October 2021

MOBILE SCARA

3D PRINTING CLUB, IITM

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OVERVIEW

The month of October was spent studying the various research papers on Chunk based slicing, Mobile 3D Printing, multi robot path planning. We developed an algorithm of our own for chunk-based slicing. And we completed construction of components of our RepRap Helios fusion model and assembled it and made a detailed report about each components of SCARA model.

THEORY

Components of RepRap Helios

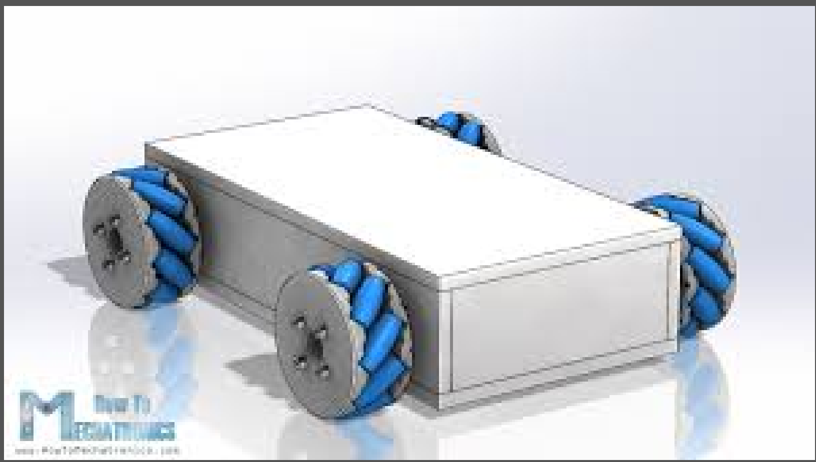
- Bottom Plate - This is where the entire printer is set up on. It is the base of the printer.
- Stepper motor - It is an electric motor that converts digital pulses to mechanical shaft rotations.
- Drive pulley - It is a pulley attached to a power source, that when in use puts force on a belt and the belt is connected to another pulley being driven, which will then spin. It is basically power transmission.
- M8x200 - It is a long rod to which all the pulleys and z idler pulleys are attached.
- Washer - A disk shaped component that keeps the screw from loosening or to distribute the load from the nut or bolt head over a larger area.
- 608 bearing - It is a 8mm Ball bearing used for assisting an object's rotation. They support the shaft that rotates.
- Distal Idler pulley - It is used to provide tension and guide the engine drive belt.
- Arms - The arms are connected to the extruder and it moves around the z axis. They are the reason for the 360 degree print bed.
- Distal drive pulley - It is a drive pulley located away from the center of body or away from the point of attachment and is used for power transmission.
- Z - Idler pulley - will help in belt movement in the z axis.

- Distal arm end - is where the extruder is placed
- M3X45 - It is a screw with hex drive type and drive size H2.5
- M3x8 - A screw with nominal diameter as 3 mm and length as 8 mm.
- M3x65 - A screw with nominal diameter as 3 mm and length as 65 mm.
- M3x25 - A screw with nominal diameter as 3 mm and length as 25 mm.
- M3x35 - A screw with nominal diameter as 3 mm and length as 35 mm.
- M3x30 - A screw with nominal diameter as 3 mm and length as 30 mm
- Slide frame - It is a frame used to support the extruder.
- Heat sink - is a component that increases the heat flow away from a hot device.
- E3d hotend mount - Hotend is a component of 3D printer that melts the filament for extrusion and helps maintain a consistent and accurate temperature for successful prints.
- Heat Block - is a part of the extruder which melts the filament as it passes through the thermal tube to be extruded out.
- Nozzle - It extrudes the filament. It conducts the thermal energy provided by the heating block to the filament , melting it.
- Belt tensioner - It maintains the correct amount of tension on the belt all the time throughout its duty cycle.
- Belts - They connect different pulleys together.
- M3x60 - A screw with nominal diameter as 3 mm and length as 60 mm.
- M3 nut - means a 3 mm outer diameter for the nut.

