Universitat Politècnica de Catalunya

Information Technology Project

Project Proposal

Talos

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Abstract

The aim of this project is to develop a security and reliable system that is capable of surveilling a determined perimeter and detecting potential trespassers. To achieve this goal we will provide the enterprises with a user-friendly API that enables them to customize and monitor every aspect of the system. Furthermore, we will provide our very own autonomous robot for this precise task.

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1 General contextualisation

1.1 Introduction

Surveillance is key to ensuring the integrity and safety of any facility, but it is very costly and not always effective when performed by humans. There are many factors that contribute to this issue, such as the unwillingness to work at certain time frames (night shift, for example) or the vast size of some properties. Consequently, due to the emergence of solid machine learning models and efficient autonomous robots and UAVs, a new security standard was born.

While autonomous vehicles have become integral to surveillance in recent years, there are still areas where they lack capability. However, we cannot improve most of the technical facets due to their complicated nature. Therefore, the aim of this project will be to improve the development and management of these robots.

The development of the project will be within the context of Universitat Politècnica de Catalunya (UPC), Informatics Engineering Bachelor's Degree. It belongs to the Information Technologies Project (PTI) subject and Information Technologies (IT) major.

1.2 Description

This project, named after the mythological automaton giant Talos, who was in charge of protecting Europa and surveilling the coast of Crete, comprises two main components that must be implemented: autonomous robots and a user-friendly interface that manages and monitors them. First, let us examine the requirements and specifications of the robot before proceeding to the development of the user interface (UI).

The autonomous vehicle will be a four-wheeled car due to its simplicity, easy implementation and the amount of space it provides to securely place the hardware. Nonetheless, we explored alternatives such as a UAV, but it would over-complicate the project and make it more costly. Its main capabilities include video recording, sensor monitoring and autonomous driving.

Although the hardware is primordial to the project, we will put the most emphasis on the UI development and its available tools, as they are what links the project to the `Information Technologies` subject and the major it belongs to. Hence, we will provide two APIs, a hosted website and an

application.

Last but not least, interconnecting the interfaces with the hardware and providing a database to store all the information is paramount to make the system work.

1.3 Justification

The PTI subject is fundamental in the culmination of specialized studies, as it encompasses the multifaceted perspective an engineer must possess. It requires them to develop a multidisciplinary project that incorporates the use of various technologies. Hence, this project must fulfill this requirement, integrate multiple technologies in order to craft a meaningful implementation.

This proposal includes website, backend, application and hardware development. Moreover, interconnecting these elements and providing functionalities will involve the use of build-automation, Dockerization, monitoring tools, artificial intelligence (AI) and others. In other words, the development of this project requires a firm understanding of diverse fields and successful integration of them. Furthermore, it fills the aforementioned gap in the market about surveillance providers, which mentioned the lack of user-friendly interfaces to easily setup and monitor a perimeter.

1.4 Innovation potential

As discussed previously, the concept of offering an interface that significantly simplifies the utilization of monitoring tools and devices is currently nonexistent. While there are some existing tools available, none of them encompass the functionalities of autonomous robots, such as configuring robots, video streaming, and alert modes. Therefore, continuing this project could substantially enhance not only the deployment process but also the overall security.

Furthermore, if some additional functionalities were to be implemented, such as a trained machine learning model for detecting intruders or a more cost and energy efficient robot, it could shape the industry. All in all, it is the next step for improving surveillance performance and making these technologies more available to the public [1].

[1] These systems are not so available to the public, they are costly and very hard to setup.

1.5 Environmental factors

In order to survey large perimeters there is a widespread tendency of hiring agents that patrol around it with some sort of non-environmentally friendly vehicle. Hence, reducing the need for the use of these by offering an alternative would reduce CO2 emissions. By making use of electrically-powered drones or cars there is no need to worry about greenhouse gases.

2 Market Analysis

In this section the idea will be exposed from a business perspective. Firstly, the current and future market status will be analyzed, followed by its possible business model and its market insertion, then discussing the competitors and finally mentioning some stakeholders that might be interested in the project.

This part is meant to outline the prospect of the project and complement the innovation potential section. It is meant to be relatively brief and concise, as its only goal is to provide insight into our thought process when deciding this idea. Hence, please do not use it as a detailed business analysis.

