Industrial Robotics Category

Assembly Challenge

Rules and Regulations 2018

The Industrial Robotics Competition Committee

These rules are a provisional summary created for your reference when organizing teams. Detailed rules are planned for release in the future. The information included in these rules and regulations are also subject to change.

Revision Date: 1.1.0 (5th, Mar. 2018)
Table of Contents

1 Background .............................................. 1

2 Description of Competition Tasks .......... 1
   2.1 Overview of the Tasks ....................... 3
   2.2 Schedule ......................................... 4
   2.3 Purpose of the Surprise Task ............... 4

3 Competition Area and Competition Procedure 5
   3.1 Lighting Requirements ...................... 6
   3.2 Network Infrastructure ...................... 6
   3.3 Time Extensions Due to Trouble .......... 6
   3.4 Competition Time and Scoring .......... 7
      3.4.1 Competition Time ....................... 7
      3.4.2 Reset ........................................ 7
      3.4.3 Task Completion and Scoring ......... 7
   3.5 Penalties ......................................... 7
      3.5.1 Withdraw from the Competition ......... 7
      3.5.2 Damage to the Field ...................... 8
      3.5.3 Interference to Other Teams .......... 8
      3.5.4 Damage to Parts ......................... 8
      3.5.5 No Show .................................... 8

4 Referee ................................................. 8

5 Robot Requirements ................................ 8
   5.1 Hardware Requirements .................... 8
      5.1.1 Power / Number of Motors .............. 9
      5.1.2 Cost ......................................... 9
      5.1.3 Duty to Install an Emergency Shutdown System 9
   5.2 Software Requirements ...................... 9
      5.2.1 CPU, Memory, Storage, etc. ............ 9
      5.2.2 Remote Control ............................. 9
   5.3 Placement of Markings ...................... 10

6 Description of Competition Tasks ............ 10
   6.1 Task-Board Task ............................... 10
      6.1.1 Overview .................................... 10
      6.1.2 Expected Technological Elements ....... 10
      6.1.3 Expected Equipment ....................... 11
      6.1.4 Parts .......................................... 11
      6.1.5 Task-Board .................................. 11
      6.1.6 Placement Mat ............................... 11
      6.1.7 Detailed Description ....................... 11
      6.1.8 Evaluation Method ......................... 12
      6.1.9 Reset ......................................... 12
6.1.10 Schedule............................................................................................................ 12

6.2 Kitting Task........................................................................................................ 13
6.2.1 Overview ........................................................................................................ 13
6.2.2 Expected Technological Elements ................................................................. 13
6.2.3 Expected Equipment ..................................................................................... 13
6.2.4 Parts ............................................................................................................... 13
6.2.5 Detailed Description ..................................................................................... 13
6.2.6 Evaluation Method ....................................................................................... 14
6.2.7 Reset ............................................................................................................... 15
6.2.8 Schedule ........................................................................................................ 15

6.3 Assembly Task .................................................................................................. 15
6.3.1 Overview ........................................................................................................ 15
6.3.2 Expected Technological Elements ................................................................ 15
6.3.3 Expected Equipment ..................................................................................... 15
6.3.4 Supplying Parts and Taking Assembled Products Out ................................ 16
6.3.5 Detailed Description ..................................................................................... 17
6.3.6 Evaluation Method ....................................................................................... 17
6.3.7 Reset ............................................................................................................... 18
6.3.8 Schedule ........................................................................................................ 18

6.4 Promotion of energy-saving ............................................................................... 18
6.5 Presentations ...................................................................................................... 19

7 Safety ...................................................................................................................... 20

8 Conclusion (Robotics for Happiness) ................................................................... 20
1 Background

George Devol applied for his historic Programmed Article Transfer patent in 1954. This patent was approved in 1961, and in the same year, the Unimate was released from an American company, Unimation, as the world’s first industrial robot. His concept of programmable transfer machine and operating principle called teaching and playback have still remained timeless even today, and they are definitely basic concepts for industrial robots. The fact that the most industrial robots, especially arm type robots, in use today are operated by the teaching and playback method demonstrates an appreciation of universality of his ideas.

Considering the cost for implementing standard robotics systems, we find the expense of the robot itself makes up no more than roughly 20% to 30% of the total costs. In addition to the cost of peripheral equipment and peripheral devices, system integration—as to integrate all these equipment into a single system—makes up more than 50% of the total costs. This is the reason why the industrial robot itself is regarded as an incomplete product. Industrial robots, which was supposed to provide functionality as programmable universal machines, in fact often became merely a special purpose system that would not be re-programmed once they had been built up. From that reason, conventional industrial robots based on the teaching and playback method are becoming difficult to cope with the demand of high mix low-volume production in recent years. Furthermore, regression phenomena to use human workers, such as the cell production method, are happening in production sites.

However, Japan and the rest of the world are facing labor shortage and increasing labor costs. The world requires adaptable robotics systems to be implemented even in high mix low-volume production. In particular, small- and medium-size companies that operate under strict cost limitations cannot easily implement robots with large integration costs. Therefore, it is required to configure a system that does not come with many of the system integration costs by using industrial robots as lean programmable universal machines that adapt to different purposes and enable agile changes to a system to manufacture different products easily. Such requirement must be satisfied in order to promote the implementation of robotics at small- and medium-size companies as well as major enterprises.

