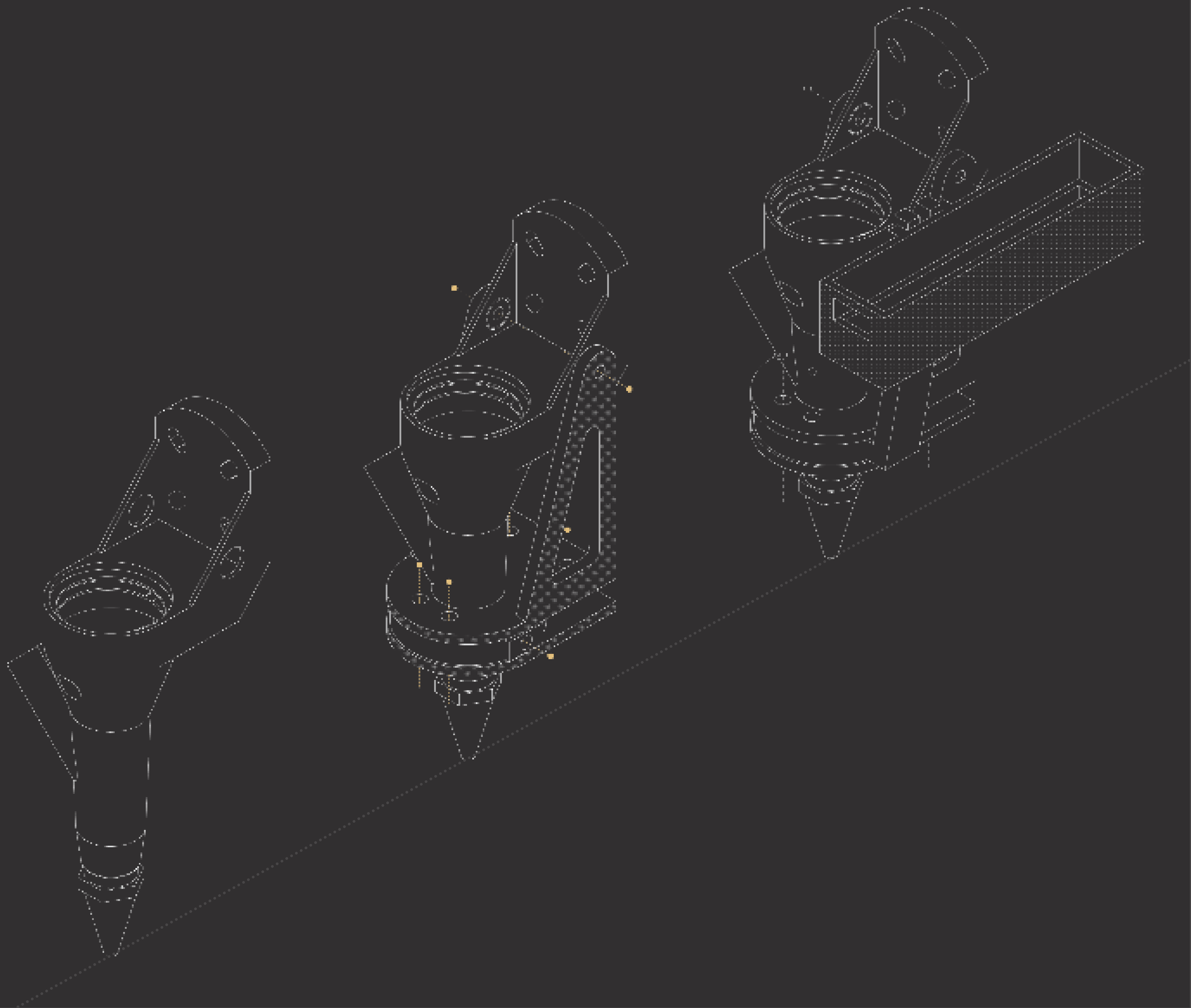


Detection to Correction

(THESIS STUDIO)

Course: Master of Advanced Architecture

Thesis Cluster: Additive Manufacturing

Guides: Oriol Carrasco | Philip Wienkämper

Highlight: Thesis Award Winner

Keywords: Python | 3D Printing Construction | Computer Vision | Depth Sensing | Custom Extruder | Error Detection

Abstract:
This project introduces an innovative strategy for optimizing the 3D printing material testing process by leveraging computer vision to detect defects in printed geometries. The primary objective is to develop an advanced error detection mechanism that collaborates with a machine learning model to dynamically adjust print parameters, such as extrusion rate and print speed, in real-time. This approach ensures high material quality and assesses the print ability of various materials, making necessary adjustments to maintain optimal performance. Our findings highlight the significant potential of integrating sophisticated computational models with real-time data analysis to enhance precision and reliability in 3D printing. This advancement paves the way for the broader adoption of 3D printing in precision-critical manufacturing scenarios, demonstrating its capability to improve efficiency and reduce material wastage.

