An Automated Algorithm for Detecting Objects from Satellite Images Using Fuzzy Logic

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Abstract: The growing popularity of satellite science has led researchers to research satellite image processing. One of the important applications of these images is the automatic extraction of an object from these images. This paper presents a new intelligent algorithm for automatic detection and extraction of identifying objects through satellite imagery. In the proposed algorithm, the fuzzy rules method is used to calculate the similarity of neighboring pixels. In this method, 3*3 windows are placed on the pixels in the image, then by applying the image processing algorithm, the similarity of the pixel in the center of the window with the neighboring pixels is calculated. After processing all the pixels of the satellite image, the edges and borders of the objects in the image appear. The Experiments results show the proper performance of this algorithm up to a maximum of 95.32% accuracy, and an average of 85.78% accuracy in identifying and extracting objects from satellite images. Also, the proposed algorithm, compared to other algorithms with similar experimental conditions, has good performance accuracy.

Keywords: edge detection, fuzzy logic system, image processing, object extraction, satellite images

I. INTRODUCTION

It is clear that in organizational environments, decision-making conditions as well as the data used are often inaccurate and ambiguous. The analysis of ambiguous data requires a special logic and analysis device that is introduced to the world today as fuzzy set theory or fuzzy logic. The main application of this logic is in conditions of uncertainty. According to this logic, many concepts and interpretations that do not fit in the form of quantitative numbers and are considered as a kind of linguistic variable can be mathematically formulated and used for decision making and reasoning. One of the applications of fuzzy logic is its use in recognizing and extracting objects within images.

Various methods have been introduced to identify the objects in the image and understand their meaning. In this paper, a new algorithm for identifying and mapping paths of satellite images based on fuzzy rules image processing is presented. Our purpose in this article, identification and the detection of object and paths from an image with a minimum of human intervention and maximum speed based on one or more computer algorithms. Having enough information from the paths is essential for the purposes of distance, traffic management, crisis management and dealing with sudden accidents, etc. For this reason, remote sensing researchers were directed to this field. Looking at the activities carried out in this field, it can be seen that performing diagnostic operations with the participation of human agents. The proposed algorithm almost eliminates human participation during detection operations using fuzzy rules methods. In the following, the steps of this algorithm are described and presented. Then the results of the implementation of this algorithm in real conditions are reviewed and presented. The results of the experiments are compared with the results of a study that performed a different way of extracting objects and paths from satellite images.

II. RELATED WORK

Due to the fact that the manual extraction of various objects from remote images, like satellite images, is a time-consuming and costly process, studies on the identification and extraction of objects from automatic and semi-automatic images have been presented, each of which has advantages and disadvantages. One of these algorithms is the method of using data Lidar. One of the disadvantages of this method is the incomprehensibility of data Lidar for all users and its high cost. The next proposed algorithm is the use of C-mean fuzzy logic. This algorithm performs the clustering operation globally and is done using user-defined parameters, which is a weakness for this algorithm. Another method proposed is to use a combination of neural network with morphological operators in image processing. In the following, we will refer to some articles written in this field.

In [1] presents a method for images classification based on the BP neural network. In this method, the image is first segmented and then clustered into several visible objects. It then calculates a probability vector using a single image library, which consists of the probability that each object in the image is visible, and each single image in the single image library. The BP neural network obtains an image class by which it can categorize the image. In another method the application of fuzzy logic method based on genetic algorithm in computer diagnostic design of medical imaging is introduced. This design has been used to differentiate myocardial heart disease from echocardiographic images and to diagnose and classify a calcareous mass from a mammogram. In this study, Gaussian distributed fuzzy membership functions (GDMF) are used [2]. In [3], the process of creating a classification has been studied to evaluate semantic classification algorithms. This study has shown that due to the high involvement in the process of forming semantic values, it is impossible to create semantic values for evaluating algorithms.

III. PIXEL SIMILARITY IN RGB IMAGES

A. *Mask-based segmentation and graph-based integration*

In the mask-based method, the 3 * 3 mask is placed on all the pixels in the image and the similarity between the central pixel of the mask and the neighboring pixels is calculated [6]. Although the mask-based segmentation algorithm is fast, it has the problem of over-segmentation, also μ_T (similarity threshold) and D_n (normalization coefficient) are other problems. However, the problem of over-segmentation can be solved using the Warshall algorithm and Transitive closure [7, 8].

B. *Calculate the similarity between pixels*

The purpose of image segmentation is to classify pixels similar to the image in a group. In the masking and graph-based segmentation algorithm, the color similarity of the pixels is calculated using the Euclidean distance.

