2^{nd} Edition

Emirates Robotics Competition (Sustainability Theme)

February 14, 2024

1 Introduction

Robotics has been identified as one of the key technologies that will have a transformative impact in various new markets and on diverse human social aspects. Modern robotic systems are being deployed to tackle multiple application domains such as disaster response, hospitality, healthcare, domestic tasks, transportation, space exploration, manufacturing, and construction. However, there is still a gap between the current state of robotic capabilities and the requirements that must be met to enable practical and impactful robotic deployments in the envisioned applications.

As the world faces increasing environmental challenges, the need for innovative and sustainable solutions has never been more critical. This edition of the Emirates Robotics Competition will focus on Environmental Cleaning and will serve as a platform for showcasing cutting-edge advancements in robotics and their potential to make a positive impact on the environment. By focusing on environmental initiatives specifically tailored to the unique challenges faced by the UAE, this competition encourages teams to devise creative solutions that contribute to a cleaner and more sustainable future.

This competition brings together talented teams from across the region, united by a common goal: harnessing the power of robotics to address the pressing issue of environmental cleaning. Robotic technologies must be developed using a human-centric approach to allow these robots to operate autonomously in dynamic, unstructured environments while collaborating and interacting with other robots and humans. We aim to focus on some of these enabling technologies by providing a demanding set of benchmark robotics challenges. This robotics competition aims to inspire undergraduate students from local universities to work on tackling robotic challenges relevant to modern societal and industrial problems.

2 Objectives

The objectives of this competition are the following:

- Challenge undergraduate students from local universities with relevant robotic problems.
- Encourage more students to advance their practical knowledge in robotics, science, engineering and closely related disciplines.
- Improve students' practical and critical thinking skills by allowing them to apply the theories they learned in real-world challenges.
- Contributing to solving environmental issues by developing systems and solutions that could tackle challenges derived from real-world environmental problems.

3 Challenge 1: Recycling Robot

In a world grappling with the mounting challenges of waste management and environmental sustainability, developing a robot with a manipulator arm capable of sorting rubbish into recycling bins can be highly desirable. As our communities continue to generate an overwhelming volume of waste, finding efficient and effective ways to divert recyclable materials becomes imperative. A robot equipped with an intelligent and dexterous arm capable of swiftly identifying and sorting different types of waste presents a game-changing solution. By automating the sorting process, this robotic arm enhances the accuracy and speed of waste segregation and alleviates the burden on human resources. Recycling and sorting rubbish is dull, dirty, tiring, and repetitive. Many of such tasks primarily involve physical interaction with objects and the environment. Grasping and manipulation are critical functional capabilities that enable a robot to achieve a physical interactive task. Robotic systems utilize robotic arms to perform valuable tasks such as pick and place, soft robotic gripping, packing, etc. These robots can be deployed to perform rubbish collection and sorting, which could revolutionize the handling and recycling of rubbish.

3.1 Objectives

In this challenge, competitors will use a manipulator arm to autonomously perform the pick-and-place of static objects. This challenge aims to develop a pick-and-place manipulation robotic system capable of picking objects (simulating typical household rubbish) of different sizes, shapes, and weights from a table and sorting them into bins. The objects will be cluttered but spaced out and not overlapping. The objects are classified as follows:

- Paper: cardboard boxes, cartons, boxes, etc.
- Glass: drink bottles, jars, etc.
- Plastic: plastic water bottles, toys, etc.
- Metal: cans, tools, etc.

No item will exceed 0.5 kg in weight.

3.2 Setup

3.2.1 Manipulator

A manipulator arm will be placed between two tables. There is no constraint on the number of degrees of freedom of the manipulator. Once the judge has indicated the start of the trial, the competing team has 10 minutes to complete the sorting task.

3.2.2 Table

Two tables will be provided for this challenge. One table will be to place the objects on top, and one for the sorting bins. The robot must be situated between the two tables. See Figure 1. Teams can bring their table/stand for their robot, or use the generic table provided by the organizers.

The table dimensions can be found here.

3.2.3 Bins

Four bins will be placed on the second table. The bins will be placed in a location similar to what is shown in Figure 2. The order of the bins may change. The bins' information can be found here.

