments of accuracy may then be derived for the entire study area, as well as for individual classes (using ERRMAT). In an iterative approach, the error matrix produced (sometimes referred to as a confusion matrix), may be used to identify particular cover types for which errors are in excess of that desired. The information in the matrix about which covers are being mistakenly included in a particular class (errors of commission) and those that are being mistakenly excluded (errors of omission) from that class can be used to refine the classification approach.



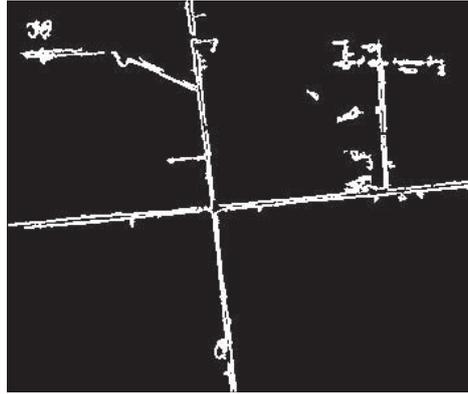
The original remote sensing image



The seed point automatically selected



The mapping of seed points on the image



The road Extraction

Scope for reaesrch in remote sensing

Remote sensing techniques in archaeology are an increasingly important component of the technical and methodological tool set available in archaeological research. The use of remote sensing techniques allows archaeologists to uncover unique data that is unobtainable using traditional archaeological excavation techniques. Automatic determination of optical parameters by using different types of images may incur into quantitative evaluations in wide range of applications. Road information has a wide range of applications in the field of traffic navigation, urban planning, and military reconnaissance. Different algorithms are implemented to improve the robustness and the efficiency, meanwhile improve the degree of automation for road extraction. Many automatic road extractions became active research of remote sensing images with the civil-protection work itself, effective satellite-based disaster-relief efforts rely on international, interdisciplinary, and interorganizational cooperation mechanisms and team work. Future work is expanded into other linear features such as rivers or some more complex roads.

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