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Various Methods of Road Extraction from Satellite Images: A Review

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Abstract:

Extraction of roads from the satellite images is a crucial part of the image segmentation. Extraction of roads is essential because number of applications are based on road information like vehicle navigation, transportation management, tourism, industrial development, urban or rural development. Images used in road extraction are mostly satellite images or aerial images. As the satellite images are of high resolution, therefore there are many obstacles like a shadow of trees and buildings, vehicles, interference from the surroundings, broken roads etc. curb the automatic extraction of the roads. In this paper, the review of techniques, algorithms and methodologies used for automatic detection of roads is presented.

Keywords: Morphology, Reference Circle, Gradient Operator, Unmasking, SVM.

I. INTRODUCTION

Roads become the necessary part of the society in today's life as its information is important in traffic and fleet management, vehicle navigation system, location based services, tourism and industrial development. So there is need of algorithms to extract roads from the satellite images. Various techniques exist to extract the roads like rule based approaches, statistical inference methods, contour method, etc. Despite the fact that much work on automatic approaches for road extraction has been taken place, the desired high level of automation could not be achieved yet. Reason behind it number of obstacles that curb automatic extraction like blurring, wrecked or misplaced road boundaries, lack of road profiles, dense shadows, and interference from surrounding objects. As a result, the existing automatic extraction is not sufficient for practical applications.

Road network information is required for a variety of applications and such information is a necessary input to many decision processes. Because of the large areas to be mapped, it is important to use highly automated means as well as cheap and readily available data. Manual extraction of road from remote sensing imagery is mostly time-consuming and costly.

The potential solution is to develop an algorithm that can automatically detect it so that road information can be used for fruitful results. The speedy growth of information processing system has led to the development of automated techniques for detection roads. This paper provides reviews of various automated techniques along with their strength and weakness. In this review, we discuss the various algorithms for automated detection of roads based on aerial image analysis.

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II. METHODOLOGY

Automatic detection of roads is very important for traffic management, location based services and especially for vehicle navigation system. Most of the automatic detection of roads works in three stages: (i) image pre-processing, (ii) detection and segmentation of roads, (iii) post-processing to link the segments and remove the unwanted results.

First stage requires an image preprocessing for the reduction of noise and contrast enhancement. Mostly Image preprocessing is performed on the green color plane of RGB image because in the green color plane higher contrast is obtained with the background. The presence of non-road regions such as roofs of buildings, parking lots, etc. which may contain similar color, contrast as that of roads, might lead to a non-road region be wrongly classified as a road region. Hence, in second stage nonroad regions are segmented from the road image for the reduction in false positives.



Fig.1. Flow chart showing methodology

III. EVALUATION and PERFORMANCE MEASURES

For automated detection of roads in aerial images three measures are mostly used: Completeness, and Quality Correctness.

Predicted	C1 (YES)	C2 (NO)
class→ ⊥		
Actual		
class		
C1(YES)	TP	FN
C2(NO)	FP	TN

Fig.2. Confusion Matrix

Correctness are defined as the ability of an algorithm to detect the correct roads from an image.

$$correctness = \frac{TP}{TP + FP} * 100$$

Completeness is defined as the ability of an algorithm to get the all road pixels in extracting image as road pixels in the actual image.

$$completeness = \frac{TP}{TP + FN} * 100$$

Quality is defined as the excellence of the road extraction.

$$Quality = \frac{TP}{TP + FP + FN} * 100$$

TP(True positive): Roads are correctly detected as roads.

FP(False positive): Non-Roads are incorrectly identified as roads.

TN(True negative): Non-Roads are correctly identified as non-roads.



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FN(False negative): Roads are incorrectly identified as non-roads.

IV. LITERATURE SURVEY

Liu Xu^[1] et al. proposed the Unsharp Mask (USM) sharpening algorithm for image enhancement, and to reinforce the road feature. A precipitous method of road extraction from satellite images was achieved by following the three operations a) image preprocessing, b) threshold segmentation, c) corrosion and expansion. In USM Gaussian low pass filter is used to noise. According suppress the to experimental results of this paper, it can effectively reduce the non- target noise and accurately extract roads from the images.

Pro of this algorithm is that it enhance the color gradient of roads from the surrounding environment. However, this method also has its shortcomings: the color of a processed image gets changed when the maximum and minimum pixel value will exceed the original image sharpening, so the choice of the template is very important.

