November 4, 2019
IROS 2019 Work Shop: The current limits and potentials of autonomous assembly

World Robot Summit (WRS) Assembly Challenge

Promoting the development of next-generation manufacturing systems through the competition

- Results of WRS 2018 and Outlook for WRS 2020 -

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What is the World Robot~~ics~~ Summit (WRS) ?

- Not a meeting of robot VIP!
- The first comprehensive robotics event sponsored by the Japanese government (METI) as part of Japan's Robot Strategy
- The WRS is a "Challenge and Expo" that brings together Robot Excellence from around the world, to promote a world where robots and humans successfully live and work together.
- Main theme: "Robotics for Happiness"

Schedule

(Pre-competition)

World Robot Summit 2018 TOKYO

@Tokyo Big Sight

October 17-21

(Main competition)

World Robot Summit 2020 AICHI/FUKUSHIMA

@Aichi international Exhibition Center in **October 8-11**

@Fukushima Robot Test Field in **August 20-22**

2018 — **2019** — **2020**

【Held alongside】
Japan Robot Week 2018
@Tokyo Big Sight
October 17-21

【Held alongside (tentative)】
RoboCup Asia-Pacific Open and Japan Robot Week 2020

Industrial robots are “semi-completed products”

- Robot installation cost -

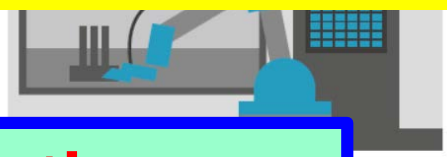
- Example: Desorption process of parts to machine tools

The cost of robot itself is only 30% of the total cost

↓

70% for Peripherals & Integration

Peripherals	安全柵	30万円×1台	90万円
	製品ストッカー	30万円×2台	
System Integration	設置工事、調整、運搬	80万円	
	安全講習	20万円	



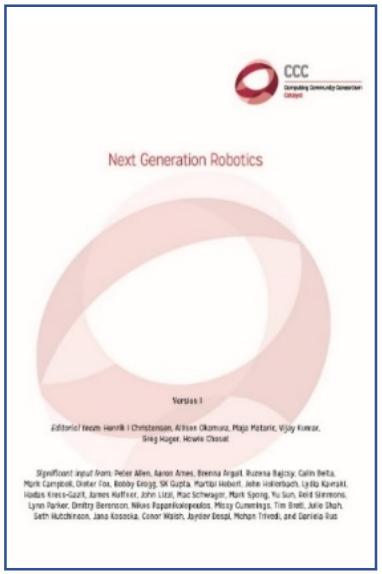
High cost for initial installation.
Once installed, difficult to reconfigure.

From the material by the Japan Robot Industry Association

3 million JPY / 10 million JPY

“Toward Agile One-off Manufacturing”

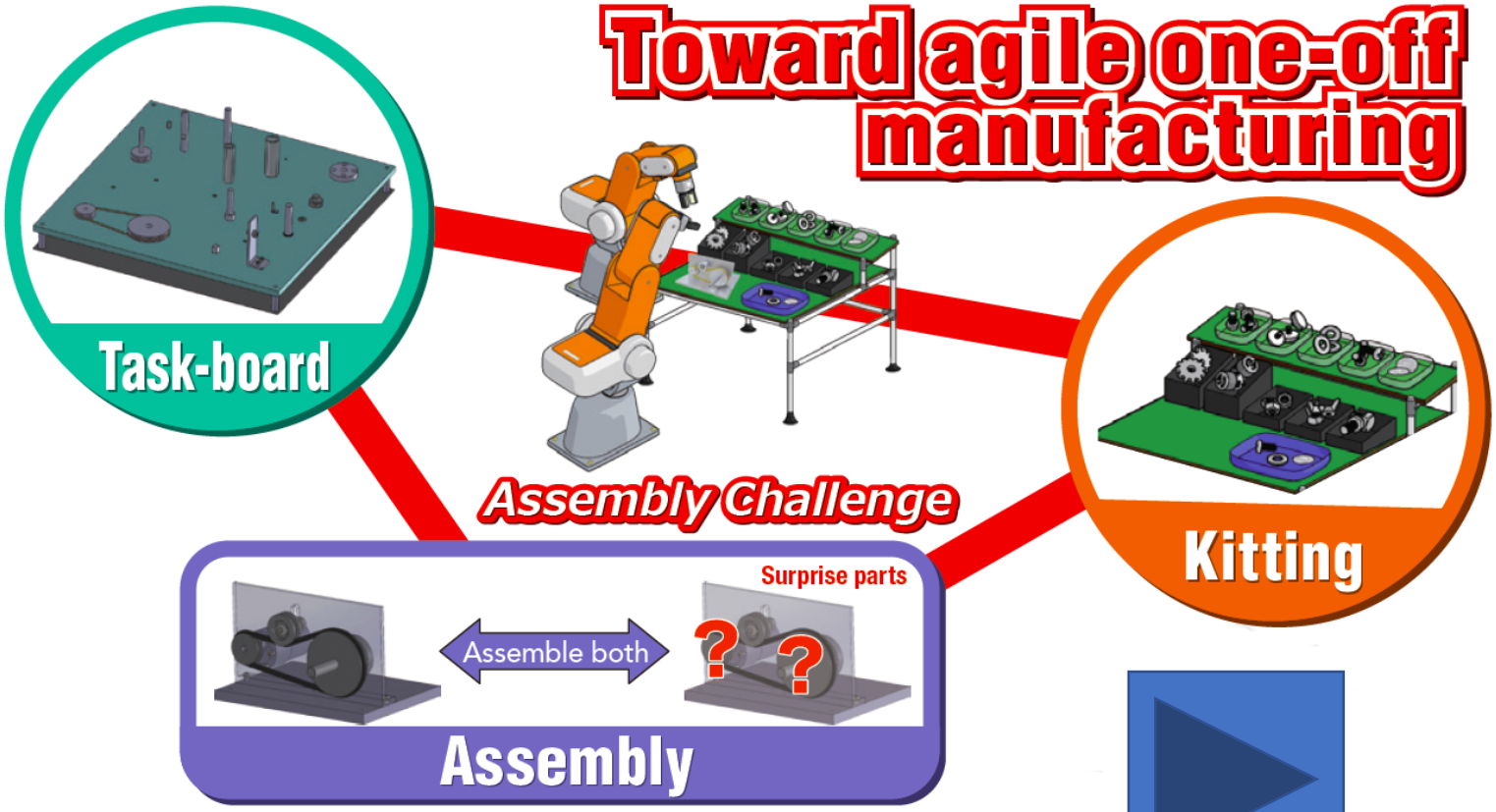
- The Industrial Robotics Category aims to realize future manufacturing systems for the high mix low-volume production that can respond to variously changing orders (even for a one-off product in an extreme case) by reconfiguring the system in agile and lean manners.



Levels of Next-generation Production Systems (Draft)

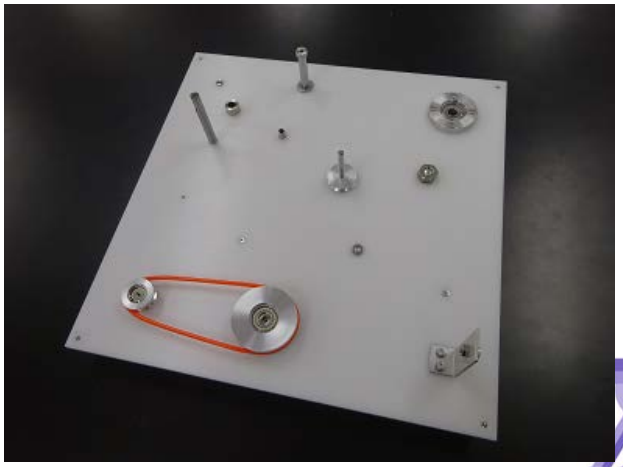
	Factors during setup changes		Factors during operation
	Agility	**Leanness**	**Productivity**
Level 5	0 day (Changeover on a same day)	100% continual use	Fully automated recovery (Even big stoppages)
Level 4	2 days	Reconfiguration using existing equipment	Automatic recovery from temporal stoppage
Level 3	1 week	50% or more	Prevention measures against temporal stoppages, etc.
Level 2	1 month	Only robots are reused	Reduction of temporal stoppage rate by absorbing part variations using sensors.
Level 1	For specific products only	0% (No reuse is assumed.)	Controls parts variations. Human intervention at temporal stoppages.

Assembly Challenge in WRS 2018



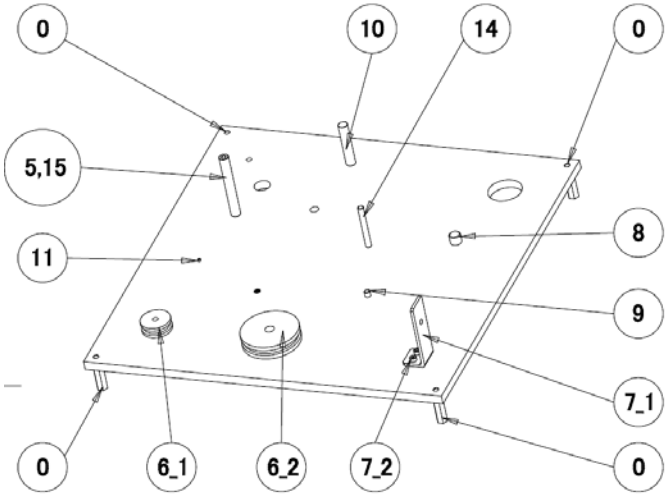
Task Board

- Elementary operations required for the Assembly Task
- Competition time: 20 min.
- Two trials (takes better one)
- Placement mat is given 10 min. prior to the competition
- Preparation phase
  - Part placement by hand
- Operation phase
  - Assemble parts by robots
- 100 points max

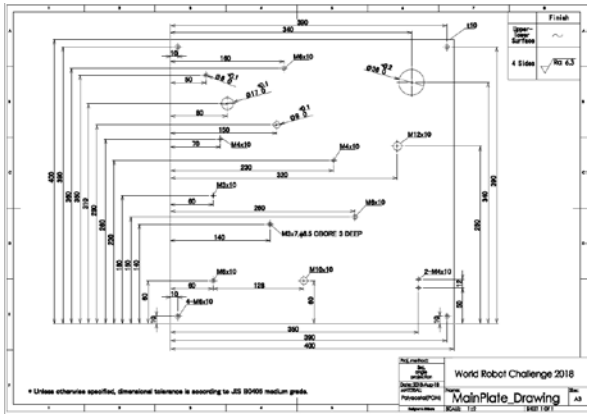


Layout Change of Task Board

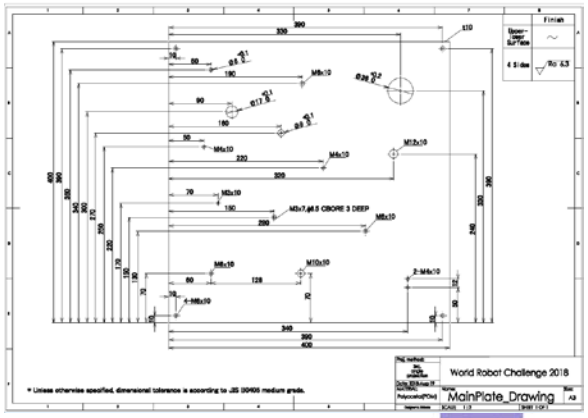
- Changed the task board layout just before the competition
  - Just minor changes in each dimension without any major layout changes
  - Announced on Day -1 (by drawing data)
- Described already in the task board section of the rule book
  - “The layout of each part of the task board is planned to ~~change~~ be changed just before the competition.”



Before

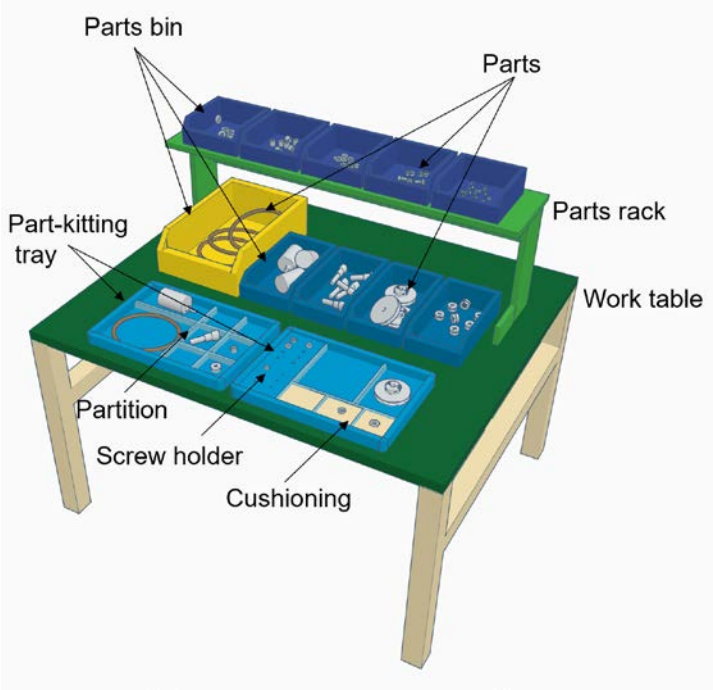


After



Kitting

- Kitting of 10 parts/set
- 3 sets in total
- Competition time: 20 min.
- Two trials (takes better one)
- Part bins and trays can be arranged as the teams like.
- Set list (orders) is given 10min. prior to the competition
- 150 points max.
  - 50 points/set ×3 sets
  - Breakdown: partial 20 points + completed 30points

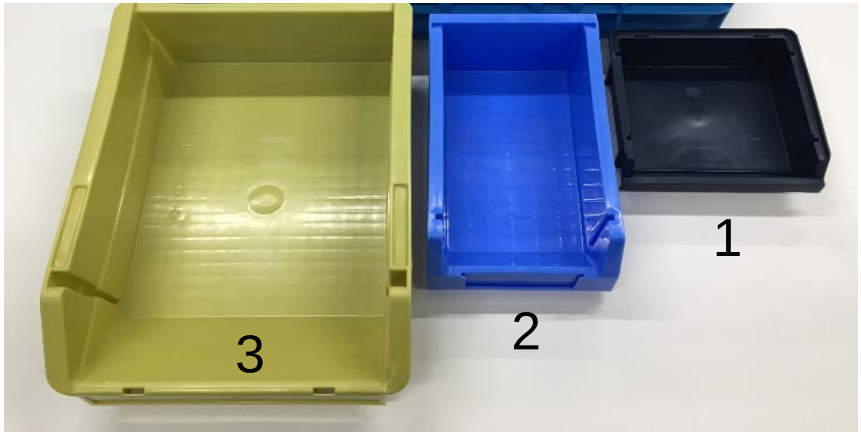


Example of ordered sets

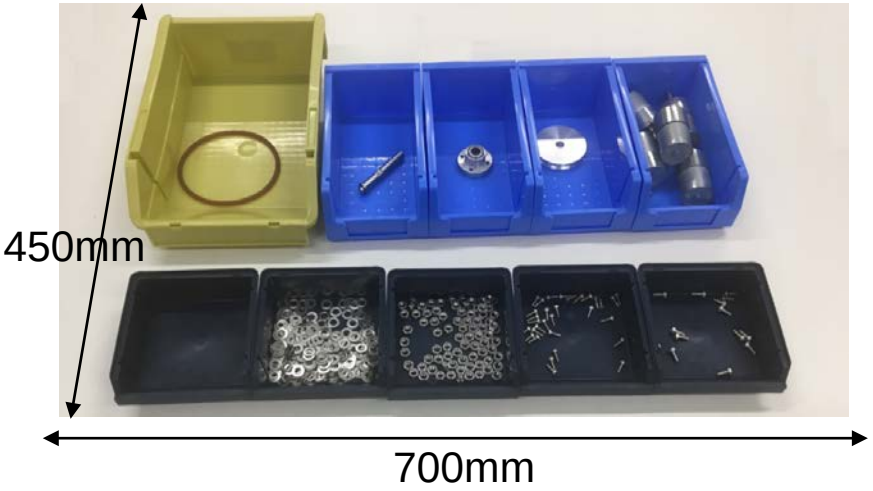
(a)

