IEEE Region 10 Robotics Competition 2022

Robotics for Healthcare

Robotics for Healthcare

Automated Robotic Mechanism for the COVID-19 Human Sample Collection

Competition Project# 3: For Postgraduates & Young Professionals

This page is intentionally blank

Table of Content

IEEE Region 10 Robotics Competition 2022

Project 3: for Post Graduate Students & Young Professionals

Automated Robotic Mechanism for the COVID-19 Human Sample Collection

1. Introduction

Doctors and Healthcare workers are at the frontline in the fight against COVID-19. Their responsibilities include conducting swab tests and medical care, which exposes them to infection despite wearing protective gear. The project aims to minimize the human intervention on sample collection by using robots.

The competition aims to:

- Create opportunities for learning by applying classroom lessons to build a robot,
- Stimulate thought process for innovative ideas, and
- Develop abilities to study a problem, conduct background research and solve the problem using technology.

In addition to stimulating technical ingenuity to solve the problem, the competition also aims to:

- Promote teamwork – Participants will need to understand team dynamics and learn how to optimize team members' abilities to achieve project goals.
- Develop leadership skills – (a) Ability to set goals and effectively communicate plans and strategies to the team members, (b) ability to listen to alternate views and make timely decisions.
- Develop project management skills – Participants are required to apply project management principles to (a) identify project goals, (b) prepare a work breakdown structure (WBS) with realistic timelines, (c) determine key milestones leading to the completion of the project, (d) manage limited resources to resolve technical difficulties without causing delays and significantly increase in project cost.
- Sound Engineering Practice – Documentation and recording keeping for (a) robot design features, (b) ability to trace back the technical errors if any, (c) foundation for future developments, and (d) proof of originality and ownership of the work.

2. Eligibility Criteria

Project# 3 of the R10 Robotics Competition is open to:

(a) IEEE Graduate Student members who are currently a registered graduate student in a regular course of study in IEEE-designated fields and

(b) IEEE Young Professional (YP) grade member graduated not more than 5 years ago.

All contestants in the competition must belong to one of the IEEE Sections in R10. Anyone who joins the IEEE as member of any grade after the start of the R10 Robotics Competition will not be accepted as an IEEE member for the competition in 2022.

Contestant(s) can be an individual or a team as explained below:

- Individual (must be an active IEEE Graduate Student member or a YP member). An individual will be considered as a one-member team.

- Team-based. The number of team members is limited to a maximum of 6 members for this project. Majority of team members must be IEEE Graduate Student members and/or Young Professional grade members. For example, in a 3 or 4-member team a maximum of one non-IEEE member can be in the team. The team can NOT have an equal number of IEEE members and non-members.
- Teams must not include any IEEE Associate member, full member, or higher grade member. However, a senior volunteer in the Section or from the industry can act as an advisor for the team. An advisor must not carry out the tasks related to building the robot or coding the algorithms. It is not necessary for the Advisor to be an IEEE member.
- Teams must not include any member from outside the Region 10.
- To qualify as a WIE team, the majority of team members must be female IEEE Graduate Student or YP members and not just the majority of female members. The team can NOT have an equal or more number of males than female members.
- Non-IEEE members in the team will not be eligible for a cash prize. However, they can receive a certificate of participation.

3. Competition Outline

This competition will be organized in three stages.

Stage 1 will be arranged locally by the IEEE Sections with an overall guideline from R10. For this project a maximum of two teams from each Section will be selected from Stage 1 to compete in Stage 2. R10 will issue general guidelines for judging the teams, but Sections will be allowed to use their selection process and criteria to nominate team(s) to represent the Section at Stage 2.

Stage 2 will be held online and organized by R10. At Stage 2, the competing team will build the physical prototype of the robot. They will create a video presentation of the robot to demonstrate its functionality.

Stage 3 (Final stage) – At Stage 3, teams will be required to demonstrate the full functionality of the robot against a human nostril model provided by R10 competition organizers. Stage 3 competition is planned to be a physical gathering subject to COVID-19 restrictions and financial viability. If the physical gathering is not possible for any reason, then the final stage will be held online.