The WRS Industrial Robotics Category aims to realize the future of industrial robotics by building agile and lean production systems that can respond to ever-changing manufacturing requirements (even for a one-off product at an extreme case) in high mix low-volume production through a competition in this category by setting a goal as ‘toward agile one-off manufacturing’. Table 1 shows the levels of next-generation production systems where the current production systems are set at level 1, and the highest objective in next-generation production systems are set at level 5. We are aiming for at least level 4 at WRS.

Assembly is one of the most difficult operations for robots. Assembly tasks are often laborious and costly for preparing peripheral devices such as parts feeder and jigs. In addition, a careful teaching is needed for precise parts alignment, and fine adjustments of the teaching data is also laborious and time consuming to overcome ‘temporary stops’ that could occur frequently right after new introduction. Therefore, the WRS Industrial Robotics Category has set product assembly as the challenge task in this competition from the numerous tasks in the manufacturing domain.

2 Description of Competition Tasks

WRS Industrial Robotics Category designed the competition of gear unit assembly as a trial task in 2017, which was one of the tasks for Manufacturing Track [1] at the 2nd Robotic Grasping
and Manipulation Competition held at the 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2017) [2]. In the WRS 2018, a Belt Drive Unit, which includes a greater degree of difficulty than a gear unit, is to be assembled.

### Table 1: Levels of Next-generation Production Systems (Draft)

<table>
<thead>
<tr>
<th>Level</th>
<th>Agility</th>
<th>Leanness</th>
<th>Factors during operation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0 days for new product (Changeover on a same day)</td>
<td>100% continual use (Introduction of universal hands able to perform jig-less assembly of multiple products, etc.)</td>
<td>Machine learning (Temporal stoppage prevention/cycle time improvement)</td>
<td>Ultimate goal Autonomous motion planning, etc.</td>
</tr>
<tr>
<td>4</td>
<td>2 days for new product (Changeover on a weekend or an overnight business trip)</td>
<td>Available for new products only by recombining existing equipment. (Universal hands able to grasp multiple products, etc.)</td>
<td>Automatic recovery from temporal stoppage (Learning through observing human intervention, etc.) Human intervention is required for big stoppages.</td>
<td>Target level at WRS Small number of universal hands</td>
</tr>
<tr>
<td>3</td>
<td>1 week for new product (Changeover in a week, e.g. during large consecutive national holidays)</td>
<td>50% or more can be reused (Use of specialized hand library, flexible jig, multi arms, etc.)</td>
<td>Operation rate improvements (Prevention measures against temporal stoppages, etc.) Automated proposals of improvements.</td>
<td>Offline planning Reduction of specialized tools with multi arms, etc.</td>
</tr>
<tr>
<td>2</td>
<td>1 month for new product</td>
<td>Reusing only robots</td>
<td>Reduction of temporal stoppage rate by absorbing part variations using sensors.</td>
<td>Levels possible with current technologies</td>
</tr>
<tr>
<td>1</td>
<td>For specific products only Changeover is not assumed.</td>
<td>0% (No reuse is assumed.)</td>
<td>Controls parts variations to ensure an enough utilization rate. Human intervention is required for temporal stoppages.</td>
<td>Many robot systems used today.</td>
</tr>
</tbody>
</table>

Figure 1: Overview of the Belt Drive Unit for the Assembly Challenge at the WRS 2018 (The tentative size of the base plate is 200 mm × 120 mm) (The design of the Belt Drive Unit is subject to change in the future)
An image of the product fully assembled is shown in Figure 1. Note that, in addition to the assembly of the part designated in advance, teams shall also assemble parts announced at the competition venue (surprise parts). This assembly requires an agile and lean system reconfiguration. At the WRS 2020, even more difficult product shall be assembled. Figure 2 shows the transition of the competition tasks and the technical challenges from the 2017 trial tasks to the WRS 2020.

2.1 Overview of the Tasks

The following three tasks related to the assembly of the Belt Drive Unit will be given in the WRS 2018.

1. Task-Board
   Teams will compete on basic technologies for an assembly by assembling a task-board that contains the necessary technical elements for assembling the Belt Drive Unit.

2. Kitting
   Teams will compete on the speed and accuracy of kitting, which is regarded as a preparation task for the Belt Drive Unit assembly, where the necessary parts should be picked from the part bin and be laid in a part-kitting tray.

3. Assembly
   Teams will compete on the speed and accuracy of assembling the Belt Drive Unit using the parts laid out in the part-kitting tray kitted and prepared in advance by the competition committee. Teams will also compete on the ability for an agile setup change to cope with a requirement of assembling new parts with different specifications from those announced in advance (surprise parts) as a new production demand.

Figure 2: Transition of the Competition Tasks and the Technical Challenges from the 2017 Trial Tasks to the WRS 2020 in the Industrial Robotics Category

Trial Task in 2017: Gear Unit Assembly
(as a part of 2nd IROS Robotic Grasping and Manipulation)

Technical challenges
- Parts mating with very tight clearances
- Object recognition
- Jig-less assembly

WRS 2018: Belt Drive Unit (+ Surprise Parts) Assembly

Technical challenges
- Flexible parts
- Three-part assembly
- Very small part (M3 screw)
- Agile reconfiguration for surprise parts

Surprise Parts
Reconfigure the system in agile and lean manners

WRS 2020: TBD (More Difficult Product/Surprise Parts Assembly)
In addition to the three tasks above, teams who got certain amount of points from the tasks will be assigned a presentation about a hard-to-understand technical details as part of the competition, where they have to present technical details which are hard to understand from the competition tasks. The final ranking will be determined from a total evaluation of the points earned in the tasks and the presentation. After the competition, distinguished teams will demonstrate their system in an exhibition open to the public in order to improve the technical capabilities of other teams.

