Retrofitting of CNC Bench Milling Machine with Raspberry Pi

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Abstract – *This paper deals with the development of a low cost open-loop controller based on the Raspberry pi in order to reuse an existing CNC machine for performing simple manufacturing operations and to make it to control the CNC machine from any place of the world through internet. The design of low-cost control unit for the small milling machine used in the educational institution is the need of hour for the optimum utilization of the available existing resources in the institution. The goal of the work is to convert the obsolete machine to working machine so that it gives the practical knowledge, hands on training about CNC machine to the students. The machine considered for our study is the MTAB make CNC bench milling machine of 20 years old which was considered obsolete due to very high repair cost. The obsolete machine was carefully studied, the problems were identified and the required retrofitting was done. To provide low-cost solution opensource software Inkscape, universal G code sender, Raspberry Pi, RPI Protoneer CNC shield was used. The raspberry pi-based control unit was designed taking its advantage of small size, low cost, the drivers can be easily mounted over it. The machine was returned to its normal working. The CNC machine can be operated through an android mobile making it as a wireless controller. The machine can be be operated, monitored and controlled from any place of the world through internet of technology. Thus, the obsolete machine was converted into a smart CNC machine with low-cost available resources.*

Key Words: Raspberry Pi, Retrofitting, Wireless controller, Internet of technology, Low cost

1.INTRODUCTION

 Milling is the machining process which uses rotating tool with multiple blades to remove material by advancing the work piece into the tool to get the required shape in the workpiece. Computer Numerical Control (CNC) milling machine employs computerized control and rotating multi point cutting tools to remove the material from the work piece to produce a custom designed part for material such as metal, plastic, glass and wood etc. Computer numerical machines (CNC) which are used in the educational institutions are brought with high cost. These CNC machines could last up to ten to fifteen years even with regular maintenance. The machine will be considered obsolete after ten to fifteen years of services. Later the institution would buy a new machine or upgrading the old machines which

process is extensively known as "retrofitting". The cost of new CNC machine or repairing it with the company persons is very high. For the educational institution it will be a big financial load.

Figure 1: The XL MILL CNC machine considered for studying

Some works were carried out regarding retrofitting of CNC machine. S. Sridevi et al [1] had developed implemented and tested a methodology of retrofitting for CNC vertical milling machine so that the service time of the CNC machine can be increased with low cost. In this they had used industrial standard breakout board, motor driver, motors and sensors. Saif Aldeen Saad obayes et al [2] had explored the theories and techniques behind procedures of wireless controller system for mini-CNC milling machine based on Raspberry Pi and Arduino. Their developed controller enables the CNC machine tool to be controlled based on wireless communication and the NC data was generated from CAD/CAM systems. Pulkit Bhasin et al [3] had designed and fabricated low-cost three axis wood working mini portable CNC milling machine for student's skill development using Arduino microcontroller, stepper motors and GRBL shield.

For our study we had considered a MTAB make XL MILL CNC machine as shown in Figure 1 which is of 20 years old machine. It was considered obsolete due to very high repair

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cost from the company personnel. We had developed a Raspberry pi and RPI Protoneer CNC shield-based CNC controller which was very compact and of low cost.

2. Overview of the system

The Raspberry pi-based controller consists of Raspberry Pi 4, Protoneer RPI CNC, wireless key board, wireless mouse, monitor, memory card etc. Raspberry Pi is very compact credit card sized computer, through this other hardwares like CNC protoneer, motor drivers can be readily interfaced with it. The Raspberry pi will help the CNC machine to control it and makes it smart through internet connectivity. The machine can be controlled using an android phone and over an internet from any place of the world. The Raspberry pi was interfaced with protoneer RPI CNC, connected with monitor, wireless keyboard, mouse and is given with 5 V power supply. The RPI CNC protoneer is also small in size and very powerful CNC controller. It is connected with spindle motor through a relay switch, A4988 drivers through which X, Y, Z stepper motors are connected. The Figure 2 shows the overview of the Raspberry pi-based CNC controller.
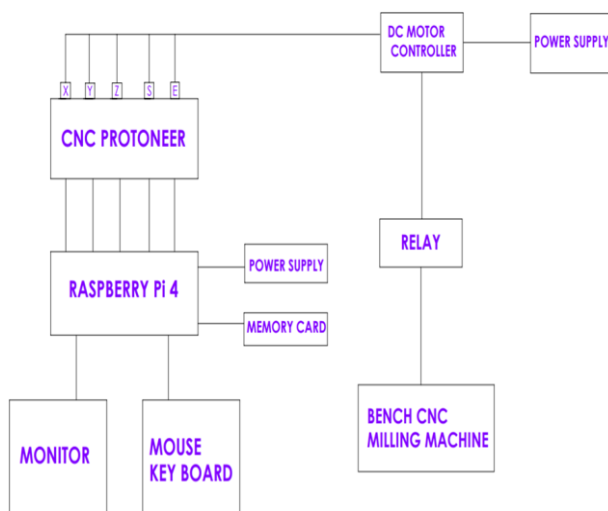

Figure 2: Raspberry pi-controlled CNC machine overview.