2.1 Market Growth

The system object of this proposal involves two main markets: the autonomous systems market and the surveillance market. If we take a close look at both markets, they both are both expected to greatly increase, the compound anual growth rate (CAGR) forecast is 17.5% and 9.2%, respectively. Both image 1 and 2 convey effectively this trend. In conclusion, it is a financially prosperous market with a great future prospect, thereby proving that Talos can prove to be a highly lucrative venture.

The market's recent inception and relationship with novel technologies allow for the surge of many different products. Moreover, there has not been enough time for the market to monopolized; not only because of its young nature, but also because of how fragmented it is. Notably, they are immense markets, as the combination of both amounts to a total of 87.7 billion USD.

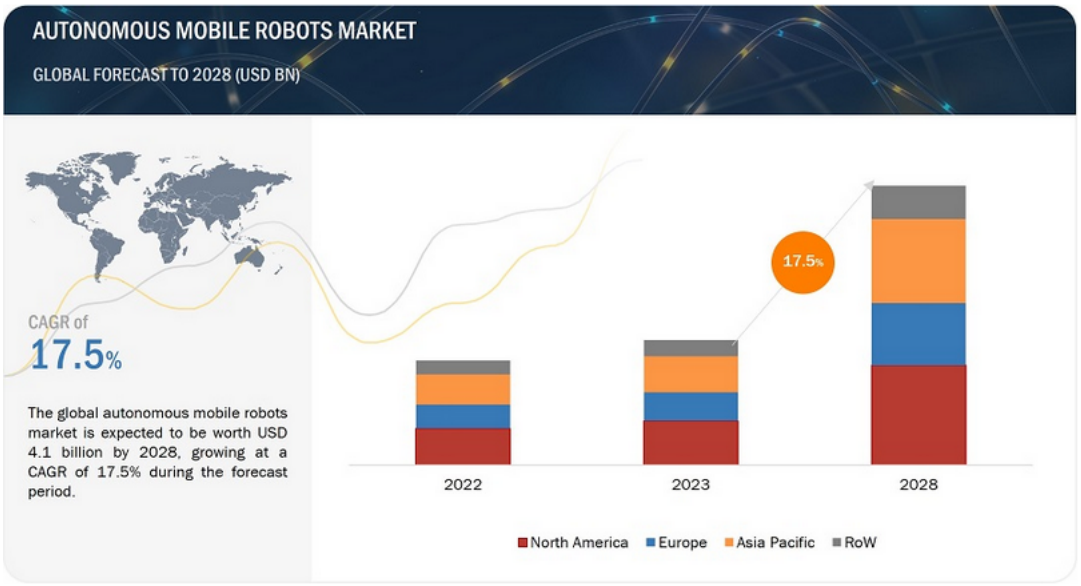

Figure 1: Autonomous mobile robots market forecast for 2028 [1].

