Tool Path Analysis and Motion Control of 3D Engraving Machine

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Abstract: This paper presents a new technique to analyze data on the coordinate x, y, z and apply these data to design the motion control to improve the efficiency of the engraving machine so that it can engrave accordingly in 3 dimensions. First, the tool path on the x-y plane is analyzed to be synchronized with the z-axis. The digital data is then sent to the motion control to guide the movement of the engrave point on the x-y plane. Tool path moves along the x-axis with zero degree and different values of the y-axis according to the coordinate of the digital data and the analysis along z-axis to determine the depth for engraving. The depth can be specified from the gray level with the 256 levels of resolution. The data obtained includes the distances on x-axis, y-axis, and z-axis, the acceleration of the engrave point's movement, and the speed of the engrave point's movement. These data is then transfered to the motion control to guide the movement of the engrave point along the z-axis associated with the x-y plane. The results indicate that engraving using this technique is fast and continuous. The specimen obtained looks perfect in 3D view.

Keywords: Engraving Machine, Tool Path, Gray Level, 3 Dimension, Motion Control

1. INTRODUCTION

This paper presents a new technique to decode the graphic into the vector coordinate and then analyze the obtained coordinate on the x, y, z plane. The digital data of the x,y,z coordinate, the acceleration of the engrave point's movement, and the speed of the engrave point's movement are sent to the motion control to guide the movement of the engrave point and the depth for engraving to create a gray 3-dimension graphic. This technique can be applied with the 3-coordinate engraving machine. The results indicate that engraving using this technique is fast and continuous.

2. ENGRAVING MACHINE

The engraving machine used in this research is the one developed from the 2-coordinate engraving machine, which can be used to engrave the specimen only on the x-y plane, to be able to engrave 3-dimensionally.

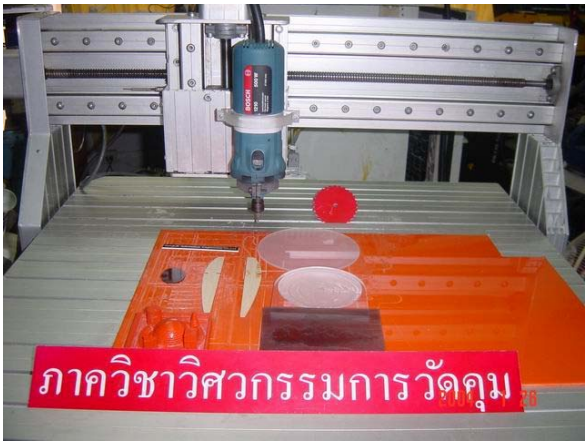

Figure 1 Engraving Machine used in this research

The commands developed to control the movement of the engraving point on the x-y-z coordinates are as follow:

t x y z a s

when

- t is the prompt command for input.
- x is the distance on the x-axis.
- y is the distance on the y-axis.
- z is the distance on the z-axis.
- a is the acceleration of the engraving point.
- s is the speed of the engraving point.

The specification of the engraving machine:
The maximun distance on the x-axis = 480 mm
The maximun distance on the y-axis = 550 mm
The maximun distance on the z-axis = 150 mm
The rotating speed of the tool = 10,000 rpm

The engraving point used in this research is the one with the pointed head as shown in Fig. 2. It is attached with the tool mounted on the z-axis so it can move on x-y plane.

Figure 2 Engraving point used in this research

3. TOOL PATH ANALYSIS

Graphics obtained from the digital camera, scanner, or any application software will be divided into numerous pixels. The path on the x-y plane is then determined. The depth can be specified from the brightness of each pixel according to the gray level with the 256 levels of resolution. Each pixel can be shown as in Fig. 3.

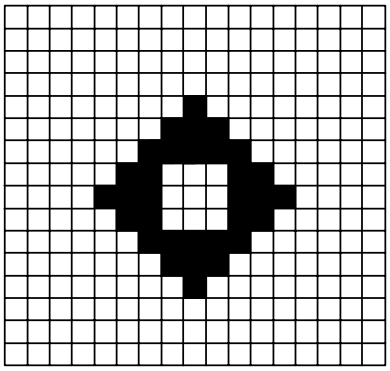

Figure 3 The each pixel of the graphics

The analysis for tool path on the x-y plane can be shown as in Fig. 4.

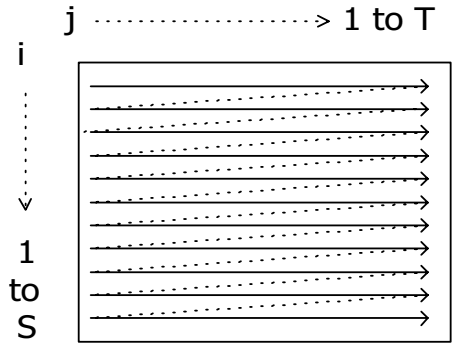

Figure 4 Scanning Direction

when

i is the number of pixels vertically.
j is the number of pixels horizontally.
S is the maximum number of the pixels vertically.
T is the maximum number of the pixels horizontally.

The resolution when scanning each time is 1 pixel. For each time a pixel is scanned, the gray level is analyzed. The matrix representing the gray level of different pixel can be shown as follow.

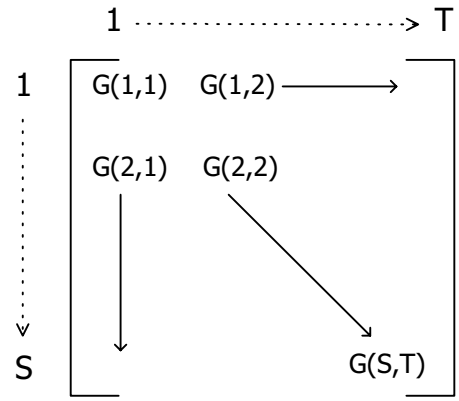

Figure 5 Matrix representing the gray level

when $G(i,j)$ is the gray level at coordinate (i,j).