2.2 Schedule

Table 2 shows the schedule of the WRS 2018. The WRS 2018 will be held alongside with the Japan Robot Week. The event will be held from Monday October 15, 2018 to Monday October 22 for eight days. The first two days will be used to set up the venue for the event. Teams will compete over the following five days (Day 1 to Day 5) to get points. The last day will be for a symposium. The competition starts in the afternoon of Day 1 and teams compete in the Task-Board first. Teams will compete in the Kitting task on Day 2. Then, teams will compete in the Belt Drive Unit assembly using the parts announced in advance on Day 3 and some surprise parts on Day 4, respectively. Technical presentations will be held in the morning of Day 5, followed by the exhibition and award ceremony scheduled for that afternoon. In addition, a symposium (closed to the public) is scheduled to be held on the last day as a place for technical exchange among the participants of the competition.

2.3 Purpose of the Surprise Task

The WRS Industrial Robotics Category aims at realizing future manufacturing systems that can respond to variously changing orders (ultimately, even an order for one-off product) by reconfiguring the system in agile and lean manners. Therefore, at the Assembly Challenge, teams compete on the ability for an agile setup change to cope with a requirement of assembling new parts with different specifications from those announced in advance (surprise parts) as a new production demand. These surprise parts will be announced right before the start of the competition. The assembly of the product including the surprise parts is called the surprise task.

At the WRS 2018, just a few of the parts shall be replaced by the surprise parts for the assembly of the Belt Drive Unit. At the WRS 2020, however, even more difficult surprise tasks may be required, for example, assembling a completely new product.

<table>
<thead>
<tr>
<th>Time for setup</th>
<th>Time open to the public</th>
<th>Closed session</th>
</tr>
</thead>
<tbody>
<tr>
<td>13th</td>
<td>Day 1</td>
<td></td>
</tr>
<tr>
<td>14th</td>
<td>Day 2</td>
<td></td>
</tr>
<tr>
<td>15th</td>
<td>Day 3</td>
<td></td>
</tr>
<tr>
<td>16th</td>
<td>Day 4</td>
<td></td>
</tr>
<tr>
<td>17th</td>
<td>Day 5</td>
<td></td>
</tr>
<tr>
<td>18th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21st</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22nd</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Competition Schedule (Tentative)
3 Competition Area and Competition Procedure

The Challenge tentatively plans to invite 16 teams to participate. Each team will be assigned an area to run robots and other systems (hereinafter system running area) and an area for operations (hereinafter operation area) as shown in Figure 3. The system running area provides enough space to install two arm type robots operating simultaneously as shown in Figure 4. A work table will be provided but a part rack, where parts bins are placed, should be prepared by the teams. A single-phase 100 V power source will also be provided. A three-phase 200 V power source will also be made available at the request of any team in addition to the single-phase 100 V power source. An air pressure source will also be provided. A drawing of the system running area will be provided in advance.

Note that it is not necessary to use all of the provided materials and power sources (work table, air pressure source, etc.) and the teams are allowed to prepare their own materials independently. When arranging the devices and materials in the system running area, teams must consider the visibility from the audience. For example, the part rack should not be placed on the traffic side of the system running area and the system running area should not be enclosed or covered by a shade. Note that the competition committee might want to set cameras inside the system running area and the operation area for providing live video to audiences and recording the operation during the competition. If a team puts up a pole that interferes with the view of a camera installed by the competition committee, the competition committee might want to install that camera to that pole. The competition committee will ban flash photography by audience.

Figure 3: System Running Area and Operation Area (Conceptual Drawing)
The number of participants allowed to enter the operations area is restricted to ten; however, this number may become less due to the layout change of the venue. Members are allowed to change for each task, but they must not be replaced during a task period.

Teams are allowed to start preparations on the team setup day. The number of people is not restricted on the team setup day, however, preparations by roughly ten people are desirable due to the narrowness of the work space.

3.1 Lighting Requirements

Teams may use the lighting provided at the venue for their lighting. The competition committee will install no additional lighting in each team area. Therefore, the brightness, hue and other attributes of the lighting may differ depending on the condition of each team area. In addition, curtains will be used to block out direct sunlight from the windows of the venue, but the brightness may vary according to the weather conditions. Each team may use shades or bring in their own lighting, but it must keep these items in the team area and not interfere with other teams. Team must be careful not to disturb the operation of refereeing or block the view of the audience with these items.

3.2 Network Infrastructure

Internet connection in each team area shall be provided. Since, it is a best effort system, however, it does not guarantee any connection speed. Considering the network load sharing with other teams, the communication band shall be limited to 64 Mbps.

The WRS 2018 will configure a wired LAN. Use of a wireless LAN will be prohibited because it may interfere with tasks in other categories. Furthermore, each team may configure their own Internet environment, but use of a wireless LAN via a Wi-Fi mobile router will also not be permitted.

