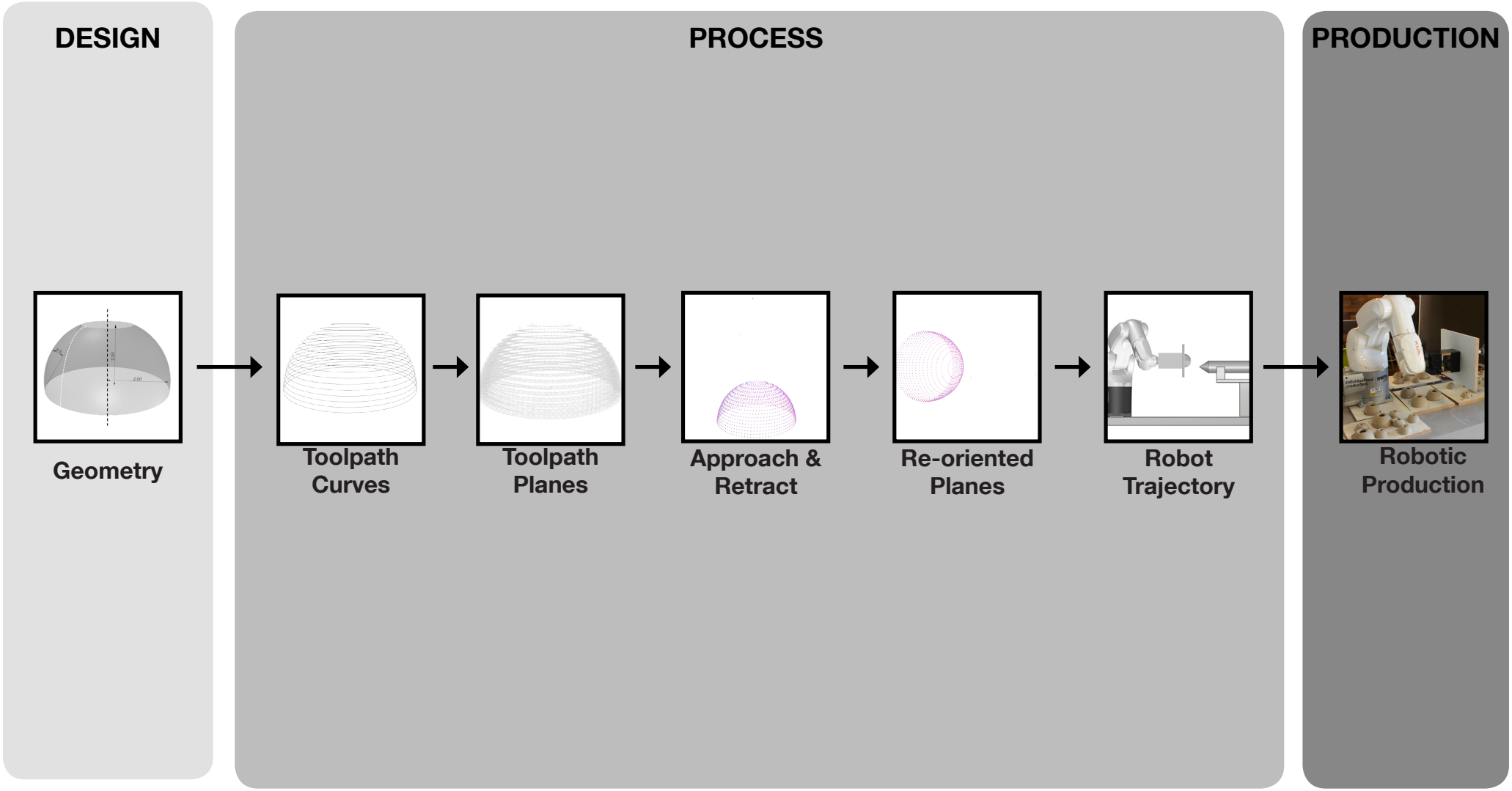
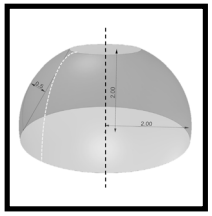
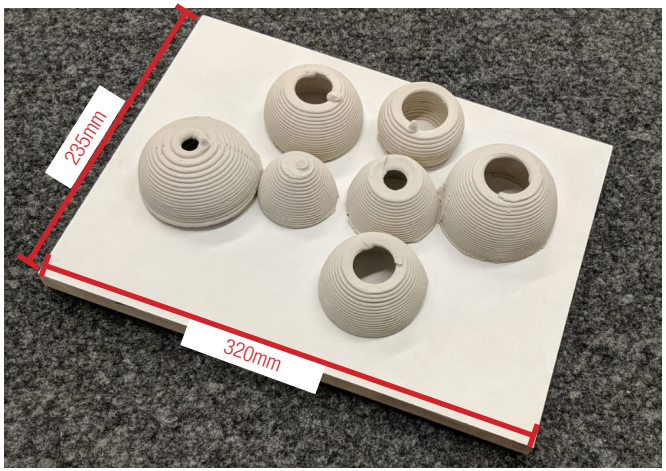
PROCESS OVERVIEW

