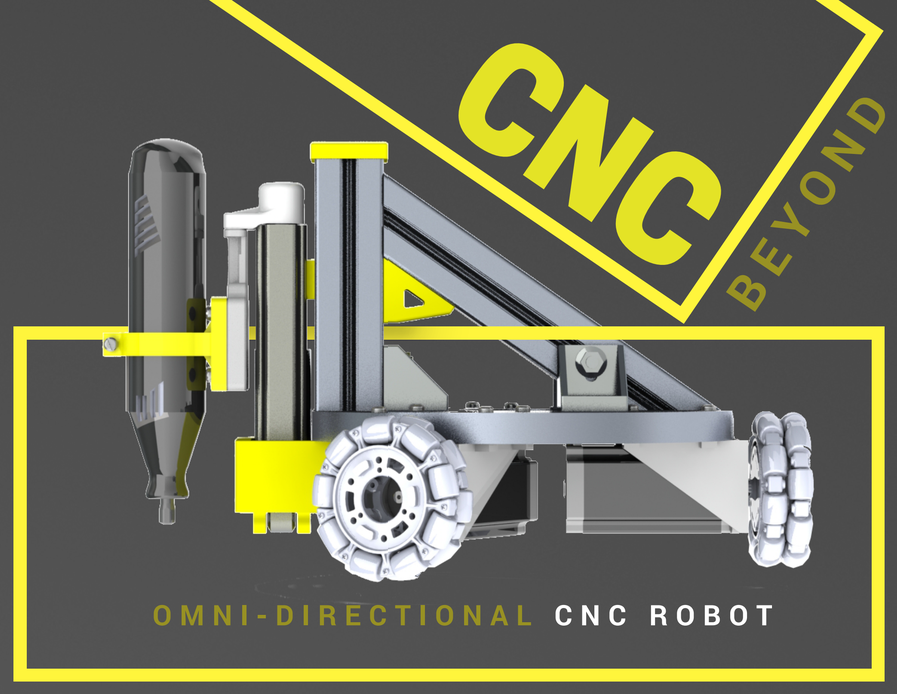
FOR MAKERS, ARTISTS, AND SPACE SAVERS IN MANUFACTURING



ESTABLISHING OUR PLACE IN THE MARKET

Hobbyist woodworkers and makers, are well versed in emerging technology and open-source design, but have limited options with respect to programmable cutting tools. Existing tools include desktop CNC mills, laser cutters, and CNC router tables designed to cut 4 ft. by 8 ft. sheets of plywood. These tools require a substantial upfront investment ranging up to several thousand dollars for larger units [1], and are normally too heavy to be deemed portable.

CNC Beyond is the only robotic, desktop CNC machine for under $1000.

While, the Goliath CNC (Figure 1) offers a different approach to the CNC machining of wood [2], with a small three-wheeled robot with a footprint similar to that of a robot vacuum cleaner and a weight of 10 kg, it is limited by positioning cables with fixed towers on the periphery of the workpiece. As well, the cost is upwards of $3000.

Figure 1. The benchmark, Goliath CNC [2]

REQUIREMENTS

PORTABLE ✓
AUTONOMOUS ✓
LOW COST ✓

To meet the needs of the target market, the product was designed to perform cutting and routing operations on plywood and hardwood up to 1" in thickness. For flexibility, tool change is made possible by custom 3D printed brackets. To allow at-home use, it operates from a standard 120 V mains electric outlet. Also, it was designed to be heavy enough to overcome slip yet also be easily carried. The consumer cost for the final design was calculated to be 951.44 CAD.

The prototype machine weighs 33 lbs and has a volume of 13.8" x 18" x 10.5".

BUILDING THE PROTOTYPE

To fill this market need, a thorough iterative design process was undertaken to refine the prototype (Figure 2).