3.3 Time Extensions Due to Trouble

Each team is responsible for any trouble that occurs in their team space during the competition and no time extensions will be given for any of the tasks. For example, this would include communication failure with a robot. However, in the event of issues that impact every team, the
competition committee may allow an extension of time after deliberation. For example, this would include power outages.

3.4 Competition time and Scoring

This section describes competition time and scoring. Deductions due to penalties will be explained in Section 3.5.

3.4.1 Competition time

The competition time for each task is made up of the preparation phase and operation phase. The preparation phase is for preparing the task in the system running area and operation area. Teams are permitted to enter the system running area during the preparation phase. Once the preparations are completed, the team leader shall signal the start of their operations to a referee to begin the operation phase. In the operation phase, everyone shall be restricted from entering the system running area because the robots and other equipment will be running. In addition, because remote control is prohibited, teams must demonstrate that they are not touching any input devices such as a keyboard by placing paper or a similar material over their input devices.

When a team chooses a “reset” as described hereafter, the participants stop the operation of the robots and other equipment and return to the preparation phase. The time bonus described hereafter will be given based on the time that remains after subtracting the time taken in both the preparation phase and operation phase from the allotted time limit.

3.4.2 Reset

Teams may choose to reset their systems such as the robots, if these systems do not operate as intended during the operation phase. In the event of a reset, the task will return to the preparation phase from the operation phase. Teams shall return the materials to the designated state as specified in each task and start the task again. Moreover, no point deductions will be taken due to a reset, but teams will lose the time taken for the preparation phase and for redoing the task.

3.4.3 Task Completion and Scoring

Referees will score in accordance with the scoring criteria of each task. Basically, referees will evaluate the state of the completely assembled products when the time has expired in each task. For the incomplete products, partial points shall be added, in accordance with the scoring system. When a prescribed number of products has been assembled earlier than the time limit of the task, the additional points shall be added in accordance with the remaining time as a time bonus.

3.5 Penalties

This section describes actions that breach the rules and regulations. Referees will determine the penalties after deliberation if an issue not addressed in this section occurs.

3.5.1 Withdraw from the Competition

If a participating team withdraws from a part of the task, or if the referees judge that the content of the competition by a team is equivalent to withdrawal, this team may be excluded from the evaluation of the ranking. Also, it may be removed from subjects of various awards.
3.5.2 Damage to the Field

Teams must not bump into or damage any materials at the competition venue. Any team who causes serious damage that would not be repaired shall be disqualified. Furthermore, this rule and regulation applies to the damage caused not only by a robot but also by a participant. However, the placement of markings is permitted based on the rules and regulations for each task.

3.5.3 Interference to Other Teams

As team space are quite close together, a team must not to cause problems to neighboring teams. This policy applies to the cases not only protruding their belongings out of each team’s designated space but also making noise, smell, lighting disturbances and so on.

3.5.4 Damage to Parts

Points shall be deducted if referees determine that a part distributed to a team has been damaged and may no longer be used in normal competition. A part deemed necessary to change shall be replaced with a spare part, but a spare part may not be available in some cases, because the number of spare parts is limited.

3.5.5 No show

Teams shall be withdrawn from a task if no team member is present in the team space at the time to start a task or if the team is clearly not ready to start a task.

4 Referee

At least two referees shall be assigned per team during the tasks. Teams must always follow the instructions of their referees. In the Industrial Robotics Category, the judging team shall tentatively be made up of people who are not the participating team members and shall not be chosen from participating teams. The decision of the referees shall be final. However, these decisions may be withdrawn when an obvious mistake has been made.

5 Robot Requirements

The robots used for the competition may be either ones prepared by each team or ones lent by the competition committee. A combination of both may also be possible. The type and specifications of the robots on loan to teams are currently being arranged and will be announced separately. Teams who would like to borrow robots should submit a loan request after that announcement. Teams may be assigned robots other than their first choice as the number of robots is limited.

5.1 Hardware Requirements

There are no restrictions on the number of robots, but teams must take into account the limited installation space for these robots. There is also no regulation about the weight, but each team needs to prepare a work table if the weight exceeds the bearing load of the table provided by the competition committee.

Furthermore, equipment such as devices that generate a great noise may be prohibited to use
if the referees deem the device inappropriate.

5.1.1 Power / Number of Motors

There are no restrictions on the type, number and power of motors used in the robots. However, the competition committee may restrict the use of such motors if they are determined to be a problem from the view point of safety and hygiene.

5.1.2 Cost

There is no cap on the costs for the robots or peripheral equipment. However, teams must pay careful attention to their own belongings at the competition venue.

5.1.3 Duty to Install an Emergency Shutdown System

An emergency shutdown system must be installed in each robot system developed by the teams. Regarding safety measures of robots and other systems, team must follow the safety regulations indicated separately.

5.2 Software Requirements

5.2.1 CPU, Memory, Storage, etc.

There are no regulations related to the computing functionality. Cloud computing that uses the Internet may also be available, but teams must take into account network troubles.

5.2.2 Remote Control

Remote control by personnel is not assumed in this competition, because it is an assembly challenge intended for the automation of production sites. Therefore, robots may not be operated remotely in the operation phase. This applies to not only the direct control via a device like a joystick, but also the control through voice, gesture and any other means of human intervention.

Figure 5: Task-Board when Assembly was Completed (Conceptual Image)
5.3 Placement of Markings

Each task stipulates rules and regulations to follow for the placement of markings on objects. These markings include QR codes, AR codes and IC tags and so on.