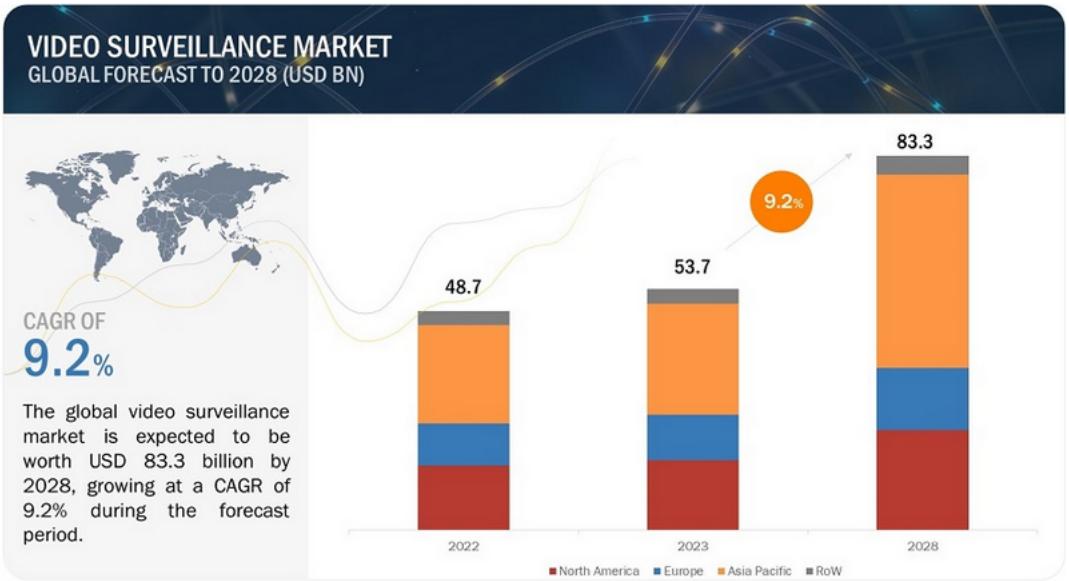

Figure 2: Video surveillance market forecast for 2028 [2]

2.2 Business model

The multiple functionalities can be divided into different business models.

1. `Robot - Hardware sales`
   The robot itself is a valuable asset for the enterprises that are asserting new security systems. The fact that it is effectively combined with the software promotes buying this one and not another.

2. `Software and APIs - Subscription model`
   Taking into consideration that the software is expected to be widely and *continuously* used it is optimum to opt for a subscription model, as it will provide an income stream that will persist for as long as the system is in place. The APIs should not be limited to providing support only for the company's robots, as it would limit their market potential and foster competitors.

3. `Services`
   Further functionalities could be implemented which allow for the customization of certain tasks. Additionally, providing a service to perform the setup (alhough it should be easy) and does maintenance can become a revenue stream.

2.3 Market insertion

This is a highly technical market that is shaped with many different companies specialized in particular functionalities. It is a fragmented, young not crowded market which is still in the early phases of its life cycle. Additionally, its novel approach to security would appeal to many large companies. Nonetheless, the following statements should be taken into account:

- Highly technical. This project encompasses too many features, starting with only a few of them is advised. For example, providing a secure and robust API with a subscription model would already attract enough attention. On the opposite hand, by implementing many functionalities which do not work reliably there is a likely probability that each one of them gets substituted with a better one.

- The **target market** are large companies and institutions, they are usually reticent to change anything unless it is necessary. However, the

ever-increasing policies regulating safety and the importance currently given to security would promote the swap.

- It is a highly scalable market design. Software does not require production means and is non-dependant on other materials or distribution time. Note that this statement is not true for the case of the robot.

- It does not require a first huge investment in order to start operating, as it does not need much infrastructure (this can change depending on whether you want to have your own servers or use infrastructure as a service (IaaS), for example).

2.4 Competitors and threats

As I previously mentioned, it is a highly fragmented market with many different specialised companies. In figure 3 many of them are listed, each one belonging to their respective industry. In order to maintain an advantage it is paramount to quickly solidify the product's position within the market. Once enterprises have adapted to the new software and management tools they will very unlikely look for more change and investment, as they disrupt the work dynamic.

Notably, its main vulnerability is the project's wide scope. Integrating so many functionalities will require a lot of hard work, as the developers will need to have a firm understanding of all different realms of computer science. In order to mitigate this threat it is advised to firstly focus one a few key functionalities, then progressively include the rest.

Figure 3: Video surveillance market landscape [2]

2.5 Logo

Every product needs a logo and a slogan. In this case it should represent reliability, security and technology. In figure 4 we can see the astonishing result.

Figure 4: Logo that will represent the venture, its product and values. This image was generating using AI [3].

3 Implementation

Having discussed the market analysis and contextualizing the project, we can proceed with its implementation. In this section the main objectives will be established, followed by a detailed and in-depth description of its basic components, finalizing by succinctly commenting on further development and some potential risks we might face during and after the development of the project.

