NFR Specification for Robots in Robocup @ Home

RULEBOOK: https://github.com/RoboCupAtHome/RuleBook/releases/tag/2024.1

Competition tasks: STAGE I

Environment

1. **RoboCup@Home Arena**
   The RoboCup@HomeArena is a realistic home setting (an apartment) with interconnected rooms. The minimal configuration consists of:
   • a bedroom • a dining room • a living room • a kitchen

INPUT: Speech recognition
Gesture

TASKS

1. Carry My Luggage

Primary goal: The robot helps the operator carry a bag to a car parked outside

Optional Goal(s): Re-entering the arena
Following the queue on the way back to the arena

Procedure

1. **Picking up the bag:** The robot picks up the bag pointed at by the operator.

   Components involved: Robot arm/gripper
   Camera

Quality Attribute(s): Picking the correct bag
Gripper adjustment/pressure according to bag
Position of holding bag should not hinder robot operations

Robot Constraints: -Bag is within payload capacity of robot arm/gripper
-Camera can resolve objects well enough for identification
-Able to perceive depth i.e distance to bag for precise grasping
-Able to perceive correctly pointing gesture to identify bag
-Arm/gripper must move accurately and smoothly to avoid collisions and ensure a stable grasp

Operational Constraints: Operator and bag are within range of camera

2. **Following the operator:**

Components involved: Camera
LIDAR

Quality Attribute(s): Keeping track of the operator
Holding the bag

Robot Constraints: Camera can resolve objects well enough for identification
Able to establish arrival at final location by prompting the operator
Adjusting its trajectory to maintain a safe distance and avoid obstacles
Feedback to operator (Optional)

Operational Constraints: The operator is within range of camera

3. **Obstacles:**

Components involved: Camera
LIDAR

Quality Attribute(s): Avoid crowds on the path [penalty]
Avoid small objects [penalty]

Avoid hard-to-see objects [penalty]
Avoid barrier-blocked areas. [penalty]

Robot Constraints: The camera can resolve objects well enough for identification

LIDAR range is enough for obstacle detection

Operational Constraints: Disruptive obstacles other than those defined are not present

4. **Optional goals:**
    a. **Re-entering the arena:**
    b. **Following the queue:**

Components involved: Camera, LIDAR

Quality Attribute(s): Identify the last human in the queue
Get in queue

Robot Constraints: The camera can resolve person well enough for labeling

Able to localize itself outside arena

Operational Constraints: Door to arena is accessible

2. Receptionist

Primary Goal: Introduce and usher two newcomers to a party and maintain appropriate gaze direction

(at person, direction of navigation).

Optional Goal(s): Open the entrance door for each arriving guest.
Describe the first guest for the second guest.

SETUP:

Location: **Living room**

The robot starts inside the Arena at a predefined location

Entrance: The entrance door is open by default. The team leader can request to close the door to score

additional points by opening it for the guests.

People: **Host:** The host's name and favorite drink will be announced before the test. The host is already sitting in the living room

Guests: Both guests have a name and favorite drink. An arriving guest will either step in front of the robot or ring the bell or knock on the door if the door is closed. Guests have to be guided to the living room to be introduced. Each of the guest will arrive separately. The sound of the bell will be provided to teams during setup period before competition (if not using door knocking).

Procedure

1. **Introductions**: When introducing guests, the robot must clearly identify the person being introduced and state their name and favorite drink. Introducing two people means to introduce them to each other.

   Components involved: Camera, Robot Arm/gripper/head

   Quality Attribute(s): Accurate person identification, gesture/addressing
   Correct person details retrieval
   Accurate recording of the person's details

   Robot Constraints: Correct information save/retrieval for each person after identification
   Information recording window enough to capture all details of person identified

   Operational Constraints: Noise should be within acceptable threshold for recording details from audio input

2. **Seating People:** The robot must point at a place or location where the guest can sit.
   Switching Places: Guests may switch places after they were seated.
   Describing the First Guest: Naming 4 characteristics of the first guest, i.e., color of clothes, color of hair, gender, and age, earns bonus points.

   Components involved: Camera, Robot Arm/gripper/head

Quality Attribute(s): Identification of sitting place and free space
Identification of first guest features. [BONUS]

Robot Constraints: Robot should be able to correctly identify furniture for seating
Robot should be able to identify free seating space
Robot should be able to correctly indicate free seating space
Robot should be able to capture person's characteristics from their appearance [BONUS]
Able to avoid collision while pointing

Operational Constraints: Seating space for all guests should be available
Ambient lighting should be good enough for feature recognition from camera feedback [BONUS]
Factors external to the arena should not influence recognition

3. **Looking at person/direction of navigation:**
- During verbal interactions and descriptions of people, robot looks at the conversational partner.
- Robot can point at the person being introduced/described or alternate gaze between two people.
- During navigation the robot looks in the direction where it is going.
- Persistently gazing towards unrelated person or incorrect direction while moving during the task deducts points.

