Robotic 3D Printing for Complex Geometries

Implementation, Development and Testing of a Robotic 3D Printing System

Scope

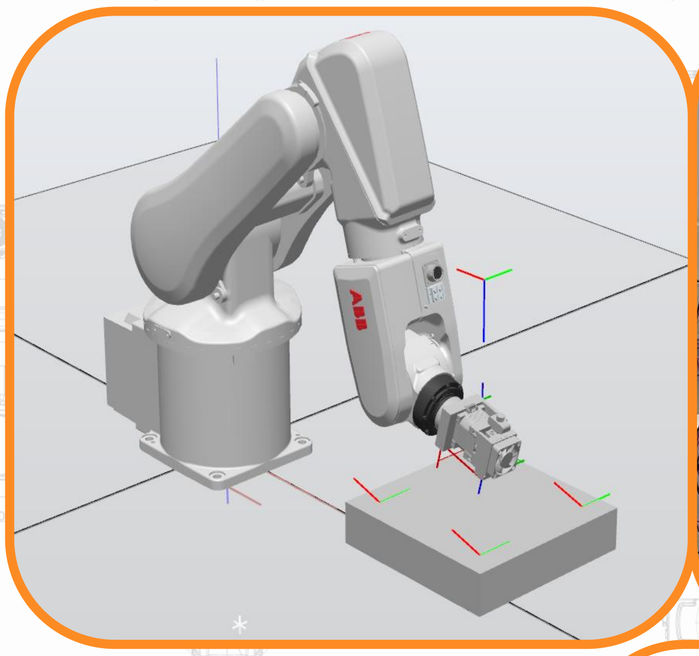
The goal of the project was to establish a **robotic arm-based 3D printing system**. This would be later developed into a **multi axis printing system** for use in further research. The system needed to:

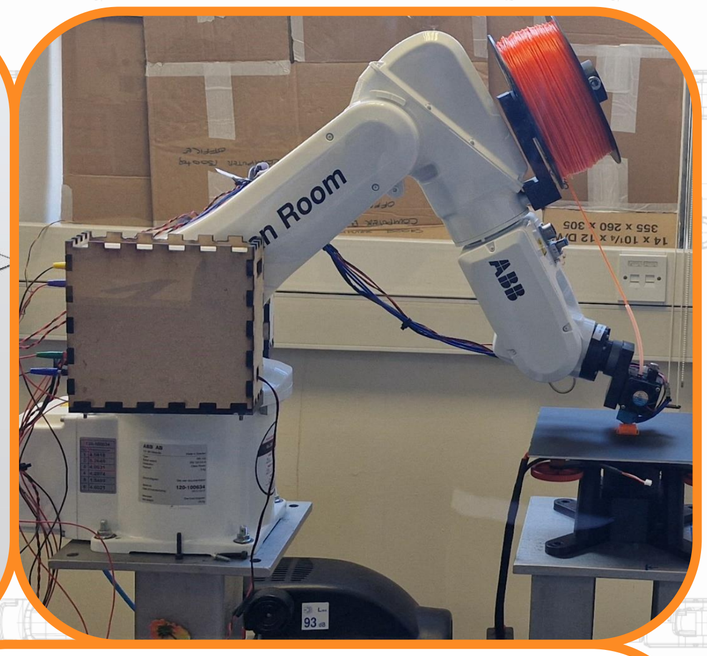
Requirements

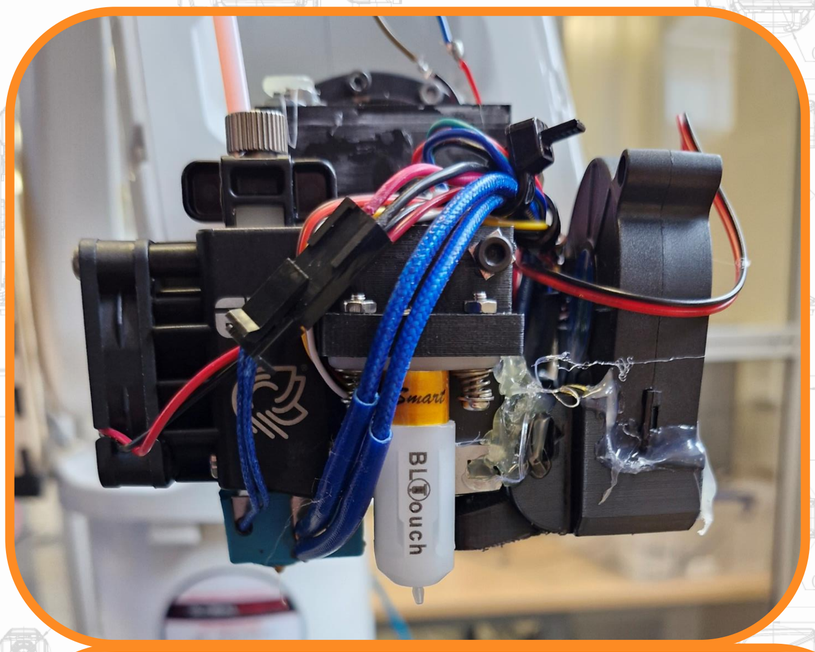
- Be based on the **ABB IRB 120** robotic arm
- Use **off the shelf** components
- Replicate the print **quality of a desktop 3D printer**
- Convert conventional **GCode into Rapid code**, used to path the robot
- Perform autonomous bed levelling