WHEELS FOR A MOBILE SCARA 3D PRINTER

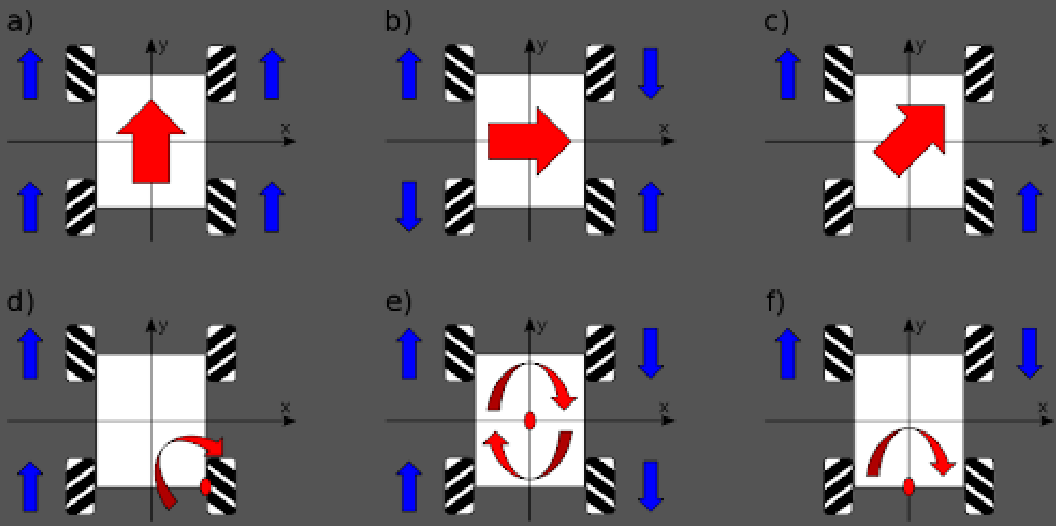
MECANUM WHEELS

The Mecanum wheel is based on a tireless wheel, with a series of rubberized external rollers obliquely attached to the whole circumference of its rim. These rollers typically each have an axis of rotation at 45° to the wheel plane and at 45° to the axle line. Each Mecanum wheel is an independent non-steering drive wheel with its own powertrain, and when spinning generates a propelling force perpendicular to the roller axle, which can be vectored into a longitudinal and a transverse component in relation to the vehicle.



This is a typical four mecanum wheel model

This will be the most efficient choice for a 3D printer due to its multi directional movement unlike the typical powertrain with steering.
STEPPER MOTORS are used for designing 3D printers for more accurate positioning.



Explanation of the movement corresponding to each configuration
https://www.youtube.com/watch?v=Xrc0l4TDnyw

POSITIONING

Although we predict slipping will not be a significant issue if we cap the maximum acceleration of the robot, it still happens occasionally due to imperfect contact between the wheels and the floor and imperfect alignment of the wheels, which leads to degradation of printing accuracy over time as shown

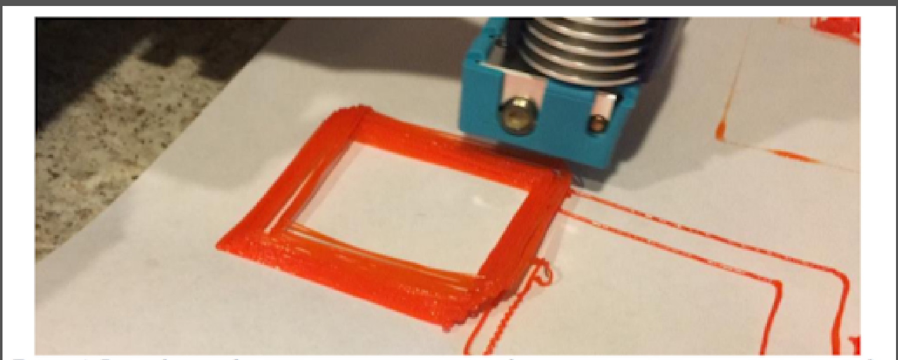
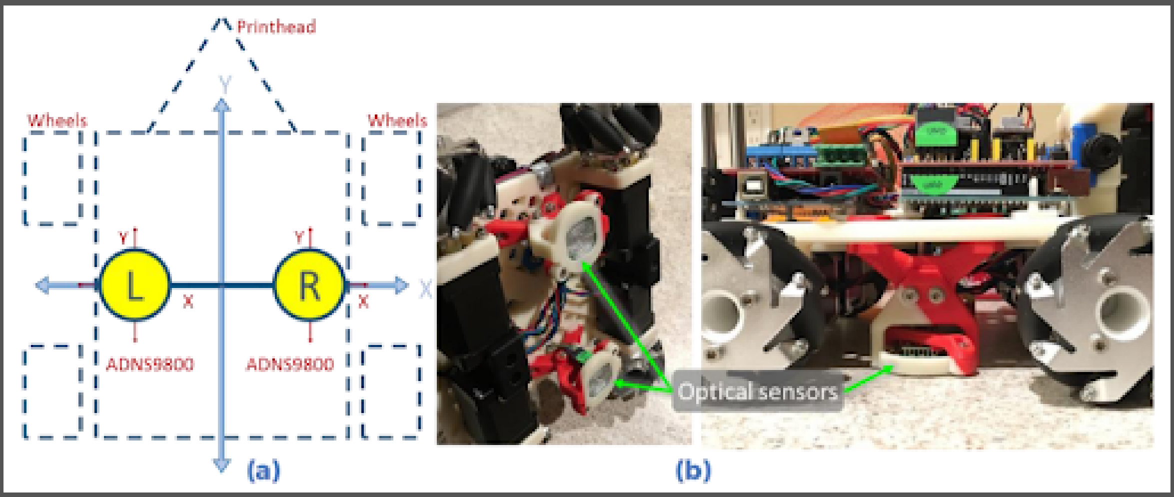


