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Regular Target Recognition Based on FAST Feature Point Extraction and Contour Recognition

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ABSTRACT

The research of regular target recognition based on FAST feature point extraction and contour recognition aims to develop an efficient target recognition method. In this method, the key feature points are extracted from images by FAST (Features from Accelerated Segment Test) algorithm, and then the target is identified and located by contour recognition technology. By combining these two technologies, the accurate detection and positioning of the target are realized, and the accuracy and efficiency of the target recognition are improved. In the experiment, this method shows good performance, high recognition accuracy and robustness. This research result provides a new idea and method for the further development of the field of object recognition, and has important theoretical and application value.

KEYWORDS

Computer Graphics; Image Processing; Monocular Camera

1. INTRODUCTION

Under the background of the rapid development of modern technology, the use of monocular visual recognition to guide the motion control of autonomous robots has aroused great interest of researchers and enterprises. With the rapid development of computer vision and image processing, geometric shape recognition[1-2] has become a highly prominent research fieldThe research in this field has profound practical application value and can be widely used in various fields such as industrial automation, intelligent service and automatic driving. Among the many companies at the forefront of technology, Tesla [3] is undoubtedly the most prominent. Tesla is known for its unique multi-camera fast motion control technology, which not only guarantees the flexibility of robot movement, but also effectively manages costs.

Multiple camera setups offer several advantages over monocular cameras. A significant advantage is their ability to capture more depth information in 3D vision, which improves the accuracy of object recognition and positioning. However, although monocular cameras have limitations in depth information acquisition, the cost is significantly lower. For applications that do not require high-precision visual information, monocular cameras offer a more cost-effective solution. Therefore, in practical production and life applications, the motion control system of robot regular object recognition based on monocular vision continues to play a pivotal role.

The aim of regular target recognition based on FAST feature point [4-5] extraction and contour recognition is to develop an efficient and accurate target recognition method to solve the challenge of target detection in complex environments. By combining FAST feature point extraction and contour recognition technology, this research aims to improve the accuracy and robustness of target recognition, and achieve fast and accurate recognition of regular targets. The main purpose of this research is to promote the progress in the field of target recognition, and provide effective technical support for real-time target recognition systems applied in the fields of automatic driving, security monitoring, intelligent robots, etc. Through this research, we hope to provide new ideas and solutions to solve the problem of object recognition in complex scenes in real life, so as to promote the development and application of artificial intelligence technology in practical applications.

2. REGULAR OBJECT RECOGNITION ALGORITHM BASED ON CONTOUR RECOGNITION AND FEATURE POINT EXTRACTION

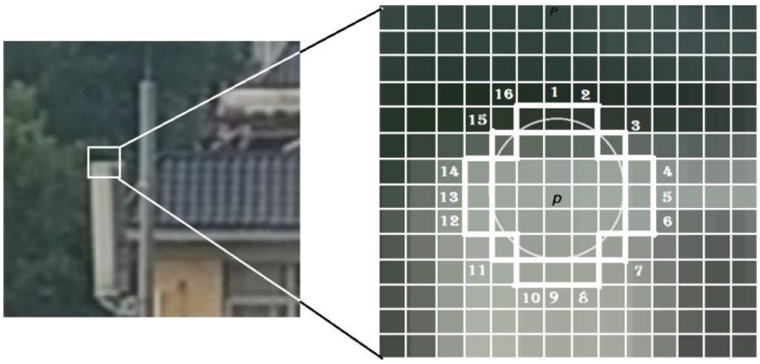
2.1. FAST Algorithm Principles

The FAST feature point recognition algorithm is a feature detection method used in the fields of computer vision and image processing. Its primary objective is to efficiently locate key points within an image, which typically manifest as corners or points with significant pixel intensity variations. FAST algorithm has gained widespread attention due to its rapid execution speed and robustness, making it particularly suitable for real-time applications[6] and large-scale image processing[7].

The acronym "FAST" stands for "Features From Accelerated Segment Test." The fundamental concept of this algorithm revolves around comparing the grayscale values of a pixel with its surrounding neighboring pixels to determine whether it qualifies as a key point. Here's how FAST feature point detection operates[8-9]:

Select a pixel point, denoted as P, within the image and record its grayscale value as Ip. Subsequently, set a predefined threshold value, denoted as t.

