Duplicate a Key using Image Processing

Montri Cheewanantakul[1] and Assc. Prof. Suthian Kiatsunthorn[2]
[1]Department of Control Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok Thailand
(Tel : +66-2-917-3481; E-mail: mon.ch@hotmail.com)
[2]Department of Control Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok Thailand
(Tel : +66-2-737-3000; E-mail: suthiankiatsunthorn@yahoo.com)

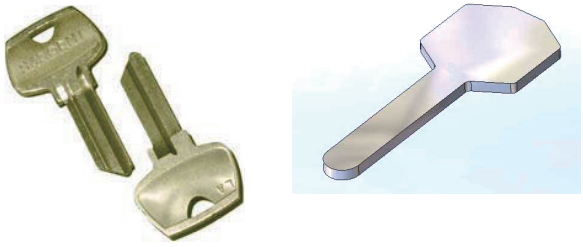
Abstract: This paper proposes to use image processing to duplicate a key grooves and a key cuts [1] . The first step of this research is taking a cross-sectional image of the key grooves and top-sectional image the key cuts. Exploiting binary image enhancement to acquire a contour of the key grooves and key cuts. Then transform the image data to contour data presented by coordinate(x,y). This information is transformed into CNC G Coding . The duplication of the key will be performed by mini CNC machine. The tolerance examination is conducted by comparing a dimension of the master key and the duplicated key.

Keywords: Image processing, Key grooves, Key cuts.

1. INTRODUCTION

Nowadays, most people in modern society use a keys on a daily basis, to secure their home, their vehicle. Duplicate the key, normally can be made by key shop with the correct key blank support by manufacturer. Many times, the key shop could not find the same model of key blank to serve the need of a customer, illustrated Fig. 1a.

In order to rebuild the key , the key grooves and the key cuts can be milled by mini CNC machine (the price is same as keys machine), no need blank key which support by manufacturer, metal plate are used , illustrated Fig. 1b. Using the advantage of digital image processing [2], the dimension of cross-sectional image of key grooves and dimension of top-sectional image of key cuts can be transformed into G-code, command for CNC machine. Hence, how to acquire the contour of key grooves and key cuts and then convert these data to be the dimension of profile is the main purpose of the paper.

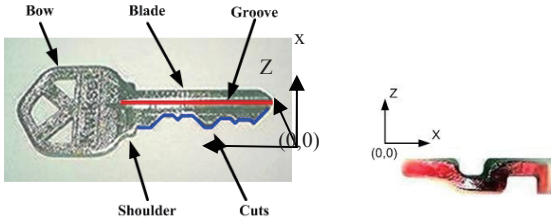


a) b)

Fig. 1 a) The blank key, support by manufacturer.
b) The metal plate, no grooves and cuts.

2. THE STRUCTURE OF KEYS

A key [3] 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. The structure of the key Illustrated in Fig. 2a and Fig. 2b.



a) b)

Fig.2 a) Picture of key's structure
b) Present milled grooves

3. IMAGE CAPTURE EQUIPMENT

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

There are many way to acquire the contour of key grooves and key cuts , by digital camera , by hand drawing , by scanner machine. For this research ,The digital camera webcam (240x320 pixel) is used to acquire the contour of key grooves and key cuts. A

reflection from surrounding object will appear on the key surface. In order to reduce this noise, the key 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. 3

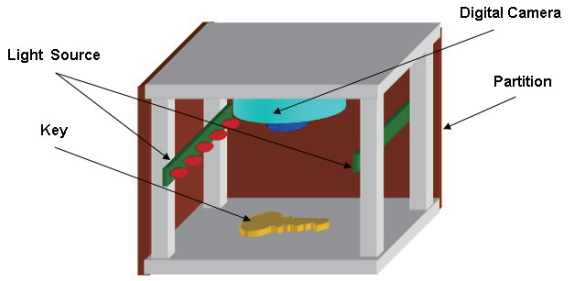
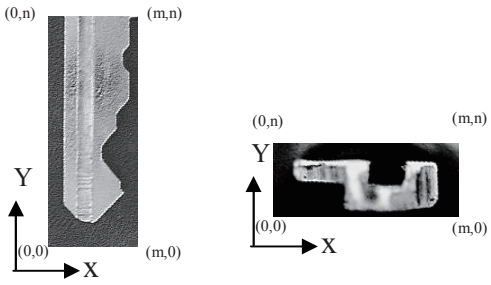


Fig. 3 Image capture equipment.

Suitable contrast is achieved by setting the background as black which means the brightness is low, and point the light source to the key grooves and the keys cuts which means the brightness is high. The captured image is shown in Fig. 4a and Fig. 4b

Processing of key 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 original image size from image capture equipment is 240 x 320 pixels. It will be cropped into 68 x 161 pixels.



a) b)

Fig. 4 a) Key Cut Image captured by capture equipment.
b) Key Groove Image captured by capture equipment.

