ME 714 Computer-integrated Manufacturing

Assignment 3

Due: March 19, 2021

Important Instructions:

- You can complete this assignment as a team. A team can consist of maximum two people.
- **Submit this assignment as a Microsoft WORD file ('.doc', '.docx' format) on Teams. ONLY ONE of the team member should upload the file to avoid confusion. The document should include the names and IDs of both the team members.**
- **Please show all the important steps while answering the questions. Clearly state ANY assumptions, whenever applicable.**
- **Any team found to have committed or aided and abetted the offense of plagiarism will receive ZERO credit for the whole assignment without any exceptions.**

1. For assembly of electronic components on a printed circuit board ('PCB' shown in Fig. 1A), an automated machine (a 'Robot') is used. The robot has an arm to pick and insert the electronic components (such as chips, transistors, resistors, capacitors, etc.) on the PCB. The PCB is mounted on a positioning table which moves it in X and Y direction such that the component is inserted at the desired location on the board. Design a stepper motor-driven leadscrew actuator for each axis (X and Y) of the positioning table. The design parameters include the range of travel in mm, the minimum number of step angles for the motor, and the minimum number of bits for the control memory for each axis. Assume pitch of the leadscrew to be 2 mm. Inherent mechanical errors in the table positioning can be characterized by a normal distribution with a standard deviation of 5 microns. Dimensions of the PCB are shown in Fig. 1A. Example component is shown in Fig. 1B. All the components have identical lead diameters of 0.5 mm. [8]
   Note: Clearly state all your assumptions in your answer.

2. Design a robot for the assembly of electronic components on a printed circuit board (PCB) ('PCB' shown in Fig. 1A). Once a PCB is placed at a fixed position in the robot workspace, the robot should be able to pick up the electronic components (such as chips, transistors, resistors, capacitors, etc.) from a convenient location in its workspace, move them to the desired hole location, and insert them vertically in the PCB. *The robot should be cylindrical with TLL (Twist, Linear, Linear) joint configuration. Also, the configuration of the last link and end effector must be such that the robot does not collide with previously inserted components*. [15]

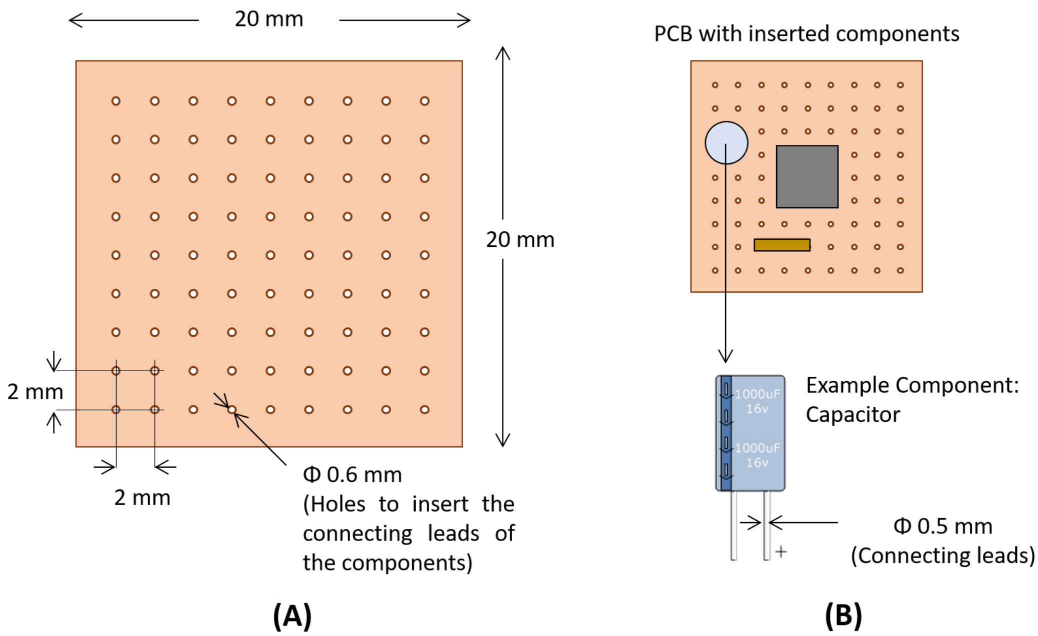

Figure 1: (A) Blank PCB, and (B) Assembled PCB with a typical electronic component

Please provide a sketch, schematic or a 3D model of the robot to describe your design along with the design parameters. The design parameters for the robot must include the joint parameters $(a_i,\ \alpha_i,\ d_i,\ \theta_i)$ (provide a value for a fixed parameter and a range for a variable parameter) as well as some of the other important geometrical information such as the dimensions of the base link, coordinates of the base with respect to the global reference frame attached to the center of the PCB (assume the PCB has zero thickness).

Find the transformation matrix that connects the base reference frame on your robot to the end-effector reference frame (Neglect wrist/gripper to simplify the problem).

To make your robot reach the center of the hole at the lower left corner of the PCB in Fig. 1A), what should be the specific values of the joint parameters $(a_i,\ \alpha_i,\ d_i,\ \theta_i)$?

Note: clearly state your assumptions, if you need to make any.

