Visual Object Tracking Using Fuzzy-based Thresholding and Kalman Filter

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***Abstract*—Analysis of movement and detection of objects are important branches of image processing and computer vision due to their promising applications such as robotics, industrial automation and the military. In this paper, we propose a new approach for visual object tracking using fuzzy-based thresholding and Kalman filter. In the proposed algorithm, knowledge of three different thresholding methods (i.e. mode method, iterative thresholding and double thresholding) is used to create "if-then" fuzzy rules. The designed fuzzy-based thresholding method combines the mentioned three different thresholds in order to provide the appropriate threshold which will be utilized to segment the object from the background. Finally, the segmented frame is applied to a Kalman filter to predict the next path when the object moves. To evaluate the effectiveness of the proposed method, we compared the obtained position of the object based on the proposed method with the results of the gravity center method and also their real positions. The experimental results show that the proposed approach can improve the tracking stabilization when objects go across complex backgrounds.**

***Index Terms*—Visual object tracking, segmentation, fuzzy, kalman filter.**

I. Introduction

Using analysis of objects in pictures, we can find information such as distance between the object and the camera, speed of the object, structure of moving object, and movement of the camera. Therefore, studying a movement has a fundamental role in the comprehension of a picture. So far, many studies have been done to find the best methods of object detection. Major weakness in most of these studies is that there is a need to have object-dependent information. For example, having knowledge about the size, shape, color or number of objects in the scene is necessary for the detection of object or objects in the scene. Therefore, providing an appropriate approach which is effective and efficient even when we have no information about the object and background, is one of the challenging problems in this field. In the past decade, extensive studies on moving objects and modeling track have been conducted in which object's view has been introduced as the foundation for the object's tracking [1]. In [2], Verges and Aranda, proposed a method to track moving objects based on adaptive color histogram and Kalman filter. In this method, object properties such as object size and its color are used for modeling the object. Although, this method is efficient, but it encounter a problem when we have no knowledge about the size and color of the object.

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In this paper, we present a method to detect and track an object in an unknown environment, using information from a frame of a camera at any time with the intensity of non-uniform lighting environment. For this purpose, using three histogram-based methods, i.e. mode method, iterative thresholding and double thresholding, three threshold values for segmentation of object in a frame of image is calculated. Then, a fuzzy system with "if-then" rules provides the optimal threshold value to segment and detect the object. Finally, a Kalman filter will predict the next object path when the object moves. The experimental results show that the proposed approach can improve the tracking stabilization when objects go across complex backgrounds.

In the following, Section II presents the proposed fuzzy-based object tracking approach. In Section III, the proposed method is examined under various experimental conditions. Finally, the paper concludes in Section IV.

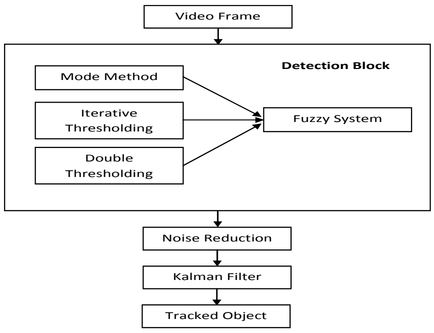

Fig. 1. Flow chart of the proposed object tracking algorithm.

II. The Proposed Fuzzy-Based Object Tracking Approach

The overall flowchart of the proposed object tracking algorithm is illustrated in Fig. 1 There are three main steps in the proposed algorithm: (1) object segmentation and detection block, (2) noise reduction and (3) object tracking using Kalman filter.

In this algorithm, knowledge of three different thresholding methods (i.e. mode method, iterative thresholding and double thresholding) is used to create "if-then" fuzzy rules. The designed fuzzy-based thresholding method combines the mentioned three different thresholds in order to provide the proper and optimal threshold which will be utilized to segment the object from the background. Finally, the segmented frame is applied to a Kalman filter to predict the next path when the object moves. The following subsections will describe the algorithm in detail.