Figure 4. Degradation of printing accuracy over time: the printer is printing a square repetitively.

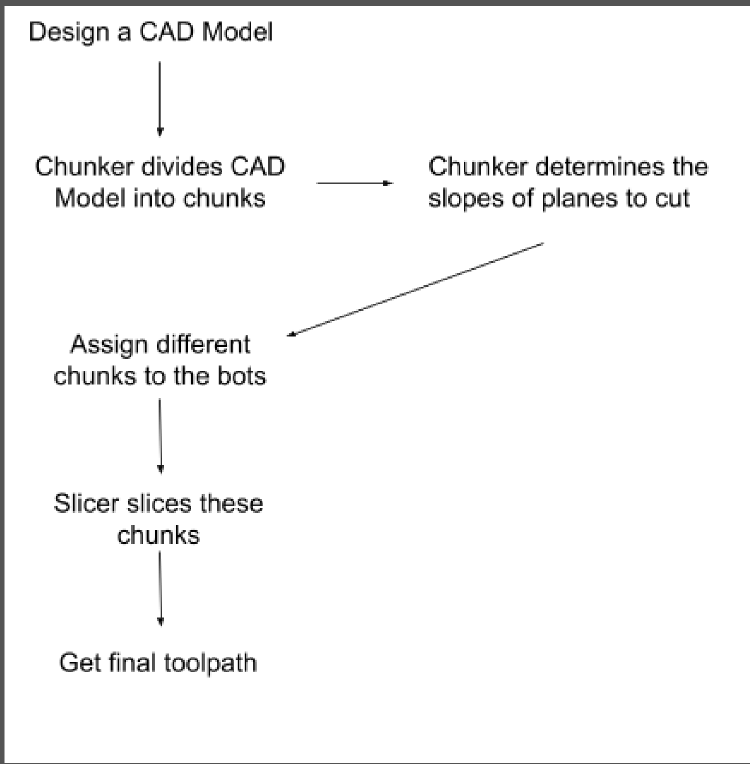
Therefore, a feedback control system is deemed necessary for the positioning. To choose an appropriate position sensor, a few requirements need to be satisfied:
1. **Mobility**: the sensor can be carried by a mobile robot and provide location information relative to the ground;
2. **Resolution**: the sensor needs to have sufficient resolution for the targeted accuracy (~100 um).
3. **Sampling frequency**: we need to be able to query the sensor at a sufficiently high frequency so that the robot can correct its position in real time.
4. **Response time**: the sensor can be read in relatively short time and doesn't significantly interfere with the operation of the stepper motors.
5. **Speed and acceleration**: the sensor needs to be able to provide correct movement information at the max printing speed and acceleration.
6. **Cost**: the sensor cannot be costly to keep the total cost of the mobile printer below

- Among various position sensors, an optical mouse sensor satisfies our requirements. It takes a series of pictures at very fast rate and determine the relative movement by comparing the pictures using an optical flow algorithm laser mouse sensor (ADNS-9800 sensor) performs better and its positioning accuracy is within 5%.
- In addition to the XY movement, the mobile printer is subjected to one additional degree of freedom (DOF) – rotation about the Z axis due to inaccuracy in the wheels. The orientation of the robot must be corrected to perform quality printing over time.
- However, the IMU(Inertial Measurement Unit) sensors are not accurate enough to report the correct orientation of the robot due to the small and slow rotation of the robot during printing (the robot usually only rotates a few degrees over 20 minutes).
- Solution for this problem is by using two optical mouse sensors as shown

