Project title:

Enhancing Remote Inspection through the Development of an Unmanned Ground Robot with Mecanum Wheels

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Acronyms

AI Artificial Intelligence.

API Application Programming Interface.

BERT Bidirectional Encoder Representations from Transformers.

BI Business Intelligence.

GPT Generative Pre-trained Transformer.

IoT Internet of Things.

LLM Large Language Model.

LM Language Model.

NLP Natural Language Processing.

SAP System Analysis Program.

VPA Virtual Private Assistant.

VR Virtual Reality.

Chapter 1

Project Framework

Introduction

In this chapter, I will provide an overview of the project I worked on during my internship. Firstly I will introduce the organization that hosted my internship and explain their role in the project, next I will describe the background and context of the project, including the problem it aimed to solve and the target audience. After that, I will outline the specific objectives that were set for me during the internship. Finally, I will discuss the methodology that I used to approach the project, including any frameworks, tools, or techniques that were employed.

1.1 AVAXIA Group

In the following segment, we will present AVAXIA Group, the company that graciously hosted this project, and discuss its hierarchical structure as reflected in its organizational chart and the distribution of roles. This in-depth look will provide a clearer understanding of the company's capabilities, and the significant role it plays within its industry.

1.1.1 Company Overview

AVAXIA Group is a technology consulting firm that holds an esteemed position in the international market. Headquartered in Dubai, AVAXIA has a far-reaching global footprint, with additional offices stationed in Japan and Tunisia. This strategically presence allows AVAXIA to serve a diverse clientele effectively and to maintain a pulse on emerging technological trends across the world.

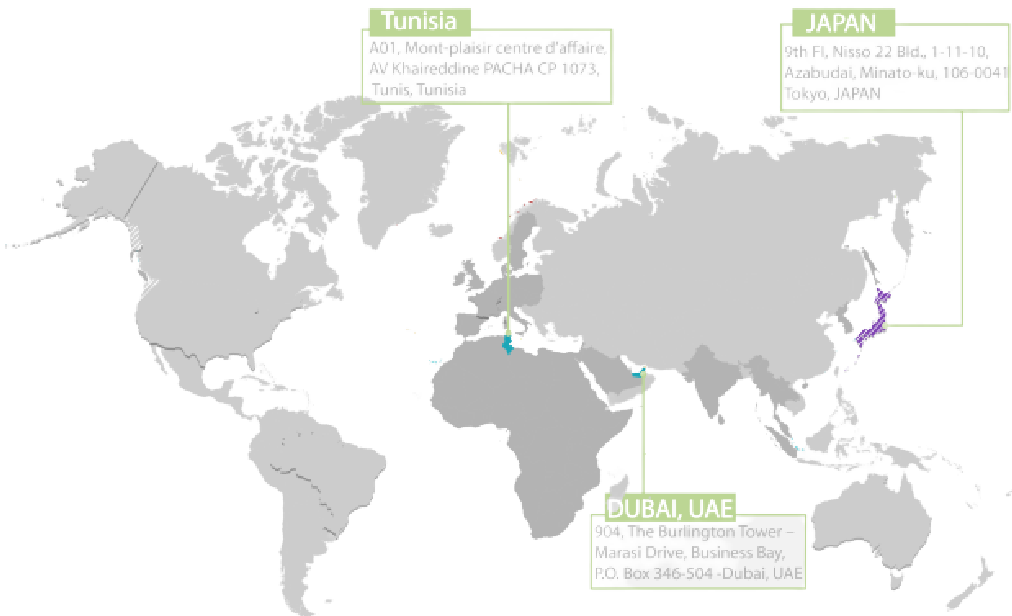

Figure 1.1: AVAXIA Group offices.

This logo serves as the visual identity for the Avaxia Group:

Figure 1.2: AVAXIA Group Logo.

1.1.2 Company Presentation

Avaxia Expertise and Services:

Avaxia Group provides a suite of services, including:

- **Systems Integration**: Avaxia Group offers systems integration solutions focusing on data integration and management. This includes application integration and API Development and Management, utilizing tools such as Dell Boomi Atmosphere and NIFI data flow management.

- **Business Intelligence and Big Data**: The firm offer services such as data capturing, data modelling, data discovery, online analytical processing, data visualization, and predictive analytics. Using industry-leading platforms like SAP BW, Business Object, and Big Data Management tools such as Hadoop.

- **SAP Technical Expertise**: Avaxia Group provides a suite of SAP related services, including infrastructure management, performance optimization, tuning, landscape architecture design, system installation, configuration, upgrade, troubleshooting, and incident management. They also offer landscape auditing to ensure system stability and performance.