For more info:

Click here!

Testing Period:

When testing new materials for 3d printing, the testing period is long and mostly dependant on trial and error testing method with different parameters.

Large Scale 3D Printing Construction:

While constructing or printing large scale structures, supervision of layer to layer adhesion, tool path and layer width is of atmost importance, but is difficult to monitor and needs good coordination between workers and high human labor.

Understanding the printing parameters:

Methodology:

When testing new materials for 3d printing, the testing period is long and mostly dependant on trial and error testing method with different parameters.

DATA COLLECTION & CLEANING:

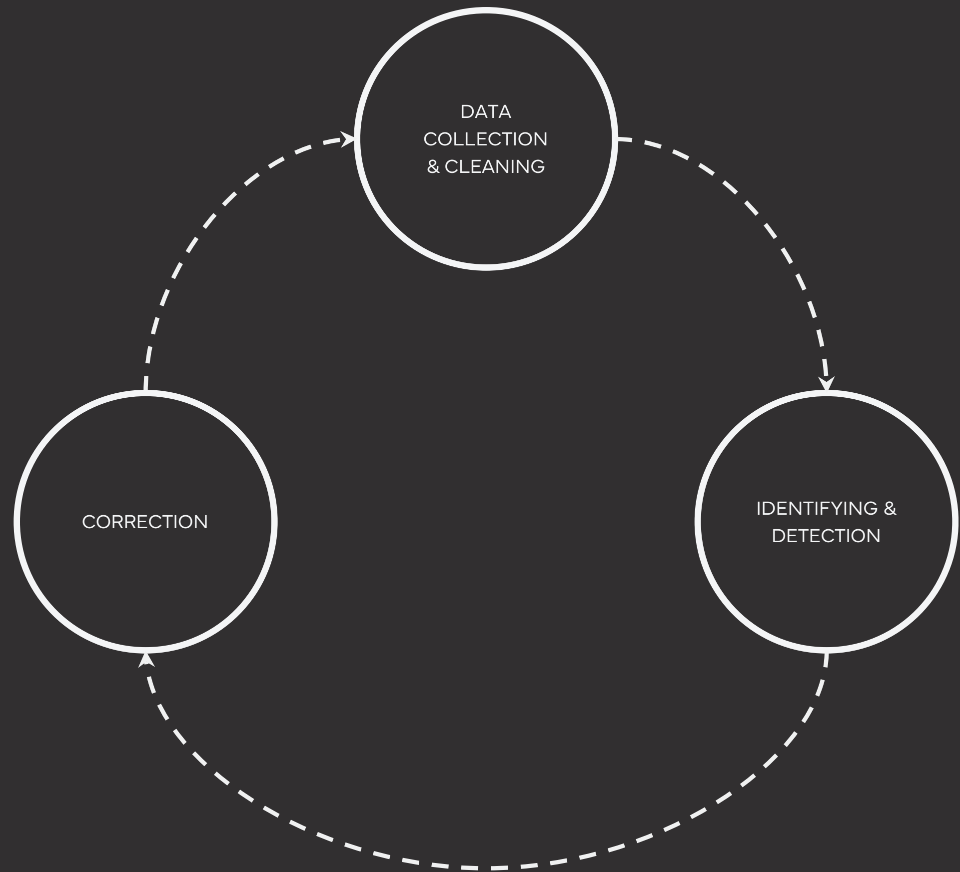
- DATA COLLECTION :
  SENSOR PLACEMENT
- DATA CLEANING :
  STANDARDIZING DATA

PROCESSING AND DETECTION:

- DATA DECODING :
  DATA ANALYSING
- DETECTION :
  ERROR CONDITIONS

RECTIFICATION :

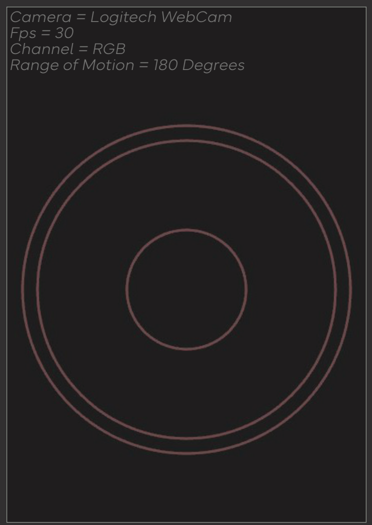
- PARAMETER CHANGE :
  CONDITION BASED AUTONOMOUS CHANGE
- DOCUMENTATION :
  ERROR AND CHANGE



