Operational Concept Documents

OPSCON v0.1

Diversos Systems

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DIVERSOS
SYSTEMS

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1.Scope

1.1 General

The purpose of this project is to design and implement an autonomous robot capable of navigating and efficiently avoiding obstacles. The goal is to create a competitive system where two teams design their own autonomous robots to navigate through a series of obstacles. The winning team will be determined by the performance of their robot in the competition. This project will require the use of various technologies, including software to program the navigation system, as well as hardware for the robot itself.

The competition will be done both in simulation and in a physical environment replicating one of the environments proposed in BARN competition (Benchmark for Autonomous Robot Navigation) or creating a similar circuit.

1.2 Identification

This project is being developed by teams of engineers who will study and prepare the necessary knowledge to design the obstacle avoidance system. Each team is composed of a group of eight engineers, each with a specific role such as Project Manager, Product Manager, Design Manager, Modelling Manager, or Impact and Sustainability Manager.

1.3 Document overview

This document offers a detailed view of the autonomous robot system designed for obstacle evasion. It includes details about prototypes, specifications of the selected robot, as well as potential operational scenarios. Its audience includes the project team, stakeholders, and all individuals involved in system operations. Additionally, it provides a comprehensive overview of the competition and the various developmental stages.

1.4 System overview

The autonomous robot system for avoiding obstacles consists of three main components: the autonomous navigation software to detect obstacles, the design of a basic obstacle course for the competition, and the robots themselves. Besides, a small drone could be used by the ground robot to provide aerial views of the environment.

2. Stakeholders

2.1 Government (European, Spanish and Madrid)

Because the project involves Autonomous Ground Vehicles (AGVs) with the possibility of using an Unmanned Aerial Vehicle (UAV) as a guide, the regulations of both need to be considered.

Regarding UAVs and AGVs standards in Europe, currently the drone regulation is governed by two different regulations. Specifically, Commission Implementing Regulation (EU) 2019/947 and Commission Delegated Regulation (EU) 2019/945. Both regulations are key to ensuring total safety during drone operations. As of January 1, 2021, regulations 2019/947 and 2019/945 are fully applicable throughout the European Union, replacing previous drone legislation in EU member states.

Regarding National and Regional Laws for UAVs, they all refer to European legislation, such as the Consolidated Implementing Regulation (EU) 2019/947, including amendments from Implementing Regulation (EU) 2020/639, Implementing Regulation (EU) 2020/746, Implementing Regulation 2021/1166, and Implementing Regulation (EU) 2022/425; and Consolidated Delegated Regulation (EU) 2019/945.

All these laws influence the initial stages of the project, in aspects such as the location of the competition or the weight of the drone.

2.2 Competition management team

In this scenario, the other team is being regarded as a significant stakeholder due to its influence on various elements concerning the competition tests and drone specifications. Their impact is particularly notable in setting the conditions for the competition. It is crucial for the competing teams to be well-informed about the objectives, enabling them to adapt, prepare for diverse scenarios, and ultimately meet the project's goals.

2.3 The university (ETSII)

Responsibility falls on them to provide the team with testing facilities and support for the competition, along with financial backing. Their influence spans the entire project duration. To ensure both teams have the essential equipment, space, and facilities to succeed, it's imperative to keep them informed about the project's requirements.

2.4 Teaching team (Clients)

Within our project, the group of professors wears multiple hats as stakeholders. Besides teaching systems engineering and technical concepts like ROS and C++, they also function as “clients”.

Their role extends beyond teaching; they provide guidance and expectations akin to clients, shaping our project's direction. This dual role ensures a comprehensive understanding of the project.

3.Current system

This section is intentionally empty.

4.The competition

The BARN competition sets the stage for our project, challenging teams to design robots capable of overcoming obstacles within defined scenarios. To ensure a realistic and comprehensive evaluation, our OpsCon delves into essential aspects, including drone and test regulations, and provides insights into the scoring system that will determine the success of our autonomous system in the competition.

4.1 Drone regulations

The system incorporates the use of a small drone as an integral part. Adherence to both local and European drone regulations is paramount for ensuring safe and compliant operations. Specifically, the project aligns with Commission Implementing Regulation (EU) 2019/947 and Commission Delegated Regulation (EU) 2019/945, which govern drone operations in the European Union. These regulations cover aspects such as drone identification, operational limitations, and safety protocols during flight.

