Mobile 3D Printer
Team 1

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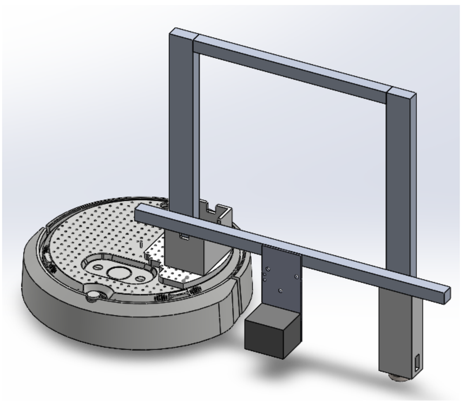
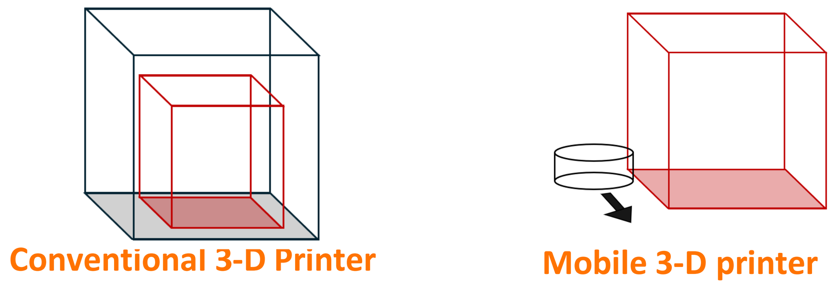
Abstract

- In conventional thermoplastic 3D printing, the scale of printable objects is limited by the size of the printer. A mobile 3D printer removes this constraint and can theoretically print objects which are arbitrarily large, with limitations on the geometry of the shape
- Our goal was to integrate conventional printing apparatus with a Create3 robot and print simple shapes (0.5m side length for a square, triangle, and circle)
- The key challenge in printing with thermoplastic is accuracy; ½ of the nozzle width is the minimum required accuracy to create a closed shape which is a difficult measure to achieve.
- We were able to successfully mount the printing apparatus to the robot and extrude material with combined movement of the print head and robot, however despite our efforts we could not complete multiple layers of print or achieve enough accuracy to create a closed shape.
- For future improvements upon this project, it is recommended that either the scale of print be reduced, or the size of the printing material be increased.



Introduction

- Traditional 3D printers are limited to printing objects which are smaller than itself. This project aims to expand the size of objects which can be 3D-printed; the world is our print bed!

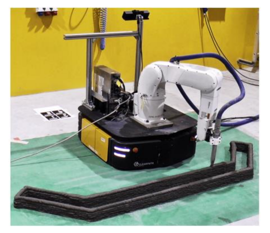


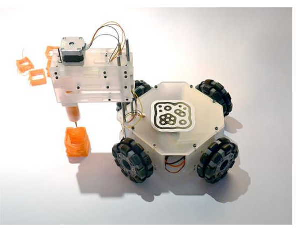
- Our sponsor's requirements were to use conventional 3D printing filaments (e.g. PLA), and to have autonomous printing by means of a Create3 Robot base
- This is the first iteration of this project, and our progress will be taken further by capstone groups in the future
- Our end-goal for this semester was to successfully integrate printing apparatus with the Create3 and to print a circle, square, and triangle (0.5m side length) with PLA. This would require a minimum robot movement accuracy of 0.2mm (half of our printer nozzle width)

Literature Review

- The mobile 3D printers that already exist fall into 2 general categories:
  - Printing large with nonconventional materials (clay or foam mixtures); these printers are physically large [1]
  - Printing small with conventional materials; these printers are physically small [2]

Our challenge is to print large with conventional materials

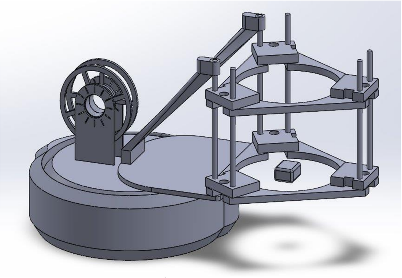

NTU 3D printing Robot [1]


PUC Rio 3&D Bot [2]

Methods & Discussion

As we ran into issues with our robot, we had to modify our scope:

- From making our own 3D printer to repurposing an existing one (Anycubic Mega Zero)
- From using slicing software to send printer instructions to writing G-code for manual instructions


December Concept:

Printer Testing

- The Mega Zero printer was modified to move only in the x- and z- directions. Various G-code commands written and sent to the printer successfully.