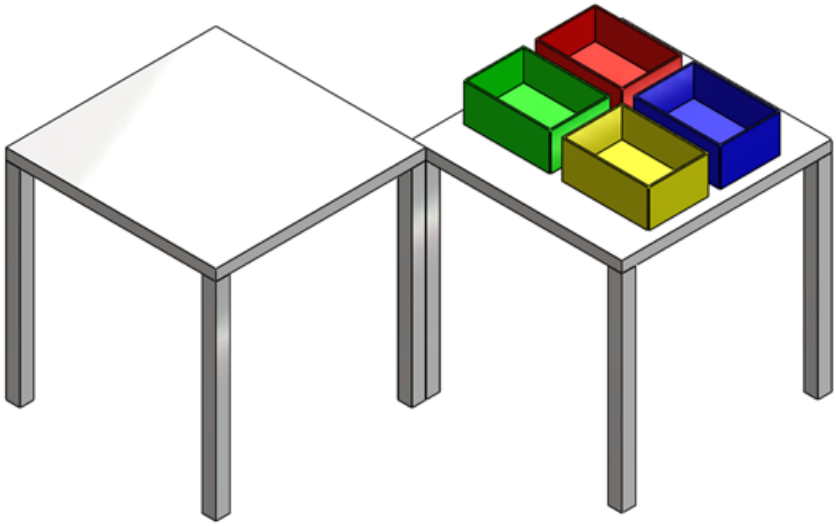

Figure 1: Side view of tables arrangement.

3.2.4 Objects

On top of the object's table will be a selection of 16 items (4 from each waste category). Sample objects can be seen in Figure 3.

3.2.5 Perception

The perception sensor(s) (e.g., cameras, lidars, etc.) used for object detection may be mounted on the robot or placed on the robot's table. No additional sensors or hardware can be placed outside the robot's table footprint.

3.2.6 Grasping

Any gripper may be used (default grippers or custom-built grippers). Any gripping method may be used (fingers, suction, etc.).

3.2.7 Manipulation

The manipulator has to successfully grasp objects using the gripper, lift the object and move it towards the designated bin without colliding with other objects, and finally drop it in the bin.

3.3 Trial Run Specifications

The following steps and instructions will be followed during each run (this could be updated closer to the competition date):

- Each team will be given 10 minutes to finish the challenge run.

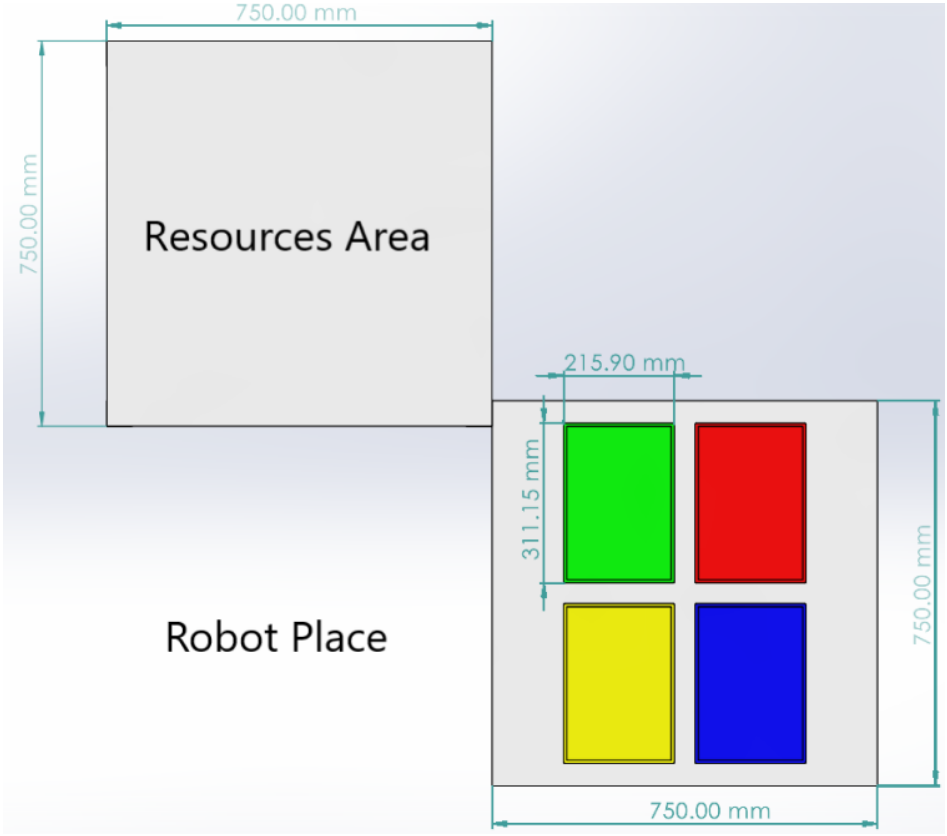

Figure 2: Tables top view.

