CNC Router

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Statement of Purpose:

The purpose of the project is to improve upon the 2018-2019 senior design team's CNC Router Table project. The project should provide educational, commercial, and industrial benefits, this includes: a reduction of cost, increase in efficiency and opportunity to showcase electrical, mechanical and software components in an educational environment.

Scope and Methodology:

To begin, a CNC router is a computer numerical control, which is a machine that is very similar to the commonly used handheld router that is utilized for cutting various materials. A CNC router can aid in the cutting of materials like steel, wood, aluminum, composites, plastic, and foam. (1) This project will be focusing on the use of wood but could eventually utilize the other materials. Much of the mechanical work was completed by the 2018- 2019 senior design group, which will be built upon with our design. The router will be designed to determine the size of the board being placed, with medal arms holding it in place. This will be achieved by adding mechanical and electrical components to the existing CNC router.

Applicability and Who Will Benefit:

By adding these improvements, students will be able to learn and understand the electrical and mechanical mechanisms within this project. To make it adaptable for labs, there will be an option to change the designs and sizes of boards according to the professor's instructions. The improved router can also be used for industrial use, due to its versatility and

adaptability. Giving the router a manual/auto switch, a company can cut costs when needed but not having a person run the machine. This project will immediately benefit Miami University, due to its location. The CNC router is located at Miami University in Hamilton, Ohio, which will be incorporated into mechanical and electrical engineering courses once completed. In the future, the changes being made could benefit manufacturing factories in cutting costs and increase productivity within the factory.

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Objective:

The initial goal is to improve upon the Computer Numerical Controller Router project from the 2018-2019 Senior Design Team. Also, provide a system that could be used in both educational and industrial environments. The router originally was limited in use but provided a way for a future class to improve upon. Some changes made were:

- Add a fully functional automatic option with that addition of an auto-manual switch.
- Introduce an Automated Guided Vehicle (AGV) for this autonomous feature and establish communication between the Router and the vehicle.
- The size and location of the workpiece would be detected with an optical sensor. The system would detect up to three different sizes of wood.
- Once the workpiece is detected, a windshield wiper motor would move two clamps into place to keep the workpiece steady.
- One of three chosen shapes from the program used would then be cut onto the board.

An overall versatile system could be used in many different environments that provide immense benefits, given the function. Potentially, students would be able to use this project in an educational environment, given the mechanical, electrical and software components. Alternatively, this project, with added improvements could be used in an industrial or commercial environment with added benefits. These benefits stem from the autonomous components implemented with the addition of the auto-manual switch. With this component, it could potentially reduce man- power and costs, while increasing productivity.

Unfortunately, due to unforeseen circumstances, the automated guided vehicle was unable to be introduced and the mechanical components were not mounted on the router. The router was left on campus in March of 2020, when campus was closed. Instead, this deviation from the original plan gave an opportunity to improvise with the usage of a home-used laser engraver.

This laser engraver took the place of the router left on campus and allowed for the completion of a simulation of the project.

Background:

The original router from the 2018-2019 Senior Design team is pictured above. The X and Y axis of the controller are controlled by NEMA 34 Stepper Motors and the Z axis is controlled by a NEMA 23 Stepper motor. A breakout board was originally used to distribute the signal brought in by MACH 3 software. The entire design utilized G-Code, which is a linear, step-by-step programming language used in CNC machining. The router could recognize one particular size of wood and a predetermined design could be cut into the wood. The overall goal was to expand the operation of the entire system. (1)

Figure 1. Original router designed by the 2018-2019 Senior Design Team.

Mechanical Components:

The 2018-2019 senior Design Group was able to complete the frame and have a working mechanical and electrical component as a base for the new project. Due to the frame being completed there were several other components to be attached to complete the new CNC router. The main components that were created included: a chain drive, motor, control panel, clamping arms and a torque switch. With these new components added, a board may be placed, and the clamping arms would be able to hold it in place while the router completed its design. These components were built and welded together but left to be welded or attached to the frame of the router.

