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Survey on Methods of Road Extraction using Satellite Image

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***Abstract*— Road extraction can be defined as extracting the roads from an image by accessing it through the features of road. Analysis of high resolution satellite images has been an important research topic for urban analysis. One of the important features of urban areas in urban analysis is the automatic road network extraction. Road extraction can be done by mainly three methods: Manual, automatic, semi-automatic. In this paper we review various method of road extraction using satellite image. Our approach is road extraction from VHR (very high resolution) image. So there are various methods like geodesic method, SVM, level set, mean shift, shape feature etc.**

Keywords*— Geodesic, SVM, level set, Mean shift, Shape feature

I. INTRODUCTION

Geographical information extraction from remotely sensed images has been an active research subject with a variety of applications in recent years, such as, urban planning, resource management, natural disaster analysis, transportation system modeling. [1].Roads in dynamic cities tend to change very frequently even within a short period of time. Road maps of these areas have to be updated periodically, preferably from current satellite images to meet the urgent need of urban planners. [2]

Road information can be extracted from images in three ways: manual extraction, semi-automated extraction and fully automated detection.[3] Manual extraction is subject to the analyst's experience and skills. Roads can be recognized reasonably well even from noisy images that contain incomplete information about roads if s/he is familiar with the study area. However, this manual method is expensive and time consuming. Automatic extraction of roads from satellite images faces several challenges because the image appearance of roads depends upon the spatial resolution of the satellite images. In addition, the extraction is hampered by noise on satellite images. Ground objects such as trees along a street can obstruct the image of roads. Vehicles on the road may cover certain parts of a road and make it difficult to detect on the image.[2] Semi-automatic extraction of roads from satellite images is efficient way of extracting the road.it provide best robustness, quality and completeness. Accuracy is also improved by semi-automatic method. In this method seed point provide by user [4]. There are many difficulties inherent in a fully automatic process when extracting geographic information, and the good results that we have achieved with the semi-automatic approach used in parcel extraction, we have implemented a semi-automatic tool for the road segmentation. Due to the lack of robustness of automatic extraction tools, the best way to increase the productivity lies in designing semi-automatic tools. If an automatic process is prone to fail, the best approach is to let the operator gain full control of the process, rather than oblige this operator to search for the incorrect results on the whole image. Therefore, with our approach, the user provides the initial position of the feature to be extracted by giving some seed points along the road and editing the results interactively, whenever this is required. In any case, the knowledge needed to make the system fully automatic, for such a general purpose—several image scales, broad and narrow roads, etc.—could be so complicated that it may make the system inefficient [5].

This paper is organized as follow. In section II, we describe survey of different road extraction methods. In section III, we describe comparative analysis of different methods. In section IV, represents conclusion and future work.

II. SURVEY OF DIFFERENT METHODS

A. *Geodesic Method[4]*

The geodesic method is used to link seed points and identify the central line for roadways. Let f denote the probability density estimation map, which is modeled as a 2-D function $f : \Omega \rightarrow R$. The image domain Ω is usually defined as $\Omega = [0, 1]$. In road linking, a road that connects two seed points $\boldsymbol{x}s$ and $\boldsymbol{x}e$ can be approximately defined as a smooth curve that has a constant gray value $c \in R$. Based on this definition of road model, a saliency map $W(\cdot)$ at the pixel $\boldsymbol{x}$ is then defined as

$$W(\mathbf{x}) = |f(\mathbf{x}) - c| + \varepsilon \quad (1)$$

where ε (i.e., $\varepsilon = 0.01$) is a small value that prevents $W(\mathbf{x})$ from vanishing, and c is the gray value at the start point $\mathbf{x}s$ c = $f(\mathbf{x}s)$). According to (1), the area through which the road passes should have low values of $W(\mathbf{x})$. Based on the saliency map, the length of a smooth curve on the image $\gamma : [0, 1] \rightarrow \Omega$ is defined as a weighted length as follows:

$$L(\gamma) = \int_0^1 W(\gamma(t)) \, || \, \gamma'(t) \, || \, dt$$

where $\gamma\_(t) \in R2$ is the derivative of γ. For linking road seed points, γ is generally constrained by

$$\{\gamma : [0, 1] \rightarrow \Omega \setminus \gamma(0) = \mathbf{x}s \text{ and } \gamma(1) = \mathbf{x}e\}$$

The minimal path $\gamma*$ is defined as

$$\gamma* = \underset{\gamma \in (xs, xe)}{\operatorname{argmin}} L(\gamma).$$

Advantage of this method is it provides a practical solution for accurate road centerline extraction, and it does not produce spur. Limitation of this method is that it can tend to follow the boundary of the road but does not coincide with the true centerline.

