

Grand Challenges on Indoor Robot Learning

1. Introduction

More recently, service robots have emerged as a highlight for both academic and industrial field. We start to see applications of robot in our daily life, such as public service robots in locations like airports and hotels. There is even greater potential in applications that are more *personal*, *private*, and *customized*, such as home assistant, elderly care, smart retail etc. To realize such great potential of service robots, one of the long-time technology bottlenecks is *the lack of efficient and robust robot learning capability*. That is, just the mainstream supervised learning (including Deep Learning) based on large amount of pre-annotated data is not good enough for robotic applications that requires learning continuously in *perception*, *cognition*, *manipulation*, and *interaction with users*. Indoor environment provides an ideal environment for robot learning especially self-supervised and continual learning, since robots have opportunities interacting with their surroundings more effectively.

The grand challenge aims to provide a platform to evaluate the latest progress of the field. The challenge is designed to have two perspectives: *the perception/cognition* and *the physical tasks*. Teams with different background in all related fields are encouraged. This include but not limited to the field of robotics, machine learning, and computer vision. Collaborations are also strongly encouraged. We believe this grand challenge will have significant social, academical, and industrial achievement in future research, and paves a way to large-scale deployment of convenient service robot in the next 5 to 10 years.

2. Task design principles

- Adding industry level testing track (robot needs to be fully autonomous) and with clear mid-term goal to speed up the technology advances in robot learning: **highest score from 40-60 in the first year to 90-100 in the third year** (full score at 100).
- **Tasks selected for industry level testing should be must-have instead of nice-to-have**, i.e. critical in real service robot applications such as home service, elderly care service, healthcare assistance, smart retail etc.
- Try to make robot learning **self-supervised** (with limited user interaction to avoid burden on users) instead of pre-trained, which is more meeting real application needs.
 - e.g., through self-supervision, autonomous collection of data from local environment, limited interaction with users, or leverage any domain specific information robot can get from local environment.
- Focus on indoor scenarios where robot has more opportunities to interact with users and environment, and thus have more opportunities to do learning.
- Different tracks to verify technology advances in different levels.
 - Full system vs single technology
 - Robot learning for different skills: Perception/cognition skills (memory/knowledge), Physical skills.
- **Manipulation tasks also consider balance between manipulation and learning.**

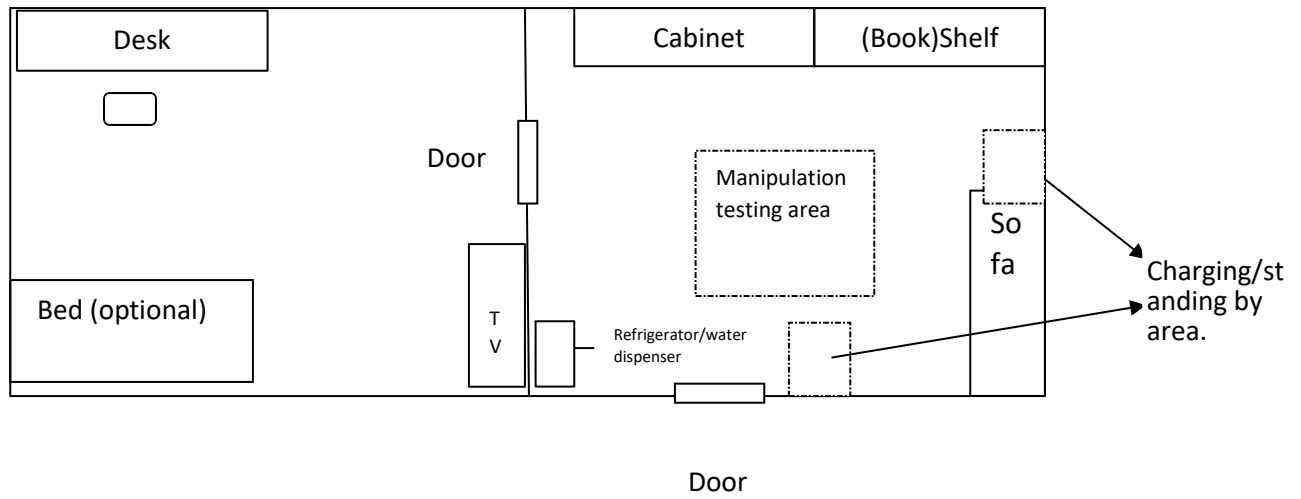
3. General Setup

All the testing and learning happens in a home like testing facility. And each robot needs to stay in this testing facility for 3-7 days for a full testing. Below are the detailed requirements for the testing facility.

Important Note: Most description below is for a full testing facility (i.e., it can test all the tasks. For cities with distributed local testing facilities, also for annual final competition such full testing facility will be provided for participating teams to use.), for teams who participated in first stage testing, and just need to do one or a few of the tasks (especially manipulation learning tasks), a simplified testing facility can be conveniently set up locally in each team's local lab, and much less space is needed. See details on section 3.6.

3.1 Room layout

2-3 rooms (one living room, one bedroom, one optional kitchen room for manipulation tasks). If there are only two room, then a manipulation testing area can be set up in the living room.



3.2 Furniture/objects configurations

1. Living room: ≥ 14 -16 square meters; Bedroom: ≥ 14 -16 square meters; Kitchen room is optional; manipulation tasks will be tested either in living room or Kitchen room.
2. Door size: Width ≥ 1.2 meters, height ≥ 1.8 meters
3. Wall: The walls of the room can be constructed of lightweight materials (e.g., hollow foam, etc.), height ≥ 1.8 meters.
4. The space of some testing facilities needs to be reused in spare time (in one year of period), so better choose furniture which can be easily disassembled.
5. Cabinet/Shelf.
Cabinet and shelf are the kind of multi-layered which can put a variety of items. Shelf has no doors, and cabinet has doors. Both may have drawers. Styles are not too restrictive, such as one sample from IKEA below (Fig. 1).