(b)

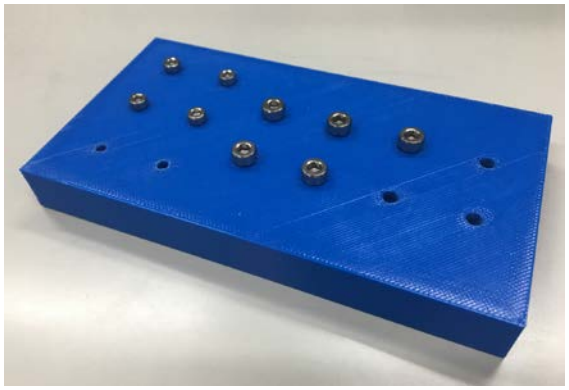
(c)



Parts bin



10 parts-bins out of 15 parts-bins



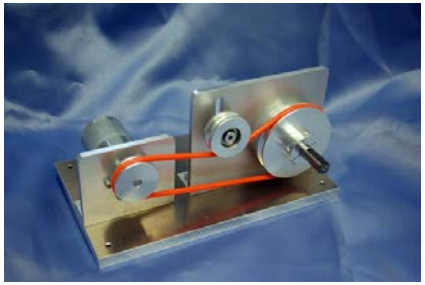
Screw holder (Sample)

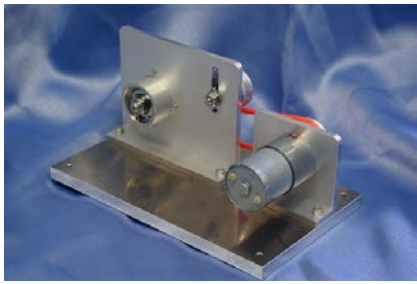
Part-kitting tray

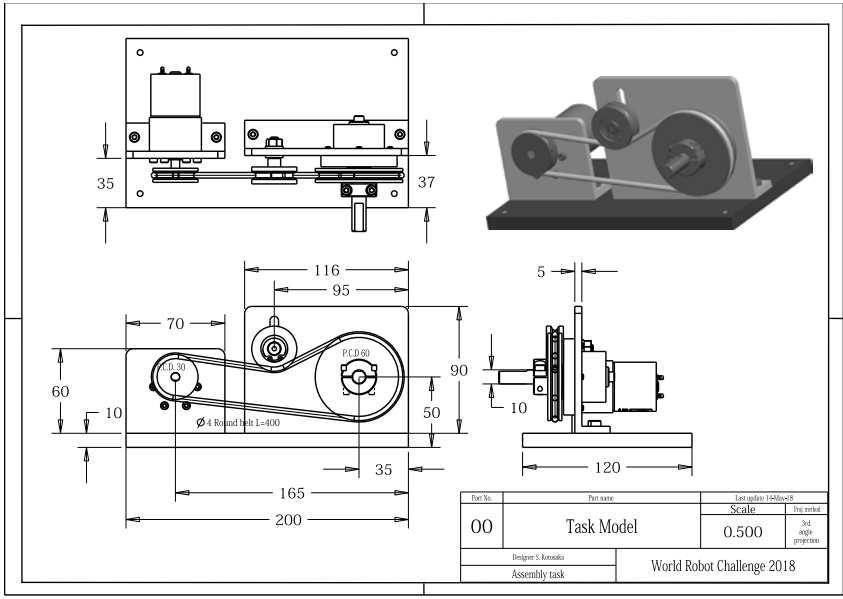
Conceptual Image

Assembly

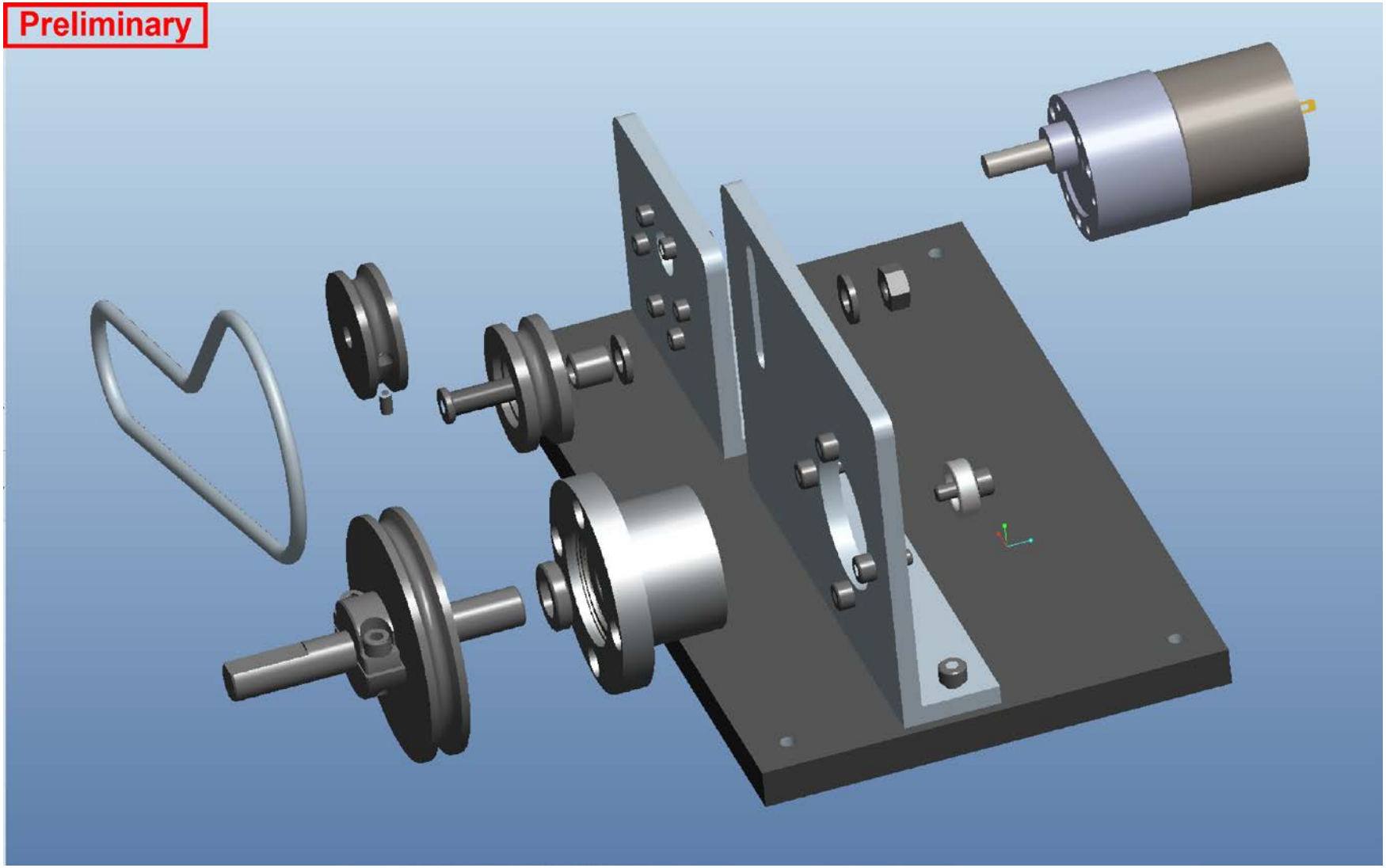
- Assembling belt-drive unit (19 kinds, 33 parts)
  - Day 3: 2 normal sets
  - Day 4: 2 normal sets + 1 special set incl. surprise parts
- Competition time:
  - Day 3: 45min. ×2 trials
  - Day 4: 60min. ×1 trial
- Surprise parts
  - CAD model is given ~~60 min.~~19 hours prior to the competition
  - Real parts are give ~~10 min.~~2 hours prior to the competition





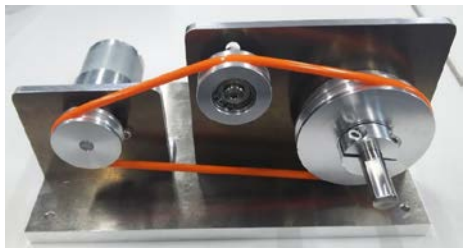


Preliminary

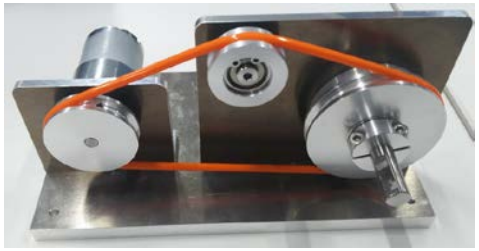


Surprise Parts

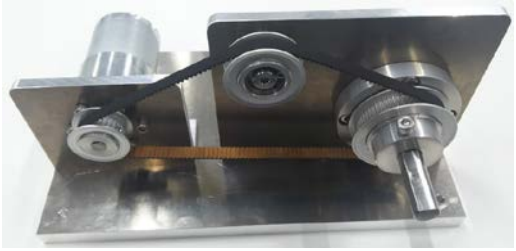
- 5 levels of difficulty: #0 - #4
- Inclined allocation of points depending on the difficulty



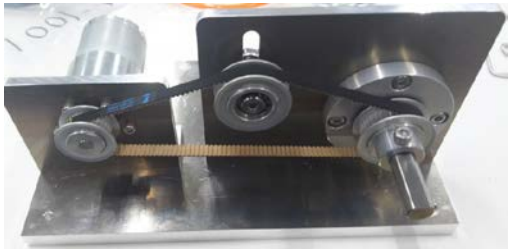
#0 (10)



#1 (15)



#2 (50)



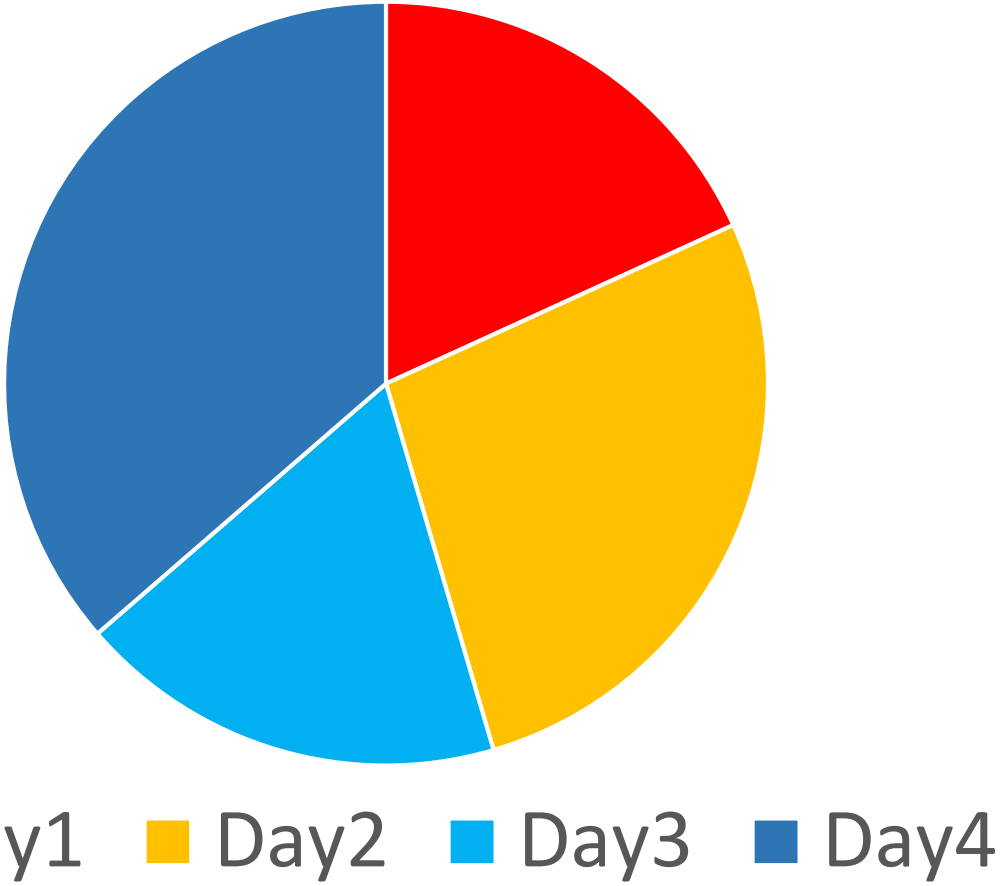
#3 (55)

#4 (65)

Point Allocation

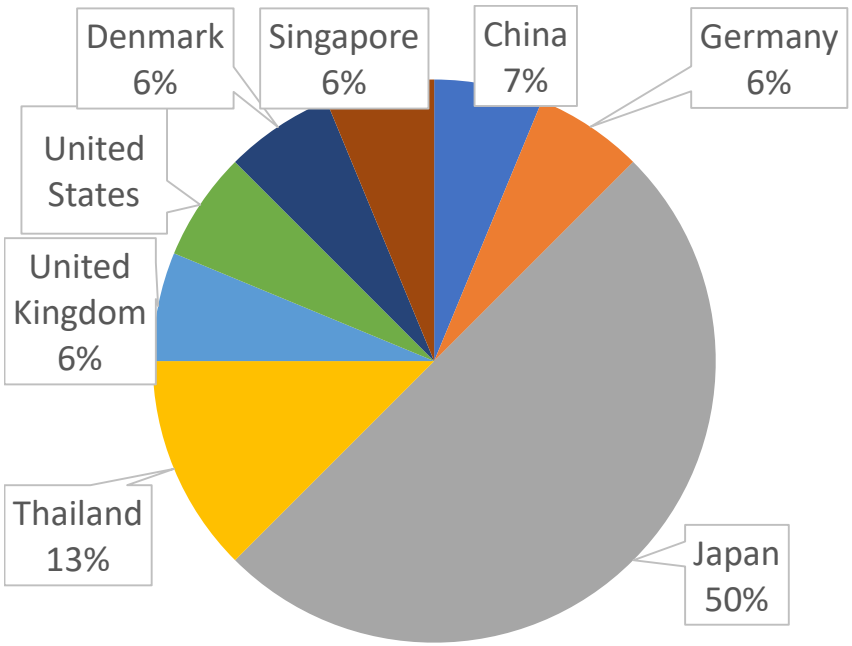
Day	Task	Points	Remarks
Day 1	Task board （20 min. × 2 tries）	100	Higher score in 2 tries Time bonus is added separately
Day 2	Kitting （20 min. × 2 tries）	150	Higher score in 2 tries Time bonus is added separately
Day 3	Assembly （w/o surprise）	100	Higher score in 2 tries Time bonus is added separately
Day 4	Assembly （w/ surprise）	200	Time bonus is added separately
Total		550	