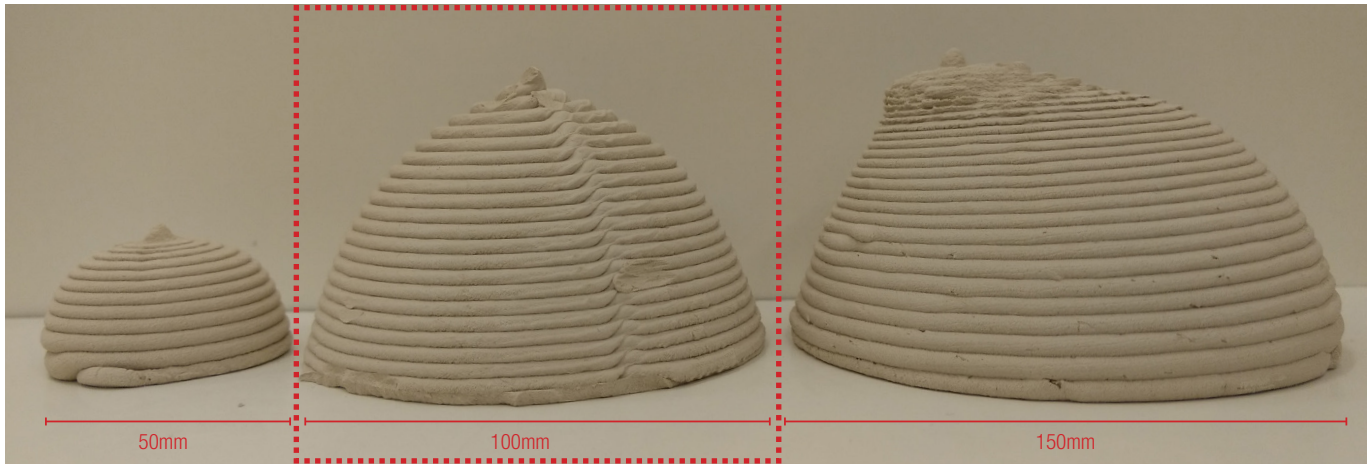


GEOMETRY

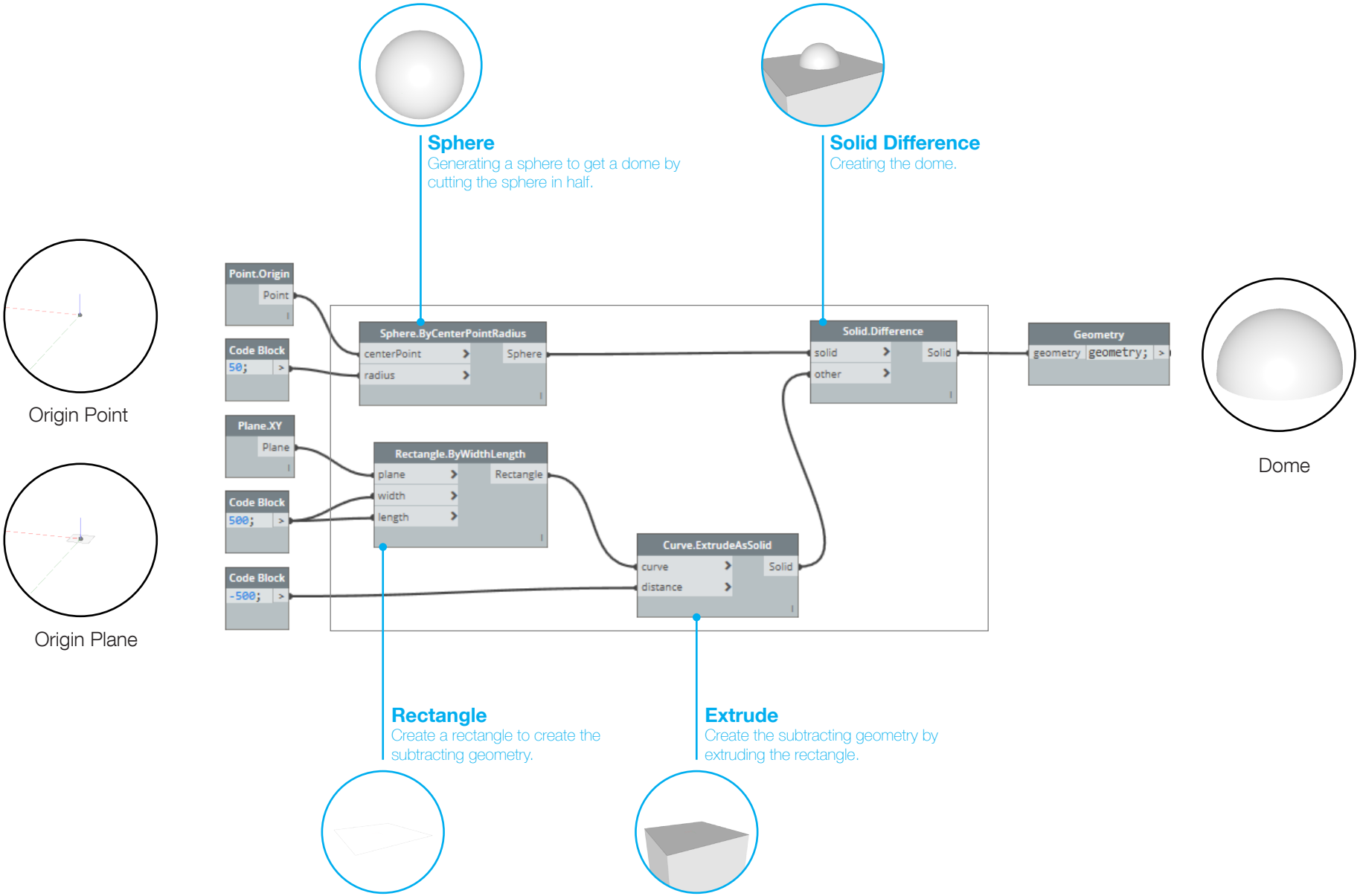


The size of the geometry to be printed cannot extended beyond the size of the plate. A tolerance of atleast 10mm is required on all sides. As the printing is vertically executed, the height of the design needs to be limited to a maximum of 100mm, beyond which the clay will start sagging due to its own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

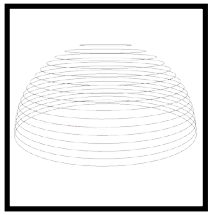




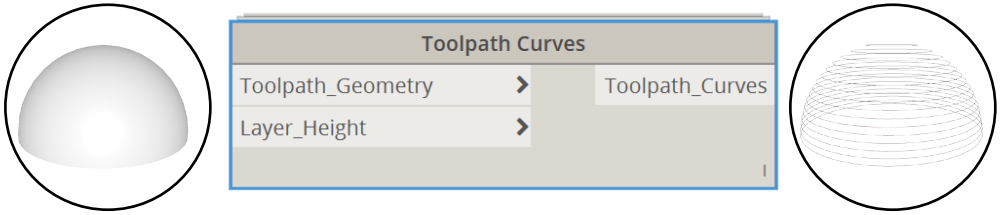
GEOMETRY


Sphere
Generating a sphere to get a dome by cutting the sphere in half.
Solid Difference
Creating the dome.
Origin Point
Origin Plane
Point.Origin
Point
Code Block
50;
Plane.XY
Plane
Code Block
500;
Code Block
-500;
Sphere.ByCenterPointRadius
centerPoint
radius
Sphere
Rectangle.ByWidthLength
plane
width
length
Rectangle
Curve.ExtrudeAsSolid
curve
distance
Solid
Solid.Difference
solid
other
Solid
Geometry
geometry
geometry;
Dome
Rectangle
Create a rectangle to create the subtracting geometry.
Extrude
Create the subtracting geometry by extruding the rectangle.

