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Duplicate a blank key using image processing

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Abstract: This paper proposes and evaluates the use of digital image processing for profiling a key groove. The first step of research is taking a cross-sectional image of the key. Exploiting Laplacian edge enhancement to acquire a contour of the key grooves. Transform the image data to surface data presented by coordinate(x,y). This information is used as an input for CNC Coding program. The duplication of key blank will be performed by CNC. The tolerance examination is conducted by comparing a calculated image proposed to the key-groove with a measured value from vernier. The error is less than 5%.

Keywords: Image processing, Key grooves, Laplacian, Edge detection,

1. INTRODUCTION

Nowadays, most people in modern society use keys on a daily basis, to secure their home, their vehicle, or to access their workplace, among other uses. Duplicates of the key can normally be made by a key shop with the correct key blank sold by manufacturer. Many times, the key shop could not find the same model of key blank to serve the need of a customer. The modification of the closest one may take a lot of time. Moreover, the duplicated key may be useless.

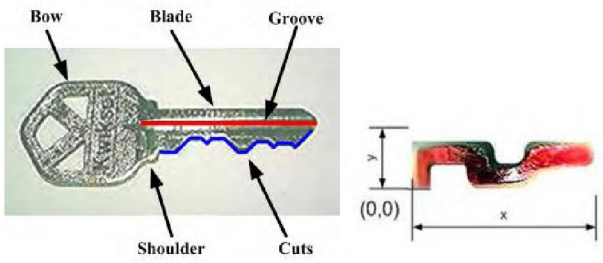
In order to rebuild the key blank, the key groove can be milled by CNC machine. Using the advantage of digital image processing, the cross-sectional image of key groove can be transformed into any format up to the requirement of use. Therefore, command for CNC machine, G-Code, shall be generated from the digital image. Hence, how to acquire the contour of key groove and convert these data to be the dimension profile is the main purpose of the paper.

In Sec.2, the basic characteristic of the key are described. Image capture equipment is proposed to efficiently capture the key groove image in Sec.3. In Sec. 4, a processing flow is proposed to find out a co-ordinate which can be translated to G-Code. And, in Sec. 5, the experiments and results are shown and demonstrated. Finally, conclusion is proposed in Sec.6.

2. THE STRUCTURE OF KEYS

A key [1] is an instrument, almost always portable, for opening and closing a lock by arranging the lock's tumblers according to a preset pattern of key cuts called a combination. It usually consists of a specially-shaped piece of flat chromium coated metal, with cut notches, (forming teeth) and milled grooves which fit the shape of the lock and can open the correctly combination lock by being turned in the lock housing. This portion of the key is referred to as the blade. The wider grip, referred to as the bow, is found at the top of the key to facilitate turning. Illustrated Fig. 1a.

A groove [5] is one of several milled or stamped indentations running the length of the key blade of a cylinder key to clear the keyway wards of lock, illustrated Fig. 1b. Duplicates key blank can be accomplished when the profile of the milled grooves are obtained. The groove image can be presented through (x,y) coordinate.



a) b)

Fig.1 a) Picture of key's structure
b) Present milled grooves and coordinate(x,y)

3. IMAGE CAPTURE EQUIPMENT

Based on the image processing principle, the first of all is taking a picture of key grooves.

3.1 Key grooves capturing

The key is normally coated by chromium. A reflection from surrounding object will appear on the key surface. This will affect to the quality of the image. In order to reduce this noise, the key grooves image will be captured in the closed box which the direction of light incident and the illumination of light source can be controlled. The capture equipment shown as Fig. 2

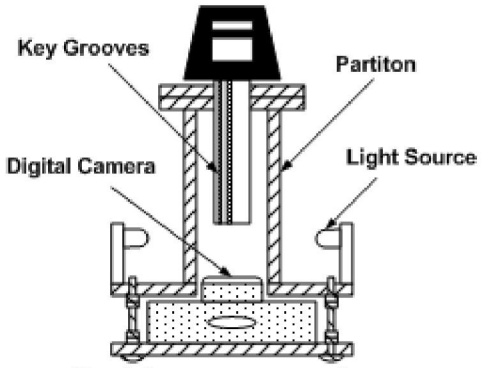


Fig. 2 Image capture equipment

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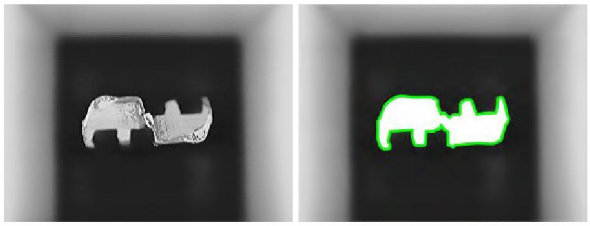
Suitable contrast is achieved by setting the background as black which means the brightness is low, and point the light source to the grooves which means the brightness is high. The captured image is shown in Fig. 3a and the highlighted contour is shown Fig. 3b

