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1. General Information

1.1 Introduction

The GNSS Innovation Quest (GIQ) is an annual nation-wide engineering competition for students in Singapore. Using advanced satellite and robotics technologies, students build up interdisciplinary engineering skills by developing solutions that can improve the lives of fellow Singaporeans. GIQ caters to students of varying levels through its two differentiated categories, with a unifying theme of “Autonomous Systems for a Digital Singapore”.

Teams get scored based on their ability to design an Autonomous Mobile Robot (AMR) to tackle a series of challenges in a physical test environment and their ability to communicate their project through a report and presentation.

- The **Starter Category** is catered towards students looking to get a head start in the fields of Science, Technology, Engineering, Arts and Mathematics, and is suitable for participants (16 – 19 y/o) without any satellite or robotics background. This category takes participants through the design process from concept to prototype.

- The **Advanced Category** (17 – 25 y/o) is catered towards students looking to build their portfolio, gain recognition for their engineering ideas and gain valuable industry connections. Students can showcase their ideas to industry expert and obtain valuable experience for their professional careers.

1.2 Background

SiReNT is an SLA initiative developed to enable real-time high precision Positioning, Navigation and Tracking (PNT) as well as Global Navigation Satellite System (GNSS) needs. SiReNT is developed with differential technologies which improve accuracy and reliability for global navigation. The network consists of 9 GNSS reference stations operating 24/7 and supports systems such as NAVSTAR GPS, GLONASS, QZSS, Beidou and Galileo.

1.3 Focus Areas

The overall focus for GIQ is to:

- Enable participants to learn about cutting-edge technology and gain valuable insights into the industry.
- Introduce the importance of precise GNSS and its role in robotics, fostering new and innovative ideas for future projects.
- Develop participants' engineering, design, problem-solving, and critical thinking skills.
- Build confidence and experience in developing robots with basic GNSS technologies.

2. Guidelines and Code of Conduct

2.1 Teams and Mentors

1. Team Members
    a. Teams in both the Starter and Advanced categories are allowed a maximum of 6 members.
2. External Team Support
    a. Teams are allowed to seek the guidance and support of coaches/mentors.
    b. The support can be from the team's academic institute or external.
3. Each team may only participate in one of the GIQ categories per annual season.
4. Students may only register themselves in one team per season.
5. Coaches or mentors may be registered to work with multiple teams at once.
    a. For example, a coach from X Polytechnic may choose to register themselves as coach for multiple teams coming from within or even outside of the institution.
    b. Coaches are encouraged to not share information between teams to facilitate fair play.
6. Member of any team that has won the Top Prize in either category during a previous season will be restricted from participation in the Starter category.
    a. Starter category team members should **NOT** be comprised of any previous season winners.
7. The maximum age for each category reflects the age that participants turn in 2024.

2.1.1 Fair Play

Teams should be fair and respectful towards other participants, coaches, judges, and organisers.

All entries into/exit from the venue is prohibited unless a substitute is required. In such situation, permission must be approved from the organisers.

Once the demos start, teams will not be allowed to do any additional changes to their prototypes.

2.1.2 Behaviour

Teams are expected to demonstrate integrity during the competition.

Any alleged discrepancies in the rules or scoring should be handled in a **respectful** manner.

2.1.3 External assistance

Coaches and mentors may aid teams in matters such as procurement and acquisition of hardware, software, components, or fabrication of hardware.

Coaches, mentors, and external supporters may support the teams by providing design feedback and review, but they should not be undertaking the entire project for the teams.

2.1.4 Spirit

Teams should have experimentation and learning as the ultimate goal.

"***It is not whether you win or lose, but how much you learn that counts."***

2.1.5 Violations

Teams that violate the code of conduct may be disqualified from GIQ. It is also possible to disqualify only single person from further participation.

In less severe cases of violations of the Code of Conduct, a team will be given a warning. In severe or repeated cases of violations of the code of conduct a team may be disqualified immediately without a warning.

