CYPRUS INTERNATIONAL UNIVERSITY

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

DIGITAL TECHNOLOGIES IN INDUSTRY

By

HASHEM VASEGHI

PARFAIT ZAINA NGOI

FELLY NGOY

JUDE KABEMBA

BOIMA FAHNBULLEH

GREGORY MWEMA

OLUTOYE OPEYEMI

February 14, 2025

Nicosia, NORTH CYPRUS

CYPRUS INTERNATIONAL UNIVERSITY

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

DIGITAL TECHNOLOGIES IN INDUSTRY

By

HASHEM VASEGHI

PARFAIT ZAINA NGOI

FELLY NGOY

JUDE KABEMBA

BOIMA FAHNBULLEH

GREGORY MWEMA

OLUTOYE OPEYEMI

February 14, 2025

Nicosia, NORTH CYPRUS

DIGITAL TECHNOLOGIES IN INDUSTRY

By

Hashem Vaseghi	22004087	Electrical and Electronic Engineering
Parfait Zaina Ngoi	22015208	Electrical and Electronic Engineering
Felly Ngoy	22013357	Computer Engineering
Jude Kabemba	22013160	Computer Engineering
Boima Fahnbulleh	22013081	Mechatronics Engineering
Gregory Mwema	22012501	Mechatronics Engineering
Olutoye Opeyemi	22013786	Mechanical Engineering

DATE OF APPROVAL: ....

APPROVED BY:

ASST. PROF. DR. ZİYA DEREBOYLU

Asst. Prof. Dr. ALİ SHEFIK

ACKNOWLEDGEMENTS

We extend our heartfelt appreciation to everyone who contributed to the success of this project. First and foremost, we express our deepest gratitude to **Asst. Prof. Dr. ZİYA DEREBOYLU** and **Asst. Prof. Dr. ALİ SHEFIK** for their invaluable guidance, continuous support, and encouragement throughout the project. Their expertise and insights were instrumental in overcoming challenges and ensuring the project's progress.

We are also grateful to **Cyprus International University** for providing us with the resources and platform to pursue this project. Special thanks to the faculty members of the **Faculty of Engineering** for their technical advice and mentorship, which greatly enriched our learning experience.

Our sincere thanks go to our entire team for their dedication and collaboration. Each member brought unique skills and perspectives, contributing to the successful integration of mechanical, electronic, and software systems. This project would not have been possible without their united commitment and hard work.

We also extend our gratitude to our families and friends for their unwavering support, encouragement, and motivation during the challenging phases of the project.

Finally, we would like to thank the organizers of the Teknofest Aerospace and Technology Festival for providing us with the opportunity to showcase our work and compete in the Digital Technologies in Industry competition.

This project is a testament to the collective effort and support of everyone involved. Thank you all for being part of this journey.

ABSTRACT

The research introduces CIU_Fox as an autonomous guided vehicle (AGV) that develops capabilities to transform factory and warehouse internal transportation operations. The designed AGV features autonomous navigation with a safe lifting capability using obstacle detection and collision avoidance systems for moving loads up to 200 kg. This system combines LIDAR with time-of-flight (ToF) sensors and barcode scanners to create a precise automated navigation system which monitors operations and handles loading duties. The mechanical structure incorporates an aluminum alloy frame together with a scissor-compartment mechanism and NEMA 23 stepper-motor powered differential steering. A Raspberry Pi 4 manages the system through ESP32 modules that run software programs built in Python and C++ within the ROS framework. The robot development followed four sequential stages that led to its physical assembly. Resources limitations required the project team to conduct final stage testing through the Gazebo simulation pipeline instead of building physical components. Coding for path planning alongside obstacle avoidance and load management functions while achieving complete integration of mechanical electronic software system components stands as major accomplishments. The commercial application scope of the AGV remains promising in multiple industrial sectors including manufacturing storage facilities and logistics operations because it shows potential to optimize operational efficiency while decreasing expenses and protecting worker safety. This work illustrates why interdisciplinary teams need to bring innovative solutions to modern industrial design using state-of-the-art technology applications. Research efforts will focus simultaneously on two fronts which include enhancing the AGV's operational excellence while evaluating opportunities to connect it with broader industrial system networks.