4.2 Test regulations

The testing phase of the BARN competition follows a set of predefined regulations to standardize evaluation and ensure fairness among participating teams. These regulations encompass guidelines for the construction of obstacle courses, specifications for testing environments, and safety measures during testing. Teams are required to comply with these regulations to guarantee a level playing field and the overall success of the competition.

4.3 Scoring

The scoring system in the BARN competition is designed to evaluate the performance and efficiency of autonomous robots in navigating through obstacle courses. Key components of the scoring system include:

- **Time Efficiency:** Teams are awarded points based on the time taken by their autonomous robots to complete the obstacle course. Faster completion times result in higher scores, emphasizing the importance of efficiency in navigation algorithms.
- **Obstacle Avoidance**: Successful avoidance of obstacles is a critical criterion for scoring. Points are deducted for collisions or failures to navigate around obstacles, encouraging teams to implement robust obstacle detection and avoidance strategies.
- **Precision and Accuracy:** Precision in following the designated path and accuracy in reaching the target point influence the overall score. Deviations from the prescribed route or inaccuracies in reaching the destination may result in point deductions.
- **Innovation and Technical Excellence:** The competition values innovation and technical excellence. Additional points may be awarded for novel approaches, advanced algorithms, or unique features that contribute to the overall effectiveness of the autonomous system.

- **Compliance with Regulations:** Adherence to drone and test regulations is a fundamental aspect of scoring. Teams must demonstrate a commitment to safety and regulatory compliance throughout the competition.

The scoring criteria aim to holistically assess the capabilities of autonomous robots, encouraging participants to balance speed, accuracy, and innovation to achieve the highest scores in the BARN competition.

5. Operational scenarios

Operational scenarios are described as the sequence of events that take place between the product and the environment, users and the product components. As well, it may describe the expected utilization in terms of action.

5.1. Physical testing scenarios

The spaces reserved for testing the product, whether complete or in development, must have been authorized for this purpose. Because the product will be tested within an urban area, there must be a test space free of non-team members within two hundred meters to avoid possible inappropriate interactions by people who do not know the safety measures.

If the weather conditions do not allow it, or the people responsible for the testing space do not allow the test to be done outside, an open-plan indoor space must be available, high in height and with sufficient dimensions.

A flight area must be defined that can only be accessed when the device is motionless. Team members testing the device should remain at a sufficient distance from this area to be able to take cover or move in case the device loses control.

Even so, when handling the device, and to avoid possible injuries, whoever physically manipulates the device to put it in the starting place or pick it up, must wear protective gloves resistant to cuts that the propellers may cause.

The team must previously ensure that there is good network quality to avoid possible range losses. Before arranging the use of the test space, the team must go to the place and check this aspect to avoid loss of time for the team itself and the person or entity with whom the management would have to be done.

5.2. Tests outline

Different tests will be carried out by type of requirement and device:

UAV		UGV	
Test Type	**Descriptio n**	**Test Type**	**Description**
Take off /	The device		

Landing	must be able to take off, land in a stable manner, and respond appropriately to the controller in time and place.		
Speed/ Acceleration	The device must achieve the speeds and accelerations established by software.	**Speed/ Acceleration**	The device must achieve the speeds and accelerations established by software.
Obstacles detection	The device must be capable of detecting and avoiding pre-established obstacles, avoiding them without danger.	**Obstacles detection**	The device must be capable of detecting and avoiding pre-established obstacles, avoiding them without danger.
Connectivity	Connectivity with the device must not be lost at any time and the response times of the device with respect to the controller must be acceptable.	**Connectivity**	Connectivity with the device must not be lost at any time and the response times of the device with respect to the controller must be acceptable.
Battery	The battery must last at least half an hour from the moment of the first takeoff to the landing of the last cycle that can be done.	**Battery**	The battery must last at least half an hour from the moment of the first movement to the stop of the last cycle that can be done.