Surround pixel P with a circular region comprising 16 pixels, often determined using the Bresenham algorithm. This circular region contains a total of 16 pixels, Schematic diagram of algorithm as are shown in Figure 1:



1**Figure 1.** Schematic diagram of algorithm

Examine the grayscale values of these 16 pixels. If there are n consecutive pixels among them where either all grayscale values are greater than Ip + t or all grayscale values are smaller than Ip - t, then pixel point P is considered a key point. Typically, the value of n can be set to either 12 or 9.

The speed of the FAST algorithm lies in its ability to rapidly eliminate the majority of non-key point pixels. This is achieved by inspecting pixels at only four specific positions, which are located at positions 1, 9, 5, and 13 on the circle. First, positions 1 and 9 are checked, and if they both satisfy the condition (either both greater than Ip + t or both smaller than Ip - t), then positions 5 and 13 are examined. If at least three out of these four positions meet the condition, pixel point P is considered a candidate key point. This efficient initial screening process significantly accelerates key point detection.

Finally, for candidate key points identified through the initial screening, a comprehensive examination is conducted, which involves inspecting all 16 pixels on the circle to confirm whether they meet the criteria for key points. Pixels that satisfy the criteria are ultimately determined as key points.

The efficiency and robustness of the FAST algorithm have made it widely applied in image processing, particularly in scenarios that demand rapid processing of large volumes of image data.

2.2. Image binarization

In a binary image, each pixel displays only black and white, which is generally represented as 0, while white is 255. To convert an image into an image containing only these two colors, the binarization of this image is a process of contrast. In this process, the gray value of each pixel is compared to a pre-set standard value. If the grayscale is less than this condition, it will be reset to 0. In contrast, when the standard value is above, it is set to 255.

There are many kinds of binarization methods, but each has its own limitations. The method of experimental research has certain limitations. The traditional gray-level segmentation algorithm is easy to cause the loss of target pixel or background pixel in the image. According to the ratio between the number of pixels in the same gray image and the image, the algorithm adopts the preset threshold method, which has strong adaptive ability.

OTSU threshold method is a kind of binary processing technology that has been well obtained in the world. The main idea of this method is to find a threshold which can maximize the gray difference between foreground and background and the whole image. The specific steps are as follows:

(1) The proportion of pixels of the same gray level in the whole image set P. Where n is the number of pixels in the entire image block, where N is the number of pixels in the entire image block, and the proportion of each gray level is:

$$P_i = \frac{n_i}{N} \tag{1}$$

(2) Probability calculation of region P and region P. According to the preset KAN value, all the pixels in an image are divided into P and P, P includes the gray dots in [0, y-1], and P includes the gray dots in [Y,L-1]. Then, the probability of regions P and P is:

$$P_0 = \sum_{i=0}^{Y-1} P_i \tag{2}$$

$$P_1 = 1 - P_0 \tag{3}$$

(3) Calculate the average gray level u and u of each region P and P, and the average gray level u of the entire image. Its calculation formula is as follows:

$$u_0 = \frac{1}{p_0} \sum_{i=0}^{Y-1} iP_i \tag{4}$$

$$u_1 = \frac{1}{p_1} \sum_{i=Y}^{L-1} iP_i \tag{5}$$

$$u = P_0 u_0 + P_1 u_1 \tag{6}$$

(4) Use the following expression to calculate the total change Z of the two zones

$$Z = P_0 (u_0 - u)^2 + P_1 (u_1 - u)^2 \tag{7}$$

2.3. Edge extraction

In image processing, boundary extraction is the most critical step in image, especially when the second derivative is zero, it is one of the basic characteristics of image. The key of edge extraction technology is to find a light-dark transition point in the image, so as to determine the turning point of the image. This method is based on object recognition and region shape extraction, and plays a key role in the whole image processing.

