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Recognition of Raised Characters for Rubber Tires Classification

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ABSTRACT

This paper discusses the recognition of raised alphanumeric markings on rubber tires for their classification. The main subject of this paper is the finding, separating, and recognizing the characters raised on rubber tires, which is different from the recognition of printed characters.

The computer simulation result shows that the proposed system can be successfully applied to the industrial automation of rubber tires classification.

INTRODUCTION

The application of industrial robots for automation can be extended if the robot is equipped with a visual sensor that allows it to recognize and classify the industrial objects. For this task the visual sensor needs the model of the objects which have to be recognized and classified. This paper discusses the recognition of raised alphanumeric markings on rubber tires for their classification.

Several methods for the rubber tires classification have been proposed. One method is based on the size, thickness, and surface of tires[1]. Another one is devoted to extracting the character region[2], which is the preprocessing step for character recognition.

In this paper, an automatic tire classification system based on the recognition of raised characters is proposed. First we briefly describe three preprocessing steps, and then present the character recognition step. Also we show the experimental results and their discussions. Finally, a conclusion is given.

PREPROCESSING

Preprocessing consists of three steps: detecting contour maps, separating and straightening character regions, and extracting the individual character. A brief discussion of each step is described below.

Detecting Contours[3,4]: The rubber tire images are generally dark and the characters are raised from the surfaces on the rubber tires for their identification. In this research, the tire images are obtained by considering the proper character size for correct recognition, which approximately ranges between 25 × 25 and 30 × 30. Thus a tire is made up of four images. Fig. 1 shows the 512 × 480 real tire image with each pixel uniformly quantized to 8 bits.

Fig. 1. A tire image.

As the raised characters approximately have the same gray values as the background, the gradient value of the character region is similar to that of the uniform region. Therefore, the conventionl edge detection methods are not satisfactory to detect contours maps. If we consider gray values over the character region, it is observed that the character consists of one-pixel-thick raised lines. The line operator is expected to be more effective than the conventional edge operators. Thus a modified line operator scheme suitable for the tire images is proposed. Fig. 2 illustrates the proposed line operator in the horizontal direction.

We apply the line operator along four directions: horizontal, vertical, diagonal, and anti-diagonal directions. The direction along which the raised characteristic of surfaces is especially observed is chosen and its gradient value is assigned to the gradient value at a pixel considered. The contour map is constructed with pixels whose gradient values are larger than the threshold. Of course, the isolated contour points and the redundant contours are eliminated. The proposed line operator is shown to be less sensitive to noise due to the smoothing effect of neighboring pixels.

ll	l	p	r	rr

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G0 = abs(4p-l-ll-r-rr);
G = max(G0, G45, G90, G135);
if (G > threshold)
            p is a contour point;
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Fig. 2. Proposed line operator.

Fig. 3 shows the extracted contours by applying the line operator to the tire image shown in Fig. 1. The experimental result shows that the proposed operator well preserves the contours of characters, which are suitable for the next step of character recognition.

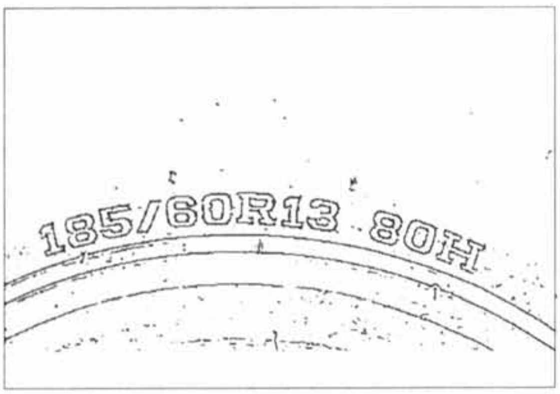


Fig. 3. Extracted contours by the proposed operator.