Point Allocation Ratio



Participating Teams

- 16 teams selected
  - Domestic 8 teams
  - Foreign 8 teams



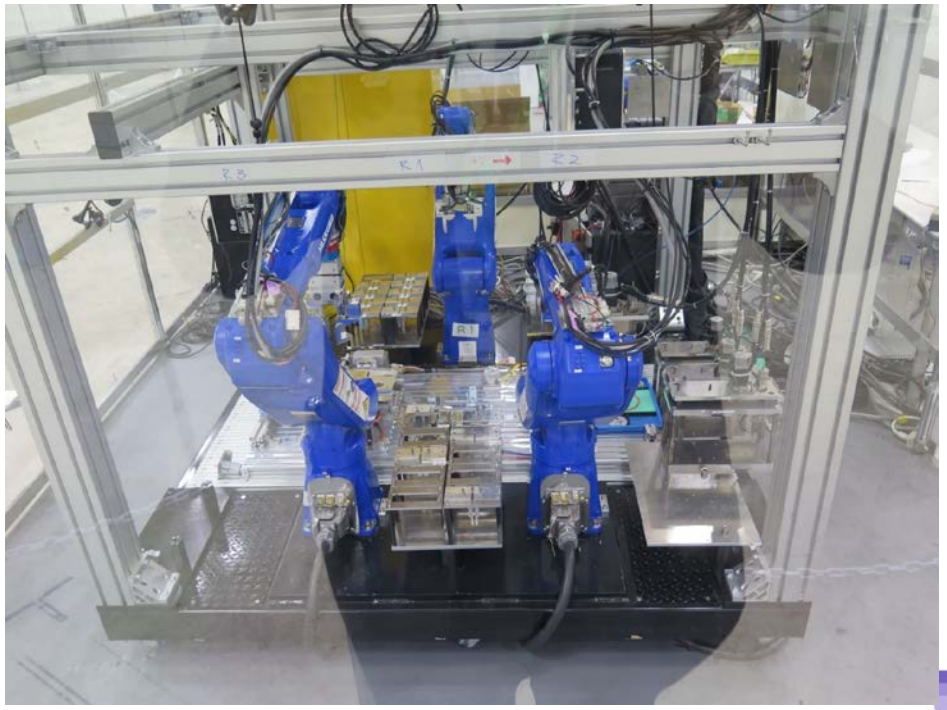
Regions/countries of the accepted teams

Competition Schedule

<table>
<tr><th>13th</th><th>14th</th><th>15th</th><th>16th</th><th>17th</th><th>18th</th><th>19th</th><th>20th</th><th>21st</th><th>22nd</th></tr>
<tr><td colspan="4">Time for setup</td><td>Day 1</td><td>Day 2</td><td>Day 3</td><td>Day 4</td><td>Day 5</td><td>Post Competition</td></tr>
<tr><td colspan="4"></td><td colspan="5">Time open to the public</td><td>Closed session</td></tr>
<tr><td colspan="2">Venue setup</td><td colspan="2">Team setup</td><td colspan="3">Assembly Challenge</td><td>Exhibition, etc.</td><td rowspan="3">Symposium</td></tr>
<tr><td rowspan="2">Team entry prohibited</td><td rowspan="2">Team Cargo delivery allowed in the afternoon</td><td colspan="2" rowspan="2">System setup/adjustments, Safety inspection after setup</td><td rowspan="2">Task-Board task</td><td rowspan="2">Kitting task</td><td colspan="2">Assembly task</td><td rowspan="2">Exhibition, and award ceremony</td></tr>
<tr><td>Without surprise parts</td><td>With surprise parts</td></tr>
</table>

A-3: Team The Robot System Integrators

- Joint team from Robot System Integrators, Shouei Techno Service Inc., MUJIN, Sanmei Mechanical Inc., Nikko FA Inc., and Tsukuba Engineering Inc.

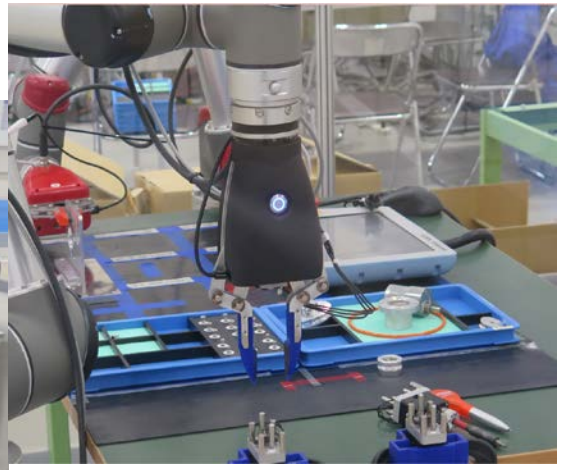


B-1: JAKS

- Joint team from Kanazawa University and Shinshu University

B-2: Robotic Materials Inc.

- Joint team from Robotic Materials Inc. and University of Colorado, U.S.A.

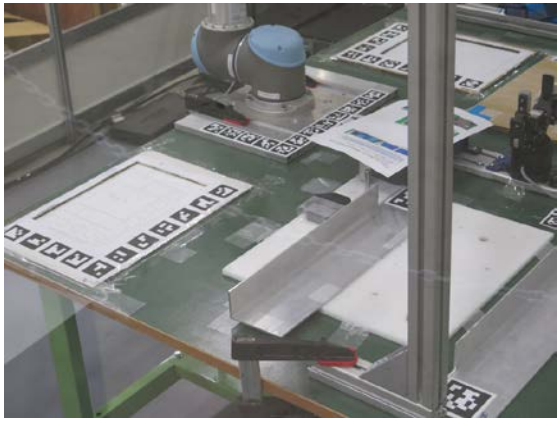


B-4: SDU Robotics

- University of Southern Denmark, Denmark

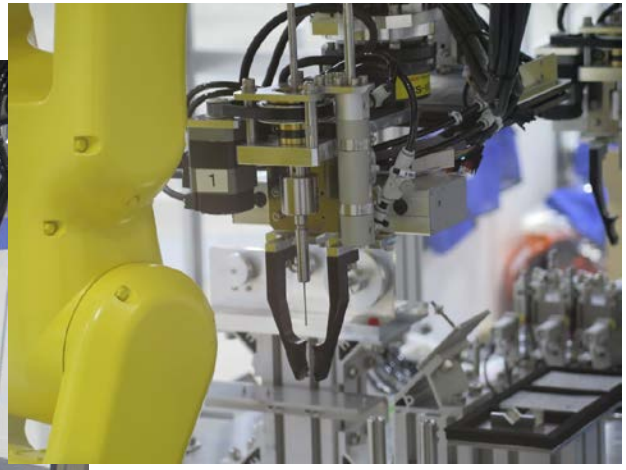
C-4: BerlinAUTs

- Team from Technical University of Berlin, Germany



D-1: FA.COM Robotics

- Team from a SIer in Tochigi Pref., Office FA.com Co.Ltd.



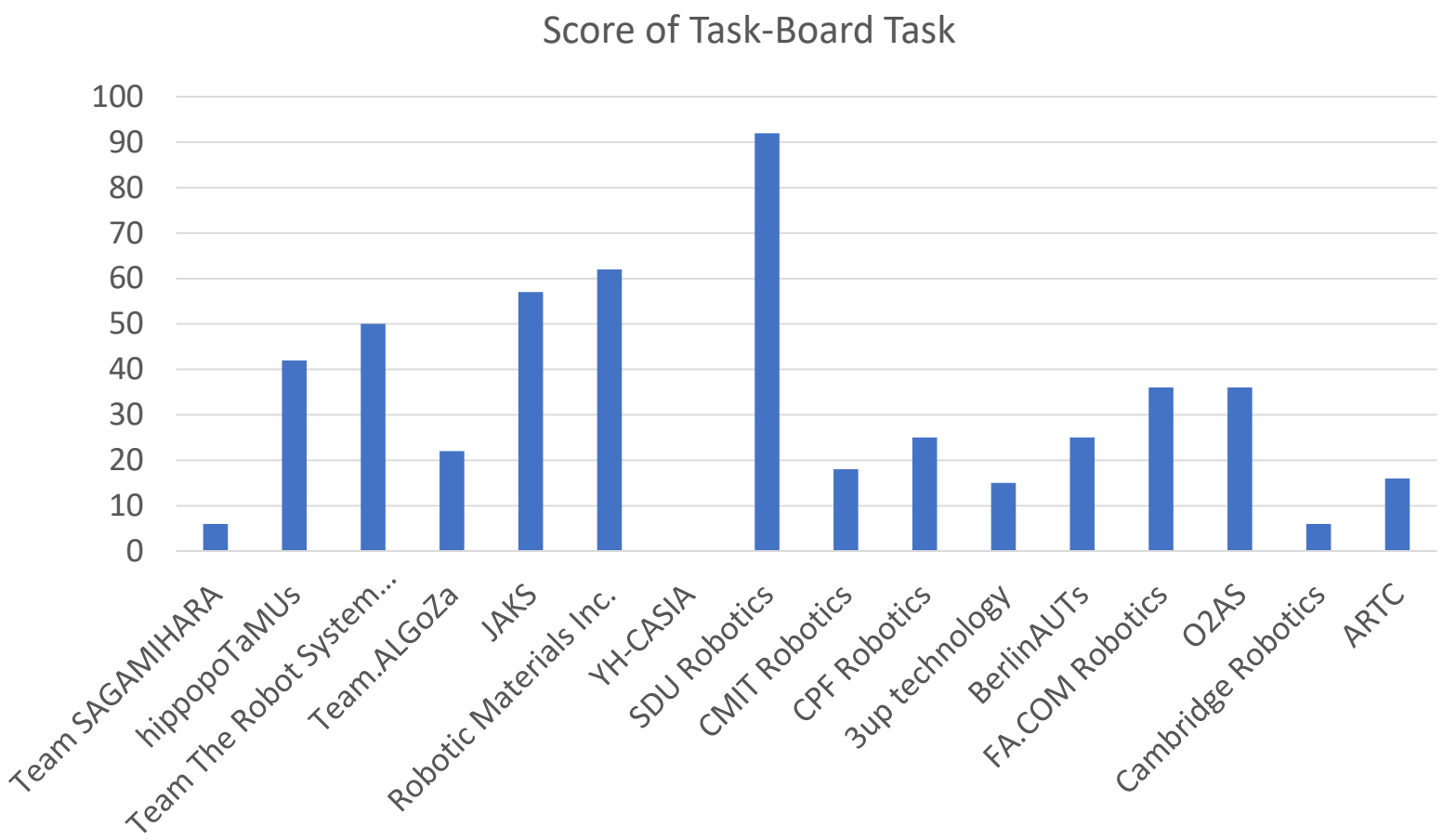
D-2: O2AS

- Joint team from OMRON, Osaka University, AIST, and SenseTime Japan, Japan

D-3: Cambridge Robotics

- Team from University of Cambridge, UK

(Day 1) Result of Task-Board Task



(Day 1) Remarks of Task Board

- Task-board task was intended to be a basic examination
  - Almost perfect sore was only by SDU
  - A team took an approach defocusing on the original purpose
- Layout change of the task board was a sort of surprise?
  - Announced on **Day (-1)** by drawings
  - Try 2 could be prepared with the real board (about 4 hours) ⇒True ability is Try 1?
- Preparation time and score
  - High score teams tend to have shorter preparation time
- Number of resets and score
  - TBC
- SDU
  - Replace only the claws of the hand
  - Assembly completed except for a washer⇒Miss time bonus
- JAKS
  - Used another part as a jig
- Robotic Materials Inc.
  - Single arm with single two-fingered universal hand

Analysis of Task Board (Try 2)

	Parts	Challnge
Peg-in-hole	9mm Spacer for bearings	**93.3**
	17mm Spacer for bearings	**86.7**
	6mm Bearing retainer pin	80.0
	Bearings with Housing	73.3
Ring and shaft	M10 Washer	73.3
	Pulley	66.7
Belt hooking	4mm Round belt	60.0
Insertion	M6 Washer	60.0
	M10 End cap	53.3
Tightening two parts	M12 Nut	46.7
	M3 Setscrew	33.3
	M4 Bolt	26.7
	M6 Nut / M6 Bolt	**6.7**
	M3 Bolt	**6.7**

Parts	Success
17mm Spacer for bearings	**80.0**
9mm Spacer for bearings	**80.0**
6mm Bearing retainer pin	60.0
M10 Washer	60.0
4mm Round belt	46.7
Pulley	46.7
Bearings with Housing	40.0
M6 Washer	33.3
M10 End cap	33.3
M3 Setscrew	26.7
M12 Nut	20.0
M6 Nut / M6 Bolt	**6.7**
M3 Bolt	**6.7**
M4 Bolt	**6.7**

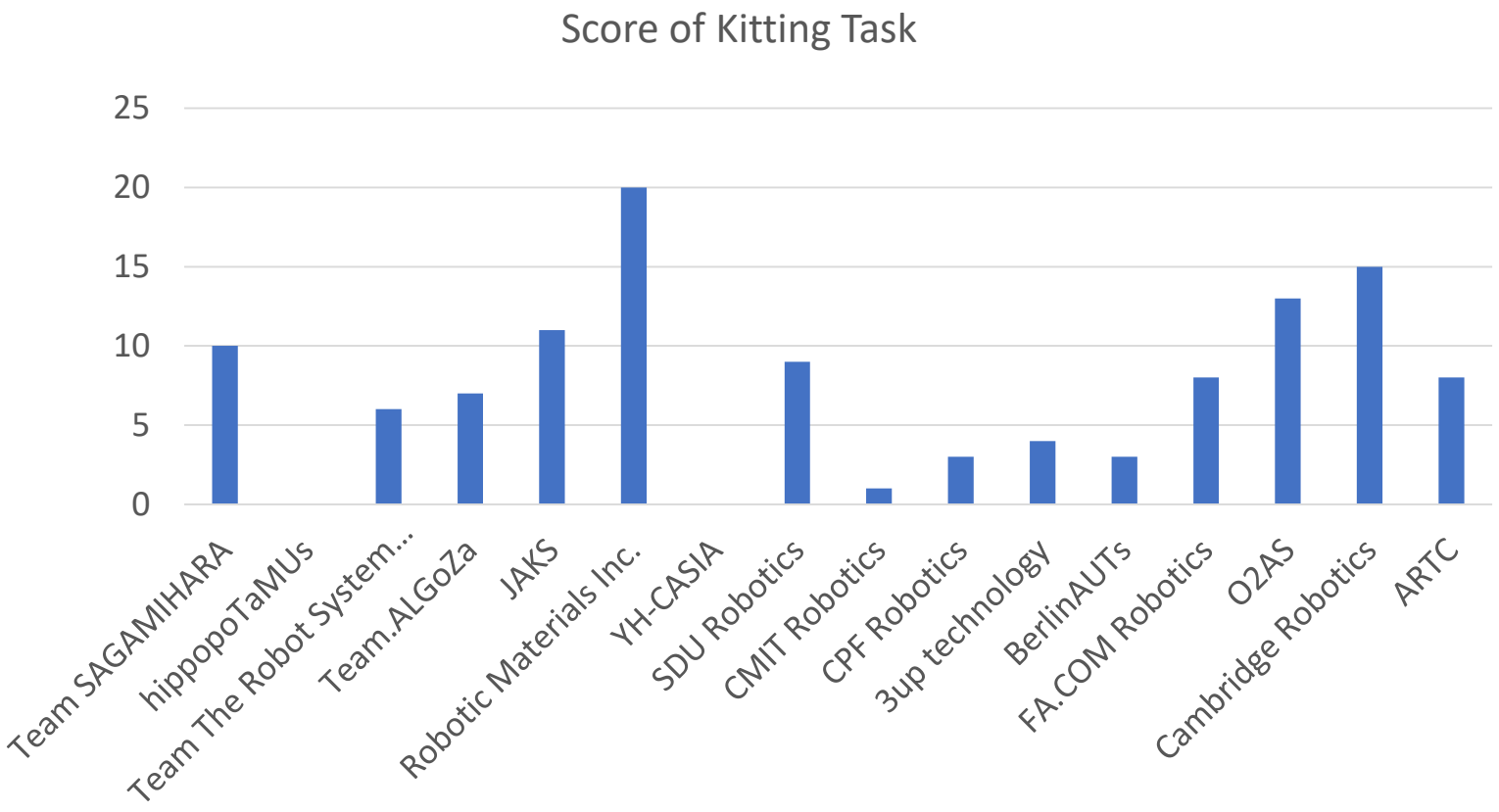
- Challenge : Tried anyway (teams who were deducted or got points for Level 1 or more)
- Success : Got Level Max

