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Fuzzy System for Detection of Manmade Areas in Satellite Images

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Abstract

In this paper a new fuzzy system proposed to detect manmade areas in satellite images. By using edge and local entropy data extracted from raw image as inputs of the fuzzy system, it is shown that the proposed method provides fast, general and useful strategy for detecting manmade areas.

Keywords: Manmade areas, satellite images, fuzzy logic, edge detection, local entropy.

Introduction

Image analysis and processing plays an important role in modern science and technology with applications in very diverse areas such as arts, medical sciences, traffic control, etc.[1] Utilization of computer methods and diverse algorithms for image repairs such as noise reduction, object detections such as in security systems or cancer diagnosis, scene analysis such as in traffic control has been studied in many research works i.e. Nixon and Aguado[2].

Detection of manmade areas in aerial and satellite images is one of the interesting and very useful applications in the field of image analysis. Automatic detection of manmade objects like buildings and roads in the images for the aim of supervision, geographical database management, statistical data analysis and many other applications is a complicated task because of very large amount of mess data in satellite images and tangling of manmade and natural objects in the image. So it is of importance to detect and separate manmade from natural areas in the satellite images. Previous works has been done on the aerial images[3] and almost focused on the detection of some determined objects such as buildings in Mayer[4] or roads in Mena[5].

To provide a method for detection, some studies have been done based on models of the objects to be detected. Mayer[4]utilizes model based method for detection of buildings. Other methods based on statistical models such as hidden Markov model in Li et al.[6], Gaussian model in Solka et al.[7] Weibull model in Carlotto[8], and Fractional Brownian motion model in Cooper et al.[9] have been proposed. In Cao et al.[10] and Karantzalos and Argialas[11] methods based on level set and evolution based Mumphord-Shah model are proposed. Feature extraction based method for detection of buildings has been studied in Sirmacek and Unsalan[12].

In most of previous works complicated methods and ad hoc models have been used which are not necessary in many general applications or fast needs. In this paper we propose a new method based on fuzzy logic to provide a fast system of manmade area detection in satellite images. In the proposed method two local properties of edges and entropies of image are used as inputs of system. By this utilization there is no specification on the model of objects or information. It is also a general framework which could be used for diverse kinds of images and areas.

In section local information for manmade areas detection, the edge and local entropy properties are discussed as useful inputs for manmade area detection. Brief introduction of fuzzy logic and proposed system is presented in section fuzzy detection system of paper. Results of utilization of proposed method are presented in section simulation and results and concluding remarks are the last section.

Local Information for Manmade areas detection

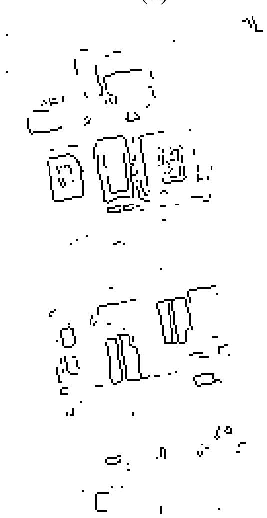
Digital images are described as matrices of values for each pixel. To extract information and analyze the image, one needs to perform some algorithms and calculations on these intensity matrices. So for a two dimensional image we have the function $I(x,y)$for each pixel in the position of (x,y). Operations on this function can extract global information such as distribution of intensities in the whole image, or extract local information such as gradient of intensity in a small neighborhood of a pixel.

In this paper we propose utilization of two kinds of local information for manmade area detection: i. edges of image and ii. local entropies.

Edges: We assume that edges in a satellite image may be more likely belonging to manmade areas than natural areas. Most of manmade objects such as buildings, roads, cars, and etc have clear edges, but in contrast natural scenes such as trees, pastures and lakes have curvedor messy boundaries.

Many algorithms have been proposed for extraction of edges in digital images. We utilize Canny method[13] for this task. For a *I(x,y)* function of an image one can replace every pixel by its binary edge value (being of an edge or not) and extract a function *E(x,y)*. In figure 1 a satellite image and its edge extracted image are shown. It is seen that most of edges are from manmade areas.

