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A New Technique .for Road Extraction Using Mathematical Morphology, Fuzzy and Genetic Algorithm

Shweta Gupta, Gajendra Singh
CSE Dept, SSSITS SSSITS Sehore (M.P.) India
HOD (CS/IT) Dept, Sehore (M.P.) India

Abstract
Today large volumes of data are provided by the Remote sensing systems. Extraction of road from these images provides variety of applications such as map implementation, road transportation creation, maintenance and so on. Manual analysis of Satellite images are very tedious and time consuming job. Automatic extraction of roads is scientifically challenging due to noise present in the atmosphere and different road characteristic. In this paper Automatic road extraction approach is presented. In this method Genetic algorithm, Fuzzy and mathematical morphology is used. Results shows that the proposed method is successful in the road extraction and provides better results.
Keywords— Road extraction; Genetic Algorithm (GA); fuzzy; Geographic information system (GIS), Mathematical morphology;

I. INTRODUCTION

Road extraction from digital imagery are widely used in a variety of applications like map implementation, transportation planning, traffic management, automated vehicle navigation and guidance, tourism, emergency management, crop estimation etc. According to human interaction road extraction system can be classified into semi automated and automated system. A semi automated system [1] is a system in which some human interaction is needed to input the system. Fully automated system doesn't require any input from user. Manually extraction of road from aerial is an extremely time-consuming and tedious task. As time grows, the extraction of knowledge from information needs to be effected at minimum cost, while challenges must be faced such as the increase of the data quality requirements, as well as the exponential growth of the aerial images available. For these reasons, techniques designed to make the tasks related with knowledge extraction easier are welcomed in this field, but they must be accompanied by a high degree of reliability.

Automated Extraction of roads from spaceborne remotely sensed imagery has been an active research and development topic for the last twenty years. World's first commercial remote sensing satellite, 1m resolution Ikonos was launch in the year 1999. High resolution imagery not only provides greater accuracy, but in turn also increases the computational and problem complexity due to noise and artifacts. Many research works have been done for automatic and semi-automatic extraction of road networks from satellite images.

II. RELATED WORK

Since last twenty years a large number of techniques have been developed for automated and semi automated approaches of analysis of road extraction. J.B. Mena [2] in his survey paper "State of the art on automatic road extraction for GIS update: a novel classification" review the nearly 250 reference papers. M.F.Auclair, D.Ziou, C.Amenakis and S. Wang [3] in their survey paper "Survey of work on road extraction in aerial and satellite images" explained that Road Extraction algorithm can be divided into three parts; their input data, their goals and the methods used to achieve these goals.

H. Liu, J. Liu, M. A. Chapman[4] in their paper "Automated Road Extraction from Satellite Imagery Using Hybrid Genetic Algorithms and Cluster Analysis" Present an approach based on Genetic Algorithms with fitness calculation of clustering of high resolution imagery.

Mohammadzadeh, A., Tavakoli, A., and Valadan Zoej, M.J [5] in their paper "Road extraction based on fuzzy logic and mathematical morphology from pan-sharpened IKONOS images" proposed a new fuzzy segmentation method for road detection in high resolution satellite images with only a few number of road samples. Afterward by using an advanced mathematical morphological operator, road centrelines were extracted.

M. Mokhtarzade, M. J. Valadan Zoej , H. Ebadi [6] in their paper "Automatic road extraction from high resolution satellite images using neural networks**,** texture analysis**,** fuzzy clustering and genetic algorithms" have proposed the methodology using two stages:

a) Road Detection is done by using the neural network and texture parameters.
b) Road Vectorization is done using the road raster map.

In the last step the information is extracted by using fuzzy shell based clustering.

Jalal Amini [7] combine the mathematical modeling and fuzzy to extract the road form high resolution IKONOS image. Feature extraction is done by four membership function: Mean, Standard deviation, Skewness, and Kurtosis. Roads are identified base on converted features to specific fuzzy sets in fuzzy modeling step. The skeleton of identified roads is extracted by mathematical morphology in last step. On the other hand, in [8] Jeon et.al considers SAR images as curvilinear structures. Perceptual Grouping factors combined with Genetic algorithm are applied to find road from these curve segments.

