PROCESS OVERVIEW
The size of the geometry to be printed cannot extended beyond the size of the plate. A tolerance of atleast 10mm is required on all sides. As the printing is vertically executed, the height of the design needs to be limited to a maximum of 100mm, beyond which the clay will start sagging due to its own weight.
Sphere
Generating a sphere to get a dome by cutting the sphere in half.

Solid Difference
Creating the dome.

Extrude
Create the subtracting geometry by extruding the rectangle.

Rectangle
Create a rectangle to create the subtracting geometry.

Origin Point

Origin Plane

Dome

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In this step the toolpath curves are generated from the geometry. The toolpath curves define the path where the extruder prints on the plate. The curves are developed by sectioning the geometry at specific height which depends on the radius of the extruder nozzle. This signifies thickness of each layer. After various experiment in order to achieve better stability and consistency, the radius of the extruder nozzle is considered as the thumb rule for the height of each layer.
TOOLPATH CURVES

Bounding Box to Polysurface
Transforming the box to a polysurface.

Bounding Box
Creating a bounding box around the dome.

Explode
Taking apart the polysurface to extract its bottom face.

Get Item
Extracting the bottom face.

Intersect
Intersecting the dome with the layers to shape them.

Bounding Box to Cupoid
Transforming the box to a solid geometry.

Cupoid Height
Measuring the height of the cuboid to create the sequence.

Code Block
Dividing the cupoid height by the set layer thickness to get the amount of layers.

Sequence
Creating a sequence of numbers to place the layers inside the dome.

Offset
Placing the layers inside the dome.

Perimeter Curves
Creating the toolpath curves by extracting the perimeter curves of the layers.

Bounding Box to PolySurface
Transforming the box to a polysurface.

Geometry
Extracting the bottom face.

Intersect
Intersecting the dome with the layers to shape them.

Cupoid
Creating the toolpath curves by extracting the perimeter curves of the layers.

Polysurface
Transforming the box to a polysurface.

Layer Thickness
Measuring the height of the cuboid to create the sequence.

Sequence
Creating a sequence of numbers to place the layers inside the dome.

Offset
Placing the layers inside the dome.

Perimeter Curves
Creating the toolpath curves by extracting the perimeter curves of the layers.
TOOLPATH PLANES

In this step the toolpath planes are generated from the toolpath curves. Although the toolpath curves define the path for the extruder to travel, as the robot allows 6 degrees of freedom (DOF) the orientation of tip of the extruder with respect to the plate. For easier understanding the experiment is conducted only with 3 DOF i.e on the same plane.

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TOOLPATH PLANES - 3DOF

Start Point & End Point
Extracting the start and end points of the toolpath curves to generate its planes.

Curve Length
Measuring the lengths of toolpath curves to divide each curve into equal segments.

List Create
Combining start and end points with the dividing segment points of the toolpath curves to one list as origin for the toolpath planes.

Curve, Start Point
Calculating the start point of the toolpath curves.

Curve, End Point
Calculating the end point of the toolpath curves.

Curve Length
Calculating the length of the toolpath curves to divide them into equal segments.

List Create
Combining start and end points with dividing segment points into one list as origin for the toolpath planes.

Curve, Points for Segment Length
Calculating the points for segment lengths.

Plane Normal & Plane X Axis
Extracting normal and x-axis from the world plane to create the toolpath planes.

Points Equal Segment Length
Dividing toolpath curves into equal segments and extracting the points.

Plane
Creating toolpath planes on the toolpath curves.
Approach and retract plane are added through an algorithm at specific distances by the user through careful calculated so that collisions are avoided and a successful print is achieved.
**APPROACH & RETRACT**

- **First Item**: Extracting the first coordinate to create the start point for the safe retract.
- **Geometry Translate**: Moving the first coordinate by the set length to create the toolpath start point.
- **List Create**: Combining the coordinates with the moved start and end coordinates to one list.
- **Last Item**: Extracting the last coordinate to create the end point for the safe retract.
- **Geometry Translate**: Moving the last coordinate by the set length to create the toolpath end point.

**Toolpath Planes**

**Toolpath Coordinates**

**Plane to Coordinate System**: Transforming the toolpath planes to coordinates.

**Z Axis**: Extracting the z axis of the coordinate system as direction to move the first coordinates.

**Z Axis**: Extracting the z axis of the coordinate system as direction to move the last coordinates.

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RE-ORIENTED COORDINATES

The planes generated are derived from geometry and its location, which are independent of the robotic setup. Hence to position the plate by robot in the required position the toolpath planes are required to be oriented to the robot and extruder coordinate system. The robot and extruder coordinate system is calibrated before the start of the process.
The next part of the process is to develop the robot trajectory or the inverse kinematics (IK) for the robot to reach its desired position in order to fabricate. We use KUKApc for Dynamo for solving the IK. The feedrate of the robot should be altered depending on the rate of material flow from the extruder for a stable and consistent print.

Robot Setup

Robot
Geometry
Extruder

Robot Speed: 0.2m/s
Robot Speed: 0.3m/s
Robot Feedrate: 0.4m/s
Layer with high stability and consistency
# ROBOTIC TRAJECTORY

- **File Path**
  - Loading the name of the model of the tool.

- **File Loader**
  - Loading the model of the tool.

- **Get Imported Object**
  - Loading the objects of the model.

- **Convert to Geometries**
  - Converting the objects to geometries for simulating the robotic process.

- **Linear Movement**
  - Translating the coordinates to a movement for the robot with a set speed.

- **Simulation Slider**
  - Controlling the simulation by moving the slider.

- **Simualtion**
  - Simulation of the robot trajectory.

- **Reoriented Toolpath Coordinates**
  - Coordinates for reoriented toolpath.

- **File Loader**
  - Loading the model of the tool.

- **Convert to Geometries**
  - Converting the objects to geometries for simulating the robotic process.

- **Custom Tool**
  - Inserting the tool in the robot simulation.

- **Agilus KR3 R540**
  - Selecting the robot type.