For Stage 2 & 3, R10 will specify the assessment rubrics to evaluate the performance of the robots as well as the team performance in meeting the competition aims. The broad judging criteria for each stage are given below. At each stage, entries will be judged for the technical content, innovation, practical implementation, and potential for further development into a marketable product.

4. General Rules

1. The robots should be built from scratch and must not use commercially available robots to enter the competition.
2. Robots must not have any sharp edges or corners and spiky parts that can cause injury to anyone.
3. For Stages 2 and 3, participants must upload all documentation through a portal by the closing dates announced by R10.

4. The competition will be conducted in English, i.e., all submissions, including project documentation must be in English. However teams will be allowed to arrange the services of a translator to answer judges' questions at all three stages of the competition.
5. The deadlines for each stage will be posted on the R10 Robotics Competition website. Contestants are required to check and ensure meeting the deadlines.
6. The judges' decision will be final in all three stages, and no appeal against the judges' decision will be entertained.
7. R10 Director can cancel the competition if the participation rate is very low or for any other reason deemed by the R10 Director as valid for the cancellation.

5. Problem Description and Objectives

The direct involvement of humans in the COVID-19 sample collection poses a health risk to the sample collectors due to the chance of them getting infected by the virus. This is a problem that needs to be addressed with the help of robotics and automation.

Therefore, this competition aims to design and build a fully autonomous robot with appropriate sensory feedback to collect swab samples from human nostrils for the COVID-19 test. The human nostrils can be modeled using two mini tubes, as shown in Fig.1. The robot should be able to automatically adjust its path to accommodate the natural variation of the human nostril position and orientation, as described in Fig. 1. The robot is expected to be fixed with the base. Once the sample is taken, the sample stick should be put into a test tube (which has a barcode attached to it containing patient information) as located in a pre-defined position. Therefore the robot movement can be considered as a point-to-point movement where the first point (point to take a sample) can be varied for different people. The robot should be tested in three different postures.

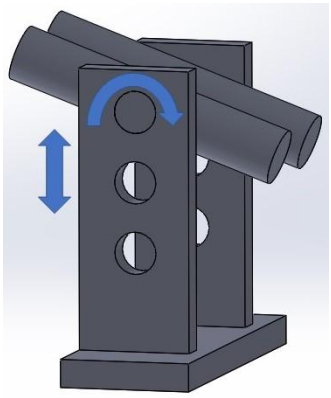

Figure 1: The concept of the human nostril model with the ability of the height and angular orientation variation.

5.1 General Robot Specifications

1. The robot should be desktop and portable.
2. The maximum number of degrees of freedom is four.
3. Maximum payload capacity 1Kg.
4. The weight of the robot should not exceed 5Kg.
5. Implementable to any standard facility without major modification.

6. The total material cost for the project must not exceed US$ 750. This figure does not include the labor cost.

5.2 Stage 1

Participants are required to start the work on the problem given in section 5 above. At Stage 1 participants are expected to study the problem and validate the robot design concepts digitally.

5.2.1 General Objective: Stage 1

The general objective of stage one is to develop a complete virtual prototype of the swab collector robotic system. At this stage, the robot should be designed using any CAD software from scratch. The design should meet the general specifications in section 5.1 above.

5.2.2 Specific Objectives for Stage 1

- Conduct background research for robot design and safety requirements,
- Contemplate design features for optimum functioning of the robot,
- Comprehensive consideration of all the components, coding, and subtasks for building the robot,
- Develop digital CAD model for proof of concept and to test algorithms,
- Estimate cost for implementation in hardware,
- Project documentation,
- Achieve TRL 3 – 4 (See Appendix I).

5.2.3 Restrictions & Requirements

- The participants cannot use predeveloped CAD models from websites like GrabCAD etc.
- Rough sketches and notes will NOT be accepted as proper engineering notes/report. Participants must do proper documentation of robot design features modeled components with interconnections and codes written.