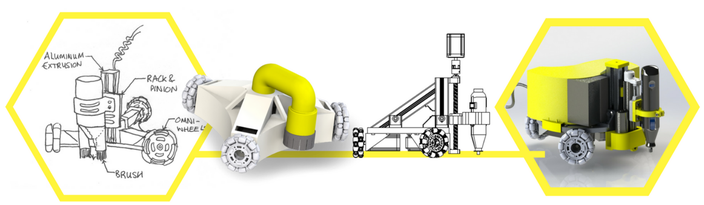


Figure 2. Design iterations

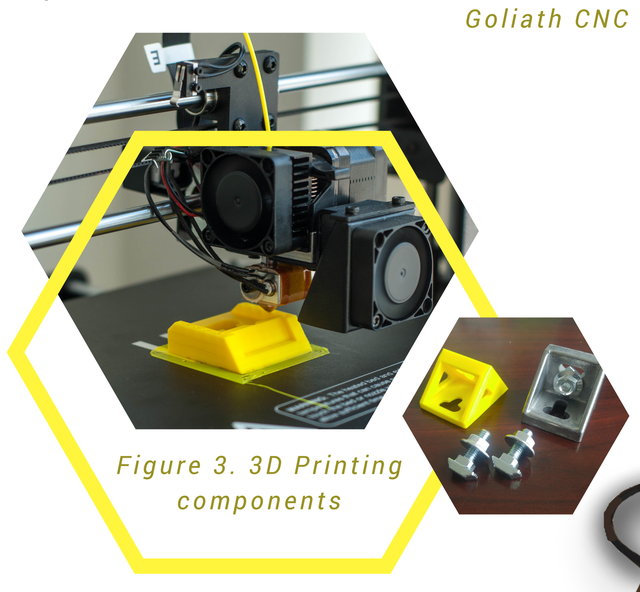


Figure 3. 3D Printing components

Rapid prototyping through 3D printing (Figure 3) was used extensively for the proof of concept. Structural components such as the base plate and aluminum extrusions were over-sized for their purpose in order to ensure a rigid and stable test bed.

VALIDATION

With a cutting force of 80N, a stress analysis of the main chassis was conducted using SolidWorks SimulationXpress. With distributed loads ranging from 50 N to 80 N, no yielding is expected based on von Mises stress analysis. Maximum deflection is on the order of micrometers and should not pose any problems.

Furthermore, the wheel design was chosen to minimize vibration and maximize range of motion, and supplementary damping was added to stabilize the z-axis.

FINAL DESIGN

Movement along the x-y plane is achieved by 3 omni-wheels mounted to stepper motors arranged 120° apart. The prototype uses a rotary tool as the tool head on the z-axis. Motion on the z-axis is achieved by an electrical 12 volt linear actuator that is tied to a slide potentiometer for position feedback. The structural system of the CNC Beyond robot is centred around a ½ inch aluminum plate base. Aluminum extrusions are used to mount the z-axis as well as the control board and power supply. Most mounting is achieved using metric fasteners and 3D-printed brackets.

Figure 4. Built CNC Beyond prototype

[1] "Personal CNC Mill - Tormach PCNC 1100", Tormach.com, 2018. [Online]. Available: https://www.tormach.com/product_pcnc_1100.html. [Accessed: 10- Feb- 2018].

[2] "Goliath CNC - An Autonomous Robotic Machine Tool for Makers", Kickstarter, 2018. [Online]. Available: https://www.kickstarter.com/projects/2130625347/goliath-cnc-an-autonomous-robotic-machine-tool-for. [Accessed: 05- Jan- 2018].

ACKNOWLEDGEMENTS

The authors would like to thank those who financially supported the development of a working prototype. Their contributions allowed new components to be purchased in order to better represent the design and lead it closer to success: *Rony Shohet, Dr. Filippo Salustri, Lior Beyderman, Heather Marsman, Farhan Riaz, and Dr. Ahmad Ghasempoor.*

As well, Dr. Frankie Stewart (the Faculty Advisor), Dr. Filippo Salustri, and Alan Machin were essential sources of advice and are gratefully acknowledged for their guidance in this project.