In a color image, two neighboring pixels (P1, P2) appear in RGB color space with two points. The distance between points is calculated using the equation (1).

$$\|p_1 - p_2\| = \frac{1}{\sqrt{3}} (\Delta R^2 + \Delta G^2 + \Delta B^2)^{\frac{1}{2}} \quad (1)$$

where ΔR, ΔG and ΔB are the difference of the gray level and are defined as equations (2), (3), (4). Where, R, G and B are the first letters of the words Red, Green and Blue, respectively.

$$\Delta R = |L_{R,1} - L_{R,2}| \quad (2)$$

$$\Delta G = |L_{G,1} - L_{G,2}| \quad (3)$$

$$\Delta B = |L_{B,1} - L_{B,2}| \quad (4)$$

In RGB images, the similarity of two pixels is calculated using the equation (5) and the similarity value changes between [0, 1].

$$\mu\,(P_1 - P_2) = e^{-(\frac{\|P_1 - P_2\|}{Dn})^2} \quad (5)$$

Also, the value of D_n in this Equation is considered as the normalization coefficient, which is determined by the user. In this algorithm, the threshold value μ_T is used to obtain the similarity of two neighboring pixels.

IV. METHOD

In this study, we present a new approach and evaluate it with previous researches. In general, the steps of this research are done in three phases. In the first phase, 3*3 windows are placed on the pixels in the image. Then, the similarity of the pixel center of the window with the neighboring pixels is calculated. Then, average of the obtained similarities is taken and the result is placed in the center pixel. The color spectrum shows the similarity of the elements of the 3*3 window. After performing this operation, the borders of the objects in the image will be displayed on all pixels. The proposed innovation is that the fuzzy rule method will be used to calculate the similarity of neighboring pixels. In the second phase, the Thresholding operation is performed on the result obtained from the first phase. Finally, in the third phase, the center point of the histogram diagram will be obtained using the mean method. The result gives the threshold value.

In order to find the similarity of the two pixels in the field of image processing, the Euclidean distance in the color space is used. Three components RGB (Red, Green, Blue) are used to calculate the similarity of neighboring pixels in color images. In a color image, the difference in gray level between two pixels is defined by the variables ΔR, ΔG and ΔB in Equations (2), (3) and (4) respectively. The assignment of membership functions based on the developed rule as well as the membership functions used for each color channel are defined in the following. Three membership functions are assigned for gray level differences. The three language values "Z: Zero, M: Medium and B: Big" are assigned to the gray level differences, as well as "0: Zero, 1: Medium and 2: Big" for the language variables. Seven linguistic values are defined for the color similarity between pixels P_1 and P_2 whose membership function is shown in Fig. 1. In this study, as shown in Table 1, these seven linguistic values have been used.

In the created fuzzy system, there are three inputs and one output for the color similarity of the pixels, the created rules are:

Rule 1: if (ΔR is Zero) and (ΔG is Zero) and (ΔB is Zero) then (P_1 and P_2 are Quite Like)

Rule 2: if (ΔR is Zero) and (ΔG is Zero) and (ΔB is Medium) then (P_1 and P_2 are Very Similar)

Rule 3: if (ΔR is Zero) and (ΔG is Zero) and (ΔB is Big) then (P_1 and P_2 are Much Like)

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Rule 27: if (ΔR is Big) and (ΔG is Big) and (ΔB is Big) then (P_1 and P_2 are Lack of Resemblance)

Table 1. Linguistic values

number	linguistic values	abbr.
1	Lack Of Resemblance	LOR
2	Very Little Resemblance	VLR
3	Little Resemblance	LR
4	Moderate Resemblance	MR
5	Much Like	ML
6	Very Similar	VS
7	Quite Like	QL

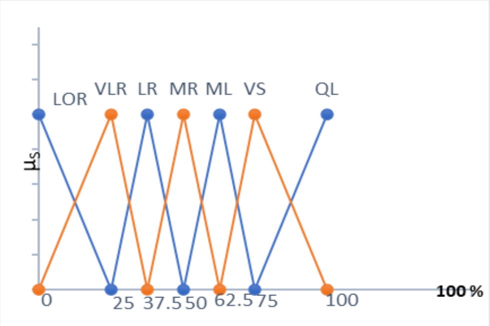


Fig 1. Membership function for color similarity

In a fuzzy system, fuzzy values are generated by obtaining real numbers from the input. In order for language values to be effective in defining the system, the transparency process is used. Using the methods in this field, the fuzzy values obtained from the decision section of the system output are converted into definite values. The weighted mean method is the most common method. In this research, the weighted mean method has been used to defuzzification and find the numerical values of color similarity of two independent pixels P_1 and P_2. Equation (6).

$$S = \frac{\sum_{j=1}^{Z} S_j \mu_{prem}^{j}(L)}{\sum_{j=1}^{Z} \mu_{prem}^{j}(L)} \qquad (6)$$

Where, Z represents the total number of rules and S_j represents the central value of the similarity membership function for the j_{th} of the rule. In addition, μ_{prem}^{j} indicates the degree of membership of the j_{th} rule and is calculated using the equation (7).

$$\mu_{prem}^{j}(L) = \mu^{j}(\Delta R)\, \mu^{j}(\Delta G)\, \mu^{j}(\Delta B) \qquad (7)$$

As a result, the similarity values of the two neighboring pixels correspond to [0, 1]. In this membership function, the sensitivity increases and the similarity of color becomes closer to human perception.

V. Result

The Images used in this research has been prepared from the General Surveying Office of Northwest Iran. This Images was taken using an Ultra-Camera and it has a high accuracy and quality because it was equipped with GPS and IMU system at the same time as satellite photography. We used two images to compare the results of this study with the previous method [9]. The first image is a satellite image of a road and another satellite image has been used in this research, which is a large image of Moghan plain, as well as the results of experiments on these images have also been analyzed.

