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早稲田大学大学院理工学研究科

博　士　論　文　概　要

論　文　題　目

A Study on Edge Detection and Curve Finding for Image Processing

画像処理におけるエッジ抽出と曲線検出についての研究

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Extracting features (edges, curves, etc) from the images is very important for image analysis and computer vision because the image features are the base for the other processing tasks, such as image segmentation, pattern matching, compression and classification. Many works have been made for the problem of feature extraction over the recent decades. But it has not been settled completely yet up to now. The difficulty concerns mainly following two facts. One is the existence of noises in the images and the incompleteness of the present algorithm, which makes erroneous information be detected. The other is the occlusion due to the projecting of the three dimension real world into the two dimension image data, which makes information fail to be detected.

Recently, a lot of approaches have been proposed to overcome the difficulty described above for obtaining high accurate extraction. Relaxation method for edge detection is one of them. In this method, the initial edge probability and nonedge probability for each point in the image are estimated from the digital gradient of the image, and they are corrected in an iteration process. Because the neighboring and correlative information in the images is used in the iteration process, the effect of noises can be cleared off, and the edge detection performance can be improved. However, these advantages are achieved by the cost of many iterations and a long operating time. And it is difficult to obtain satisfactory detection for different images as well as for different parts with different edge measures in the same image, because a set of fixed weight coefficients are used in the algorithm.

The Hough Transform is an elegant way for extracting global features like parametric curves and two dimensional shapes from the images. The reliable detection can be obtained from incomplete information and noisy images because global information about the image is used in the transform. However, its large computation and memory requirements prevent it from being widely used for the practical computer vision tasks.

This dissertation mainly deals with the solutions to these problems mentioned above. The objectives of the dissertation involve following three aspects.

1). Developing a hierarchical relaxation method for edge detection to improve the detection performance and decrease the computational cost. Extending the method for edge detection in the moving images.

2). Presenting an Inverse Hough Transform method for the accurate detection of curves in the images. It can decrease the storage and computation requirements greatly so that it can be applied to detect the high dimensional curves in the images.

3). Proposing a new approach for the description of two dimensional shapes using the R Transform, then realizing a computer vision system for tool recognition based on the R descriptor.

The dissertation consists of six chapters.

Chapter 1 is concerned with the overview, objectives and outline of the dissertation.

In Chapter 2, the basic principle of the relaxation method, the hierarchical representation of images and their applications to edge detection are discussed at first, then a hierarchical relaxation method for edge detection is proposed. The original relaxation algorithm is improved by introducing a new definition of compatibilities and an adaptive weight coefficient in the relaxation process. The relaxation process starts from a low resolution image to obtain an approximate detection result, which can be refined at the high resolution image by a few iterations. By using multiresolutional information in the hierarchical image, satisfactory detection can be obtained in the all parts of the image, and the convergence speed of relaxation processes can be improved greatly. The experimental results and quantitative analysis showed that a better detection can be obtained with fewer computation by the proposed method than the original one.

Chapter 3 is concerned with the extension of the hierarchical relaxation method for detecting edges in the moving images. The relaxation process is performed on the temporal-spatial pyramid, which is a multi-resolution data structure for the moving images, formed hierarchically not only in the spatial directions but also in the temporal direction. The accurate and high speed edge detection for the moving image can be obtained by using information in the neighboring frames as well as the processed results in the higher layers of the pyramid.

In Chapter 4, a new approach to detect curves using the Inverse Hough Transform is presented. The key idea of this method is to make the voting process on the image space instead of that on the parameter space in the conventional method, then convert the local peak detection problem into a parameter optimization problem. This leads to substantial savings, not only in the storage requirement but also in the amount of calculation required. The experimental results and qualitative analysis showed that in comparison with the conventional Hough Transform methods, the new method has advantages of high speed, small storage, arbitrary parameter range and high parameter resolution. It can be applied to the detection for the arbitrary two dimensional shapes, three dimensional surfaces and high dimensional hypersurfaces.

In Chapter 5, a new shape description method using the R Transform is proposed. R Transform is a much faster transformation than the Fast Fourier Transform (FFT). It has the invariance of cycle-shifting and reflecting, but is not invariant to variations in translation, rotation and size. A normalization procedure is proposed to make the R descriptor be invariant in target shifting, translating, scaling and rotating. A computer vision system for tool recognition based on the R descriptor is also discussed in this chapter. It was shown that the system has the advantages of high speed, high accuracy and high reliability.

Finally, the conclusions obtained from this study are summarized in Chapter 6.