6 Description of Competition Tasks

The Assembly Challenge is composed of three tasks: the task-board task, the kitting task, and the assembly task. In addition, presentations will be held on Day 5 in order to evaluate technical aspects that cannot see only from the performance of the tasks. The team rankings will be determined by the results of three tasks as well as the results of the presentations. Note that the descriptions for each task shown below are tentative. The evaluation procedure and restart status after reset are all subject to change.

6.1 Task-Board Task

6.1.1 Overview

In this task, the robot of each team is required to assemble parts laid out on a placement mat in the designated locations on the task-board (Figure 5)\(^1\). Teams will not know the initial layout of parts in advance because the placement mat will be distributed right before the task. The appropriate tools may be used as necessary. Through this task, teams will compete on the elemental technologies necessary to assemble the Belt Drive Unit.

6.1.2 Expected Technological Elements

The main technological elements expected for this task include object detection technologies and motion planning technologies.

---

\(^1\) The idea and design of the Task-Board for WRS 2018 were largely inspired by the task board designed by the NIST, which was used for the 2nd Robotic Grasping and Manipulation Competition held at IROS 2017 \([2]\).
6.1.3 **Expected Equipment**

The main equipment expected for this task includes vision sensors, force sensors, robots, robot hands, and tools.

6.1.4 **Parts**

Parts related to the Belt Drive Unit assembly shall be used. The parts shall be laid out on the placement mat placed on the work table in the preparation phase. The details of each part are scheduled for release in advance as technical data such as 3D CAD models. No markings attached to these parts is allowed.

6.1.5 **Task-Board**

Teams shall place the task-board on the work table when starting the task. The task-board may be placed anywhere inside of the designated area. Some parts such as the bolts for the nuts to assemble will be installed on the task-board in advance. Markings may be attached to the task-board to detect the position of the task-board. The details of the task-board are schedule for release in advance as technical data such as a 3D CAD model.

6.1.6 **Placement Mat**

There are multiple types of placement mats specifying different part layout. One of those placement mats will be distributed at random to each team. Teams shall put the placement mat on the work table in the preparation phase. Markings may be attached to the placement mat to detect the position and orientation of the placement mat. Furthermore, the details of the placement mat, including the layout of the parts, will not be released in advance.

6.1.7 **Detailed Description**

The competition shall be made up of a preparation phase and an operation phase. The task-board, placement mat, and parts will be placed initially in a designated area outside the system running area before the task starts. When the task starts, teams will set the task-board and placement mat in the appropriate position and then arrange the parts as indicated in Figure 6 by hand all during the preparation phase. Referees will confirm the accuracy of the part layout done by teams. Teams may make the necessary preparations, such as securing the task-board with a vice, installing a non-slip mat beneath the task-board, laying out necessary tools, and teaching their robots, during the preparation phase. Teams will then declare the start of the operation phase to a referee once all preparations are completed. Thereafter, the operation phase will begin, and the robot will assemble the parts to the task-board. During the operation phase, teams are not allowed to touch the robot, the parts, the tools, the task-board, or the placement mat. The size of the task-board and the placement mat are tentatively set for 400 mm × 400 mm.

In the operation phase, the robot system will conduct the following procedure for approximately 20 parts laid out on the placement mat as shown in Figure 6; (i) the robot system shall pick up a part from the placement mat, (ii) the robot system shall then assemble the part to the task-board in the designated location. The above procedure shall be repeated for each part. Teams will try to accurately assemble as many parts as possible within the time limit of the task. The team may decide the order to assemble the parts. Since the assembled parts remain in position on the task-board, they may interfere with the robot system in the subsequent procedure. The part layout is
drawn on the placement mat and shown to the team right before the task. The team can prepare the tools as necessary. Tools modified in advance may be used according to the procedure. The tools to be used may also be attached to the robot hand in advance.

6.1.8 Evaluation Method

When the competition ends, points will be awarded with the task-board still placed inside the system running area. Basically, points are given based on the number of completed parts. Points are also assigned based on the completeness of the assembly. Evaluation items include whether the nut is fully seated on the task-board and whether the set screw has been fully screwed in. If all of the parts are completely assembled, extra points will be given as a time bonus based on the amount of time remained until the time limit of the task. Parts not assembled on the task-board should be placed on the placement mat when the time limit of the task is reached. If some parts, which were not assembled to the task-board, are not on the placement mat, deductions will be taken based on the number of parts. Tools placed in the designated area during the preparation phase must also be placed in the designated area when the time limit of the task is reached. If some of these tools are not placed in the designated area, deductions will be taken based on the number of tools. Lubricant may not be used on the parts or the task-board.

6.1.9 Reset

In an event such as system failures, teams can declare “reset” and start again from the initial setup. More specifically, teams shall return to the preparation phase and remove all of the parts assembled on the task-board, and then place all the parts on the placement mat again before starting the task again.

6.1.10 Schedule

Each team will compete twice in the task on Day 1. The better score of the two trials shall be adopted. The time limit for the task is scheduled for approximately 30 minutes.