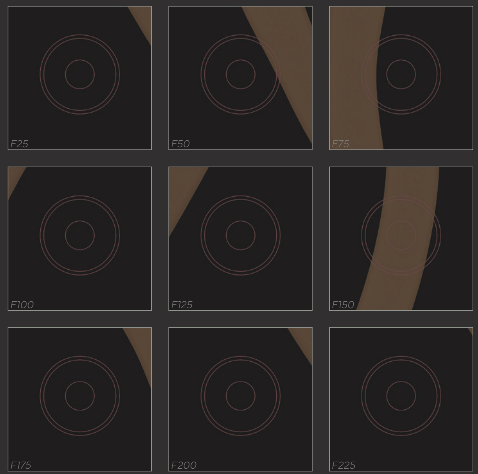
Data Collection:

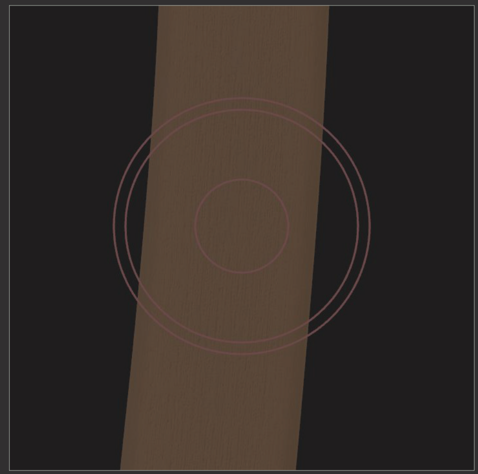
Data Sensor
Using a camera with low megapixel image output and focal length to capture images of layer as close as possible while reducing the amount of data, for faster processing.

End Effector
Designing the end effector for supporting the camera and and motor for rotating the camera as per the printed layer.

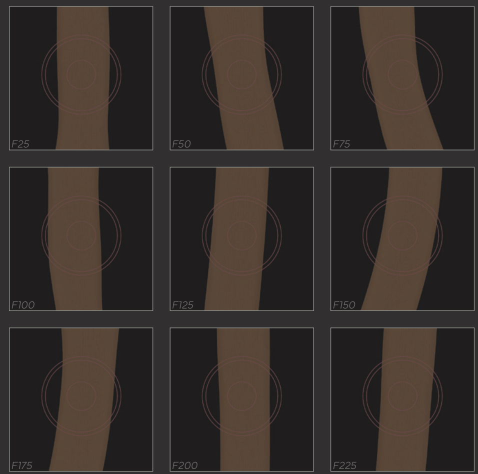


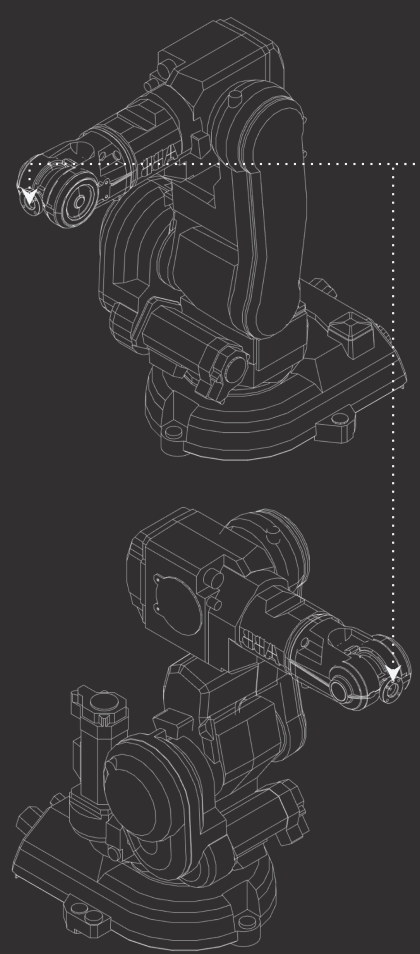
Without Motor for Rotation
The layer will keep going out of frame and gives a consistant output image.