Chain Drive:

The chain drive moved rotational force from the motor to the clamping arms. Using sprockets of different sizes, we got a 1.5x torque advantage from the motor. A spring tensioner was being built before the pandemic hit; it was never finished or photographed. Lock nuts that have a conical end were used to center the sprockets for welding. On the left- handed rods, the

right-handed threads were drilled on the nut, and slid onto the rod. The sprockets were centered and welded together.
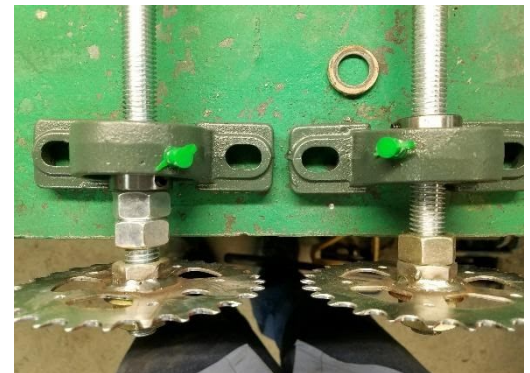
Figure 3. Left and right- handed rods used for the clamp

Wiper Motor:

A wiper motor was chosen for power because of its high torque, and it being cost efficient. Having a worm

gear motor was also great because it will "park" itself. It will not rotate without being powered. This provided an opportunity to clamp the workpiece without loosening after the jaws made full clamping force. A motor from a car with a large windshield was used to help provide the extra torque. At peak lock-up force, it should draw almost thirty amps. The thirty amps provided along with the twelve volts would create around 360 Watts or .481 horsepower.

Figure 4. Wiper Motor used for the clamp operation.

Control Panel:

A control panel was added for auto and manual use. The switch on the left was to close in manual mode, the one to the right of that was to open. The start switch was to the right pictured in figure 5. The buttons used on the control panel were standard arcade video game buttons. The E-Stop panic button's purpose is to stop the operation in the event of an emergency. Two Normally Closed (NC) contacts were used that could handle high electrical current. The hole on the bottom was for a DPDT (double pole, double throw) selector switch for manual/auto control. This switch provided the option to have a fully autonomous mode.

Figure 5. *Control Panel*

Clamping Arm:

The clamping arms were made from ⅝ threaded rod. The loss of process speed was expected so coarse thread was used but the wiper motor had enough torque to mitigate that. If a fine thread were used, the motor would provide enough power to fold a sheet of ¼ plywood in half. One rod was right hand thread, the other left hand. The rods were joined by a right hand/left

hand coupling nut in the center. This would ensure that no matter what, the workpiece would always be centered.

Torque Arm:

Power was limited by the torque arm. When full torque was reached, the motor's sprocket would "climb the chain" and hit a limit switch knocking out the manual mode relay or sending a signal to the controller that the workpiece was clamped. An adjustable spring would be mounted to the bottom of the arm, allowing adjustment of the torque applied.

Figure 6. Motor welded on the torque arm

Electrical Components:

The purpose of changing the electrical components of the original CNC router was to integrate a new system for communication and design with changing out the black board with Raspberry Pi. This allowed for communication to an AGV (automated guided vehicle) and add new physical components to the system with extra pinouts for future development and programming. For the new project this semester, it was decided to add new physical components to communicate to the Raspberry Pi to allow future students to understand the mechanical and electrical components throughout an entire system.

The main component in the electrical communication is a Raspberry Pi, this was switched out from the original Blackboard. The original Blackboard had very limited inputs and output while the Raspberry Pi has 40 GPIO's (general purpose input output) pins. This allowed for the CNC router along with its motors and stepper drivers to run along with other applications attached to the Pi. For the new project this semester, it was decided to add new physical components to communicate to the Raspberry Pi to allow future students to understand the mechanical and electrical components throughout an entire system. An auto/ manual switch would have been added, to allow the AGV to utilize the router while not in use by a person. An optic sensor would have been mounted, which could detect if the AGV is positioned correctly. Once the optic sensor sees that the AGV is in position, it would send a signal to continue the communication process. Two four- channel transmitters would have been added to communicate to the AGV, two channels will be used on the CNC router while one will be used on the AGV. A communication chart is shown below:
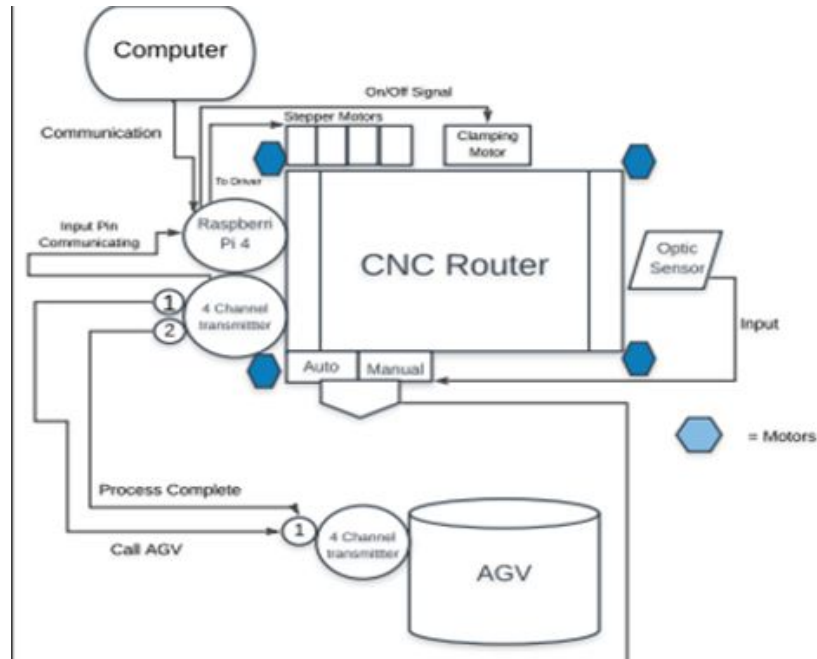
Figure 7: Original communication plan before the stay at home order.