Correlations among the Tasks

	Day1	Day2	Day3	Day4
Day1	1			
Day2	**0.23**	1		
Day3	**0.29**	0.37	1	
Day4	**0.20**	0.26	**0.91**	1

- **Calculated from scores (excluding technical evaluation points) of 15 teams (excluding China team)**
- **Correlations between task board and other tasks are low**

(Day 2) Result of Kitting Task



Point Allocation

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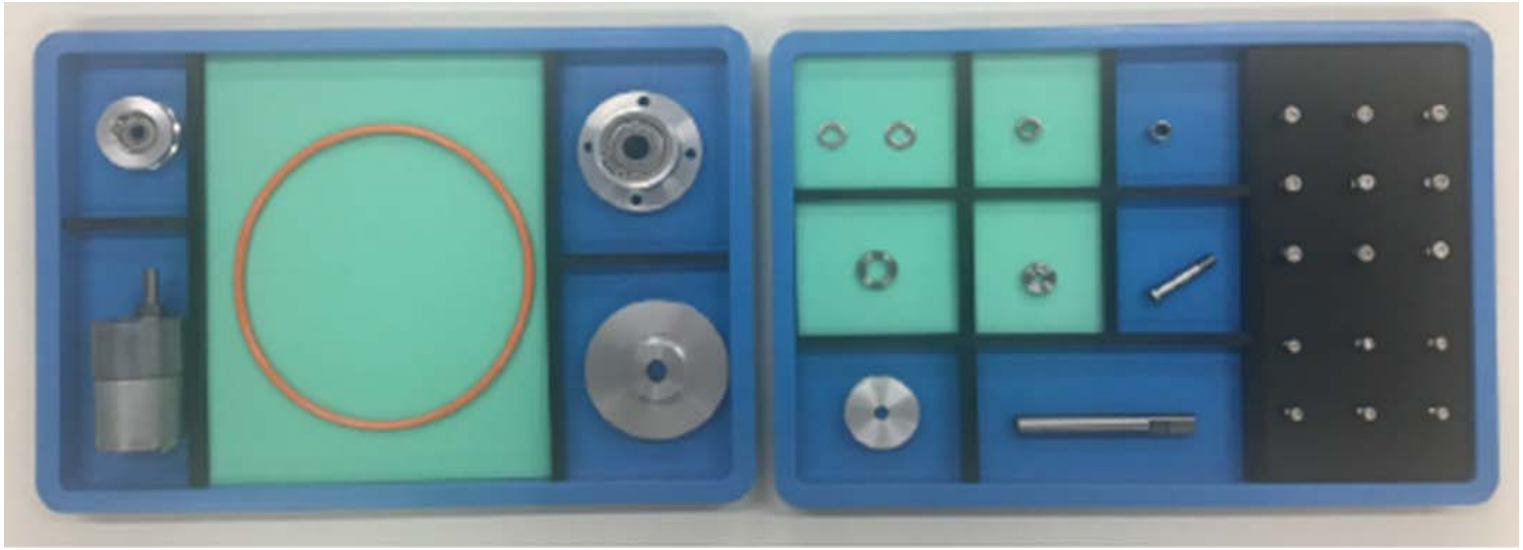
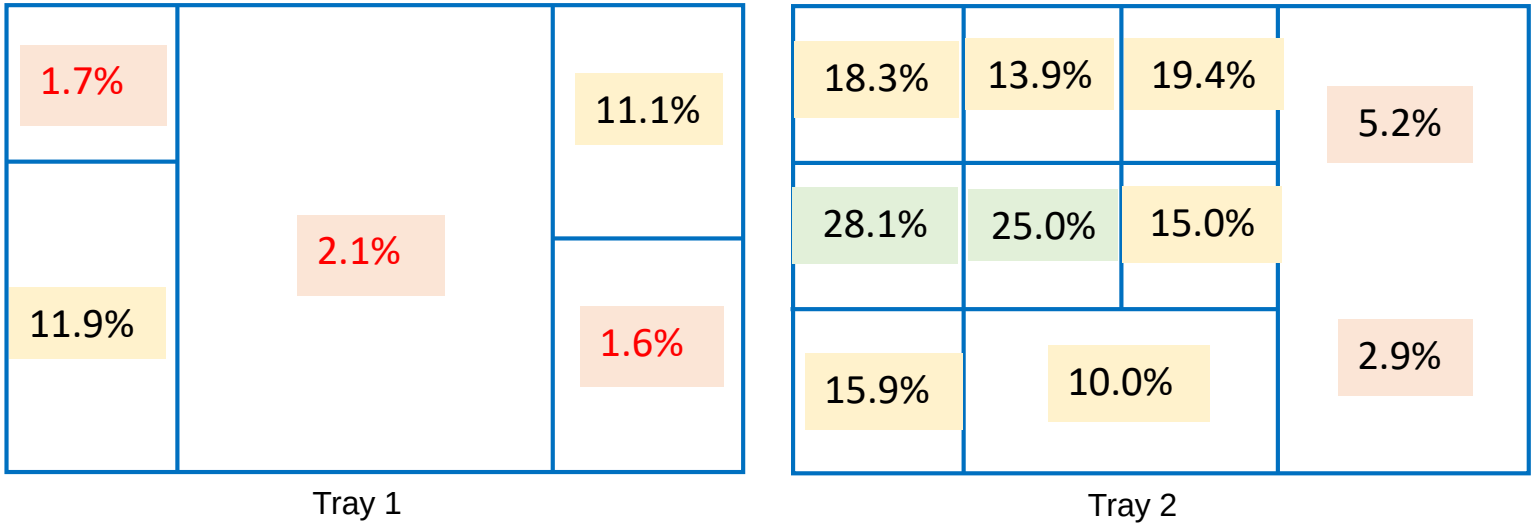
Day 4	Assembly （w/ surprise）	200	Time bonus is added separately
Total		550	

(Day 2) Remarks of Kitting Task

- The amount of parts in the parts bin was low
  - Due to the limited budget
  - Unexpected for teams?
- Every team had troubles in object recognition
  - Some teams had a problem of malfunction of the prepared sensor
  - Strategy to build up points with only available parts without aiming to complete the set
- System integration was insufficient.
  - Especially joint teams from different institutions
- Unexpected use of reset
  - Grasp failed → Call of reset → The judge shuffles the part bin
- JAKS
  - Grasp exactly one belt with a tactile sensor, and then drop the other entangled belts by shaking motion
- Robotic materials
  - If recognition is not successful, the robot grabs the part bin and shake it.
- SDU
  - Scoop the screws with their custom-made spoon and align the direction of the screws
- Cambridge
  - Pick up parts with clay-like sticky material attached to the end-effector

Success rates of each part in Kitting Task



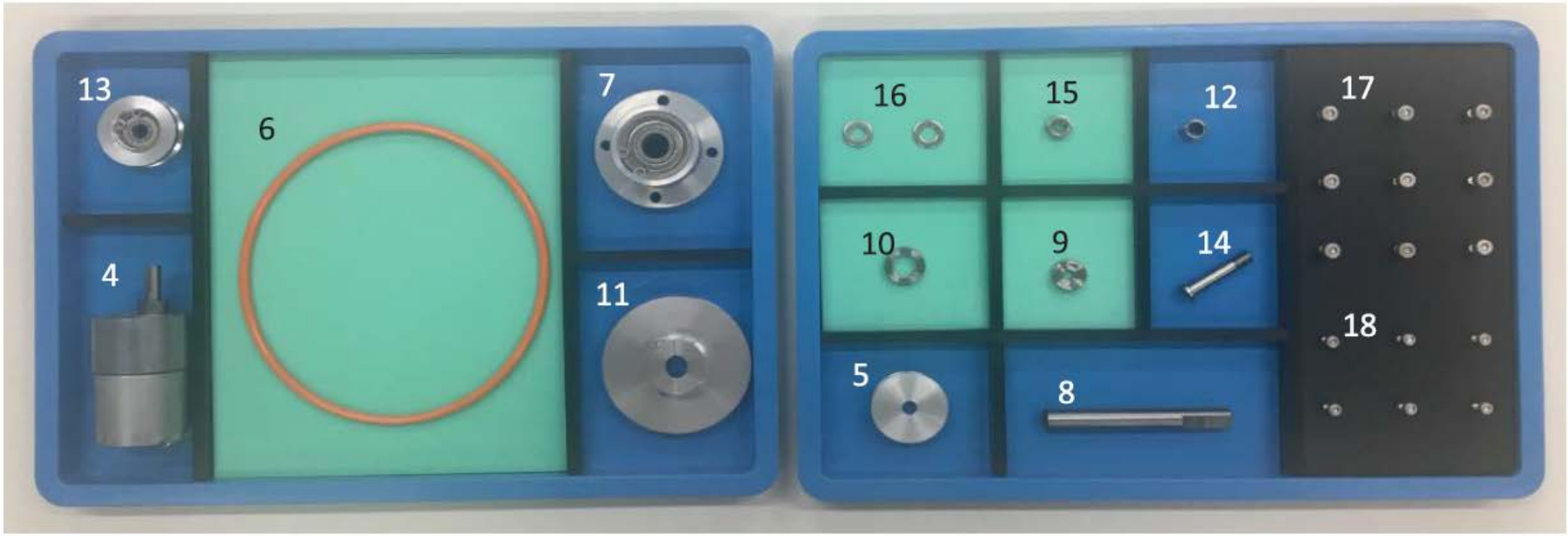


Success rates of each part in Kitting Task

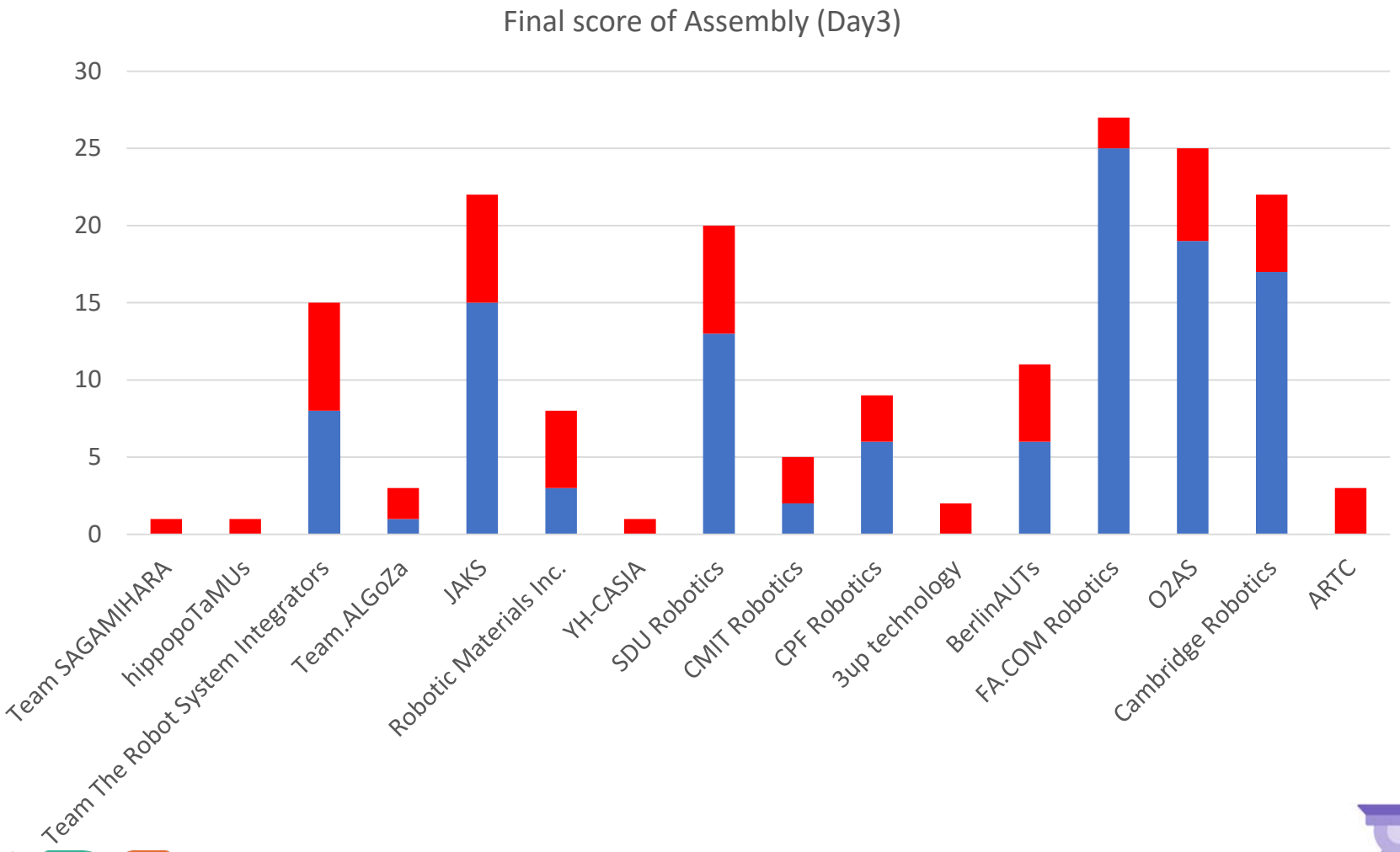
- Extremely small / large parts were avoided.

