Smart End Effector for 6-DOF Robot

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***Abstract*—Collaborative robots, or Cobots for short, are a quickly emerging technology in Industry 4.0 [1]. These robots work alongside humans to perform repetitive tasks. The robot must change its tool or end effector in order to accomplish multiple tasks. Unused tools are securely stored in a tool rack, like in a CNC machine. The robot arm must interact with the rack to change tools. Improvements are needed to existing tool rack systems. We have worked to design a smart system by integrating microcontrollers into system components. A functional prototype was constructed to demonstrate the smart system.**

I. INTRODUCTION

Although Industry 4.0 is the revolution of smart manufacturing, many existing tool rack solutions are lacking smart capabilities. Many systems are purely mechanical, and all of the tool change process data is programmed into only the robot arm. The robot arm stores the home position of all the tools. If tools are manually swapped or misplaced, the robot arm would return to the saved tool position and select the incorrect tool. Operations performed with and incorrect too could result in catastrophic damage to production parts or the tools themselves.

In this project, we wanted to design a smart end effector and rack with the help of microcontrollers. The microcontrollers store data regarding the tool positions and control most of the tool changing system. This takes some workload off the robot operating system. The robot operating system and the microcontrollers work as one to change and control various tools.

The robotic tool change system consists of three components: the end effector, tool rack, and tool. The end effector is mounted to the robot arm and selects tools from the rack. Figure 1 below shows how the components interact.

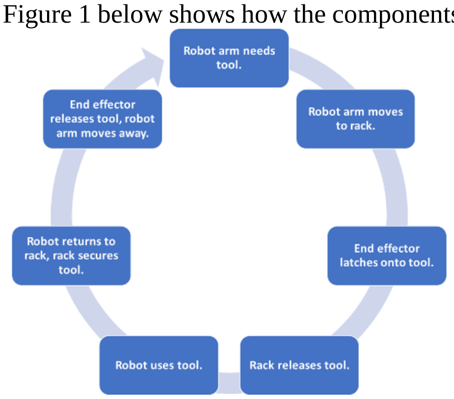

Figure 1 Robotic Tool Change Process

II. METHODS AND MATERIALS

A. Electrical

Parallax FLiP microcontrollers are integrated into each component to control system functions. Each microcontroller holds code that operates each subsystem to run correctly. The microcontrollers communicate with other subsystems using infrared communication. The system's power is provided by NiMH AA batteries which total to 9 volts per subsystem. All electrical solder connections were made on through-hole protoboards as seen in figure 2. Sockets were soldered onto these boards to allow for swapping of microcontrollers and driver boards.

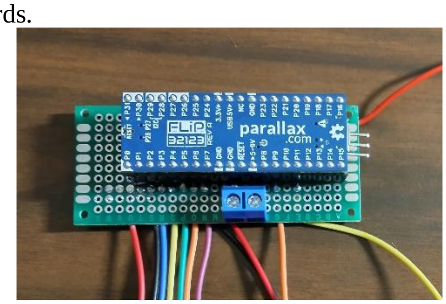

Figure 2 Parallax FLiP mounted on THT proto board.

B. Demonstration Tool

As seen in figure 3, this prototype uses a gripper as a demonstration. Many different types of tools can be used with this system. The gripper currently in use on the prototype is actuated via a NEMA 17 stepper motor. The gripper demonstrates the precise control possible with a microcontroller and stepper motor. The demonstration tool also has infrared LEDs to communicate with the tool rack and end effector.

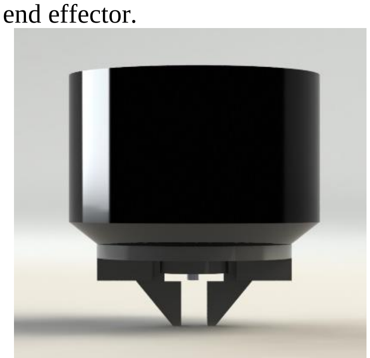

Figure 3 Solidworks rendering of the demonstration gripper.

C. Tool Rack

The tool rack, shown in figure 4, holds the tools when they are not in use. It will be located near the collaborative robot so that the tool can be removed or changed easily. The tool rack has been outfitted with both an IR receiver and a limit switch to detect the position of the tool. Currently, on the prototype, there is only room for one tool on the rack. However, on the commercial version of product there would be multiple tool holders. The tool rack mechanism opens and closes to secure and release tools.

Another important feature of the tool rack is communication with the human operator via a display screen. A small OLED screen is mounted on the tool rack at a 45-degree angle for easy viewing. The OLED screen displays information about the tool in the rack. The screen also tells the operator whether the tool rack is open or closed.

Figure 4 Solidworks Rendering of the Tool Rack

D. End Effector

The end effector (figure 5) is always attached to a robot arm. It has an internal servo mechanism to latch onto different tools. The end effector has copper contacts on the bottom that pair with contacts on the tool. These contacts provide power to the tool as well as signal connections between the microcontrollers in the end effector and tool.

The ring on the end effector may seem a bit bulky, but this was required to fit the six AA batteries needed to supply this component with 9V. This bulky ring can be eliminated in an industrial environment by feeding a DC power line to the end effector. A power connection to the robot arm will replace the bulky ring. For other components, the batteries were able to easily fit into the available space, resulting in slimmer overall parts.

Figure 5 Solidworks Rendering of the Smart End Effector

III. Results and Discussion

We were able to fabricate a working prototype of the smart end effector and tool rack. The end effector, tool, and tool rack all work together as one system. Figure 6 displays the assembled prototype.

Looking into the future, the team has identified areas of the project that could be expanded upon. These areas include minimizing the size of the components, testing the system with multiple tools and rack positions, testing with a robot arm, and developing printed circuit boards to replace the through hole proto boards.

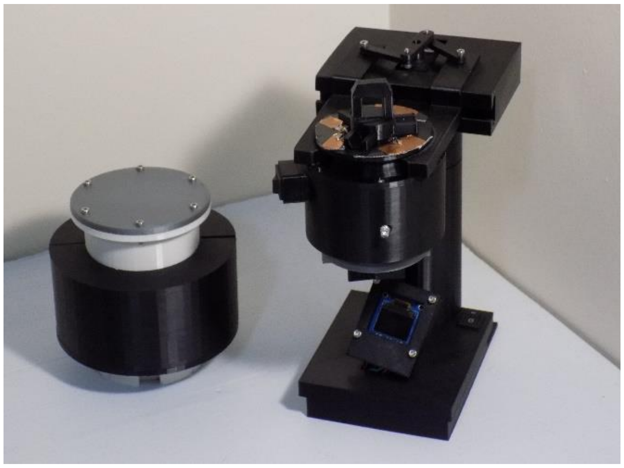

Figure 6 Assembled system components.

IV. CONCLUSION

This smart end effector and tool rack system offers a mechatronics solution to the tool changing process for collaborative robots. This product more closely aligns the robotic tool change process with the smart manufacturing goals of Industry 4.0. This project is ready for further development, flowed by implementation into manufacturing processes.

ACKNOWLEDGEMENT

The team would like to acknowledge our faculty advisor Dr. Frank Nickols as well as our TA Amin Roostaee for the help and guidance throughout the semester. Their efforts greatly helped the success of this project.

References

[1] Why cobots?: All the benefits of COLLABORATIVE ROBOTS. (n.d.). Retrieved from https://www.universal-robots.com/products/collaborative-robots-cobots-benefits/