III. Proposed Methodology

The proposed algorithm uses an automatic approach for road detection. Figure 1 shows the block diagram of algorithm. The details of steps are presented in this section.

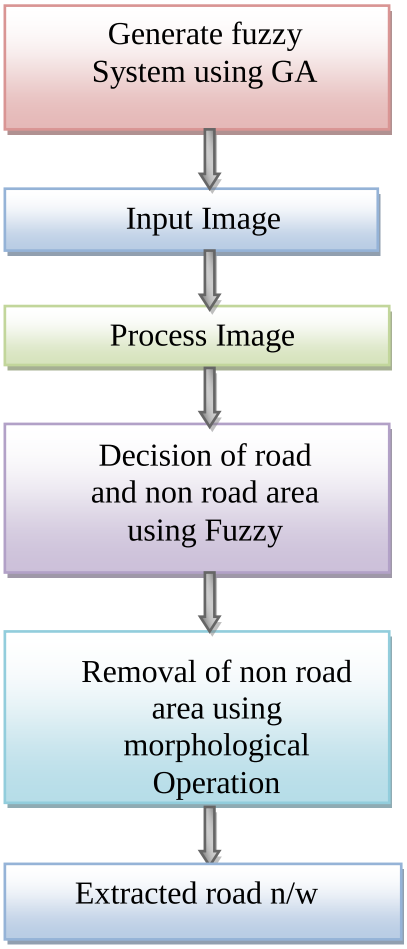

Figure 1: Proposed Algorithm Step

A. Data

IKONOS images are used in this study to extract roads automatically. The image provide panchromatic and multispectral (Blue, Green, Red,) bands which has 1m and 4m resolution respectively. Sample image used in this study is shown in Figure 2.

Figure 2: Sample Input image

B. Algorithm

The techniques used in this algorithm are Fuzzy, genetic algorithm and mathematical morphology operation. The approach is described in this section. R G B colour values of image are used to create fuzzy system.

1. Fuzzy System:

Mamdani fuzzy inference system is created by using three inputs and one output. The three inputs consist of RGB values of a images and the output is road. All the three colours are normally present in the Road area. Figure 3 shows the fuzzy system.

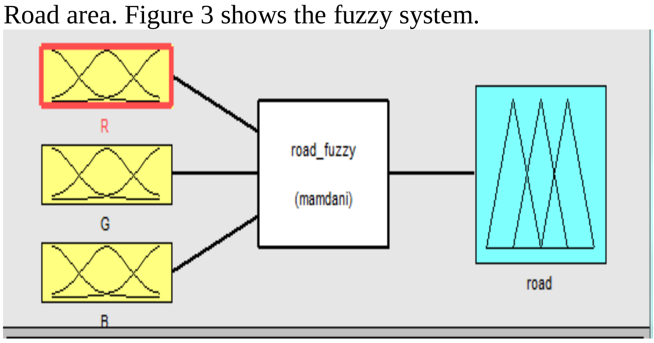

Figure 3: Proposed Fuzzy System

We define two fuzzy membership function trapezoidal and triangular and three linguistic variables: low, medium and high. Fuzzy membership function provides the characterization of fuzzy sets by establishing a connection between linguistic variable. The trapezoidal function represents the road area of an image and triangular membership function represents non road area. This decision is taken by using all the three linguistic variables low, medium and high. Medium variable define the road area. Figure 4 shows the membership function plot used in the system .

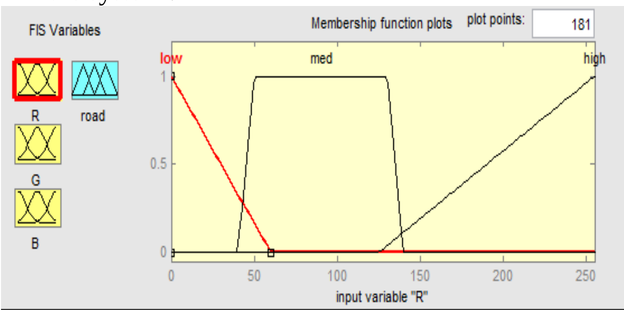

Figure 4: Membership function plot

Fuzzy Rule base is prepared using the three input variable and one output variable. There will be 27 rule for this syetm.