3.1 Objectives

There are numerous objectives we aim to achieve, yet only a few are realistic and obtainable due to time constrains. Hence, here is a list with only the most essential ones,

- Interconnecting the hardware and software components comes as a first priority when deciding upon the success of the project. Therefore, a lot of endeavors will be invested into ensuring its completion.
- In order to monitor and survey, it is fundamental to have visual interface that allows the user to observe the current situation within the perimeter of their facilities.
- While our intention does not involve developing a cutting-edge robot, it remains crucial that it possesses a degree of autonomy. Clients should not depend on manual piloting for operation.
- The development of the UI will require the use of multiple technologies, thereby allowing for a lot of creativity when choosing the development tools. Nevertheless, it has been decided that using the most widely used technologies which are also modern will be our course of action. In other words, it will be necessary to experiment with
- The last step is to test whether the whole system works and interacts with each other. Achieving this would mean the success of the project.

3.2 Basic components

In order to make the project successful, we must specify all the components our application will encompass. This will provide a clear road map for our

project. Please consider that these components will be the essential elements for us to determine the project is complete. Below are the specifications for all of our essential components:

3.2.1 Web Application

The primary goal of this component is to handle the visualization of all the results. Specifically, our main objective is to present the data gathered by our surveillance robots in a user-friendly and intuitive manner. Moreover, this element will be capable of video-streaming the robot's camera. Last but not least, it will feature an authentication mechanism to ensure that only the owner of the robots has access to them.

We will use the following tools: HTML5, CSS3, React and JavaScript. Nonetheless, it is important to note that they are subject to change depending on the state of the project.

3.2.2 Mobile Phone Application

The Mobile Phone Application shares identical characteristics with the Web Application. Just like its web counterpart, the Mobile Phone Application incorporates an authentication mechanism to only allow authorized owners to view data from their robot. Additionally, it will include a live video streaming of the robot's camera. However, we will be using a different tool called Flutter for the development of this application.

3.2.3 Autonomous robot

In our project's hardware setup, we will be using a Single Board Computer (SBC), specifically the Lichee Pi 4A, which has a RISC-V processor[2]. This will serve as the robot's controller, managing various components of it.

Furthermore, it will feature several sensors for data acquisition and monitoring. These sensors include an on-chip temperature sensor, a camera, a gps evaluation board, a velocity sensor and a temperature and humidity sensor for environmental monitoring. In order to facilitate movement and maneuverability, we will incorporate Mecannum wheels to execute turns with ease.

[2]This SBC was chosen instead of Raspberry PI due to the Europe's recent endeavors in fostering its inception and standardization in the continent. The European Union (EU) is aiming to reduce its dependence in foreign architectures [4].

The wheels will be moved by DC motors and controlled by a motor controller or an H-Bridge.

Last but not least, the non-hardware parts of the robot (wheels, chassis etc.) will be 3D printed. However, we do not intend to model all our prints, as it would prove too difficult and time consuming.

3.2.4 API

We also need to have a mechanism that establish a communication between the surveillance robots and the server. This is due to the fact that we need to transmit instructions to the robots regarding their next destination. Additionally, we will need to communicate the web page, the mobile phone application and the backend, such as the MongoDB database. Therefore, it is essential to have this communication channel between the different parts of our project and the backend of our server.

3.2.5 Dockerization

Like many modern projects, this component is essential for deploying application with their respective dependencies into containers. It's isolation and portability makes it key for distributing our software as well as replicating the environment across various enterprises, ensuring the software works flawlessly.

3.3 Further development

Having finalized the basic components, there are many features that can be enhanced and functionalities that might be worth adding. Consequently, in this section more insight is provided into the possible upgrades that we may incorporate into our project.

In first place, a potential improvement involves the use of tools such as Grafana and Prometheus. Grafana would provide a very comprehensible user interface to view the monitored data

Following that, another enhancement could involve integrating a trained machine learning algorithm that distinguishes between a potential trespasser and authorized workers of the enterprise. Subsequently, we could fortify the security of the robots by implementing authentication and authorization mechanisms to control the access between the server and the robotic units.

Lastly, another improvement involves enhancing the maneuverability of the robots by making a more sophisticated algorithm. This algorithm would enable the robots to compute the optimal path for controlling the selected area with precision. Additionally, it could have a sensor that would prevent collisions improving safety and efficiency.

3.4 Potential risks

The following list aims to outline potential setbacks that the team might encounter or implementation features that if, poorly managed, could result in a complete system failure or significant damages.