A typical computer display can present 256 different shade of grey (8 bit grey scale). Processing of key groove image will be performed in spatial domain. Pixel values will be modified according to rules that depend on the original pixel value. In this paper, the digital camera uses focal length is 6.0 mm. and F-number is 2.0. The original image size from image capture equipment is 240 x 320 pixels. It will be cropped into 68 x 161 pixels.



a) b)

Fig. 3 a) Captured image by CMOS 240 x 320 pixels
b) The edge of the key grooves

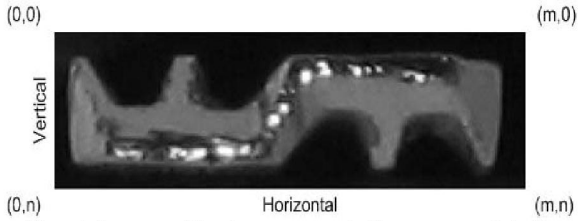


Fig. 4 the coordinate represents the groove details

3.2 Edge detection

Edge detection is based on pixel brightness slope occurring within a group of pixel. A large value corresponds to a steep slope and means a large change in gray level. Edges are, by definition, sharp brightness changes. A large slope indicates the presence of edge as shown in Fig.5 The edge are any sharp brightness transition rising from black to white or falling from white to black.

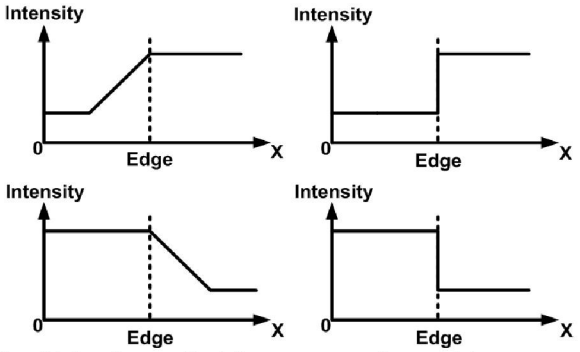


Fig. 5 The slope of brightness occurring within a group of pixel

4. THE PROPOSED SYSTEM

Based on the criteria in the previous section, the proposed flow to find the contour of key groove is illustrated in Fig. 6 The considered pixel A[i,j] will be replaced by the calculation of itself and its 8 neighbors in a 3 x 3 square block.

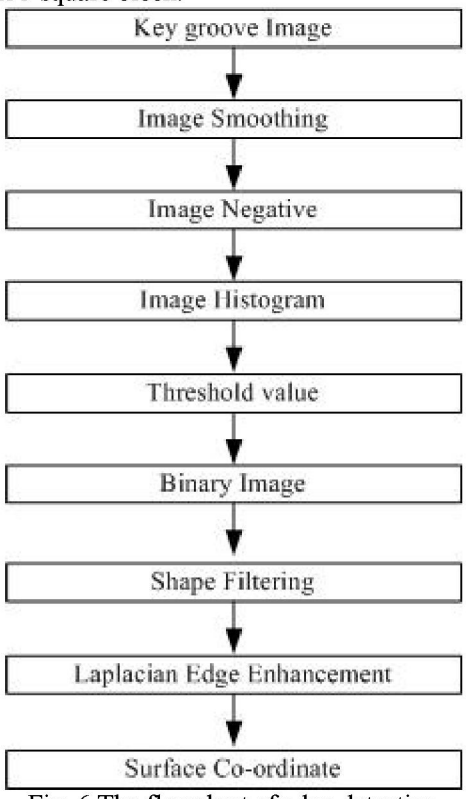


Fig. 6 The flowchart of edge detection

4.1 Image Smoothing

In order to reduce a noise occurred while capturing process, a low pass filter LPF[i,j] is used. A low pass filter LPF[i,j] of the digital image A is an average value of the brightness of each pixel in 3 x 3 square block as shown in Eq. (1).

$$LPF[i,j] = \sum A[i+k,j+l]/9 \quad (1)$$

where $k = -1, 0, +1$; $l = -1, 0, +1$
$i = 0$ to m; $j = 0$ to n

4.2 Image Negative

According to the capturing process, background is a dark region. Reversing all of the contrast range produces the equivalent of a photographic negative, which improves the visibility of details. A negative image NEG[i,j] of the digital image A is obtained from the subtraction of the maximum intensity and the original image[3] as shown in Eq. (2)

$$NEG[i,j] = 255 - A[i,j] \quad (2)$$

4.3 Image Histogram

Brightness histogram is a plot shows the number of pixels in image having each of the 256 possible values of stored brightness. Hence, the histogram H(k) of the digital image A is a plot of the frequency of occurrence of each gray level(K) in A [3] as shown in Eq. (3)