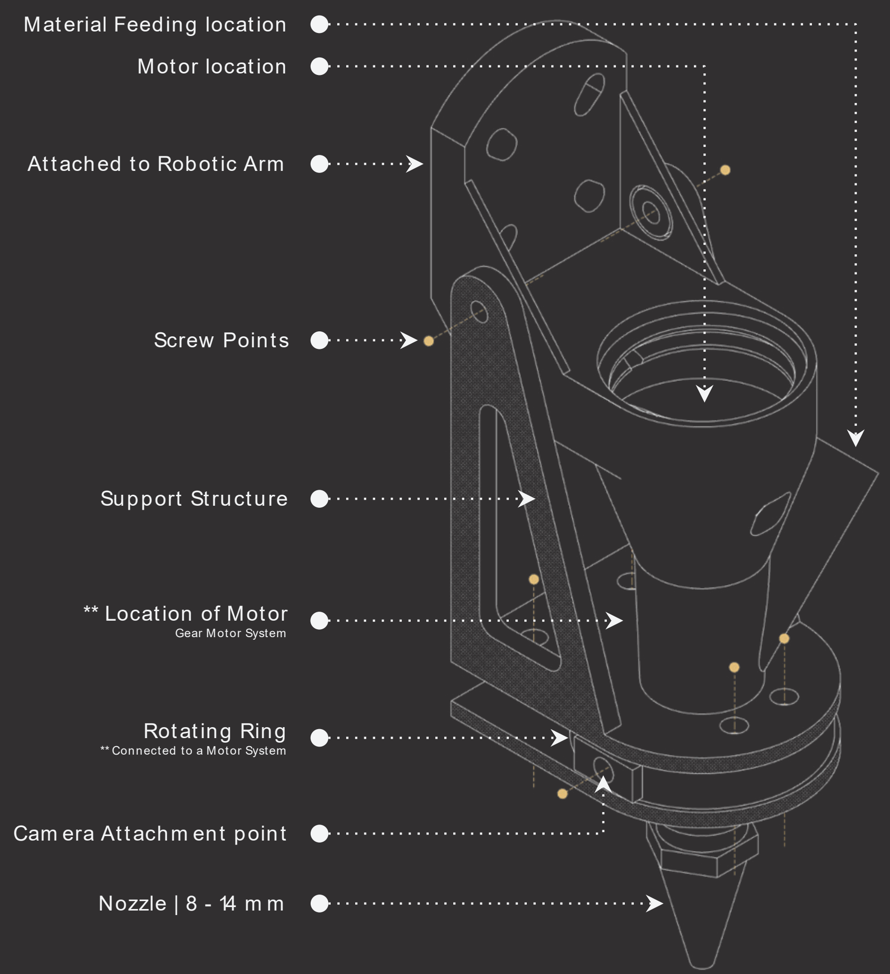




With Motor for Rotation
The layer does not go out of frame and gives a consistant output image.







Data Processing:
In order to decode the image into useable data and image frames are put through set filters for removing noise and defining edges

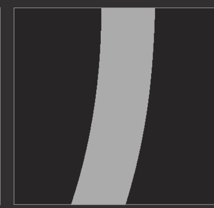
Slicing & Reshaping
Original : 1280 x 720
Reshaped : 640 x 360
Frame rate : 30 fps
Time : 0.004 s

Brightened
Size : 640 x 360
Frame rate : 30 fps
Time : 0.014s

Sharpened
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0008s

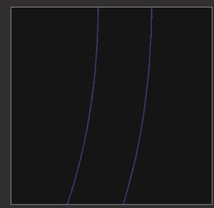
Highlight & Shadow
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0172s

Grayscale
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0004s

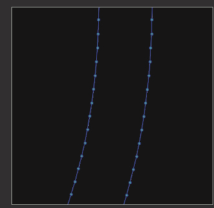


Threshold
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0005s

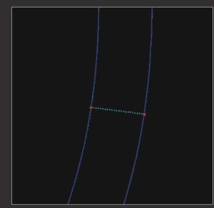
Edge Detection
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0005s



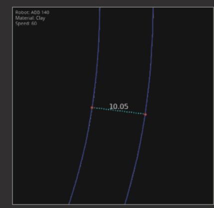
Rebuild Curve
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0028s



Evaluate Curve
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0028s



Perp. Length
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0014s



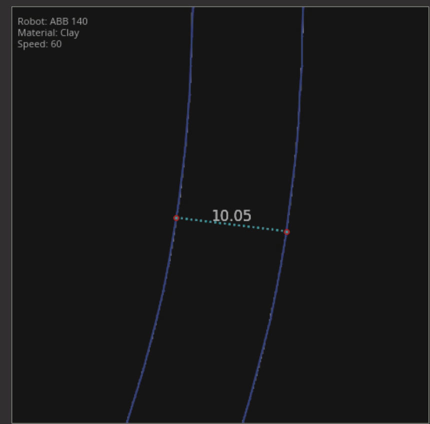
Scaling Length
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0014s

Scaling with Object Distance
Camera : Logitech WebCam
Frame rate : 30 fps
Format : BGR channel
Distance from Print : 123.8 mm
Sensor width : 25.4 mm
Focal Length : 3.67 mm
Image width : 360 px