Not only does the Raspberry Pi have 40 pins for inputs and outputs, it also has capability of holding up to four USBs, along with an HDMI and ethernet ports. This allowed for a user to display the Raspberry Pi using a monitor and controlling it with a keyboard and mouse by using the USB port for a dongle. To get more capability out of the Raspberry Pi 3, a Raspberry Pi CNC board V2.6 was purchased, to run a CNC machine. (5) Due to the hat only using 12 of the 40 pins on the Raspberry Pi 3, more room was able to be utilized for the other physical components. The CNC hat has the capability to withstand up to 12 to 36 volts and 1.13 amps, making this the perfect controller to have for the CNC router. The hat can operate the X, Y, and Z motors through stepper drivers (Longs DM860A) going to the router. (5) There is also a port to control the spindle of the router head, to make designs in the board using pulse width modulation (PWM). The PWM allows for better control over the milling process.

Mach3 software was used for the design of the 2018-2019 senior design group, which allowed the group to control the original router using G- code. Due to the controllers being switched out for the Raspberry Pi the software was also switched. Raspberry Pi allows applications to be downloaded onto the controller thus allowing an application called bCNC to interpret the G- code. bCNC is an advanced fully featured g-code sender for GRBL and is a cross platform program (Windows, Linux, Mac) written in python. (3) (4) Once a G- code file is added to the CNC program a port is opened, for serial communication to take place between the CNC hat and Raspberry Pi. To create the design a program called Fusion 360 by Autodesk was utilized. This program allows users to create a design, choose what type of machine they are working with and the size/kind of bits they will be using, to generate a more accurate G- code with Fusion 360.

Due to the stay-at-home order for the covid-19 project was not completed in its entirety. The size of the router hindered the ability to transport it away from the school, causing the team to create a new project at the home of one of its members. A frame and other electrical components were used to create a laser engraver which was completed in place of the original project. Unfortunately, the physical components that were going to be added were not able to make it onto the laser engraver due to the size. The communication for the laser engraver is comparable to what was originally going to be changed out on the CNC router. The laser engraver frame originally had an off-brand Arduino along with three motors, two controlling the Y axis and one controlling the X axis. By following the original plan for a CNC router, the off-brand Arduino was replaced with the Raspberry Pi and powered with 12.5 volts with a power supply. The motors were originally attached by molded quick disconnect cables with both Y axis

in separate terminals. Using the screw block quick disconnect terminal the Y axis was connected in the same terminal series. The reason for connection in series was due to allowing enough current to be drawn for the motors attached to run with enough power and for the axis to run in the same direction. Using A4988 stepper motor carrier and jumpers, allowed for a more accurate executed design using 1/16th resolution for the design. (2) Using resources found in the home environment, the laser engraver was able to operate and follow patterns generated by the G-code.

Conclusion:

Even though the mechanical components were not physically attached to the router fixture or total communication was achieved with the automated guided vehicle, an avenue was left open for future students to take the project, improve it and implement in the proper setting. They can utilize the mechanical components that were designed, built, and welded together, like the control panel, wiper motor, spindles and bearings and the chain drive. Those components can be easily mounted on the router. With the electrical and software components, communication was established between the Raspberry Pi and the home-used laser engraver that simulated the router.

Overall, a unit is provided that includes all aspects of electro-mechanical engineering technology that could be used in an educational environment for years to come. Students could learn the mechanical, electrical and software components and interactions associated between them. The project is left open for future senior design groups to build and improve what was accomplished in the past year.

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