4. THE PROPOSED SYSTEM

Based on the criteria in the previous section, The proposed of flowchart is to find the contour of the key grooves and the key cuts is illustrated in Fig. 5. 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.

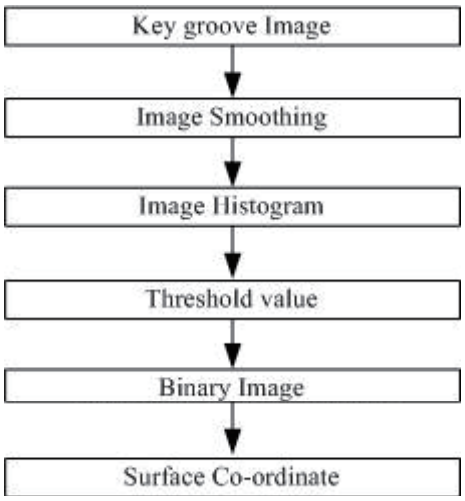


Fig. 5 The flowchart for get key surface Co-ordinate.

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 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 as shown in Eq. (2)

The pixel intensities will be clustered around two well-separated values. A suitable threshold Kt[4] for separating these two groups will be found somewhere in between the two peaks in the histogram.

$$H(k) = \sum A[i,j] = K \quad (2)$$

where K = 0 to 255

4.3 Binary Image

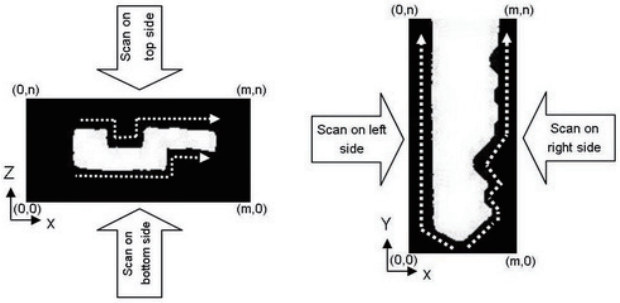
Binary images are images whose pixels have only two possible intensity values. They are normally displayed as black and white. Numerically, the two values are often 0 for black, and either 1 or 255 for white. Binary images are often produced by thresholding a grayscale, in order to separate an object in the image from the background. 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 threshold value Kt ,get from image histogram. as shown in Eq. (3)

$$B[i,j] = 0 \; ; A[i,j] \geq Kt \quad (3)$$
$$= 1 \; ; A[i,j] < Kt$$

4.4 Data conversion

The binary image of key groove from the previous section will be scanned 2 time top and bottom is illustrated in Fig. 6a, to get the key grooves dimension in pixel unit and then convert into millimeter unit . The binary image of key cut from the previous section will be scanned 2 time left and right is illustrated in Fig. 6b, to get the key cuts dimension in pixel unit and then convert into millimeter unit .

This research use the computer programming (Visual Basic 6.0) to processing the image , follow Eqs. (1) ~ (3). And convert the dimension of key grooves and key cuts by count the number of pixel at the edge both X axis and Z axis for the key grooves, and count the number of pixel at the edge both X axis and Y axis for the key cuts, then convert the number of pixel into millimeter unit. After that create the G-Code for mini CNC machine.

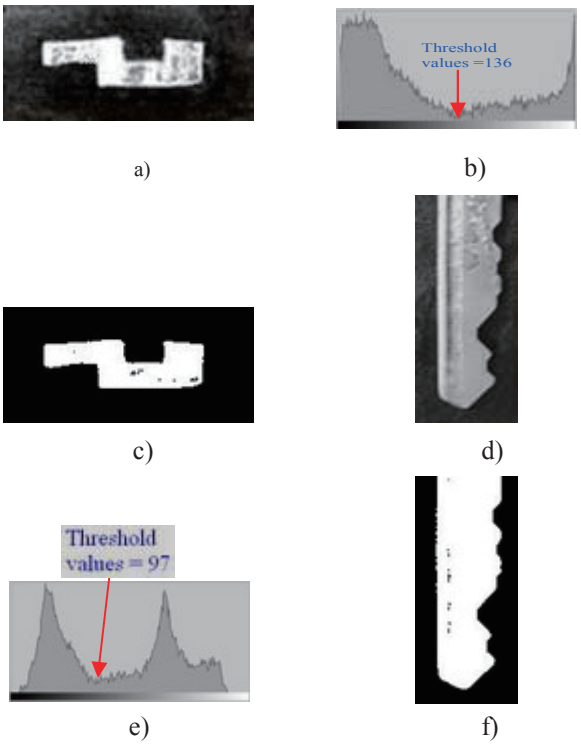


a) b)

Fig. 6 a) Key grooves scanned , top and bottom.
b) Key cuts scanned , left and right.