Fig. 1 A shelf example (KALLAX from IKEA)

6. TV table: Put a TV (or just LCD Display) on the TV table.
7. Refrigerators/water dispensers: A fridge and water dispenser can be put here. This area can also put other devices such as cooking machine.
8. Temporary area for manipulation tasks: This area allows the table etc. to be set up to test the manipulation learning tasks, and it can be disassembled after the testing if needed.
9. Furniture does not have special size requirements. Just leave enough space for robot to move (about 50cm wide).
10. Objects: Some background objects will be put in the cabinet/shelf and the drawers in them, at least below objects should be included (see object list in appendix). And 2-3 random “new” objects will be prepared for each testing period (one week), these will not be notified to the teams until the testing starts.

3.3 Volunteers and Participating team

1. Volunteer

Volunteers will perform daily activities or related interactions with robots as defined in below detailed task definitions. The activities include:

General: Get up, leave home, back to home, eating (lunch), drinking water, go to rest room,

other activities: Watching TV (at Sofa), Reading book, Use computer, Dancing (Waltz style)

Chronic disease related: Take medicine

2. Participating team

Most of the tasks emphasize self-supervised learning capability from robots, so participating team will not be allowed to enter the testing facility to help the robot, unless specified in a specific task definition. They can ask the volunteer to help restart the robot, install software or data in case the robot has issues, but they are not allowed to take and access any pictures/videos/voice/sensor data in the testing lab once the test starts. Manual annotations of the data are only allowed in registration phase (as defined in below task definitions) and are not allowed during all the other phases (learning phase etc.), unless it is specified.

3.4 Robot Inspection

General inspection will follow RoboCup@Home robot inspection procedure. After inspection and approved by local testing facility team, a robot can participate in the testing, or else it will not be allowed to do any testing.

For this competition, robot will stay with human volunteers in the same environment, so co-bot arm with good safety (e.g., have force sensors on each joint) is suggested to be used to ensure better safety.

3.5 Safety related rules

Robot speed should be limited to no more than 2 m/s at any situation. Robot arm speed should be kept under x m/s at any situation.

Robot arm should have ways to stop moving while collision with people.

While robot arm is moving (e.g., practice on manipulation tasks), robot should notify people in the room with voice and other ways (e.g., lighting) which can be easily noticed, and people should keep 1.5 meters away from robots.

While robot is moving, an operator (volunteer) should keep close eye on it and prepare to click stop button (remote control) at any time when the robot is suspected to have safety threats to people in the room (e.g., suddenly moving faster, or rolling fast).

3.6 Simplified testing facility

For simplified testing facility, less space is required. Each team is responsible to set up such facility locally, recruiting volunteers, and pay for all the cost (to save cost, for furniture/objects you can reuse existing items from your local resources). The details about simplification of testing facility are as below.

- For all tasks, space configuration no need to be exactly the same as the full testing facility, just enough space for the specific task.
- For task 4.1.1 and 4.1.3, space configuration no need to be exactly the same as the full testing facility, just enough space for volunteers to stay in the environment and be observed by the robot.
- For task 4.1.2, 4.2.1, furniture can be simplified as 1-2 furniture (but it needs to have shelf, door, drawers), also for objects no need to be exactly the same objects as listed in the appendix, just providing roughly the same categories of objects is enough.
- For all other learning for manipulation tasks, just enough space for robot to do the operation is enough, such as a table, and leave enough space around the table for robot to operate.

Note for referee to judge from remote, each team also need to provide remote video connections and store the video, as mentioned on the website.

For teams who are using simplified testing facility, please notify the organizer with rough descriptions and pictures about the testing facility. Thus, we can confirm if your testing facility is meeting the requirements.

4. Tasks and scoring

4.1 Learning for interaction

4.1.1 Learning for person recognition

Testing goals: With initial brief registration of a person (face mainly), robot needs to learn to recognize a person from 3 modalities: face, body and voice in one week, and robust to any viewpoints/lighting/background clutter. The accuracy each day will be tested.

The final score of this task will be the accuracy achieved in the last day.

■ Initial registration phase:

- **Location:** Any empty space in the home like environment
- **Instruction:** Two volunteers appeared before robot (one by one) and do face registration with robot (robot will take 5-15 pictures of the face). Voice registration of less than 20 seconds is also allowed. The two volunteers can turn around before the robot (body-based person ID can take this opportunity to do registration). Then the two volunteers will leave.

■ Learning phase:

- **Learning opportunities:** The two volunteers will stay in this environment for at least 5 hours each day, performing some daily activities: using computer, get water, chatting, studying, reading book etc. **Each volunteer will chat to robot 3 times each day, the topic can be any free chatting topics.** Robot should take advantage of the chances staying with the two volunteers in the same environment to maximize learning.
- **Limited help from users:** Robot can ask the two volunteers to give confirmation of their identity occasionally, but the maximum number of such interaction should be no more than 2 times each day. No other help from human is allowed beyond this.
- **Changing clothes:** Volunteers will only change clothes (both upper cloth and trousers) at the morning of 3rd. day and the 5th day.
- **Distractor:** There are 1-2 other volunteers will act as distractors, just to confuse the robot. The distractors will also stay in this room for about similar amount of time as the two volunteers. But the robot is not required to recognize the distractors.

The distractors can stay together with the two volunteers (e.g., chat with the two volunteers), and no need to mind too much about occlusion between people, but also not try to block the view of the two volunteers all the time. Just do it naturally is fine.

- **Testing phase:** Testing will be conducted at the end of each day. In this test robot needs to recognize a person from both face, body and voice from recorded testing cases (with annotation from volunteer). The later days can include all the data collected before.