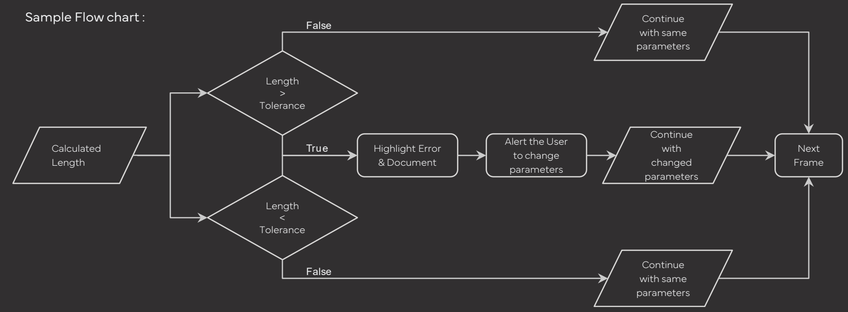
```
FoV_horizontal = 2 * np.arctan(sensor_width_mm / (2 * focal_length_mm)) * (180 / np.pi)

pixels_per_mm = image_width_px / (2 * distance_mm * np.tan(FoV_horizontal / 2 * (np.pi / 180)))
```

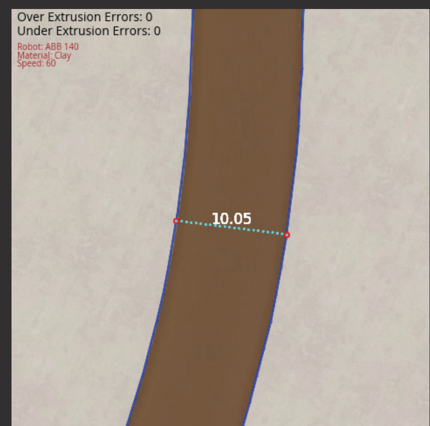
Setting Conditons
Setting conditions for detection of different types of errors from the data collected from the camera. The conditions are set for easy.



Sample Flow chart :

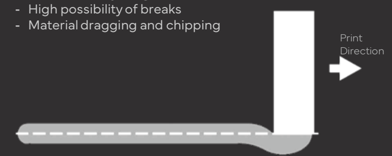


Overlaying Images
Overlaying the results on the origina frames for tolerance adjustment and for checking accurancy of detection. Also overlaying decoded information on the image to showcase change and alert user about errors.

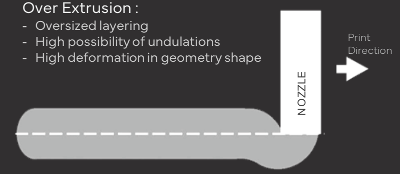


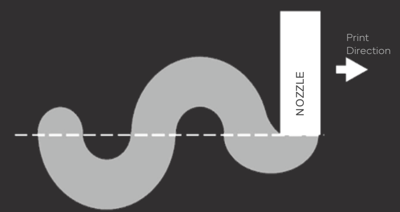
Types of Errors:

Under Extrusion :
- Undersized layering
- High possibility of breaks
- Material dragging and chipping

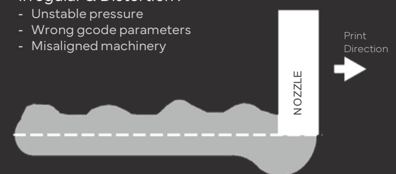


Over Extrusion :
- Oversized layering
- High possibility of undulations
- High deformation in geometry shape





Irregular & Distortion :
- Unstable pressure
- Wrong gcode parameters
- Misaligned machinery



Data Collection with Depth Camera:

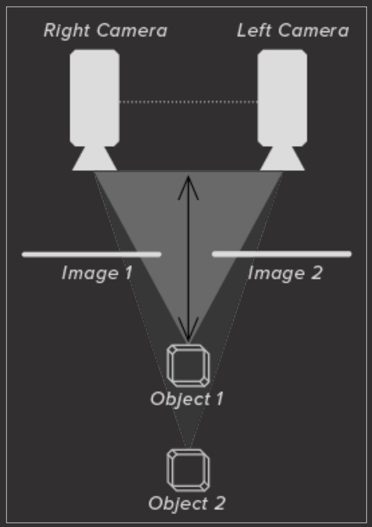
Data Sensor
Using a depth camera for getting both color and depth map of layer for fast processing and low data management

End Effector
Designing the end effector for supporting the camera and and motor for rotating the camera as per the printed layer.

