The Thirteenth International Symposium on Artificial Life and Robotics 2008(AROB 13th '08),
B-Con Plaza, Beppu, Oita, Japan, January 31-February 2, 2008

Object Tracking for Mobile Robot based on Intelligent Method

Min-Jung Lee	Tea-Seok Jin	Jin-Hyun Park	Gi-Hyun Hwang
RIC	Mechatronics Eng.	Mechatrnoics Eng.	Computer Eng.
Dongseo Univ.	Dongseo Univ.	Jinju National Univ.	Dongseo University
Busan, 617-716, Korea	Busan, 617-716, Korea	Jinju, 660-758, Korea	Busan, 617-716, Korea
mnjlee@gdsu.dongseo.ac.kr	jints@dongseo.ac.kr	uabut@jinju.ac.kr	hwanggh@gdsu.dongseo.ac.kr

Abstract

This paper proposed the real-time tracking algorithm in the active camera system, which is based on the intelligent method. To separate the object from background, the similarity of the color is analyzed through the fuzzy inference engine. And after segmentation, the local difference method between the continuous images is used to track the moving object. The experiment is performed using the developed embedded camera system with an ARM processor.

keywords: Color Image Segmentation, Fuzzy Method, ARM Processor

1 Introduction

These days, many researchers have studied about an intelligent robot. The robot is composed of three parts such as manipulation, navigation and human-robot-interaction (HRI). Most of navigation algorithms for robots, including mobile robot and humanoid, have generally performed by sonar, infrared and vision sensor.

In order to embody navigation algorithms, researchers are interested to treat in object detection and tracking based on the image information from CCD camera [1].

To pursue the tracking of a moving object, the image segmentation among image processing stages is basic and important. Usually, the segmentation is the process of dividing the image into signification regions. The good performance of the segmentation can pass to the image recognition field of rather high level [2-5].

The image segmentation can be divided into two kinds of method. The first method is to separate a movement of the object from background and track the object. The second is that the tracking algorithm is fulfilled after the object separates from background based on the object detection. The key point of the first method is how to find movement information of the object. There are several algorithms [6,7]. For example, using the difference between two continuous images is very simple method. Another method is an optical flow which is a technique used to describe image motion. It is usually applied to a series of images that have a small time step between them, for example, video frames. The optical flow is calculates a velocity for points within the images, and provides an estimation of where points could be in the next image sequence. Those algorithms have the good point that can track the moving object, regardless of the size and the shape of objects. But the uncertainty of the tracking target makes it difficult to track a specific object among some moving objects. Especially, those algorithms should need some compensation algorithms in the active camera system, which it spends lots of time to track the object.

But since in an active camera system the background movement always exists, the difference method cannot be applied. To compensate the above problem, Don Murray and Anup Basu have proposed the tracking algorithm using a geometrical structure of camera, a morphological filtering and edge information of the image [8]. The main idea of their algorithm is how to raise the rate and the speed of recognition.

To embody the above methods, lots of memories and the fast microprocessors are needed. Therefore, most of tracking algorithms are fulfilled in the computer system in stead of embedded system. But, because main controller of the developed robot is composed of embedded system, the above algorithm is difficult to be applied to the robot system.

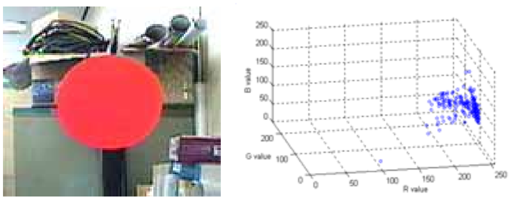
This paper proposed the real-time tracking algorithm in the active camera system, which is based on the intelligent method. To separate the object from background, the similarity of the color is analyzed through the fuzzy inference engine. And after segmentation, the local difference method between the continuous images is used to track the moving object. The experiment is performed using the developed embedded camera system with an ARM processor.

2 Color Space

The development of the hardware has been made it easy to process binary or gray images as well as color images. Color images have more information than the black-and-white images, and have been used in the lots of field such as cellular phone, digital TV and game. It is possible to reduce a time for image recognition because the color information of objects can easily separate the concern object from the complicated background.

We can make some color by mixing the three primary colors properly, and the color model can be represented as three axes which is three primary colors. Many color spaces may be used in image processing: RGB, YIQ, HIS, HSV, etc. This paper used the HIS and RGB model.

Fig. 1 shows the RGB distribution of object color.



(a) (b)

Fig. 1. RGB distribution of object color: (a)Object, (b) Distribution.