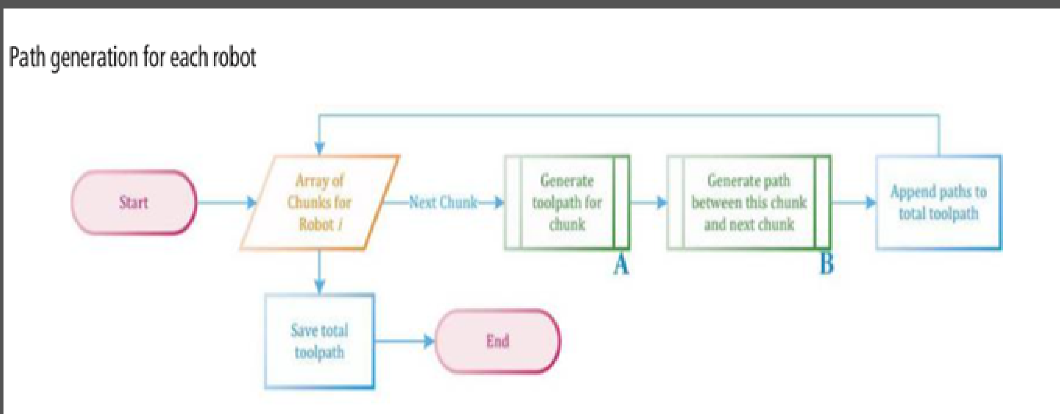


When the robot rotates, the two mouse sensors will report different measurements in Y direction, from which we can derive the rotated angle of the robot based on the distance between the two sensors.

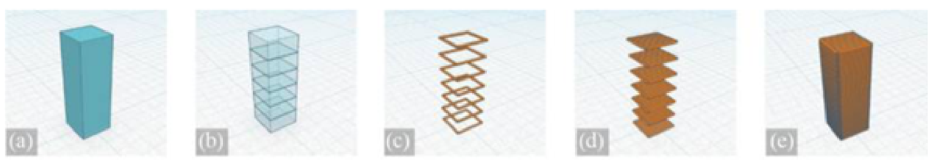
Basic Algorithm for overall process-



Algorithm for developing toolpath for chunking-



Note: Generate tool path for each chunk and generate path to transition between chunks



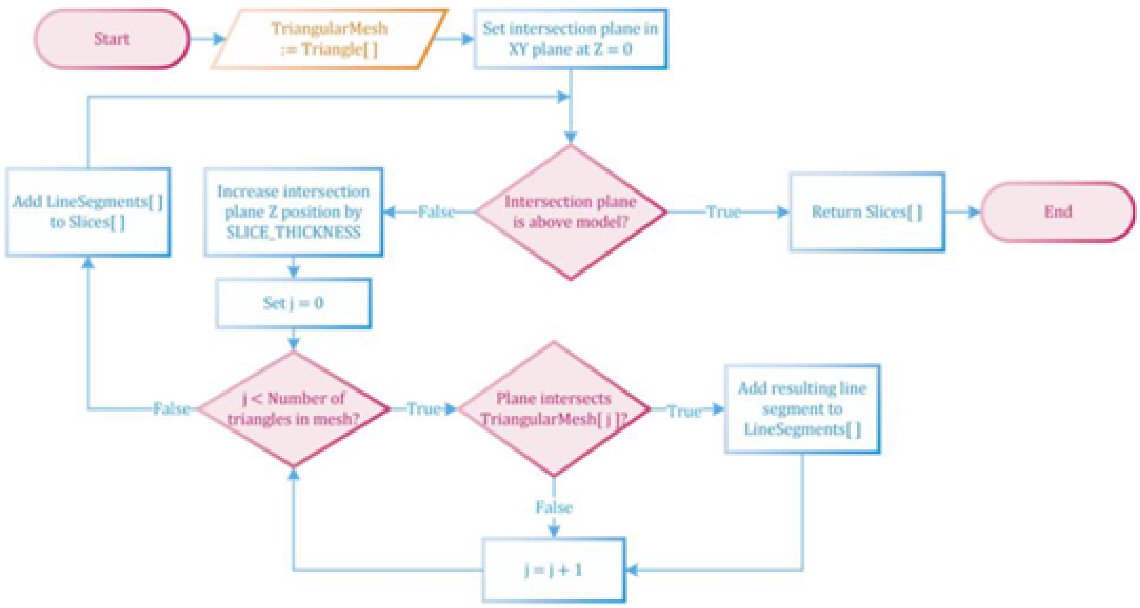
Notes: (a) Original model; (b) model split into horizontal layers; (c) perimeters calculated for each layer by intersecting the triangular mesh with a plane at each layer; (d) generate infill path for the perimeter at each layer; (e) combine all the tool path generated at each layer

