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A Novel Chaotic Vision Modeling for Mobile Robots based on Two Dimensional Chaos Optimization

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Abstract. The image segmentation of a robot binocular stereo vision system is the key issue in imaging processing. In this paper, the method of 2-D maximum entropy threshold image segmentation with chaos optimization algorithm is used to segment the images information collected by a robot vision system, and the algorithm is checked by a real robot binocular stereo vision system. Moreover, for a real environment simulation a new programming interface library for IEEE 1394 video devices on Linux is proposed. The simulation experiments of the proposed method in comparison to the best previous research are shown better efficiency in using space information of an image and shortening the calculation time.

Keywords: Robot Vision Simulation, Chaos Optimization, Artificial Vision, Chaotic Vision Modeling.

1. Introduction

Visual systems have been discussed from various points of view [1]. Furthermore, various types of intelligent methods [2] have been applied for image processing in real world applications thanks to the development of cheap and small digital cameras and signal processing boards with low energy consumption.

The image segmentation is a key step between image processing and image analysis, and it plays an important role in the research of a robot vision system. Many types of image segmentation techniques have been proposed in the literature. They can be grouped into three main categories corresponding to three different definitions of regions: the methods in the first group, called pixel based segmentation methods, define a region as a set of pixels satisfying a class membership function. In this category are included the histogram based techniques [3] and the segmentation by clustering algorithms [4]. The methods in the second group, corresponding to the area based segmentation techniques, consider a region like a set of connected pixels satisfying a uniformity condition. The growing region techniques [5] and the split and merge algorithms [6] are two examples of this group. The last type of segmentation methods corresponds to the edge based algorithms, where a region is defined as a set of pixels bounded by a color contour [7].

In our research, in order to solve the problems of time-consuming, trapping into local optimal and other issues brought by the various methods that mentioned above, we using chaos characteristic of randomness, ergodicity and sensitivity to the initial value, propose the method of two-dimensional maximum entropy threshold image segmentation with Tsallis entropy and chaos optimization algorithm. The choice of these chaotic Systems with local interconnections is motivated by their well-established implement ability in real environment and high speed operation. In fact, due to the local features of proposed chaos image segmentation techniques, our proposed approach being suitable encoding procedures already been adopted to map original images into binary segmented ones.

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In this paper, the the proposed method is mentioned in section II. In Section III the hardware platform and small application are described. The ability of the proposed architecture to detect and recognize scaled and translated image is investigated and discussed on suitable test situations was mentioned in the last section.

2. Proposed Method

2.1. Tsallis Entropy

Let $f(m, n)$ be the gray value of the pixel located at the point (m, n). In a digital image $\{f(m, n)|m \in\{1, 2,\ldots, M\}, n \in\{1,2,\ldots,N\}\}$ of size $M\times N$, let the histogram be $h(x)$ for $x\in\{0,1,2,\ldots,255\}$. For convenience, we denote the set of all gray levels $\{0, 1,2,\ldots,255\}$ as G. Global threshold selection methods usually use the gray level histogram of the image. The optimal threshold is determined by optimizing a suitable criterion function obtained from the gray level distribution of the image and some other features of the image.

The pixel's gray value, $f(x, y)$, and the average of its neighbourhood, $g(x, y)$, are used to construct a two-dimensional histogram using:

$$h(i, j) = prob\,(f(x, y) = i\ and\ g(x, y) = j) \tag{1}$$

where $i, j\in G$, for a given image, there are several methods to estimate this density function. One of the most frequently used methods [5] is the method of relative frequency. The normalized histogram is approximated by (1).

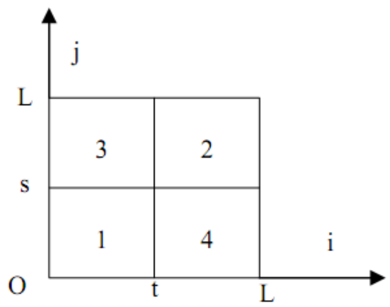

Fig. 1: A two dimensional histogram plane with 4 regions.

