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Real-time Surface Acquisition of Tire Sidewall for Reading Embossed Information

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***Abstract*— This paper proposes the method for modelling the tire sidewall surface to extract the embossed character in real-time. The information on tire sidewall can be read easily after the reconstruction process. The surface based model is reconstructed by the base-line correction. Orthogonal polynomial approximation is employed to create the base-line correction and then the statistical technique is used to generate the residual data to relief the embossed surface. The complete embossed relief surfaces with a variety of degree orthogonal polynomial are compared for selecting the suitable degree. A prototype system of the laser-scanning for tire sidewall is implemented. The testing results have shown better images of tire surface. This method can be developed to the optical character recognition system for 3D range data of tire sidewall as well.**

***Index Terms*— Orthogonal polynomial, 3D surface modeling, Embossed segmentation,**

I. Introduction

LABELS are designed to facilitate the storage, distribution of goods or products, and information to identify them. Furthermore, these can be ensured of the quality by tracking their progress through the supply chain. The critical product such as tire manufacturing process that is essential to track the process from vulcanization until its use on the road in order to control of the quality. The marking must be durable enough to withstand the volatiles from daily use. The classical solution is the embossed label code into the surface of the tire sidewall. The code on tire sidewall contains information of the manufacturer, including the tire identification number (TIN) and any labeling code requires by law.

According to the transportation regulation of the United States of America (49 CFR 571.109), the DOT code appears as an alphanumeric 4-digit date code placed on all new tires [1] as shown in Fig. 1a.

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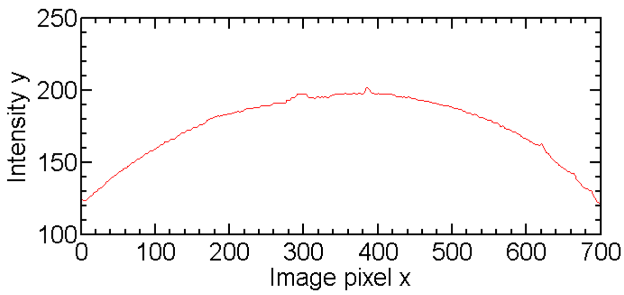
Optical character recognition or pattern recognition is the process of converting images text, into machine readable data; basically, there is based on pattern recognition, which was processed on a binary image that was acquired by scanner or digital camera (Bar code, QR code). However this technique is problematic to perform image segmentation and classification, which were based on edge detection algorithm. The machine vision using digital camera acquired image directly is not suitable because the image of tire sidewall surface is dark and the surface of tire has a curvature form [2][3][4]. The solution to these problems is acquired the 3D tire sidewall surface image by utilizing the 3D scanner.

Edges on 3D surface image are caused of discontinuing depth (see Fig. 1b) on a tire cross section image acquired by laser light sectioning method. Peaks on curve are anomalies of surface, which are included the stamped character that are uniform in curvature data. Normally, edges in images provide low-level cues in image segmentation processing that can be several causes such as depth, textures, and lighting [5]. Practically, segmentation can be performed by digitization of image [6],[7] thresholding algorithms is the simplest method, which are not appropriated to utilized to arbitrary surface.

(a)



(b)

Fig. 1. a) example of the embossed code on tire sidewall b) the cross section image of tire sidewall, which was acquired by laser light sectioning method.

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A tire sidewall cross section image (Fig. 2) can be considered as a wave form signal. Peaks of wave signal are added by background signals or noise providing the base-line. In analytical instrument, the base-line correction is the common problem for many algorithms utilized to removal baseline, such as derivative methods and frequency analysis, which are not appropriate for real-time applications. Recently, an iterative method based on curve fitting for estimation of base-line was proposed [8], [9].

This paper presents a solution to automatic extraction of characters and digits which are embossed on tire sidewall surface in real-time by utilizing the base-line correction to perform the surface relief to ensure that the achieved image is suitable for further processing.

II. Method

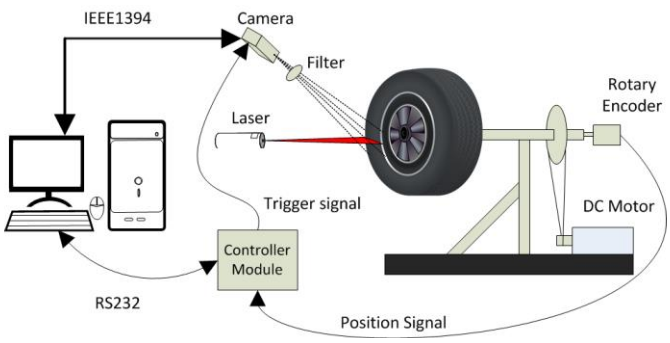

Fig. 2. Tire sidewall surface acquisition system.