To obtain the similarity of the two neighboring pixels, the threshold value of μ_T is used, which you will see the effect of this parameter on the images. In order to test the image segmentation capability of the proposed method, the simulation results were compared with the results by the method in [9]. Fig. 2(a) is the satellite color image "road". Fig. 2(b) shows the performance of algorithm [9] in image classification using fuzzy rule-based systems with $\mu_T = 0.98$. Finally, the performance of proposed method in this research is shown in Fig. 2(c). Fig. 3(a-c) also shows the performance of algorithms on another satellite color image "plain" as input image with $\mu_T = 0.95$.

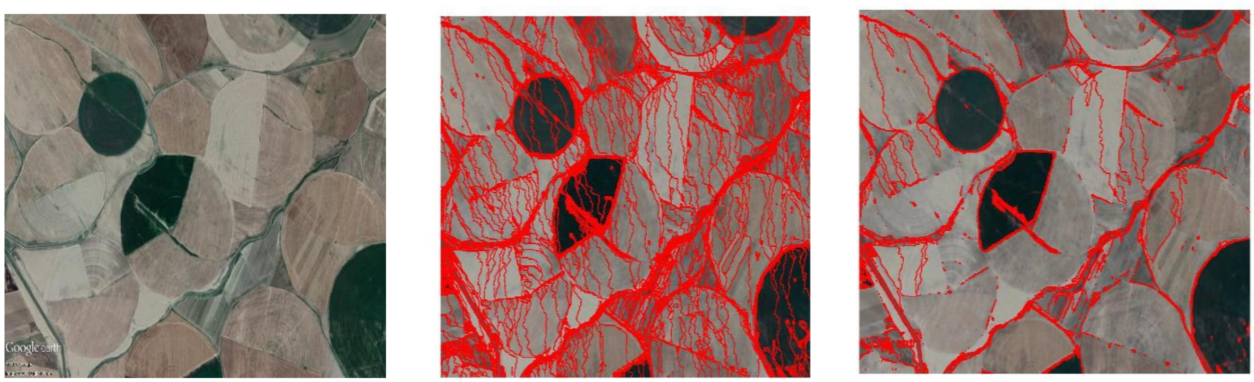
From the simulation results, it can be seen that the proposed method has a better performance than the [9] method, and the proposed method has a higher accuracy in detecting areas in satellite images.

VI. Conclusion

In this paper, we present a novel method for extracting objects to identify objects as well as extracting paths from satellite images using a fuzzy logic system. The proposed method is based on fuzzy rules and uses a three-step algorithm to analyze image objects. The results of this paper show an average of 85.78% extraction accuracy. The Experiments results show the proper performance of this algorithm up to a maximum of 95.32% accuracy. Our approach uses the value of fuzzy membership to identify image edges and extract objects from images. In our experiments, the proposed algorithm successfully identified 91.2% of the objects extracted from satellite images that correspond to the reality of the earth. We also compared our results with result of a state-of-the-art algorithm on two images. Comparison of the achieved results showed that the proposed method is more effective and has better performance. As a result, we can suggest that our system can identify objects from very high-resolution satellite images in a reliable and usable way.

a b c

Fig 2. The image segmentation in "road" color image: (a) the original "road" image, (b) image segmentation based the method [9] and (c) using the proposed method.



a b c

Fig 3. The image segmentation in "plain" color image: (a) the original "plain" image, (b) image segmentation based the method [9] and (c) using the proposed method.

REFERENCES

[1] G. Karypis, EH. Han, and V. Kumar, “Chameleon: Hierarchical clustering using dynamic modeling,” Computer, 1999, pp. 68-75.

[2] B. Boutsinas, and T. Gnardellis, “On distributing the clustering process,” Pattern Recognition Letters, 2002, pp. 999-1008.

[3] J. Yu, “General C-means clustering model,” IEEE transactions on pattern analysis and machine intelligence, 2005, pp. 1197-211.

[4] R. Adams, and L. Bischof, “Seeded region growing, ” IEEE Transactions on pattern analysis and machine intelligence. 1994, pp. 641-7.

[5] A. Tremeau, and N. Borel, “A region growing and merging algorithm to color segmentation,” Pattern recognition, 1997, pp.1191-203.

[6] R. Demirci, U. Güvenç, and H. T. Kahraman, “Görüntülerin renk uzayı yardımıyla ayrıştırılması,” İleri Teknoloji Bilimleri Dergisi, 2014, pp. 1-8.

[7] A. Faktor, and M. Irani, “Clustering by composition,” – Unsupervised discovery of image categories, InEuropean Conference on Computer, 2012, pp. 474-487.

[[8] M. Sezgin, and B. Sankur, “Survey over image thresholding techniques and quantitative performance evaluation,” Journal of Electronic imaging, 2004, pp. 146-65.

[9] S. Jabari, Y. Zhang, “Very high resolution satellite image classification using fuzzy rule-based systems,” Algorithms, 2013, pp. 762-81.