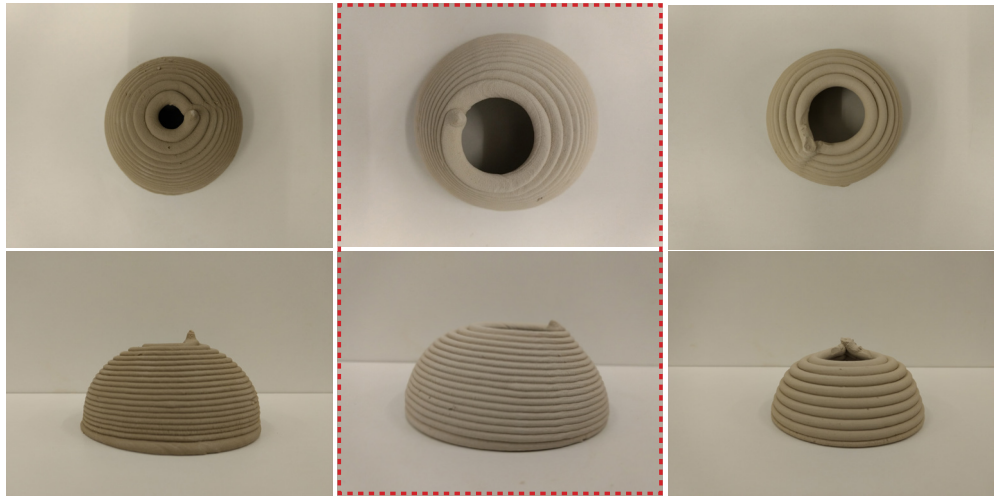
TOOLPATH CURVES



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 thickeness 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.

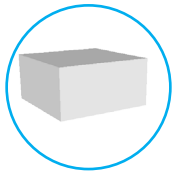


Layer with higher stability and consistency



Contour Height: 2mm | Contour Height: 3mm | Contour Height: 4mm

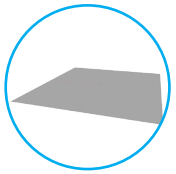
TOOLPATH CURVES



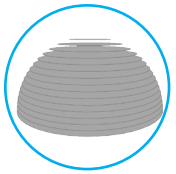
Bounding Box to Polysurface
Transforming the box to a polysurface.

Bounding Box
Creating a bounding box around the dome.

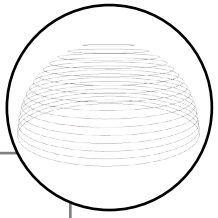
Explode
Taking apart the polysurface to extract its bottom face.



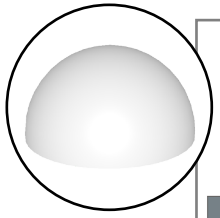
Get Item
Extracting the bottom face.



