

IROS 2010 Grasping and Manipulation Competition: Manufacturing Track

Background

We are entering a new manufacturing era where more and more small and medium sized enterprises (SMEs) are looking to implement robotic solutions into their production operations. SMEs represent the majority of manufactures worldwide and they most often produce in batches with product variation from batch to batch, often called high-mix, low-volume production. To support production in such an environment where robot expertise is often limited, and cost is always a factor, robot systems must be easy to deploy and reconfigure with minimal retooling.

Assembly is one of the most difficult operations for robots typically implementing part feeders to present parts to the robot, and specialized tooling or jigs to ensure that a part can be positioned by a robot within the required assembly tolerances. These positioning tolerance requirements can also lead to time consuming robot programming strategies to precisely align a part for assembly. This competition challenges teams to develop robot systems that are easy to deploy and program with the goal of handling small batch assembly operations with part variations between batches. The robot systems will also be tested on their ability to disassemble parts.

Teams will compete with the goal of disassembling and assembling a task board containing a variety of insertion, meshing, screwing, and deformable material routing operations using an autonomous robot system. Less time spent fixturing and programming the system for operation will inevitably lead to more components being disassembled and assembled in the allotted time and possibly time bonus points upon full completion of the process faster than the allotted time. The main system components expected to achieve a truly autonomous system includes one or more of the following: vision sensors, force sensors, robots, robot hands, flexible gripper systems and tools as well as the use of part and assembly CAD data.

Teams should design and test the operation of their systems prior to the competition using the three task boards and associated parts found at: <https://www.nist.gov/el/intelligent-systems-division-73500/robotic-grasping-and-manipulation-assembly/assembly>. These initial task boards will be used by teams to qualify for the competition. More details on this can be found on the manufacturing track website. All information submitted for review by the competition organizers will be kept confidential.

On the day of the competition, teams will be presented with a task board and parts to be disassembled and assembled that incorporate a subset of the parts from the website above. In addition, CAD data for the parts and task board will be supplied. The boards must first be disassembled and then assembled by the competing robot systems per the following rules.

Rules

The manufacturing track is composed of two sub-tasks, disassembly and assembly. The disassembly subtask 1 starts with a fully assembled task board where components are removed from the task board and placed in a kit. The assembly subtask 2 starts with an empty task board, where components are presented in kit form and assembled onto the task board. Team rankings will be determined by the results of these two sub-tasks. Note that the task board presented with these rules is an example and these rules are tentative and subject to change.

Task 1: Board Disassembly/Assembly

Parts (figure 1a & 1b):

- 1) Board with slip-fit holes, threaded holes, female electrical connectors, cable routing components and initial belt drive components.
- 2) Components (tentative):
 - a. Metric pegs of various diameters and cross-sectional shapes
 - b. Standard Socket Cap Screws (sizes M4, M6, M8)
 - c. Various male electrical connectors
 - d. Gears
 - e. Ethernet cable
 - f. Belt drive assembly components
- 3) Kit mat
- 4) Computer Aided Design (CAD) data for all parts and the task board.

This task consists of the following two subtasks:

Subtask 1: Board Disassembly

Subtask 2: Board Assembly

Each using a task board as exemplified in Figure 1. In this task board example, 4 sections are shown bolted together using connecting plates and screws for reconfigurability.

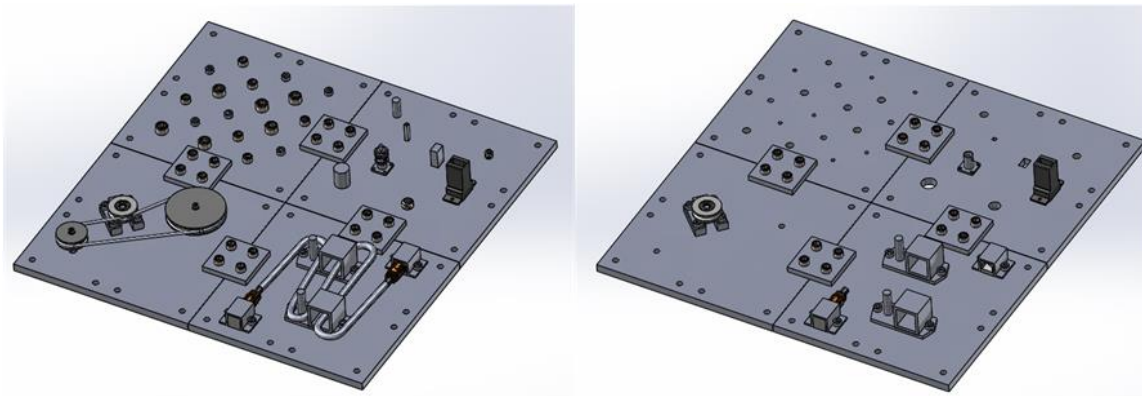


Figure 1: Example of a four-section reconfigurable task board fully assembled (left) and unassembled (right).