- **Functional Consultancy**: Avaxia assists with business solution designs for new deployments of SAP functional modules. Their services include end-to-end process analysis, re-design, optimization, and functional deployment management and test planning (fit-gap, design, UT, etc).

- **Customized Software Solutions**: In addition to pre-packaged solutions, Avaxia Group can design and build customized software solutions.

- **R&D Manager**: Avaxia Group stays ahead of the curve by leveraging emerging technologies to provide innovative solutions. This includes the use of machine learning, robotics, augmented reality, and the Internet of Things (IoT).

1.1.3 Organizational Chart

As previously stated, AVAXIA is present in three different countries and operates with a geographical hierarchical structure, each of its regional branches, is managed by a dedicated country manager.
Branches operate with a significant degree of autonomy, each with its own set of functional departments, team leaders of these departments report to their respective manager.
In addition, Avaxia employs cross-functional teams span across regions from various functional departments working together on specific projects or responsibilities that have a company-wide impact.

This structure facilitates effective collaboration and communication to ensure that work is well-organized within each subsidiary. The figure below shows the organizational chart:

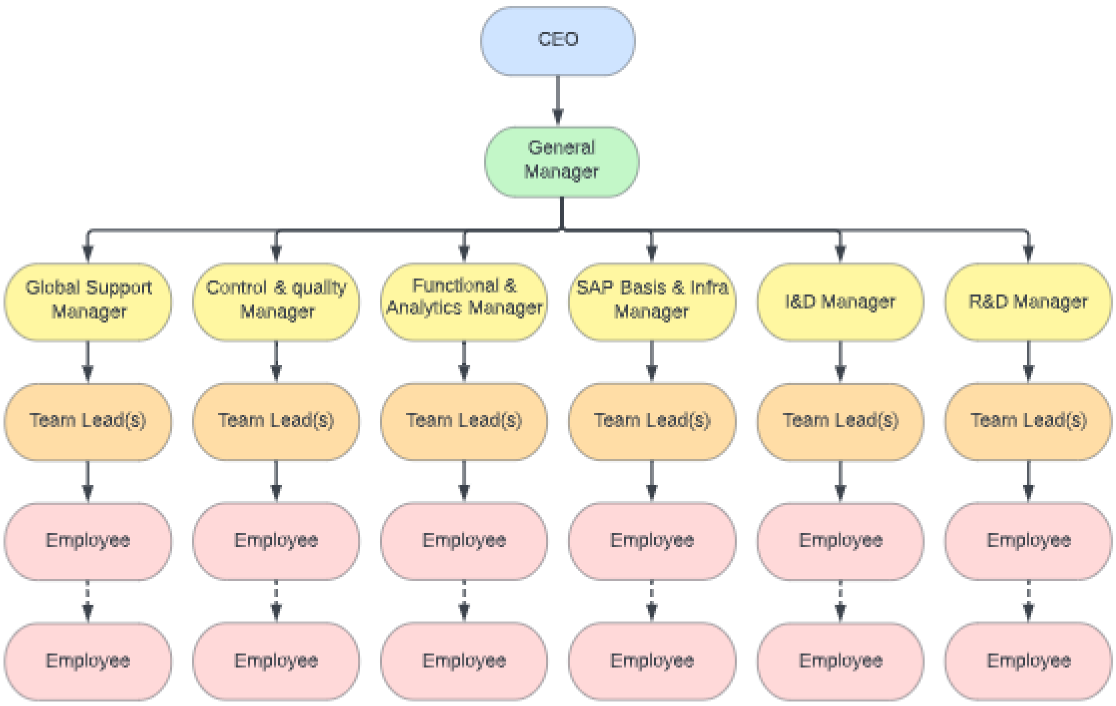

Figure 1.3: Organizational Chart.

As we can see, there is a total of six managers supervised by a general manager, which handles coordination, for the six managers, let's take a further look in to their roles:

- **General Support Manager**: Overseeing the service department team, which includes handling customer service interactions, upgrades, reports etc...
- **Control and Quality Manager**: Monitoring the staff and steps involved in production processes and ensuring that products meet high-quality standards and are ready for production.
- **Functional and Analytics Manager**: leading a team in performing high-level business analyses and developing analytical solutions to improve the company's operating performance.
- **SAP Basis and Infrastructure Manager**:

  is responsible for the operation/ administration of NTUC SAP systems.
- **I&D Manager**: Planning, executing, and managing the integration of new applications into existing systems and software throughout the company.
- **R&D Manager**: leading the research, planning and implementation of new programs, services and products.

1.2 Project Context

This project was conceived and executed as an End-of-Studies project, marking the culmination of my academic journey in pursuit of an engineering degree. Hosted by AVAXIA Group, which provided an encouraging environment for innovation and practical application.

The project's fundamental objective was to optimize the process of remote inspection and monitoring procedures.