The figure 5 shows the some rule of fuzzy system.

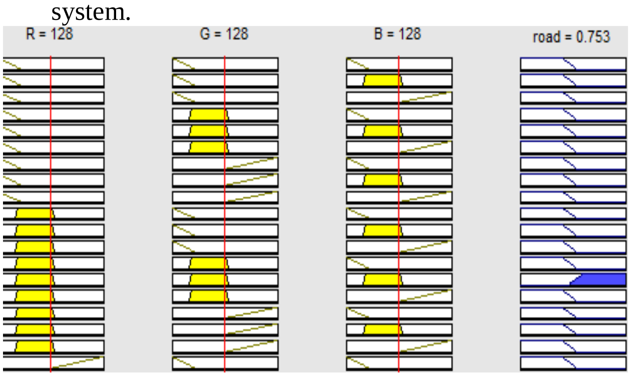

Figure 5: Fuzzy Rule Generation

2. Optimization of fuzzy system using genetic algorithm:

To improve the performance of genetic algorithm Fuzzy control techniques can be applied. For a very large application domain fuzzy and genetic crossbreeding is used. The initial random population is created using if-then rule of fuzzy logic system. The fitness function is calculated for each population. The new population will created by performing crossover and mutation. The algorithm will be terminated when the termination condition number of generation exceeds. The generated best population will be the solution of problem.

Let an n-input, single output fuzzy controller be given by the following set of linguistic rules:

IF ($X_1 = A_1$) and ……and ($X_n = A_n$) THEN (Y=B)

For all i∈{1,……,n}, let Ai assume a linguistic value in the range $\{a_{i,1}, a_{i,2}, \ldots\ldots, a_{i,n(i)}\}$ and let B assume a linguistic value in the range $\{b_1, b_2, \ldots\ldots, b_m\}$. This method is used to find a validation of all possible rules that can be created. To validate all the rules within a reasonable time period only a selected number of rules will be created at random, and these will be considered as a population of genetic algorithm. Hence, a chromosome is represented by:

C^K

$a^K_{1,j1}$	$a^K_{2,j2}$	……	$a^K_{n,jn}$	$b^K_{k,}$

Where $\forall i \in \{1,\ldots..,n\} : j_i \in \{1,\ldots..,n(i)\}$ and k∈{1,……m}. A chromosome exists by taking all the possible linguistic input values together with a single linguistic output value; hence chromosome length will be n+1.

Given a population of N randomly determined chromosome, it is sufficient to define a crossover and mutation operator in order to be able to apply the techniques. A crossover at crossover point q∈ {1,…..,n+1} will be defined as follows: for all $K_1, K_2 \in \{1,\ldots., N\}$,

a^{K1}_1	……	a^{K1}_q	a^{K1}_{q+1}	….	a^{K1}_n	b^{K1}
a^{K2}_1	……	a^{K2}_q	a^{K2}_{q+1}	….	a^{K2}_n	b^{K2}

Parents C^{K1} and C^{K2}

a^{K1}_1	……	a^{K1}_q	a^{K2}_{q+1}	….	a^{K2}_n	b^{K2}

Child

In particular, Mutation is performed when q = n, the rule antecedents will be matched with another consequences.

$a^K_{1,j1}$	$a^K_{2,j2}$	…	a^K_{q,j_q}	….	a^K_{n,j_n}	b^K_k

C^K : Before Mutation

$a^K_{1,j1}$	$a^K_{2,j2}$	….	$a^K_{q,\hat{j}_q}$	….	a^K_{n,j_n}	b^K_k

C^K : After Mutation

With $\hat{j}_q$ a random linguistic value in {1,….,n (q)}to replace j_q. The rule base should be optimized by this nonlinear technique, after a number of runs. This is especially where a number of possible rules become large.

3. Process image

After optimization of fuzzy rules using Genetic algorithm the input image is processed. In this step we extract the feature of image i.e. RGB values of image.

4. Decision of road and non road area

In this step the processed image is then used to find out road and non road area by using optimized fuzzy rule created in the second step of the algorithm.

Fuzzy-GA approach extracts the road from the image as shown in figure 6, but also extracts the noise like shadow of tree, building etc. This noise will remove by applying morphological operation .