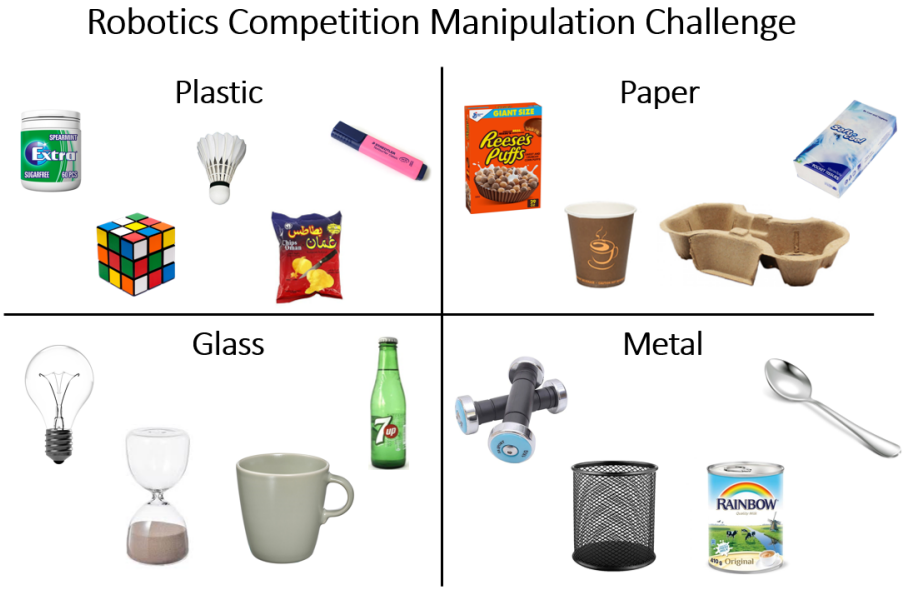

Figure 3: Sample objects for manipulation.

- After the judge gives the starting signal, the team can press the start button or run the code.
- During the trial run, the team cannot manually or remotely interfere with any system components (e.g., P.C., gripper, manipulator, joystick, or software).
- If any interference in the robotic system is detected, the judge will be forced to cancel the run, and the team will lose any points accumulated during this run.
- During the challenge run, a team can request a reset. The reset allows the team to adjust their setup and ask the judge to start the run again. Each reset will be subject to a penalty as specified in the scoring Table **??**, and the time will continue during a reset.
- During each run, the team will have to detect the objects on the table, select an item they would like to manipulate, pick it using their manipulator's arm, and place it inside the bin corresponding to the category of the object on the side of the table.

3.4 Scoring Criteria

The scoring criteria defined in Table 1 will be used during this challenge.

Behaviour	**Points**
Successfully grasping and picking up objects	+2
Successful placing/dropping objects in correct bin category	+2
Damaging object (e.g., crushing the bag of chips)	-1

Collision with table	-1
Collision with other objects	-0.5
Each challenge reset (max three resets allowed)	-1

Table 1: Challenge 1 Scoring Criteria

Competitors will participate in two rounds during the competition. The highest score obtained by each competitor from these two rounds will be considered for determining the final ranking. In case of tie scores between two or more competitors, the fastest time will be used as a tiebreaker.

4 Challenge 2: Rubbish Collecting Mobile Robot

In our ever-expanding urban landscapes, the challenge of efficient waste management looms larger than ever. Developing a mobile robot capable of autonomous navigation and rubbish collection has emerged as a crucial innovation to tackle this pressing issue. With urban areas experiencing exponential population growth and an ever-increasing volume of waste generation, traditional waste collection methods are often insufficient and inefficient. However, a mobile robot with autonomous driving capabilities presents a groundbreaking solution. These autonomous robots can collect and transport rubbish by seamlessly manoeuvring, alleviating human resource burdens and streamlining waste management processes. Beyond its practical benefits, implementing such a mobile robot demonstrates our commitment to embracing cutting-edge technology for sustainable urban development. By leveraging automation, artificial intelligence, and robotics, we can revolutionize waste collection practices and move closer to creating clean, liveable cities that prioritize environmental preservation and enhance the quality of life.