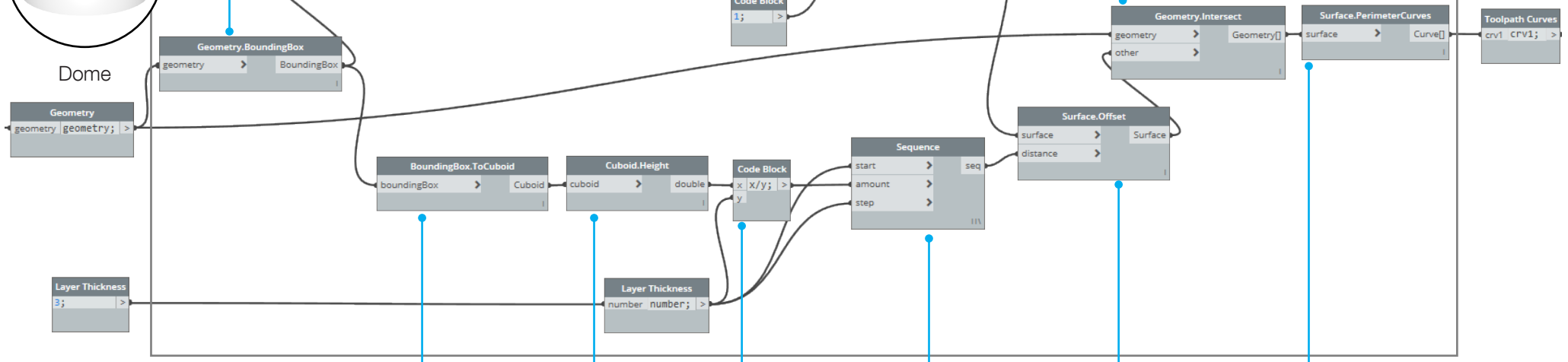
Intersect
Intersecting the dome with the layers to shape them.



Toolpath Curves



Dome



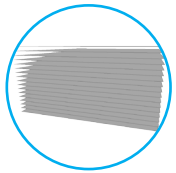
Bounding Box to Cupoid
Transforming the box to a solid geometry.

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.

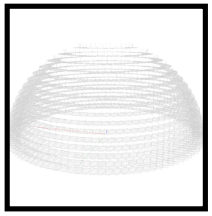
Sequence
Creating a sequence of numbers to place the layers inside the dome.

Offset
Placing the layers inside the dome.

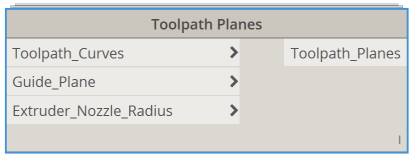
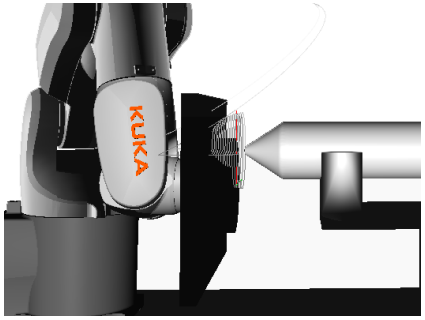
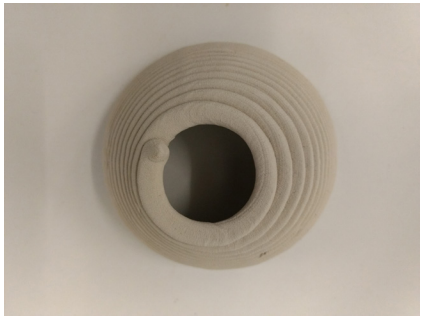
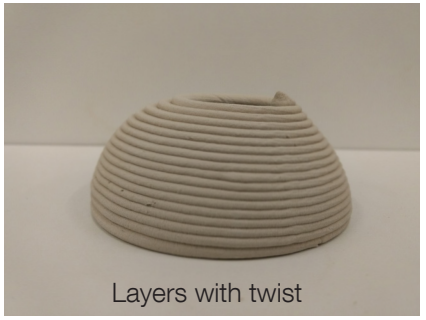
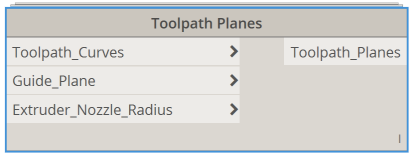
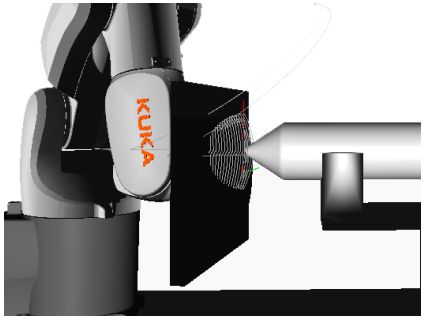
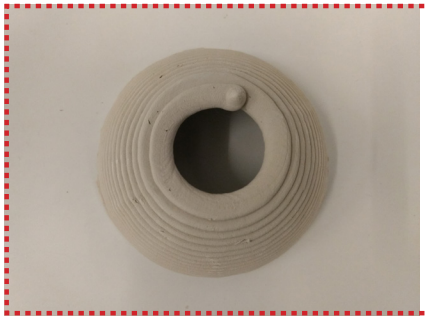
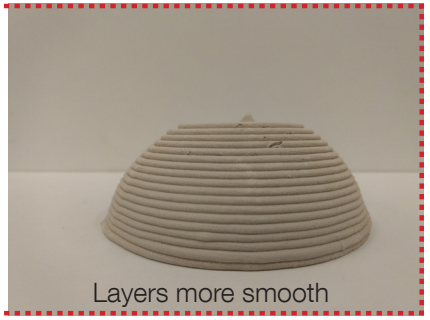


