A Mobile Robot Recognize Blurred Targets via an Improved Histogram Equalization

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Abstract. Target recognition is a precondition for guiding robots to complete tasks. However, if the target is blurred, recognition will be difficult, which will lead to an inefficiency operation for robots. For the sake of improving the robot operation efficiency, it is essential to improve the image quality of recognized blurred target. Since image enhancement is taken as a powerful ways for improving image quality, it has gained largely attentions from researches. In fact, most of enhance methods are proposed based on histogram equalization, and until present, focus of research is still on improvements of histogram equalization. Hence, this paper proposes an improved histogram equalization for blurred targets in mobile robot recognition. Compared with the traditional histogram equalization methods, our method has less calculation time and better performance of real-time. Furthermore, the proposed approach also has strong robustness in blurred target recognition via a mobile robot.

1. Introduction
Target recognition is always a popular topic in computer vision, which purpose is to find the correct location of the object. Thus, target recognition could be applied in robot vision to assist robots to finish specific missions. However, in practical applications, robots usually have to operations on blurred target. But, recognize blurred object is difficult for robots, thereby leading to an inefficiency operations of robots. Accordingly, in order to solve this problem, it is necessary to improve the image quality of blurred target.
As a useful ways for improving the image quality, image enhancement has attracted concerns from researches. Over past few years, numbers of enhance methods have been studied. For instance, Tarik Arici et al. proposed a general framework based on histogram equalization for image contrast enhancement [1]. Research of Wu et al. was via enhance contrast and suppress background to achieve intensify the image [2]. You put forward an enhancement method on the basis of logarithmic mapping to enhance contrast [3]. In the case of poor illumination, Bhattacharya et al. researched on an localized image enhancement method, which was via using singular value decomposition to increase local contrast for given color images [4]. Hossain et al. proposed a novel contrast enhancement approach in medical image processing, for detecting cartilage shape change of the knee joint [5]. The authors of literature [6] presented a histogram normalization enhancement method in gradient field for infrared images to identify and tracking target. Kheirkah et al. via studied histogram-based threshold to improve the image quality of medical video image [7]. Wang et al. came up with an enhancement approach named content-adaptive histogram equalization, which was via using contrast-adaptive
contrast improvement and contrast-dependent saturation adjustment to improve intensity contrast for outdoor images [8].

Apparently, among these recent years of approaches, mostly are innovations based on histogram equalization, which indicates that improvements of histogram equalization is still a focus of research on image enhancement. Hence, an improved histogram equalization approach is proposed in this paper, which is used for blurred target recognition via a mobile robot.

The overall paper is organized as follows. Section 2 briefly overview the theoretical of histogram equalization to provide a research fundamental and motivation for our method. Afterwards, Section 3 describe the proposed method. In Section 4, experiments are performed and results are exhibited. Lastly, in Section 5, the paper is summarized and future work is discussed.

2. Overview of histogram equalization

In fact, principle of histogram equalization is relative simple, and largely novel ideas are based on it. Thus, this work proposes an improved histogram equalization for blurred targets in mobile robot recognition. In this part, histogram equalization will be overviewed.

Define original image as $I$, the grayscale of $I$ is $L$, $I(i, j)$ represents the gray value at a coordinate position $(i, j)$, and $I(i, j) \in [0, L-1]$, $i=I(i, j)$.

Then, the probability density function of grayscale in $I$ could be expressed as,

$$\xi(k) = \frac{x_k}{X} \quad (k = 0, 1, \ldots, L-1)$$

(1)

Where, $X$ is the total number of pixels, and $x_k$ is the number of pixels with grayscale $k$.

Consequently, the cumulative distribution function of grey level in $I$ is defined as,

$$l(k) = \sum_{i=0}^{k} \xi(i) \quad (k = 0, 1, \ldots, L-1)$$

(2)

Principle of histogram equalization is via cumulative distribution function to maps the original image into an enhanced image, with approximate uniform gray level distribution. Thus, the corresponding mapping relation could be described as follows,

$$f(k) = (L-1) \times l(k)$$

(3)

Through above calculation, original image $I$ is enhanced due to merging the gray level. Nonetheless, the brightness of enhanced image is uneven, and some details in image are easy to loss. Thus, quite a few improvement researches based on histogram equalization is proposed. However, among these studies, five most representative research results have been widely accepted, which have been achieved successful to some extent from different aspects [9-13]. But in practical applications, compared with tradition histogram equalization, their real-time is insufficient. Thus, to solve this problem, this paper proposes an improved histogram equalization, which is used for blurred targets in mobile robot recognition.

3. Improved histogram equalization

This work is to deal with blurred targets recognition in practical applications, which means real-time is significant. Thus, our idea is the proposed algorithm could real-time enhance the image, meanwhile has relative flexibility performance. That is, we will attempt to use flexible local region to replace the global image.

3.1. Local region

In this work, entire image is replaced via local region in recognized blurred target, to achieve real-time enhance image, and finally improve the efficiency of recognition. When select a local region, we first need to convert the entire image into a gray image and display it. Afterwards, local region with suitable location and size is selected out according to the actual application needs. Next, image of
selected target area is displayed, which is enhanced region. Especially noteworthy, original image always unchanged during this process.

3.2. Enhance for local region
In our approach, we first define a local region with a variable position and size to acquire enhanced image, which aims at acquiring flexible local region to achieve enhancement with different requirements in applications. Afterwards, intensify this image via histogram equalization. Lastly, replace the original image corresponds to the local region with enhanced image to form a new partially enhanced image.
Especially, in new enhanced image, only the region of local selected is enhanced, and the other regions remain the same as the original.

4. Experiments

4.1. Design of experiment
In order to confirm the proposed algorithm is effective, procedure of experiment is designed as shown in figure 1.

4.2. Experimental results
The proposed algorithm is focus on the need for blurred target recognition via a mobile robot. Thus, a blurred image captured via the mobile visual system is shown in figure 2.
Since our method is based on histogram equalization, then in our experiments, comparison will be performed between histogram equalization and our approach.
4.2.1. Visual effect. In fact, the proposed method is a local enhancement method. Hence, in our implement, region of our approach is randomly selected. The visual effect of enhancement as show in figure 3.

![Figure 2. Original Blurred Image](image)

(a) Histogram Equalization  
(b) Proposed Method

![Figure 3. Visual Effect of Enhancement](image)

Obviously from figure 3, the proposed method is superiority to histogram equalization in visual effect of enhancement, which states that our method is effective and useful.

4.2.2. Real-time. In this experiment, each algorithm was tested five times with the same computation device. The computation time of each algorithm is shown in table 1.

| Times | Histogram Equalization | Proposed Method |
|-------|------------------------|-----------------|
| 1     | 323.425                | 141.450         |
| 2     | 311.590                | 139.536         |
| 3     | 326.614                | 138.589         |
| 4     | 331.503                | 136.637         |
| 5     | 324.433                | 134.562         |

It can be known from table 1 that the proposed method costs less computation time than histogram equalization, which computation time is shortened by nearly 1.5 times, and the real-time performance is better.

5. Conclusion and Discussion
In this paper, an improved histogram equalization method is proposed. The experimental results demonstrate that our approach has less computation time and better real-time performance than traditional histogram equalization. That is, from the aspect of applications, our method is superiority to traditional histogram equalization.
In future, we intend to perfect our work, and add more detail comparisons and analyses among our algorithm and others. Moreover, more evaluate criterions of algorithm are also could be considered and added, to further indicate the advantage of our proposed method.

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