4.1 Objectives

The primary objective of the rubbish collection challenge is to promote and showcase advancements in robotic technologies and autonomous systems related to efficient and effective rubbish collection in real-world scenarios. The challenge aims to foster innovation and problem-solving skills among participants while addressing the pressing global issue of waste management and environmental sustainability. In this challenge, competitors are required to achieve the following objectives:

- design and develop an autonomous mobile robot capable of navigating through a designated arena that simulates a real-world scenario for rubbish collection.
- collect multiple rubbish items of different sizes, shapes, and materials using a customized mechanism.
- dispose of the collected rubbish items in specific disposing points in a controlled manner to avoid spillage or damage.
- showcase innovative designs and algorithms for autonomous navigation and efficient rubbish collection.

4.2 Setup

The challenge arena is an open area containing various types of rubbish items and obstacles, surrounded by border barriers. The goal is to simulate a real-world scenario, such as a park, where the robot can efficiently collect rubbish items in a complex and confined space, as shown in Figure 4.

4.2.1 Challenge Environment

The arena constitutes a rectangular space measuring 10 meters by 8 meters, enclosed by border barriers constructed from durable materials like plastic, cardboard, or plywood, capable of withstanding the robot's movements. The arena's flooring is composed of concrete material.

4.2.2 Rubbish Items

Multiple rubbish items will be strategically placed throughout the arena to simulate real-world scenarios and challenges. The rubbish items will vary in shape, size, material, and weight to test the capabilities of the participants' robots and rubbish collection mechanisms. Rubbish items will be included as listed below and shown in Figure 5:

- Paper: newspaper, cartons, boxes, etc.

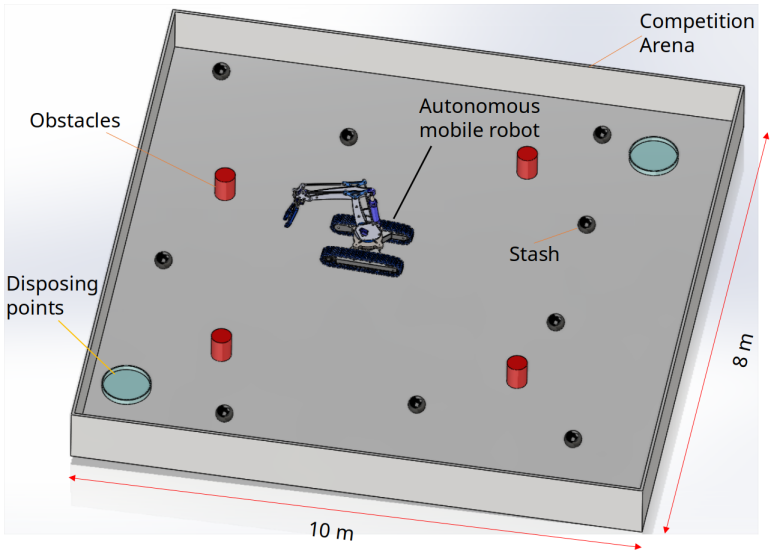

Figure 4: Challenge 2 Navigation Arena

- Glass: drink bottles, jars, etc.
- Plastic: plastic water bottles, toys, etc.
- Metal: cans, tools, etc.

To add variability and ensure fairness, the rubbish items will be placed in different locations within the arena, including areas near the border. The placement of the different items will be randomized for each round of the competition to ensure unpredictability and prevent reliance on memorization.

Figure 5: Sample of Rubbish Items

Figure 6: Disposal Rubbish Bin

4.2.3 Obstacles

In the autonomous navigation arena simulating a park environment, participants can expect to encounter various challenging obstacles that mimic real-world scenarios. These obstacles may include dense clusters of plants, cones, benches, and picnic tables. Participants must demonstrate their robot's ability to navigate safely and efficiently through this diverse and dynamic park environment.