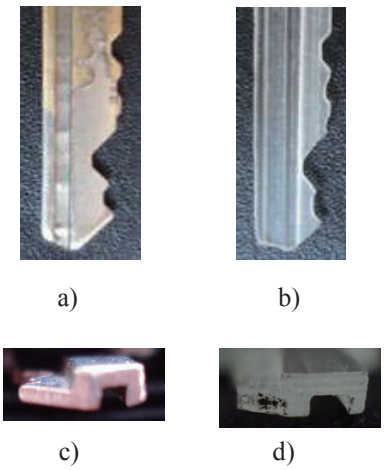
5. EXPERIMENTS

In this experiments, acrylic is used for duplicated a key ,the key is tested each stage follow the flowchart and using Visual Basic 6.0 to calculate the Eqs. (1) ~ (3).The profile of key grooves and key cuts is developed and tested as shown in Fig. 7. The contour image data will be transformed into coordinated data(x,y,z) and then convert into G-code, the complete duplicated key shown in Fig. 8



a) b)
c) d)
e) f)

Fig.7 a) Key grooves Smoothing image.
b) Key grooves Histogram , threshold value = 136.
c) Key grooves binary image .
d) Key cuts Smoothing image.
e) Key cuts Histogram, threshold value = 97.
c) Key cuts binary image .



a) b)
c) d)

Fig.8 a) The master key cut.
b) The Duplicated key cut
c) The master key groove.
d) The Duplicated key groove.

The tolerance examination is conducted by comparing a duplicated key with the master key .The measurement point of key grooves show in Fig. 9 and measured value

show in Table 1.The measurement point of key cuts show in Fig. 10 and measured value show in table 2.

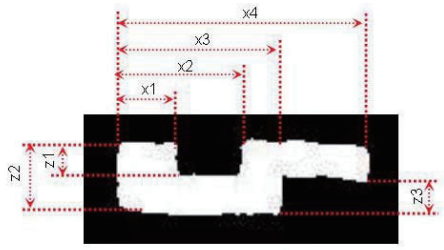


Fig. 9 Show the measurement point of key groove.

Table 1 Key groove compared value

Ref. Test	Size (mm.)			
	Master	Duplicated	Error	% Error
x1	0.85	0.83	0.02	2.35
x2	2.00	1.95	0.05	2.50
x3	3.15	3.10	0.05	1.59
x4	5.60	5.50	0.10	1.79
z1	0.95	0.93	0.02	2.11
z2	1.70	1.65	0.05	2.94
z3	0.70	0.72	0.02	2.86

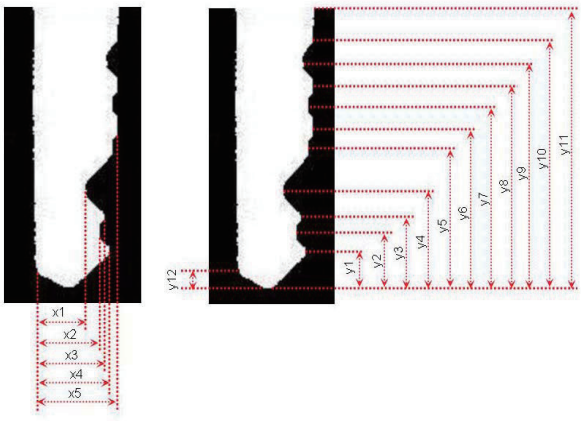


Fig.10 Show the measurement point of key cuts.

Table 2 Key cuts compared value.

Ref. Test	Size (mm.)			
	Master	Duplicated	Error	% Error
x1	3.70	3.60	0.10	2.70
x2	4.70	4.65	0.05	1.06
x3	5.30	5.20	0.10	1.89
x4	5.60	5.50	0.10	1.79
x5	6.15	6.00	0.15	2.44
y1	3.10	3.03	0.07	2.26
y2	4.80	4.70	0.10	2.86
y3	5.65	5.50	0.05	2.65
y4	7.95	7.75	0.20	2.52
y5	11.00	10.85	0.15	1.36
Y6	12.70	12.55	0.15	1.18
y7	14.00	13.65	0.35	2.50
y8	15.65	15.35	0.30	1.92
y9	17.45	17.20	0.25	1.43
y10	19.00	18.75	0.25	1.32
y11	21.30	21.00	0.30	1.41
y12	1.25	1.22	0.03	2.40

6. CONCLUSION

The duplicated key from this research is quite good accuracy , compare with master key , the percent error is less than 3% , the result show in table 1 and table 2. The duplicated key is able to unlock the lock, it can replace the master key.. The accuracy of duplicated key is concern with quality of captured image , software algorithm for convert captured image to G-code, and mini cnc machine set up.

Mini cnc machine show in Fig. 11 and digital camera webcam show in Fig. 12 , these equipment are easily found in the market and price not higher than a keys machine. The good point of using mini cnc to duplicate the keys is no need blank key which support by manufacturer. Some special kind of key, key shop cannot find the blank key ,so they can not duplicate a key by use key machine. When duplicate a key by use key machine, the master key is inserted into the key machine for remember the master key cut by touch along the master key cut, this way may made damage to master key. But if use the method follow this research, just take a photo ,no need to touch master key , so master key never damage.

Fig.11 Mini CNC Machine.

Fig.12 digital camera webcam.

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