- Testing cases will include variations:
 - Near frontal face: 1 time
 - Body only (non-frontal face): 20 times (from non-frontal face positions, e.g., left, right, back, also with pose variations like sitting/standing etc., and lighting variations. Details will be provided before testing.).
 - Voice only: 2 times, volunteers not seen (in another room), normal style talking (background noise relatively low), only one person talking each time.
 - Body+voice: 2 times (volunteer in non-frontal face position, and talk)

- **Scoring:** Score will be the accuracy of person recognition for all the testing cases, i.e. number of accurately recognized testing cases/number of all testing cases. Final score will be the accuracy in the last day's testing. The intermediate testing scores is for reference purpose (for analyzing the improvement of each robot's learning process).
- In addition, there is a subjective evaluation score, used to assess the advancement of the technology used by the team, as well as technical breakthroughs in the direction of autonomous continuous learning of robots. The subjective score accounts for 30% of the final total score.

4.1.2 Learning for object recognition and finding

Testing goals: With initial brief registration of a few new objects, robot needs to learn to recognize these new objects in 3-7 days, and robust to any viewpoints/distance/lighting/background clutter etc. The accuracy each day will be tested. **The final score will be the accuracy achieved in the last day.**

- Initial registration phase:
 - **Location:** Any empty space in the home like environment
 - **Instruction:** 10 new objects (**selected by referee randomly just at the beginning of the first day of the testing period**) is showed to robot, allow to do registration of the object for 30 seconds short video (e.g., volunteer handle it and show before the robot). One frame can be annotated with object boundary, or any other annotation needed (testing team can notify organizer one week before the testing).
- Learning phase: Robot needs to learn to recognize the 10 new object instances. Active recording is allowed, i.e., robot can actively collect data if needed.
 - **Learning opportunities:** The new objects will stay in this environment for the whole testing period. Volunteers will change position of them in some of the days as mentioned below. Robot should take advantage of all chances staying with these new objects in the same environment to maximize learning.
 - **Limited help from volunteers:** Robot can ask the two volunteers to give confirmation of an object's identity occasionally, but the maximum number of such interaction should be no more than 3 times each day. No other help from human is allowed beyond this. (Team member of participating team can't enter the testing lab, also can't ask Volunteer to help them to do annotations etc.)
 - **Changing positions:** Volunteers will change positions of these new objects at the morning of each day. Different places, with different height will be possible, including cases where part of the subject is obscured.
- Testing phase: Testing will be conducted at the end of each day. In the test, the robot needs to find 10 specific objects in the environment as per the instructions. It can be executed multiple times for the best result. Ideally, it should reflect the process of continuous learning and the continuous improvement of the success rate in finding objects.

- **Finding object cases:**
 - At each day, each object is tested under 2 conditions. The testing conditions are decided by volunteers and referee together. The testing conditions are selected from the following cases:
 - Lower/higher place:
 - Low/normal lighting:
 - Objects in cluttered background:
 - Different distance:
 - Different viewpoint:
 - At the end of each day, the robot is asked to find the pre-defined 10 objects. Therefore, there are 10 test cases every day. If the robot finds the object successfully within 15 minutes, it is regarded as a successful case.
 - Scoring: Final score will be the best score of finding object cases in the last day. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).
- **Subjective evaluation score:**
 - In addition, there is a subjective evaluation score, used to assess the advancement of the technology used by the team, as well as technical breakthroughs in the direction of autonomous continuous learning of robots. The subjective score accounts for 30% of the final total score.

4.1.3 Learning for activity recognition

Testing goals: Based on initial generally trained activity recognition, robot needs to learn to recognize 3 selected activities (will be notified to teams at least 1 month before testing) more accurately in one week, and robust to any viewpoints/distance/lighting/ background clutter etc. The accuracy each day will be tested. **The final score will be the accuracy achieved in the last day.**

Activities set: Activities are divided into two levels of difficulties: low and high. Low difficulty level activities include “walking,” “handshake,” reading,” “sweeping,” “playing guitar.” High difficulty level activities include “eating,” “drinking,” “writing,” “typing on keyboard,” “putting on clothes,” “combing hair.”

- **Initial registration phase:**
 - **Location:** Any empty space in the home like environment
 - **Instruction:** 3 activities (1 from low level difficulty and 2 from high level difficulty) should be chosen from the activity set. They are shown to the robot in the first day at an appropriate time and place, allowing registration of the activity with a 30 second short video by the robot.
- **Learning phase:** Assume generally trained activity recognizer will still have issues, Robot needs to learn to recognize the 3 activities accurately in one week by leveraging more learning opportunities. Active recording is allowed, i.e., robots can actively collect data if needed.
 - **Learning opportunities:** The 3 activities will be conducted by volunteers at an appropriate time and place (e.g., eating at noon time and at dinner table or sofa) in this environment for the whole testing period. Robots should take advantage of all chances to maximize learning.

- **Limited help from users:** Robot can ask the two volunteers to give confirmation of an activity occasionally, but the maximum number of such interaction should be no more than 3 times each day. No other help from humans is allowed beyond this.

- **Testing phase:** Testing will be conducted at the end of each day. In this test robot needs to continuously learn and recognize the 3 activities from recorded testing cases (with annotation from volunteers). For the recorded testing, the later days should include all the data collected before.
 - Recorded testing cases are collected under normal indoor lighting conditions and will include variations listed as follows. Note that each variation must be included when collecting testing cases.
 - Different distances: 2 times with 1 meter and 3 meters
 - Different viewpoints: 3 times with at least 3 significantly different viewpoints
 - Different cluttered backgrounds: 10 times (**may replace background images by editing, but all background images should be from the testing environment, i.e., the two/three rooms for testing**)
 - Interrupted and resumed: 3 times. (The activity is interrupted and resumed)
- **Scoring:** During testing volunteers will choose randomly to perform one of the 5 activities (3 chosen by the team and 2 others from the activity set. Note that the team can use any algorithm to handle those cases that are not continuously learned.) The team should vary conditions as indicated earlier. Score will be the accuracy of activity recognition for all the testing cases, i.e., number of accurately recognized testing cases/number of all testing cases. Final score will be the accuracy in the last day's testing. The testing scores for the other days are for reference purposes (for analyzing the improvement of each robot's learning process).
- In addition, there is a subjective evaluation score, used to assess the advancement of the technology used by the team, as well as technical breakthroughs in the direction of autonomous continuous learning of robots. The subjective score accounts for 30% of the final total score.