Figure 7: Layout Example of the Kitting Task (Conceptual Image)
6.2 Kitting Task

6.2.1 Overview

In the kitting task, the robot of each team is required to pick up the ordered parts, which are necessary to assemble the Belt Drive Unit, from each parts box (parts bin) installed on the parts rack and place them at the specified locations and poses in the part-kitting tray. Teams will compete to prepare as many of these part sets as possible within the competition time.

6.2.2 Expected Technological Elements

The main technological elements expected for this task include object detection technologies as well as object grasping and motion planning technologies.

6.2.3 Expected Equipment

The main equipment expected for this task includes robots, robot hands, force sensors, vision sensors, parts, parts bins, a parts rack, and a work table.

6.2.4 Parts

A list of parts to be picked will be given to each team as a set list before the task starts. The set list will be provided to the teams as digital data, for example, a USB memory. The contents of the set list will be different for each team.

The parts used in this task are the same ones used in the assembly task. Markings to those parts are prohibited.

Multiple parts bins will be placed on the parts rack. Multiple pieces of the same part shall be put randomly in each parts bin. Markings can be put on these bins so that the robot can know what kind of parts are inside those bins as well as the position and orientation of the bins themselves.

The parts rack shall be placed on top of the work table. Teams are allowed to attach markings to the parts rack so that their robot can detect the position and orientation of the parts rack. Moreover, the parts rack can be secured to the work table.

The part-kitting tray shall be a flat tray, and its inside is divided by several partitions. Teams are allowed to attach markings to the trays so that their robot can detect the position, orientation, and type of part-kitting tray.

Teams shall use the parts, parts bins, and part-kitting trays specified by the competition committee. In addition, teams will be given CAD models for all of the specified items in advance. If necessary, teams can prepare their own parts rack where the specified parts bins can be arranged as they like. Note that no parts rack will be provided by the competition committee. A work table will be provided by the competition committee, but teams can prepare their own work table. The parts rack and the work table prepared by the teams must satisfy the rules and regulations.

A conceptual image of the overall layout is shown in Figure 7.

6.2.5 Detailed Description

Teams shall be required to pick up necessary parts specified in the set list from the parts bins arranged on the parts rack and place them in the part-kitting tray by their robot. Each part shall be placed at designated location and orientation in the part-kitting tray. Screws shall be inserted in the specified holes in an upright position, considering the easy access to the parts in the
following assembly task. Teams shall prepare as many parts sets specified by the set list as possible within the competition time. However, there is an upper limit on the number of parts sets that teams can prepare.

Before the task starts, the part-kitting trays are placed in a specified area outside of the system running area. When the task starts, teams can move the trays to a place where the Kitting task can be performed by their robot. The completed part-kitting trays shall be carried to a specified area outside of the system running area within the time limit of the competition. Teams are allowed to supply and take the part-kitting trays out by their hands. For safety reasons, however, teams must suspend all systems when entering the system running area. Teams may take a part-kitting tray out even if not all of the parts have been placed when the team determines that it is impossible to continue. The part-kitting trays may be carried out of the system running area one by one, or, some trays together.

Referees will randomly change the state of parts in the parts bins before the competition starts so that the teams cannot start from an easy condition intentionally made by the team. Furthermore, referees will randomly change the location of the parts bins on the parts rack so that the robot has to recognize the parts bins by itself. A conceptual drawing of the overall layout is shown in Figure 8.

6.2.6 Evaluation Method

Points will be given for part sets carried out within the task period. Points are given based on the number of completed part sets. Partial points are also assigned to the incomplete part sets based on the number of parts placed in those sets. Extra points will be given as a time bonus if all the parts set are completely prepared within the task period. Deductions will be taken for parts which are not placed properly in the specified location and orientation in the part-kitting tray. However, temporary placement is allowed to change the orientation of parts. A deduction will be taken if a part is dropped off during the task or if more than the number of necessary parts is picked up from the parts bin. However, a deduction will not be taken if such an extra part is returned to the parts bin. Time bonus points will not be awarded if there is an incomplete part set or a part set subject to the deduction.

![Figure 8: Conceptual Sketch of the Layout of the Kitting Task](image-url)
6.2.7 Reset

If teams choose to reset, they shall re-start just from the initial state of the incomplete part set that they had been working on. In this case, the team shall re-start from an empty state of the part-kitting tray that they had been working on. The time taken for the reset will be included in the competition time.

6.2.8 Schedule

Each team shall attempt Kitting task two times on Day 2. The better score of the two trials shall be adopted. The competition time given to each task shall be about 30 minutes. The set list will be given to each team just before the task starts.

6.3 Assembly Task

6.3.1 Overview

In this task, teams shall compete on the speed and accuracy for assembly of a model product that includes technological elements necessary to assemble industrial products. For WRS 2018, the Belt Drive Unit was designed for the model product. More specifically, teams shall compete on the ability of their robot system to assemble the Belt Drive Unit from the parts taken from the part-kitting tray which is already set by the competition committee. This task takes place over two days. On the first day of the assembly task (Day 3), teams are required to assemble Belt Drive Units from the parts which specifications are opened to public in advance. On the second day of the assembly task (Day 4), it is required to assemble a new Belt Drive Unit that contains some surprise parts that are different from the original parts used in the first day, while keeping the nature of the model product. The details of surprise parts shall be announced at the appropriate time just before the task starts on Day 4. Several sets of parts necessary for assembling the Belt Drive Units shall be provided to each team. Teams shall be required to assemble as many Belt Drive Units as possible. Note that, however, there is an upper limit on the number of parts sets to be provided.