092 093 094 091 090 090 088 089 ...
129 130 131 131 133 136 138 137 ...
099 099 100 095 093 091 088 090 …
134 135 136 135 136 137 138 137 ...
123 123 118 111 107 103 099 099 ...
132 133 133 133 134 137 139 139 …
124 125 123 119 118 116 112 112 …
131 132 134 136 137 139 143 146 …
129 128 126 126 127 126 122 118 …
138 140 142 141 141 142 144 145 …
169 169 170 169 169 170 169 165 ...
130 131 132 136 136 136 137 139 …
……..
……..
……..

Figure 6 The matrix gray level of the Fig. 10

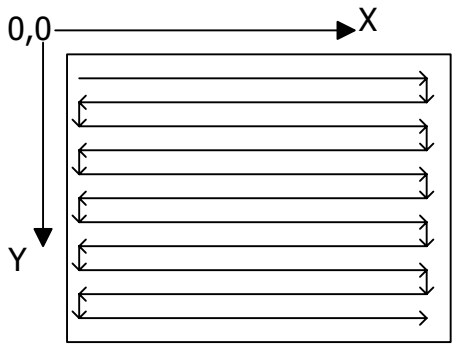

Figure 7 Tool path of the engraving machine

The analyzed path of the engraving point is then rearranged to be continuous and shortest as shown in Fig. 7.

4. DESIGN OF THE SYSTEM

The overall system can be graphically displayed as in Fig. 8.

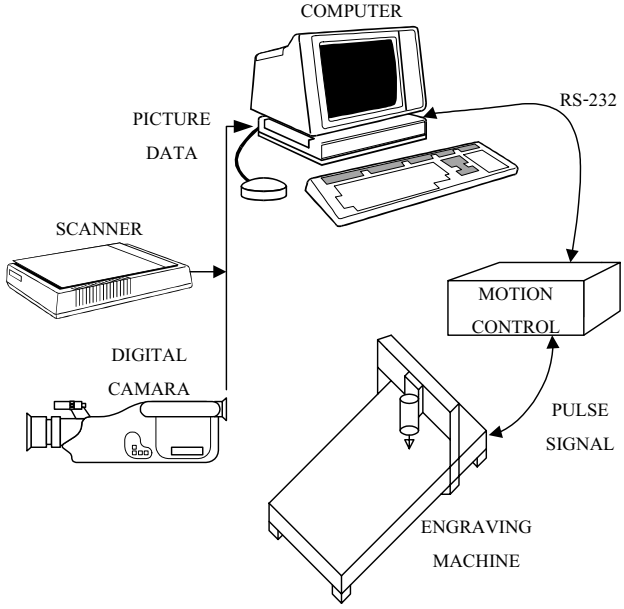

Figure 8 Overall System

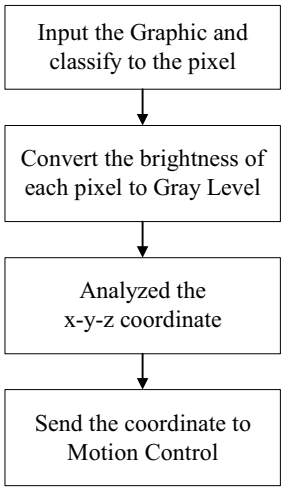

Figure 9 Flow chart

The initial graphic from scanner or digital camera will be computed and analyzed to obtain the path of the engrave point on the x-y plane and the depth for engraving along the z-axis. Fig. 9 displays the flow chart of the software.

After using software to generate continuous and shortest data, the data is transferred to the motion control through the serial port RS-232. The transferring includes sending, pixel by pixel, data associated with the movement along the x-axis, equal to the distance of the movement of 0.26 mm., and those associated with the depth for engraving long the z-axis. Once each line is completed, data associated with the y-axis is transferred pixel by pixel. This continues repeatedly.

5. EXPERIMENTAL RESULT

Our experiment starts with obtaining the gray level of the original graphic. Then, the path and the depth are obtained and transferred to the engraving machine so it will 3-dimensionnally engrave on the 2mm-thick finished-surface black specimen.

5.1 The original BMP file

Fig. 10 is a BMP file of the microsft wall paper. Each pixel of the Fig. 10 is converted to the gray level and graved to the 3 D picture which can be shown in Fig. 11 and Fig. 12 respectively.

Figure 10 Original graphic used in the experiment

Figure 11 Graphic after convert to the gray level

Figure 12 The 3D picture of the Fig. 10

5.2 The original DWG file

The plot file which is a vector of the DWG file is also anaslyzed and graved to 3D similar to the original DWG file as shown in Fig. 13.

Figure 13 The 3 D picture of DWG file.

5.3 The original picture from digital camera

The picture from digital camera is down loaded to the PC and converted each pixel to the gray level. The picture which graved to 3D picture can be shown in the Fig. 14.

Figure 14 The 3 D picture which original from digital camera

5.4 The original NC file.

The NC file is a text file of tool path which generated by CAD-CAM software (Mastercam Unigraphic). The NC file is analyzed and graved to 3 D can be shown in Fig. 15.

Figure 15 The 3 D picture which original NC file

6. CONCLUTION

This paper present a new technique to decode the graphic into the vector coordinate and then analyze the obtained coordinate on the x, y, z plane before sending to the motion control to guide the movement of the engrave point and the depth for engraving to create a gray 3-dimension graphic. This technique can be used the many original picture and applied with the 3-coordinate engraving machine. The results indicate that engraving using this technique is fast and continuous.

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