Applications

- **Bioprinting** and organ printing
- **Construction** and housing
- Advanced component **manufacturing**







Print Head control

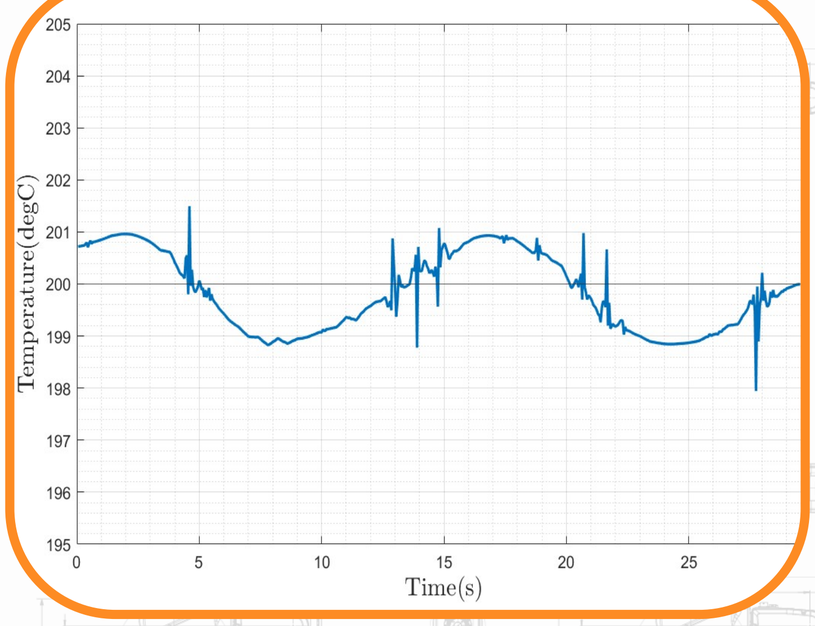
Filament is **fed to extruder via a stepper motor**, which is controlled by a stepper driver.

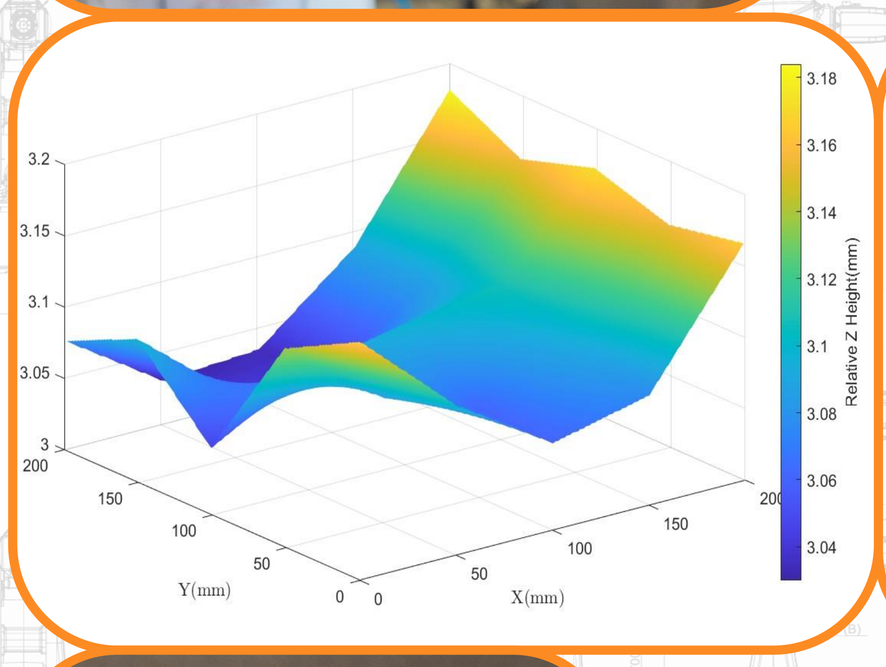
An **Arduino sets the stepper motor** at a target speed. The Arduino also **communicates with the robot controller** for inputted movement speed.

