ÇANKAYA UNIVERSITY
FACULTY OF ENGINEERING
COMPUTER ENGINEERING DEPARTMENT

Project Report

Version 1

CENG 407

P202308
Automated Gıided Vehicle (AVG)

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Abstract

Used to transport bulky and heavy items in the warehouse. We started this project to increase such Industry 4.0 examples and produce such products in our country. To ensure the safe operation of AGV, this article introduces a visual surveillance system by taking full advantage of it. Measurements from forward and downward cameras. Especially the AGV we will use in the front camera estimates their position and attitudes by following landmarks in the detected environment. advanced image sequences. It also allows us to use the mapping created by the tool with the ROS software. Also, downward camera. It is used to detect QR codes fixed to the ground. The AGV poses in the absolute reference frame. The QR we detect leads to the most accurate result with the virtual shipping area we create ROS software and image processing

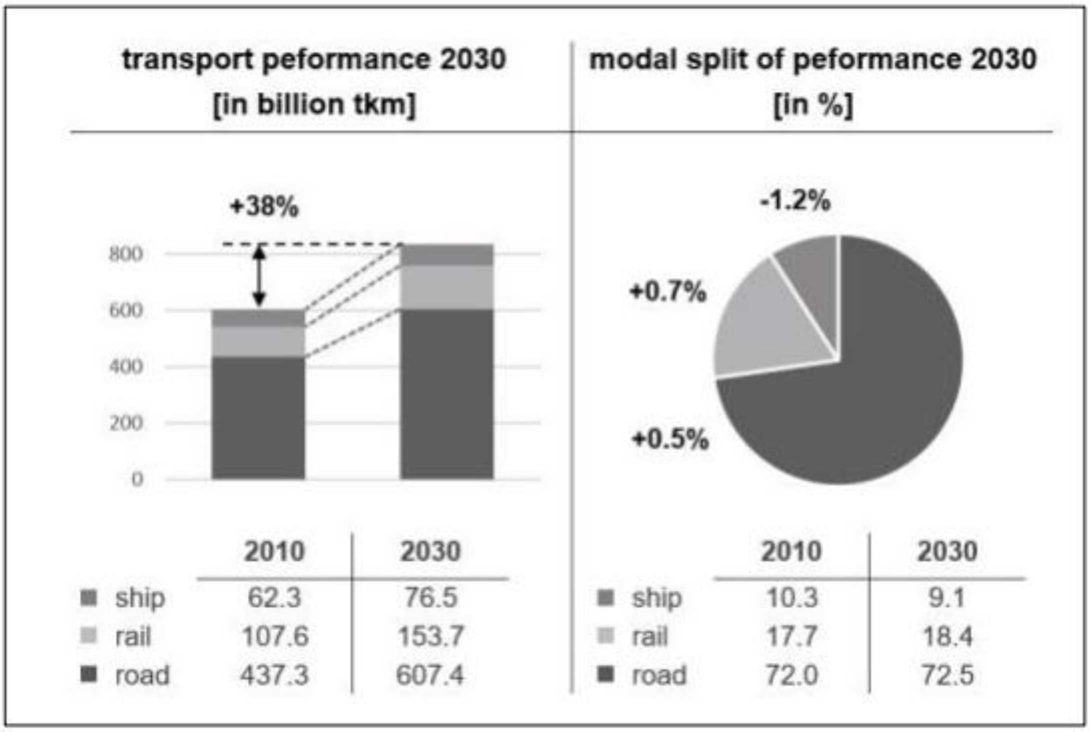


Fig. 1 freight transport performance [1] [2]

Özet:

