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# Remote Inspection with Low-cost robots

RILey



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FONTYS ADAPTIVE ROBOTICS

# General Information

Fontys Adaptive Robotics Minor.

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*Table 1: General information*

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# 1. Introduction

The main purpose of this project is to investigate whether a low-cost robot, which is intended to be controlled remotely, can be adapted to perform autonomous multi robot environmental inspection. A small and cheap robot is extremely suitable for this application. It could be used anywhere and could easily be taken with you. With affordable robots, it would also be possible with multiple robots to scan a large location faster. The partnership for this project consists of several stakeholders: SITA Robotics which is a company that wants to put its product on the market, TMC and Avular that are 2 technology partners and finally Fontys that is a research partner that needs to come up with innovative solutions.

# 2. Project Definition

## 2.1 Problem Definition

The main question of this project is to determine whether a low-cost robot, which is intended to be controlled remotely, can be adapted to perform an autonomous multi robot environmental inspection. With affordable robots, it should also be possible with multiple robots to scan a large location faster. One of the challenges is that the existing low-cost robot does not have the processing ability to perform the necessary sensor analysis and processing of the associated algorithms on the platform itself. Because of this, all sensor data from the robot needs to be sent wirelessly to a server, this server will then do all the necessary data processing and uses the analyzed data to control the robot, so that it can take any actions on this. Therefore, the robot must have the least number of sensors, but still be able to do the job accurately enough to be useful for the server. A mockup robot must be made to verify the simulations. The problem comes down to making multiple robots autonomously search for specified objects by working together.

## 2.2 Project Goals

The project can be defined in goals as well. The main goal is to create a system capable of commanding and communicating with the swarm of robot platforms. This system should be able to combine the sensory information it receives into a comprehensive mapping solution that also highlights objects of interest which are detected by the robot swarm's cameras. This requires research in multiple subjects. The current state of the robot needs to be analyzed to understand what it's capable of. Based on this a working mockup robot needs to be made. It may be necessary to add or even change out some of the sensors. In the section Time and Planning it is stated what kind of subgoals are needed to achieve the main goal.

## 2.3 User Requirements

The user requirements and their handling priority can be found in Table 2: User Requirements below.

| No | User Requirements | MoSCoW |
|---|---|---|
| **1** | Must go through the use case without getting stuck | Must |
| **2.1** | Should detect at least 3 useful objects for example doors, windows, humans, walls etc. | Should |
| **2.2** | Could detect 10 useful objects | Could |
| **3.1** | The robot must not collide with static objects | Must |
| **3.2** | The robot should not collide with moving objects | Should |
| **4** | Multiple robots could map simultaneously in the same environment | Could |
| **5** | Multiple robots should cover more ground in the same amount of time than 1 robot | Should |
| **6** | The robot won't need to go on stairs or ramps | Won't |
| **7** | Must be able to manually override the autonomous operations | Must |
| **8** | The robot must return to starting point if it's below a certain battery level | Must |
| **9** | Must model an URDF/3D model of the robot | Must |
| **10** | Must simulate the robot model using Gazebo for validating the other requirements | Must |
| **11** | Robot could create a map of its environment | Could |
| **12** | Should use a limited set of sensors | Should |
| **13** | Could add additional sensors/smart cameras | Could |
| **14** | The robot must only act based on commands it receives | Must |
| **15** | The battery could last at least an hour between charges | Could |
| **16** | The budget used shouldn't exceed €1000 | Should |
| **17** | The sensor-data must be processed server-side | Must |
| **18** | Must make a simple mock-up robot | Must |

*Table 2: User Requirements*

## 2.4 Project Boundaries

The project will be primarily seen as failed if the end result doesn't consist of all (must) requirements. In addition, other (unexpected) situations may arise. For example, if the product ultimately turns out not to be profitable or the client isn't satisfied with the result, this will cause many unexpected/unnecessary costs.

# 3. Phasing

The V-model will be used to measure progress for this project. There are different phases of the project that are chronologically executed. Also, testing is a part of each phase so that nothing will be overlooked.

## 3.1 Problem Analysis

The existing low-cost robot does not have sensors to navigate in its environment, nor does it have the capability to perform the necessary sensor analysis and processing of the associated algorithms on the platform itself. Some sensors need to be integrated to allow the robot to navigate autonomously. Additionally, all sensor data from the robot should be sent wirelessly to a server. This server will then perform the necessary data processing and send its guidance back to the robot, so that it can change its movement accordingly.