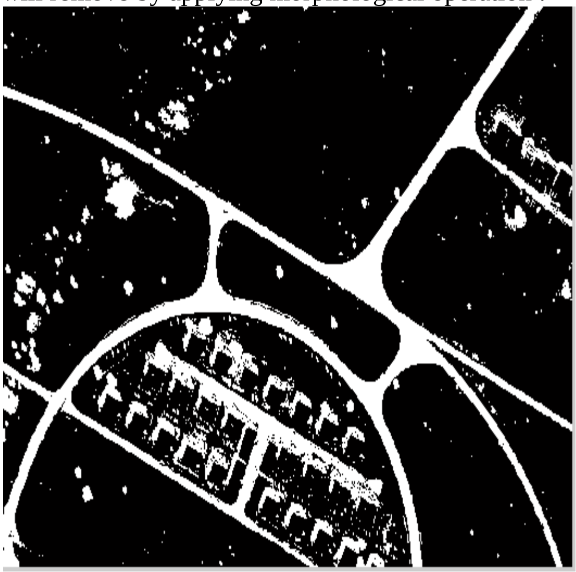

Figure 6: Image after applying Fuzzy-GA

5. Mathematical Morphology

Binary images may contain numerous imperfections. In particular, the binary regions produced by simple thresholding are distorted by noise and texture. Morphological image processing pursues the goals of removing these imperfections by accounting for the form and structure of the image. These techniques can be extended to grayscale images [9]. In the proposed system the morphological operation dilation followed by erosion and branch point is performed.

Morphological operation takes two inputs one is binary image and second is structuring element. Comparing the structuring element the neighbourhood of each pixel determines the output of the operation. A structuring element S is binary array. The same structuring element is used for all the operations. Dilation can be defined as:

$$Y=F\oplus S$$

And Erosion can be defined as:

$$Y=F\ominus S,$$

Where, S is the structuring element for morphological operation and F is the input image.

The branch points are a point where two points meet. Junction is also known as branch points. For example:

0 0 1 0 0	becomes	0 0 0 0 0
1 1 1 1 1		0 0 1 0 0
0 0 1 0 0		0 0 0 0 0
0 0 1 0 0		0 0 0 0 0

To manipulate noisy images where a few pixels have incorrect binary values these methods are useful. The above mentioned operations are performed in satellite images and finally a noise free and precise road image is obtained.

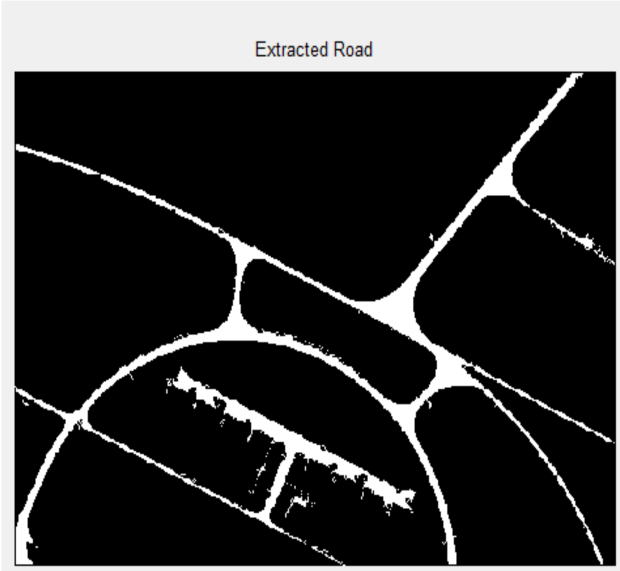

Figure 7: Extracted road network.

4.3 Proposed Algorithm:

Step1: Develop fuzzy System

a) Set the three inputs R G B and one output ROAD.
b) Set Linguistic variable low, med, high for input RGB.
c) Set membership function triangular and trapezoidal.
d) Create all possible fuzzy rules using variable input, output, low, high, med and membership functions.

Step 2: Optimize Fuzzy System using Genetic algorithm:

a) The fitness function is created using fuzzy rule.
b) Initialize the variable population size p, number of generation g, lower bound LB and upper bound UB.

c) Pass the parameter: fitness function, p, g, LB and UB in Genetic algorithm to optimize fuzzy rules.
d) Apply Roulette wheel selection, Crossover ratio: 0.8 and Mutation ratio: 0.3 to generate the population.
e) Repeat step (c) and (d) until termination condition g occurs.
f) Create Fuzzy Structure using optimized Genetic algorithm values to take decision of road and non road area.