Depodaki hacimli ve ağır eşyaların taşınmasında kullanılır. Bu tür Endüstri 4.0 örneklerini artırmak ve bu tür ürünleri ülkemizde üretmek için bu projeye başladık. AGV'nin güvenli çalışmasını sağlamak için bu makale, görsel gözetim sisteminin tüm avantajlarından yararlanarak tanıtmaktadır. İleri ve aşağı kameralardan alınan ölçümler. Özellikle ön kamerada kullanacağımız AGV, tespit edilen ortamdaki yer işaretlerini takip ederek konum ve tutumlarını tahmin eder. gelişmiş görüntü dizileri. Ayrıca aracın oluşturduğu haritalamayı ROS yazılımıyla kullanmamıza da olanak tanır. Ayrıca aşağı doğru kamera. Yere sabitlenen QR kodlarını tespit etmek için kullanılır. AGV mutlak referans çerçevesinde poz verir. Tespit ettiğimiz QR, oluşturduğumuz sanal gönderim alanı ROS yazılımı ve görüntü işleme ile en doğru sonuca ulaştırıyor.

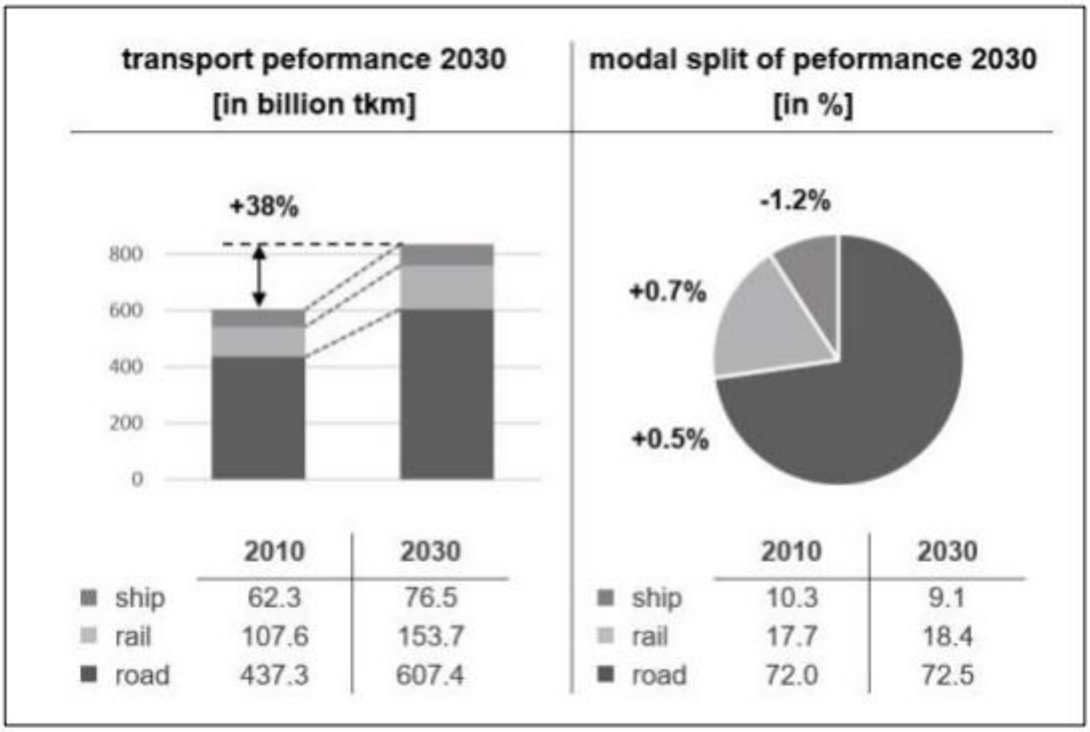


Fig. 1 freight transport performance [1] [2]