5.2.4 Judging Criteria for Stage 1

- Assumptions made for the CAD model
- Validation & verifications methods adopted for acceptance of the CAD model
- Working functions of the model
- Ability to respond to dynamically changing operation environment
- Estimated weight and volume if implemented in hardware
- Estimated cost required for building the system – must be within limit specified under General Robot Specifications in section 5.1 above.

5.3 Stage 2

5.3.1 General Objective: Stage 2

(a) Development of a functional prototype of an autonomous robot for sample collection for COVID-19 test from human nostrils (as described in Fig. 1) with minimum or no operator intervention,

(b) Determine safety requirements and incorporate safety features in the robot and

(c) Determine risk factors for the project and develop strategies to mitigate or manage risks.

5.3.2 Specific Objectives for Stage 2

- **Learning Objectives**
  - Decomposition of problem and development of a comprehensive plan to build the robot. The plan must identify key milestones with timelines and potential project risks.
  - Application of project management principles and teamwork
  - Documentation
- **Technical Objectives**
  - Review design features for optimum functioning of the robot,
  - Development of hardware and algorithms,
  - Testing and acceptance procedures in the lab environment.
  - Record test results
  - Achieve TRL 4 (Appendix I)

5.3.3 Restrictions

- The participants cannot use hardware developed for another project or use a commercially available robot for the competition.
- Robots must operate autonomously and must not be operated via any remote control system.
- Rough sketches and notes will NOT be accepted as proper engineering note/report. Participants must do proper documentation of robot design features with components interconnections and codes written.

5.3.4 Submission Requirement

For Stage 2 assessments, teams will be required to submit:

(1) A submission form with team details and endorsed by the Section Chair or by someone authorized to endorse on behalf of the Section Chair.

(2) A video presentation no longer than 6-minute in mp4 format, showing the performance of the Robot with explanation of key innovative feature incorporated into the robot design. Any video more than 6 minutes long may result in disqualification of the team.

(3) Project Engineering Notebook (pdf file) showing work breakdown structure with timelines and team members responsible for the task, project completion time and budget.

(4) A plan for further development of the robot to meet Stage 3 requirements. An estimated budget with a cost breakdown must be included in the plan. Teams who do not submit this plan may not qualify for R10 funding.

5.3.5 Judging Criteria for Stage 2

At Stage 2, the judging will be based on (a) project video presentation (b) quality of documentation, and answers to questions asked by the judging panel. The broad judging criteria for Stage 2 may include (The detailed rubrics for this stage is attached as Appendix II):

1. Video (Clarity and quality of video, quality of technical content, and factual and technical accuracy),
2. The originality of the research process and solution to meet the stated objectives,
3. Evidence of thought process for developing the project plans, identification of potential risks, and risk mitigation strategies (from submitted documents),
4. Design innovation,
5. Safety features,
6. Testing accuracy and
7. Quality of documentation (Design details, software code, and testing procedures with results).

5.4 Stage 3

5.4.1 General Objective: Stage 3

Enhance Stage 2 prototype to build a more functional autonomous robot for:

(1) Sample collection for COVID-19 test from human nostrils model (developed by IEEE R10) with minimum or no operator intervention,

(2) Validation of the safety features of the robot,

(3) Conduct acceptance testing in a lab operational setup,

(4) Robot to contest in Stage 3 against the standard testbed (developed by IEEE R10)

5.4.2 Specific Objectives for Stage 3

- **Learning Objectives**
  - How to identify and mitigate technical risks
  - Setting testing procedures and conducting acceptance tests
  - Application of project management principles and teamwork
  - Documentation
- **Technical Objectives**
  - Robot enhancements from prototype to a more functional robot with safety features;
  - Development of hardware and algorithms;
  - Testing and acceptance procedures in a lab operational environment;
  - Report test results and

- Achieve TRL 5 and show the potential to achieve TRL 6 and above. (Appendix I).