ÖZET

Araştırma, fabrika ve depo içi taşıma operasyonlarını dönüştürme yetenekleri geliştiren özerk bir yönlendirmeli araç (AGV) olarak CIU_Fox'u tanıtmaktadır. Tasarlanan AGV, 200 kg'a kadar yük taşıyabilmek için engel algılama ve çarpışma önleme sistemleriyle donatılmış güvenli kaldırma kabiliyetine sahip otonom navigasyon özellikleri sunar.

Bu sistem, operasyonları izleyen ve yükleme görevlerini gerçekleştiren hassas bir otomatik navigasyon sistemi oluşturmak için LIDAR, zaman-uçuşu (ToF) sensörleri ve barkod tarayıcıları birleştirir. Mekanik yapı, alaşımlı alüminyum çerçeve, makaslı kompartman mekanizması ve NEMA 23 step motorla çalışan diferansiyel yönlendirme sistemi içerir.

Sistem, ROS çerçevesinde Python ve C++ ile geliştirilen yazılım programlarını çalıştıran ESP32 modülleri aracılığıyla bir Raspberry Pi 4 tarafından yönetilir. Robot geliştirme süreci, fiziksel montaja kadar uzanan dört aşamalı bir sırayla tamamlanmıştır. Kaynak kısıtlamaları nedeniyle fiziksel bileşenler yerine Gazebo simülasyon ortamında son aşama testleri gerçekleştirilmiştir. Yol planlama, engel önleme ve yük yönetimi fonksiyonlarının kodlanması ile mekanik-elektronik-yazılım bileşenlerinin tam entegrasyonu projenin temel başarıları arasındadır.

AGV'nin ticari uygulama kapsamı, üretim tesisleri, depolama alanları ve lojistik operasyonlar gibi çeşitli endüstriyel sektörlerde operasyonel verimliliği artırma, maliyetleri düşürme ve işçi güvenliğini koruma potansiyeli nedeniyle umut vaat etmektedir. Bu çalışma, disiplinlerarası ekiplerin en son teknoloji uygulamalarını kullanarak endüstriyel tasarıma yenilikçi çözümler getirmesi gerektiğini vurgulamaktadır. Araştırma çabaları, AGV'nin operasyonel mükemmelliğini artırmanın yanı sıra endüstriyel sistem ağlarına bağlanma fırsatlarını değerlendirmek üzere iki paralı hedefe odaklanacaktır.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE
INTRODUCTION

The manufacturing industry is undergoing a digital transformation, driven by advancements in technologies like artificial intelligence, autonomous robots, and the Internet of Things. These innovations aim to enhance efficiency, productivity, and competitiveness in industrial processes. TEKNOFEST's Digital Technologies in Industry Competition challenges participants to design an autonomous guided robot for factory logistics, addressing real-world tasks such as navigation, load handling, and mapping. This report explores the strategies used to overcome these challenges and achieve the competition's objectives. By doing so, it highlights the critical role of digitalization in advancing industrial automation and fostering innovation.

1.1 TEKNOFEST COMPETITION RULES

The following rule apply to the operation of guided robots during the competition:

1.1.1 autonomous operation

The guided robot must perform all tasks autonomously within the specified scenarios, including line-following.

1.1.2 Overload warning

The robot must issue an overload warning if it lifts a load exceeding the specified limit and continue carrying the load only after the weight is reduced below the limit.

1.1.3 Charging task

If the robot's charge level falls below a certain threshold, teams can earn additional points by having the robot autonomously navigate to the charging area and begin charging. Teams must inform the jury in advance if they wish to perform this task, which will be conducted at a time deemed appropriate by the jury.

1.1.4 Obstacle navigation

The robot should autonomously stop at loading/unloading points and navigate around obstacles if they are not removed. Obstacles will be detected by sensors, and the robot must stop at an appropriate distance. If the obstacle remains, the robot should autonomously go around it and complete its tasks.

1.1.5 Qrcode labels

QRCODE labels at loading and unloading positions must be readable by appropriate sensors on the robot.

1.1.6 Control screen (gui)

Teams must prepare a graphical user interface (GUI) that allows them to monitor the vehicle's status and issue commands when necessary. However, interventions via the control panel will incur penalty points.

1.1.7 No manual control

The robot cannot be controlled by joysticks, portable hand controls, phones, or tablets.

1.1.8 Load handling display

The pick-up or dropping of loads must be displayed on the control panel (GUI) using sensors.

1.1.9 Mapping for advanced competitors

Advanced-level competitors are required to map the track. For mapping, advanced teams will be given a specific amount of time after the loaded course is revealed. The teams are expected to map and display the competition area within the allocated time.