2.2 Safety

2.2.1 Construction

All sharp protrusions or objects from the robot must be taped up or removed.

Robots must have all active components such as gears properly protected and covered with resistant materials or hard plastic.

Electrical components should be covered with non-conductive materials or electrical tape.

2.2.2 Batteries

When batteries are transported or moved, the use of safety bags is strongly recommended.

Measures should be taken to avoid short circuiting or chemical leaks.

The use of Lithium Polymer Batteries (LiPo), Lithium-Ion Batteries and Dry Cell batteries is allowed. However, they should not exceed the power limits. In the case of a battery fire, please seek help from the referees or judges.

3. Quest

This edition of the GNSS Innovation Quest is task-based – participants will be required to design AMRs with basic navigation and path planning capabilities under the theme “Autonomous Systems for a Digital Singapore”.

3.1 Starter Category

3.1.1 Objective

The objective of this GIQ is to design an autonomous mobile robot capable of navigating through a scaled down pre-defined course in a controlled local environment.

3.1.2 Quest Description

With increasing innovations in the field of autonomous vehicles in the last decade, large corporations, start-ups, investors, and city planners see a high potential in self-driving vehicles. However, driving autonomously in our daily life still poses numerous challenges.

Teams will need to tackle the ongoing research challenges surrounding self-driving vehicles to build a prototype solution. This provides a learning journey to boost foundational skills by developing prototypes utilising precise GNSS.

The course can be defined by the team, the overall goal is for the AMR to move from point A to point B. The higher the complexity of the path overcome by the vehicle, the higher the score of the team. Refer to Section 3.1.4 for a detailed breakdown of the scoring.

3.1.3 Deliverables

3.1.3.1 Quest Round (Demo)

Teams will have to develop, integrate, and apply a scaled-down robot equipped with on-board sensors (LiDAR, IMU etc.) and positioning (Precise GNSS and High-Resolution Map) to enable autonomous navigation. The teams can build the vehicle using the robotics platform of their choice. Teams will use routing algorithms for navigation to create a robot capable of **navigating between two points**.

The pre-defined course will be prepared by the team, with the goal of solving as complex a course as possible for the vehicle. Teams may prepare and use any suitable obstacles and props that highlight features and capabilities of their AMR for use in the demo. This demo should be pre-recorded.

3.1.3.2 Quest Log

Report

Students will be required to submit a project report (not exceeding 20 pages) detailing their design and its use case scenarios. The report should include an introduction section with some background research on the topic. This report should also demonstrate an understanding of SLA's point cloud database of Singapore. In terms of financial planning, teams are encouraged to carefully plan their budget and reach out to potential sponsors and suppliers before and during development of their AMR.

The report should contain a team section with a description of the team member's backgrounds and their roles within the team, making sure to specify their individual contributions in building the prototype.

Presentation

Teams will have to prepare for a slideshow presentation, after which there will be a Q&A session with the judges regarding their project.

3.1.4 Scoring

The weightage of each category is as follows:

- Quest Round (Demo) [25%]
- Quest Log (Report) [35%]
- Quest Log (Presentation) [25%]
- GIQ Bootcamp [15%]

Each of the categories above will be further broken down into different tasks. Each task will be awarded a specific number of points. This breakdown should give teams enough information to design and develop their solution for the GIQ.