Subtask 1: Task Board Disassembly

Description:

A fully assembled manufacturing task board is placed on the table alongside a kit (Fig. 2). The kit area and the task board location are set by the team on a table surface within the robot system workspace. Screws, pegs, gears, male electrical connectors, routed cables, and belt drive components are already assembled on the task board. The goal is for the competing robot system to remove all components from the board and place them in the predefined kit space. Points are assessed on a per part basis.

Base Time Limit: 40 minutes

Number of parts to disassemble: 40

Achievable Points: 120 + Time bonus

Setup:

- 1) Team places assembled task board on table in designated area

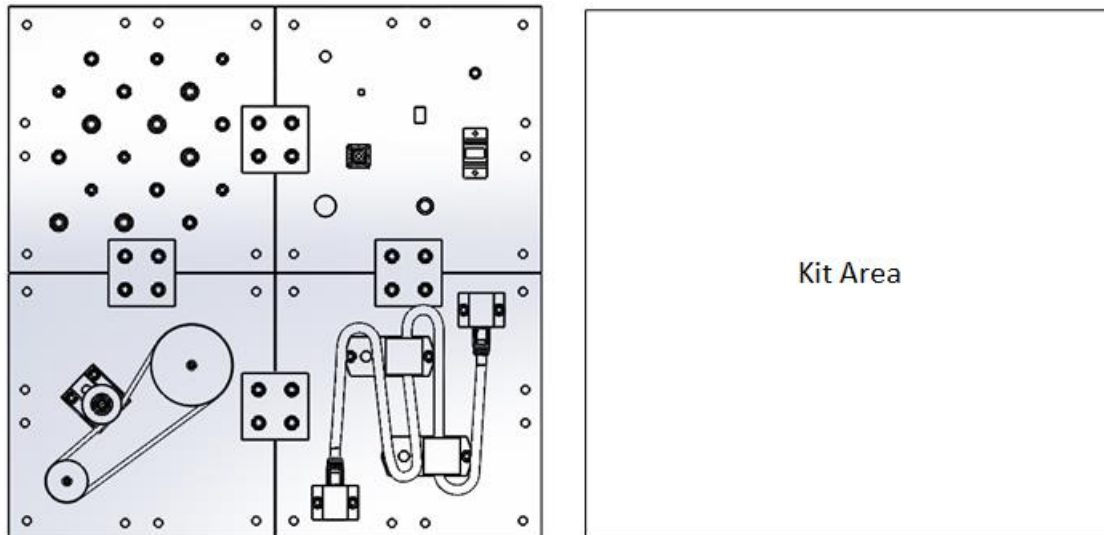


Figure 2: Layout for disassembly-subtask 1 showing assembled task board and kit area in which to place disassembled components.

Steps:

- 1) The robot system disassembles a part from the task board
- 2) The robot system places the removed part into the associated kit area
- 3) Repeat for 40 parts.

Scoring:

- 1) 2 points for each part removed from the board
- 2) 1 point for each part placed into the kit area
- 3) Time Bonus: $Time\ bonus = INT((base\ time[sec] - spent\ time[sec]) / 40) \times 1\ point$

Rules:

- 1) Time bonus points are only available if all 40 parts are successfully disassembled into the kit.
- 2) A part is considered removed from the task board even if it is dropped by the robot system.
- 3) No points for placement in kit area if part overlaps defined boundary.
- 4) No manual or teleoperated intervention by human operator (e.g., no manual tool changes)
- 5) No restriction on number of arms, grippers, sensors used.
- 6) Use of hand tools (i.e. wrenches, electric drivers) is allowed provided the robot acquires these tools without human assistance.
- 7) Perception system markers (i.e. reflectors, AR tags, QR codes) may not be placed on the individual parts to be disassembled.
- 8) Perception system markers can be placed on the task board and kit
- 9) Working area is the area where the end-effector of the robot can move. The maximum size of the working area is the table top which is estimated to be 1.5 x 0.75 meters. Judges will work with teams to achieve random placement of board and kit area.
- 10) A reset is allowed in order to make program changes. During a reset, all 40 parts must be reassembled to the task board the assembly and reset in kit area. All accumulated points are reset to zero.

Subtask 2: Task Board Assembly

Base Time Limit: 80 minutes

Number of parts to assemble: 40

Achievable Points: 200 + Time bonus

Description:

The manufacturing task board and kit are placed on the table. The locations of the kit and task board is set by the team. Pegs, male electrical connectors, routed cables, screws and belt drive assembly components are placed in the kit area by the teams. The goal is for the robot system is to pick all screws, pegs, gears, male electrical connectors, routed cables, and a belt drive assembly from the kit layout/bolt dispenser and assemble them into their defined locations on task board. Points are assessed on a per part basis.