A. Laser light sectioning scanner system.

The laser light sectioning method is a non-contact solution for acquiring the surface image by reconstructing 2D images of laser sheet that is projected onto tire surface from one-point perspective view. In this work, the system consists of a motorized rotary stage and a set of slim line laser light source which projected in perpendicular with tire sidewall, the area camera is used to capture the projected laser light on surface during rotation (see Fig. 2) [2]. The cross section images are acquired synchronously by using a rotary encoder. The raw 3D geometry of the surface contained the embossed character can be generated by reconstructing the 2D cross section images in real-time.

B. Orthogonal polynomial base-line correction.

The algorithm is based on base-line estimation, which achieved by fitting a polynomial function $f(x)$ from an original signal $y(x)$, which can be expressed in concise matrix form as

$$y = Xa + e \tag{1}$$

The vector e must be follows to the least square method by making e to minimum [9]. The fitting coefficient a can be solved by pre-multiplying the transpose X^T which can be expressed as

$$X^T y = X^T Xa \tag{2}$$

and, the fitting coefficient is

$$a = (X^T X)^{-1} X^T y \tag{3}$$

then, the fitting function is

$$Z = X(X^T X)^{-1} X^T y \tag{4}$$

the residual surface becomes,

$$R = Z - X(X^T X)^{-1} X^T y \tag{5}$$

where by, T is transposing matrix and -1 is matrix inversion, respectively. However, to calculate the matrix inversion $(X^T X)^{-1}$, is needed much more time for computation [8],[9]. In real-time applications, the computations time should be reduced to minimal as much as possible, which can be solved by using orthogonal polynomials property that are yielded diagonal normal matrices $(X^T X)$. Consequently, the matrix term $(X^T X)^{-1}$ can be computed easily by the equations

$$\begin{aligned} &X_0 x = 1, \\ &X_1 x = x - \bar{x} \\ &X_n(x) = x^n + k_{n,n-1} X_{n-1}(x) + k_{n,n-2} X_{n-2}(x) + \ldots \\ &+ k_{n,0} X_0(x) \end{aligned} \tag{5}$$

$$\begin{aligned} &k_{n,j} = -\sum_{i=1}^{m} x_i^n X_j(x_i) \Big/ \sum_{i=1}^{m} X_j^2(x_i), \\ &j = n-1, n-2, \ldots, 1, 0, \end{aligned} \tag{6}$$

where, $\bar{x}$ is average of x. All algorithms were implemented by C++ using OpenCV library by Intel in real-time with 1.70GHz Intel Core I5-3317U.

C. Embossed relief procedure

After a cross section image of surface, the embossed relief can be done as follows: first, converting a cross section image to data as a vector matrix: second, modelling the base-line vector by utilizing orthogonal polynomial approximation: third, the residual vector is computed by using (4): fourth, after performing the residual relief is done and the result is shown in Fig. 3a. The trend of residual data is inclined from the base-line to perform the thresholding correctly. The trend of residual data must be related to horizontal base-line by utilized linear approximation technique.

Normally the embossed characters is higher peak than the tire pattern, this means that the embossed data can be easily extracts by calculating the standard deviation of the residual vector as shown in Fig. 3b. The residual data after removal unwanted signal by standard deviation is shown in Fig. 3c. This technique can be used to reconstruct the 3D surface lifting the embossed characters apparently.