Various components such as RPI CNC Protoneer, stepper motor drivers etc are connected to the Raspberry pi. The Figure 3 shows the schematic view of the Raspberry pi CNC controller. The Raspberry pi will be installed with Raspbian operating system. The Universal G code sender GRBL is crucial in the working principle of the CNC machine. It's a firmware that we need to install or upload to the Raspberry pi so it can control the stepper motors of the CNC machine. In other words, the function of the GRBL firmware is to translate the G-code into motor movement.

The GRBL machine settings has to be made for the accurate and precise movement of the CNC machine as per the commands given in the Universal G code sender.

Travel Resolution along X, Y and Z axis \$100, \$101 and \$102 in steps/mm is calculated as

$$\text{Steps per mm} = \frac{\text{steps per revolution} * \text{microsteps}}{\text{mm per revolution}} = \frac{200 * 2.5}{5} = 100$$

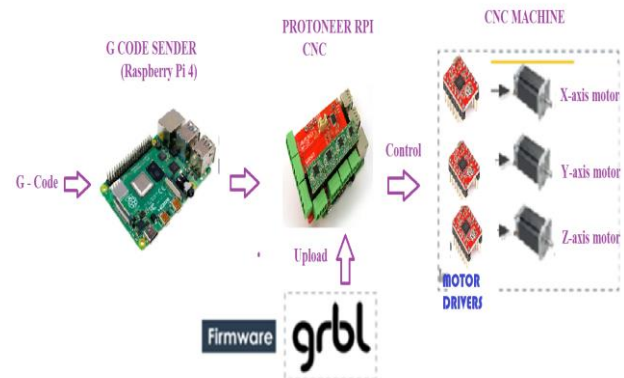The travel resolution, maximum rate, acceleration is calculated along X, Y and Z axis.

Figure 3: The schematic view of the Raspberry pi CNC controller

The GRBL machine settings were calculated and fed to the Universal G code sender.

3 Making the CNC Machine Smart

Using the available resources, the machine is made to work smartly by adding the convenient smart features to the machine as shown in the Figure 4. Firstly, using computer aided design tool such as Auto Cad, a part design is made for the required geometry, the CNC program can be written by manual programming for simple drawings or G codes can be generated using Inkscape software tool.

The generated G codes are uploaded to the Universal G code sender GRBL controller which was installed in the Raspberry Pi. The Universal G code sender will send the signal to the CNC RPI protoneer shield. The RPI CNC Protoneer will give the command to the spindle motor and stepper motors through A4988 drivers. The work table is moved in X, Y and Z axis according to the G code commands. The spindle motor rotates the tool and the machining process will be completed.
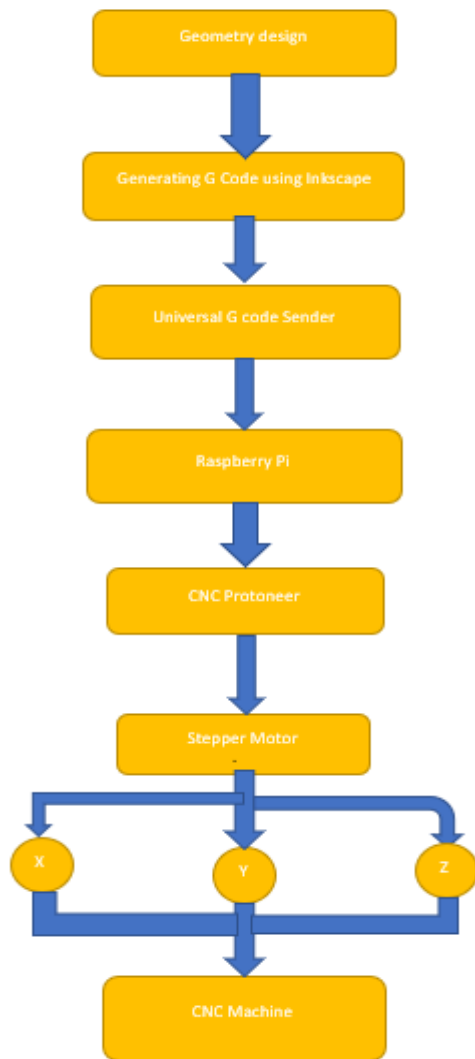
Figure 4: Block diagram showing the flow of work

