

Design and Manufacturing of Cutting Motion Control System on 3-Axis Router Machine for Wood Carving

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Abstract—The carving profiles on wood surfaces could be made automatically by feeding a cutting tool on the trajectory profile carving will be formed. The cutting tool motion trajectory adjusted to the desired profile path by controlling the tool motion in both rotational and translational motion in the x, y, and z-axis direction. The cutting tool placed on the tool post that can move in the z-axis, the tool post placed on the movable holder in the x-axis, the tool post and holder are placed on two movable support poles in the y-axis. The three-axis motion mechanism carried out by three servo motors. Motion control is done using pulse width modulation (PWM), by adjusting the number and frequency of pulses in each servo motor. The number of pulses and pulse frequency was controlled by a microcontroller that receives data from a computer by serial communication. The number of pulses and the frequency of pulses are determined based on the coordinates, and speed of motion that must be achieved by the cutting tool in a profile path will be formed.

Keywords—router machine, wood carving, servo motor, microcontroller, PWM

I. INTRODUCTION

A router machine is a machine used to make carvings on the wood surface profile to improve the appearance of the wood. The main tool used in router machines is cutting tools which have the same as the cutting tools installed on the milling machine. The cutting tools rotate at high speed and cut the wood surface until it forms the desired indentation in the router machine, a mechanism is made that can control the motion of the cutting tool so that it can rotate and move in three-dimensional space in the x, y, and z-axis directions [1-6].

One example of a router machine can be seen in Figure 1. The tool holder is connected to the DC motor shaft. DC motors are placed in a holder that can move in the direction of the z-axis. The cutting tools holder is placed on the support which slides in the x-axis direction. The supports attached to two poles can move in the direction of the y-axis [1,5].

Each drive mechanism cutting tools in the third axis direction driven by a motor drive can use servo motors or stepper motors. A stepper motor is an electromechanical device

that works by converting electronic pulses into discrete mechanical movements. Stepper motors work by a sequence of pulses given to the legs of the stepper motor function. A stepper motor drive has required the motor driver that works to transform electrical impulses into a sequence of pulses in the legs of the stepper motor function. Resolution per step on the stepper motor is difficult to change by the wishes of programmers. Resolution per step on the stepper motor can be reduced under the resolution of the base. If a stepper motor has a resolution of 1.8o, the resolution can be reduced to 0.9o, 0.45o, 0.225o, and so on [7].

A servo motor is a device or rotary actuator designed with a closed-loop feedback control system so that the motor shaft can be adjusted angularly according to the input given. Servo motor consists of three main parts, namely the motor, control system, and encoder. The function of the encoder as a sensor provides a feedback signal to the control system whether the desired target is correct or not. The resolution per step of the servo motor can be adjusted according to the wishes of the programmer by setting certain parameters. The rotational speed and torque of the servo motor shaft are higher than the rotational speed and torque of the stepper motor shaft.

Referring to the above references, to move the motion mechanism cutting tools can move in three-dimensional space, can use two types of motors the above. The control system is needed to control the three motors on each axis of motion the motor can move simultaneously with different speeds and numbers of revolutions for each axis of motion. Motor control can be done by adjusting the number of pulses and the frequency of pulses given to each motor [8-10].

In this paper, the motor used to drive the mechanism of the cutting tool is a servo motor because the rotational speed and torque of the servo motor shaft are higher than the rotational speed and torque of the stepper motor shaft.

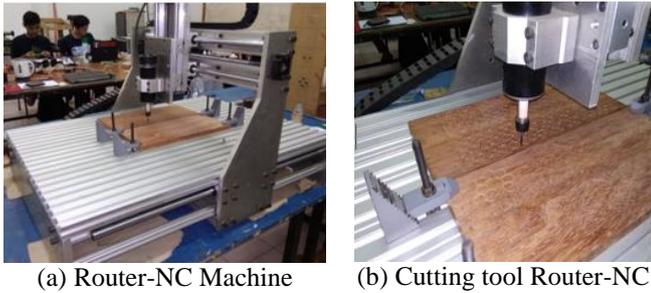


Fig. 1. Wood carving router machine [1].