Mapping should be performed using devices such as laptops and tablets belonging to the team members at the control desk. Additionally, teams are expected to create a control panel (GUI) that displays competition details such as speed and total task time. The mapping should be detailed, and QRCODE labels should be displayed on the map as they are read.

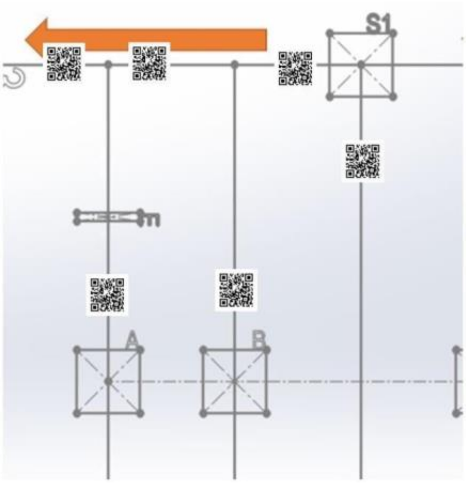

Figure 1.1: QRCODE Layout

1.2 DETAILS OF THE COMPETITION AREA

For the competition, there will be 2 rectangular-shaped representative factory areas of approximately 150 square metres each. These areas will include a track representing the layout of roads and internal logistics roads. Additionally, there will be a separate area where a table is located for each participating competitor team to use. The following details apply:

1.2.1 Power supply

The competition area will have a 220 VAC power supply. A control desk will be located at the edge of the track for the competing team to control their guided robot. At the control desk, 220 VAC voltage will be provided, and each team is responsible for performing AC/DC conversion using their own converter. The highest DC voltage level that can be used is 50V.

1.2.2 Track layout

The track will resemble a factory area with designated pick-up and drop-off points. The distribution of these points may vary for each competing team, as determined by the referees. The track area will consist of two similar sections, allowing two different teams to compete simultaneously.

1.2.3 Sample view of the track

The sample view of the track will be provided separately for reference(fig. 1.3).

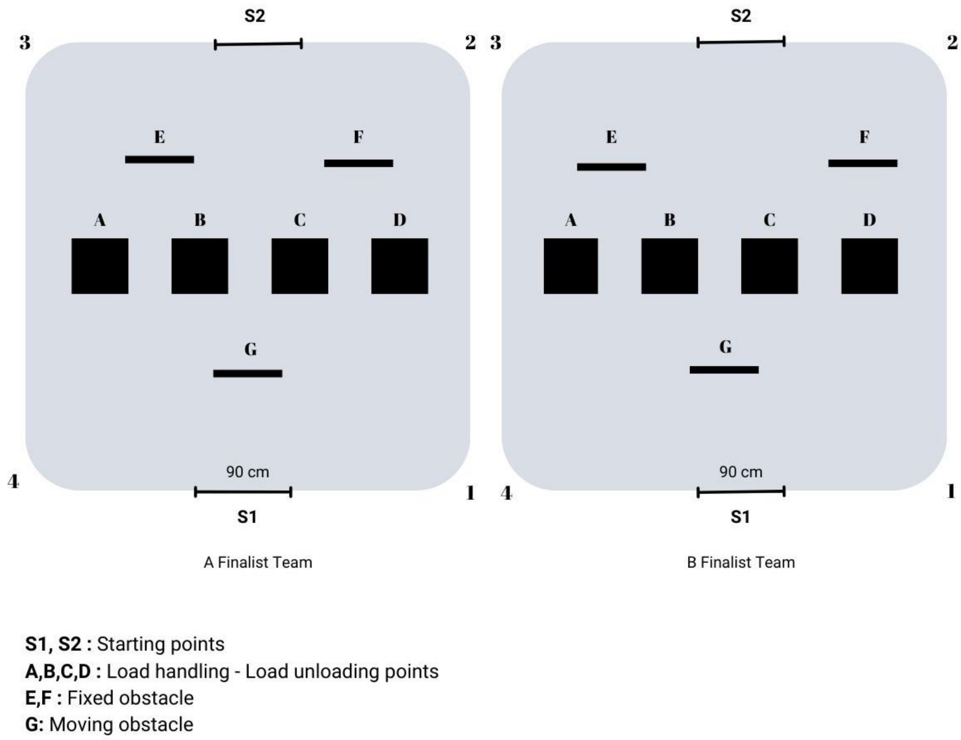

Figure 1.2: Sample Track Area

1.3 LOAD HANDLING ROBOT TECHNICAL SPECIFICATIONS AND LIMITATIONS

The maximum dimensions of the load handling robot are as follows: 1,000 mm in length, 900 mm in width, and 500 mm in height. The dimensions of the load handling robots must not exceed these specified limits. However, when the mechanism used to lift the load platform is operated, the robot may exceed the height limit. The height restriction applies only to the situation where the vehicle is not operating under load.