Components involved: Camera, Robot Arm/gripper/head

Quality Attribute(s): Maintaining gaze towards addressee during conversation
Maintaining gaze in the direction of movement
Sudden movement should be avoided

Robot Constraints: Correct identification of person to address
Gaze response is synchronized with verbal response

Operational Constraints: Person to address within discoverable range of robot

3. Serve Breakfast

Primary Goal: Place breakfast items on a table (bowl, spoon, cereal box, and milk carton) and prepare cereal.

Optional Goal(s): Pour milk into the bowl
Place the spoon next to the bowl

SETUP:

Location: - Start location: Before the test, the robot waits outside the Arena and navigates to the kitchen when the door is open.
- Test location: Kitchen.

People: - None expect human assistance, if required.

Furniture: - Table: The robot serves breakfast on the table which is announced beforehand.
- Chairs: Chairs may be placed around the table and won't be removed.
- Doors: The robot does not need to open any doors to find the breakfast items

Objects: - All objects used in the test are in their predefined locations when the test starts.

Procedure:

1. **Table selection:** At least two hours before the test, the referees announce the surface that will be used as a table.

   Components involved: N/A
   Quality Attribute(s): Robot can register the surface as a table
   Robot Constraints: N/A
   Operational Constraints: N/A

2. **Test start:** The robot moves to the kitchen when the arena door is open.

Components involved: LIDAR, Camera
Quality Attribute(s): Recognition of door opening
Recognition of kitchen area
Robot Constraints: –
Operational Constraints: –

3. **Serving breakfast:** To serve breakfast, the robot has to place breakfast items on a table (bowl, spoon, cereal box, and milk carton).

Components involved: Camera, arm/gripper

Quality Attribute(s): Adaptability to item types
Identification of breakfast items correctly
Picking and placing items gently

Robot Constraints: Arm/gripper is suitable to hold required items
Grab and place accuracy is maintained throughout the actions

Operational Constraints: Ability to grab and place is unhindered by items
Enough space is available on table to place all required items

4. **Pouring cereal:** After placing the breakfast items on the table, the robot should pour cereal into the bowl.

Components involved: Camera, Arm/gripper

Quality Attribute(s): Grab cereal container with good grip and orientation
Pour without spilling outside bowl [PENALTY]

Robot Constraints: Able to grab cereal box with enough degrees of freedom to get into pouring orientation
Able to align cereal box with bowl
Able to detect when the bowl is full
Grasp pressure of carton adjusted to not hinder pouring action

Operational Constraints: Cereal box and bowl size are appropriate to be handled by robot

Cereal box has enough cereal

5. **Optional Goals:**
    a. **Pouring milk:** After pouring cereal, the robot pours milk into the bowl to fully prepare the breakfast
    b. **Placing the spoon next to the bowl**

Components involved: Camera, Arm/gripper

Quality Attribute(s): Grab milk container properly
Pour without spilling outside bowl
Identify bowl position to place the spoon next to

Robot Constraints: Grasp pressure adjusted to hold liquid container/carton
Grab and place accuracy is maintained throughout the actions

Able to gauge amount of milk to be poured

Operational Constraints: Carton has enough milk

4. Storing Groceries

Primary Goal: Move five objects from a table to the cabinet, grouping them by category or similarity

Optional Goal(s): Opening the cabinet door
Moving a tiny object
Moving a heavy object

SETUP:

Locations: - Start location: Before the test, the robot waits outside the Arena and navigates to the testing area
when the door is open
- Test location: The testing area has a cabinet and a table nearby.

People: None expect for human assistance, if required

Furniture: - Table: The table has 5–10 objects placed on it and the robot can choose which ones to grasp and in what

order. On small tables, objects will be added as the robot frees up space.

- Cabinet: The cabinet contains objects arranged in groups either by category or likeliness on different shelves
- Cabinet door: The cabinet door is open by default, but the team leader can request the door to be closed and score additional points for opening it. If the robot fails to open the door, it must clearly state this and request the referee to open it.

Objects:
- Table objects: The object on the table are arranged arbitrarily.
- Cabinet objects: Some of the objects are placed behind the cabinet door and cannot be accessed unless the door is open.