- `Feeble security`
  Inadequate security of measures or a poor implementation can result in the system being breached. Aside from loss of data, the biggest issue would be remote hackers having access to mobile robots which have cameras and sensors attached, as they could provide insight into the perimeter and its operations.

- `Imprecise machine learning model`
  Not detecting trespassers makes the system unreliable and might result in lawsuits. In other terms, no one wants an alarm that does not activate when it matters most.

- `Connectivity and protocol issues`
  The hardware might be incompatible with certain protocols or limit the bandwidth. Hence some data or sensor might not be able to be sent or in lower rates.

- `Incompatibility`
  Although there is always a previous check before implementation, sometimes some features are incompatible with one another, which in turn results in having to discard that feature or start from scratch with a new one.

- `Deadlines`
  There is a limited amount of time and a lot of tasks to complete. Therefore, some functionalities will have to be discarding or modified according to the state of the project and the time available. This project has

been designed with "scalable work" in mind, meaning that its scope can be adjusted depending on the work load[3].

4 Cost analysis

There are many adjustments to be made, so this section does not aim to provide a precise cost analysis. However, it is still paramount to have an estimate of the costs. In consequence, the following section will analyze the potential expenses of the entire project:

Item	**Units**	**Cost (€)**
Lichee Pi 4A (16 + 128GB) [5]	1	222.17
Temperature & humidity sensor [6]	1	6.49
Speed sensor [7]	1	3.88
USB Camera [5]	1	9.29
GNSS/GPS Module [8]	1	12.18
3D Printer filament [9]	1	30.49
Hosting services	1	*free*
Engineer salary (2 month equivalent) [10]	4	24579.5
Total	-	24567.32

Table 1: Estimated cost of the project [own compilation].

Table 1 provides some insight into how costly the 2 month development can be. Please note that it is a very basic approach and is not in detail, as it lacks additional components such as electricity, cables, real hosting services provider (the FIB one is provided free of cost)... Nonetheless, it is useful in order to see an approximation.

5 Organization

5.1 Team

The team is comprised of 4 members, all of whom study Informatics Engineering at UPC. While work packages will be assigned individually, each

[3]Completing the basic tasks is considered a success and the project completed, the rest are just improvements on an already accomplished result.

member will also hold a managerial role, defining the scope of their responsibilities.

- Joan Llonch Majó - Director of Web Development
  3^{th} year student majoring Information Technologies.
- Luis Jesús Valverde Zavaleta - Head of Backend Development
  3^{th} year student majoring Computer Engineering and Information Technologies.
- Guillermo Vidal Sulé - Hardware Chief Architect
  4^{th} year student majoring Information Technologies.
- Oriol Vilella Jam - Chief Mobile Development Officer
  3^{th} year student majoring Information Technologies.

5.2 Work packages

The workload will be divided into multiple work packages in order to better organize the team members. Notably, they will not be divided with much detail, as it would result in an egregious amount of tasks. Hence, each work package represents a set of tasks which are related (for example: all functionalities require some testing, but instead of making a work package for every single one of them, it will all be included in one).

1. `WP1 - Mobile application UI`
   Objectives - Develop a user-friendly and highly intuitive interface.
   Description - Craft an aesthetically pleasing and intuitive mobile application with the Flutter framework. It should be available for both Android and iOS. Its focus is on the designing part of the application, not the most complex functionalities.
   Expected outcome - Consistent and presentable UI which is somewhat intuitive.

2. `WP2 - Website UI`
   Objectives - Develop a user-friendly and highly intuitive website.
   Description - Using a planned set of tools that effectively combines each other so as to build a welcoming website. It involves carefully choosing these tools, learning how to use them and developing the final

product.
Expected outcome - A website which can be interacted with and that follows interface design guidelines.

3. `WP3 - Database`
   Objectives - Making a safe, manageable and scalable database.
   Description - Databases are the backbone of backend development. This task will involve designing its tables, fields and deciding which are the most optimum tools. Ensuring it is supported with a robust security will also be an integral part of the work package.
   Expected outcome - The expected outcome for the database work package is a fully functional and optimized database system designed and implemented according to project requirements.