5.4.3 Restrictions

- The participants cannot use hardware developed for another project or use a commercially available robot for the competition.
- The robot must operate autonomously and must not be operated via any wireless communication, i.e., wi-fi or Bluetooth connections must be only for software update and must be off during the robot's operation.
- Rough sketches and notes will NOT be accepted as proper engineering notes/reports. Instead, participants must properly document robot design features modeled components with interconnections and codes written.

5.4.4 Submission Requirement

For Stage 3 assessments, teams will be required to submit:

1. A 6-minute video presentation in mp4 format; any video more than 6 minutes long may result in disqualification of the team;
2. Project Engineering Notebook (pdf file) recording work breakdown and timelines with team members responsible for the task, and project completion time and budget;
3. A business plan detailing the development phases and cost for turning the prototype robot it into a marketable robot;
4. The draft of a paper ready for submission to a conference. A previously published paper will not be accepted;
5. Up to two team members will be required to physically attend the final round with the Robot to demonstrate its working. Robot performance will be assessed during competition rounds at a venue arranged by R10.

5.4.5 Judging Criteria for Stage 3

Following judging criteria will be used for the assessments of the submitted robot in Stage 3. (The detailed rubrics for this stage is attached as Appendix III) :

1. Safety of the patient and the operators and the equipment
2. Sample collection cycle time
3. Sample Collection accuracy
4. Evidence of project management practices applied in the project
5. Business value and commercialization potential
6. Teamwork
7. Presentation and Q&A session with the judging panel.

The above list is not exhaustive, and the judging panel may look into other factors if required, particularly when there is an issue of a tie between the multiple teams. The decision of the judges is final at every stage of the competition.

6. Prizes

The R10 Robotics Competition will offer an attractive prize scheme to encourage innovation and entrepreneurship, promote STEM and enhance IEEE visibility in the communities. Generally, the prize scheme will consist of:

Stage 1 Prizes: These will consist of certificates and maybe cash prizes depending on the sponsorship from the local industry and relevant government departments. Sections would also be encouraged to invite local school children to participate in the competition and offer them some prizes for encouragement and inspiring them to study STEM subjects.

Stage 2 Prizes: In Stage 2, the top teams will win the financial support to enhance their robots and improve their chances to be successful in the final stage (Stage 3) of the competition. Those not able to qualify for Stage 3 but demonstrate innovative/interesting ideas in Stage 2 will get a consolation prize.

Stage 3 Prizes: The prize scheme for Stage 3 will consist of

1. One Grand Prize of the competition
2. Prizes for the competition project:
    a. A cash prize for the first position and a certificate,
    b. A second position cash prize equivalent to 70% of the first cash prize plus certificate, and
    c. A third position prize equivalent to 50% of the first cash prize plus certificate.
3. There will be one special prize for IEEE Women-in-Engineering members for the encouragement of young women studying engineering-related courses or working in engineering professions. This is expected to inspire young females to study STEM courses.

It will be up to team members to decide how to split the cash prize among team members who are IEEE members. Cash prizes are not for non-IEEE members but they can receive participation certificates.

R10 Director can approve a different cash prize arrangement instead of above mentioned scheme. The prizes for 2022 will be announced on the R10 Robotics Competition website.

7. Important Dates

7.1 Important Dates for Contestants

R10 Robotics Competition Start Date: Monday, 07 March 2022

Stage 1

- **Teams' working period**: 7th March 2022 – Closing date fixed by the local IEEE Section, which should not be later than 15 May 2022.
- **No later than 30 May 2022**: Selection of Projects Team by the IEEE Section
- **Friday, 10th June 2022**: Deadline for IEEE Sections to inform R10 about the teams for Stage 2.

Stage 2

- **1st June 2022 – 31st July**: Teams' working period
- **30 June 2022**: Deadline for Teams Registrations with R10

- **05 August 2022**: Deadline to submit competition material to R10
- **21 & 22 August 2022**: R10 online Stage 2 Competition
- **28th August 2022**: Announcement of Stage 2 winners.