1. What is the Transporter rover?

In the dynamic realm of autonomous warehouse robotics, our innovative project stands as a beacon of technological advancement, seamlessly integrating cutting-edge functionalities to redefine the intricacies of logistics operations. Our autonomous warehouse robot is not merely a machine but a transformative solution designed to navigate the complexities of the warehouse environment, locate products, and orchestrate their efficient delivery to predetermined destinations. This embodiment of advanced technology and operational precision sets a new standard for warehouse management. At the heart of our autonomous warehouse robot lies a sophisticated line-following mechanism, meticulously engineered to trace predefined paths with unparalleled precision. This mechanism not only ensures the seamless pickup of products but also orchestrates their transportation with a choreographed finesse to designated delivery points. The synergy between technology and operational efficiency is the cornerstone of our project, reshaping the landscape of warehouse management. Upon the successful completion of a delivery mission, our autonomous warehouse robot engages in a strategic decision-making process. Dynamically calculating the nearest charging and parking points based on its current location, the robot showcases adaptability through advanced algorithms. The subsequent journey to these calculated points is guided by a state-of-the-art line tracking management system, allowing the robot to navigate effortlessly, even in the face of dynamic obstacles. The adaptability of our robot is further underscored in its response to obstacles, whether they are fixed structures or dynamic entities. In such scenarios, the robot exhibits a sophisticated level of agility, executing strategic maneuvers or temporarily halting until the obstruction is cleared. This proactive approach not only ensures the safety of transported goods but also contributes to the overall safety and efficiency of the warehouse environment. As our autonomous warehouse robot reaches the parking point, another layer of intelligent decision-making unfolds. Employing advanced image processing, the robot calculates the most suitable parking location, optimizing spatial utilization within the warehouse. This fusion of technology and efficiency ensures a seamless orchestration of operations, enhancing the overall warehouse management ecosystem. A distinctive feature of our project involves envisioning the robot entering a waiting state, strategically positioned between two objects or vehicles. This intentional pause is not just a functional aspect but a strategic operational decision. It facilitates the fluid flow of goods within the warehouse, contributing to an organized and efficient task flow that aligns with the dynamic nature of modern logistics. In summary, our autonomous warehouse robot project transcends the conventional boundaries of logistics, ushering in a new era of efficiency and precision. The amalgamation of advanced line-following mechanisms, intelligent decision-making processes, and adaptive responses to obstacles positions our robot as a transformative force, redefining the narrative of autonomous logistics in warehouse management.

2. Literature Search

2.1 Indruction

Automated guided vehicle (AGV), It provides benefits in carrier loading. It is possible to travel along the road. In warehouses [1], [2]. General scenarios of AGV Includes transportation of raw materials, semi-finished products production lines, storage, and collection operations storage and distribution [3], [4]. In normal AGV path, AGV may deviate gradually. Deviation from the expected path due to cyber-attacks, wireless command blocks, and untimely adjustments are a few of them [5]. This deviation can cause collisions between AGVs and cargoes, the chaos of transportation, the entire production process and even disaster losses of warehouse personnel [6]. Thus, it is necessary to build an AGV surveillance system to estimate the AGV trajectories online and issue an alarm in the presence of path deviations. Generally, the AGV surveillance methods could be classified into vision based, laser based, magnetic based, wire based, color tape-based methods [6]. Among the surveillance methods, computer vision is a promising category because of its impressive advantages in costs, small size, abundant information, and computational efficiency [6]. For the sake of this, the vision-based surveillance system has been widely explored in both the academic and industrial fields. However, the vision system has the limitation of the inherent disadvantages regarding its long-term drift & considerable computational costs, landmark tracking failures in the context of the texture less environments, scale ambiguities [7]. These problems have impaired its potential applicability's in the AGV surveillance scenarios. To solve these problems, this works makes full sue of the downwardlooking camera to compensate for the forwardlooking camera drawbacks. The downward camera captures the QR codes posted on the floor and estimates the absolute poses with reference to the global warehouse frame. Because the downward-looking visual surveillance has the relatively higher accuracy, it could remarkably reduce the accumulated forward-looking camera estimation drifts and make up for the errors of the estimated AGV poses over the adjacent QR code distances. Despite the advantages of the downward-looking and forward-looking visual surveillance, the fusion still has several issues that need to be solved for AGV surveillance. Firstly, the forward-looking and downward-looking cameras are supposed to be rigidly fixed and precisely calibrated before fusion. Yet the traditional calibrations are unable to find the appropriate visible views [8]. In addition, the solution of minimizing the downward and forward-looking visual residuals may get stuck in the local minimum or even cause system failures due to the inappropriate fusion strategy. To address these issues, this paper designs an innovative forward-downward visual fusion strategy. Firstly, the coordinates between the downward-looking camera and forward-looking camera are calibrated using the SE3 model. The transformation between the multi-view references is estimated by aligning the trajectories in a consistent manner. Secondly, the AGV positions and orientations are jointly estimated by the visual-QR measurements. Lastly, the map points and keyframes are jointly optimized in the modified graph optimization framework. The contributions of this paper are summarized as follows.