Perimeter Curves
Creating the toolpath curves by extracting the perimeter curves of the layers.

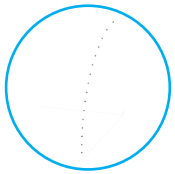
TOOLPATH PLANES



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 oritentation of tip of the extruder with respect to the plate. For easier understanding the experiement is conducted only with 3 DOF i.e on the same plane.

Toolpath	Toolpath - Custom Node	Simulation	Plan	Elevation
3DOF				
6DOF				

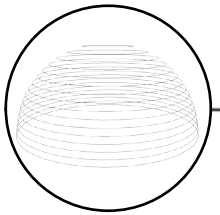
TOOLPATH PLANES - 3DOF



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 in 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.



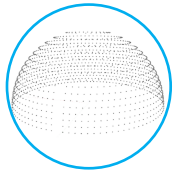
Toolpath Curves

Toolpath Planes

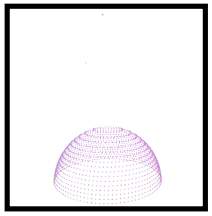
Plane Normal & Plane X Axis
Extracting normal and x axis from the world plane to create the toolpath planes.

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

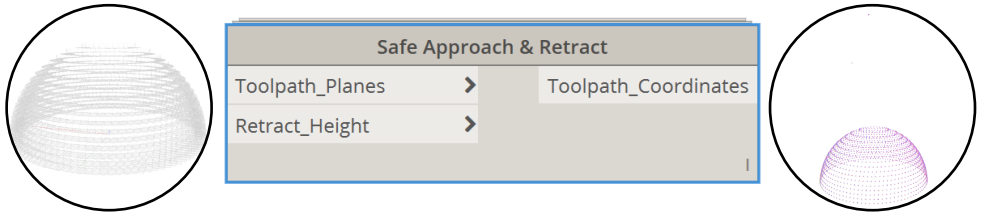
Plane
Creating toolpath planes on the toolpath curves.