A. Object Detection

Object representation is the cornerstone of tracking [1]. Thresholding techniques are image segmentations based on image-space regions. The fundamental principle of thresholding techniques is based on the characteristics of the image. It chooses proper thresholds to divide image pixels into several classes and separate the objects from the background [3]. For this purpose, in this paper, three different methods, i.e. mode method, iterative thresholding and double thresholding are used. The mode method is suitable for images with similar objects and similar light intensity field. The iterative thresholding is proper for non-uniform lighting and double thresholding is suitable for non-uniform object color [4]. Knowledge of these three different thresholding methods is used to create "if-then" fuzzy rules.

B. Fuzzy-Based Thresholding

TABLE I: OUTPUT T WITH INPUT T1=VS.

T1=VS	T3=VL	T3=L	T3=M	T3=S	T3=VS
T2=VS	VS	VS	VS	VS	VS
T2=S	S	S	S	S	VS
T2=M	L	M	M	S	VS
T2=L	L	L	M	S	VS
T2=VL	VL	L	M	S	VS

TABLE II: OUTPUT T WITH INPUT T1=S.

T1=S	T3=VL	T3=L	T3=M	T3=S	T3=VS
T2=VS	L	M	S	S	VS
T2=S	L	M	S	S	S
T2=M	L	M	M	S	S
T2=L	VL	L	M	S	S
T2=VL	VL	L	M	S	S

TABLE III: OUTPUT T WITH INPUT T1=M.

T1=M	T3=VL	T3=L	T3=M	T3=S	T3=VS
T2=VS	L	M	S	S	VS
T2=S	L	L	M	S	S
T2=M	L	L	M	S	S
T2=L	L	L	M	S	S
T2=VL	VL	L	M	M	S

TABLE IV: OUTPUT T WITH INPUT T1=L.

T1=L	T3=VL	T3=L	T3=M	T3=S	T3=VS
T2=VS	L	L	M	S	VS
T2=S	L	L	M	S	S
T2=M	L	L	M	M	S
T2=L	VL	L	M	S	S
T2=VL	VL	VL	L	M	M

TABLE VI: OUTPUT T WITH INPUT T1=VL.

T1=VL	T3=VL	T3=L	T3=M	T3=S	T3=VS
T2=VS	VL	L	M	S	VS
T2=S	VL	L	M	S	S
T2=M	VL	L	L	M	M
T2=L	VL	VL	L	M	M
T2=VL	VL	VL	L	L	L

Fuzzy systems, knowledge-based designer and fuzzy rules are governing their design. In other words, we can design a fuzzy system by its basic knowledge and the expectation of inputs and output, regardless of the model system [5]. In this paper, three threshold values calculated from three mentioned methods are applied to a fuzzy system as inputs. Three input threshold values and output with five similar functions, as VS (Very Small), S (Small), M (Medium), L (Large) and VL (Very Large) are defined. So, the number of fuzzy rules for the designed fuzzy system is 125. In Tables I to VI, output functions, T, by applying designed rules for the three inputs T3, T2, T1 with 5 functions is presented.

C. Noise Reduction

Images acquired through modern sensors may be contaminated by a variety of noise sources. In this stage, for eliminate noise, the closing operation (dilation then erosion) is used that can fill small holes and gaps. This operation generates a certain amount of smoothing on an object's contour [6]. Then, obtained areas compared with the area which has 10 pixels using the following simple rule:

- If object area smaller than 10 then the object is noise.

Finally we consider the largest region as a target object. Fig. 2 shows the segmented object with four different methods. As Fig. 2 indicates, the obtained result using fuzzy system is better than the others.

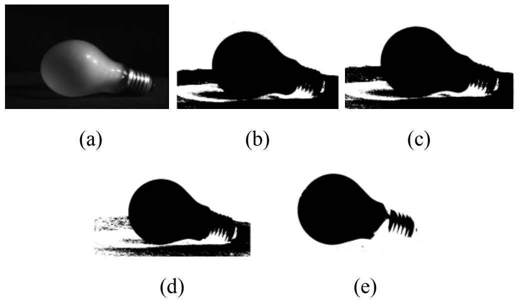

Fig. 2. Original image and its segmented versions. (a): original image, (b): segmented version using mode method, (c): segmented version using iterative thresholding, (d): segmented version using double thresholding, (e): segmented version using fuzzy thresholding and noise reduction.