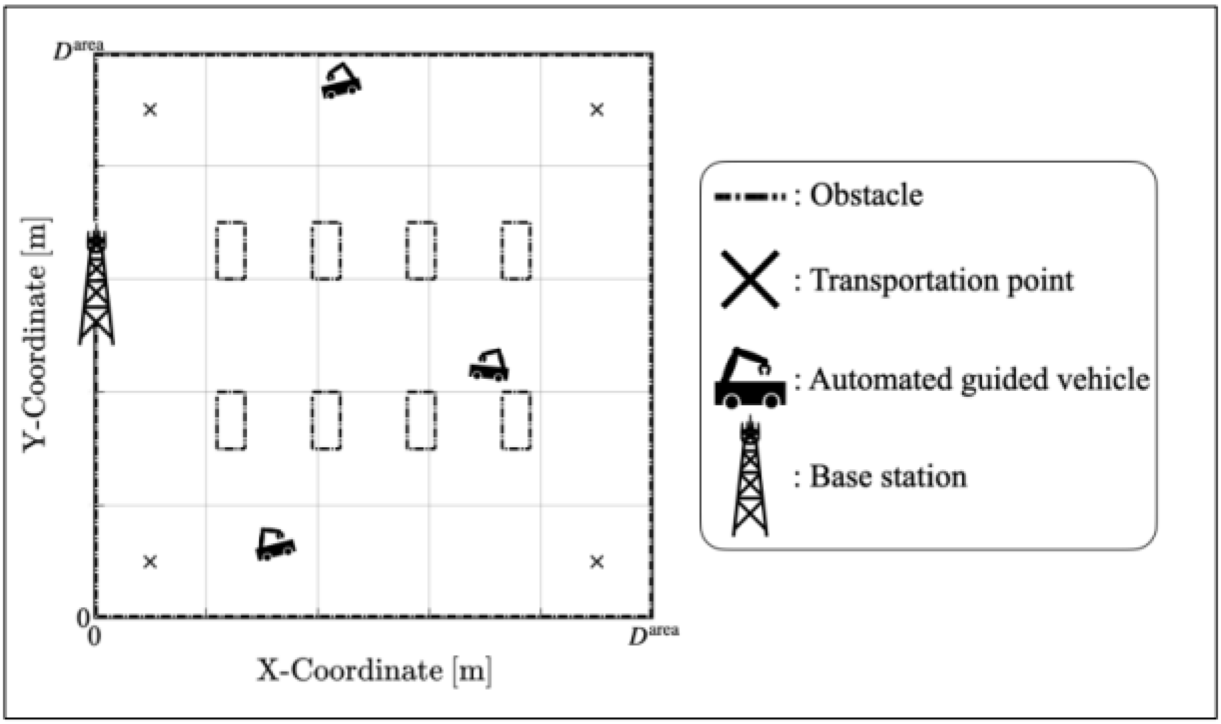


Fig. 3. Indoor factory environment.

Automation of storage facility and management has made a new generation of industries that primarily focusses on automated goods transportation in storage facilities, live shipment tracking, automated dispatch, and merchant resource management. A Warehouse management system must satisfy the following:

• To decrease the time of storage retrieval inside very large storage facilities.

• To minimize the storage space to accommodate more goods in smallest possible storage area [9],[10].

• To decrease the time to take a product from placing order by a consumer to delivery of the order to consumer.

• To increase the sales and operations capability of a storage facility [11].

• To observe the current trading environment and to pull insights of the consumer behavior there by increasing sales and generating profits.