3. Propose a process plan to manufacture the robot designed by your team in Question 1. The process plan should be represented as a part-machine incidence matrix. [5]

   The parts that need to be fabricated are the parts that constitute the links and joints for your robot (fasteners are bought ready-made). All the surfaces that have relative motion between them are required to have a smooth surface $(Ra < 20\ nm)$. Rest of the external surfaces will be spray-painted to prevent corrosion. Assume all the parts will require some drilling operation to accommodate actuators, electronic components etc. You have following machines in your shop (i) Saw, (ii) 3-axis CNC vertical milling machine, (iii) Drill, (iv) Lathe, (v) Polishing wheel, and

(vi) Spray-painting equipment. The raw material is available in the form of sheets, rectangular blocks or cylindrical rods of stainless steel.

4. Once you have a process plan as a part-machine incidence matrix, write *a function* in MATLAB or Python to generate possible cell designs based on the Single Linkage Cluster Analysis (SLCA) algorithm. Include the code in your report. *Make sure your code is generic enough to accept ANY size part-machine matrix.* [22]

5. Seeing how you can successfully build a functional prototype of the robot, you team would now like to start manufacturing these robots on a commercial scale. As a first step, you would like to redesign the base with your company's name (a brand name) on it. [15]

   Design a new base for the robot with following considerations,

   - Your base design conforms to the dimensions provided in Fig. 3
   - Curve C can be any curve except a straight line.
   - Your brand name is milled on any of the flat surfaces on the base part. The brand name of your team should be formed by the initials of one of the members (the 'CEO') and last digit of his/her IIT Bombay ID (E.g. Soham Mujumdar with ID XXXXXXX1 has the brand name 'SM1'). The depth of the letters should be at least 2.5 mm and width should be at least 5 mm.

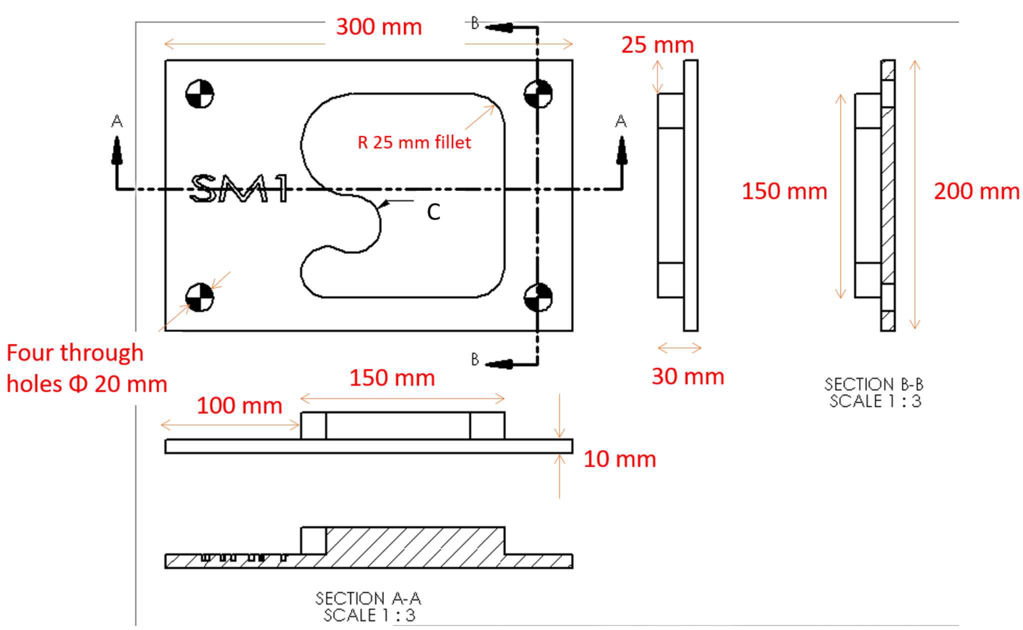

Figure 2: CAD of the robot base

Use CAM function in PTC Creo Parametric to generate NC program and tool path for your base part. *Note: Creo parametric has a free student license. Step-by-step instructions for an example* *part are uploaded for your reference. Alternatively, you may use any other CAM software that you can access.*

- Use a workpiece block with the dimensions (L x W x H) 300 mm x 200 mm x 30 mm
- Create the reference at the lower left corner of the top surface of the block
- Create a mill window that is slightly larger than the block
- The milling operations consist of two sub-operations: roughing with Tool 1, and finishing with Tool 2 (see tooling parameters below).
- Use drilling to drill the holes using Tool 3.
- Provide two screenshots of tool paths generated by the software. One for roughing, one for drilling.
- Provide the complete G-code generated by the software.

Parameters	Tool 1	Tool 2	Tool 3
Type	End Mill	End Mill	Basic Drilling
Cutter Diameter	19.05 mm	3.175 mm	20 mm
Cut Feed Rate	250 mm/min	125 mm/min	150 mm/min
Step Over	7.5 mm	n/a	n/a
Max Step Depth	5 mm	1 mm	n/a
Clearance	5 mm	5 mm	5 mm
Spindle Speed	1000 rpm	1500 rpm	1000 rpm

Figure 3: Tools and machining parameters