Procedure:

1. **Table location:** At least two hours before the test, the referees announce the table and cabinet that will be used in the test, as well as a rough location of the table

Components involved: N/A
Quality Attribute(s): N/A
Robot Constraints: N/A
Operational Constraints: N/A

2. **Cabinet door; heavy and/or tiny object:**
The team informs the referees:
- whether the cabinet door should be closed
- whether a heavy and/or a tiny object should be used in the test

Components involved: N/A
Quality Attribute(s): N/A
Robot Constraints: N/A
Operational Constraints: N/A

3. **Test start:** The robot moves to the testing area when the arena door opens.

Components involved: Camera, LIDAR
Quality Attribute(s): Identification of testing area
Robot Constraints: N/A
Operational Constraints: N/A

4. **Storing groceries:** After identifying the table (and optionally opening the cabinet door), the robot moves the objects from the
table to the cabinet

Components involved: Camera, Arm.gripper

Quality Attribute(s): Proper placement of items in cabinet
Correct categorization of items
Placing similar items together
Adaptability to item types
Picking and placing items gently

Robot Constraints: Gripper/arm able to reach and/or align to table and proper cabinet shelf
Identify cabinet shelf and free space to put items
Recongnize likeliness of item types to determine placement position
Recognize when all items have been placed

Operational Constraints: Ability to grab and place is unhindered by items
Enough space is available on the cabinet to place all required item

STAGE II

TASKS

1. Clean the Table

Primary goal: All tableware and cutlery on the table is placed inside the dishwasher (five objects in total)

Optional goal(s): Opening the dishwasher door
Pulling out the dishwasher rack
Placing the items in the dishwasher correctly

Placing a dishwasher tab inside the dishwasher

SETUP:

Location: Test location : Kitchen

People: None expect for human assistance, if required

Furniture: - Dining table: A dining table is located close to the dishwasher.
- Tray: A plastic tray, which may have other tableware and cutlery placed inside, is located either on top of the dishwasher or on one of the racks. Objects can be placed either in the dishwasher rack or in the tray, based on the team's choice.

Objects: - Table setting: The table has a total of five objects disposed of in a typical setting for a meal for one person. Silverware: Any two objects (fork, knife, or spoon).
Tableware: Any three objects (except silverware), at least one of which is a dish.
- Dishwasher tab: The tab can be found at a location that is announced before the test and should be autonomously placed inside the tab slot in the dishwasher

Procedure:

1. **Dishwasher door and rack**
   - whether objects will be placed in the dishwasher rack or in the tray
   - whether the dishwasher door should be closed and, if the door is open, whether the rack should be pushed In

Components involved: N/A
Quality Attribute(s): N/A
Robot Constraints: N/A
Operational Constraints: N/A

2. **Test start:** The robot moves to the kitchen when the arena door is open.

Components involved: Camera, LIDAR
Quality Attribute(s): Identification of kitchen area
Recognition of door opening
Robot Constraints: N/A
Operational Constraints: N/A

3. **Table clean up:** The robot cleans the table by putting all items that are on it in the dishwasher.

Components involved:	Camera, Arm/gripper
Quality Attribute(s):	Correct placement position of items in dishwasher Gentle placement of tableware
Robot Constraints:	Grab items with good grip and orientation Holding on to item properly until placed Pulling/pushing tray within safe limit
Operational Constraints:	Size and weight of items

2. Restaurant

Primary goal: Detect calling or waving customers, reach a customer's table without prior guidance/training. Take and serve all orders

Optional Goal(s): Use an unattached tray to transport the order.

Setup:

Location: - This task takes place in a real restaurant fully equipped and in business. When this is not possible, the test can be conducted in any place with the appropriate locations other than the Arena.

- The robot starts next to the Kitchen-bar. It is a table located near the restaurant's kitchen.

People: - A member of the TC awaits at the other side of the Kitchen bar for orders to be placed. The Professional Barman (member) assists the robot on request.
- There may be real customers and waiters around.
- There are at least three tables occupied with professional customers (members of the OC/TC).
- There are at least two tables occupied with regular customers.

- Customers may call the robot any time, even simultaneously.

Furniture: The furniture is not standardized

Objects: - Objects to fulfill orders are located on the Kitchen-bar.
- Orders have two or three objects randomly chosen.
- All edible/drinkable objects from the list of standard objects are eligible to be part of the orders.