• To perfectly synchronize IT infrastructure and real time data analytics. To continuously operate the storage facility and handle huge loads of goods and products, shifting to an automated robotic solution increases the chance of faster manipulation and transport of goods, faster dispatching, and faster processing time [12],[13]. To increase the capacity of a warehouse to withhold a huge stock either the area of the warehouse needs to be enormous, or stocks must be piled up on one another. This results in low space for human controlled vehicles inside the warehouse to move the stock to one place to another which sometimes leads to congestion and jams there by clogging up entire orders and halting the dispatch process. This problem can be efficiently solved by automated robotic warehouse transport bots which are controlled by sophisticated algorithms and technologies like data acquisition, software synchronization, job scheduling, real time updates and inter robot communication and positioning systems that periodically adapt to the warehouse operation procedure and can be changed and modified by humans when needed [14].

2.2 RELATED WORKS;

Proposed high-performance autonomous Inventory MAV for operation in warehouses. BLUE Navigates warehouse aisles and detects placed stock on shelves with a multi-mode sensor installation including one RFID reader and two high-resolution cameras. [15] Proposed a method for extracting deviation of AGV navigation path based on chromaticity threshold segmentation. This method adopts the idea of pre-closed-loop control, realizing AGV's path automatic tracking, key point turning, automatic driving, and recognition of the navigation line laid on the ground through the path tracking controller. However, in factories or workshops with a single scene, there exist problems such as significant changes in lighting and excessive brightness or darkness, which result in issues with setting the chromaticity threshold and consequently lead to the failure of AGV's navigation system and erroneous path planning.[16] proposed a Spatial Convolutional Neural Network (SCANN) to detect lanes by replacing layer-to-layer convolution in traditional feature maps with spatial slice-to-slice convolution, thereby transmitting information between rows and columns of pixels. However, the overall time complexity increases and real-time performance decreases, making it difficult to quickly identify whether there are anomalies in the AGV's driving process. [17] Proposed an efficient lane detection algorithm based on iterative search and Ransac curve fitting, which improves the robustness of the vehicle navigation system. However, in environments where the color characteristics between the lane and the background are not distinct, such as AGV workshops or factories, the reliability of AGV navigation is reduced. [18] Using visual detection technology to detect the motion status (position, attitude, velocity) of AGV can quickly identify whether the AGV system has anomalies. Existing detection methods are mostly based on the firstperson view, which results in long-term error accumulation and does not consider the impact of occlusion and lighting changes in factory environments on detection, leading to low detection accuracy. At the same time, the downward-facing camera has a limited field of view and can only capture a limited range of images, resulting in distortion in capturing image details

2.3 SYSTEM MODEL;

The This paper designs the AGV surveillance system by fusing the forward-looking and downward-looking visual measurements. The downward camera detects the QR codes pasted on the AGV running paths. The 2D positions and orientations relative to the global frame of the digital workshop could be estimated. Besides, the forward-looking images are also exploited to estimate the AGV poses in the optimization framework. Our method firstly performs the initialization on the parameters: the frame transformation matrix TCF CD between the forward-looking camera frame (short as CF frame) and downward-looking camera frame (short as CD frame), and the initial 3D points pw 1, pw 2, ···, pw M using the Maximum-A Posteriori alignment strategy. After the initialization, the AGV surveillance will be split into tracking thread and local mapping thread. The tracking thread will yield the initial AGV poses and the captured 3D points. The local mapping thread will update these estimates in the graph optimization manner. It should be noted that the downward camera captures the QR info and estimate the AGV positions more accurately, but the QR codes are merely available intermittently (i.e., there is a certain distance between the adjacent QR codes). Comparably, the forward-looking visual sensor could constantly collect the forward image sequences while the AGV is running, though the presence of long-term drifts. Figure 3 shows a material handling system for an indoor factory considered in this paper with a square area of D^area[m] on one side having multiple obstacles (such as walls, shelves, pillars, etc.). The communication system consists of a single BS multiple AGVs, which are indexed by i, where i ∈ I and I = {1, 2, . . . , I}. BS and multiple obstacles are fixed and placed as shown in Fig. 3. The twodimensional location of BS is expressed by u^bs = [x^bs [m], y^bs [m]] ^T and the height of BS antenna is denoted by H^bs [m]. The two-dimensional locations of multiple obstacles are represented by a set U^obs. Each AGV travels to its allocated destination to transport materials and goods during a simulation time T^sim [sec]. The two-dimensional location of AGV i at time t, where t ∈ [0, T^sim], is represented by ui(t) and the antenna height of AGV i is denoted by Hi [m]. This paper assumes AGV i follow the motion equation given as follows [19]:

$$x_i(t) = x_i(0) + \int_0^t v_i(t) \cdot \cos\theta_i(t)dt, \tag{1a}$$

$$y_i(t) = y_i(0) + \int_0^t v_i(t) \cdot \sin\theta_i(t)dt, \tag{1b}$$

$$v_i(t) = v_i(0) + \int_{t_0}^t \dot{v}(\hat{t})d\hat{t}, \tag{1c}$$

$$\theta_i(t) = \theta_i(0) + \int_0^t \left(\omega_i(0) + \int_0^{\hat{t}} \dot{\omega}(\tilde{t})d\tilde{t}\right) d\hat{t}, \tag{1d}$$

Where vi(t) [m/sec], ωi(t) [rad/sec], θi(t) [rad] are the linear and angular velocities and the heading direction of AGV i at time t. Furthermore, the velocity and acceleration are constrained as follows:

$$-V \leq v_i(t) \leq V, \tag{2a}$$

$$-\Omega \leq \omega_i(t) \leq \Omega, \tag{2b}$$

$$-A^{\mathrm{v}} \leq \dot{v}_i(t) \leq A^{\mathrm{v}}, \tag{2c}$$

$$-A^{\omega} \leq \dot{\omega}_i(t) \leq A^{\omega}, \tag{2d}$$

where V [m/sec], **Ω**[rad/sec], Av [m/sec2], Aω [rad/sec2] are maximum velocities and accelerations. This paper assumes that each AGV communicates with BS, i.e., transmits sensing information and images as it travels to its destination for materialΔ handling.

2.4 DOWNWARD CAMERA POSE ESTIMATION;

The In the warehouse, the array of QR codes is pasted regularly on the ground. Every QR code has a label ID that is consistent to the global coordinate in the warehouse. If the downward camera scans the QR code, the corresponding QR ID qri and the linear displacements on X-Y axes & the angular displacement, i.e., {Δx, Δy, Δφ} will be computed. In this paper, it is assumed that the AGV is moving on the planar ground. In other words, the AGV moves in the 3-DOF fashion, i.e., translations on X-Y plane and rotations along the Z-axis. Given the i − th QR label qri, the corresponding QR code coordinates (with reference to the building coordinate system) could also be derived, denoted by {xqri, yqri , zqri }. Together with the relative displacements {Δx, Δy, Δφ} CD, the downward camera positions {xCD, yCD , zCD } Win the world frame could be computed.

$$\begin{pmatrix} x_{C_D} \\ y_{C_D} \\ z_{C_D} \end{pmatrix} = \begin{pmatrix} \cos\Delta\varphi & \sin\Delta\varphi & 0 \\ -\sin\Delta\varphi & \cos\Delta\varphi & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_{qr_i} - \Delta x \\ y_{qr_i} - \Delta y \\ z_{qr_i} \end{pmatrix}$$

Afterwards, the AGV body positions {xB, yB, zB}^W in the world frame could also be derived as follows.

$$\begin{pmatrix} x_B \\ y_B \\ z_B \end{pmatrix} = \boldsymbol{T}_{BC_F} \cdot \boldsymbol{T}_{C_F C_D} \cdot \begin{pmatrix} x_{C_D} \\ y_{C_D} \\ z_{C_D} \end{pmatrix}$$

2.5 Design of an AGV system

In this section of the report, it is concluded that the dimensions of the design should have a length of 420 mm, a width of 317 mm and a height of 220 mm as a result of the scanning and examination of the data results during the design of the automatic guided vehicle. The load capacity calculated so far and expected to lift is 5kg and it is agreed that it should be capable of lifting a load up to 60 mm into the air. It was decided that the vehicle should have two large and three small (drunk wheels).