(a)



(b)

Figure-1

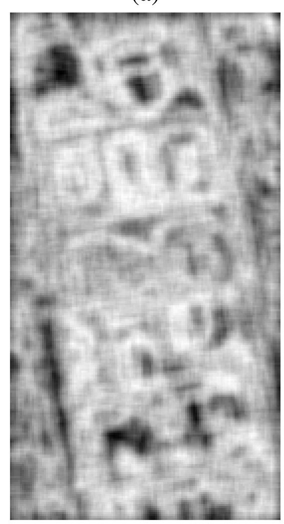
(a) A typical satellite image, (b) Edge extracted image of (a)

Local Entropy: For a signal the entropy measure can be used to determine its order and disorder level[14]. If the levels in the signal provide a distribution of probabilities p_i , entropy of that signal is defined as

$$H = -\sum p_i \log p_i \ . \qquad (1)$$

For a digital image, local entropy for each pixel is the entropy of pixels in a window around that pixel. By calculating local entropies for each pixel in *I(x,y),* an entropic image *H(x,y)* is obtained. In figure-2 the satellite image and its entropic image for window size of 9 pixels are shown. Manmade areas are almost brighter than natural areas.

(a)



(b)

Figure-2

(a) A typical satellite image, (b) Entropic image of (a) for window size of 9

Fuzzy Detection System

Two properties of image based on edges and local entropies can provide some raw information about manmade or natural objects. But they are not enough in the single manner and need to combine in a system to make better decisions. We propose a system based on fuzzy logic for fusion of extracted information as edge and entropies.

Fuzzy logic is a kind of reasoning to take account of uncertain information and situations[15]. In contrast with conventional logic in which an object belongs to a set with total confidence, in fuzzy sets the objects are members of sets with different levels

of certainty[16]. For example an object *x* can be member of set *A* with membership degree of 0.7 and be not its member with degree 0.3.
In a fuzzy system variables are not simply described by a single number but are presented by membership function which shows the degree of membership of each value.

Based on the principles of fuzzy sets and logic, inference systems can be designed to map between input and output variables[17]. This mapping is accomplished by utilization of some *if-then* rules such as

If x_1 is *A,* and x_2 is *B,* then *y* is *C.*

In this statement $\boldsymbol{x_1}$ and $\boldsymbol{x_2}$ are inputs, $\boldsymbol{y}$ is the output; *A, B* and *C* are fuzzy variables. So based on membership values of inputs and outputs to variables, the rule has a overall share in the whole reasoning and decision system which determines final output of the system.

We propose a fuzzy inference system between inputs *E(x,y)* and *H(x,y)* of a satellite image and output of degree of being manmade. In the fuzzy system values of edge extracted image and local entropy for each pixel are used to calculate a degree for that pixel to be of manmade areas or not. The schematic of the system is shown in figure 3.

Simulation and Results

Based on discussion of previous sections, a fuzzy inference system with structure of figure 3 is designed for manmade areas detection in satellite images using Matlab. Membership functions for inputs and output are defined as triangle membership function as shown in figure 4 for local entropy input. Rules between these inputs and outputs are defined as shown in figure 5.