Sensor Testing

- Our sponsor lent us an XSENS sensor to improve our robot accuracy. It was found that the accelerometer data was not precise enough for our purposes and was thus omitted from the project

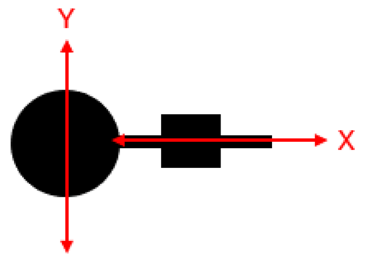
Robot Testing

- The minimum robot speed was found to be 0.03 m/s which correlates to a 1800 mm/min printing speed. Through G-code, we were able to successfully print at this speed. To test accuracy, standardized tests were conducted. This consisted of navigating simple shapes: 0.5m square, triangle, and circle radius measuring start and end position. Outcomes are summarized in the results section.

Design Challenges

Integrating Printer and Robot Movements

- Our final design has a 3D printer which is capable of x-z movement relative to the robot, and the robot contributes the y movement. This requires precise printer-robot timing and accuracy of movement to create a successful print.



- Conventional 3D printers print from above, but a mobile 3D printer deposits filament from the side which introduces a navigation challenge; the printer may run into/on top of already printed material if the navigation is not accurate

Equipment Restrictions

- Included in the sponsor's requirements was the use of the Create3 robot base, and to print using conventional 3D printing filament. The Create3 is not able to meet the precision needs of filament printing. To have a successful print, we must purchase and integrate accurate sensors or limit the range of objects which can be printed.

Software

- For our mobile 3D printer, we could not use traditional or available toolpathing software to map the path of the robot while printing. Challenges such as running over printed material or boxing in our printer with printed material, are not experienced by conventional 3D printers; a custom navigation software must be created for wide-scale applications.

Budget

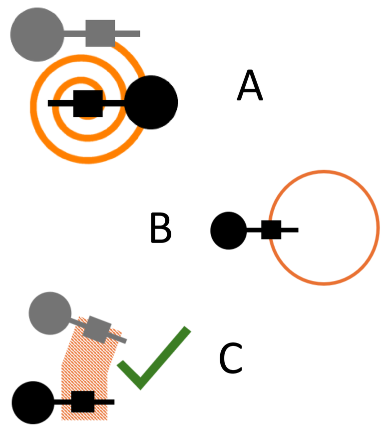
- To improve the accuracy of the robot, sensors that were outside our budget would need to be integrated. A limitation of the quality and usefulness of the sensors we had access to created unique challenges in achieving our accuracy requirements

Results

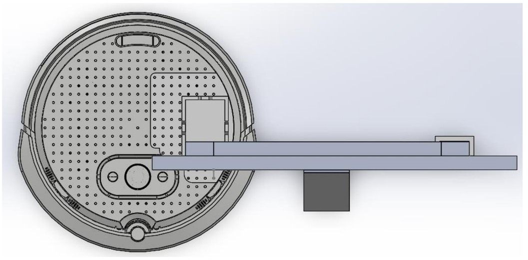
- Even though the robot accuracy was found to have improved by adding the printing mechanism to it, the accuracy remains insufficient for 3D printing with thermoplastics. The distance between the start and end positions of a square, triangle, and circle are shown in the table to the right. Recall that the minimum required accuracy is 0.2mm. Additional sensors were not found to be helpful in improving this accuracy