Our normalization is accomplished by using a posteriori class probabilities, $p_1(t,s)$ and $p_2(t,s)$ hence we further approximate $p_2(t,s) \approx 1 - p_1(t,s)$. Thus the Tsallis entropies associated with object and background distributions are given by:

$$\begin{aligned} H_b^{\alpha}(t,s) &= \frac{1}{\alpha-1}[1-\sum_{i=0}^{t}\sum_{j=0}^{s}\left(\frac{p(i,j)}{p_l(t,s)}\right)^{\alpha}] \\ H_w^{\alpha}(t,s) &= \frac{1}{\alpha-1}[1-\sum_{i=t+1}^{255}\sum_{j=s+1}^{255}\left(\frac{p(i,j)}{1-p_l(t,s)}\right)^{\alpha}] \end{aligned} \tag{2}$$

$$p_l(t,s) = \sum_{i=0}^{t}\sum_{j=0}^{s} p(i,j) \tag{3}$$

Where, if we consider that a physical system can be decomposed into two statistical independent subsystems A and B, the probability of the composite system is $p^{A+B} = p^A p^B$, then the Tsallis entropy of the system follows the non-additive rule as a criterion function.

$$\phi_{\alpha}(t,s) = H_b^{\alpha}(t,s) + H_w^{\alpha}(t,s) + (1-\alpha)H_b^{\alpha}(t,s)H_w^{\alpha}(t,s) \tag{4}$$

We obtain our optimal threshold pair $(t^*(\alpha), s^*(\alpha))$ by maximizing the above criterion function $\phi_{\alpha}(t,s)$.

3. Hardware Implementation

3.1.Programming Interface

In this section we proposed the real implementation of proposed algorithm. Using this system, we are able to develop an image processing system easily with a high performance and inexpensive PC. As development environments on the Linux operation system (OS) have high flexibility, it is utilized well in research fields of a robot vision.

We made a sample program to evaluate a performance of the API. Fig. 2 shows a screen shot of the sample program. The display has a resolution of 1024×768 pixels. Each image captured from two cameras has a resolution of 720×480 pixels.

Performance

Fig. 3 shows motion sequences and running times of each thread in the sample program with one camera. A total running time of each thread is less than the video rate of 1/30 *sec*, all threads work well.

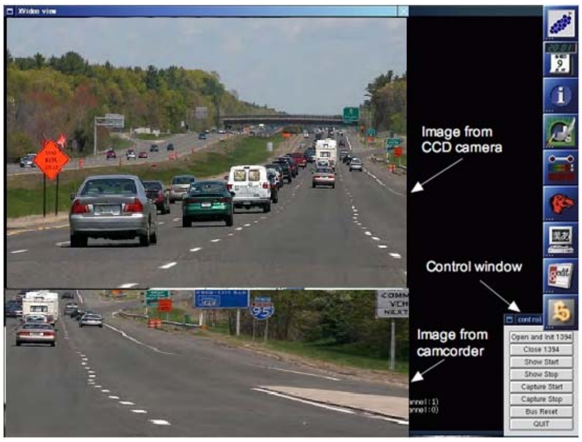

Fig. 2: Screen shot of proposed program.

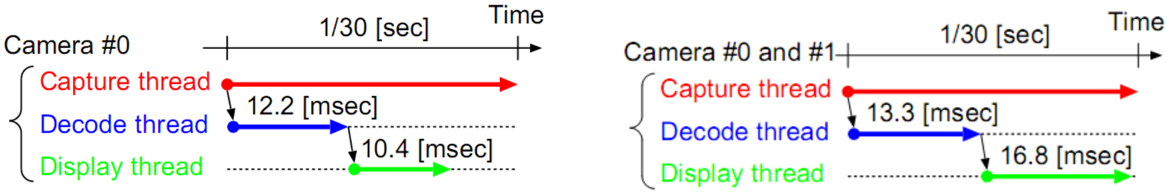

Fig. 3: (Left) Running time of each thread with one camera, (Right) Running time of each thread with two cameras.

The results, in which two cameras were used as shown in Fig. 2, are shown in the right of Fig. 3. Although total running time of decoding and displaying thread was barely less than the video rate, the image displaying was not smooth on the display. We believe that a set of threads are not completed within 1/30 *sec*.

4. Simulation Result

4.1.Laboratory Equipment

In this study, two video camera sensors are used to be the main component of the robot vision system, and the two sensors have the same properties of the CCD array. The camera was made by Logitech Company, and its area array CCD size is 1/3. The image processing system in the robot system controlling software is made up of an image acquisition system, an image processing based on proposed chaos based image segmentation system and an image output system. In the beginning of the experiment, adjust the focus to make the images clear. Then take images of grasping block within the visual range of the robot. This equipment was shown in Fig. 4.