APPROACH & RETRACT



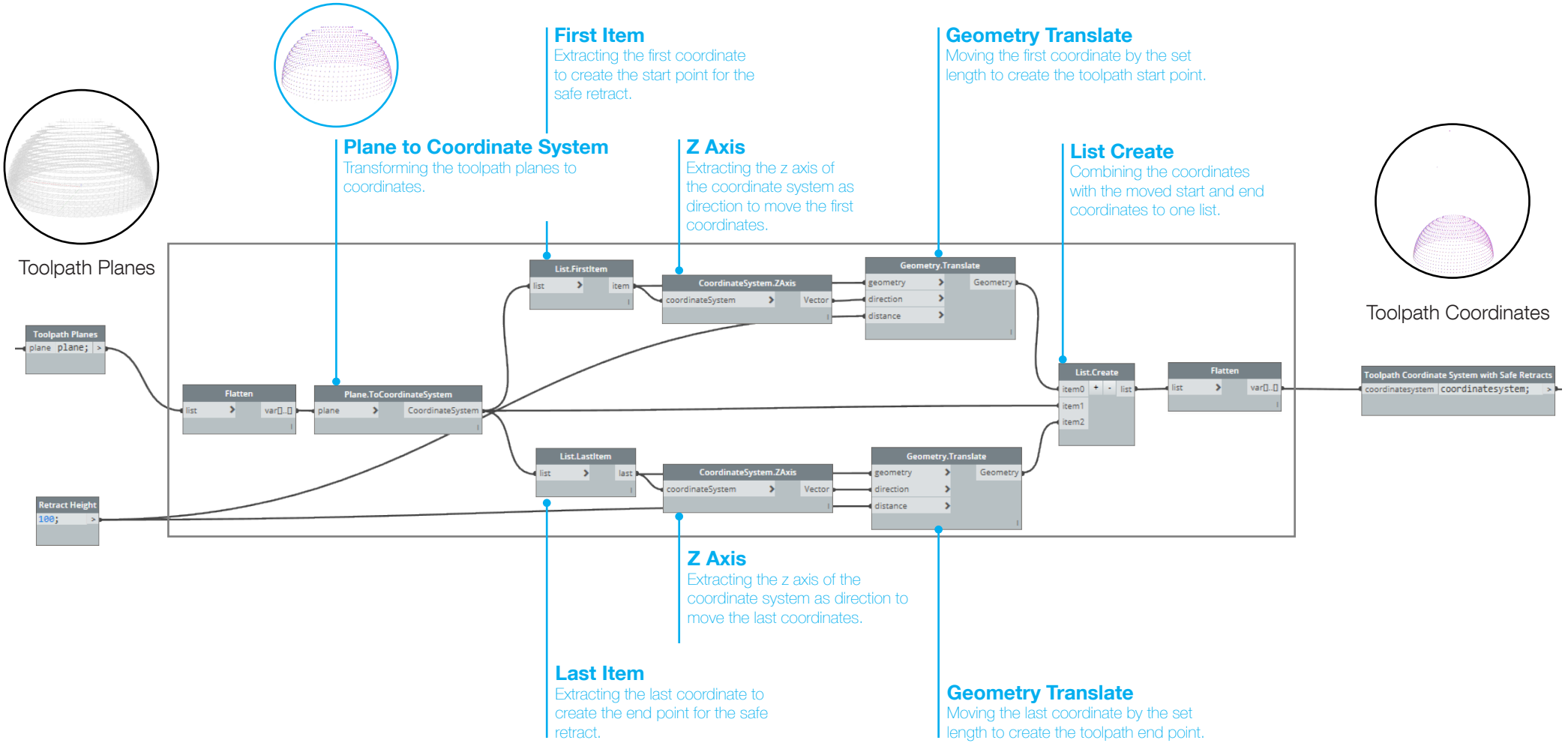
Approach and retract plane are added through an algorithm at specific distances by the user through careful calculated so that collisions are avoided and a sucessful print is achieved.



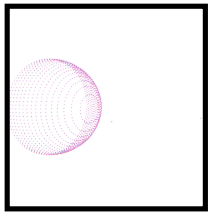
Toolpath Planes

Toolpath Coordinates

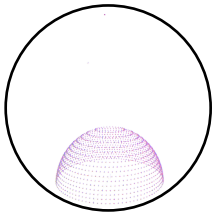
APPROACH & RETRACT



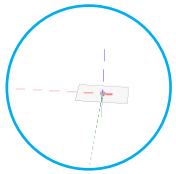
RE-ORIENTED COORDINATES



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.

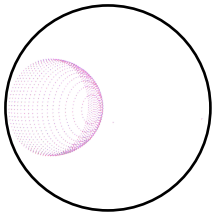


Toolpath Coordinates

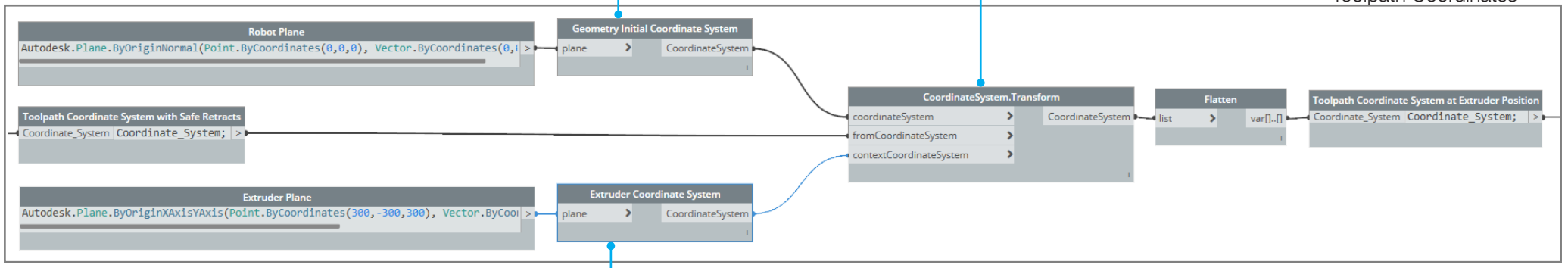


Plane
Creating the base coordinate system of the dome as reference to reorient the toolpath coordinates.