An additional challenge will be how the robot can locate itself with a limited set of sensors in an (un)known environment. This localization will also have to be carried out remotely.

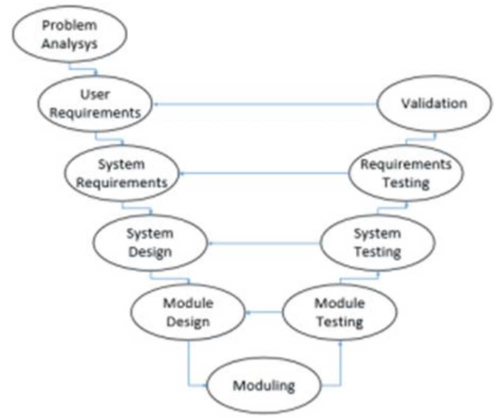


*Figure 1: V-model*

## 3.2 User Requirements

The client plays a major role in defining the user requirements. There will be a set of questions made regarding the RILey robot that the client needs to answer so that user requirements can be fully defined. In this phase it is very important to ask good questions and get the best answers because this will be the foundation of the whole project.

## 3.3 System Requirements

In this phase of the project the user requirements will need to be translated into technical system requirements. The main research subjects will be:

1) Will the already integrated sensors be useful for navigation and object detection?

2) Which sensors are sufficient to get enough information to execute the SLAM algorithm reliably?

3) Which camera specifications are needed to detect the wanted objects?

4) How will the communication protocol look like (what does the robot process and what does the server process)?

5) How will the robot autonomously navigate and map with SLAM an unknown building location from the inside?

6) How will the robot detect moving objects?

7) Is using more RILey robots beneficial for reaching the end goal faster?

## 3.4 System Design

The current RILey robot needs to be modified to fulfil the needs of the user requirements laid above. This means additional hardware needs to be integrated therefore the mechanical construction needs to be changed. The electrical system needs to be modified to supply every module power and this will influence the battery life. Every module also needs to communicate correctly with the controller or server so a communication architecture should be made.

## 3.5 Module Design

In this phase the different software modules are going to be designed. There needs to be an algorithm which covers the movements of the RILey robot in order to make a map of the environment. The robot should detect moving objects when it's in surveillance mode, therefore an algorithm needs to be designed to find the difference in static object and moving objects. Also there needs to be some reliable object recognition with vision technology. The robot must know the type of object it sees and how certain it is that it is the actual object and not some different object. After that there needs to be defined what the computer in the robot is going to process and what the server is processing. The goal is that the actual robot will do as little processing as possible, the robot will only control the motors and send information like camera feed over Wi-Fi to the server. The server then has all the smart algorithm computing like SLAM and object detection. At last, there needs to be a module designed that can control multiple robots to speed up the process of mapping a building or locating objects.

## 3.6 Implementation

When everything is defined and designed the actual implementation begins. Here the robot gets physically be built with its modifications. There will be some mechanical work probably 3D printing for concept because it is fast and easy. The electrical connection needs to be made reliable and as clean as possible so no cables will be sticking out. Then the software code needs to be uploaded to the robot(s) and set up the server so the two of them can communicate.

## 3.7 Module Testing

In the module testing phase the designed modules are being tested on their functionality. The movement algorithm for mapping an environment will be tested in a simulation program called Gazebo. If it's possible it will be also tested on the real RILey robot in the physical world. When the movement algorithm is being tested it simultaneously tests the SLAM algorithm with making a map of the explored space. The vision detection algorithm can be tested with graphically printing the information what the robot thinks the object it is looking at.

## 3.8 System Testing

The different modules also need to work together to make the system work. In order to test this, a use case scenario is created where the robot needs to map the location and detect a certain object after that, the initially detected object will move to a different location, and it needs to log where the object new location is at. Additionally, this process can be sped up by testing multiple RILey robots in the same environment mapping the location together and scanning objects.

## 3.9 Requirements Testing

If the system testing is successfully finished it is important to validate if the user requirements are met. At least the “must” requirements need to be fully integrated. After that the focus will be on the should and could requirements. Because this is a large project it is not expected to fulfil all user requirements in the given timeframe.

## 3.10 Validation

in this phase it will be interesting how robust the system is behaving and if it will work in a different environment other than the use case. Eventually it is not a useful product if it can’t adapt to change. The end goal would be that it can navigate in any environment and can track as many objects as possible. In this phase there will be recommendations written for other developers to build off from.