Step 3: Read the high resolution Image F.
Step 4: Processing of image:
a) Extract Feature of an image i.e. R G B colour information i.e. intensity I of input image.
b) Store all intensity value in i.e.

R G B ←F (I)

c) Apply Fuzzy rules to detect road and non road area.
d) Define structuring element S.
e) Apply Morphological operation on input image F using structuring element S, i.e. dilation $Y=F\oplus S$, Erosion $Y=F\ominus S$, and branch point to remove the non road area like shadow and tree structures.

Step 5: Stop the algorithm**.**

IV. EXPERIMENTS AND DISCUSSION

The proposed system has been implemented and tested in MATLAB version 8.0 under Microsoft Windows 7 operating system. This algorithm is implemented on personal computer, which utilizes 2.10 GHz Intel core i3 processor and 2 GB primary memory.

This approach has been tested 7 different IKONOS satellite images. Reference image are prepared for all images to evaluate the performance. Two quality measures [10] completeness and correctness are used to check the performance of the system.

Completeness:

The completeness is defined as the percentage of the reference network which lie within the buffer around the extracted data. Completeness varies from 0 to 1. The optimum value of completeness is 1.

Completeness = MRP/ RP

where, MRP- No. of reference road pixels matched with extracted road pixels

RP – No. of reference road pixels

Correctness

The correctness is the percentage of the extracted data which lie within the buffer around the reference network. Correctness varies from 0 to 1. The optimum value of completeness is 1.

Correctness = MRP/ EP

EP – No. of extracted road pixels

Table 5.1: Performance measure of proposed system

Sr.no.	Performance measures (in %)	
	Completeness	Correctness
Test Image 1	100	100
Test Image 2	93.139	90.936
Test Image 3	94.682	90.639
Test Image 4	97.896	88.749
Test Image 5	96.64	87.812
Test Image 6	88.082	93.024
Test Image 7	90.005	69.403

As data and information of the same area was not available we cannot be directly compared the proposed method to other algorithms. This makes a conclusive comparison difficult. To compare the result different reference methods are used.

Table 5.2: Accuracy result of [11]

	Completeness	Correctness
Lines	0.63	0.42
TUM-G	0.47	0.78
TUM-S	0.66	0.87

Table 5.6: Accuracy result of [9]

Images	Performance measures (in %)	
	Completeness	Correctness
A	66.62	94.46
B	66.11	97.42
C	64.56	77.75
D	79.79	77.03
E	82.55	62.91

Table 5.3: Accuracy result of [10]

	Completeness	Correctness
Site 1	0.77	0.76
Site 2	0.61	0.59

Fig. 8 shows the results of the performance measures Completeness and correctness of the test images. From the Fig. 8, it can be visualized that our proposed system performs well in the given test images

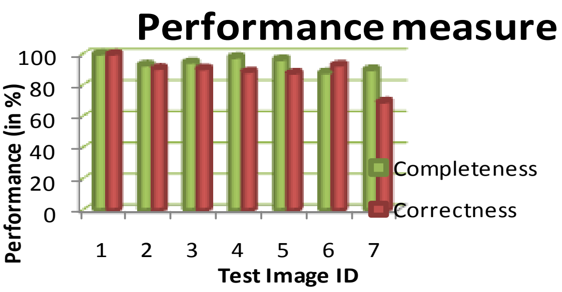

Figure 8: Result of performance measure of testing image

V. CONCLUSION AND FUTURE WORK

In this paper we have proposed an efficient technique of Road Extraction from satellite images. The proposed algorithm has been performed to extract the rural roads exactly. The technique has been implemented and compared against previous existing technique. From the comparative results, it can be visualized that the proposed technique has achieved a remarkable performance improvement over the conventional technique. The technique outperforms in almost all of the satellite images that are subjected for road extraction. This shows that the proposed technique is effective in extracting the rural roads from the satellite image even rather than the previous technique.

The future work will focus on to deal with noisy data and further improvement of detection method.

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