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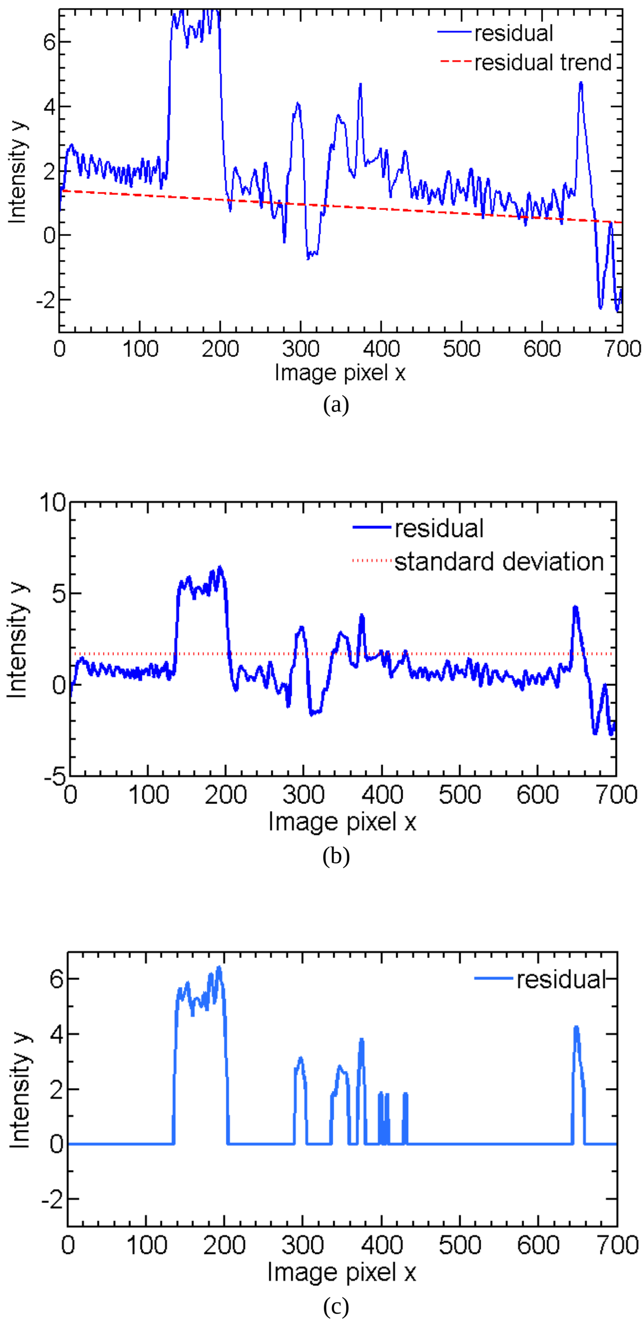

Fig. 3. a) residual data with trend data b) the standard deviation of residual data. c) residual embossed character edges after removed by standard deviation.

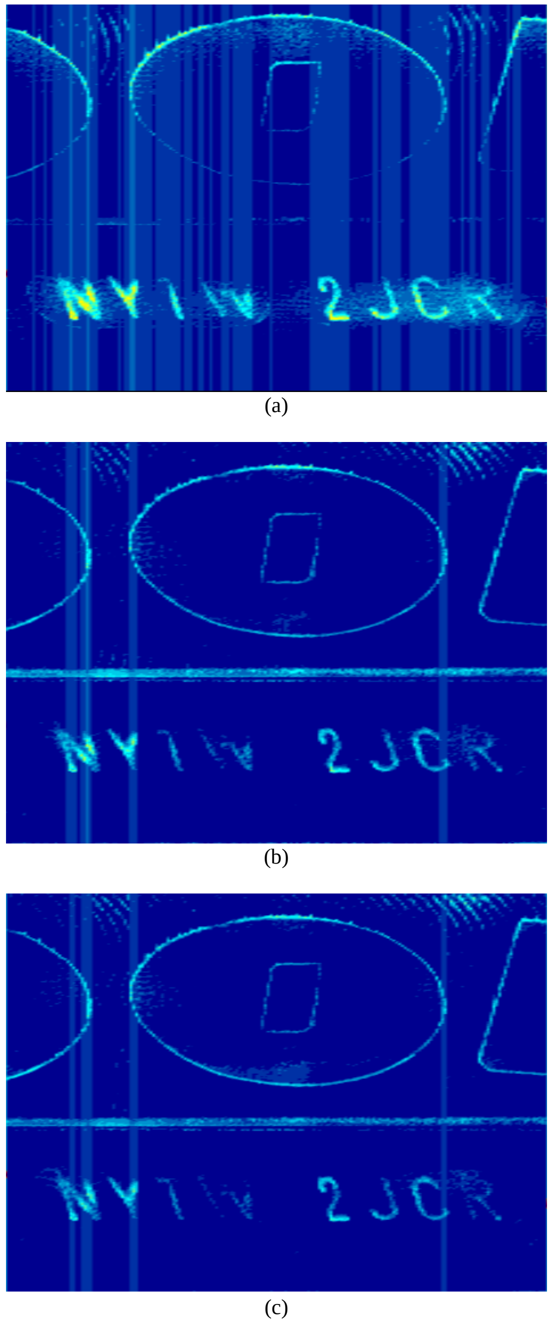

Fig. 5. the 3D surface at DOT code region with different degree of orthogonal polynomials a) degree of 5. b) degree of 10. c) degree of 15.