3.1. Control of CNC Machine using a smart phone.

The CNC machine is made to monitor and control using an android mobile. It permits the wireless control of the machine using a WIFI network. The mobile will work as a Pendant and can be carried any where around the machine. The program can be written in the mobile and can be uploaded to the CNC machine. The work zero point can be made to set by using jog command over X, Y and Z axis as shown in Figure 5.
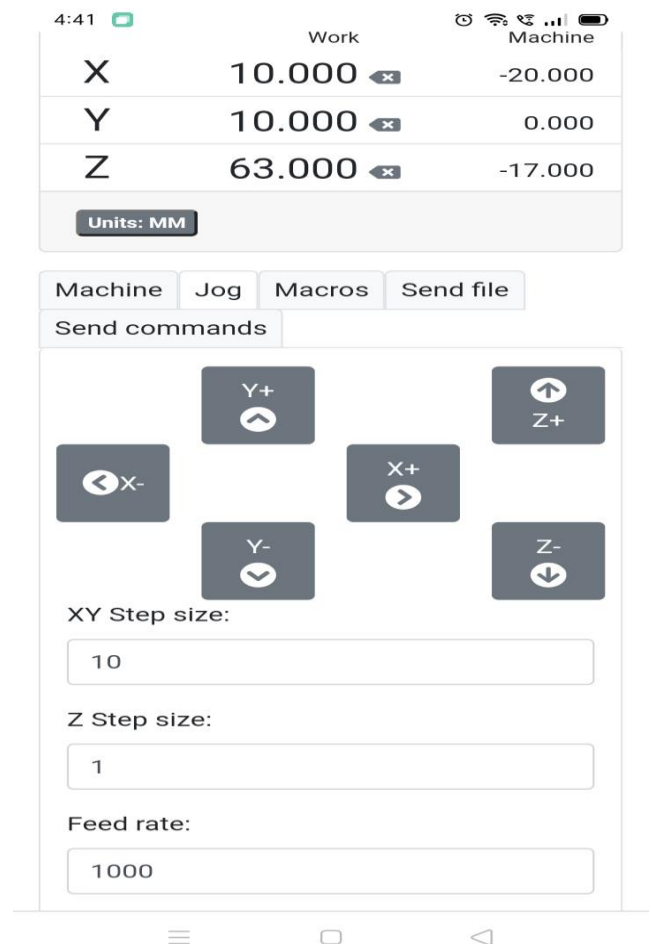

Figure 5: The pendent screen of the CNC machine on the mobile phone.

The feed rate, step size can be set along X, Y, Z axis and the worktable can be moved according to the workpiece. The Program can be paused and stopped at any time during the milling operation through the smart phone.

3.2 Controlling of CNC milling machine with internet

The CNC machine is made to work remotely from any place of the world through Virtual network computing. The virtual network computing uses remote frame buffer RFB protocol for remote access of the system.
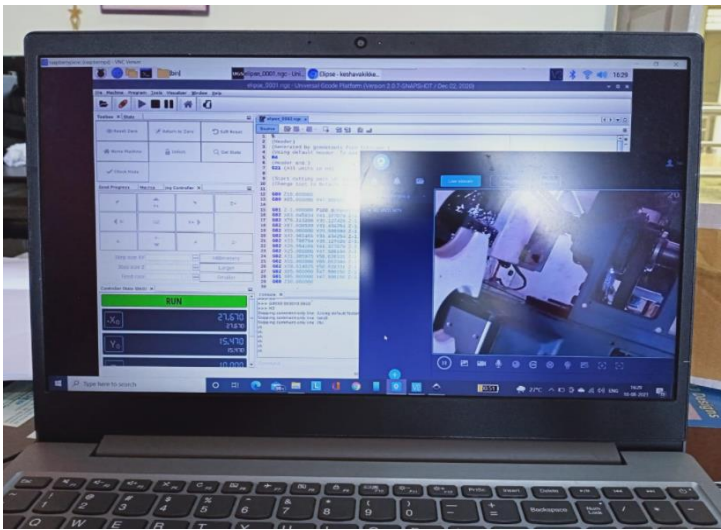
Figure 6: Remote computer with UGS controller and IP camera

An internet protocol IP camera is used for viewing the live video of the CNC machine in a remote computer. The remote computer controls the CNC machine with universal G code sender through VNV Viewer. The program can be written and uploaded to the CNC machine, the live machining process can be viewed from the IP camera. This helps the remote computer operator to take corrective actions required remotely and makes our CNC machine smart.

4. RESULTS AND DISCUSSION

The obsolete machine was converted into a working machine with very low cost. The raspberry Pi was tested for its working for long hours. Any shape of the milling process can be done through the CNC machine.

A program was written manually for a profile milling which included linear and circular interpolation. The program was fed to the CNC machine, the machining was done and got the workpiece as shown in Figure 7. The dimensions were accurate as we specified in the program.

Figure 7: Profile milling done using CNC milling machine

The complex CNC programs can be genera ted using Inkscape. A CNC program for a letter MCE was generated using Inkscape. The G codes were sent to the CNC machine and the machined workpiece as shown in Figure 8.

Figure 8: Machined workpiece of the program generated using inkscape.

Students can get the hands-on training about the CNC machine. The CNC machine can be conveniently controlled through an android mobile making the machine wireless. The remote person located at any place of the world can monitor and control the CNC machine whenever required.

5. CONCLUSION

Using the raspberry pi-based CNC controller the obsolete CNC machine was converted into a smart machine towards industry 4.0.

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