II. METHODS

A router machine that is made to operate automatically requires a control system. The control system that is designed has two main tasks, namely regulating the rotational speed of the cutting tool and regulating the movement of the cutting tool in three-dimensional space. The schematic of the router machine control system design can be seen in Figure 2.

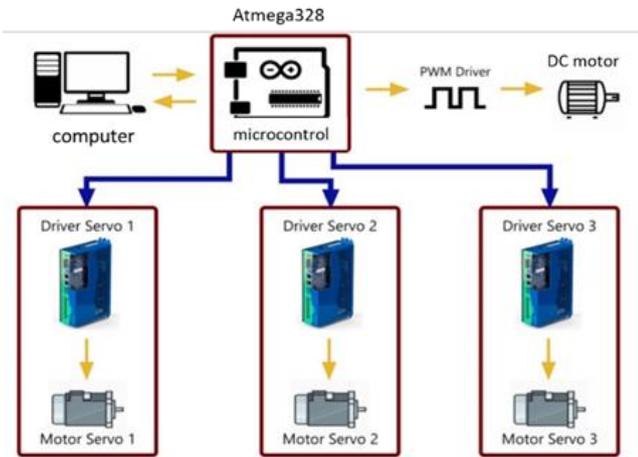
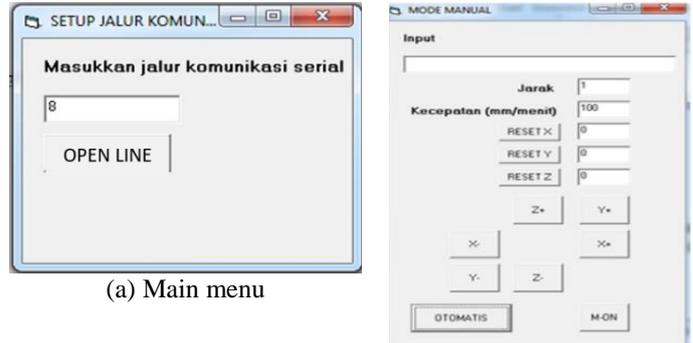


Fig. 2. The schematic of the router machine control system [1].

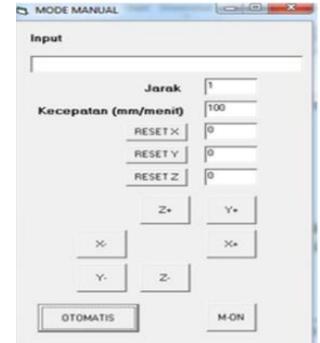
In general, the movement data written on the computer is sent by the computer to the microcontroller via serial communication. The movement data by the microcontroller is used to adjust the rotational speed and movement of the cutting tools. When the tool movement has been completed, the microcontroller will send a signal to the computer that the control commands that have been sent by the computer have finished executing. The computer immediately sends the next instruction.

Computers used to write the control data used to control the router machine. The program display on the computer consists of the initial display, the automatic mode displays, and the manual mode display. The initial display appears when the program application is run. The initial view can be seen in Figure 3(a).

This initial view is used to determine the serial communication line that will be used for data transfer from the computer to the microcontroller or vice versa. The serial communication line in use will be detected automatically when the initial display appears. The user needs to confirm the serial communication line used by clicking the OPEN LINE button.



(a) Main menu



(b) Manual Mode



(c) Automatic Mode

Fig. 3. Dialogue on the control system program.

When the MANUAL button on the automatic mode is clicked, the manual mode display will appear. The manual mode display can be seen in Figures 3 (a) and 3 (b). The manual mode display is used to adjust the tool position before the cutting process is carried out. To return to automatic mode, click the AUTO button.

The microcontroller that is used to translate movement data into motion is the Atmega328 which is already connected to the Arduino Uno control board. The Arduino Uno control board can be seen in Figure 4.

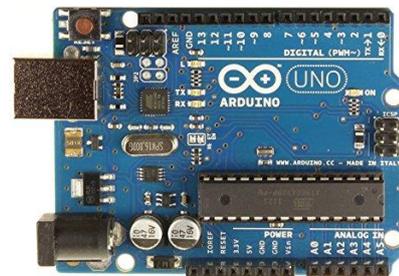


Fig. 4. Arduino Uno control board [6].