The chunker algorithm is as follows,

1. First we creates an Array of Chunks and assigns it to a particular bot (say i)
2. Then we generates a toolpath for that particular chunk (by using slopes to divide the model into chunks, this is done to ensure proper bonding)
3. The chunker also makes a toolpath between two chunks (that is the path between one chunk and another)
4. Finally after making the appropriate tool paths we add it to the array of the Array of Chunks that we created in the 1st step
5. After all the chunks are completed the final toolpath is saved and the algorithm ends
6. The general idea to create chunks is to go from the inner to the outward direction (that is either left or right from the center)

Algorithm for slicing and getting toolpath-

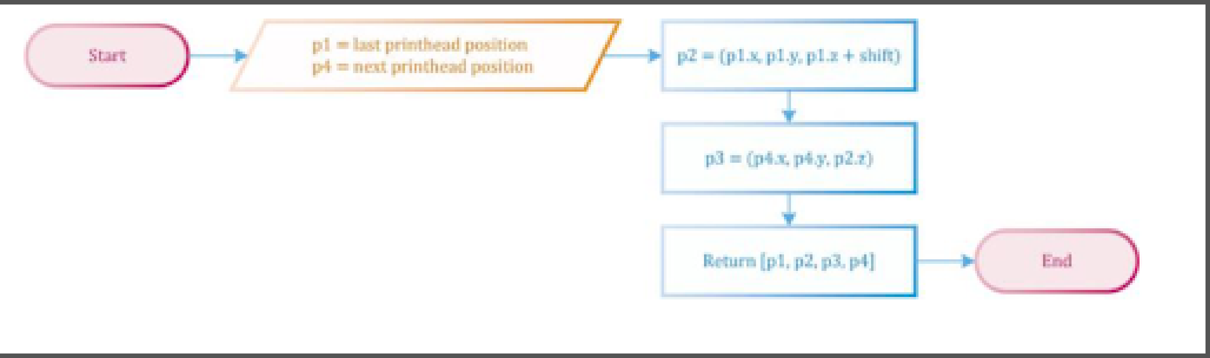
Figure 8 Process for calculating the line segments for the perimeter path of a layer



The slicer algorithm is as follows,

1. First we create a variable called Triangular Mesh
2. We then set the intersection plane of the model to be the xy plane (that is z=0 plane). This is the base of the model
3. Now we check if the intersection plane is above the model, if no that means there are more slices left hence we increase the intersection plane height by the slice thickness
4. On doing so we get the position of the new slice
5. We then divide that slice into triangular meshes
6. If the triangular mesh is less than a fixed number of triangular mesh we make further more meshes till we get the required number of triangular meshes
7. We now save all these line segments to the LineSegment variable, this variable is then added to the Slices variable which contains all the line segments of all the different slices
8. We then do this with every slice till the intersection plane is above the model to finally get the resultant Slice variable

Algorithm for movement of robot from one chunk to another:



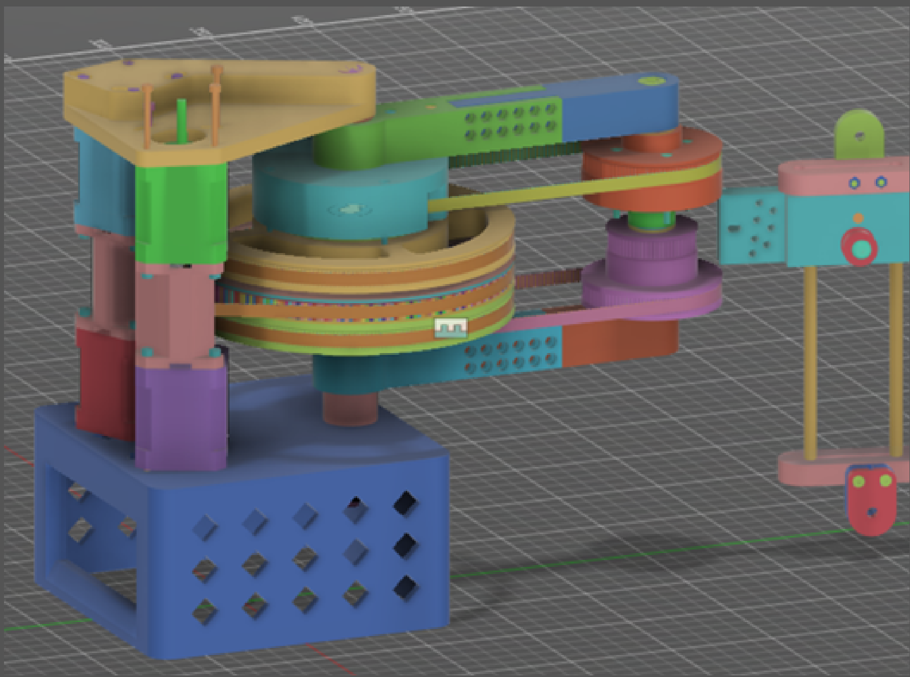
1.To move from one chunk to another first we find the four points necessary.