Xufeng Guo^[2] et al. [2011], proposed a method of extraction of roads on the basis of automatic selection of seed that starts the road extraction based on the combination of geometry and color features.

Yan Li and Ronald Briggs ^[3] et al. proposed a two stage method of reference circle and central pixel that are amenable to the distortions which are expected over the roads. The reference circle provides the feature of direction and shape of the roads that address the major issues that have caused all existing extraction approaches to fail, such as blurring boundaries, interfering objects, heavy shadows, etc. Both visual and geometric characteristics of roads are taken into account. The central pixels play an important role throughout the extraction process, including filtering, segmentation, and grouping and optimization. Once a centerline is found, then based on the statistical estimation of the road width, the contour of the road can be derived according to all the central pixels. The proposed approach is efficient, reliable, and assumes no prior knowledge about the road conditions, surrounding objects and color spectrum of roads.

Juan Wang,^[4] et al. [2012] proposed a method for four road extraction strategies: linear road, curvilinear road, crossing the and road breakage road based on mathematical morphology. Various Mathematical Morphology operations are used to keep image features and remove the redundant structure like erosion, dilation, opening. closing Different structuring elements are used depends on the structure of the road. Its operations are simple, flexible and fast.

Beril Sırmac^[5] et al. [2010] proposed the spatial voting method besides edge detection for road extraction. Non-linear Bilateral filtering is used to smooth the image. Spatial voting matrix (SVM) is generated by extracting canny edge and gradient information which is used to signify the possible locations of road networks. By processing iteratively voting matrix, it detects initial road pixels. At last tracking algorithm is applied to detect the missing road pixels on the voting matrix. The negative point of the method is that tracking algorithm decrease the operation speed.

Shengyan Zhou^[6] et al. proposed a technique of road extraction based on



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Support vector Machine (SVM) that focus on the problem of extraction of feature and classification. It is an effective approach for self-supervised online learning. It reduces the possibility of wrong categorization of road and non-road classes and improves the road detection algorithm.

Sahar Movaghati^[7] et al. proposed Extended Kalman filtering with particle filtering. It helps in finding different road branches. It is based on two modules EKF and PF. The EKF module properly find and estimate the coordinates of the road median. while the PF module is only utilized in critical situations, i.e., when the EKF module stops due to road obstacles or road junctions. When the EKF module faces a severe obstacle, then update profile cluster procedure cannot successfully create new profile clusters. To initialize the PF module, the EKF module transfers the information about its last successful step of the present road segment onto the PF module. At last clustering is done to merge all branches created in EKF and PF module to extract the road. PF module slows the speed of the algorithm which is the limitation of this method.

Xiangyun Hu,^[8] [2014] et al. proposed various features to detect road centerlines from the residual ground points. The main purpose of it is to separate connected nonroad features like parking portion and bare grounds from the roads. Three features are applied to detect the roads. Adaptive mean shift finds the center points on the road, Stick tensor voting is applied to enhance the salient linear features of the road and Hough Transform is applied to extract the arc primitives of the road centerline. One problem of this method. the heavy

computational cost in the tensor voting step and another problem is the identification of the contextual objects of roads, like lane markings, road junction patterns, vehicles, and road edges.

Fatemeh Mazrouei Sebdani^[9] et al. [2012] use Hough Transform to extract the roads. In the preprocessing region of interest (ROI) is applied with wiener filter to remove the noise. After it image is segmented by thresholding and Hough Transform method. Morphology operations are applied at last to improve the output results. Positive point of this method: no need of any prior knowledge of road width, mark length and other parameters. Negative point: Can't use this method for real time applications as it is time consuming and also applicable for 2-D images only.

Hao Chen ^[10][2014] et al. proposed an algorithm to overcome the problem of extraction of defects result due to noise using traditional methods. This method proposes an algorithm based on the global features. It uses Top-down approach to extract the roads. Global topological perception is applied prior to the perception of other locally featured properties (centerlines) which are extracted using Burns algorithm. Topological information about roads is derived from vector data.

Jiuxiang Hu,^[11][2007] et al. used two-step approach to extract the roads from aerial images, i.e. detection and pruning analysis. This method involves detection of road footprints, track the roads, and grow a road tree. Footprint of a pixel is the local homogeneous region around a pixel enclosed by a polygon and Spoke wheel operator is used to get the road footprint. A



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toe - finding algorithm is used to find the direction of foot –prints. Bayes decision model based on the (A/P) area-to-perimeter ratio of the footprint, is used to trim the paths that leak into the surroundings. This paper helps in efficiently trimming the paths that lead to the improvement of performance, correctness and quality of the extracted roads.