B. Mean Shift Method[6]

Mean Shift method is a clustering technique used to classify a large amount of data into different categories does not require information about specific object and extracts road information exactly by object-oriented method and can capture different-scale roads according to the user's requirement. The basic steps for mean shift method is Use kernel density estimator (weighted average e.g. Gaussian) to shift the means of pixels in the image and Stop when each mean sequence has converged after that Use the converged means to delineate segments. Finally, basically a pair of pixels belong to segment if their convergence color and spatial components are within some given range For segments with fewer pixels than a given threshold, place them into neighboring segments.

Advantage of this method is Greater accuracy, completeness and correctness. Limitation of this method is Mean shift is fixed kernel bandwidth. The change in the road width requires an adjustment of the kernel bandwidth to consistently track the road.

C. Level Set Method [6]

Level set method is a search algorithm that determines evolving curve's boundary pixels the level set propagates as long as the speed function is greater than zero. For the road extraction problem speed function has to be greater than zero, at the edges of the true road boundary. Therefore Level set is an efficient technique for extracting road.

Advantages of this method is Greater accuracy, completeness and correctness. Limitation of this method is Level set method does not remove unexpected road segments. Future work of this method is Refining the results of the level set method such as removing unexpected road lines generated and extracting unidentified road regions.

D. SVM Classification Method [7]

The SVM (Support Vector Machine) performance is as good as or significantly better than other competing methods in most cases .SVM is a supervised classification method, which can still work when road materials and intensity change. The steps which we have studied in paper of road extraction is as following.

- For each pixel, MPs(Morphological Profile) are constructed as the input features.
- For each class, 5% of ground truth data are selected as the training samples.
- Select Gaussian kernel, and the parameters, namely, penalty parameter *C* and kernel parameter γ, are selected by using fivefold cross-validation.
- Use the best parameters selected in step 3) to train the SVM classifier. Classify the whole imagery using the classifier trained in step 4)

Advantage of this method is still work when road materials and intensity change. Limitation of this method is Need to train SVM for each input image which limits applicability of the method in practice. Future work is To collect massive amount of road segment to perform SVM training offline this does not require interaction form user

E. Shape Feature Method

There are many shape feature methods but we have studied the linear feature index to extract road segments. LFI can be calculated by following steps.

The minimum bounding rectangle (MBR) of each homogeneous region is detected. Based on MBR, every homogeneous region is converted to a new rectangle which satisfies

$$LW = n_p$$
$$\text{s.t. } D^2 = L^2_{MBR} + W^2_{MBR}$$
$$L = D$$

where L is the length of the new rectangle, W is the width of the new rectangle, np is the area of the road segment (also known as pixel number), D is the diagonal length of MBR, LMBR is the length of MBR, and WMBR is the width of MBR.

LFI can be calculated by

$$LFI = \frac{L}{W} = \frac{L}{\frac{np}{L}} = \frac{L2}{np}$$

In terms of roads' characteristics, they should have large values of LFI, so regions with small values of LFI can be regarded as nonlinear features and will be removed. [8]

III. COMPARATIVE ANALYSIS

TABLE 1 COMPARISION OF DIFFERENT METHODS

Method	Advantage	Limitation	Future work
Geodesic method	It Provides a practical solution for accurate road centerline extraction, it does not produce spur.	It does not suitable for low resolution imagery, it consider road boundary but not consider true centerline	True centerline extraction and automatic selection of seed points
Mean shift Method	Greater accuracy, completeness and correctness	Mean shift is fixed kernel bandwidth. The change in the road width requires an adjustment of the kernel bandwidth to consistently track the road.	Variable kernel bandwidth
Level set Method	Greater accuracy, completeness and correctness	Level set method does not remove unexpected road segments.	Refining the results of the level set method such as removing unexpected road lines generated and extracting unidentified road regions.
SVM classification method	SVM is a supervised classification method, which can still work when road materials and intensity change.	Need to train SVM for each input image which limits applicability of the method in practice.	To collect massive amount of road segment to perform SVM training offline this does not require interaction form user
Shape feature method	LFI can detect linear features well. The nonlinear features have all been removed by performing LFI.	---	---

IV. CONCLUSION AND FUTURE WORK

In this paper, we have carried out different methods of road extraction. And we have also done comparative analysis of different methods. From this analytical survey we have conclude that the semi-automatic method is best for extraction of road from satellite images. Because, If an automatic process is prone to fail, the best approach is to let the operator gain full control of the process, rather than oblige this operator to search for the incorrect results on the whole image. By this method we can achieve best completeness, correctness, quality, accuracy.

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