1.2.1 Problem Statement

Remote inspection and monitoring play a crucial role in various industries, including manufacturing, infrastructure inspection, construction, and hazardous environments.

Traditional methods often involve human operators physically entering these spaces, which can be time-consuming, expensive, and potentially dangerous.

This viewpoint led to the suggestion for developing a robust, efficient, and sophisticated POC of an unmanned ground robots capable of navigating indoor environments, this envisioned technology would allow for seamless and risk-free monitoring, revolutionizing the way inspections are conducted in various environments.

1.2.2 Background and Motivation

The rapid advancements in robotics, sensing, and communication technologies have paved the way for the development of unmanned ground robots capable of navigating indoor spaces.

These robots offer the potential to automate processes, reducing human intervention and associated risks.

The motivation behind this project lies in creating a versatile and agile robot that can efficiently operate by harnessing the capabilities of mecanum wheels, which enable omnidirectional movement.

1.2.3 Project timeline

The project's timeline spanned six months from January 16th to June 15th of 2023, this period was marked by intensive research, design, development, and testing stages, each playing a critical role in the successful completion of the project. The project provided an opportunity to apply the knowledge acquired throughout my studies and marked a significant milestone in my educational and professional development.

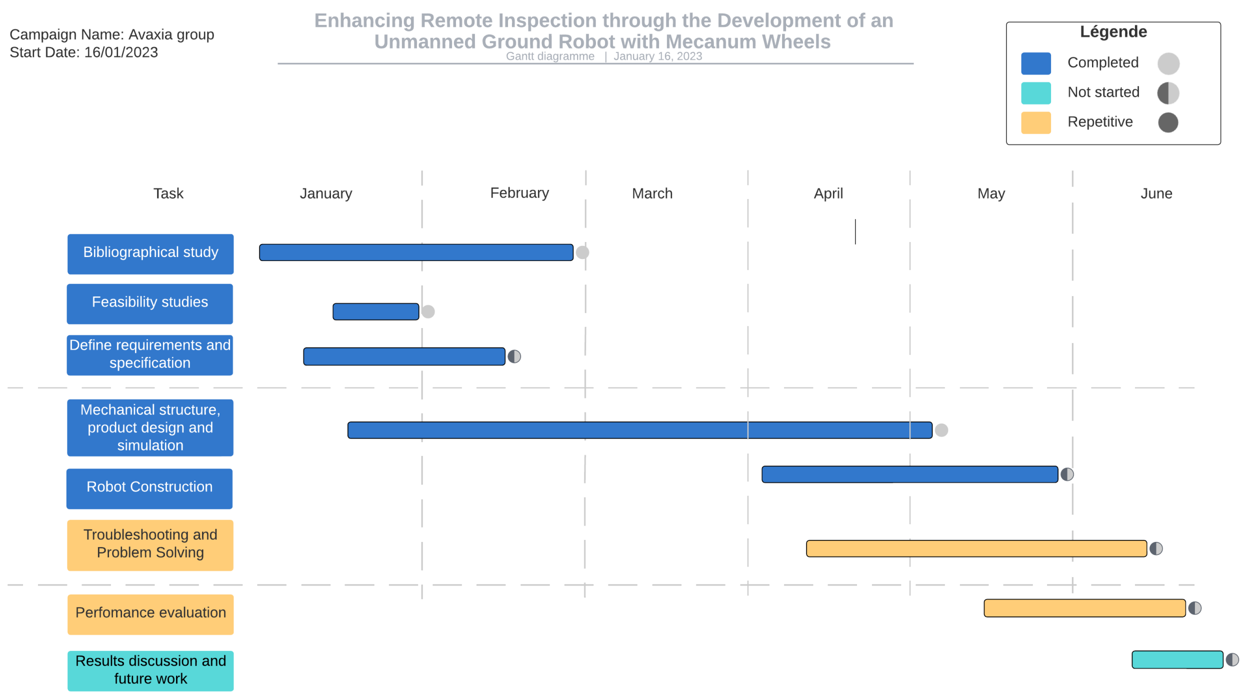

Figure 1.4: Gantt diagramme.

1.2.4 Methodology

In order to achieve the outcomes presented in this report, a project management methodology was crucial.

Therefore, we made a deliberate decision to adopt the lean startup methodology as our framework for developing a Minimum Viable Product (MVP). This chosen approach is designed to expedite product development cycles and determine the feasibility of a proposed business model. It accomplishes this by effectively minimizing overhead costs and fostering adaptability in response to changes. This methodology emphasizes the importance of conducting iterative experiments, gathering feedback, and making data-driven decisions to ensure efficient resource allocation and maximize the potential for success.