The maximum load amount that robots must carry is 125 kg. Robots that lift more than 125 kg and do not provide an overload warning will be deemed to have failed to fulfill this task. The competition organization will provide loads with dimensions of 30 cm x 30 cm x 10 cm (fig. 1.3a)and a weight of 25 kg each. These loads will be placed on a platform with a maximum height of 50 cm from the ground)(fig. 1.3b), allowing the robot to easily position itself underneath and lift the load from all directions. The weight of the load platform provided by the competition organization will also be 25 kg.

The positions for load pick-up and drop-off will be defined using QRCODE tags. These tags will ensure precise identification of the designated locations for the robot to perform its tasks.

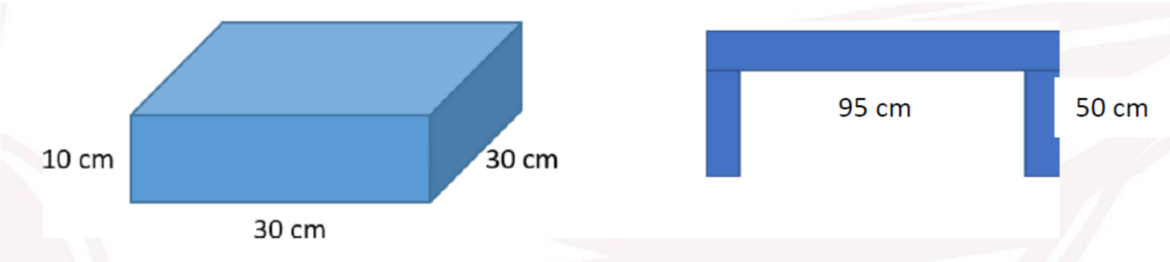

Figure 1.3: Load (a) and platform (b)

1.4 SAMPLE SCENARIO

The robot must first navigate around the corner points according to the scenario type, starting from the initial position without any load, and return to the starting point. During this process, teams are required to complete the mapping task. A total of four unloaded scenarios are illustrated in fig. 1.4.

Following the unloaded navigation, the robot should proceed to point A from the starting point to pick up a load and then continue to point C. Upon reaching point C, the robot must leave the load there and proceed to point D without carrying any load. After arriving at point D, the robot should pick up another load and transport it to point B. Once the load is delivered at point B, the robot must complete the task by returning to the starting point without any load. fig. 1.5 depicts four loaded scenarios, which vary depending on the starting points.