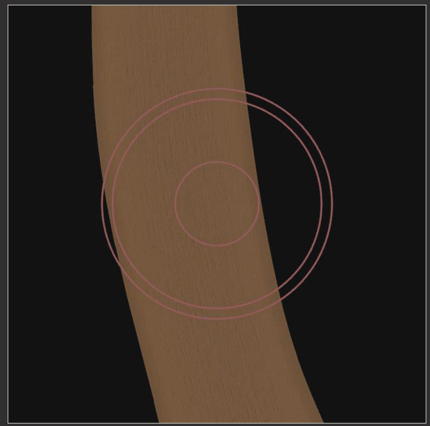
Advantages:
- *Better for edge detection*
- *Less data for processing*
- *Multi-layer error detection*

Camera Specifications
Camera : Stereolabs ZED Mini

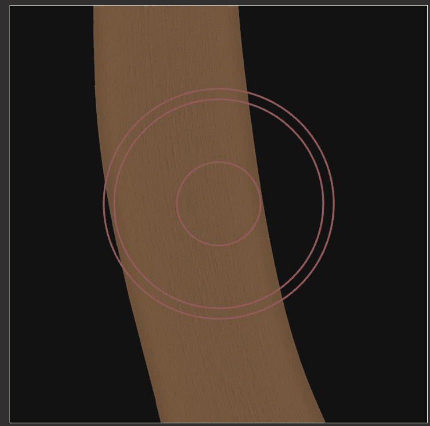
Frame rate :	*30 fps*
Format :	*RGBA channel*
Range :	*0.2 m to 10 m*
Mini. Range :	*0.1 m*
Max. Range :	**15 m*
Sensor width :	*25.4 mm*
Focal Length :	*1.44 mm*
Image width :	*720 px*



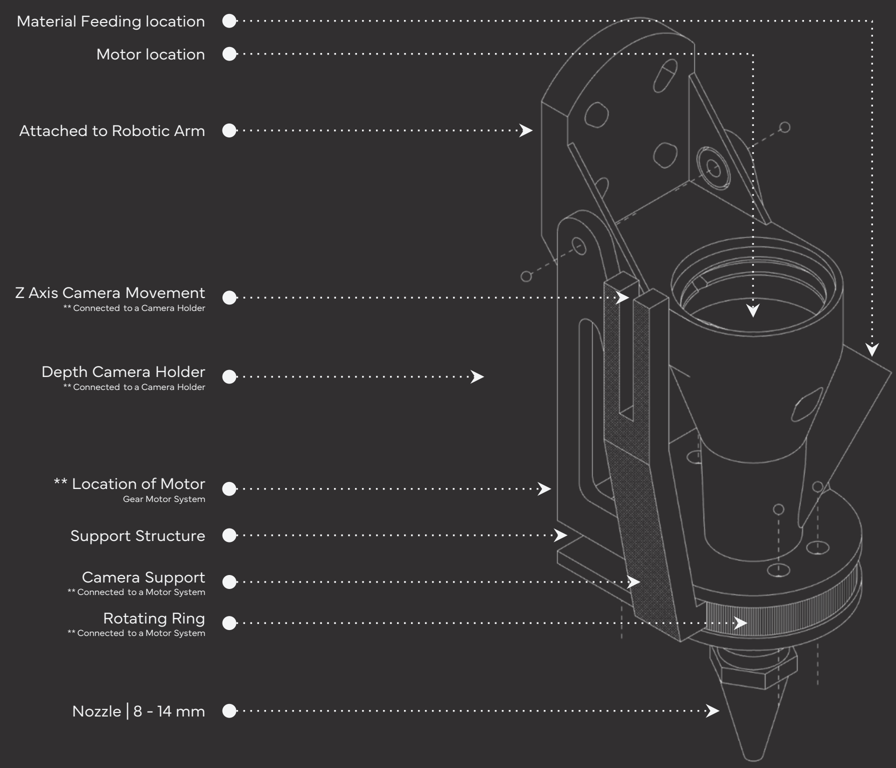
A depth camera works with two cameras in order to generate a depth map of the captured image.