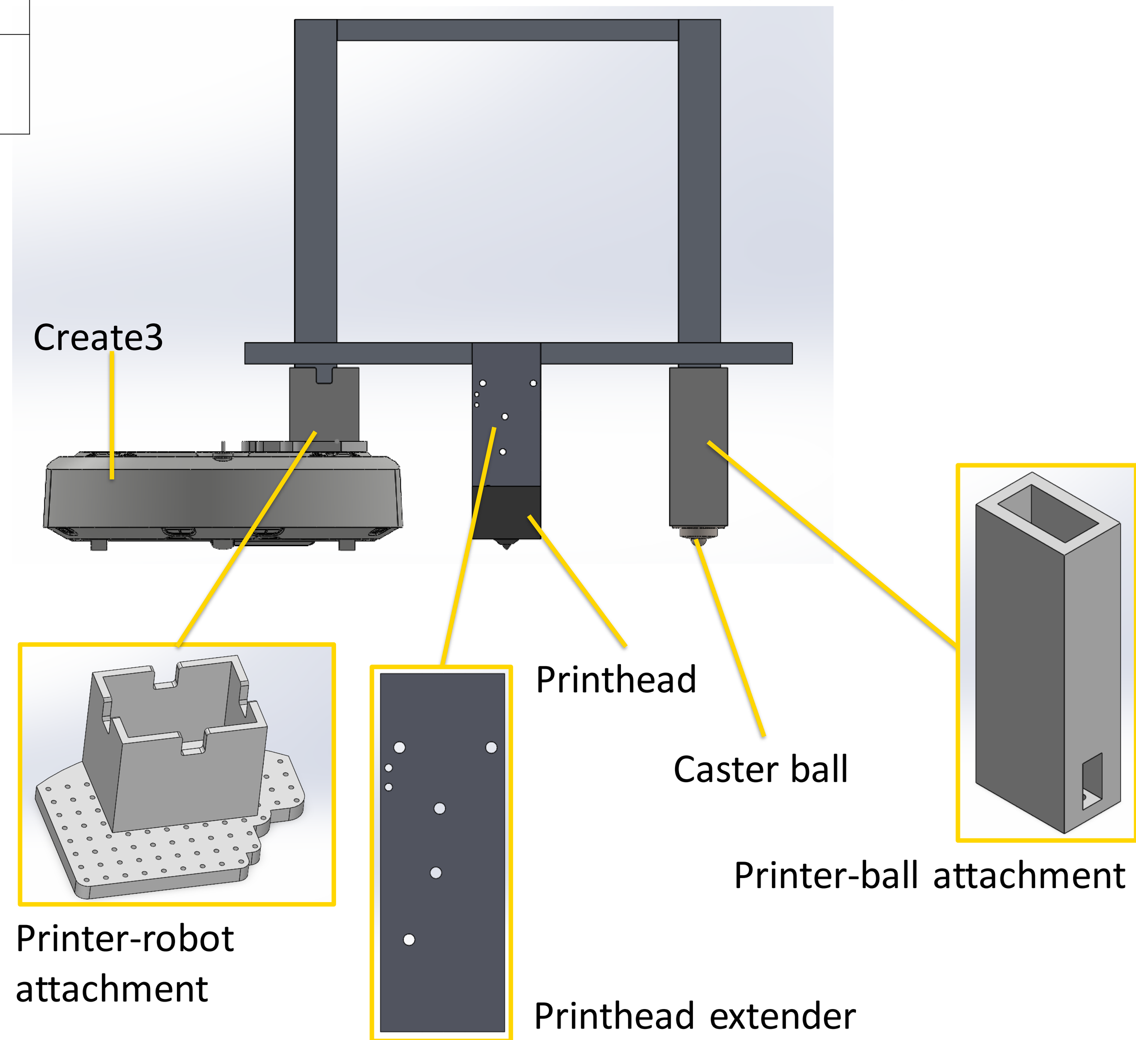
	Robot Drift (m)	Robot & Printer Drift (m)
0.5m Square	0.071	0.075
0.5m Triangle	0.185	0.063
0.5m R Circle	0.090	0.007

- The printer, even with sufficient accuracy, is limited in the shapes it can create due to its geometry. Additionally, it may not be able to create multiple layers of an arbitrary shape without driving over printed material (A) or becoming partially "stuck" inside a printed shape (B). There are shapes and prints that are still feasible (C), which maintains the relevancy of the design.
- The physical printer-robot prototype was successfully designed and created, and we are able to write custom G-code and robot paths to extrude material and move the robot simultaneously; further improvement in accuracy will increase the quality of the print



Final Design


Simplified top view



Note: certain design components (spool mount, battery bank, printer interface) have been omitted from this diagram for simplicity

Conclusions & Next Steps

- This project will be iterated upon in coming years. The main point of improvement is of course accuracy. Exploring more applicable sensors and navigation methods will be integral in seeing progress in the quality and complexity of achievable prints.
- For the next team, it is strongly suggested to follow one of the two following options:
  - Reduce the size of attempted prints and focus efforts on accuracy improvement and navigation/toolpathing software if print is using conventional thermoplastic filament
  - Switch printing material to a wide-track material such as clay or a concrete-foam mixture to soften accuracy requirements and maintain large-scale printing

References

[1] M. E. Tiryaki, X. Zhang and Q. -C. Pham, "Printing-while-moving: a new paradigm for large-scale robotic 3D Printing," *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Macau, China, 2019, pp. 2286-2291, doi: 10.1109/IROS40897.2019.8967524.

[2] H. Milkert, "3&Dbot Mobile 3D printer has no print volume limitations," 3DPrint.com | The Voice of 3D Printing / Additive Manufacturing, https://3dprint.com/15508/3dbot-mobile-3d-printer/

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