Procedure:

1. The referee requests the team to move the robot to the start location.

Components involved: LIDAR, Camera
Quality Attribute(s): Start location is properly identified
Robot Constraints: Navigation path to starting waypoint can be established
Operational Constraints: Starting waypoint is within mapped area

2. The referee gives the start signal and starts the timer.

Components involved: N/A
Quality Attribute(s): N/A
Robot Constraints: N/A
Operational Constraints: N/A

3. The team leaves the area after the start signal.

Components involved: N/A
Quality Attribute(s): N/A
Robot Constraints: N/A
Operational Constraints: N/A

4. A TC member follows the robot ready to press the emergency stop button.

Components involved: N/A
Quality Attribute(s): N/A
Robot Constraints: N/A
Operational Constraints: N/A

5. The robot detect calling or waving customer and reach a customer's table.

Components involved: Camera, LIDAR

Quality Attribute(s): Identify calling and waving motion
Establish navigation to the correct table
Clear communication with the customer/barman regarding order placement
Maintain gaze with customer during communication

Robot Constraints: Able to identify waving and calling gestures from a person
Able to isolate multiple instances of same gestures from different person
Able to associate multiple gestures from a person as coming from a single person
Able to associate table with customer gesturing
Able to localize the identified customer/table for taking order
Able to resolve simultaneous calling from customers in different tables
Immediately stops all motion upon encountering *dangerous situations*

Operational Constraints: Tables and customers are within identifiable range
Gesture from customer is well defined
Customer does not change table after gesturing

6. The robot take the customer's order, place the order, and deliver it.

Components involved: Camera, LIDAR, arm/gripper, Microphone

Quality Attribute(s): Order items are correctly recognized
Politely refuse order items outside of edible/drinkable objects from list of standard objects
Placing of order should correspond to correct table

Robot Constraints: Take order from all customers in a table upon reaching (optional)
Put order items on the customer table (Optional)
Correctly indicate to barman the orders from customers/table

Does not touch anything outside of order items and tray

Immediately stops all motion upon encountering *dangerous situation*

//Associate order to customer/table even when viewed from a different side

Operational Constraints: Tables and customers are within identifiable range
Customer does not change table after gesturing
Ambient noise level low enough for clear registration of orders [person's voice lvl]

7. Optional goal: The robot can use an unattached tray to transport the order.

Components involved: Arm/gripper

3. Stickler for the Rules

Primary Goal: Identify party guests breaking the house rules, politely clarify to the guest what to do

and confirm that the guest is following the rule.

Optional Goal: Politely clarify to the guest what rule is being broken.

Setup

Locations:
- This task takes place inside the Arena.
- The robot starts at a predefined location in the living room.
- There is a forbidden room in the house.

People:
- There are at least five party guests inside the Arena.
- Four of the guests are breaking the rules.
- Guests may not follow the robot's instructions.

Furniture: All furniture are in their predefined locations

Objects: All objects are in their predefined locations

Procedure

1. **The referee requests the team to move the robot to the start location.**

   Components involved: LIDAR, Camera
   Quality Attribute(s): Start location is properly identified
   Robot Constraints: Navigation path to starting waypoint can be established
   Operational Constraints: Starting waypoint is within mapped area

2. **The referee gives the start signal and starts the timer.**

   Components involved: N/A
   Quality Attribute(s): N/A
   Robot Constraints: N/A
   Operational Constraints N/A

3. **The team leaves the area after the start signal.**

   Components involved: N/A
   Quality Attribute(s): N/A
   Robot Constraints: N/A
   Operational Constraints N/A

4. **A TC member follows the robot ready to press the emergency stop button.**

   Components involved: N/A
   Quality Attribute(s): N/A
   Robot Constraints: N/A
   Operational Constraints N/A

5. **The robot Identify party guests breaking the house rules.**

   Components involved: LIDAR, Camera

   Quality Attribute(s): Precision in the identification of rules being broken

   Robot Constraints: Able to track and identify guest activities accurately
   Able to match activity with ruleset and identify deviations
   Stay at a distance far enough to have the guest, and surroundings in the same frame

   Operational Constraints Ruleset is provided in advance
   Guests are within the operational area

6. **The robot politely clarify to the guest what to do.**

   Components involved: Communication means (speaker/ gesture)
   Quality Attribute(s): Clear communication of issue and resolution
   Robot Constraints: Able to associate rule violation with the correct guest
   Operational Constraints

7. **The robot confirm that the guest is following the rule.**

   Components involved: Communication means (speaker, gesture)
   Quality Attribute(s): Precision in the identification of resolution
   Robot Constraints: Able to track and identify guest activities accurately
   Able to match activity with ruleset and identify conformation
   Operational Constraints The guests is cooperative with the robot requests

8. **Optional Goal:** Politely, the robot clarifies to the guest what rule is being broken