Part No.	Part Name	Rate [%]
10	Bearings Spacers for Inner Ring	28.1
9	End Cap for Shaft	25.0
12	Bearing Spacers for Inner Ring	19.4
16	M6 Flat Washer	16.3
5	Pulley for Round Belt - Setscrew, P.D. 30mm	15.9
15	M6 Hex Nut	15.9
14	Bearing Shaft Screw	15.0
4	Geared Motor	11.9
7	Bearing with Housings	11.1
8	Drive Shaft	10.0
17	10mm M4 Socket Head Cap Screw	5.2
18	10mm M3 Socket Head Cap Screw	2.9
6	Polyurethane Round Belt	2.1
13	Idler for Round Belt - Wide	1.7
11	Pulley for Round Belts - Clamping Type, P.D. 60mm	1.6

Part# for Kitting Task

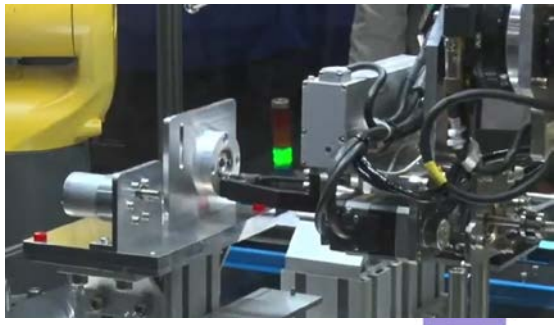


(Day 3) Result of Assembly Task

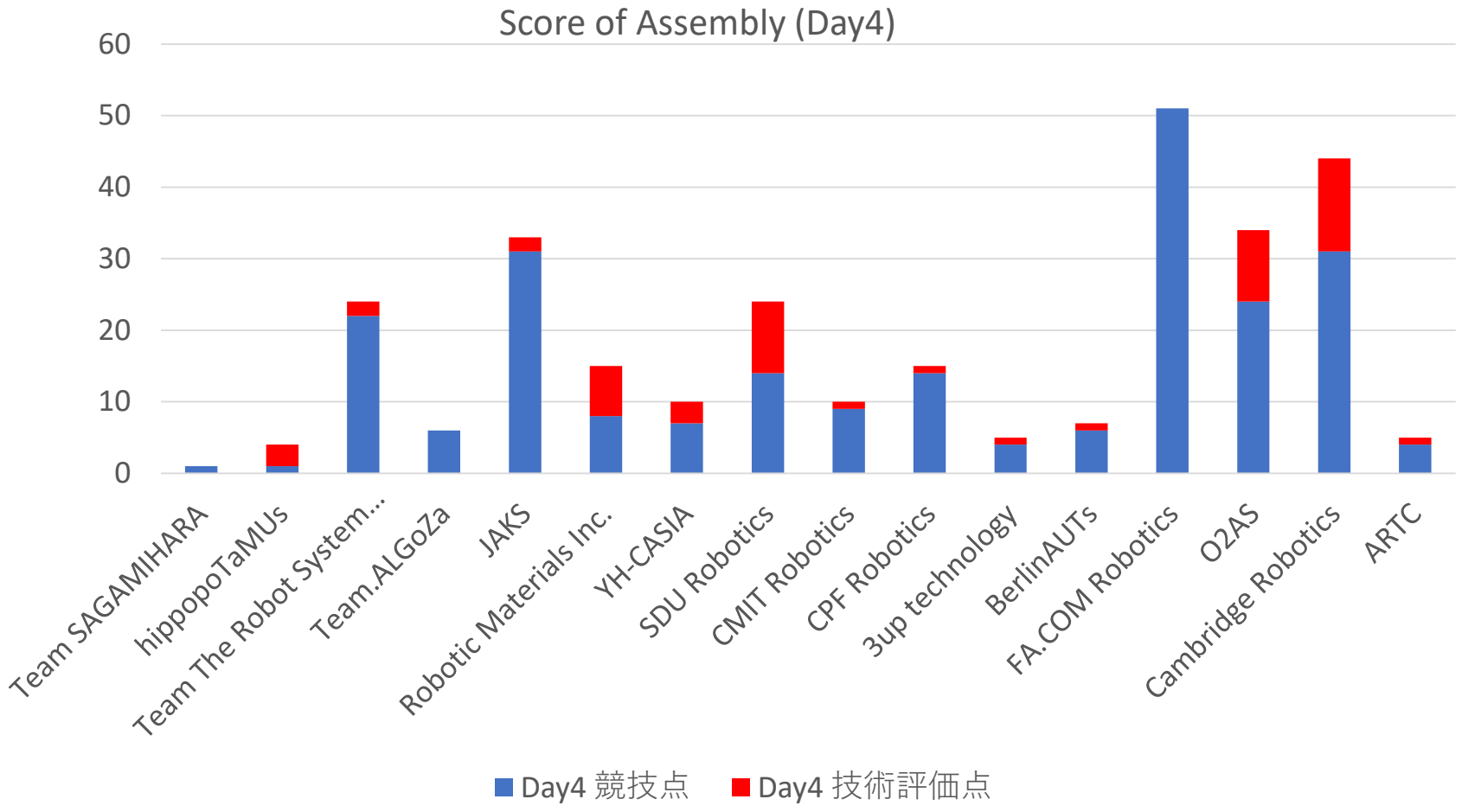


(Day3) Remarks of Assembly Task

- Each team performed only the subtasks that they can do and carry them out
- Debugging by repeating retries
- Cambridge
  - Pick the screw with grease! (many mistakes in Try 2 → warmed up with lighting?)
- O2AS
  - Centering of the axis by re-grasping with two robots
- SDU
  - Poor accuracy of screw chucking ?
- Robotic Materials
  - Assemble the motor to the plate with two robots (jig-less) → Different strategy in Try2
- FA.COM
  - Screw-driver built-in hand
  - Top score, but the point is lower in the second try (System tuning for the next day?)

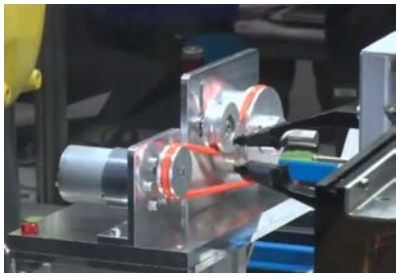


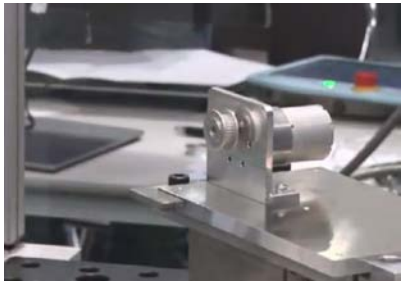
(Day4) Result of Assembly Task

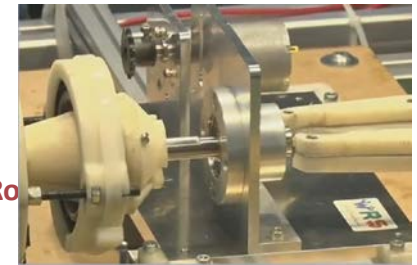


(Day4) Remarks of Assembly Task

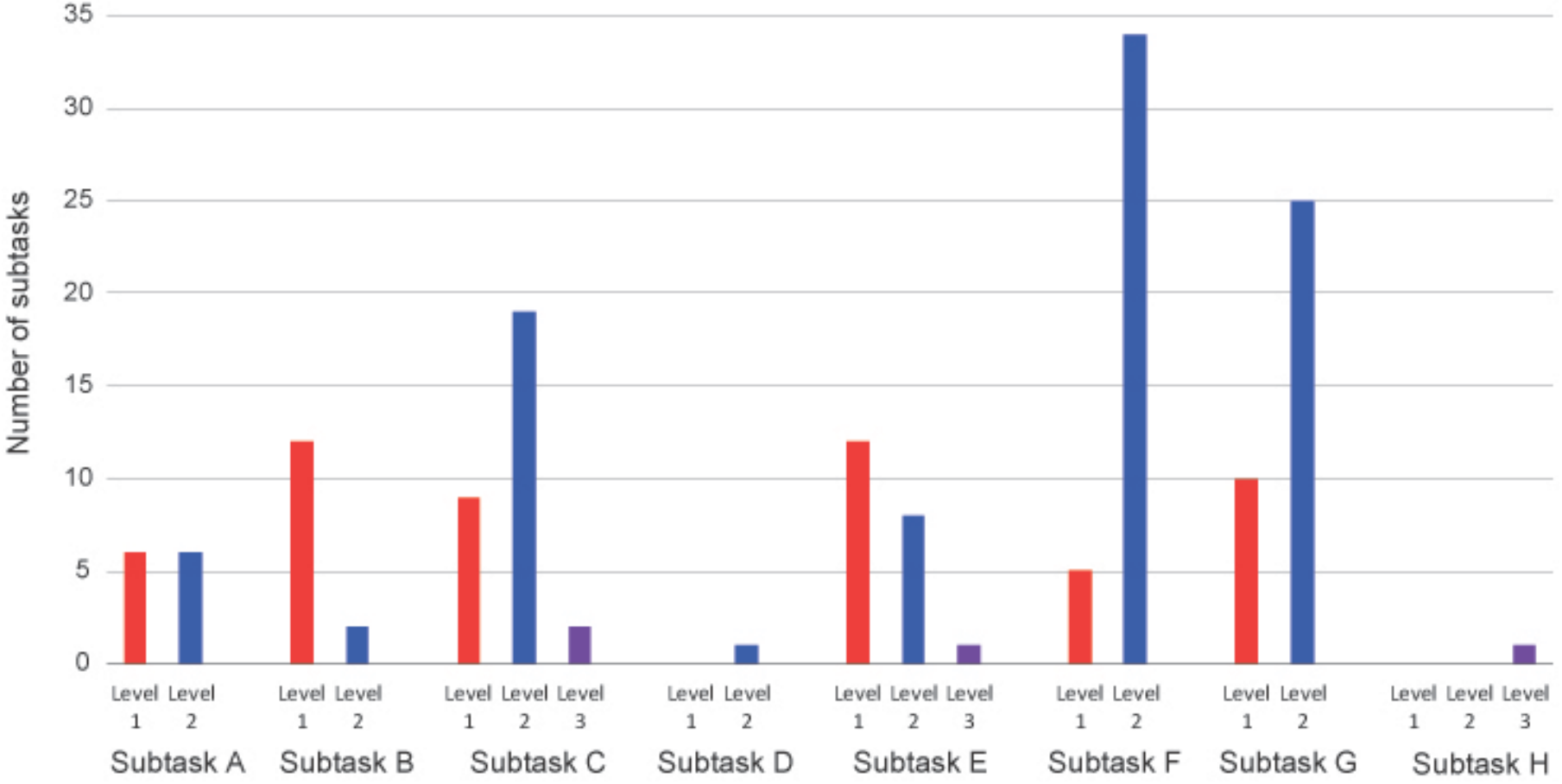
- Many team ended up with imperfect #2 unit, without assembling surprise parts
- JAKS
  - Chose the easiest surprise parts and earn points with the third unit (only this team)
- FA.COM
  - Completed one unit in 53 minutes although it was the normal one
- SDU
  - Stuck at the motor installation which went well in Day 3→Position relationship drifted?
  - 3D-printed claws for surprise parts pulleys
- Cambridge
  - Choose the highest level of surprise parts and challenged the task until the last seconds of time limit
  - Grease is used to prevent the end cap from falling off
- 3up technology
  - Challenged the third unit even after the finish of the competition in order to improve the technology
- YH-CASIA
  - Finally earn points on Day 4!





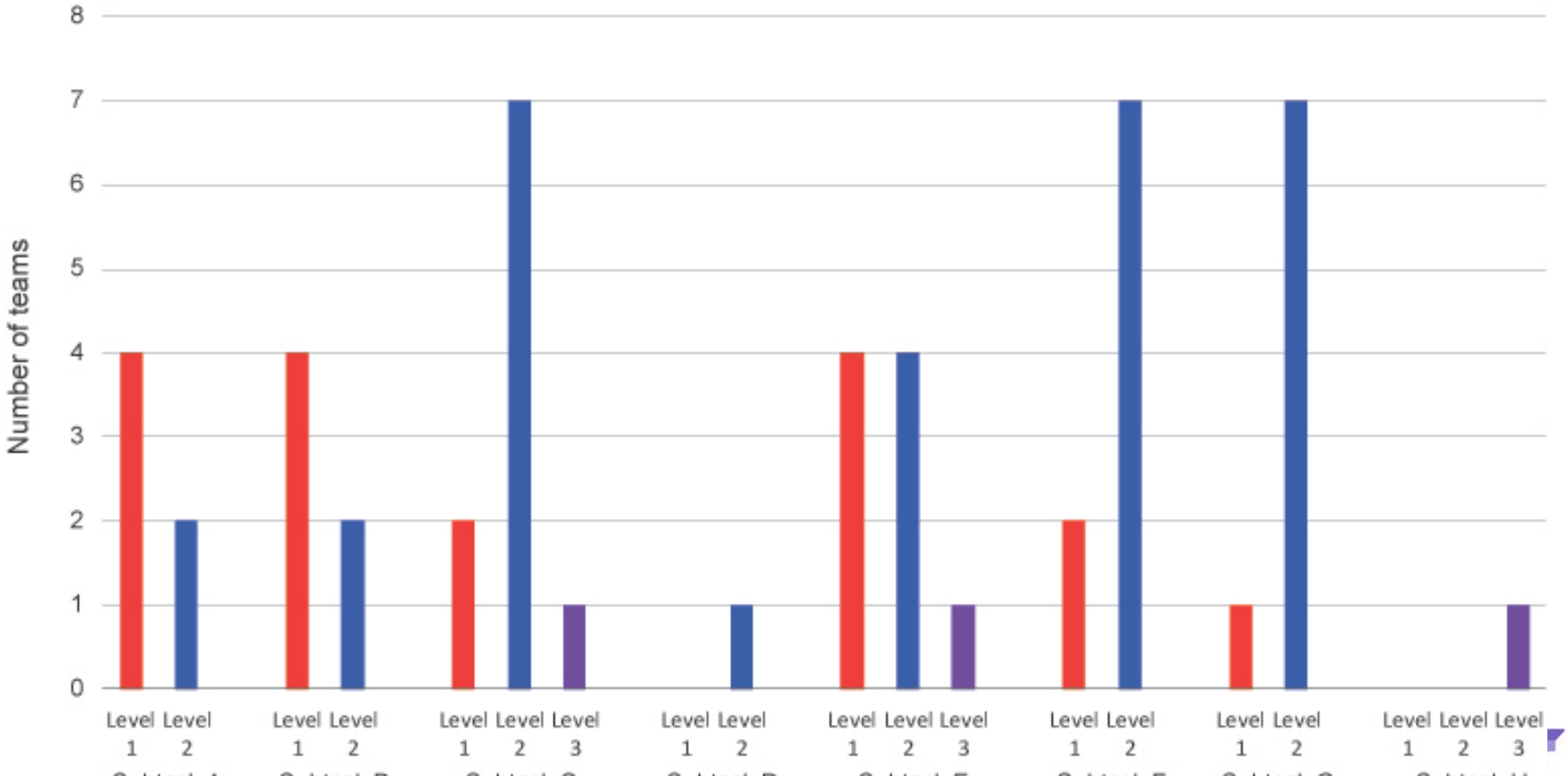


Total Number of Completed Subtasks



Total Number of Teams Who Completed Each Subtask

- F,G and then C, E →First ones or Easy ones

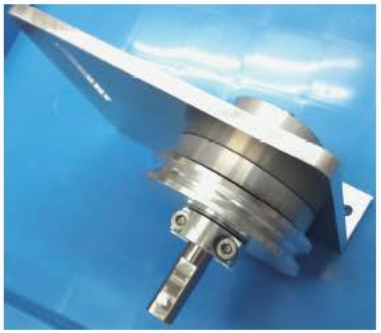


Subtasks

(a) Subtask A

(b) Subtask B

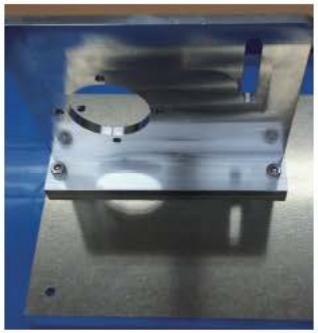
(c) Subtask C



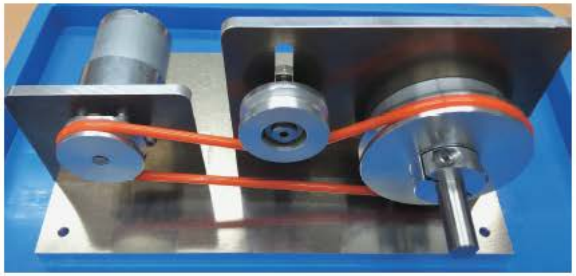
(d) Subtask D (only the difference from Fig. A6(c))