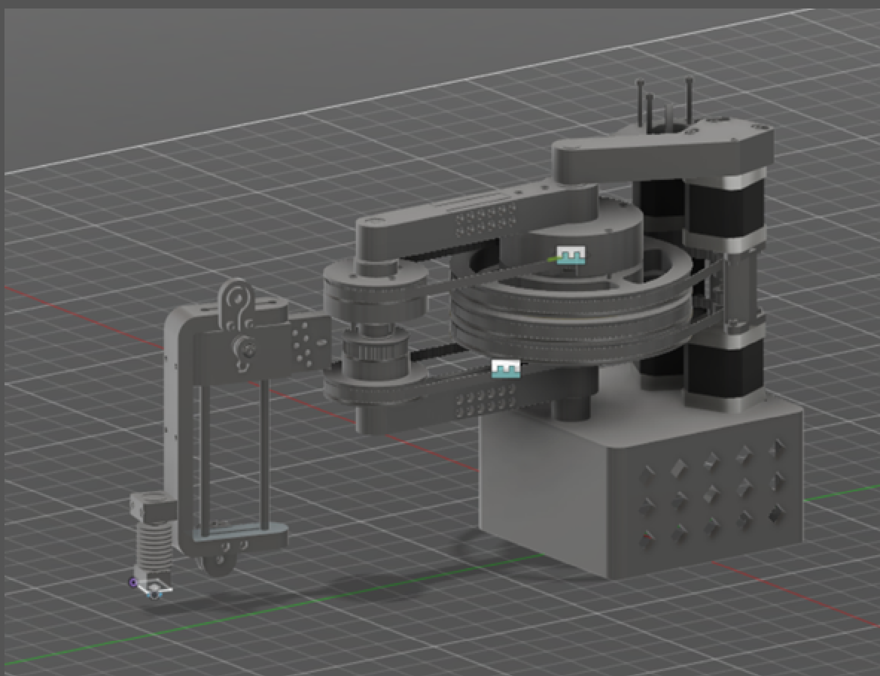
- P1- The endpoint of the current chunk
- P2- The start point of the next chunk
- P3 and P4- The two points in between

2.From P1 we shift the print head up by some distance (shift) this is the point P2
3.From P2 we move the extruder head to another position P3 (this has the same x and y coordinates as P4)
4.Now the z coordinate of the chunk will vary according to the slicer and which slice the printer is printing

OBJECTIVES MET IN THE MONTH OF OCTOBER :-

- Algorithm of chunk based slicing
- Assembling the components of fusion model to whole scara model and report on components of SCARA model
- Some screen shots of fusion model done till now below





PROPOSED PLAN OF ACTION FOR THE MONTH OF NOVEMBER :-

- For the machine learning team the next task will be to find out how to implement the algorithm they have decided upon as well as how to implement existing algorithms like chunk based slicing and write some pseudo code.
- The reprap Helios team will have to what changes can be made to the reprap model which we have made to make it more useful for the ultimate goal of the project and also analyse each part of the model in the BOM and search in the net if they can find cheaper alternatives or more efficient alternatives
- Making of mecanum wheels for mobile SCARA
- Writing audrino codes for project
- Research on deep learning and see how to apply it in project
- Understanding how slicer works and how we can integrate slicer for our project and what modifications we have to make for slicer to print indefinitely

REFERENCES :-

- https://www.youtube.com/watch?v=VaZ-skIrfO0&t=47s
- https://github.com/NicholasSeward/proto_RepRap_HELIOS

THANK YOU!