$$H(k) = \sum A[i,j] = K \quad (3)$$

where K = 0 to 255

4.4 Binary Image

Binary image is displayed using two extreme gray tones, black and white, which are ordinary represented by 0 and 255, respectively, in a gray-scale display. The binary image B[i,j] is obtained from the process of image threshold which is a simple comparison: each pixel value in digital image is compared to Kt[3] as shown in Eq. (4)

$$B[i,j] = 0 \; ; A[i,j] \geq Kt \quad (4)$$
$$= 1 \; ; A[i,j] < Kt$$

4.5 Shape Filtering

Shape filtering K[i,j] is obtained from the multiplication of the binary image and the original image[4]. The result is the pixel of original image that multiplied by 1 as shown in Eq. (5)

$$K[i,j] = B[i,j] \times A[i,j] \quad (5)$$

4.6 Laplacian edge enhancement

Laplacian edge enhancement operation extracts all of the edges in an image, regardless direction. The result image appears as an omni-directional outline of the objects in the original image. Constant brightness regions become black, while changing brightness regions become highlighted. The calculation is shown as Eq.(6)

$$E[i,j] = 9 \times K[i,j] - \sum K[i+k, j+l] \quad (6)$$

where k = -1, 0, +1; l = -1, 0, +1

4.7 Data conversion

The co-ordinate is used to present the characteristic of groove surface. The edge image from the previous section will be scanned with horizontal index from left to right. The key consists of two sides: top and bottom, the scan will be performed 2 times with the vertical index from bottom to top and top to bottom to find the first white pixel, illustrated Fig.4.

5. EXPERIMENTS

In the experiments, one safety car key is to test each stage of the flow using Matlab7 to calculate the Eqs. (1) ~ (6). The selected threshold value is 186. The profile of grooves was developed and tested as shown in Fig. 7. The contour image data will be transformed into coordinated data(x,y) depicted as Fig. 8

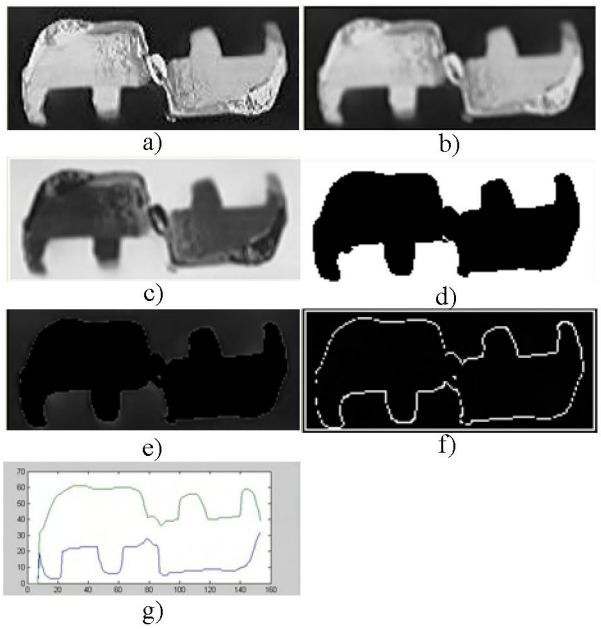


Fig.7 a) Key Cross sectional 68 x 161 Pixel
b) The groove after applied Low pass filter
c) The groove after applied Negative image
d) A binary image after threshold Kt=186
e) The extracted groove from the background
f) A contour of groove
g) A co-ordinate presents the groove

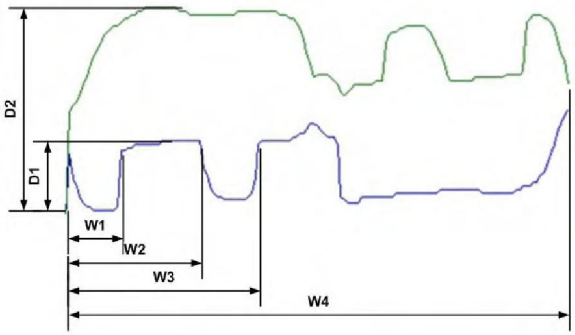


Fig.8 Present the contour of groove and reference distance for tolerance examination

The tolerance examination is conducted by comparing a calculated image proposed to the key-groove with a measured value from vernier as shown in Table 1.

Table 1 The calculated and measured values

Ref. Test	Size (mm.)			
	Virnier	Caculate	Error	% Error
W1	0.84	0.87	0.03	3.9
W2	2.20	2.27	0.07	3.2
W3	3.10	3.20	0.10	3.3
W4	8.30	8.50	0.20	2.4
D1	1.12	1.16	0.04	3.6
D2	3.30	3.40	0.10	3.0

6. CONCLUSION

The key cross-sectional image gives high contrast. This encourages a program to select more appropriate threshold value. Due to Table1, the error percentage is less than 5%. This information will be used as an input data for CNC coding program to generate a command code for CNC. The profile of key groove is acquired without a surface destroying.

7. REFERNECES

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