Stage 3

- **29th Aug – 16th Oct:** Teams working period
- **17 Oct 2022**: Deadline to submit competition material to R10
- **1st – 4th November 2022**: Two-day **R10 Level Competitions** (R10 will confirm the exact dates and venue on Sunday 22 August 2022 at Stage 2.

7.2 Important Dates for IEEE Sections

- **31 March 2022**: Deadline for submitting R10 Funding Proposal
- **15 April 2022**: R10 intimation of accepted proposals for funding
- **25 March – 30 July 2022**: Sections to organize local robotics activities
- **25 March 2022:** IEEE Section to announce a Stage 1 Closing Date, which should not be later than 15 May 2022
- **No later than 30 May 2022**: Selection of Teams by the IEEE Section for Stage 2
- **10 June 2022**: IEEE Sections to inform R10 about the teams for Stage 2
- **15 August 2022**: Section robotics activities report for payment of approved R10 funding.
- **30 October 2022**: Funds transferred by R10 to Sections

Appendix I

Technology Readiness Level Definitions	
TRL 1	**Basic Research**: Initial scientific research has been conducted. Principles are qualitatively postulated and observed. The focus is on new discoveries rather than applications.
TRL 2	**Applied Research**: Initial practical applications are identified. The potential of material or process to solve a problem, satisfy a need, or find application is confirmed.
TRL 3	**Critical Function or Proof of Concept Established**: Applied research advances and early-stage development begins. Studies and laboratory measurements validate analytical predictions of separate elements of the technology.
TRL 4	**Lab Testing/Validation of Alpha Prototype Component/Process**: Design, development, and lab testing components/processes. Results provide evidence that performance targets may be attainable based on projected or modeled systems.
TRL 5	**Laboratory Testing of Integrated/Semi-Integrated System**: System Component and/or process validation is achieved in an appropriate environment.
TRL 6	**Prototype System Verified**: System/process prototype demonstration in an operational environment (beta prototype system level).
TRL 7	**Integrated Pilot System Demonstrated**: System/process prototype demonstration in an operational environment (integrated pilot system level).
TRL 8	**System Incorporated in Commercial Design**: Actual system/process completed and qualified through test and demonstration (pre-commercial demonstration).
TRL 9	**System Proven and Ready for Full Commercial Deployment**: Actual system proven through successful operations in the operating environment, and ready for full commercial deployment.

Appendix II

Assessment Rubrics for Stage 2

Test against test rig developed in-house				
Safety of the patient and the operators and the equipment such as **excessive pressure on the nostrils should be detected, any moving object during the motion of the robot should be detected, and required limit switches for the robot should be available.** (30 points)	The robot has **at least three safety features** both in hardware and in software, and all are fully functional (22.5-30)	The robot has at least **two safety** features both in hardware and in software, and **not all are fully functional** (15-22.5)	The robot has only **one functional safety feature.** (7.5-15)	The robot does **not have any functional safety features.** (0-7.5)
Test against test rig developed in-house				
Sample collection cycle time (20 points)	The robot can perform the whole cycle of sample collection **within 2mins** (15-20)	The robot can perform the whole cycle of sample collection within **2 to 4 mins** (10-15)	The robot can perform the whole cycle of sample collection within **4 to 6 mins** (5-10)	The robot cannot perform the task **<6min** (0-5)
Test against test rig developed in-house				
Sample Collection accuracy (20 points)	The robot can perform the task smoothly and accurately with the variation of the nostrils height and angle **(at least can perform a successful test for 3 different positions and angles of the nostrils)** (15-20)	The robot can perform the with moderate accuracy with the variation of the nostrils height and angle **(at least can perform a successful test for 2 different positions and angles of the nostrils)** (10-15)	The robot can perform the with marginal accuracy with the variation of the nostrils height and angle **(at least can perform a successful test for 1 position and angle of the nostrils)** (5-10)	**The robot cannot perform the task either smoothly or accurately.** (0-5)
Design innovation (10 points)	The robot has a significant level of innovative design features **(at least 3**	The robot has a moderate level of innovative design features.	The robot has a marginal level of innovative design features.	The robot has no innovative design features. (0-2.5)