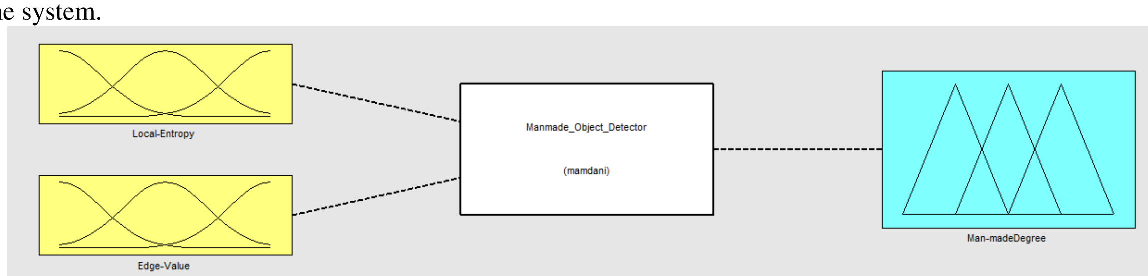


Figure-3
Schematic of fuzzy system for manmade areas detection

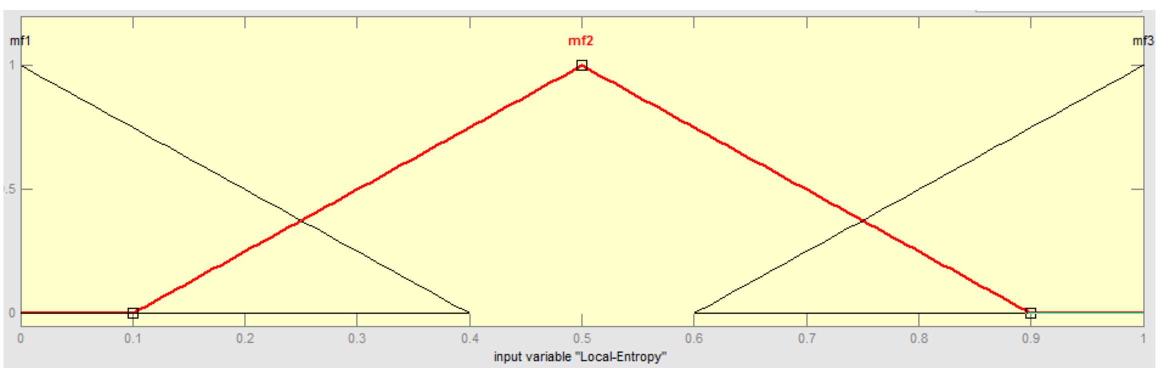


Figure-4
Membership functions of inputs and output

1. If (Local-Entropy is mf1) and (Edge-Value is mf1) then (Man-madeDegree is mf1) (1)
2. If (Local-Entropy is mf1) and (Edge-Value is mf2) then (Man-madeDegree is mf1) (1)
3. If (Local-Entropy is mf1) and (Edge-Value is mf3) then (Man-madeDegree is mf2) (1)
4. If (Local-Entropy is mf2) and (Edge-Value is mf1) then (Man-madeDegree is mf1) (1)
5. If (Local-Entropy is mf2) and (Edge-Value is mf2) then (Man-madeDegree is mf2) (1)
6. If (Local-Entropy is mf2) and (Edge-Value is mf3) then (Man-madeDegree is mf2) (1)
7. If (Local-Entropy is mf3) and (Edge-Value is mf1) then (Man-madeDegree is mf2) (1)
8. If (Local-Entropy is mf3) and (Edge-Value is mf2) then (Man-madeDegree is mf2) (1)
9. If (Local-Entropy is mf3) and (Edge-Value is mf3) then (Man-madeDegree is mf3) (1)

Figure-5
Nine possible and rules of the system

These rules create a mapping between 2 inputs and 1 output of the system which could be shown by means of a surface as depicted in figure 6.

By utilization of the fuzzy system on satellite images the degree for each pixel for being manmade or not is determined. In figure 7 one of the results for satellite image of a city and its suburb is shown for example. Manmade areas such as buildings in the city and roads (areas with higher value for manmade degree) are brighter and natural areas are shown by darker pixels in final result.