4. `WP4 - Backend integration`
   Objectives - Integrate the previously developed database with the mobile and web application.
   Description - Connect the frontend to the backend using a programming language, such as PHP. While PHP is mentioned, another alternative will be chosen, as PHP is considered outdated and gradually falling into disuse.
   Expected outcome - Having both UIs being able to interact with the storage, either by providing data visualization or making *writes*.

5. `WP5 - Autonomous robot`
   Objectives - Build an autonomous robot.
   Description - Integrating the multiple components of an autonomous robot in order to make an autonomous robot. It includes selecting the sensors, designing an optimum distribution, 3D printing the multiple parts and coding its firmware. Notably, its degree of intelligence will not be a top priority, it can be further improved in the future.
   Expected outcome - A robot that has a few basic move commands and is able to read data from a set of sensors.

6. `WP6 - Robot-API interconnection`
   Objectives - Send and receive data from the robot.
   Description - Communication is paramount for the integration of the hardware and software components. Firstly, the robot must be able to communicate the input read from its sensors. On the other hand,

sending it the route it must follow is also needed in order to implement its autonomous features.
Expected outcome - Being able to send and receive data from the robot, at the very least.

7. `WP7 - Testing`[4]
   Objectives - Ensure that all features work accordingly.
   Description - Write a set of devised set of tests, perform them and act based on their results. It includes individual tests on each functionality and integration ones.
   Expected outcome - Fair amount of bugs are expected, but they are also expected to be resolved.

8. `WP8 - Documentation`
   Objectives - Producing a reliable and comprehensible documentation.
   Description - Redacting the multiple documents that encompass the various functionalities of the final product. It should be comprehensible and coherent, having a consistent flow. The online LaTeXtool called Overleaf [11] will be used in order to generate it.
   Expected outcome - Multiple documents that effectively convey the results of the project.

1.

[4]There will be specialized tests during the whole development process, but it is not feasible for each one of them to have a particular task. Hence, this work package will include the whole testing.

5.3 Package assignment

Nombres / Work Package	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8
Joan Llonch Majó		R		C			C	C
Luis Jesús Valverde Zavaleta			R	C		C	C	C
Guillermo Vidal Sulé					R	R	C	R
Oriol Vilella Jam	R			R			R	C

Table 2: Work packages assigned to each member, being either responsible (R) or contributor (C) [own compilation].

5.4 Gantt diagram

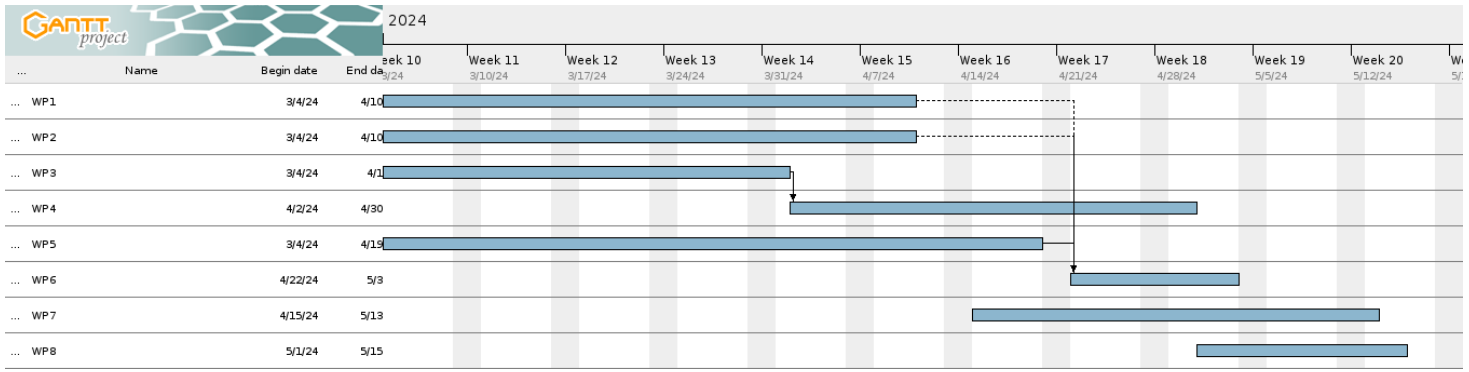

Figure 5: Gantt diagram generated using Ganttproject [12]

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