# 4. Project Control

## 4.1 Organization

The project will be organized using a parallel waterfall model, where the group may be divided into sub-groups, each overseeing one or more modules in the project at any given time. The waterfall model is favored over a SCRUM approach largely due to the nature of the project. In this case, many of the goals and requirements depend on previously achieved steps, and there are planning limitations stemming from the hardware dependency and real-life scenario tests that are needed to validate the system.

The group will not have a de-facto project leader, given the divide-and-conquer strategy described above, however within each sub-group there may be individualized leadership and strategizing. Overall, the team will hold daily meetings in which the status of each sub-group of people will be explained and inter-modular planning will occur based on results. At the same time, one person will be assigned to the role of main team communicator. They will communicate with the clients about the project developments.

## 4.2 Time and Planning

Milestones:

1) Contact the company and receive the robot and documentation

2) Define user requirements

3) Successfully create the robot simulation environment

4) Mapping an environment and transmit it to the server

5) Object recognition and localization by 1 robot

6) Communicate with multiple robots

7) Merging the mapping, and object recognition localization with multiple robots.

8) Delivery of final products and report

# 5. Risks

There are always project risks during the duration of the project. Not all these risks can be avoided. Identifying risks in time can negate much of the negative consequences of the risk. Achieving this requires that potential risk is known, and how to combat the consequences of each of them.

## 5.1 Project Risks

Not all risk can be identified or are worth mentioning. Therefore, some common risks are mentioned.

- **Not enough time**. Due to the lack of time, one or more requirements cannot be met.

- **No clear project objective.** The objective should be crystal clear to every member of the group. This is needed to work towards the same goals.

- **Communication problems.** Communication is key in group projects. Improper communication can lead to delays in the project

- **Incomplete project planning**. An incomplete planning can lead to more work required that predicted in the beginning.

- **Absence of project members.**

- **Absence of project tutor.**

- **insufficient support external companies**

- **COVID-19 Lockdowns**

- **Delayed arrival of goods**

- **Poor performance of group member(s)**

## 5.2 Risk Classification

Classifying risk is done using the impact of the risk when things go wrong, and the chance this events occurs. The impact is measured in the amount of time lost, because time is one of the most important resources during projects. The multiplication of these two factors determines the risk degree. Besides the risk degree the risk priority is useful the know. This can be quantified by multiplying the risk impact with the vulnerability you have for the risk. This can be summarized in the following formulas:

$$Risk = Risk\ impact \times Probability$$

$$Risk\ priority = Risk \times Vulnerbility$$

| Rating | Name | Progress loss |
|---|---|---|
| 1 | Incidental | Less than a day |
| 2 | Minor | One day to one week |
| 3 | Medium | One to two weeks |
| 4 | Major | Two weeks to a month |
| 5 | Extreme | More than one month |

*Table 3: Impact scale*

| Rating | Name | Chance of occurrence during project |
|---|---|---|
| 1 | Incidental | 0 – 10% |
| 2 | Minor | 10 – 25% |
| 3 | Medium | 25 – 50% |
| 4 | Major | 50 – 75% |
| 5 | Extreme | 75 – 100% |

*Table 4 Probability scale*

| Rating | Name | Description |
|---|---|---|
| 1 | Incidental | Almost no impact on project result |
| 2 | Minor | No severe impact on project result |
| 3 | Medium | Project result at risk |
| 4 | Major | Serious risk for project |
| 5 | Extreme | Fatal risk for project |

*Table 5 Vulerability scale*

| Risk | I | P | V | Risk degree | Risk priority |
|---|---|---|---|---|---|
| Not enough time | 4 | 3 | 4 | 12 | 48 |
| No clear project objective | 2 | 2 | 1 | 4 | 4 |
| Communication problems | 1 | 1 | 2 | 1 | 2 |
| Incomplete project planning | 2 | 2 | 1 | 4 | 4 |
| Absence of project members | 3 | 1 | 2 | 3 | 6 |
| Absence of project tutor. | 2 | 1 | 1 | 2 | 2 |
| insufficient support external companies | 2 | 2 | 2 | 4 | 8 |
| COVID-19 Lockdowns | 4 | 2 | 3 | 8 | 24 |
| Delayed arrival of goods | 2 | 3 | 2 | 6 | 12 |
| Poor performance of group member(s) | 2 | 1 | 2 | 2 | 4 |

*Table 6: Classification of risks*