Setup:

- 1) Team places disassembled (empty) task board on table in designated area (see Figure 3)
- 2) Team places components in designated kit area. Teams can design their own kits.

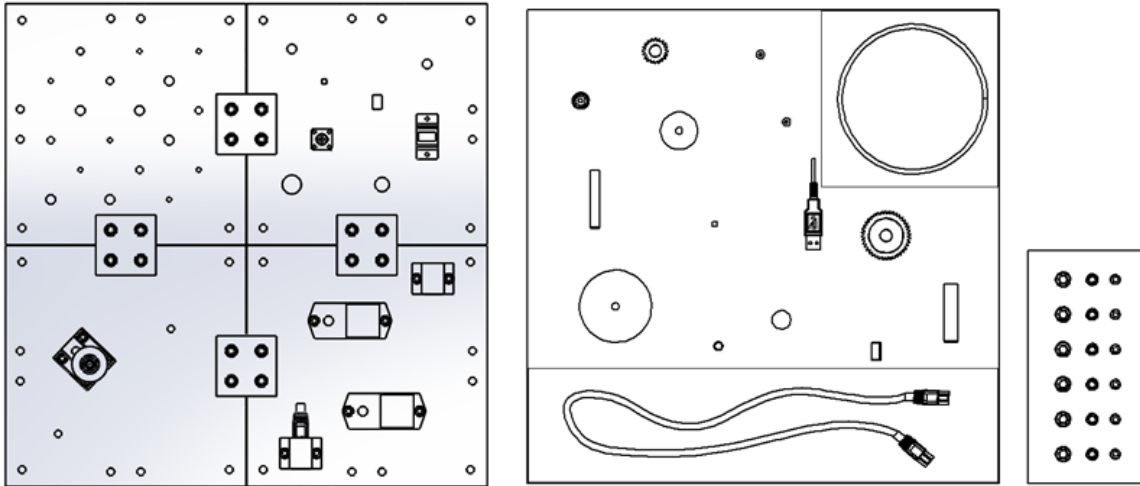


Figure 3: Layout for assembly-subtask 2 showing empty task board and kit area with a method of dispensing screws.

Steps:

- 1) The robot picks a part from the kit area
- 2) The robot system assembles the part into its location on the board.
- 3) Repeat for each of 40 parts.

Scoring:

- 1) 1 points for each part that is picked up from the kit layout.
- 2) 1 points if the part contacts the task board surface before the grasp is removed or if the part is dropped onto the task board (part must remain on task board).
- 3) Up to 3 points for each part assembled using the following criteria:

Part Type	Points	Description
screws	2	Screw cannot be lifted from hole and freely turns to tighten
	1	Screw is fully threaded with head seated against board
pegs	2	Insertion into hole
	1	Constrain bottom of peg against underlying surface to board
connectors	2	Insertion into corresponding connector
	1	Fully seated or snapped connection
spacers	2	Insertion onto shaft
	1	Constrain spacer bottom to task board surface
pulleys	2	Insertion onto shaft
	1	Constrain pulley to top surface of spacer
tensioner	2	Fully seated against stop
	1	Screw seated to prevent tensioner from sliding
gears	2	Insert 1 st gear onto shaft seated against board
	1	Gear mesh (1 st gets a point when 2 nd is meshed with it)

4) Time Bonus: $Time\ bonus = INT((base\ time[sec] - spent\ time[sec]) / 40) \times 1\ point$

Rules:

- 1) Time bonus points are only available if all 40 parts are successfully assembled onto the task board.
- 2) Points only awarded for assembly of a part into its designated location. (e.g. no points for inserting 8mm peg into 16 mm hole)
- 3) No manual or teleoperated intervention by human operator (e.g., no manual tool changes)
- 4) No restriction on number of arms, grippers, sensors used
- 5) Use of hand tools (i.e. wrenches, electric drivers) is allowed provided the robot acquires these tools without human assistance.
- 6) Perception system markers (i.e. reflectors, AR tags, QR codes) may not be placed on the individual parts to be assembled.
- 7) Perception system markers can be placed on the task board and kit
- 8) Working area is the area where the end-effector of the robot can move. The maximum size of the working area is the table top which is estimated to be 1.5 x 0.75 meters. Judges will work with teams to achieve random placement of board and kit area.
- 9) A reset is allowed in order to make program changes. During a reset, all 40 parts must be reassembled to the task board the assembly and reset in kit area. All accumulated points are reset to zero.

Time Shift

120 (=40 + 80) minutes are allotted to each team including setup time for completing subtask 1 and subtask 2. A team can stop subtask 1 and move on to subtask 2 anytime. Subtask 1 may not be worked once subtask 2 is started. A team can divide the time between subtasks as desired. After 120 minutes, Task 1 activities must be stopped.

Note: Time for setting up kit for assembly subtask 2 is included in the 120 minutes.