This competition aims at realizing the future manufacturing by developing agile and lean production systems which can respond to the variously changing manufacturing demands in high mix low-volume production (ultimately the one-off manufacturing).

An overview of the Belt Drive Unit used in this task is shown in Figure 1. In addition, the main dimensions are indicated in Figure 9. However, these specifications are subject to change according to the refinements made to these rules and regulations.

6.3.2 Expected Technological Elements

The main technological elements expected for this task include assembly planning technology, grasping and motion planning technology for precision assembly, coordinated multi-arm control technology, and agile system configuration technology.

6.3.3 Expected Equipment

The main equipment expected for this task include force sensors, vision sensors, robots with the appropriate range of motion, robot hands able to handle all of the parts (multiple types of hands may also be used), and assembly tools as necessary.
6.3.4 Supplying Parts and Taking Assembled Products Out

Parts necessary for assembling the Belt Drive Units are provided to teams as parts sets arranged in part-kitting trays. Note that parts sets prepared in the Kitting task are not used at all. Instead, complete parts sets prepared by the competition committee will be provided, assuming that the previous Kitting task was completed without any problem. Screws shall be provided in an upright position in the tray. The base plate and panel shall be distributed separately from the parts placed in the part-kitting tray.

Teams shall be given CAD models for all of the parts in advance. However, CAD models for the surprise parts shall be provided at the appropriate time such as just before the task starts.

Before the task starts, the part-kitting trays containing the parts for the Belt Drive Unit and other parts which cannot be placed inside the tray, such as the base plate, are placed in a specified area outside of the system running area. When the task starts, teams must bring them into the system running area where assembly work will be performed in the preparation phase. When the assembly is completed, assembled products should be carried out to a designated area outside of the system running area within the time period of the task. Teams can take a product out even if not all of the parts have been assembled when the team determines any further efforts pointless. Assembled products may be carried out one by one, or, some products together.

Teams may bring parts and part-kitting trays into the system running area or take completed products out from the system running area by their hand. However, teams must shutdown all systems when entering the system running area.

No markings must be attached the parts. However, teams are allowed to attach markings to the working environment where robots perform the assembly task. Teams may install their own
jigs and sensors in the system running area. A work table shall be provided to teams, but they can bring their own table if necessary.

The conceptual image of the system layout is basically the same as the Kitting task (see Figure 8).

6.3.5 Detailed Description

The competition time shall be made up of a preparation phase and an operation phase. In the preparation phase, teams can prepare their working environment (e.g. installing jigs) and bring in the parts as described previously. Robots must not perform any assembly tasks in this phase. Teams will then declare the start of the operation phase to a referee once all preparations are completed. Thereafter, the operation phase will begin, and the robot will assemble the Belt Drive Units. During the operation phase, teams should go outside the system running area and cannot touch the robots, the working environment, or the parts at all (except when a reset is declared).

The assembly may be executed in any order, but the level of completion of the assembled product is evaluated in sub-task basis shown below. In the case of a reset, teams shall return to the beginning of the sub-task that they had been working on. The sub-tasks of the Belt Drive Unit assembly are as follows:

- **Sub-task A** -- Assembling the motor to the panel with the screws
- **Sub-task B** -- Assembling the motor-shaft-pulley to the motor shaft
- **Sub-task C** -- Assembling the output shaft, screws to secure the output shaft, washers, double bearings, and the screws to attach the bearings to the panel
- **Sub-task D** -- Assembling the output-shaft-pulley to the output shaft
- **Sub-task E** -- Assembling the tension pulley and adjusting the belt tension
- **Sub-task F** -- Assembling the panel and the base plate with the screws to connect both
- **Sub-task G** -- Assembling the belt

6.3.6 Evaluation Method

The products assembled within the competition time shall be carried to a specified area outside of the system running area. Points are given based on the number of the assembled products that have been carried out to the designated area as well as the level of completion of each product, encouraging the teams to completely assemble all necessary number of products within the competition time. Furthermore, if all of the specified number of Belt Drive Units are assembled completely within the competition time, extra points shall be given as a time bonus based on the amount of time that remains in the competition time for the task. Note that only products carried out to the designated area shall be evaluated. Also note that evaluation is made only for the final product in sub-task basis, regardless of the process of assembly.

The evaluation criteria of completion level shall include the state of parts fastened to other one and the state of parts attached to the panel (secureness of the assembled parts, correctness of the part direction, etc.). In general, teams are not allowed to skip the task and replace it by manual operation.

Teams may declare “reset” if their robot system fails and cannot recover by itself. If teams choose “reset”, they shall return to the initial state of the sub-task that they had been working on.
and start it again. The “reset” will be treated as a temporal stoppage in the actual manufacturing site. Teams have to make sure to stop the robots and ensure safety when returning to the initial state in the preparation phase after declaring a reset.

To encourage teams to develop agile and lean manufacturing systems, large bonus points will be awarded to the teams who successfully assemble the surprise parts on the second day of the assembly task (Day 4).

6.3.7 Reset

When teams choose “reset”, they shall return to the initial state of the sub-task that they had been working on and start it again.

