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# Recognition of Basic Planar Objects Using Computational Geometry Methods

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Making computers recognize a planar object exactly is useful for development of factory products. Positioning problem in factory systems using digital images is one of the applications. This problem is to recognize an accurate position of the planar object from an image taken with a digital camera. Planar objects such as crosses and circles are put on parts of products. We recognize the positions of those planar objects on the products. By doing so, we can recognize an accurate position of a product.

Known techniques for recognition of basic planar objects are sub-pixel processing of edge in which luminance gradient of the neighbor boundary is differentiates and the boundary is detected with high precision, and pattern matching such as normalized correlation method, and so on. The sub-pixel processing method can find an edge with the accuracy of 0.1 pixel. Consequently, positioning is possible with the accuracy of 0.1 pixel.

Those techniques take errors arising from CCD cameras into account. But, they do not define a strict model of the errors arising from CCD camera. Consequently, those techniques are not suitable for accurate positioning. It has been requested to establish accurate positioning for application to factory products because there exists scenes where even an extremely small gap is not allowed.

On the other hand, computational geometry-based techniques for detecting accurate shapes of boundaries of images have been studied. For example, Prasad et al[1] detects accurate linear boundaries and accurate crossing points of straight lines. Fleischer[2] applied computational geometry oriented boundary detection to super-resolution.

Thanks to these researches, defining the mathematical model input from CCD cameras properly, we can detect boundaries with a precision finer than pixel width. Applying these techniques, we can recognize basic planar objects, in the same manner.

This paper discusses the positioning problem in factory systems using digital images. we propose a technique which recognizes positions of basic planar objects with accuracy higher than existing techniques. Input is an image taken by a CCD camera which included a basic planar object. We assume this planar object has an 'ideal' shape.

Luminance values of all the pixels in an input image express an accurate shape of the basic planar object on the planar square lattice. Digital images correspond to planar square lattice. There exists a square corresponding to a pixel. Pixels have luminance values. And there values correspond to the area of the planar object in the square.

Our algorithm recognizes two types of objects; crosses and circles. Crosses may be rotated. First, we detect an accurate center point and accurate shape (length of the sides for a cross, and radius for a circle.) of the basic planar object, assuming no quantization error. Next, we extend the algorithm for recognition of a circle to the that of recognition with some quantization error. We establish such a methodology. Generally, luminance values in an input image are given in integers. Therefore, we cannot avoid quantization errors. We just know the luminance values of all pixels including the errors. Consequently, we cannot detect the accurate center point and accurate radius of the circle. Accordingly, we want to get the domain of the possible circle center.

We implemented the recognition algorithm of a circle with quantization errors. We checked the size of area of a domain which must contain the circle center, using this algorithm. The size of the area depends on bit length for quantization. The quantization bit length of digital cameras is often 8-bit or 12-bit. Therefore, we assumed that the inputs are quantized in these granularities. We made experiments, examined the domain included in the center point by all means. As a result, we achieved the accuracy of 0.0054 pixel width when we used 8-bit quantization. And we achieved the accuracy of 0.00036 pixel width when we used 12-bit quantization. As it has been mentioned above, the existing techniques are able to detect the center point of the circle with the accuracy of 0.1 pixel.

However, it must be remarked that outputs of our recognition algorithm with quantization error are circle center and its radius. We assumed that one-pixel is a square of size $1\times1$. The value of the radius in the output value is based on this square of size $1\times1$. Therefore, strictly speaking, what we checked is that a center point exists in a circular area of diameter 0.0054 when 8-bit quantization is used. And, it is that a center point exists in a circular area of diameter 0.00036 when 12-bit quantization is used. In addition, it should be noted that our technique based on computational geometry differs from the existing techniques in the sense that we assume input basic planar objects are of ideal shapes.