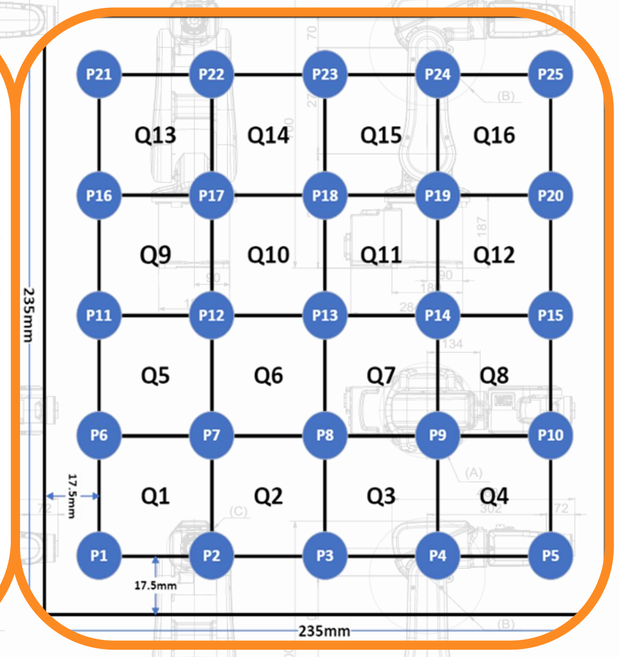
Hot end temperature controlled by **bang-bang** controller.

Capabilities

- **Extrude** a specified length of filament within **±0.1mm**
- Maintain a target temperature of **200°C within ±1°C**
- **Synchronise** movement and extrusion speed for continuous flow
- **Retract** filament upon command







Bed Levelling

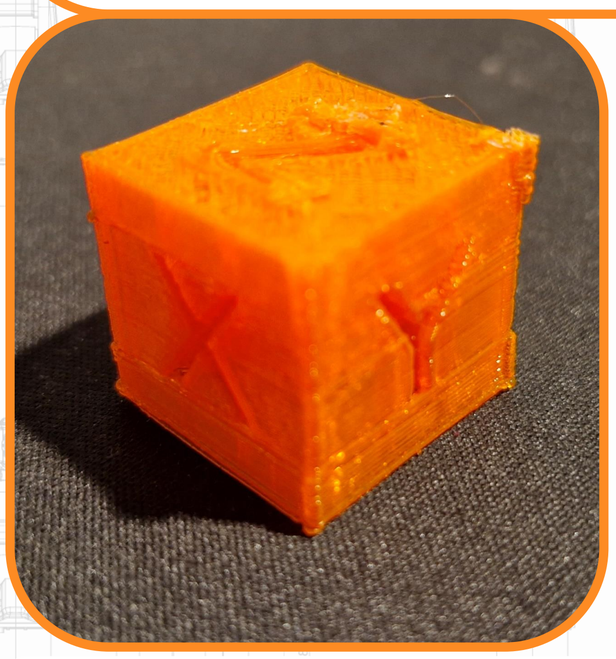
BLTouch probe used to measure bed height at **25 points**. Height **mesh** generated using **bilinear interpolation** method.

Mesh used as a **lookup table**, and difference in bed height was applied to local coordinates.

Further development will allow for printing on more **complex surface** geometries. This includes **non-planar printing**.

Capabilities

- **Alter robot coordinates** based on relative bed height
- **Adjust angle** of print head based on **local bed angle**
- **Measure** bed height with an accuracy of **±0.03mm**
- Account for **variance** in bed height of **±0.6mm**



Print Testing

Several test prints conducted, ranging from **basic 2D** line prints to **3D models**, such as the **Calibration Cube** and **Benchy**. These were used to test and tune **systems parameters.**

Tuning Parameters

- **Z offset** – Distance between nozzle and bed
- **Cooling capacity** – Fans used to cool molten material
- **Extrusion multiplier** – Flow loss compensation
- **Retraction length** – Amount of filament pulled from nozzle

Capabilities

- Extrude a constant line width of **0.46mm, 115%** of the nozzle's **diameter**
- Achieve a **dimensional accuracy** of **±0.46mm**

Conclusions

System was **successfully** able to demonstrate printing with the **quality of a desktop printer.**

Bed levelling was able to **account** for a high degree of **inaccuracy.**

All **components** used were **off the shelf**, hobby grade. **No** use of proprietary, **expensive software.**

System ready for further **development** for **multi axis printing.**

Setbacks

Print Failure

Poor **bed adhesion** and **jammed nozzles** resulted in failed prints. Rectified by changing **filament brand**, and calibrating **z offsets**.

Signal Conversion

Arduino and **robot controller** use different voltage signals. **Voltages** needed to be **converted.**

Teamwork

Coordination with other members working on project to ensure effective **management of lab time.**

Improvements

Improve positional Accuracy

Recalibrate the machine and assess degree of inaccuracy. Implement **external guided motion.**

Temperature control

Implement **PID** temperature control on **hot end** and **bed**.

Further Integration

Write code to **automatically spit** larger files.

Improve Print quality

Perform further **tuning** on print parameters.

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ABB, “Product specification IRB120,” 29 May 2019. [Online]. Available: https://library.e.abb.com/public/6aed5e91083f4fceb358eea2fe4c1bab/3HAC035960%20PS%20IRB%20120-en.pdf?x-sign=edIex5StIjpgmJBJJ95tak9NHdyuuut6mzzJHESGKt5i1JG8dhLRBdvggKptgBJn. [Accessed 25 March 2024].

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