4.2 Learning for manipulation

4.2.1 Pick/place of new (not well trained) objects from cluttered environment

- **Testing goals:** 3 new objects (**selected by referee randomly just at the beginning of the first day of the testing period**) is showed to robot, allow to do registration of the object for 30 seconds short video (volunteer handle it and show before the robot). One frame can be annotated with object boundary, or any other annotation needed (testing team can notify organizer one week before the testing).
- Initial set up/registration phase:
 - **Location:** Any empty space in the home like environment
 - **Instruction:** 3 objects is showed to robot in the first day, allow to do registration of the object (30 seconds short video recording) by robot.
 - Learning phase: Robot needs to learn to pick and place the 3 objects from cluttered environment (i.e., objects are put in shelf/cabinet/drawers, and mixed with other objects, even hidden) accurately in one week by leveraging more learning opportunities. Active recording and exploration are allowed, i.e., robot can actively collect data, and can try to manipulate the object for practice (note that crashing objects will have lower score, so discretion needs to be taken).
- **Learning opportunities:** Robot should take advantage of all chances to maximize learning, such as active perception, physical manipulation of the objects etc.
- **Limited help from users:** Robot can ask the two volunteers to help occasionally (including asking them to demonstrate grasping/placing of the objects, or ask them to give hints/corrections), but the maximum number of such interaction should be no more than 3 times each day. No other help from

human is allowed beyond this.

- **Testing phase:** Testing will be conducted at the end of each day. In this test robot needs to pick up/place the three objects from places selected by referee (from speech/text command). 10 times will be tested for each object.
- **Scoring:** Score will be the times of success for all the testing. **If one object is crashed, then one success time will be deduced from the total number.** Final score will be the times of success in the last day's testing. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).

Scoring table	Score	Notes
Task completeness	0, 2, 5, 10	10: complete the task 5: complete the task, but collision happened 2: complete the task with human define object position 0: None completed

- In addition, there is a subjective evaluation score, used to assess the advancement of the technology used by the team, as well as technical breakthroughs in the direction of autonomous continuous learning of robots. The subjective score accounts for 30% of the final total score.

4.2.2 Fruit Garnishing

- **Testing goals:** Fruit garnishing process is showed to robot one time each day. Robot needs to learn this skill and do successful fruit garnishing by itself.
- **Initial set up phase:** A few piles (4-5) of fruits put on a table. The categories of fruits are chosen by the organizing team for each testing (may change each time).
- **Initial registration phase:** Not needed.
- **Learning phase:** Fruit garnishing process is showed to robot one time each day (see one picture below as one example of the final status. Note that the final layout is up to volunteer and can be random each time.). Robot then needs to learn to do this by itself. Active recording and exploration are allowed, i.e., robot can actively collect data, and can try to practice for up to 10 minutes each day (Fruits will stay in the table for 10 minutes. Note that crashing fruits in the practice stage will also result in lower score in testing, so discretion needs to be taken).
- **Learning opportunities:** Robot should take advantage of all chances to maximize learning, such as active perception, physical manipulation of the objects etc.



- **Limited help from users:** Robot can ask the two volunteers to help occasionally (e.g., asking them to demonstrate grasping/placing of the objects, or ask them to give hints/corrections), but the maximum number of such interaction should be no more than 3 times each day. No other help from

human is allowed beyond this.

- Testing phase: Testing will be conducted at the end of each day. In this test robot needs to do fruit garnishing testing for 2 times. Before each testing, fruits will be dispersed on the table,

initial layout can be randomly picked by volunteers, possibly fruits will be placed over each other.

- **Scoring:** The score will be graded based on speed, motion accuracy, task completeness, and aesthetics value. Detailed scoring standard is as below. Final score will be the score in the last day's testing. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).

Scoring table	Score	Notes
Speed	1-3	1: >3 minutes, 2: 2-3 minutes, 3: <2 minutes
Fruit intact Rate	1-3	3: 100%; 2: 80%; 1: 50%
Task completeness	0, 4, 6, 10	10: All tests completed successfully 6: More than 50% completed successfully 4: Less than 50% completed 0: None
Aesthetics value	1-3	Subjective given by referee teams

Notes: Soft gripper may be used here to avoid crashing fruits.

4.2.3 Garbage pick-up, categorization and place

- **Testing goals:** Pick up garbage on desk (from eating) put on correct garbage bins (needs garbage categorization into different categories, food, dry, paper/metal, bottles/cans).
- **Initial setup phase:** Volunteers have a great meal, then left the table as it is.
- **Initial registration phase:** Not needed.
- **Learning phase:** Robot then needs to learn to do garbage collection by itself. Active recording and exploration are allowed, i.e., robot can actively collect data, and can try to practice for up to 10 minutes each day.
- **Learning opportunities:** Robot should take advantage of all chances to maximize learning, such as active perception, physical manipulation of the objects etc.
- **Limited help from users:** Robot can ask the two volunteers to help occasionally (e.g., asking them to demonstrate grasping/placing of the one garbage item, or ask them to give hints/corrections?), but the maximum number of such interaction should be no more than 3 times each day. No other help from human is allowed beyond this.
 - **Testing phase:** Testing will be conducted at the end of each day. In this test robot needs to do garbage collection testing for 1 time. Before each testing, garbage items will be dispersed on the table, initial layout can be randomly picked by volunteers, possibly garbage items will be placed over each other.
- **Scoring:** The score will be graded based on task completeness (each garbage item put on correct garbage bin, also not dropping in the middle of the moving). Detailed scoring standard is as below. Final score will be the score in the last day's testing. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).