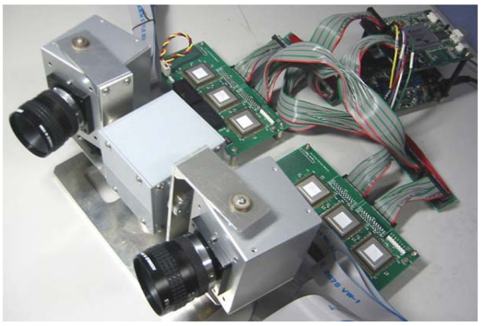

Fig. 4: Our robots with two camera.

First, the source image of block in the visual range of the robot is shown in Fig. 5. Because the binarization image segmentation uses image gray value histogram, therefore, the source map shown in Fig. 5 was pretreated, then change the image segmentation threshold artificially to adjust the image effect. When the threshold is selected as 79, the image processing system obtained the optimal source map segmentation effect, as shown in Fig. 6. Then we used the methods and procedures of two-dimensional maximum entropy based on chaos to conduct image segmentation. The segmentation result shown in Fig. 7.

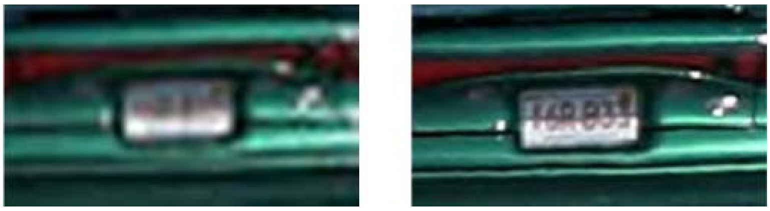

Fig. 5: Source map (respectively, left and right camera view).

Fig. 6: The binary segmentation map.

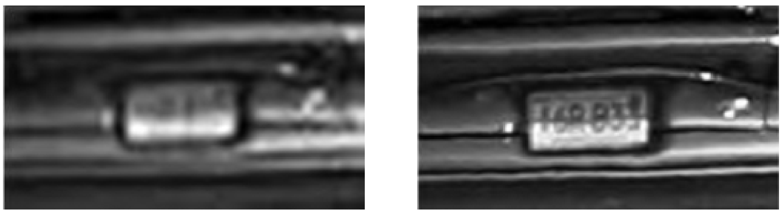

Fig. 7: The segmentation map of two-dimensional maximum entropy based on chaos.

We still used Fig. 7 as the source map, the genetic algorithm [6] and PSO [9] were respectively used to optimize the maximum entropy threshold function.

The experiment result shows, maximum entropy image segmentation method with chaotic algorithm could make the inner area of an image uniformed and can let the boundary shape of image accuracy. Various types of segmentation algorithm optimization results were shown in Table 1. From the data of Table 1 we can see compared with the genetic algorithm, the method of two-dimensional maximum entropy image segmentation with chaos optimization algorithm uses location velocity model dynamic tracking and updates the individual extreme and the global extreme. Therefore, only a few times' iteration will be able to search the optimal threshold vector and compared with PSO [1], the proposed method has good reliability, hardly to fall into local optimum, and good convergence characteristics.

Table 1: Optimization results

Algorithm / Parameter	Chaos Based Algorithm		PSO		GA	
	Left View	Right View	Left View	Right View	Left View	Right View
Optimal threshold	7675	4956	57104	8182	115123	9383
Optimal threshold value	11.5735	11.0608	10.0853	10.2963	13.157	10.045
Iterations	2	3	11	11	maximum iterations Is 100	maximum iterations Is 100

5. Conclusion

This article demonstrates the advantages of the novel proposed method in practice and improved the image segmentation of mobile robot, after study the method of two-dimensional maximum entropy image segmentation with chaotic optimization algorithm, and compared with other algorithms.

In addition, we proposed a novel API for a robot vision system with multiple IEEE 1394 vision devices on the Linux OS. The multi-threaded API provides a simple and flexible develop environment. The performance of the API was confirmed by a sample program. The results show that the method of two-dimensional maximum entropy image segmentation based on chaotic optimization algorithm uses the spatial information more effectively. The method also improves the efficiency of image segmentation. After optimizing an image, it is easier computer for a computer to study, process and recognize the characteristics of an image. This paper also laid a good foundation for the study of posture control and work piece recognition of robot with a vision sensor.

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