Fig. 5. PWM Driver.

The control board has a tracking digital I/O of 13 units and some of these pathways can be used to control a DC motor rotation by utilizing pulse width modulation (PWM). PWM driver is a signal amplifier that comes from the microcontroller. The input section of the PWM driver receives the PWM signal from the microcontroller. The output section of the PWM driver outputs a PWM signal with a larger voltage value in accordance with the external voltage supplied to the PWM driver. The PWM driver can be seen in Figure 5.

A servo motor is a rotary actuator or device designed with a closed-loop feedback control system so that the rotational speed and the number of rotational rotations of the motor shaft can be adjusted. A servo motor is a device consisting of a three-phase AC motor, a series of gears, a control circuit, and a potentiometer. The servo motor is equipped with a servo motor driver. The servo motor driver has two input legs. The first input foot is used to determine the direction of the servo motor shaft rotation while the second input leg is used to adjust the number of servo motor rotations.

Communication between the computer and the microcontroller is done using serial communication. Data that can be sent via serial communication is 8-bit data. Thus, if the data sent has a value of more than 255 then the data needs to be split into two pieces of data. Router machine control data consists of two types of data, namely control data to adjust the rotational speed of the cutting tool and control data to regulate cutting tool movement. The control data format for setting the router machine can be seen in Table 1.

TABLE I. G-CODE SYNTAX CONTROL OF THE ROUTER MACHINES

Syntax	Description
G0 Xa Yb Zc	Moving the cutting tools with a line trajectory at a predetermined speed
G1 Xa Yb Zc Fd	Move the cutting tool in a line with adjustable speed
G2 Xa Yb Zc Id Je Ff	Moving the cutting tool with a trajectory in the form of a circular arc in the direction of rotation according to the clockwise direction of the speed that can be adjusted
G3 Xa Yb Zc Id Je Ff	Move the cutting tool with a trajectory in the form of a circular arc in the direction of rotation counterclockwise at an adjustable speed
Sx	Determining the cutting tool rotation with the adjustable rotating speed

The pattern of sending the cutting tool movement data is basically sending the cutting tool movement data to move the cutting tool with the tool path in the form of a line with an adjustable speed. If the code used is code G0, then the tool speed has been determined by the program. If the code used is code G2 or G3, the arc path is converted into several line segments and then sent one by one to the microcontroller.

The strategy for sending data from the computer to the microcontroller must be arranged so that the movement data sent by the computer can be translated into motion by the microcontroller. The first data sent is the movement code data. If the computer wants to control the movement of the cutting tool, the computer will send the number 255. If the computer wants to control the rotation of the cutting tool, the computer sends the number 254. The next data is data related to cutting tool movement data or rotational speed data. The maximum number of data sent is 245.

The data related to the movement amounted to 15 pieces while the data related to the rotating speed of the cutting tool amounted to one. The data related to the movement are the direction of motor rotation, the value of multiples of 245 from the number of motor revolutions, the residual value for 245 from the number of motor revolutions, the value for the multiples of 245 from the pulse delay, and the residual value for 245 from the pulse delay. Because the number of motor rotations is three, the cutting tool movement data is 15 data. The data related to the cutting tool rotation is the speed of cutting tool rotational.

If the microcontroller accepts the number 255 then the variable number2 is assigned the value 0. If the microcontroller accepts the number 245 then the numeric variable is assigned the value 16. If the microcontroller receives a number less or equal to 245 then the variable numbers are added by 1. The variable numbers in this case shows what data the microcontroller is receiving. The data received by the microcontroller will be entered into a variable in accordance with the data received by the microcontroller. If the variable number 2 is equal to 15 then all the movement data has been completely received by the microcontroller. The microcontroller will drive the three servo motors according to the movement data that has been received from the computer. If number 2 is equal to 17 then the data related to rotational speed has been completely received by the microcontroller. The microcontroller will activate the DC motor rotation at the rotational speed according to the data received.