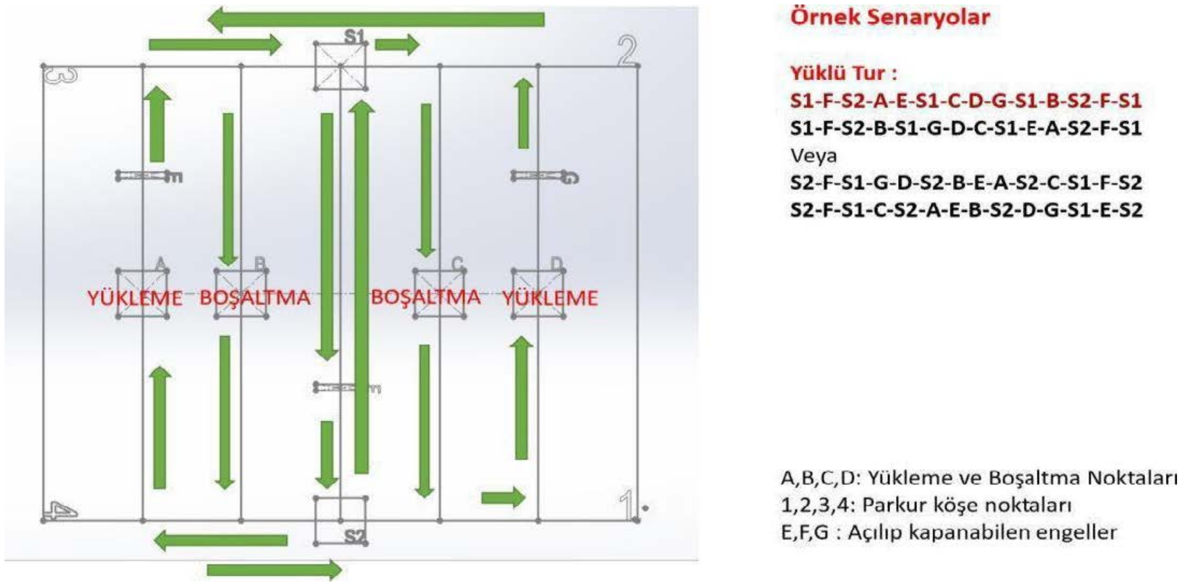

Figure 1.4: Sample Loaded Scenario

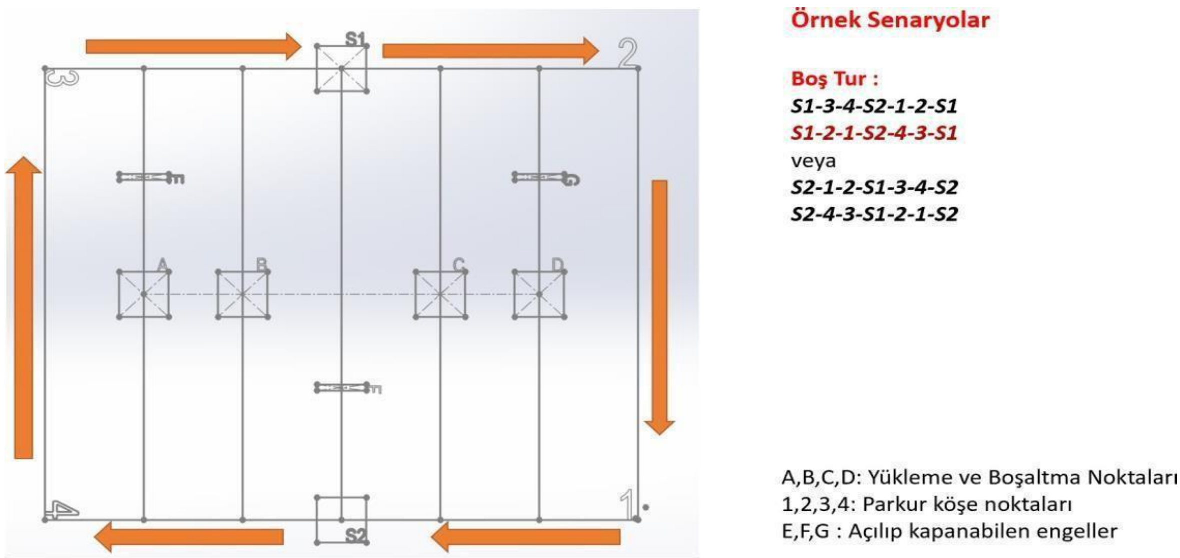

Figure 1.5: Example No Load Scenario

CHAPTER TWO
LITERATURE SURVEY

Today's industries activity have merged with the robotic and automation world and day by day having the precise and betterquality product make the sense of using new technology. Between all types of robot, the AGV (automated guided vehicle) robot has the special place between others and improvement in technology helps this design to grow and become more helpful in various applications. The AGV robot is a programmable mobile robot integrated sensor device that can automatically perceive and move along the planned path [**?**] This system consists of various parts like guidance facilities, central control system, charge system and communication system [**?**].

The initial used and Invention AGV is not clear exactly and was mentioned in different articles and reference for many times but the earliest time of using this system in industries is mentioned in 1950s [**?**] (fig. 2.1) and even mentioned in some reference that the first AGV in the world was introduced in UK in 1953 for transporting which was modified from a towing tractor and can be guided by an overhead wire [**?**].