The boundaries of objects in an image have two important properties: orientation and grayscale. In the boundary region of the image, the gray level of the image has a smooth transformation, and is parallel to the boundary of the image, and the gray level of the image in the image has also undergone a great change. In the image, the image in the image is composed of the image in the image, and the brightness of the image in the image is determined by the brightness of the image in the image, brightness and other parameters. For a continuous image f (x, y), the directional derivative is greatest along its boundary. Therefore, the boundary detection of the image is to find a local maximum point of f (x, y) gradient in the image, and its corresponding direction.

The following formula represents the gradient along the direction:

$$\frac{\partial f}{\partial r} = \frac{\partial f}{\partial x} \cdot \frac{\partial x}{\partial r} + \frac{\partial f}{\partial y} \cdot \frac{\partial y}{\partial r} = f_x \cos\ \theta + f_y \sin\ \theta \tag{8}$$

2.4. Algorithm combination approach

The algorithmic flow of identifying regular objects can be carried out as follows:

Image preprocessing: First of all, the input image is preprocessed, including gray-scale processing, denoising and image enhancement, so as to improve the effect of subsequent processing.

FAST feature point extraction: Key feature points are extracted from pre-processed images by using FAST (Features from Accelerated Segment Test) algorithm. FAST algorithm can detect corner features in images quickly and effectively, and extract these feature points as the basis for subsequent processing.

Binary image processing: the pre-processed image is binary processed and the image is converted into a black and white binary image. This step can be achieved by methods such as threshold segmentation to better highlight the contour features of the target object.

Edge extraction: The edge extraction process of the binarization image is carried out to obtain the edge information of the target object. Common edge extraction algorithms include Sobel, Canny, etc., which can effectively extract the edge features of target objects.

Contour recognition: The contour recognition algorithm is used to process the image after edge extraction and identify the contours of regular objects in the image. This step can be achieved through methods such as contour detection and fitting, so as to accurately locate and identify the target object.

Target matching and recognition: Finally, by matching with the predefined regular object template, the accurate recognition and classification of the target object is achieved. Feature matching algorithm or template matching algorithm can be used to realize the matching and recognition of target objects.

The whole algorithm process combines FAST feature point extraction, binarization image processing and edge extraction algorithms together, and realizes accurate recognition and positioning of regular objects through image feature extraction and processing.

3. EXPERIMENTS AND RESULTS

The experimental design involves running the algorithm on a hardware platform with an ESP32S3 chip as the image processor and an OV2660 camera. The camera equipped with the algorithm is used to identify geometric shapes such as circles and squares to draw corresponding conclusions. The scenes where circles and squares are recognized during the experimental process are shown in Figure 2 and Figure 3.

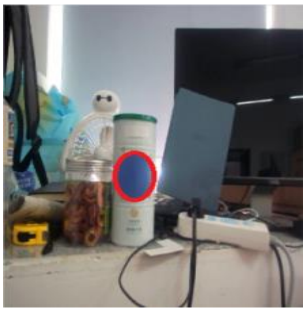


Figure 2: Identify circular figures

Figure 3: Identify square figures

The experimental results are shown in Table 1.

Table 1 Experimental Results Table

Geometry	Total Frames	Successfully Recognized Frames	Recognition Rate	Average frame rate
circular	550	470	85.4%	38
square	450	427	94.8%	49
line segment	600	567	94.5%	57
triangle	400	353	91.2%	42

Through a series of experiments as described above, I obtained corresponding results, providing an opportunity to validate and gain a deeper understanding of the correctness and reliability of the design approach. While the experimental results did not completely align with expectations, a careful analysis and comparison revealed that this was not due to issues with the design approach itself, but rather stemmed from minor errors. Therefore, although the experimental results did not fully meet expectations, they validated the correctness of the design approach and identified areas for improvement. For instance, future improvements could involve integrating deep learning for image recognition. This insight is valuable for optimizing my design approach and enhancing my research capabilities.

4. CONCLUSION

The method has demonstrated high speed and good accuracy in experiments. Therefore, it is evident that our approach can effectively recognize various geometric shapes in images, providing reliable image analysis tools for industries such as industrial automation, robotic vision, and medical image analysis. However, we acknowledge that there is still room for improvement in our method, particularly in scenarios involving rapidly changing and complex shape recognition. Future research will continue to enhance and expand upon this method to meet the evolving demands of various applications.

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