(e) Subtask E

(f) Subtask F



(g) Subtask G

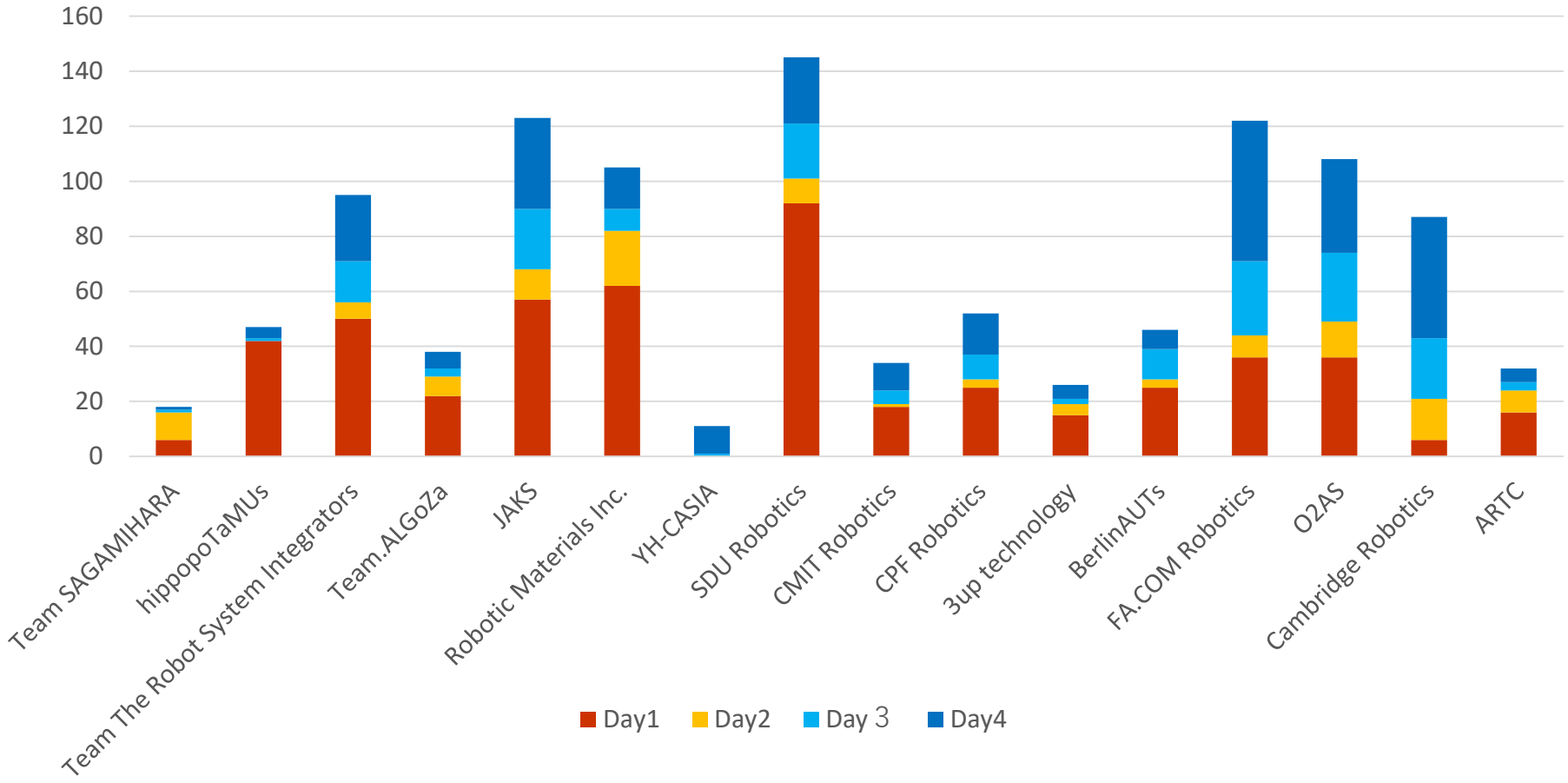


(h) Subtask H (only the difference from Figs. A6(a) through (g))

Total Score

	Team	Day1	Day2	Day3	Day4	Total	Place
A-1	Team SAGAMIHARA	6	10	1	1	18	15
A-2	hippopoTaMUs	42	0	1	4	47	9
A-3	Team The Robot System Integrators	50	6	15	24	95	6
A-4	Team.ALGoZa	22	7	3	6	38	11
B-1	JAKS	57	11	22	33	123	2
B-2	Robotic Materials Inc.	62	20	8	15	105	5
B-3	YH-CASIA	0	0	0	11	11	16
B-4	SDU Robotics	92	9	20	24	145	1
C-1	CMIT Robotics	18	1	5	10	34	12
C-2	CPF Robotics	25	3	9	15	52	8
C-3	3up technology	15	4	2	5	26	14
C-4	BerlinAUTs	25	3	11	7	46	10
D-1	FA.COM Robotics	36	8	27	51	122	3
D-2	O2AS	36	13	25	34	108	4
D-3	Cambridge Robotics	6	15	22	44	87	7
D-4	ARTC	16	8	3	5	32	13

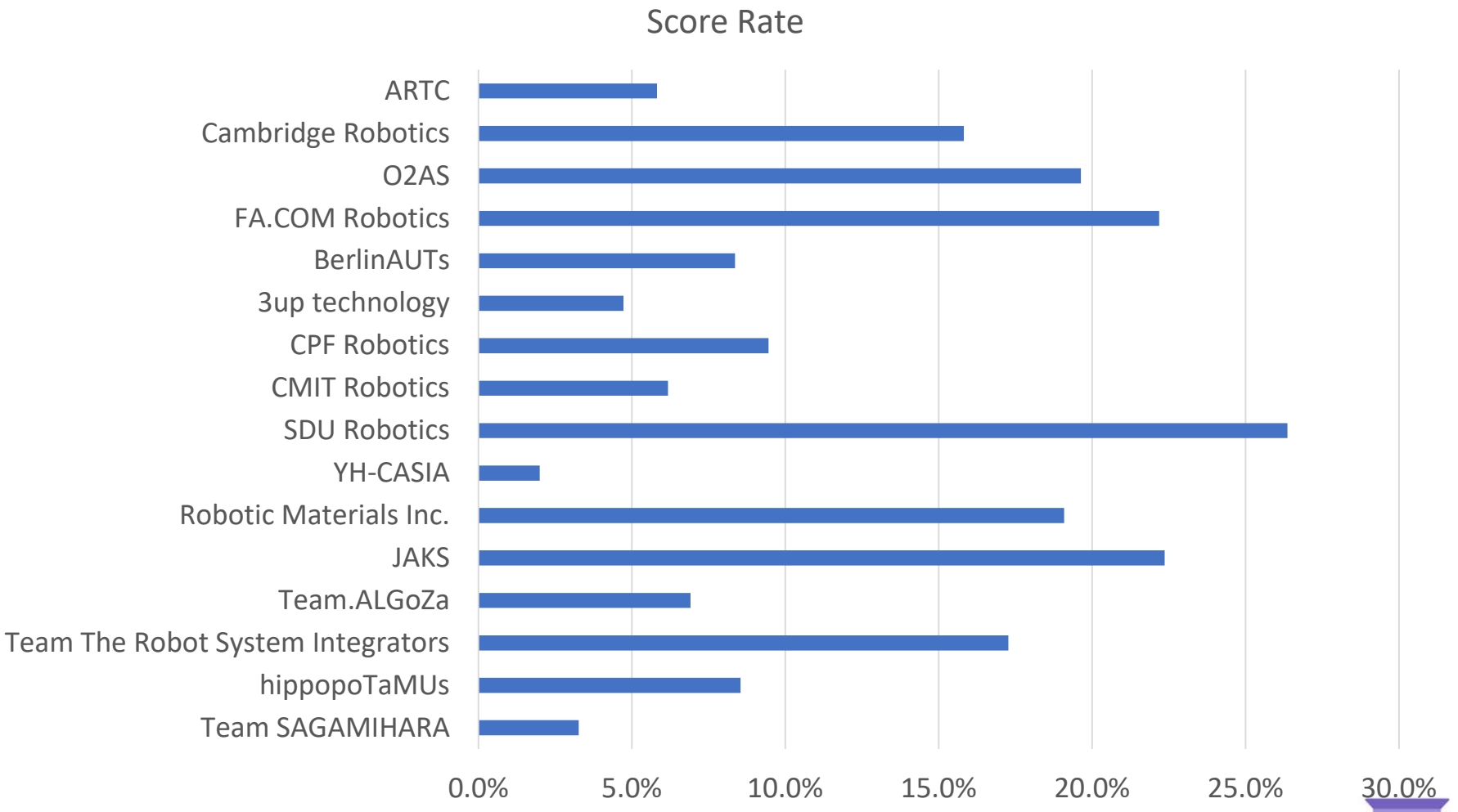
Breakdown of Points



Lessons Learned

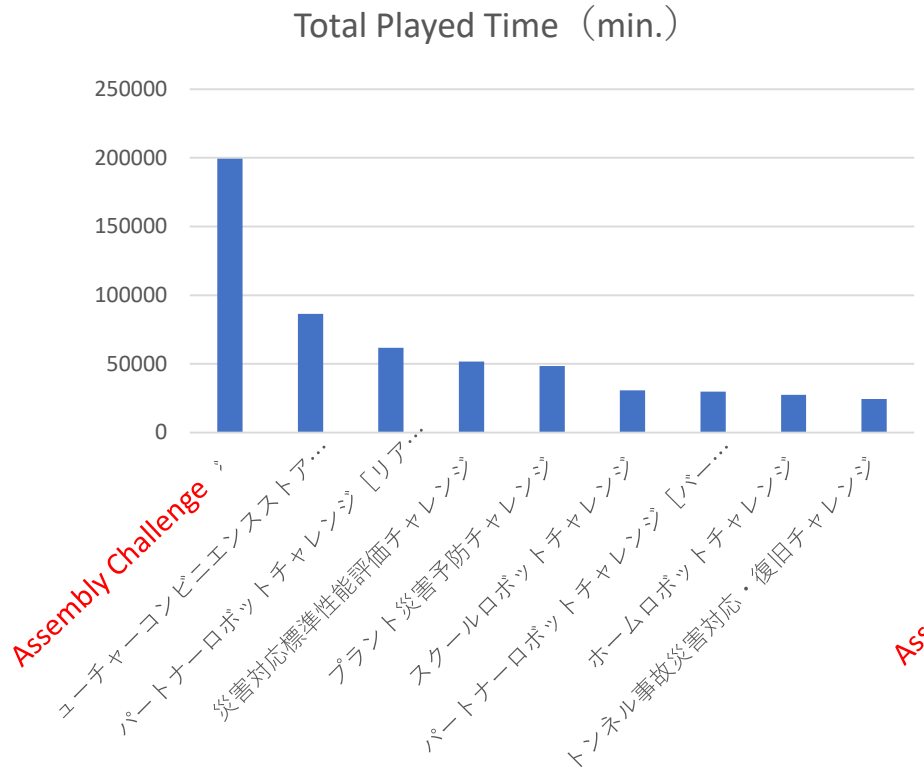
- Frequent rule update
- Completion bonus for assembly task too low?
  - Kitting
    - 50 points/set = Partial 20 points + Completed 30 points
  - Assembly
    - 45 points/unit = Subtask 31 points + Product evaluation 14 points
- Consistency between task board and assembly
  - It ended up that the task board has become more difficult, for example, to pick screws and washers.
- Problem setting of Kitting task
  - Parts bins must be arranged In the preparation phase → Maybe unrealistic (the motion range of the robots must be considered)
- Granularity of subtasks of assembly
  - Uneven difficulty of subtask
- Surprise parts
  - Even the chairperson was surprised !
- Carrying in and out by team members in the middle of the competition
  - Difficult to secure security and secure the final state of their outcome

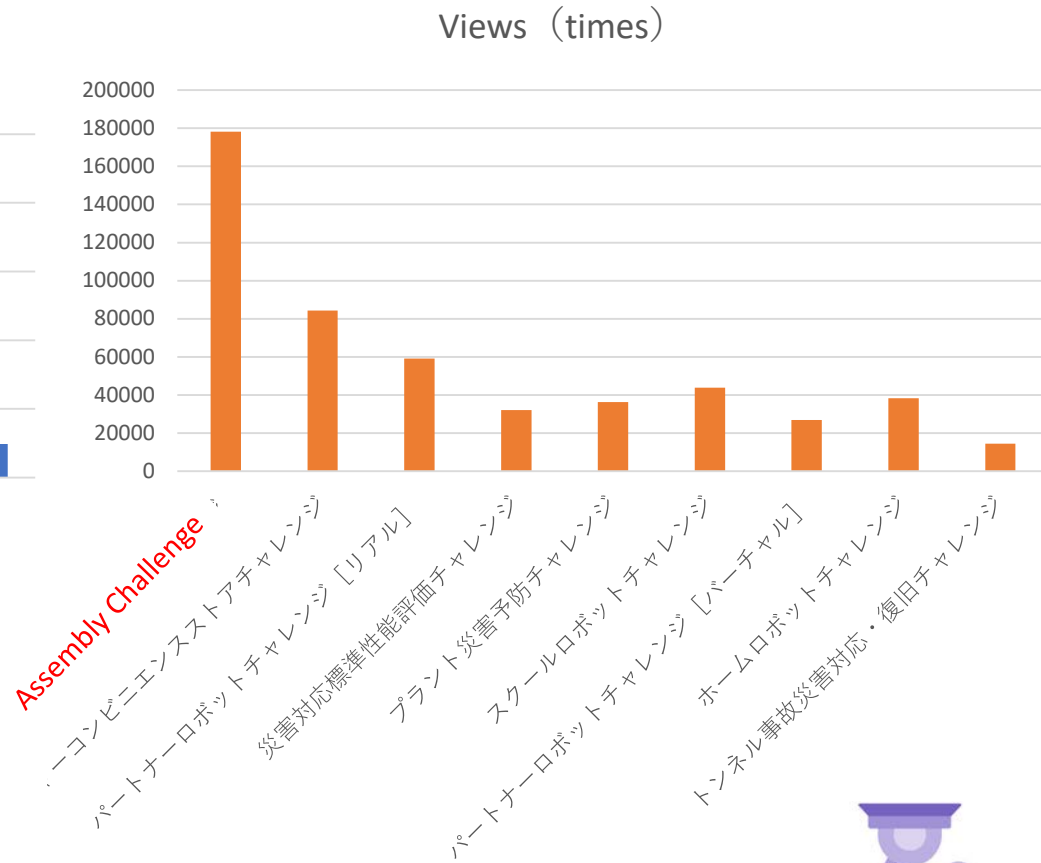
If it is a university subject, all teams failed !