In Fig. 1, the color distribution of the concern object shows nonlinear feature. But the color is spread of the center part of object, and the color of the edge parts can be easily affected by the background color.

3 Segmentation

This paper fulfilled segmentation using the fuzzy inference engine. To do segmentation, this paper assumed that there is no unexpected change of illumination.

We extracted the concern object through two step process with real-time method.

Fig. 1 shows that the color is spread of the center part of object, and the color of the edge parts can be easily affected by the background color.

To extract the object from background, this paper normalized the value of RGB data using eq. (1).

$$\begin{bmatrix} nr \\ ng \\ nb \end{bmatrix} = \frac{1}{255} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

This paper set the seed value which is calculated by averaging the normalized RGB data of concern object.

Fig. 2 shows the block diagram for the proposed fuzzy inference engine.

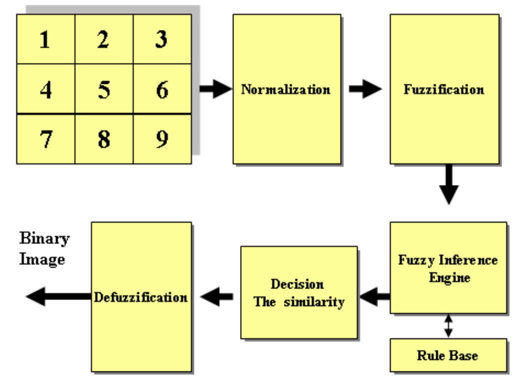


Fig. 2. Block diagram for the fuzzy inference engine.

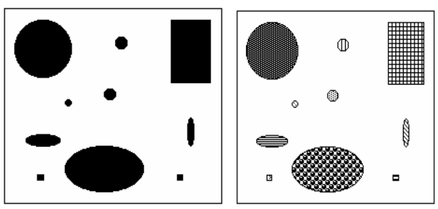
In order to search the object candidate, we used 9 pixels (3X3 pixel on image) as inputs of the fuzzy inference engine. The fuzzy inference engine used in this paper is different from the general inference engine. In this paper, we add the decision part to the inference engine in order to send the binary image as the output of the fuzzy inference engine. Therefore, the computation time is reduced.

4 Labeling

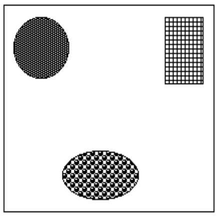
Color images include candidate regions with similarity color. Therefore, the label algorithm is used to search the concern object region. Through the label algorithm, each region with similarity color is classified.

The algorithm finds the region gathering vicinity pixels in the binary image. And the found regions were labeled. This algorithm can remove the noise.

Fig. 3 shows the concept of label algorithm. Fig. 3-(a) shows the binary image and after label algorithm, the labeled image is shown in fig. 3-(b). We can get the noise filtered image (fig. 3-(c)) through the process of size filtering.



(a) (b)



(c)

Fig. 3. Labeling : (a)binary Image, (b)labeled Image, (c)Noise filtered Image.

In this paper, the fuzzy inference engine converts the color image to the binary image based on fuzzy segmentation. The converted binary image is labeled by the label algorithm. Finally, though the process of size filtering, the labeled regions are compared with the size of the concern object. And the regions less or more than the size of object are removed.

5 Tracking Object

To track some moving objects is to separate objects from background. The tracking method can be divided into two methods. One of methods is to separate the motion of objects from background. Another is to track objects based on the continuous object recognition.

This paper used the other that after recognition of the object color and of the object shape, some moving objects are tracked with on-line method. In order to track with on-line method, this paper used two steps. The first step is to search the object candidate in the global region. If a concern object found among some objects, the proposed algorithm search the concern object in the local region defined by a programmer.

After the concern object is recognized, the algorithm is to define he center of the object and to search the object in local region.

Fig. 4 shows the global and local search.

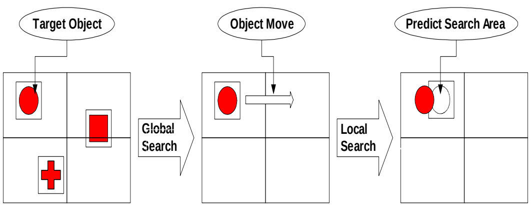


Fig. 4. Global and local search.

To calculate the averaging value of objects from the normalized RGB data, eq (2) and (3) is used in order to assign search region.

$$x_c = \frac{1}{A}\sum_{(i,j)\in R} i, \quad y_c = \frac{1}{A}\sum_{(i,j)\in R} j \qquad (2)$$

$$r = \sqrt{\frac{Area}{\pi}}, \quad Search\ Area = \left(2\times\left(r+5\right)\right)^2 \qquad (3)$$

Where R is region, A is the total pixel number of the region, x_c and y_c is the center of the region.