Extraction of the arc slope and separation of the character region: It is required to straighten the character region for effective recognition of characters. For this goal, the slope of an arc is detected by using the Hough transform and then it is used to flaten the character region. The line detected is related to the approximate slope of an arc. The Hough transform calculates the parameter by the given mapping function expressed in eq. (1). The line equation detected by the Hough transform is easy to represent the contour data, due to the simplicity of describing a line by two parameters: a slope and a crossing point at y-axis. Duda and Hart proposed the Hough transform mapping function as defined in eq. (1) to represent the equation having an infinite slope[5]. In Fig. 4, ρ_n denotes the distance from the origin to a straight line, and θ_m signifies the angle between the X-axis and the perpendicular line to a given straight line. (x_i, y_i) represent all the points on the line which satisfy eq. (1) as given below

$$\rho_n = x_i \cos\theta_m + y_i \sin\theta_m. \tag{1}$$

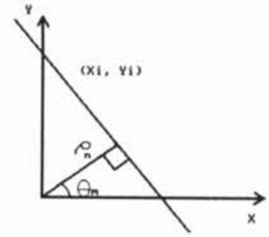


Fig. 4. Transform to ρ_n-θ_m parameter space.

We use the Hough transform for detecting the slope of each arc, by which a tire is separated into 5 arc regions consisting of several characters. The slope of each arc approximates the arc to the line if each part of a tire is not extremely curved. After detecting the contours of alphanumeric markings in a tire image, we apply the Hough transform to the subimages. The subimages are extracted overlapped to guarantee the whole coverage of each character by any subimage. The number of subimages is to be properly determined. If we have a large number of subimages, the computational complexity becomes large. With a small number of subimages, the distortion of characters by rotating a subimage by an angle detected becomes severe. Therefore, we divide the whole character region into five overlapped subimages, and calculate the slope of each arc.

Fig. 5. Detected slopes superimposed on Fig. 3.

Extraction of the individual character: The character regions are segmented from the contour map based on the horizontal projection values and are then separated into the individual character. First the tire's arc is eliminated by horizontal projections, and then the individual character is separated by vertical projections. But there exists a difficulty when the character is broken or overlapped, in which one character is separated into two characters or two characters are touched. To solve this problem, we estimate the size of a character considered, and if the size of a separated character is too small we combine that character with the next one.

CHARACTER RECOGNITION

Character recognition, one of the pattern recognition applications, is achieved through the classification or matching based on the features of each character. This section briefly discusses the conventional character recognition schemes and the proposed algorithm, which is based on the several features such as cross points, partial projection, distance, and partial width.

Conventional character recognition methods[6,7]: The typical methods for character recognition are divided into three categories: the template matching method, statistical method, and structual method.

The template matching method uses all the reference character sets with which an input character is matched. The statistical method performs the recognition based on various features extracted from input characters. In this method, the features are represented by N-dimensional vectors, and then the prototype character which is the most similar to the input character is chosen. The structural method performs the recognition based on the structural relationships between primitives of a character. In this method, the connectivity of each stroke is used as the primitive for character recognition.

Character recognition algorithm: In our research, a statistical recognition method on the binary image is used. Several features such as cross points, partial projections, distances, and partial widths are adopted. They are briefly described below.

Cross point: We first use the number of horizontal or vertical cross points (at which gray level changes from white to black or vice versa horizontally or vertically) to classify characters into various groups. In Fig. 6, 1, 2, 3, and 4 show the example of vertical cross points in the middle of a character.

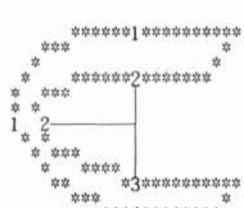


Fig. 6. Cross points.

Partial projection: The partial projection is also used to classify the characters. Vertical projections on the left and right sides are used, and then the ratio of projection value to character height is used as a feature. Similarly, horizontal projections at the top and bottom are used, and then the ratio of projection value to the character width is defined as a feature.

Distance feature: The distance feature is defined by the distance from the enclosed rectangular window to the black points of the character at several positions, as shown in Fig. 7.

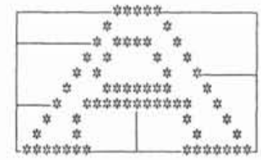


Fig. 7. Distance feature.

Partial width of a character: The ratio of the black pixel width to the character width is used. This feature is efficient when the number of candidate characters for matching is not large. In this paper, this feature is observed to be effective for recognition of characters such as '1', '7', and '/'.

In this paper, by using several features, we recognize characters hierarchically. We first extract standard features and then learn them. We use the statistical method to match the input features with those of prototypes.