D. Kalman Filter

Kalman filter has been successfully used in different prediction applications or state determination of a system such as object tracking [7]. Kalman filter is a recursive estimator which has two distinct phases: predict and update. The predict phase uses the estimate from the previous time step to produce an estimate of the current state. In the update phase, measurement information from the current time step is used to refine this prediction to arrive at a new, more accurate estimate [8].

III. EXPERIMENTAL RESULTS

The proposed algorithm was tested on a recording film and then synchronized with the time (real-time), by video camera connected to a computer. To evaluate the effectiveness of the proposed method, we compared the obtained position of objects based on the proposed method with the results of gravity center method and also their real positions. Figures 3 shows some sample frames and the tracked object obtained using the proposed method and the gravity center method. It should be mentioned that the green circle is the tracked object based on the gravity center method and the red circle is the tracked object based on the proposed method. As Figure 3 indicates, the proposed algorithm has obtained better results in comparison with the gravity center method. Tables VII and VIII also show the obtained position of the tracked object using the gravity center and the proposed methods in comparison with the real position of the object. It can be observed from these tables that the obtained position of the proposed method is more accurate than that of the gravity center method.

Fig. 3. Object tracking using the proposed method and the gravity center algorithm. The green circle is the tracked object based on the gravity center method and red circle is the tracked object based on the proposed method.

TABLE VII: COMPARISON RESULTS FOR PERSON MOBILITY.

Frame Number	Gravity Center (Cx, Cy)	The Proposed Method (Cx, Cy)	Real Position (Cx, Cy)
24	83.7232 52.7313	84.1648 60.0927	80 61
34	64.0879 45.8286	73.0983 52.8413	72 52
44	81.3338 52.2621	78.7532 57.0706	76 59
54	79.8916 54.6621	78.8362 61.9391	79 62
64	79.5059 53.9343	79.7505 61.4721	79 61
74	83.8932 57.2664	90.3778 66.8594	88 66

TABLE VIII: COMPARISON RESULTS FOR MACHINE MOBILITY.

Frame Number	Gravity Center (Cx, Cy)	The Proposed Method (Cx, Cy)	Real Position (Cx, Cy)
15	199.88 69.75	225.20 79.54	210 73
18	194.25 167.75	197.19 75.02	198 72
21	188.26 67.02	186.49 57.0706	187 76
24	18618 65.92	183.98 73.75	181 71
27	187.3 65.94	186.18 73.40	198 73
30	193.68 60.72	184.84 72.81	182 70

IV. CONCLUSION

This In this paper, we have presented a novel approach to track the objects in complex backgrounds. In the proposed algorithm, knowledge of three different thresholding methods is used to create "if-then" fuzzy rules. The designed fuzzy-based thresholding method combines the mentioned three different thresholds in order to provide the appropriate threshold which will be utilized to segment the object from the background. Finally, the segmented frame is applied to a Kalman filter to predict the next path when the object moves. It is a very encouraging finding that the proposed approach outperformed the gravity center method. Performance evaluation also indicates that the proposed algorithm can improve the tracking stabilization when objects go across complex backgrounds.

V. CONCLUSION

This study indicated that the neural network's training time is reduced significantly by combining an adaptive fuzzy control system with a neural network in order to adaptively vary the learning parameters and reduces the training time in real-time applications. The method proposed in this paper takes advantages of the concept of the adaptive fuzzy controller systems to tune the learning parameters and reduce the training time by 30% in trajectory generation tasks for soccer robots and it yields 92% accuracy. In addition, this technique can reduce the possibility of overshooting and sometimes help the network get out of a local minimum .The network's ability to converge during training and the final performance are dependent on the learning parameters. Our study reinforces this fact, as our simulations have presented that a "wrong" value of learning rate can lead to poor accuracy. Furthermore, the methodology is flexible, and can be exercised on other neural network applications.

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