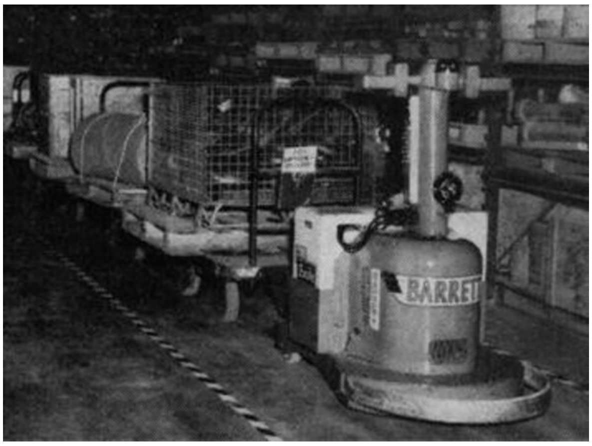

Figure 2.1: one of the Old AGV picture

AGVs are widely applied in various kinds of industries including manufacturing factories and repositories for materialhandling. After decades of development, it has a wide application due to its high efficiency, flexibility, reliability, safety and system scalability in various task and missions. AGV operates all day long continuously that cannot be achieved by human workers. Therefore, the efficiency of material handling can be boosted by having the collaborating task with number of AGV . In this case, administrator can enable more AGVs as the system is extensible. AGV has capability of collision avoidance and emergency braking, and generally the running status is monitored by control system so that reliability and safety are ensured. Generally, a group of AGVs are monitored and scheduled by a central control system. AGVs, ground navigation system, charge system, safety system, communication system and console make up an AGV system. [**?**]. This report examines the design aspects and considerations for this type of robot, providing readers with key insights into the technologies commonly utilized in this field.

2.1 KEY TECHNOLOGIES IN AGV DEVELOPMENT

2.1.1 Navigation systems

Modern AGVs employ various navigation techniques, including:

- **Laser-guided navigation**: Uses LiDAR sensors to detect reflectors and map the environment.
- **Vision-based navigation**: Utilizes cameras and computer vision algorithms for path planning and obstacle avoidance.
- **Inertial navigation**: Relies on gyroscopes and accelerometers for position tracking.
- **Natural feature navigation**: Uses environmental features (e.g., walls, racks) for localization without predefined markers.

2.1.2 Localization and mapping

Simultaneous Localization and Mapping (SLAM) algorithms are widely used for real-time environment mapping and AGV positioning. SLAM integrates data from sensors like LiDAR, cameras, and ultrasonic sensors to create accurate maps.

2.1.3 Path planning and control

AGVs use algorithms such as A*, Dijkstra's, or Rapidly-exploring Random Trees (RRT) for optimal path planning. Advanced control systems ensure smooth motion and collision avoidance.

2.1.4 Communication and coordination

Multi-AGV systems rely on wireless communication protocols (e.g., Wi-Fi, 5G) and centralized or decentralized control strategies to coordinate tasks and avoid conflicts.

2.2 APPLICATIONS OF AGVS

AGVs are widely used in various industries:

- **Manufacturing**: For transporting raw materials, components, and finished products.
- **Warehousing**: For order picking, inventory management, and goods transportation.
- **Healthcare**: For delivering medical supplies and meals in hospitals.
- **Agriculture**: For automated harvesting and crop monitoring.

2.3 CHALLENGES AND LIMITATIONS

Despite their advantages, AGVs face several challenges:

- **High Initial Costs**: The development and deployment of AGVs require significant investment in hardware and software.
- **Dynamic Environments**: AGVs struggle in unstructured or highly dynamic environments with moving obstacles.
- **Battery Life and Charging**: Limited battery capacity and the need for frequent charging can disrupt operations.
- **Safety Concerns**: Ensuring safe interaction with human workers and other equipment is critical.

2.4 RECENT TRENDS AND INNOVATIONS

- **Integration with AI and Machine Learning**: AGVs are increasingly leveraging AI for predictive maintenance, adaptive navigation, and task optimization.
- **Collaborative AGVs**: Development of AGVs that can work alongside humans (cobots) is gaining traction.
- **Swarm Robotics**: Research is exploring the use of multiple AGVs working collaboratively in a decentralized manner.

- **Autonomous Mobile Robots (AMRs)**: AGVs are evolving into AMRs with higher autonomy and flexibility.

2.5 NOTABLE RESEARCH AND CASE STUDIES

- **Research on SLAM for AGVs**: Studies have focused on improving SLAM algorithms for better accuracy and robustness in dynamic environments.
- **Energy-Efficient AGVs**: Research has explored energy-saving techniques, such as regenerative braking and optimized path planning.
- **Human-AGV Interaction**: Studies have investigated intuitive interfaces and safety protocols for human-AGV collaboration.