Scoring table	Score	Notes
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Task completeness	0, 4, 6, 10	10: All tests completed successfully 6: More than 50% completed successfully 4: Less than 50% completed 0: None completed
Efficiency	1,2,3	3: High ; 2: Mid; 1: Low

- In addition, there is a subjective evaluation score, used to assess the advancement of the technology used by the team, as well as technical breakthroughs in the direction of autonomous continuous learning of robots. The subjective score accounts for 30% of the final total score.

Notes: Needs to have a standard categorization (different country currently have different standards).

4.2.4 Learn to use electronic device

- **Testing goals:** Learn to use electronic device such as water dispenser, cooking machine etc. from verbal instructions/gestures/demonstration by human (one time each day). Each usage involves multiple step tasks.
- Initial setup phase: A new electronic device is put in the room.
- Initial registration phase: Not needed.
- Learning phase: Volunteer will teach robot one time each day on how to use this electronic device (The teaching will take a curriculum style, first teach basic parts like buttons/knobs and their operations, then the steps of actions and the pre-condition/post-effect of each action. A video example will be provided to show the teaching process as reference to volunteers.). Robot then needs to learn to operation this electronic device by itself. Active recording and exploration are allowed, i.e., robot can actively collect data, and can try to practice for up to 10 minutes each day.
- **Learning opportunities:** Robot should take advantage of all chances to maximize learning, such as active perception, physical manipulation of the objects etc.
- **Limited help from users:** Robot can ask the two volunteers to help occasionally (e.g., asking them to demonstrate a sub step, or ask them to give hints/corrections), but the maximum number of such interaction should be no more than 3 times each day. No other help from human is allowed beyond this.
 - Testing phase: Testing will be conducted at the end of each day. In this test robot needs to do operation of the electronic device for 2 times.
- Scoring: The score will be graded based on task completeness. Detailed scoring standard is as below. Final score will be the score in the last day's testing. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).

Scoring table	Score	Notes
Task completeness	0, 4, 6, 10	10: All tests completed successfully 6: More than 50% completed successfully 4: Less than 50% completed 0: None completed
Penalty	-1	Damage of each button/knob will get one point penalty

- In addition, there is a subjective evaluation score, used to assess the advancement of the technology used by the team, as well as technical breakthroughs in the direction of autonomous continuous learning of robots. The subjective score accounts for 30% of the final total score.

Note: For cooking machine, materials for cooking are prepared and put in cooking machine, robot just need to operate the cooking machine. Other specific instructions are determined by the device used on-site and the results of discussions with the referee.

Notes: Possibly some prior knowledge needs to be ready for robot to do this task. Also some can be learned in the testing period.

4.2.5 Get water and medicine in emergency

- **Testing goals:** This test will mimic in the context of an emergency situation (heart attack), and robot needs to get water (use cup to get water from a water dispenser) and medicine for the patient. Robot can be trained by volunteer to get water and medicine, from verbal instructions/gestures/demonstration (one time each day).
- **Initial registration phase:** Volunteer needs to tell where the medicine and the water dispenser is.
Registration of medicine bottle: The medicine bottle (for heart attack) is showed to robot in the first day, allow to do registration of the medicine bottle (30 seconds short video recording) by robot.
- **Initial setup phase:** A volunteer mimic the situation of heart attack, and robot gets the message explicitly from command line command or user interface (no need to do detection of the heart attack event).
- **Learning phase:** Volunteer will teach robot one time each day on how to use the water dispenser (The same as in the above electronic device task). Active recording and exploration are allowed, i.e., robot can actively collect data, and can try to practice for up to 10 minutes each day.
- **Learning opportunities:** Robot should take advantage of all chances to maximize learning, such as active perception, physical manipulation of the objects etc.
- **Limited help from users:** Robot can ask the two volunteers to help occasionally (e.g., asking them to demonstrate a sub step, or ask them to give hints/corrections), but the maximum number of such interaction should be no more than 3 times each day. No other help from human is allowed beyond this.
 - **Testing phase:** Testing will be conducted at the end of each day. In this test robot needs to get the water and medicine for 4 times (each time medicine bottle will be moved to different places as the initial registration place).
- **Scoring:** The score will be graded based on task completeness and timeliness. Detailed scoring standard is as below. Final score will be the score in the last day's testing. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).

Scoring table	Score	Notes
Task completeness	0, 4, 6, 10	10: All tests completed successfully 6: More than 50% completed successfully

		4: Less than 50% completed 0: None completed
Timely	0, 10	10: timeliness; 0: Late
Penalty	-1	Mistakes including dropping the medicine bottle/water cup, pouring of water will each get one point penalty

4.2.6 Feeding a person

- **Testing goals:** Robot needs to learn how to feed a person. Robot can be trained by volunteer from verbal instructions/gestures/demonstration (3 times each day, also robot can ask for help for 3 times).
- Initial setup phase: A manikin will be set up in the room.
- Testing process: Robot learns to 1). find the location of food and then 2). use a tool (e.g., a spoon or a fork) to fetch the food, and then 3). send fetched food to the manikin's mouth for feeding with the tool.
- Testing equipment: A manikin (those typically used in health care domain) will be used, and on the mouth some sensors will be put there to get the force/touch, too much force will be penalized for testing score.
 - Initial registration phase: N/A
 - Learning phase: Volunteer will teach robot 3 times each day on how to feed a person (from verbal instructions/gestures/demonstration, a video example will be provided.). Active recording and exploration are allowed, i.e., robot can actively collect data, and can try to practice for up to 10 minutes each day.
- **Learning opportunities:** Robot should take advantage of all chances to maximize learning, such as active perception, physical manipulation of the objects etc.
- **Limited help from users:** Robot can ask the two volunteers to help occasionally (e.g., asking them to demonstrate a sub step, or ask them to give hints/corrections), but the maximum number of such interaction should be no more than 3 times each day. No other help from human is allowed beyond this.
 - Testing phase: Testing will be conducted at the end of each day. In this test robot needs to feed the manikin for 4 times (each feeding action is one time).
- Scoring: The score will be graded based on task completeness. Detailed scoring standard is as below. Final score will be the score in the last day's testing. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).
 - In addition, there is a subjective evaluation score, used to assess the advancement of the technology used by the team, as well as technical breakthroughs in the direction of autonomous continuous learning of robots. The subjective score accounts for 30% of the final total score.