2.6 Frame Design

In this section of the report, it is concluded that the dimensions of the design should have a length of 420 mm, a width of 317 mm and a height of 220 mm as a result of the scanning and examination of the data results during the design of the automatic guided vehicle. The load capacity calculated so far and expected to lift is 5kg and it is agreed that it should be capable of lifting a load up to 60 mm into the air. It was decided that the vehicle should have two large and three small (drunk wheels).

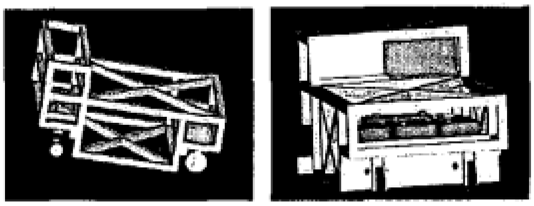


Figure IV: Hellerurk's frame design

This design approach increases the strength of the system and as a result the system can lift more weight. A static analysis is conducted, in order to validate the strength of the aluminum structure. Specifically, the model of the structure is tested, in different loads, in order to estimate the limits of the design. Our main concern is to fmd out if the yield limit of the material used is exceeded and plastic deformations are developed. For the estimation of the stresses developed, the ANSYS specialized Finite Element Analysis @EA) program is used. Finite Element Analysis is used more and more in the development of new products, providing the manufacturers low cost redesign and optimization times. [21]

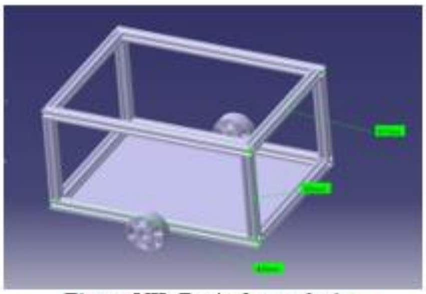


Figure VII: Basic frame design

2.7 Motor Selection

Motors The motor of AGV generally is mounted with an encoder in order to measure the distance of path. The motor type which are used in AGV are named as Geared DC motor, brushless DC motor, servo motor. these motors are selected based on their impacts on flexibility and accuracy of AGV movement. Drive mode is divided into single wheel drive, differential drive and omnidirectional drive. Single wheel drive means a driving wheel have the function of walking and steering and two driven wheels are fixed. Differential drive has two drive wheels that use the speed difference to realize rotation. Omnidirectional drive is much more flexible. With two driving and rotatable wheels, both parallel movement and differential drive function are available [22].

2.8 Load Transfer Methodology

Unit load AGV has many kinds of decks (e.g. lift, roller, chain, etc) to transport materials. In the consideration of the transfer requirements of automobile assembly production lines, we suggest a material transport control methodology to locate AGV beside the load stand accurately and retrieve and deposit the pallet automatically. [23].

2.9 Load-Transfer Mechanism Design

In order to execute the retrieving and depositing behaviors required in the long-travel materials transport process, a bothside three-level push-pull load-transfer mechanism is designed. This mechanism contains a lifting module and a translational module, as shown in Fig.VIII[23].