4.2.4 Rubbish Disposal Bins

The robot should deposit the collected rubbish items at designated areas within the arena. Two open rubbish bins, each with a height of 50 cm, will be placed at diagonally opposite corners of the arena, as illustrated in 4. Visible signage that marks the rubbish bins helps the robot identify and accurately deposit the rubbish, as shown in Figure 6.

4.3 Trial Run Specifications

The following steps and instructions will be followed during each run (this could be updated closer to the competition date):

- Each team will have a 10-minute time limit to complete their challenge run.
- The robot should be positioned within the designated start zone defined in the navigation arena.
- Once the judge initiates the start signal, the team can activate their robot by pressing the start button or running the preloaded code.
- During the trial run, no manual or remote interference with any system components (e.g. PC, controller, joystick, or software) is allowed.
- Any detected interference will lead to the immediate cancellation of the run, resulting in the forfeiture of any accumulated points during that attempt.

- Teams participating in the challenge run can request a reset if needed.
- This reset permits teams to adjust their setup and request the judge to restart the run. However, each reset will incur a penalty, as outlined in the scoring Table 2, and the timer will continue to run during the reset period.
- Each team can request a maximum of three resets; exceeding this limit will eliminate the team from the challenge run.
- In each run, the team's task is to identify the rubbish items within the arena, choose an item for collection, employ the robot's grasping mechanism to retrieve it, and then deposit it into one of the bins positioned in the arena's corners.
- To avoid incurring penalties, the robot should avoid collisions with both obstacles and the arena's border, as specified in Table 2.

4.4 Scoring Criteria

The scoring criteria defined in Table 2 will be used during this challenge.

Behaviour	**Points**
Successfully picking up objects	+2
Successful placing/dropping objects in disposal point	+2
Collision with border	-1
Collision with obstacles	-0.5
Challenge reset (max three resets allowed)	-1

Table 2: Challenge 2 Scoring Criteria

Competitors will participate in two runs during the competition. The highest score obtained by each competitor from these two runs will be considered for determining the final ranking. In case of tie scores between two or more competitors, the fastest time will be used as a tiebreaker.

5 Challenge 3: Water Cleaning Surface Robot

In an era where the health of our planet's water bodies is increasingly threatened, developing advanced robotics capable of swimming and cleaning the water surface has become an urgent necessity. Water pollution, caused by the accumulation of debris, plastic waste, and other pollutants, poses significant risks to aquatic ecosystems, wildlife, and human health. As we stand at the forefront of innovation, we must harness the potential of robotics to combat this pressing issue. A robot capable of navigating water surfaces with agility and efficiency, equipped to detect and collect rubbish, holds immense promise in mitigating the harmful consequences of water pollution. Such a robotic solution offers a practical and scalable approach to cleaning vast water surfaces and will contribute to the efforts of preserving the delicate balance of aquatic ecosystems and securing a sustainable future for generations to come.

5.1 Objectives

The primary objective of the competition is to design and develop an autonomous Unmanned Surface Vehicle (USV) capable of efficiently collecting rubbish floating on the surface of an indoor pool. The competition aims to foster innovation and advancements in autonomous navigation, rubbish detection, and collection technologies. The specific objectives are as follows:

- Autonomous Navigation: USVs should navigate the pool autonomously, avoiding obstacles and efficiently reaching rubbish collection points.
- Rubbish Detection: USVs should be equipped with sensors and algorithms to detect and identify rubbish objects accurately.
- Rubbish Collection: USVs should be capable of collecting rubbish objects effectively, using appropriate mechanisms or tools.
- Efficiency: The competition evaluates the speed and efficiency of the USVs in completing the assigned tasks.

5.2 Setup

The competition will take place in a controlled indoor pool environment with a designated area. The pool dimensions and layout are shown in Figure 7 and Figure 8. The setup includes the following components:

- Pool Area: A section of the indoor pool is cordoned off for the competition, ensuring sufficient space for the USVs to navigate and collect trash. The dimensions of the pool are (12m x 8m x2.1 m)
- Trash Objects: Plastic balls with a 6.5 cm diameter in various colours will be used to symbolize different types of trash objects. Each colour will carry its unique score when collected, as detailed in the Scoring Criteria section.
- Ball placement: The balls will be randomly scattered on the water surface.
- Collection Site: two corners will be designated as the collection site. Plastic balls must be dropped into the net to gain points.
- Starting and Endpoint: Designated starting and endpoint locations are marked for each USV to begin and finish the assigned task.
- Obstacles: the walls of the pool are considered obstacles, and colliding with them will incur penalties.