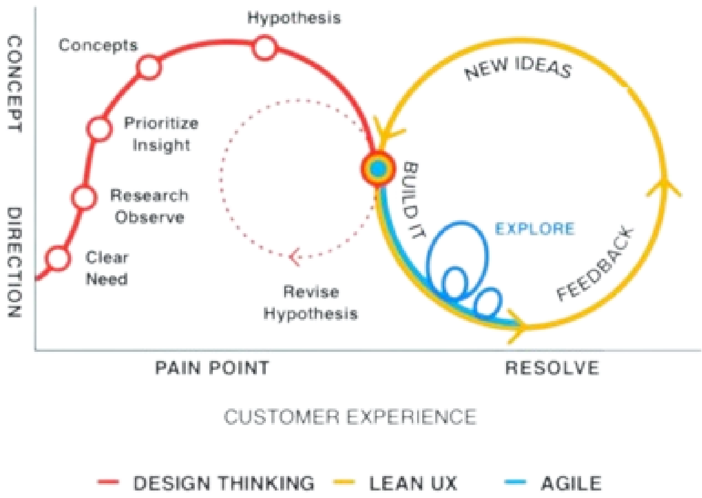

Figure 1.5: design-thinking-lean.

The primary objective is to enable rapid validation of ideas, identify potential obstacles early on, and promote an environment of continuous improvement.

By adopting the lean startup methodology, we were able to optimize our operations, remain nimble in the face of evolving circumstances, and ultimately achieve the desired outcomes outlined in this report.

Conclusion

Throughout this chapter, we've gained insights into the project's context, its objectives, and the host company, including an exploration of their primary areas of focus.The progression of this project calls for an initial theoretical study which will be discussion in the next chapter.

Chapter 2

Theoretical study

Introduction

Recent years have seen significant advancements in natural language processing (NLP) and large language models (LLMs), driven by the development of transformer-based architectures such as BERT and GPT. These models have achieved state-of-the-art performance on a range of NLP tasks. In this chapter, I will talk about the classic tools and methods used to approach NLP tasks and then learn more about Transformers, how they reshaped the field of language processing and why it is a crucial component in this in the development of this project.

2.1 History and Evolution

2.2 Mobile Robot Platform Overview

2.2.1 Definition of terms

2.2.2 Types of Mobile Robot Platforms

2.3 Robot Design and Components

2.3.1 Workspace Criteria

2.3.2 Robot Platform Selection

2.3.3 System Architecture

2.3.4 Sensor Suite Integration

2.3.5 Power and Energy Management

2.4 Mecanum Wheel Technology

2.5 Scope and Limitations

Conclusion

Chapter 3

Kinematics and Dynamics of a four-wheeled mobile robot with Mecanum wheels

Introduction

mobile robot with four Mecanum wheels. For such a system the kinematical rolling conditions lead to non-holonomic constraints. From the framework of non-holonomic mechanics Chaplygin's equation is used to obtain the exact equation of motion for the robot. Solving the constraint equations for a part of generalized velocities by using a pseudoinverse matrix the mechanical system is transformed to another system that is not equivalent to the original system. Limiting the consideration to certain special types of motions, e.g., translational motion of the robot or its rotation relative to the center of mass, and impose appropriate constraints on the torques applied to the wheels, the solution obtained by means of the pseudoinverse matrix will coincide with the exact solution. In these cases, the constraints imposed on the system become holonomic constraints, which justifies using Lagrange's equations of the second kind. Holonomic character of the constraints is a sufficient condition for applicability of Lagrange's equations of the second kind but it is not a necessary condition. Using the methods of non-holonomic mechanics a greather class of trajectories can be achieved.

3.1 Geometric Representation

This paper relates to mechanics of wheeled locomotion is the understanding of the physical interaction between the wheels and the environment , the motion of systems with so-called Mecanum wheels, as a special class of omnidirectional wheels, In many cases the Lagrange equation of second kind is the selected tool, which is correct applicable for holonomic systems. In this article we consider the classical kinematic constraint, involving point contact and rolling without slipping.

There are more complex models of rolling bodies on the surface, taking into account the contact spot, the distribution of normal pressure forces on the contact spot and rolling resistance.

3.2 Kinematics

3.2.1 Model of a Mecanum wheel

3.2.2 Kinematic constraint equations

3.3 Dynamic Models

Conclusion

Chapter 4

Mechaincal design, Work And Implementation

Introduction

this project.

4.1 Sequential design process

4.2 General dimensions

4.2.1 black box analogy

4.2.2 robot shape

4.3 Chassis and materials

4.3.1 sheet metal

4.3.2 weldment

Chapter 5

Control Systems in Omni-directional Robotic Vehicle with Mecanum Wheels

General Conclusion

Bibliography