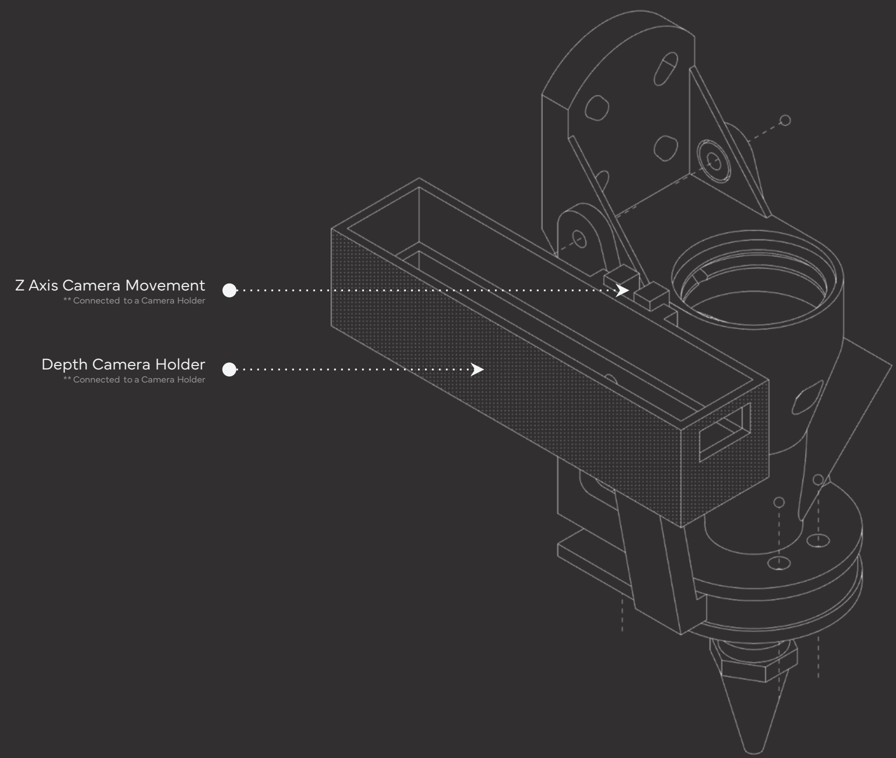


Depth Map
Size : 1280 x 720
Frame rate : 30 fps
Format : Grayscale channel

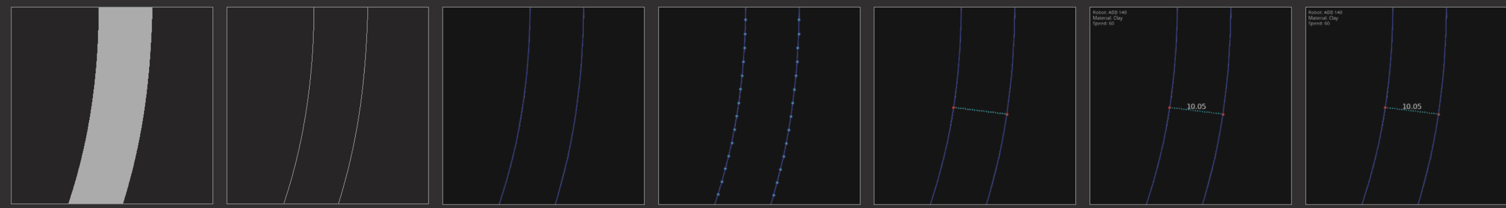


Depth Map
Size : 1280 x 720
Frame rate : 30 fps
Format : Grayscale channel





Improved Data Processing:
The improved data processing does not require any filters for removing any noise or shadows as it works with depth image i.e. a grayscale image. Thus, reducing processing time.



Slicing Depth Map
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0005s

Edge Detection
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0005s

Rebuild Curve
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0028s

Evaluate Curve
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0014s

Perp. Length
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0014s

Scaling Length
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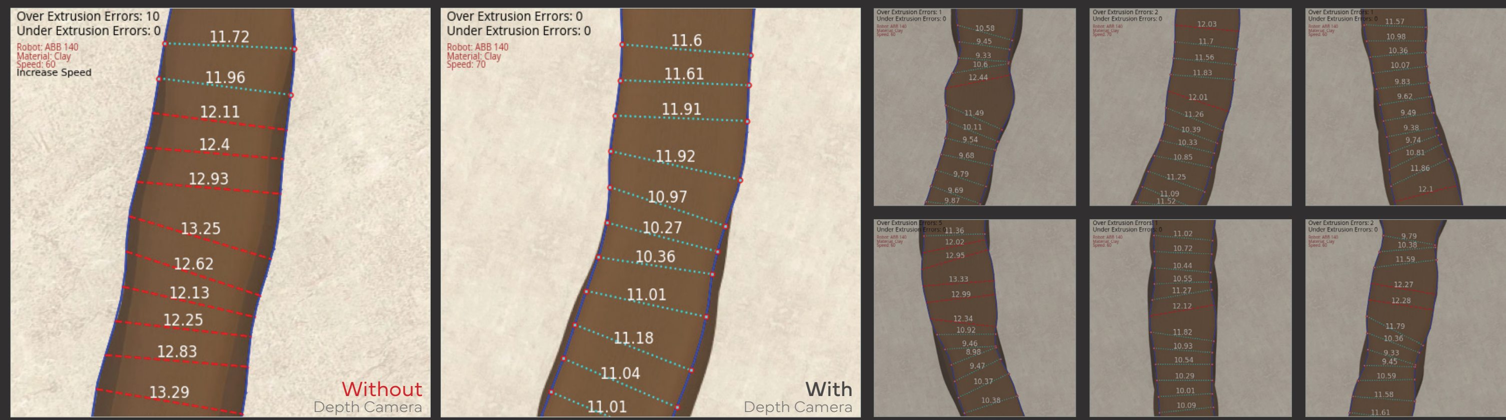
Frame rate : 30 fps
Time : 0.0014s