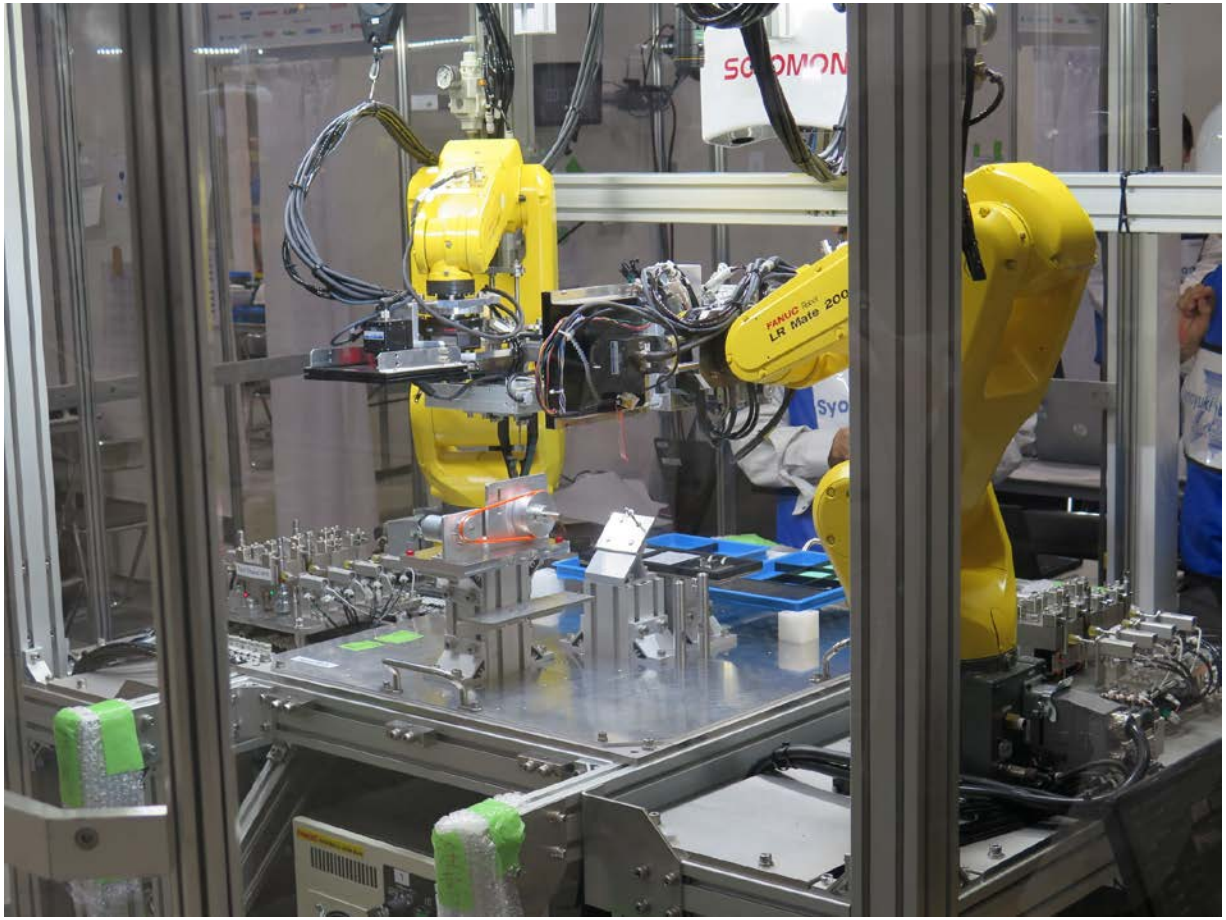
YouTube viewing statistics

- Top in both number of views and total played time





“Dad, this doesn't look like a robot at all. . .”



Summary of WRS 2018

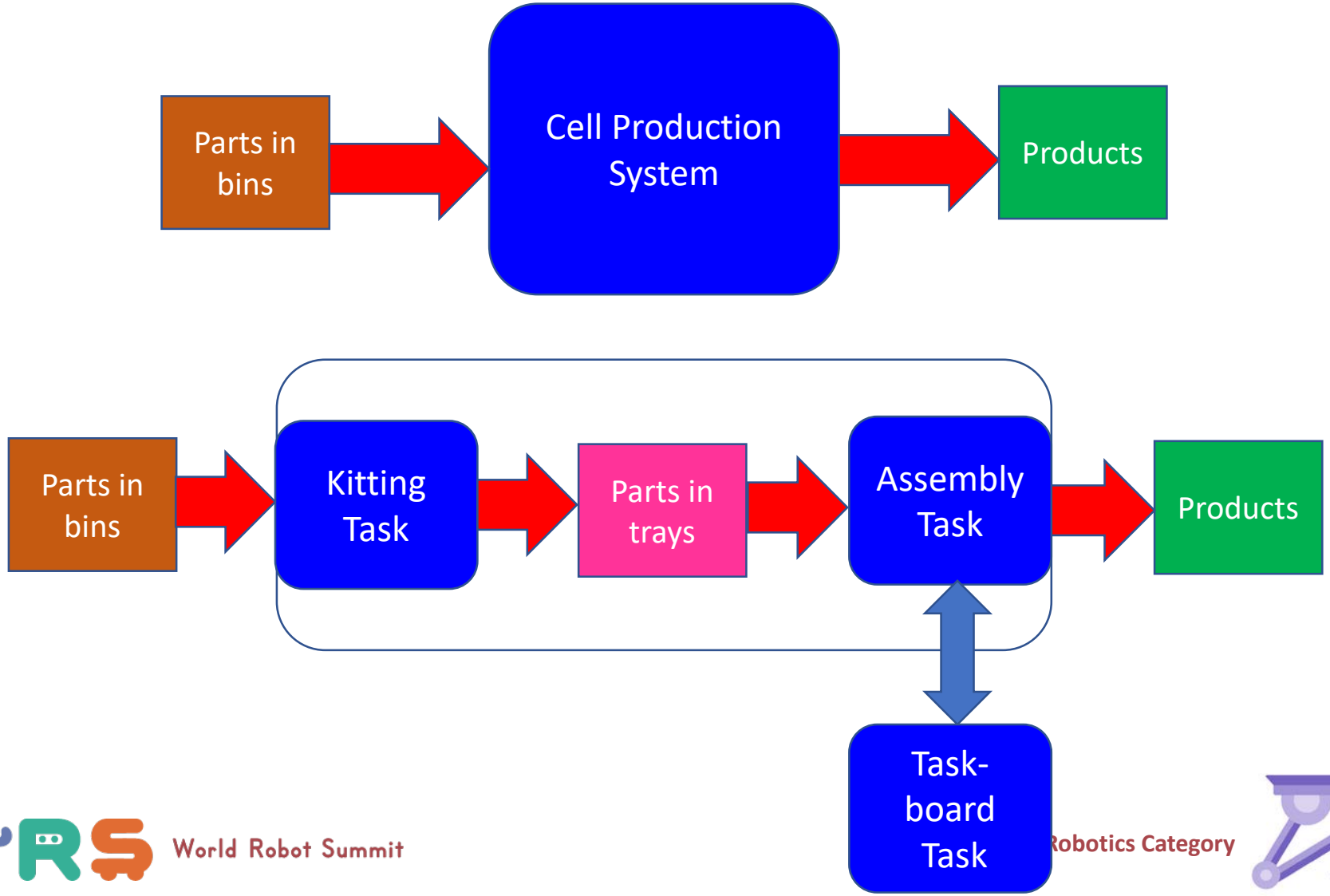
- Task board
  - The layout change on site made many teams confused. → Surprise parts in this competition?
  - Overall ranking was almost determined by the point of the task board.
- Kitting
  - Due to sensor malfunction and lighting condition etc., there is no team that got the result expected by the management side.
- Assembly
  - Only one team completed belt drive unit in Day 4. However, it was a normal product.
- Safety and health
  - Safety and health ensured by rules and contributed to the improvement of safety awareness of each team
  - The differences in the awareness on health and safety among teams were revealed.

Summary of WRS 2018 (cont.)

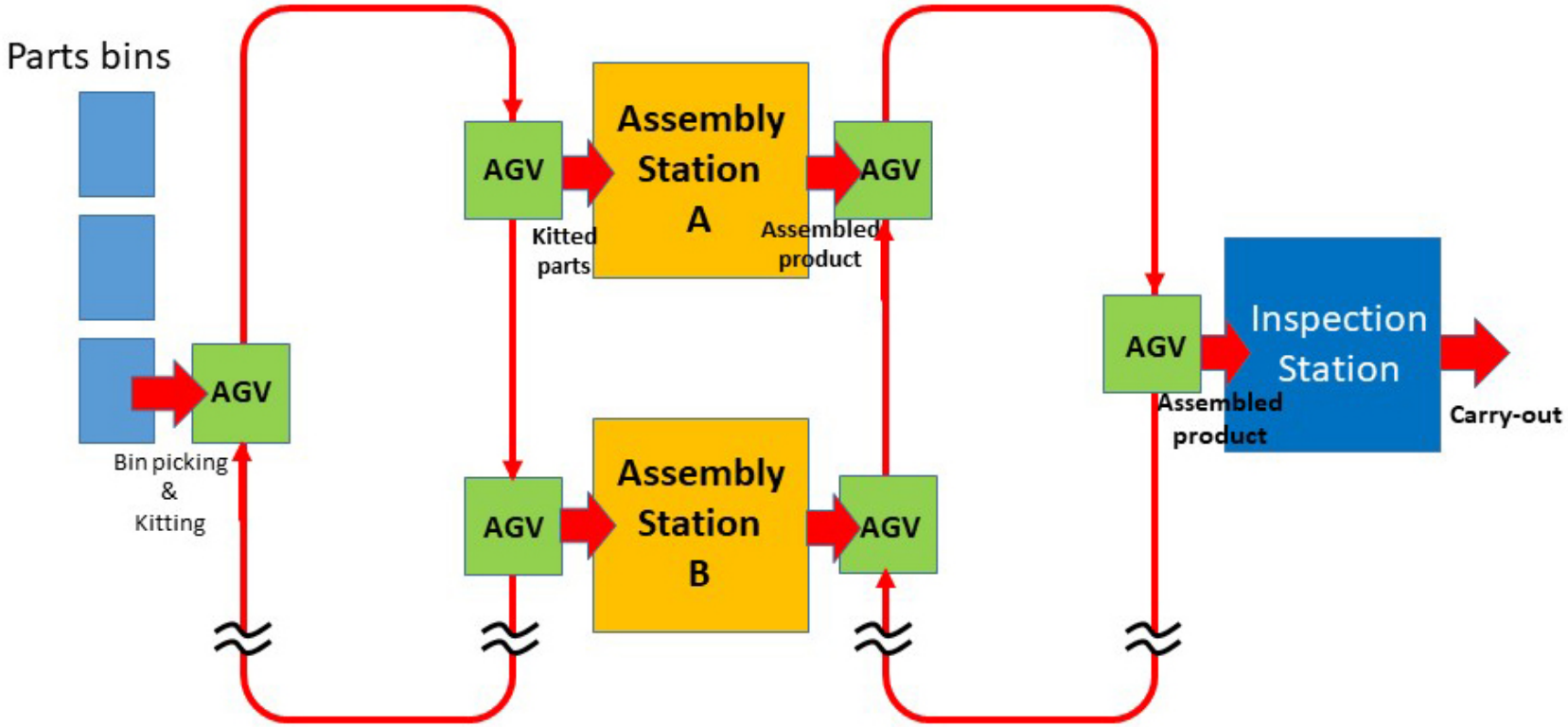
- Succeeded as a competition (?)
  - Created a brand new competition from the scratch
  - The teams realized the difficulty of the task and show their willingness to participate in the 2020 main competition?
  - Possibility of agile & lean manufacturing? （e.g. SDU, Robotics Materials, Cambridge v.s. FA.COM）
  - Human resource development (e.g., tears of Chinese team students)

Outlook for WRS 2020

Cell Production System and WRS 2018 Assembly Challenge

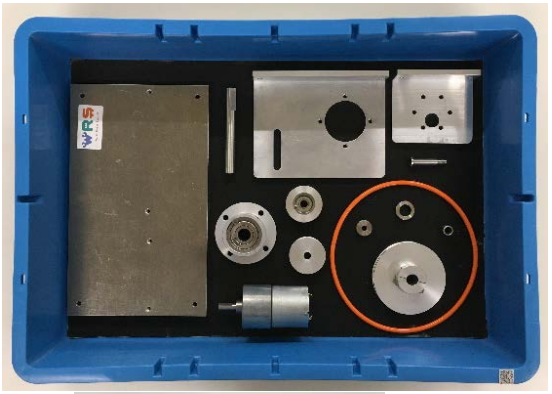


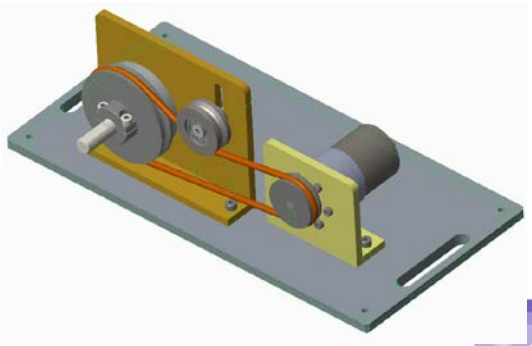
Basic Concept of the WRS2020 competition



Major Changes from WRS2018

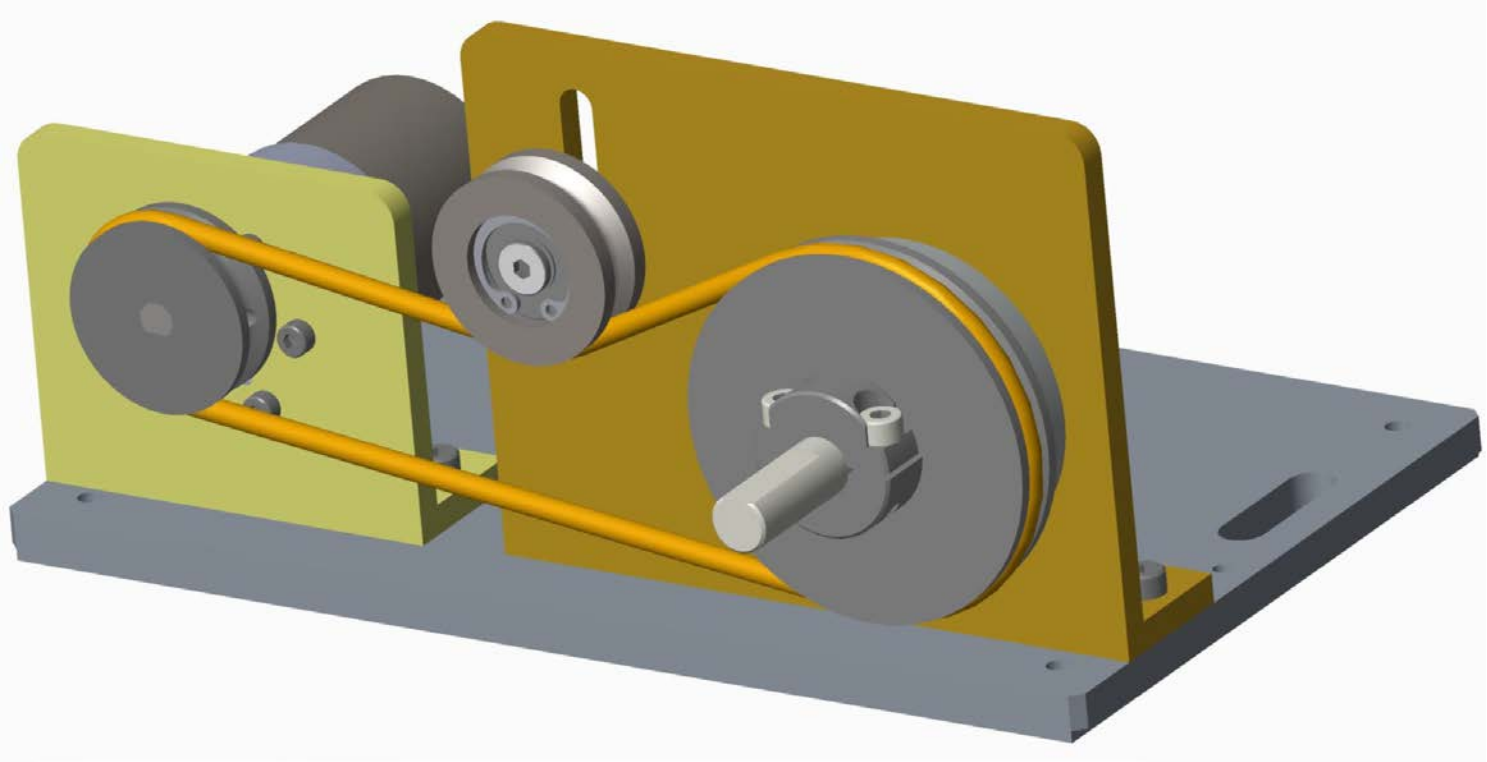
- The kitting task has been discontinued.
- Instead, the parts are kitted on the parts tray in advance and provided to the teams.
- Supplying method for small parts can be prepared by teams.
- Manual cart to carry the parts into the system operation area
- The task-board task will become more consistent to the assembly task.
- Instead of the surprise parts, the teams have to assemble surprise products that consist of the parts whose information is announced in advance, but assembly methods are announced immediately before the competition.