6.3.8 Schedule

On the first day of the assembly task (Day 3), teams will compete for assembly task without surprise parts. On the second day of the assembly task (Day 4), the assembly task shall include surprise parts. Day 4 assumes a mixed flow production line where the original Belt Drive Units and new Belt Drive Units including surprise parts should be assembled simultaneously. The competition time on Day 3, which consists of the time for the preparation phase and the time for the operation phase, shall be about 45 minutes. The competition committee is planning to carry out the competition two times for each team on Day 3. The better score of the two trials shall be adopted. On Day 4 when teams have to assemble not only the original Belt Drive Unit but also new Units including surprise parts, however, the competition will be carried out only once in 90 minutes for each team. Time allocation between the preparation phase and the operation phase will be left up to teams. Some of the top-ranking teams will be required to exhibit their system on the final day (Day 5).

6.4 Promotion of energy-saving

Realization of an energy saving society is an urgent mission for us. The WRS is also aiming at realizing an energy saving society through the challenges and exhibitions. In the industry domains, operation time of the factory is the most important factor for energy consumption. Even when the robots and other peripherals are idling, certain amount of energy is consumed. Therefore, cycle time, which is equivalent to time required for assembling one product in our case, should be shorter and temporary stop of the system and the following error recovery should be prevented as much as possible. Besides that, system reconfiguration for a new product should be done as quickly as possible, because no value is generated during the reconfiguration phase. In other words, “productivity” and “agility” are the keys for energy saving in the industrial robotics category.

To encourage the participating teams to make efforts for energy-saving, the Assembly Challenge introduced the following scoring policies:

1. Time bonus for the task-board task

   If assembly of all of the parts is completed within the task period, points will be given as a time bonus based on the amount of time remaining until the time limit of the task. Reset should be avoided because the task should be started from the initial setup.

2. Time bonus for the kitting task

   If all the required part sets are completely made within the task period, points will be given as a time bonus based on the amount of time remaining until the time limit of the task. No
time bonus will be awarded if there is an imperfect part set. Reset should be avoided because the task should be started from the initial condition for the current kitting.

The number of required kitting sets will be announced later.

3. Time bonus for the assembly task

If assembly of all of the required number of sets is completed within the competition time, points shall be given as a time bonus based on the amount of time that remains in the competition time for the task. Reset should be avoided because the task should be started from the initial condition of the current sub-task. Therefore, “productivity”, i.e. how quickly the system can assemble the target products without any failures is very important to get the time bonus.

In the second day of the assembly task (Day 4), teams are required to assemble a Belt Drive Unit using surprise parts. To cope with this new demand, teams must reconfigure their system during the competition time. Therefore, “agility”, i.e. how quickly the system can be reconfigured for a new demand, is also very important to get the time bonus.

The number of required sets of Belt Drive Unit including the ones using surprise parts will be announced later.

6.5 Presentations

Time for presentations shall be scheduled in the morning of Day 5. Only the selected teams will make a presentation. Each team must submit the technical materials set by the competition committee by Day 1 of the competition. The teams selected to make a presentation shall be notified after the end of the task on Day 4. The presentation teams shall be selected based on the content of their technical materials and performance up to Day 4. The selected teams must present on Day 5.

<table>
<thead>
<tr>
<th>Table 3: Examples of Presentation Items</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network/software</strong></td>
</tr>
<tr>
<td><strong>Hands/hardware</strong></td>
</tr>
<tr>
<td><strong>System integration</strong></td>
</tr>
<tr>
<td><strong>Industrial design</strong></td>
</tr>
<tr>
<td><strong>Creative ideas</strong></td>
</tr>
</tbody>
</table>
Each team will present for approximately ten minutes in English followed by a five minute question and answer session. The presentations will be held on a special stage where each team may also provide live or recorded video demonstrating the performance of their robots. Teams are required to explain their key technological points which are hard to understand by simply observing the competitions. The evaluation of the presentations will be added to the total score as well as treated as a reference for each society award.

Examples of items for presentation are shown in Table 3.

7 Safety

Safety is the highest priority concern for the competition. The industrial robots and other equipment used for this competition may come with great risk if they are not configured with the proper safety measures. Although the rules and regulations included herein do not describe the safety regulations for this competition, all participating teams must adhere strictly to the safety regulations provided separately. If the referees judge that actions of a certain team are dangerous or if they recognize that a certain team is violating the safety regulations, that team will not be allowed to participate in the competition.

8 Conclusion (Robotics for Happiness)

The basic theme of WRS is ‘Robotics for Happiness’. Therefore, in closing, we would like to think about what kind of ‘happiness’ will be brought about from the WRS Industrial Robotics Category.

In order to achieve the goal of the Industrial Robotics Category, ‘agile one-off manufacturing’, it is necessary to use industrial robots as ‘programmable universal machines’ being able to respond to different purposes. Ultimately, we, the Industrial Robotics Category, aims at realizing the circulation-based production society shown in Figure 10. Looking from the production system side, not only the reuse of production assets such as robots but also the reuse of production software is expected in this type of circulation-based production society. On the product side, this society would of course reuse/recycle materials and components as well as reflect the product demand immediately in production plans. Besides that, information about how and where products are used would be leveraged in the subsequent product designs.

If such types of circulation-based production systems can be established, we would be able to realize a society where people can get the product they want at the right price and timing while lowering the environmental impact. This is the happiness that we hope to bring about from the WRS Industrial Robotics Category.

We are looking forward to entries from many teams.

References


Figure 10: Circulation-based Production Society