Setting Conditons
Size : 640 x 360
Frame rate : 30 fps
Time : 0.0014s



Overlaying Images
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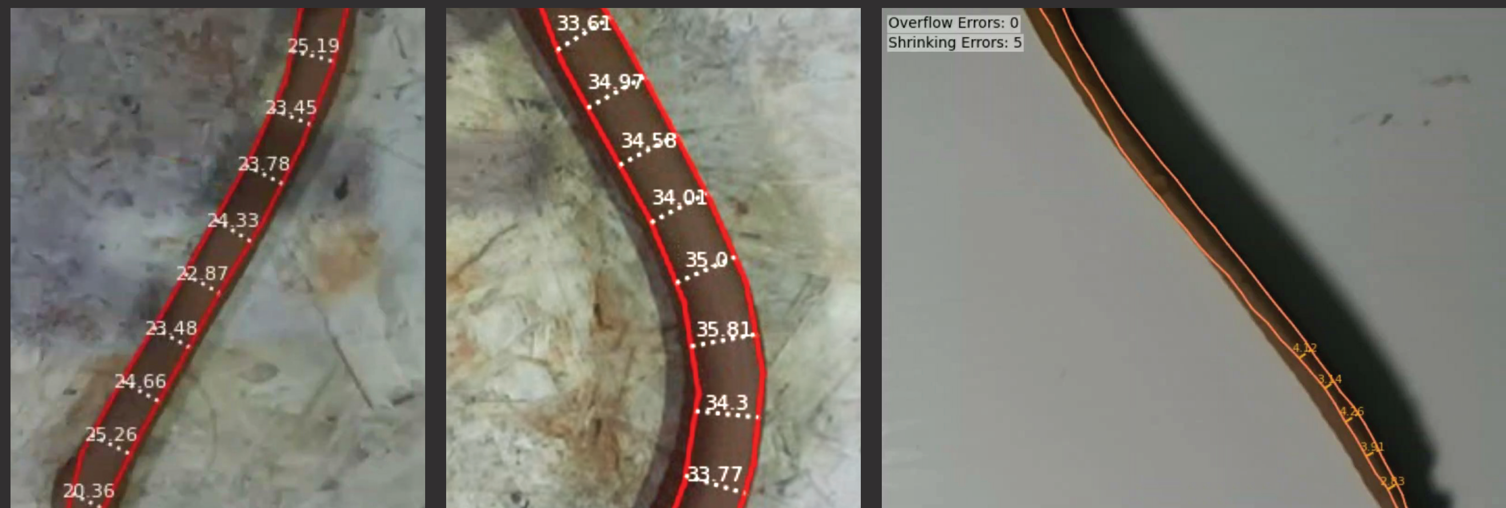

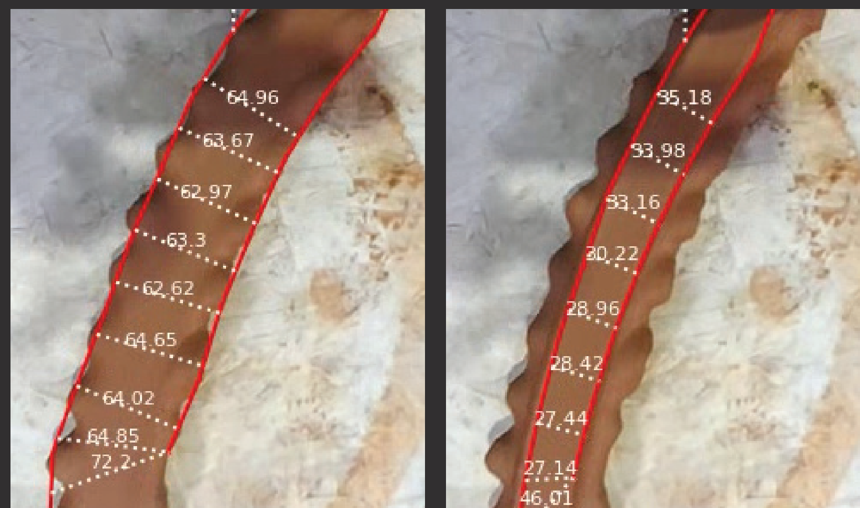

Live Testing:
For validation and proof of concept, the entire methodology was tested while alive printing. The prints were purposefully altered to output variability in layer width even while printing multiple layers one on top of the other.