Dedication

Acknowledgement

Abstract

Keywords:

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Glossary of Acronyms

- **CAN** Controller Area Network
-

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General Introduction

The latest events of the current decade have highlighted the challenges that manufacturers, suppliers, and end customers face during fluctuations in logistics and supply chain processes. Living in a VUCA world—Volatile, Uncertain, Complex, and Ambiguous—requires us to continuously adapt to changes and anticipate future events by preparing our developed environments and scaling our solutions. Simultaneously, it is crucial to maintain high standards that ensure productivity, enhance work safety, and optimize ergonomics.

In this context, the primary objective of intralogistics is to optimize, integrate, automate, and manage internal logistical flows of material and information within distribution centers, warehouses, or manufacturing plants. This subfield focuses on increasing operational efficiency by employing new technologies, such as autonomous robots.

Modernizing industrial environments through intralogistics offers significant potential for companies that adopt and adapt to it. However, convincing potential customers of the efficiency and impact of intralogistics robots presents challenges. These limitations include high training and implementation costs, changes to work routines, and the need for space and process adaptations.

A recent study from CBRE, the world's largest real estate services provider, revealed that European industrial and logistics investments increased by 16% in Q1 of 2024 compared to Q1 of 2023. Despite this, many warehouses are old, repurposed buildings that are unorganized due to the nature of their daily tasks. These brownfield warehouses are expensive to maintain and digitalize but represent ideal grounds for developing and utilizing fully autonomous systems. Unlike AGVs, autonomous vehicles possess the intelligence and capability to plan and execute their plans efficiently. They are designed to adapt to uneven terrains and unorganized working environments given the revolutionary technologies that they hold.

In this context, STILL, a KION group company, has been developing smart intralogistics solutions since its establishment more than a 100 years ago, successfully integrating automation into logistics. STILL offers a wide variety of products that cater to industries ranging from food retail to automotive manufacturing and chemical sectors. Their solutions address various customer challenges, such as reaching high shelves, order picking, palletizing, fleet management, and providing consulting services. Trusted by leading German companies like Siemens, STILL's products and services are renowned for their reliability and efficiency.

The STILL Autonomous Robots department focuses on developing and enhancing smart vehicles. These autonomous robots, with minimal cost-effective input from the warehouse environment, can perceive their surroundings, estimating their positions, efficiently planning future tasks, controlling their movements to reach destinations, executing desired actions, and making corrections if necessary. This focus on smart, autonomous vehicles demonstrates STILL's commitment to pushing the boundaries of intralogistics and automation.

In light of this, this thesis aims to contribute to the process of palletizing by optimizing a local path planning approach applied in the warehouse's stations near the shelves or spots where pallets are located for picking or in free placing areas. The developed approach seeks to plan the near-field path optimally while simultaneously avoiding obstacles.

The objective is to create predictable, repeatable, and explainable vehicle behaviors, demonstrating the autonomous vehicle's ability to generate effective solutions tailored to each specific scenario. By focusing on optimal, pattern-based near-field path planning, this thesis addresses the challenge of navigating complex intralogistics environments, ensuring maximum efficiency and safety in operations. This approach not only enhances the vehicle's performance but also showcases the potential of autonomous technology in transforming modern intralogistics.

This work encloses 4 chapters:

- **Chapter 1** gives a deep insight about the host company's structure, activities and products. Then it dives into the project context and it motivations, the studied problematic, the fundamental aspects of the work, the thesis specifications and, the work methodology.
- **Chapter 2** delves into the state of the art of the work area, then goes through a review of the literature that served as a base of the thesis and gave an overview of the existing solutions. Finally, it presents milestones followed in the course of the thesis work.
- **Chapter 3** explains the development steps of the approach: it presents the mathematical aspect of splines and their implementation in robotic path planning, explains the geometric division of the stations into transition zones, discusses the studied path discrimination approaches, and finally it explores the optimization approaches for the local path planning problem.
- **Chapter 4** explicits the steps it takes to implement the developed approach in the RACK framework, test them in the RACK simulation system, then on the automated vehicle, run different test scenarios and states the obtained results.

Chapter 1
Project scope

Chapter 1

Project scope

Introduction

This chapter is reserved to present STILL GmbH as the host company, its organizational structure, the mother company KION group. It will then proceed to describe the range of products that the company produces. The second part is dedicated to explain the problem statement, the motivation behind this thesis, and the project specifications. The final part will emphasize the work methodology adopted to carry out this project.

1 Host company: STILL GmbH

1.1 General information about STILL and KION Group and their vision

STILL GmbH, based in Hamburg, Germany, is a leading manufacturer of intralogistics solutions with 14 locations in Germany and a global sales network spanning 246 locations. Operating under the KION Group, Europe's largest forklift truck manufacturer, STILL boasts over 100 years of experience. The company develops highly efficient, client-tailored products, serving businesses of all sizes with a wide range of forklift trucks—from manually driven forklifts to high-reach trucks and fully automated vehicles—alongside consultancy services and software solutions.

STILL prioritizes smart logistics and energy optimization while maintaining award-winning product quality, catering to industries such as food and retail, automotive, and electronics. Employing over 9,000 people across departments like sales and marketing, research and development, production, mechatronics, and quality assurance, STILL remains at the forefront of intralogistics innovation.