6 Experiment

6. 1 Camera System

To develop an active camera system, we used the ARM processor and the SAA7111AH video encoding chip. Fig. 5 shows the block diagram for the active camera system. In Fig. 5, to encoding the NTSC signal from the CCD camera, the saa7111ah coverts an analog NTSC signal to a digital signal. ARM board (EZ-X5, www.falinux.com) built in the PXA255 chip is used in order to fulfill the proposed algorithm.

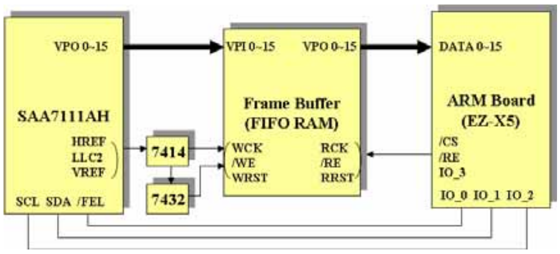
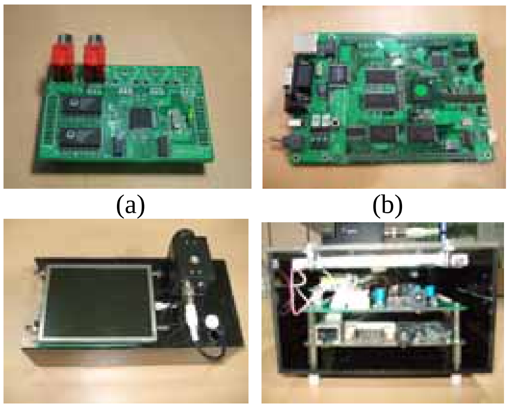


Fig. 5. Block Diagram for camera system based on ARM processor.

Fig. 6 shows the developed active camera system.



(a) (b) (c) (d)

Fig. 6. Camera system based on ARM processor: (a) Camera Encoding Board, (b) ARM board, (c) and (d) Camera system.

6. 2 Experimental Results

We have done experiment with the three types of shapes such as circle, rectangle and cross.

Fig. 7 shows the extracted result with off-line method. Because we have performed the experiment about the same color, the seed value of the circle is used in order to extract three candidate regions from background.

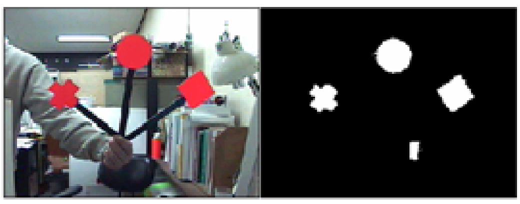
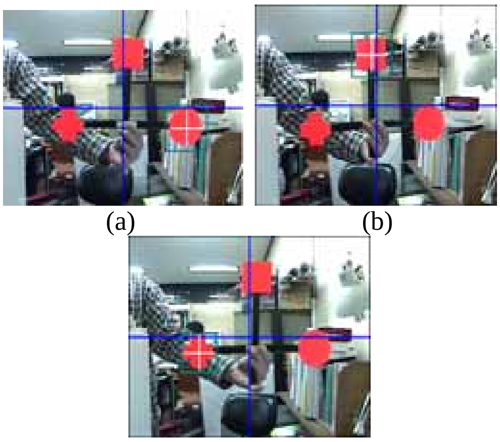


Fig. 7. Extracted image of object candidate

Fig. 8 shows the extracted images of object candidate with on-line method using the developed camera system. Fig 8-(a), (b) and (c) shows the experimental results when we select three sorts of object candidates such as a circle, a rectangle and a cross.



(a) (b) (c)

Fig. 8. Extracted image of object candidate with on-line Method.

7 Conclusion

This paper proposed the algorithm for a microprocessor which has a limitation of a memory and computation ability. Usually, image processing algorithms proposed many researchers show the good performance when those algorithms are fulfilled on the computer. But because those algorithms should need lots of computation, the microprocessor applied to robot system can not calculate those algorithms as well as can not perform to control the robot system and to track objects at the same time.

To solve the above problem, this paper used the fuzzy inference engine for extracting object candidate and tracking object. But the computation time for the proposed algorithm was about 300msec. Therefore, the development of the simple algorithm should need.

Acknowledgements

This Research was supported by the Program in the Regional Innovation Center conducted by the Ministry of Commerce Industry and Energy of the Korean Govern.

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