6. Summary of impacts

6.1. Operational Impacts

In the pursuit of designing and implementing an autonomous robot system for obstacle evasion, it is crucial to thoroughly assess and mitigate potential safety risks associated with the operational aspects of the project. Recognizing and addressing these risks is imperative to ensure the well-being of both the project team members and any individuals involved in the system's operations. The following are key safety considerations:

- **Collision Hazards**: The autonomous robots navigating through the obstacle course pose a potential risk of collisions. Robust collision avoidance algorithms and continuous testing are paramount to minimize this risk.
- **Drone Operations:** The utilization of a small drone adds complexity to the project. Safety measures must be implemented to mitigate the risk of accidents during the drone's operation, including take-off, flight, and landing. Adherence to local and European regulations governing drone use is imperative.
- **Human Interaction:** In scenarios where the competition involves interaction with humans, measures must be in place to ensure the safety of participants, spectators, and anyone within the vicinity. Clear communication of safety protocols and restricted access areas is vital.
- **Testing Environments:** The testing phase involves the deployment of autonomous robots in controlled and uncontrolled environments. Strict safety protocols must be followed during testing to prevent accidents and ensure the well-being of team members and any individuals present.
- **Emergency Response Planning:** A comprehensive emergency response plan should be established, outlining procedures in the event of unexpected incidents or malfunctions.
- **Compliance with Regulations:** Adherence to European, Spanish, and local regulations governing autonomous ground robots and aerial drones is paramount. Regular updates on regulatory changes should be monitored, and adjustments to the project plan made accordingly.

It is essential for the project team to conduct regular safety assessments, update protocols as needed, and prioritize the well-being of all stakeholders involved in the project's operational phases.

The development and deployment of the autonomous robot system have the potential to influence the environment. Considerations include:

- **Energy Consumption:** The operational phase of the autonomous robots and the accompanying drone may have an impact on energy consumption. Exploring energy-efficient technologies and sustainable power sources is essential to minimize the environmental footprint.

- **Material Usage:** The manufacturing and maintenance of robots involve the use of materials. Emphasizing eco-friendly and recyclable materials contributes to sustainable practices.
- **Waste Generation:** Throughout the project life cycle, attention should be given to minimizing waste generation, especially during prototyping and testing phases. Proper disposal and recycling procedures should be implemented.

6.2. Organizational Impacts

Effective maintenance and operational practices are vital for the success of the project. Ensuring the optimal performance of the autonomous system requires a multifaceted approach. This involves implementing a structured maintenance schedule for both the robot and the drone, encompassing regular checks on hardware, software updates, and calibration. Simultaneously, providing comprehensive operational training programs for team members involved in the system's operational phase is crucial. Such training ensures competence in handling autonomous robots and drones, thereby minimizing the risk of operational errors.

- **Skill issue:** The complexity of autonomous systems may necessitate additional training for team members. Regular skill enhancement programs and workshops in class should be conducted to keep the team updated.
- **Budget Management**: Efficient resource allocation is crucial for the successful execution of the project. Continuous monitoring of budgets, including hardware costs, software licenses, and personnel expenses, is necessary to prevent resource shortages.
- **Interdisciplinary Collaboration:** The project involves multiple teams with distinct roles. Effective coordination between these is essential to ensure seamless integration of components and adherence to project timelines.

6.3. Impacts during Project Development

- **Adaptability:** The dynamic nature of technology projects may lead to changes in requirements and objectives. The project team should be adaptable, and the development process should allow for iterative adjustments.
- **Interoperability Challenges:** Integrating different components of the autonomous system may present challenges related to compatibility. Rigorous testing and clear communication channels between team members are crucial to address and resolve integration issues.
- **Project Constraints:** The project is subject to tight timelines and budgets. Effective project management, regular progress assessments, and proactive issue resolution are necessary to stay within constraints without compromising quality.

7. Analysis of the system

As mentioned before, our system is composed by an UGV and an UAV. Although the original BARN competition does not contemplate the use of UAVs as navigational aids, our competition does. This brings some benefits and disadvantages to our system:

7.1 Benefits

The system has multiple benefits compared to a single UGV system.

- **Speed:** The combined use of a UGV and a UAV could reduce the navigation time on several environments.
- **Robustness:** The use of aerial mappings let the system find solutions to more complex environments and will be able to navigate in situations where the UGV cannot determine correctly it's position.
- **Modularity**: The system must be able to operate with or without the UAV.

7.2 Disadvantages and limitations

- **Complexity:** The high complexity of autonomous systems can lead to challenges in integration and operation.
- **Regulatory Compliance:** Strict adherence to UAV and UGV regulations may limit design and operational flexibility.
- **Safety Risks:** Potential safety risks with autonomous vehicles and human interaction during the competition.

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