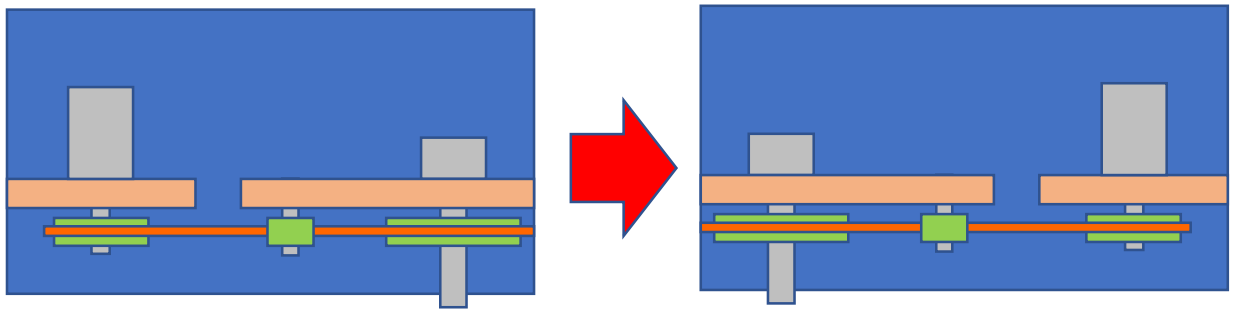
An Image of the Model Product for the WRS2020

- Belt Drive Unit



Surprise Products

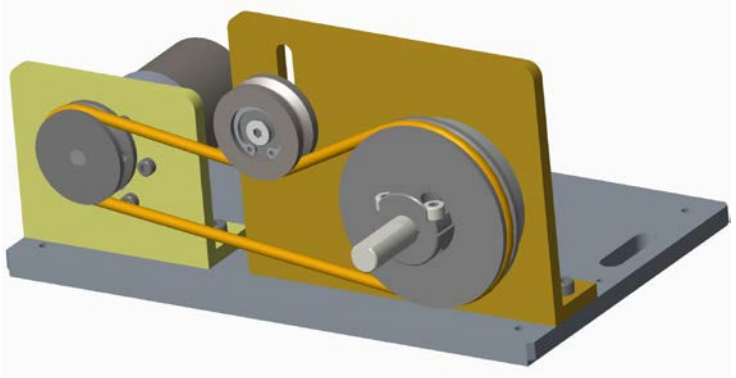
- Teams are required to assemble “surprise products,” and will be evaluated how they can respond to a new production demand in agile and lean manners.
- Information of the parts constituting the surprise products such as the size range of the parts will be announced earlier so that teams can design hands and other equipment.



An image of surprise product

WRS2019 Trial Competition

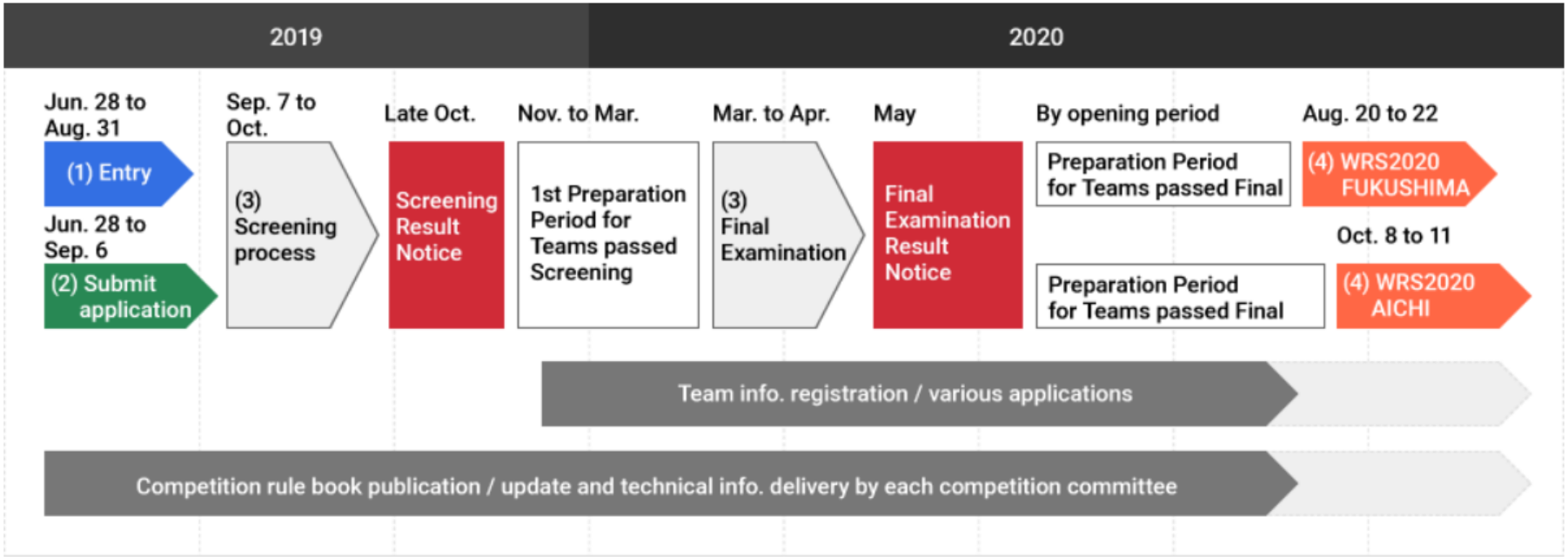
- December 17-21@iReX2019
- Assembly task only
- Trial of new elements planned for the main competition in 2020
- Four teams have been selected from the WRS2018 teams



Dec. 17	Dec. 18	Dec. 19	Dec. 20	Dec. 21
Setup Period （2 days）		Day 1	Day 2	Day 3
			Open to the public	
No carry-in	Safety inspection Adjustment	Public practice	Assembly (normal product, second round)	Exhibition Exchange event
Team setup	Safety inspection Adjustment	Assembly (normal product, first round)	Assembly (incl. surprise products)	Opinion exchange Carry-out

WRS2020 Team Selection Process

Industrial Robotics Category / Service Robotics Category / Disaster Robotics Category



*Regarding application for Junior Category, to be announced details such as application period and so on separately due to consider school summer break period.

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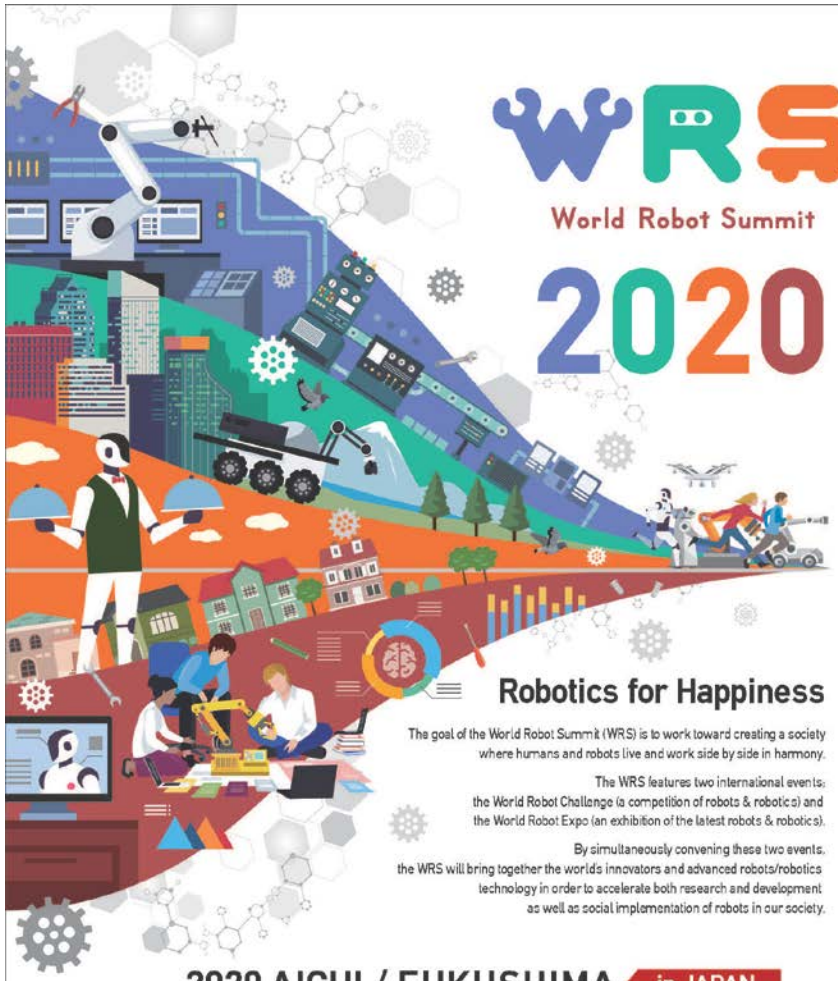
ISSN: 0169-1864 (Print) 1568-5535 (Online) Journal homepage: https://www.tandfonline.com/loi/tadr20

Assembly Challenge: a robot competition of the Industrial Robotics Category, World Robot Summit – summary of the pre-competition in 2018

Yasuyoshi Yokokohji, Yoshihiro Kawai, Mizuho Shibata, Yasumichi Aiyama, Shinya Kotosaka, Wataru Uemura, Akio Noda, Hiroki Dobashi, Takeshi Sakaguchi & Kazuhito Yokoi



WRS World Robot Summit 2020

Robotics for Happiness

The goal of the World Robot Summit (WRS) is to work toward creating a society where humans and robots live and work side by side in harmony.

The WRS features two international events: the World Robot Challenge (a competition of robots & robotics) and the World Robot Expo (an exhibition of the latest robots & robotics).

By simultaneously convening these two events, the WRS will bring together the worlds innovators and advanced robots/robotics technology in order to accelerate both research and development as well as social implementation of robots in our society.

2020 AICHI / FUKUSHIMA in JAPAN

AICHI SKY EXPO

Venue

AICHI SKY EXPO

Oct. 8 Thu › Oct. 11 Sun

FUKUSHIMA ROBOT TEST FIELD

FUKUSHIMA ROBOT TEST FIELD

Aug. 20 Thu › Aug. 22 Sat

Hosts

METI Ministry of Economy, Trade and Industry

NEDO

Website https://worldrobotsummit.org/en/

WRS World Robot Summit
2020 AICHI, JAPAN
October 8 - 11
Aichi Sky Expo

Assembly Challenge

Industrial Robotics Category

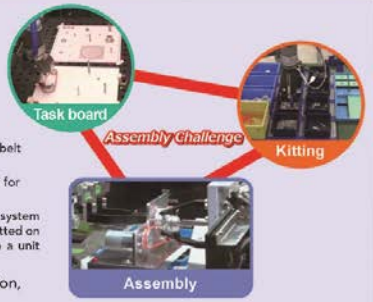
"Toward agile one-off manufacturing"

This category aims at realizing future manufacturing systems that can respond to variously changing orders in high-mix low-volume production (ultimately, even an order for one-off product) by reconfiguring the system in agile and lean manners.

Results of WRS 2018

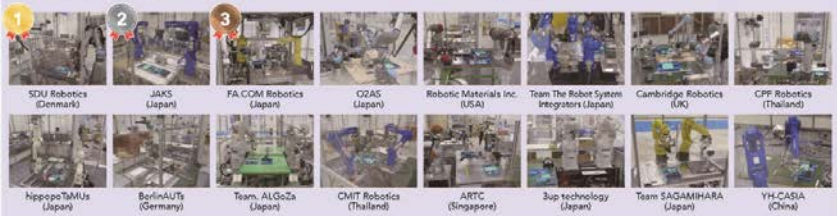
Summary

- The WRS 2018 (pre-competition) was held in Tokyo on October 17-21, 2018.
- The challenge consisted of the following three tasks:
  - **Task board:** competition of elemental technologies required for the belt drive unit assembly
  - **Kitting:** competition of kitting, which is regarded as a preparation task for the belt drive unit assembly
  - **Assembly:** competition of the belt drive unit assembly and system reconfiguration (the belt drive unit should be assembled from the parts kitted on the tray, and also system reconfiguration should be done to assemble a unit including new parts (surprise parts) as a new production demand)
- 16 teams from all over the world participated in the competition, and the 1st place team was awarded 15M JPY money prize!



The above pictures are of the participating teams: the task board (SDU Robotics), the kitting (Robotic Materials Inc.), and the assembly (FA.COM Robotics).

Robot systems of 16 teams



Call for participation in WRS 2020

Tasks of Assembly Challenge

- **Task board:** competition of elemental technologies required for the belt drive unit assembly
- **Assembly:** competition of assembling the belt drive units including new products (surprise products)

Belt drive unit (used for the WRS 2018 and subject to change for the WRS 2020)

Prize money and awards

- Prize money shall be given to the winning teams.

Important dates

- **August 31, 2019:** Deadline of registration for entry
- **Late October 2019:** Screening result notification (TBC)

What's new for WRS 2020?

- The kitting task has been discontinued, and the parts supply in the task-board and assembly tasks has been changed.
- The task-board task will be more consistent to the assembly task.
- Surprise products consist of the parts which information (e.g., the range of their dimensions) is announced earlier, so that teams can design robot hands and other devices, but should be assembled differently from the normal unit.

For further information, please contact us or access the WRS website and our facebook.

Contact industry@worldrobotsummit.org Website https://worldrobotsummit.org/en/ Facebook https://www.facebook.com/wrsindustry/