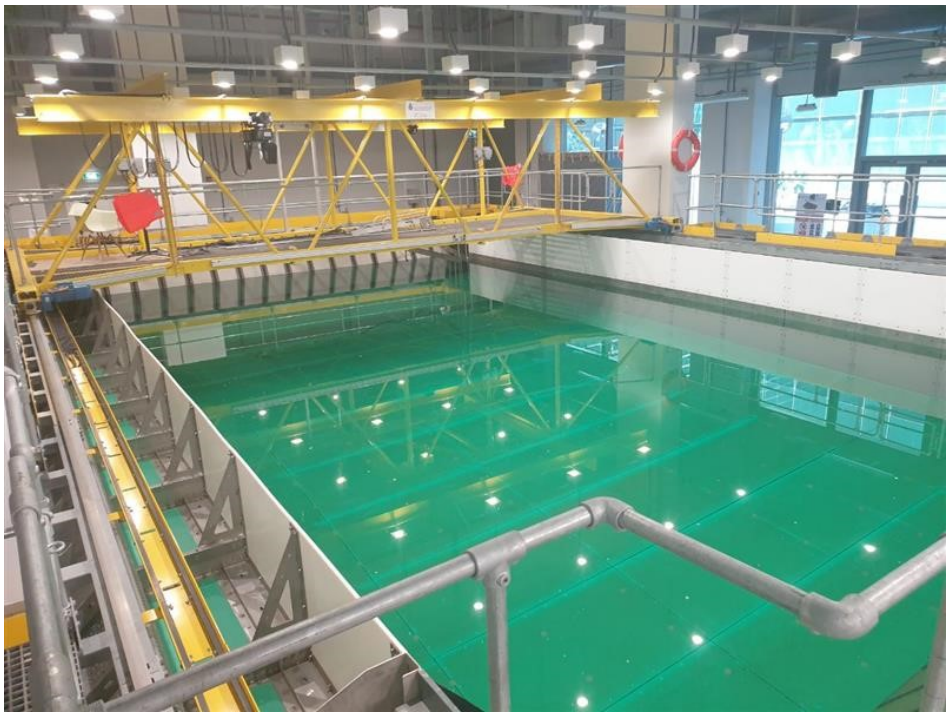

Figure 7: Khalifa University Indoor Research Pool

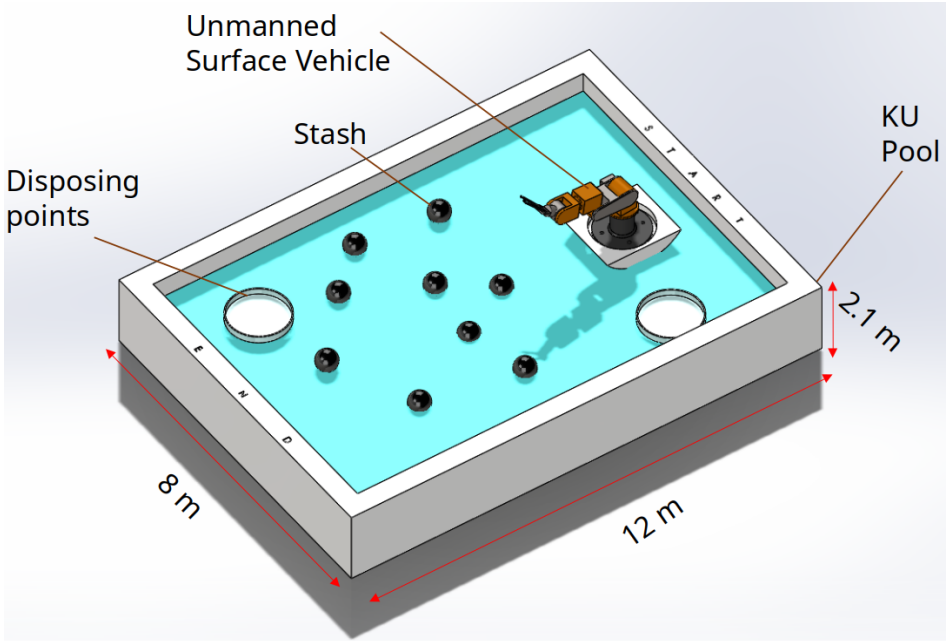

Figure 8: Layout of Challenge 3 Pool

5.3 USV Specifications

The USVs participating in the competition should adhere to the following specifications,