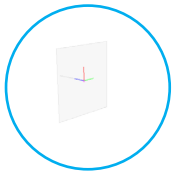
Transform
Reorienting the toolpath coordinates to the extruders position and orientation.



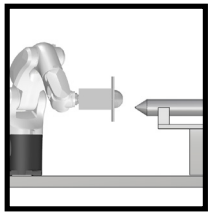
Reoriented
Toolpath Coordinates



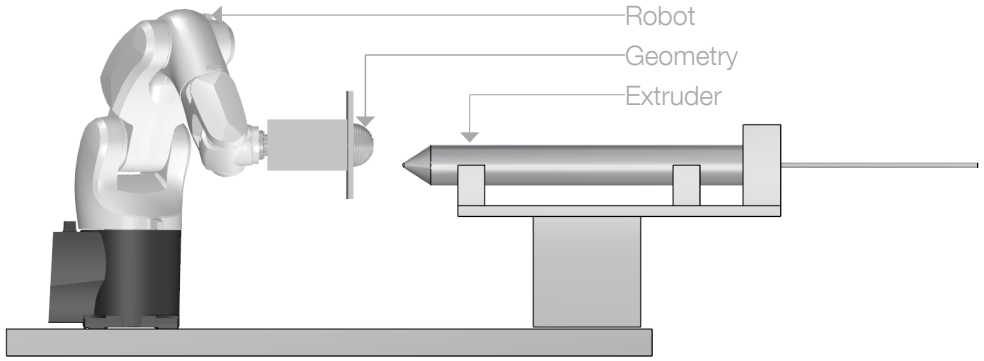
Plane
Creating the coordinate system of the extruder as reference to reorient the toolpath coordinates.



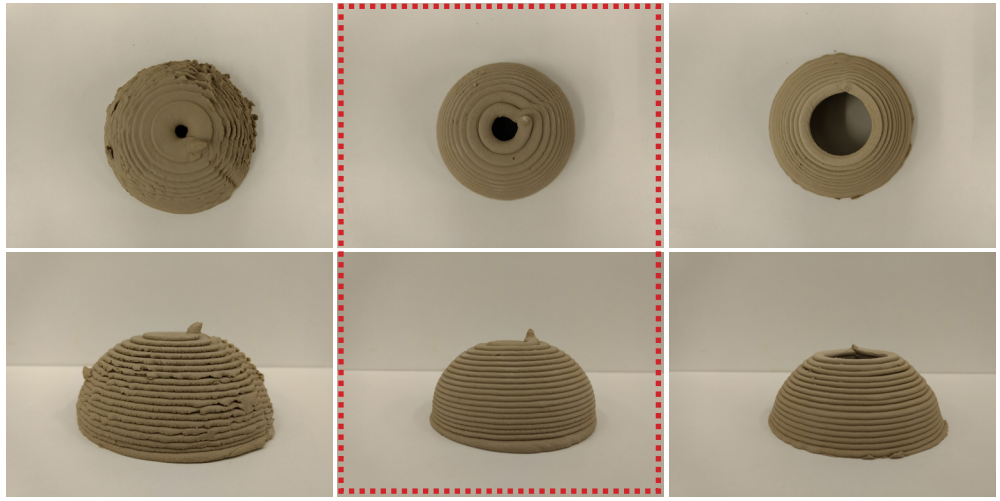
ROBOTIC TRAJECTORY



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 KUKAprc for Dynamo for solving the IK. The feedrate of the robot should be altered depending the rate of material flow from the extruder for a stable and consistent print.



Robot Setup



Robot Speed: 0.2m/s | Robot Speed: 0.3m/s | Robot Feedrate: 0.4m/s

Layer with high stability and consistency

ROBOTIC TRAJECTORY