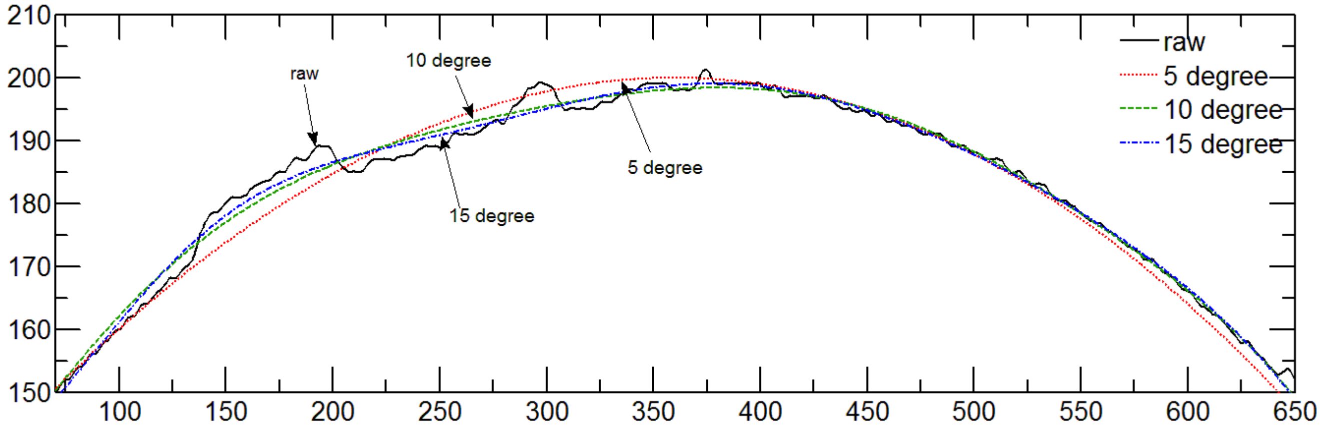

Fig. 4. raw range data curve and 3 varying of power of orthogonal polynomial .

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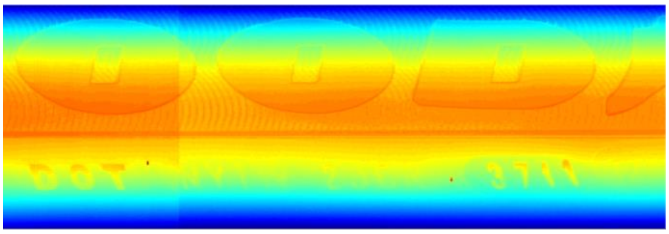
III. Results

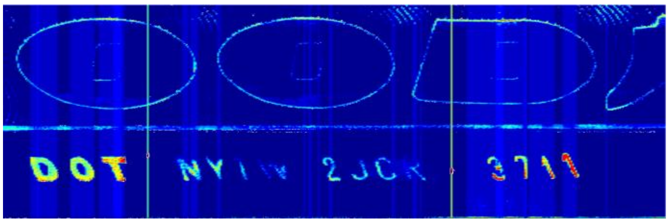
This section shows results of embossed character relief edges corresponding to the embossed relief procedure. After cross section images were acquired by light sectioning system. The range data were converted from cross section image, which was manipulated by computing the centroid and patching the line by Bresenham's algorithm. The complete surface modelling was done by utilizing orthogonal polynomial approximation. Only parameter in the procedure is the degree of orthogonal polynomial that should be set appropriately.

Fig. 4 shows the original signal with base-lines estimation with power of the orthogonal polynomial degree of 5, 10, and 15 respectively. The residual data was done by subtracting the reconstructed the 2D base-line modeled, which was approximated from orthogonal polynomials and regulated by linear approximation. A complete 3D raw surface and embossed relief image have shown in Fig. 6a and Fig. 6b respectively.

Fig. 5 shows results of the reconstructed tire sidewall surface removed by base-line with various power of orthogonal polynomial. The embossed characters with the fifth order was become apparent sufficient to perform the recognition process.



(a)



(b)

Fig. 6. a) 3D Original surface. b) 3D embossed relief surface.

IV. Conclusion

In this work, we focus on the geometric modelling to extract the embossed characters from curvature surface in real-time. The orthogonal polynomials can be used for curve fitting to reduce computation time. The trend of residual data was regulated by linear approximation to perform the standard deviation in order to provide a suitable threshold value for extracting the embossed characters on tire sidewall surface. The testing results have shown that the low power orthogonal polynomial is sufficient to model the base-line data, and the statistical method can used to enhanced the embossed characters on surface image in real-time for further processing.

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