- **Weight**: The weight of the USV should not exceed *10 kg*.
- Size: The maximum allowable dimensions should not exceed *80cm x80cm x40cm*. If a manipulator arm is installed on the USV, it will not be included in the robot's overall dimensions.
- **Kill Switch**: The USV must have a remote kill switch that, when actuated, must disconnect power from motors.
- **Autonomous Capability**: The USV must be capable of autonomous navigation, trash detection, and trash collection. It should operate without any remote control or human intervention during the competition.
- **Power Source**: The USV should have a self-contained power source
- **Safety**: The USV should not have any possible loose part that may fall in the water, which may damage the pool filtration system.

5.4 Trial Run Specifications

The following steps and instructions will be followed during each run (this could be updated closer to the competition date):

- Each team will have a 10-minute time limit to complete their challenge run.
- The robot should be positioned within the designated start zone defined in the pool with the assistance of designated staff.
- Once the judge initiates the start signal, the team can activate their USV by pressing the start button or running the preloaded code.
- It's important to note that during the trial run, no manual or remote interference with any system components (e.g. PC, controller, joystick, or software) is allowed.
- Any detected interference will lead to the immediate cancellation of the run, resulting in the forfeiture of any accumulated points during that attempt.
- Teams participating in the challenge run have the option to request a reset if needed. This reset permits teams to adjust their setup and request the judge to restart the run. However, each reset will incur a penalty, as outlined in the scoring Table 3, and the timer will continue to run during the reset period.
- Each team can request a maximum of three resets; exceeding this limit will eliminate the team from the challenge run.
- A remote-controlled boat will retrieve the contestant's USV if it cannot return to the start area.
- In each run, the team's task is to identify the rubbish items within the arena, choose an item for collection, employ the robot's grasping mechanism to retrieve it, and then deposit it into one of the collection nets positioned in the arena's corners.
- To avoid incurring penalties, the robot should avoid collisions with pool walls, as specified in Table 3.

5.5 Scoring Criteria

The scoring criteria defined in Table 3 will be used during this challenge.

Behaviour	**Points**
Green ball collection	+3 points
Yellow ball collection	+2 points
Blue ball collection	+1 point
Red ball collection	-1 point
Collision with pool walls	-0.5 points

Table 3: Challenge 3 Scoring Criteria

In case of tie scores, the highest scoring teams will have to redo the trash collecting task but with activated water currents from the KU pool. In case of another tie, the fastest team that had finished the task in on one of the rounds will be the winner of this challenge.

6 Application Process

Teams interested in participating in this competition should follow the requirements below.

Requirements

- Registering teams must consist of 3-6 members.
- At least half the team members should be from a local UAE-based university.
- Members must be enrolled in a bachelor's degree at the university.
- Teams must be supervised by a faculty member from the same university.

Application Form Information

- Team members with their field of study and their CVs
- Proposed team name
- The faculty member supervising the team
- University affiliation(s)
- List any previous experience with building robotic systems
- List any previous experience in participating in competitions
- List of robotic systems the team intends to use, or if the team will build their own

7 Prizes

The total prize money for the challenges will be AED 90K, distributed as shown in Table 4. Please note that all prizes are in AED currency.

Challenge	**1st Place**	**2nd Place**	**3rd Place**
Recycling Manipulator Robot	15K	10K	5K
Rubbish Collecting Mobile Robot	15K	10K	5K
Water Cleaning Swimming Robot	15K	10K	5K

Table 4: Prize money distribution

Additionally, winners will be provided scholarships from RIT for master's degrees. This competition encourages collaboration and open innovation. As such, a condition for accepting the prize money is that winning teams should open-source and document their code and designs on an online platform (e.g., github, gitlab etc.) and provide access to anyone to replicate these systems and build on them.

8 Organizing Entities

The competition is organized and sponsored by:

- Khalifa University (KU)
- Rochester Institute of Technology (RIT)
- Dubai Future Labs (DFL)

9 Document History

Version	**Date**	**Authors**	**Comments**
1.0	18/11/2023	Organizing Committee	Initial draft of the competition