Scoring table	Score	Notes
Task completeness (cover all the 3 steps defined in the testing process)	0, 4, 6, 10	10: All tests completed successfully 6: More than 50% completed successfully 4: Less than 50% completed 0: None completed
Penalty	-1	Mistakes including too much force on mouth (force measurement>?), too deep in the mouth. (>3cm? Tactile sensor
		in the mouth of the manikin) will each get one point penalty

Notes: Possibly some prior knowledge needs to be ready for robot to do this task. Also some can be learned in the testing period.

4.2.7 Integrated task of cooking and table cleaning

- **Testing goals:** This is an integrated task which combined some of the tasks from the above testing, the tasks include below steps: get the raw food material (already chopped and mixed) from the refrigerator, open it and put on cooking machine to cook, get the cooked food and put on table, fruit garnishing, clean the table after the meal (garbage pick up/collection, put plates into dishwasher)
 - Initial setup phase: As needed for each sub task as described above (4.2.1-4.2.6).
 - Initial registration phase: As needed for each sub task as described above (4.2.1-4.2.6).
 - Learning phase: As needed for each sub task as described above (4.2.1-4.2.6).
 - Testing phase: Testing will be conducted at the end of each day. In this test robot needs to do the whole testing one time.
- **Scoring:** The score will be graded based on task completeness. Detailed scoring standard is as below. Final score will be the score in the last day's testing. The testing scores for the other days are for reference purpose (for analyzing the improvement of each robot's learning process).

Scoring table	Score	Notes
Task completeness	0, 4, 6, 10	10: All sub-tasks completed successfully 6: More than 50% sub-tasks completed successfully 4: Less than 50% sub-tasks completed 0: No sub-tasks completed
Penalty	-1	Damage of each thing will get one point penalty

5. Testing process and use of distributed testing facility

The testing will have two stages, first stage and annual final competition. Teams needs to first participate in first stage testing. Then top ranked teams will be selected to participated in annual final competition (site TBD yet, possibly one city in China like Shanghai. And we will see how to arrange for teams not be able to come on site, possibly still through remote testing.).

For first stage testing each team are encouraged to use local simplified testing facility (as described in section 3.6) or nearby local full testing facilities (see the website for confirmed local testing facilities in some cities).

For teams who don't have access to nearby local testing facilities and not able to set up local simplified testing facility, we will try to arrange remote testing facilities (volunteers on remote testing facility can help on site operation and testing). Note that it will depend on the schedule availability of remote local testing facilities who can provide such help.

Note that in section 3 the lab set up is for a full testing facility (i.e., it can test all the tasks), for teams who just need to do one or a few of the tasks (especially for some of the manipulation learning tasks, much less space is needed), we encourage these teams to set up simplified testing facility locally (details also in section 3.6).

Each team is responsible to choose testing dates when they are ready. For teams who participate in first stage testing, we will arrange judges to watch your testing and give the score remotely. See the website for requirements for remote video connection requirements. Pls contact liehang.shi@intel.com or shining1.yu@intel.com for arrangements of your first stage testing 2-4 weeks before your chosen testing dates.

Appendix

Object list

78 object instances in 21 categories are defined in our list with 68 rigid and 10 non-rigid instances. For the rigid instances, we divide them into small, middle and big size object groups. The objects will be put in the cabinet/shelf/TV table/desk with a pre-defined location.

Non-rigid objects:

- Hat x 2:
 - https://www.amazon.com/Andongnywell-Camouflage-Baseball-Military-Adjustable/dp/B082PQ3MDM/ref=sr_1_6?dchild=1&keywords=hat&qid=1620355820&sr=8-6
 - https://www.amazon.com/Wa-Rainbow-Stripe-Summer-Beachwear/dp/B07C5NJFZS/ref=sr_1_7?dchild=1&keywords=hat&qid=1620355856&sr=8-7
- T-shirt x 2:
 - https://www.amazon.com/aihihe-Womens-Patricks-Buffalo-Tops/dp/B083PR3PN8/ref=sr_1_46?dchild=1&keywords=t-shirt&qid=1620355882&sr=8-46&th=1
 - https://www.amazon.com/Christmas-T-Shirt-Buffalo-Graphic-Comfortable/dp/B08HN352W2/ref=a9vs-vusim-pr-dp-v3m1-desktop-t2_1?pd_rd_w=XJyWJ&pf_rd_p=040e5612-0c06-40b5-af85-019ddbeed8f1&pf_rd_r=730ZY3D4HAGAGMDGMW27&pd_rd_r=f0b2e57e-3294-4078-a5df-b46b592bb89d&pd_rd_wg=UWKxb&pd_rd_i=B08HN352W2&psc=1
- Mask x 2
 - https://www.amazon.com/KN95-Face-Mask-Disposable-Efficiency%E2%89%A595/dp/B08NPSFTLR/ref=sr_1_1_sspa?dchild=1&keywords=m

[ask&qid=1620355978&sr=8-1-](#)

[spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFRSVpEODgwSjRFTjMmZW5jcnlwdGVkSWQ9QTA4MDkwODMyNUFHOFI3N1M4VU4yJmVuY3J5cHRIZEFkSWQ9QTA0MDY5MjhRVzdCSzIZSEc0V0gmd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl](#)