- Quest Round (Demo) **[120 pts Total]**
  - □ Basic Locomotion [30 pts]
  - □ Advanced Mobility Features [10 pts]
  - □ Obstacle Avoidance [30 pts]
  - □ Autonomous Navigation [30 pts]
  - □ Judges' Bonus [20 pts]

- Quest Log (Report) **[160 pts Total]**
  - □ Formatting [20 pts]
  - □ Locomotion and Mobility [20 pts]
  - □ Power Management [20 pts]
  - □ Obstacle Avoidance [20 pts]
  - □ Autonomous Navigation [20 pts]
  - □ Use Case Scenario [20 pts]
  - □ Understanding of Digital Singapore [20 pts]
  - □ Judges' Bonus [20 pts]
- Quest Log (Presentation) **[120 pts Total]**
  - □ Presentation [70 pts]
  - □ Q&A [30 pts]
  - □ Judges' Bonus [20 pts]
- GIQ Bootcamp **[15%]**
  - □ Participation

3.2 Advanced Category

3.2.1 Quest Statement

Design an autonomous mobile robot capable of mapping, obstacle avoidance, and urban terrain traversal to navigate between points at different local environments.

3.2.2 Quest Description

With increasing innovations in the field of autonomous vehicles in the last decade, mega corporations, start-ups, investors, and city planners see a high potential in self-driving vehicles. However, driving autonomously in our daily life still poses numerous challenges.

Teams will need to tackle the ongoing research challenges surrounding self-driving vehicles to build a prototype solution. Teams will develop prototypes that utilise GNSS Technologies for Autonomous Navigation, that can map and navigate a dynamic urban environment.

3.2.3 Deliverables

3.2.3.1 Quest Round (Challenge)

Teams will have to develop, integrate, and apply a scaled-down robot equipped with on-board sensors (LiDAR, IMU etc.) and positioning (Precise GNSS and High-Resolution Map) to enable autonomous navigation. Teams will use routing algorithms for navigation to create a robot capable of **navigating between points** and **performing a series of tasks**.

Students will have to deliver a working prototype of their proposed solution. The prototype will have to perform a series of tasks in a live challenge round. The venue for the live challenge round will be revealed at a later date. These tasks can be tackled using a combination of both autonomous and manual control. Points are awarded based on aspects of automation incorporated into the solution.

3.2.3.2 Quest Log

<u>Report</u>

Students will be required to submit a project report detailing background research, their design, its capabilities, and use case scenarios, this should include financial, risk, and feasibility reports, with engineering drawings, graphic models, and simulations annexed or attached separately. This report (40-page limit) should demonstrate an understanding of how their AMR's mapping capabilities can contribute to SLA's point cloud database of Singapore. The report should also contain a team section with a description of the team member's backgrounds and their roles within the team, making sure to specify their individual contributions

in building the prototype. In terms of financial planning, teams are encouraged to carefully plan their budget and reach out to potential sponsors and suppliers before and during the development of their model.

Participants will also be required to submit a video demonstrating their AMR in action.

Presentation

Teams will have to prepare for a slideshow presentation, after which there will be Q&A session with the judges regarding their project.

3.2.4 Scoring

The weightage of each category is as follows:

- Quest Round (Challenge) [35%]
- Quest Log (Report) [35%]
- Quest Log (Presentation) [15%]
- GIQ Bootcamp [15%]

Each of the categories above will be further broken down into different tasks. Each task will be awarded a specific number of points. This breakdown should give teams enough information to start designing and developing their solution for the GIQ. A complete judging matrix with the specific details of the tasks in the GIQ Advanced Category Quest Round will be released at a later date.

- Quest Round (Challenge) **[200 pts Total]**
  - □ Task 1 – Navigation to Area A (<100m Distance) [50 pts]
  - □ Task 2 – Mapping of Area A [50 pts]
  - □ Task 3 – Payload delivery [50 pts]
  - □ Task 4 – Navigation back to start point [50 pts]

- Quest Log (Report) **[200 pts Total]**
  - □ Format and background research [15 pts]
  - □ Locomotion and Mobility [15 pts]
  - □ Power Management [15 pts]
  - □ Obstacle Avoidance [15 pts]
  - □ Autonomous Navigation [15 pts]
  - □ Mapping Capabilities [15 pts]
  - □ Use Case Scenario [15 pts]
  - □ Understanding of Digital Singapore [15 pts]
  - □ Demo Video [60 pts]
  - □ Judges' Bonus [20 pts]

- Quest Log (Presentation) **[120 pts Total]**
  - □ Presentation [70 pts]
  - □ Q&A [30 pts]
  - □ Judges' Bonus [20 pts]

- GIQ Bootcamp **[15%]**
  - □ Participation

4. Regulations and Material Restrictions

1.1. The AMRs can be made using commercial platforms as a base, Commercial Off-the-Shelf Components (COTS), designed and fabricated from scratch, or any combination of the above.