The proposed recognition algorithm utilizes sequentially designed rule-based methods. By using the partial width we first divide characters into several groups. Then we sub-divide characters in each group into several subgroups using cross points and partial projection. Finally, we recognize the characters among several candidate characters by the distance feature.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The contour map is extracted by the proposed line operator and the tire's arc is straightened based on the Hough transform. Then the characters are segmented into the individual character by the vertical and horizontal projections.

The simulation results without straightening characters are given, which is used as the reference data for the following considerations: the effectiveness of staraightening characters on an arc, extracting the individual character, and the performance of the proposed character recognition algorithm. Fig. 8 shows the parts of the characters which are recognized correctly after being extracted from the original characters one by one. However, the characters which are not straightened may have a difficulty in being recognized correctly since the features vary according to the rotation angle and the correct segmentation into the individual character is somewhat difficult. Therefore, the characters have to be straightened in order to be recognized correctly.

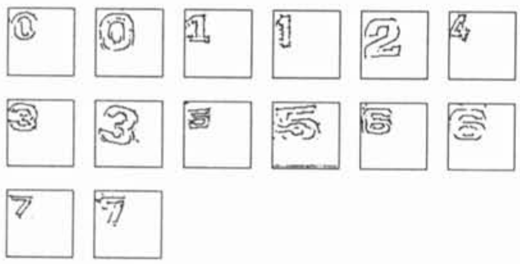
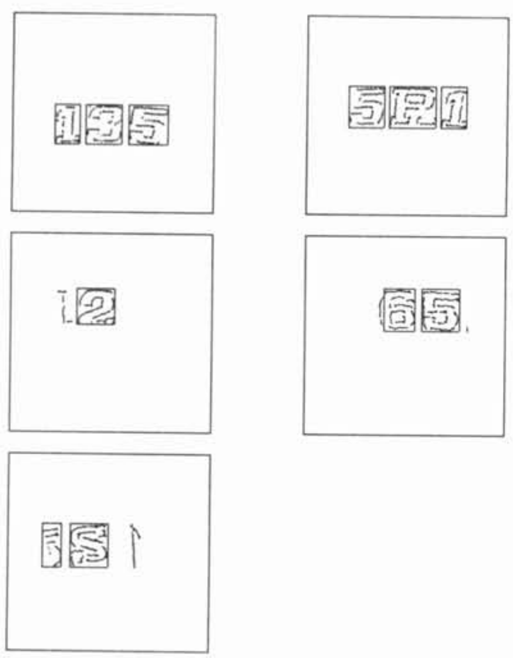


Fig. 8. Extracted characters without straightening.

Fig. 9 shows the result of the proposed scheme consisting of the preprocessing and recognition steps: the contour extraction, rotation of the character region, the extraction of the individual character, and the recognition step. The characters are sometimes broken due to the overlapping of characters, which results in the characters recognized incorrectly as underlined in Fig. 9. Note that the distance feature is introduced to classify correctly '5' in the fourth subimage, which is similar to '6' due to noise. The underlined part is recognized incorrectly due to the partial extraction of a character. Such characters are correctly recognized in another subimage. Simulation results show that the proposed scheme can be applied effectively to the classification of rubber tires.



Recognition result : 1 3 5 5 R 1 7 2 6 5 7 S

Fig. 9. Recognition results by the proposed algorithm.

The error in the preprocessing step affects the feature extraction steps for recognition, thus the preprocessing step is to be improved for reliable recognition of characters.

CONCLUSION

The efficient preprocessing and recognition steps for the recognition of raised characters on rubber tires have been presented.

In preprocessing, the modified line operator is introduced to extract the character contours. Then we straighten the character region by rotating it by the angle of a tire's arc obtained from the Hough transform. The vertical and horizontal projections are used as effective features in segmenting the individual character. In recognition step, the individual character is hierarchically recognized by the various features.

The experiments are performed with the real tire images and it is observed that the recognition of raised characters on rubber tires is performed successfully.

Our future research will be directed toward the improvement of the preprocessing step and the modification of the algorithm for reliable recognition systems. Also the hardware implementation of the proposed scheme is to be investigated further.

ACKNOWLEDGMENTS

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