- https://www.amazon.com/Disposable-Effective-Filtration-Earloops-Outdoors/dp/B08HMDH2YD/ref=sr_1_5?dchild=1&keywords=mask&qid=1620355994&sr=8-5

- bag x 2

- https://www.amazon.com/Travel-Duffel-Sports-Shoulder-pink8/dp/B07YS438FV/ref=sr_1_1?dchild=1&keywords=bag&qid=1620357065&s=specialty-aps&sr=1-1
- https://www.amazon.com/PUMA-Womens-Evercat-Dispatch-Duffel/dp/B072KHYWXQ/ref=sr_1_4?dchild=1&keywords=bag&qid=1620357092&s=specialty-aps&sr=1-4

- towel x 2

- https://www.amazon.com/Simpli-Magic-79335-Kitchen-Towels-Inches/dp/B08R6DMKDX/ref=gbps_img_m-9_475e_408b2102?smid=ATVPDKIKX0DER&pf_rd_p=5d86def2-ec10-4364-9008-8fbccf30475e&pf_rd_s=merchandised-search-9&pf_rd_t=101&pf_rd_i=15529609011&pf_rd_m=ATVPDKIKX0DER&pf_rd_r=C73FBF3AB7SM8H3WAJB4

Rigid objects small:

- Pen x 2

- https://www.amazon.com/RollerBall-Shuttle-Art-Writing-Journaling/dp/B086W87QLB/ref=sr_1_1_sspa?dchild=1&keywords=pen&qid=1620356124&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExQlAxVFRQOVFYTFkmZW5jcnlwdGVkSWQ9QTA5NjUzMzcyROJUOV0aUDVTSks3JmVuY3J5cHRIZEFkSWQ9QTAyNjEzMzQxNUplVIA5SU0yN0JNjndpZGldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWNOJmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
- https://www.amazon.com/BIC-Gel-ocity-Original-Retractable-15-Count/dp/B004F9QBDW/ref=sr_1_2_sspa?dchild=1&keywords=pen&qid=1620356139&sr=8-2-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExNDI1WlVlKlVlVFRQOVFYTFkmZW5jcnlwdGVkSWQ9QTA5NjUzMzcyROJUOV0aUDVTSks3JmVuY3J5cHRIZEFkSWQ9QTAyNjEzMzQxNUplVIA5SU0yN0JNjndpZGldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWNOJmRvTm90TG9nQ2xpY2s9dHJ1ZQ==

- Glasses x 2

- https://www.amazon.com/OLIEYE-Blue-Light-Blocking-Glasses/dp/B08MTKJKRM/ref=sxin_10_trfob_4?cv_ct_cx=glasses&dchild=1&keywords=glasses&pd_rd_i=B08MTKJKRM&pd_rd_r=49bb30f2-cc9e-48a0-a7a7-39e2766383d9&pd_rd_w=1npKm&pd_rd_wg=8TPI6&pf_rd_p=6c6f0ed1-2306-4f6f-

- https://www.amazon.com/Ephiu-Polarized-Sunglasses-Protection-Glasses/dp/B08QZYNFY9/ref=sr_1_1_sspa?dchild=1&keywords=sun+glasses&qid=1620356215&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEwNjZVQUVNrk85VUIHJmVuY3J5cHRlZEIkPUeWNjYqOTY2MlpHMkxSVUJUSFM0VCZlbmNyeXB0ZWRBZEIkPUeWNYzMTc1MzNIU1IySzcycVzlwRSZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNRpXRydWU=

- https://www.amazon.com/Leadsail-Wireless-Computer-Portable-Cordless/dp/B082HMHV366/ref=sr_1_1_sspa?dchild=1&keywords=mouse&qid=1620356232&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExSDI5R0oyWjMzMFFKJmVuY3J5cHRlZElkPUeWmQwODgyRFBYITIA3SDBNNFkmZW5jcnlwdGVkQWRJZD1BMDAYNTc2MjJlEU1E5WVlONVNHSdYmd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl
- https://www.amazon.com/VicTsing-Wireless-Portable-Receiver-Adjustable/dp/B013WC0P2A/ref=sr_1_5?dchild=1&keywords=mouse&qid=1620356244&sr=8-5

- https://www.amazon.com/Dessert-AOOSY-Stainless-Kitchen-Restaurant/dp/B08PCFP26B/ref=sr_1_35?dchild=1&keywords=spoon&qid=1620356263&sr=8-35
- https://www.amazon.com/Lekai-Stainless-Steel-Spoon-Coffee/dp/B08ZHTX7VQ/ref=sr_1_56_sspa?dchild=1&keywords=spoon&qid=1620356320&sr=8-56-spons&psc=1&spLa=ZW5jcmlwdGVkUXVhbGlmaWVyPUEzR1VSQ0tJOURPUVgyJmVuY3J5cHRlZElkPUeWNUdyMTY0M1RHRINZT1FRWINSSyZlbnNyeXB0ZWRBZEIkPUeWNTE2OTY4T0ZRQU80UUdURklWJndpZGldE5hbWU9c3BfYnRmJmFjdGlvbj1jbGlja1JlZGlyZWNOJmRvTm90TG9nQ2xpY2s9dHJlZQ==