	features either in hardware or software design). (7.5-10)	**(at least 2 features either in hardware or software design).** (5-7.5)	**(at least 1 feature either in hardware or software design).** (2.5-5)	
Project presentation via recorded video (maximum 10 mins) (10 points)	Excellent description of the project including technical aspects, design methodology, innovative features. (7.5-10)	Moderate description of the project including technical aspects, design methodology, innovative features. (5-7.5)	A fair description of the project including technical aspects, design methodology, innovative features. (2.5-5)	Poor description of the project including technical aspects, design methodology, innovative features. (0-2.5)
Project documentation (10 points)	All the technical and project management related documents are well prepared. (7.5-10)	All the technical and project management related documents are moderately prepared. (5-7.5)	All the technical and project management related documents are marginally prepared. (2.5-5)	All the technical and project management related documents are poorly prepared. (0-2.5)

Appendix III

Assessment Rubrics for Stage 3 (110 points)

Test against the provided human nostrils model by IEEE R10				
Safety of the patient and the operators and the equipment such as **excessive pressure on the nostrils should be detected, any moving object during the motion of the robot should be detected, and required limit switches for the robot should be available.** (30 points)	The robot has **at least three safety features** both in hardware and in software, and all are fully functional (22.5-30)	The robot has at least **two safety** features both in hardware and in software, and **not all are fully functional** (15-22.5)	The robot has only **one functional safety feature.** (7.5-15)	The robot does **not have any functional safety features.** (0-7.5)
Test against the provided human nostrils model by IEEE R10				
Sample collection cycle time (20 points)	The robot can perform the whole cycle of sample collection **within 2mins** (15-20)	The robot can perform the whole cycle of sample collection within **2 to 4 mins** (10-15)	The robot can perform the whole cycle of sample collection within **4 to 6 mins** (5-10)	The robot cannot perform the task **<6min** (0-5)
Test against the provided human nostrils model by IEEE R10				
Sample Collection accuracy (20 points)	The robot can perform the task smoothly and accurately with the variation of the nostrils height and angle **(at least can perform a successful test for 3 different positions and angles of the nostrils)** (15-20)	The robot can perform the with moderate accuracy with the variation of the nostrils height and angle **(at least can perform a successful test for 2 different positions and angles of the nostrils)** (10-15)	The robot can perform the with marginal accuracy with the variation of the nostrils height and angle **(at least can perform a successful test for 1 position and angle of the nostrils)** (5-10)	**The robot cannot perform the task either smoothly or accurately.** (0-5)
Business value	Well articulated	Moderately	Marginally	Poorly articulated

and commercialization potential (10 points)	business value model and commercialization potential (7.5-10)	articulated business value model and commercialization potential (5-7.5)	articulated business value model and commercialization potential (2.5-5)	business value model and commercialization potential (0-2.5)
Project management (10 points)	Well-managed project **with the achievement of all the milestones in due time.** (7.5-10)	Moderately managed project **with partial readjustment of schedule of the milestones.** (5-7.5)	Marginally managed project **with one incomplete milestone.** (2.5-5)	Poorly managed project with **more than one incomplete milestone.** (0-2.5)
Project presentation (maximum 10 mins) (10 points)	Excellent description of the project, including technical aspects, design methodology, innovative features. With a successful QnA with the judges. (7.5-10)	Moderate description of the project, including technical aspects, design methodology, innovative features. With a moderate QnA with the judges. (5-7.5)	A fair description of the project, including technical aspects, design methodology, innovative features. With a fair QnA with the judges. (2.5-5)	Poor project description, including technical aspects, design methodology, innovative features. Poor QnA performance. (0-2.5)
Teamwork demonstration. (10 points)	Excellent team management with adequate participation from all the members. (7.5-10)	Moderate team management and not equivalent participation from all the members. (5-7.5)	Marginal team management. Unbalanced contribution from the members. (2.5-5)	Poor Team management. (0-2.5)