KION Group is one of the global leaders in the fields of industrial trucks and supply chain solutions. It is the mother company of: Linde, Dematic Baoli, OM, Fenwick, and STILL who produce the goods and services of the group as detailed in Figure 1.1.

Present in 4 continents and hiring more than 42000 employees, KION's startegy is to ensure profitable ans sustainable growth while focusing on Automation and robotics deplyment as one of the main leaders of this growth.

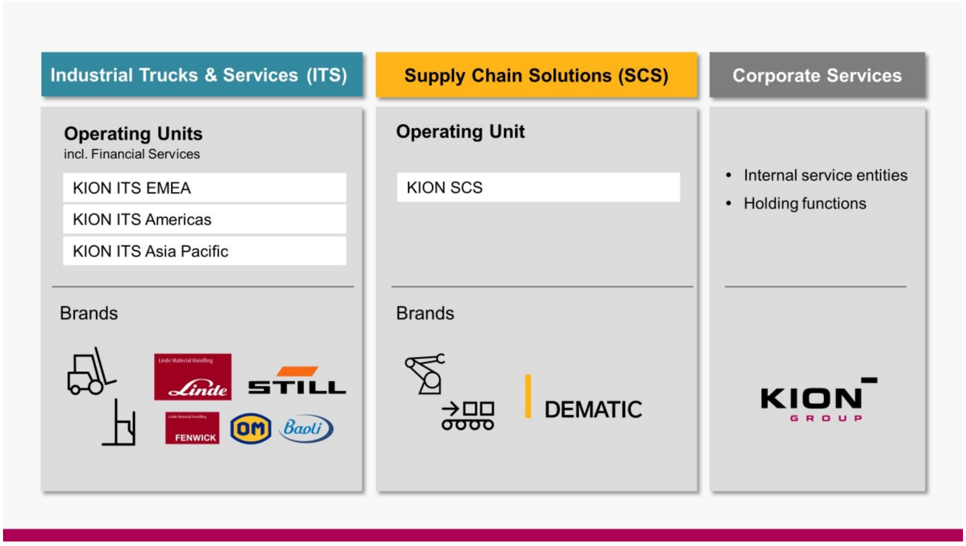

Figure 1.1: KION segment services and companies [1]

1.2 KION Management Hierarchy

The company is composed of departments managing the operations in all companies that are divided by scope of interest like R&D, Management, finances, etc.. Figure 1.2 illustrates the different areas of responsibility of the Executive Board. The Autonomous vehicles team belongs to the Mobile Automation department under CTO.

Figure 1.2: KION Executive Board responsibilities as of 01.2024 [2]

Chapter 2
Design and development of the CAN Bus software

Chapter 2

Design and development of the CAN Bus software

Introduction

Chapter 3
Design and development of the Control Interface

Chapter 3

Design and development of the Control Interface

Introduction

In this chapter, we delve into the heart of the iHEX system's functionality – the Control Interface (CI) software which forms the cornerstone of communication and control, enabling seamless interaction between the MC and the SCs. This chapter presents the design, development, and test of the CI on both the MC and SC and the integration of both of them.

1 Control Interface (CI) on the MC

1.1 Multithreaded architecture:

In the design of the CI on the MC, a multithreaded architecture was adopted to meet the dynamic and concurrent demands of communication, command processing, monitoring, and logging within the iHEX system. The use of multithreading was essential in ensuring a responsive and efficient operation of the control software.

1.1.1 Multithreading need

A fundamental requirement for the Control Interface is its ability to handle multiple tasks simultaneously. The MC must efficiently **manage communication with the server**, **manage communication with the SCs via CAN Bus**, **continuously monitor the health of the CAN network**, and **maintain a log of system activities**. This multifaceted demand necessitates a multithreaded approach to prevent bottlenecks and ensure timely execution.

1.1.2 The <pthread.h> library

Chapter 4
Design and development of Printed Circuit Boards

Chapter 4

Design and development of Printed Circuit Boards

Introduction

In Chapter 4, we dive into the essential process of creating the electronic foundation of the iHEX system—Printed Circuit Boards (PCBs). These PCBs serve as the crucial framework where all the electronic parts of the iHEX system come together, ensuring seamless communication and control. This chapter explores the design, development, and roles of four specific PCB types: Main PCB, IO PCB, LED PCB, and Dock PCB.

1 Architecture

Based on the specifications and the company needs, we designed the global hardware architecture. It is mainly composed of 4 designed PCBs:

- Main PCB is the motherboard that brings the main electronic components of the SC together. Each SC is composed of one Main PCB that is connected directly to an IO PCB.
- IO (Input-Output) PCB mainly ensures connectivity and interaction with the other SCs. It is connected to the Main PCB on one side. On the other side, it is connected whether to IO PCBs of other static SCs or Dock PCBs.
- Dock PCB ensures the interaction and control of the iHEX mobile element newly connected. If it exists, whether in a static or mobile element, it is connected to the SC through the IO PCB.
- LED PCB controls the LED strip. Each LED PCB is part of a SC. It is plugged-in directly on the Main PCB.

General conclusion

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[2] KION group website. URL: https://www.kiongroup.com/en/About-us/KION-at-a-glance/ consulted on 19/08/2024

Annexes