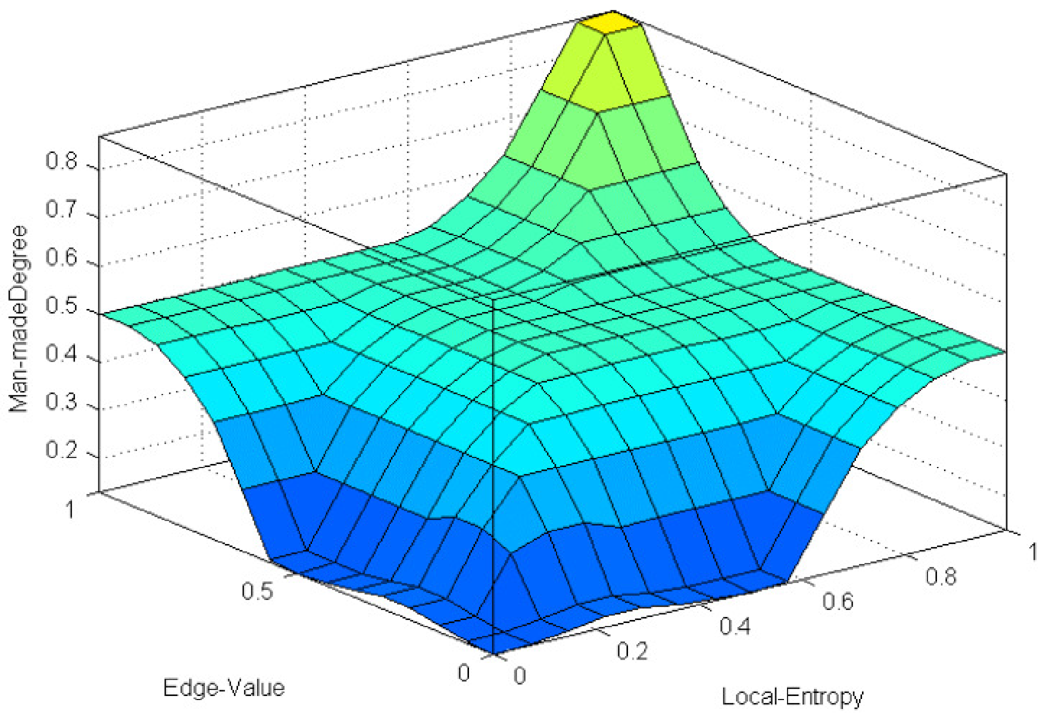


Figure-6
Surface of output versus inputs of the fuzzy system

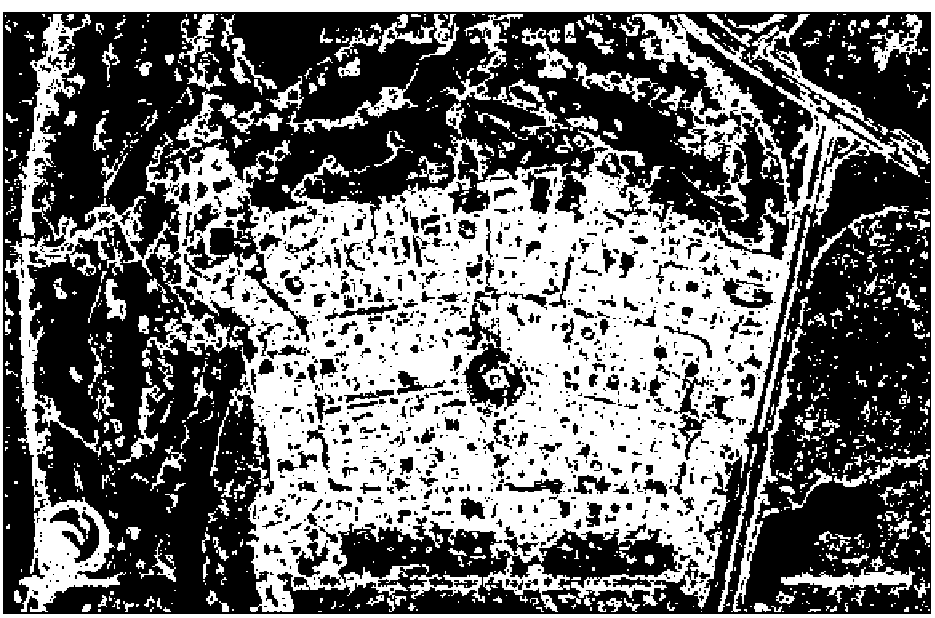


Figure-7
Example result of fuzzy manmade area detection

Conclusion

In this paper a new method for detection of manmade areas in satellite images are proposed based on fuzzy logic. By showing usefulness of edge extracted and local entropy images for object detection, these two features are used as inputs of fuzzy system. By defining some appropriate memberships and rules for the system, it utilized to determine the degree of being manmade for pixels in satellite images. The result of method showed its good and fast capability of detecting manmade areas from natural areas in a general way.

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