Mingjun Song^[12][2004] et al. used SVM to extract the roads. It helps in classifying the image into road and non-road region. Based on homogenous criteria Region Growing is used to segment. After it thresholding is applied to extract roads and then vectorization and thinning is performed to get the centerline of the road. This paper helps in extracting the very narrow roads, but unable to address the roads having tree/building shadows, gaps etc.

Rajani Mangala^[13] et al. [2011] proposed a work for Road extraction based on the gradient operation and skeletal rav formation by comparing it with ANN based road extraction method. Thresholding and coloring with morphological operations are performed to extract the road. The proposed work of this paper is applied on the rural roads. Color image to binary image conversion is performed and Gradient is operated twice to remove the noise. Thresholding is also used and after its midpoints are found out and connected. At last coloring and morphological operations are performed. This technique has provide 72%, 82% and 81% completeness. correctness and quality respectively.

TABLE 1
COMPARISON OF VARIOUS ALGORITHMS DISCUSSED IN LITERATURE
SURVEY

Sr. No	Reference	Method Used	Image (Database)	Results	Advantages/Disadvantage s
1	Liu Xu et al. [1]	Unsharp masking to effectively reduce noise using template.	Quickbird Panchromati c image	DNP	 Quick & easy method. Improper selection of template leads to the incorrect extraction of roads.
2	Yan Li and Ronald Briggs [3]	A reference circle and central pixel, to capture the essence of both visual and geometric characteristics of roads	Images from Google Map	DNP	Well address blurring, broken or missing road boundaries, heavy shadows, and interference from surrounding objects
3	Juan Wang,[^[4]	Mathematical Morphology	Remote Sensing	DNP	Easy to use.

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	et al		Image		
4	Beril Sırmac ^[5] et al	Spatial Voting Matrix besides using edge detection.	Panchromati c Ikonos satellite Image	86.85% of the road network; 9.03% false alarm rate.	Tracking Algorithm results in decreasing the operation speed.
5	Shengyan Zhou ^[6]	Support Vector machine based on online learning	Self Captured images	DNP	Automatic updating of training data reduce the possibility of misclassifying roads and non-road regions.
6	Sahar Movaghat i ^[7]	Extended Kalman Filter to find road median and Particle filtering module to curb the obstacles .	IRS and IKONOS image	Correctness 98%; Completenes s 92% (IRS) and 85% (IKONOS)	 Effectively find the branches of roads at road junction. PF module reduces the speed of the algorithm Not apply to more complex urban area.
7	Xiangyun Hu, ^[8]	Mean shift, Tensor voting, Hough transform (MTH) to extract centerline of the road.	LiDAR data of urban areas	Completenes s 81.7%; Correctness 88.4%	 Effectively detect roads in complex urban scenes with varying road widths and noise. One problem is the heavy computational cost in the tensor voting step.
8	Fatemeh Mazrouei Sebdani ^[9] et al.	Extraction using hough transform on video sequencing frames.	Road scenes in video sequences taken by stationary traffic Cameras.	FAR 2%; FRR 11%	 No need of any knowledge of road width, mark length and other parameter. Due to computational complexity, algorithm can't use in real-time application.
9	Jiuxiang Hu, ^[11] et al.	An Automatic road seeding method using footprints.	Any aerial Image	84% to 94% completeness , Above 81% correctness, Quality 82% to90%	Efficiently trims the paths that leak into the surroundings of the roads

DNP* - Data not provided.

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FAR- is the number of pixels that aren't as road line, but detect these as road line.

FRR – is the number of pixels that are as road line, but we can't extract

V. CONCLUSION

This review paper throws a light over number of existing techniques that are used in road extraction. Automatic detection of roads from an image presents many challenges. The color of roof top also analogous to that as roads and shadow of trees on road results in improper extraction of roads. There is a chance of true negative (i.e. not detect the road, even if it is road in actual) due to these problems. Also, most of

the techniques are not applied on both rural and urban area road images. In this paper, some existing methods are reviewed to give a complete view of the field. On the basis of this work, the researchers can get an idea about automated road extraction and can develop more effective and better method for it.

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