1.2. There is no restriction to both hardware and software used for the solution. However, grading will be based on parts selection, and proper utilization of components.

1.3. The AMRs should be no larger than 150x150x150 cm, with no minimum size requirements for both categories.

1.4. There is also no restriction to the means of locomotion for the solution (i.e. UAVs and crawling robots are allowed).

1.5. Teams are allowed to reach out to sponsors for components. To ensure fair play, they must also record the cost of these components in the log.

1.6. The use of Lithium Polymer Batteries (LiPo), Lithium-Ion Batteries and Dry Cell batteries is allowed provided they don’t exceed the power limits.

5. Quest Log Guidance

Locomotion and Mobility

Demonstrate the AMR's ability to traverse varying terrain, surfaces, topography, inclines, urban environments, etc. Highlighting any special features to the suspension system (Rocker-Bogie, Active Suspension, etc.).

The robot should move smoothly and efficiently between points, demonstrating controlled motion with minimal wobbling or jerking. Teams may choose to include advanced mobility features such as variable speed control or omnidirectional movement.

Power Management

The robot should efficiently manage its power supply requirements and consumption. This would involve optimising the use of motors, sensors, and batteries to maximise operational time.

The team should concisely document aspects of power management such as power source selection, energy consumption, operating time estimation, voltage regulation, battery sizing, etc.

Obstacle Avoidance

The team should document how their AMR uses on-board sensors to detect and avoid obstacles and collisions in its path during navigation.

AMRs should be equipped with suitable sensors for environmental perception such as LiDAR, Ultrasonic or Infrared Sensors, or Cameras. Teams should demonstrate an understanding of aspects including sensor data processing, obstacle avoidance algorithms, collision avoidance manoeuvres, and dynamic obstacle handling.

Autonomous Navigation

Teams can showcase the effectiveness of their AMR's autonomous navigation capabilities using a demonstration that shows the AMR successfully moving between points while avoiding obstacles, adapting to dynamic environments, and maintaining accurate localisation.

Autonomous navigation is fundamental to AMRs, teams should document how they enable this using on-board sensors, sensor fusion, real-time localisation, path planning, trajectory generation, PID control, and mapping.

Mapping (Advanced Category)

Teams should highlight the mapping capabilities of their AMRs, showcasing how it can aid in the generation of point cloud maps.

The AMRs should demonstrate their use of Point Cloud Sensors such as LiDAR to collect accurate 3D point cloud information, Point Cloud Data Processing, Structures (Voxel Grid, Octree Structures, etc.), Real-Time mapping, Localisation etc.

Understanding of Digital Singapore

Teams should demonstrate an understanding of how their AMR can contribute to the broader digital transformation efforts within Singapore – How Singapore, as a smart nation, actively leverages digital technologies and data to improve various aspects of urban life.

6. GIQ Bootcamp

Participants in both the GIQ Starter Category and the GIQ Advanced Category will be eligible for a free 2-day bootcamp. Participation in this bootcamp accounts for 15% of the final score and serves to elevate the teams' skills and provide them support in producing working prototypes.

During this bootcamp, teams will have the chance to receive live feedback and assistance from experts in the field. This includes introductions and demonstrations to the technologies used in the GIQ, a hands-on guided integration workshop for participants, practical exercises to apply GNSS technology in mapping robots, and more.

More details on the bootcamp will be released at a later date.