Setting motor movements performed by utilizing the timer on the microcontroller. Timer is an interruption to be executed for a specified time. The period interrupt timer is set for 10 micro seconds. Each interval of 10 micro-seconds a particular variable in the microcontroller (a0) would be a plus one. When the value of $a0 < a1$, the pin 13 of microcontroller rated HIGH. When the value of $a0 \geq a1 * 13$ pin microcontroller rated LOW. When the value of $a0 \geq 2 * a1$ a0 value is returned to zero. The graph of the value of a0 and the condition of pin 13 against time can be seen in Figure 6.

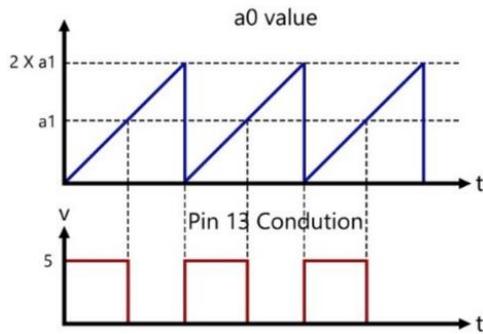


Fig. 6. Graph of a0 value and condition of pin 13.

Every time the value $a_0 \geq 2 * a_1$ the value of the variable a_4 is added by one. The variable value a_4 states the number of pulses that have been conveyed to the servo motor. When the number of pulses has reached the predetermined number of pulses, the microcontroller will send a signal to the computer that the motion execution has been completed. The other servo motor controls are similar to the control of the first servo motor. The a_x variable is replaced by b_x for the second servo motor. The a_c variable is replaced by c_x for the third servo motor. In this way the servo motor can be controlled simultaneously.

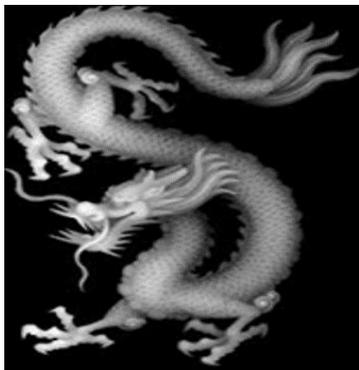


Fig. 7. The engraving motif will be made in BMP format.

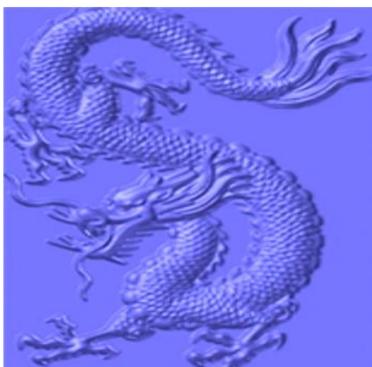


Fig. 8. Engraved motif after being imported into CAD/CAM software.



Fig. 9. Results engraving using a router machine.

III. RESULTS AND DISCUSSION

Mechanical systems and engine control systems routers that have been made need to be tested to ascertain whether the machine is able to create the desired pattern of wood carving. The engraved patterns are obtained from files in the bmp format which are typically readable by CAD / CAM programs. A file with a carved pattern can be seen in Figure 7. The file is imported into CAD / CAM software so that an engraving model is obtained as can be seen in Figure 8. The dimensions of the engraving model can be adjusted according to the wishes of the maker. After the carving model has been successfully created, the next step is to simulate the rough engraving process and the fine engraving process. The simulation results can be seen to determine whether the parameters of the engraving used for coarse and fine engraving are able to provide the desired engraving results. From the simulation can be generated NC program to do the actual carving. The NC program is opened in an application that was created to do the actual cutting. The results engraving using NC program is generated from software CAD/CAM can be seen in Figure 9. Dragon carved measure $18 \times 28 \text{ cm}^2$ would be completed within two days.

IV. CONCLUSION

From the test results, it can be concluded that the router engine control system capable of engraving by the NC program that has been generated by the software CAD/CAM. The resulting carving pattern is a fairly complex pattern. The time required to complete a carving pattern is still quite long. Still need to do experiments on engraving parameters to determine the optimum engraving.

The use of a servo motor as a driving motor gives better results, in ease of control and the work results obtained from a controlled NC router machine, when compared to using a stepper motor as a motor as used by previous researchers [3-6, 9].

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