ILR09

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TEAM F: ADD_IN

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Individual Progress

Software:
During this PR period I continued to make improvements to the path planning algorithm and GUI for the printer.

- For the path planning algorithm, I created multiple, slightly different versions. The original version always maintains the print nozzle at a fixed absolute angle to it's velocity vector, and on the side of path which points towards the centroid of the COTS item. Version two instead always points the nozzle towards the centroid of the COTS item, thus creating nozzle rotation while printing in a straight line. Version three uses a convex hull of the COTS item and always points the nozzle towards the vertex nearest the center of the path.
- For the GUI, I added persistence to the settings window. When the GUI is executed it searches MATLAB's home directory for a settings file, and if not available creates one. Every time a user modifies a setting within the GUI the change is saved. This simplifies use and enables faster testing since the user no longer needs to re-enter settings at each execution.

Firmware:

- Because of the unexpected complexity and bugs encountered in firmware, I helped Nikhil to implement the inverse kinematics portion of the firmware. The inverse kinematics works by computing the targeted position of the nozzle tip, and then generates the appropriate positions in the X and Y axis to compensate for the offset between the tip of the nozzle and axis of rotation. These calculations need to happen extremely quickly since they are performed within an interrupt service routine at (nearly) every motor step. With microstepping, the X and Y axes have 3200 steps per revolution so any bottleneck will significantly reduce the print speed. The printer's original firmware reduced computation time by precomputing the steps each axis must take at each interrupt, but this is no longer an option because the steps per axis changes as the nozzle rotates.
- Although not yet implemented, I also devised an algorithm to improve the speed of the IK calculations. Currently the function uses sin() and cos() functions and many floating point math operations. To eliminate this, I propose creating a lookup table of sin and cos values, and a linear interpolation algorithm to compute between them. The size of the lookup table can be scaled based upon memory availability, but would ideally be 6400 elements long (equivalent to the number of steps per revolution of the R axis). To avoid performing floating point math, the range of the lookup table can be scaled by a power of two (i.e. 2^14). All subsequent calculations can then be performed with integer math using scaled values, and the final result can be reduced to the correct range. Scaling can be performed extremely fast using bitshifting, thus avoiding slower multiply and divide calls.

Hardware:

- For hardware I have been helping Ihsane to CAD the nozzle assembly and design a more rigid version. His design currently relies heavily on 3D printed parts which creates significant flexibility of the assembly. If testing demonstrates this flexibility is an issue I want to be prepared with a solution.
- I also solved the nozzle jamming issue by adding a PTFE insulator into the barrel. The required wall thickness of the insulator is smaller than standard tubing sizes, thus I had to custom machine it. To do this I used a PTFE tube with an oversized ID, fixed it on both ends to an arbor (one end using a split shaft collar, the other end by clamping down in a lathe chuck) and then turned the OD in very small passes to avoid excessively torqueing the tube.

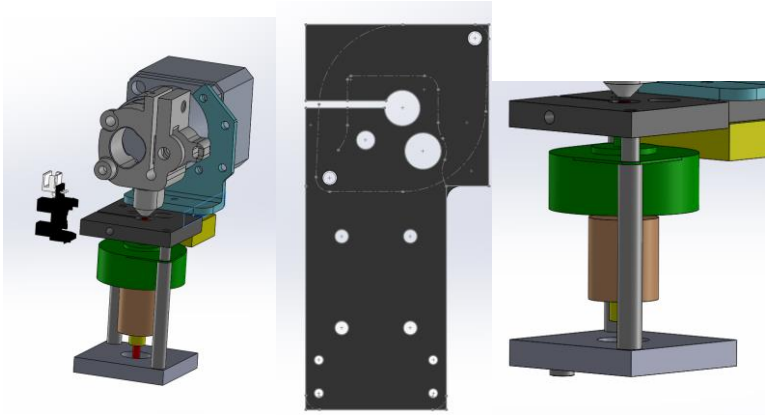

Figure 1-3: CAD Design of all-metal nozzle assembly. Left: Complete assembly. Middle: Carriage mount with flexure based on original M2 mount plate. Right: Closeup of support assembly to add rigidity near nozzle tip

Challenges

The firmware and mechanical subsystems have proven to be especially challenging. Firmware, which Nikhil initially estimated would be only a few days' work has turned into a multi-week project. Fortunately, barring a few timing issues and implementation of a homing switch sequence, it appears to finally be complete. Mechanical design has also been slow, as the mount has required numerous iterations for strength and clearance reasons. The current setup is usable; however, it is highly likely that the amount of compliance at the nozzle tip will produce low quality prints. Furthermore, there is still only partial provisions for a homing switch which will ultimately be needed for repeatable prints. In the coming weeks the team will have to manage it's resources well (both equipment and labor) so that these issues can be closed out while simultaneously testing the printer's quality.

Teamwork

Nikhil Baheti: Has continued work on firmware. His primary obstacle was debugging the IK code, which proved difficult due to non-repeatable failures suspected to be caused by race conditions/timing errors.

Ihsane Debbache: Has continued to work on mechanical design. He was able to obtain a CAD drawing of X carriage mount plate from MakerGear.

Astha Prasad: Is continuing work on software development – specifically focusing on porting our software to a web application. She has begun preliminary investigation of an appropriate framework to build out our website.

Future Plans

Our primary goal remains to get all subsystems functional and begin rapidly testing the printer to improve print quality. At a minimum, the remaining glitches in the firmware will need to be solved. It is also highly likely that another iteration of the mechanical design will be required.