- https://www.amazon.com/Kyraton-Dinner-Pieces-Stainless-Silverware/dp/B086RMQH23/ref=sr_1_7?dchild=1&keywords=fork&qid=1620356361&sr=8-7
- https://www.amazon.com/Dinner-Pieces-Homquen-Stainless-Dishwasher/dp/B08L9B5HDW/ref=sxin_9_trfob_5?cv_ct_cx=fork&dchild=1&keywords=fork&pd_rd_i=B08L9B5HDW&pd_rd_r=c8684234-d4d3-4f05-8626-3ca4583a5c4d&pd_rd_w=F8pC3&pd_rd_wg=tGSzH&pf_rd_p=6c6f0ed1-2306-4f6f-832e-d796b7d41a25&pf_rd_r=NPA4Q402BMQW27E2HVQ5&qid=1620356379&sr=1-4-fcc74f9e-0165-48d2-a9e1-f41ea92a035c

desktop&dchild=1&keywords=snacks&linkCode=oas&pd_rd_i=B00EUTM3TS&pd_rd_r=d9b035c8-0f40-47ba-9418-cf101fd3f05d&pd_rd_w=DEUyt&pd_rd_wg=IOaos&pf_rd_p=9ca0c43d-5b2f-4d08-be2c-4bf20950d3e4&pf_rd_r=248X2S8SMW6GWQ0KWQ6T&qid=1620356585&sr=1-1-c26ac7f6-b43f-4741-a772-17cad7536576&tag=cinemablend06-20

- Bowl x2
 - https://www.amazon.com/Unbreakable-Cereal-Bowls-Lightweight-Dishwasher/dp/B07YWHTV2D/ref=sr_1_4?dchild=1&keywords=bowl&qid=1620356607&sr=8-4
- Book x 20
 - https://www.amazon.com/dp/0399226907/ref=s9_acsd_ri_bw_c2_x_0_i?pf_rd_m=ATVPDKIKX0DER&pf_rd_s=merchandise-search-12&pf_rd_r=94Y43V8YAWFP6DD1NWDH&pf_rd_t=101&pf_rd_p=912614e3-2b52-463a-bdbb-07c9749935a7&pf_rd_i=283155
 - https://www.amazon.com/dp/0805047905/ref=s9_acsd_ri_bw_c2_x_2_i?pf_rd_m=ATVPDKIKX0DER&pf_rd_s=merchandise-search-12&pf_rd_r=94Y43V8YAWFP6DD1NWDH&pf_rd_t=101&pf_rd_p=912614e3-2b52-463a-bdbb-07c9749935a7&pf_rd_i=283155

Rigid objects big:

- Toy x 2
 - https://www.amazon.com/JESONN-Stuffed-Animals-Lizard-Plush/dp/B01D699XV8/ref=sr_1_10?dchild=1&keywords=stuffed+toy&qid=1620356707&s=books&sr=1-10
 - https://www.amazon.com/JESONN-Realistic-Stuffed-Animals-Beagle/dp/B01DDUNW1C/ref=sr_1_19?dchild=1&keywords=stuffed+toy&qid=1620356731&s=books&sr=1-19
- Keyboard x 2
 - https://www.amazon.com/Wireless-Keyboards-Leadsail-Ultra-Thin-Computer/dp/B08GC19BQD/ref=sr_1_1_sspa?dchild=1&keywords=wireless+keyboards&qid=1620356797&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEySTJVU05SQzhRQU5XJmVuY3J5cHRlZElkPUEwNjgyODA5MUNJSDk5M0tCOERYWSZlbnNyeXB0ZWRBZEIkPUEwNjlxNjgwMkw2OFJPU0w3TE5KUyZ3aWRnZXROYW1IPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=
 - https://www.amazon.com/Wireless-RATEL-Ultra-Thin-Ergonomic-Chromebook/dp/B08QCXMBF3/ref=sxin_9_pa_sp_search_thematic_sspa?cv_ct_cx=wireless+keyboard&dchild=1&keywords=wireless+keyboard&pd_rd_i=B08QCXMBF3&pd_rd_r=746f2ed4-e0d2-4210-a5bc-dc20711fef55&pd_rd_w=dvYoo&pd_rd_wg=2GbTv&pf_rd_p=bdaff03e-e2e6-4d0a-96ed-05f1bace8b61&pf_rd_r=95WAXBEOXW9TZ3D9CPZ&qid=1620356808&sr=1-1-a8004193-6951-43f6-852a-aff7dbba9115-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyUTZEWDUXTIA3WkRSJmVuY3J5cHRlZElkPUEwNzY5MzkzMTRQNk5WU1pKRUs2MyZlbnNyeXB0ZWRBZEIkPUE=

wOTMwMjY4Mjc2TFpOMzVDTDBVMSZ3aWRnZXROYW1IPXNwX3NIYXJjaF90aGVtYX
RpYyZyY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=

- Lamp x 2
 - https://www.amazon.com/HOKEKI-Bedside-Useful-Charger-Bedroom/dp/B08GKRB43V/ref=sr_1_8?dchild=1&keywords=lamp&qid=1620356832&sr=8-8
 - https://www.amazon.com/Wireless-Charging-Lighting-Brightness-Eye-Caring/dp/B08D8FT8CY/ref=sr_1_1_sspa?dchild=1&keywords=lamp&qid=1620356856&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFHOEdCUjU2SkdKU1QmZW5jcnlwdGVkSWQ9QTAyNDIxNzQ4NzFLOVNLU1UyODcmZW5jcnlwdGVkQWRJZD1BMDUyODA2NjI4STJCQzhBODc4S1lmd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl
- Vase x 2
 - https://www.amazon.com/Classics-Finisher-Ceramic-Flowers-Science/dp/B08KWNQYRP/ref=sr_1_9?dchild=1&keywords=vase&qid=1620356895&sr=8-9
 - https://www.amazon.com/Fantastic-Ryan-Modern-Irised-Crystal/dp/B07XP56HBS/ref=sr_1_18?dchild=1&keywords=vase&qid=1620356895&sr=8-18
- Waste can
 - https://www.amazon.com/Desktop-Wastebasket-Plastic-Countertop-Bathroom/dp/B08YYGN913/ref=sr_1_3?dchild=1&keywords=desktop+waste+can+big&qid=1620357624&sr=8-3
 - https://www.amazon.com/Freedi-Creative-Desktop-Storage-Office/dp/B07FMS4JRD/ref=sr_1_11?dchild=1&keywords=desktop%2Bwaste%2Bcan%2Bbig&qid=1620357684&sr=8-11&th=1