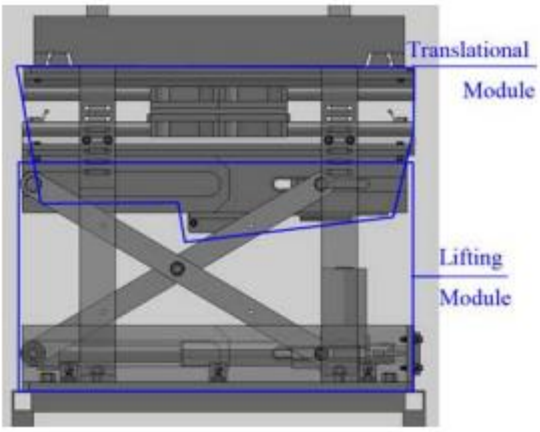


Figure VIII. Load-transfer mechanism

2.10 Manufacturing Process

The manufacturing process of the vehicle involves five distinct components. The initial phase focuses on crafting the outer shell, employing sheet metal plates for the exoskeleton. These plates are meticulously cut to the required size and shaped using a bending method. Subsequently, the shaped pieces are welded together, resulting in the completion of the exoskeleton. Moving on to the second aspect, the vehicle skeleton incorporates aluminum sigma profiles. These profiles are cut to specified dimensions and interconnected using apparatus, forming the essential framework. The third component encompasses the production of in-wheel motors and passive wheels responsible for mobility, designed in accordance with the Digital Twin specifications and fortified with epoxy, hydrophobic spray, and tubing for sealing. The fourth facet pertains to the carrier system, constructed from iron profiles and sheet metal plates. The iron profiles are cut, melted together, and welded, while the sheet metal undergoes cutting, bending, and welding processes before the two sections are merged. Finally, the fifth part involves the creation of the lift system and the conveyor belt system. The lift system incorporates iron profiles and sheet metal plates, fused through welding, while the conveyor belt system integrates iron profiles, pulleys, belts, and bearings, providing efficient movement facilitated by the fusion-welded pulleys and strategically placed bearings. This comprehensive process ensures the meticulous fabrication of each integral component, culminating in the production of a fully functional vehicle. [25]

System Configuration

The configuration of the vehicle forces is shown in figure IV. It is seen that the two sprockets in the middle of the AGV are driving wheels, which are actuated separately by two DC motors. So there are two trajectories of line and arc for this kind of AGV. The center of linking line between two driving wheels is the kinematics origin of AGV. [26] Design and Development of an Automated Guided Vehicle for Educational Purposes, Khosro Bijanrostami Submitted to the Institute of Graduate Studies and Research in partial fulfillment of the requirements for the Degree of Master of Science in Mechanical Engineering Eastern Mediterranean University September 2011 Gazimağusa, North Cyprus

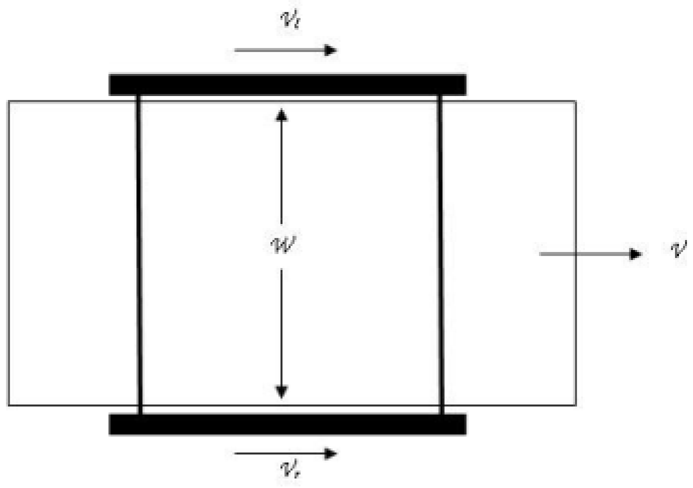


Figure IV: Vehicle Forces

V= linear AGV velocity (mm/s) □ = angular AGV velocity (rad/s) W = distance between two sprockets = 400mm Vr = velocity of right wheel (mm/s) Vl = velocity of left wheel (mm/s)

2.11 Electrical and Electronic Design of AGV system

Plated through-holes, commonly known as vias, are holes that facilitate connections between the layers of a circuit board, allowing the transmission of electric current. Leaded circuit components mounted on the board are inserted into these holes, serving as pathways for interlayer transmission. In surface mount technology, there are copper or solder-coated pads on which the components rest, providing a flat surface. Some conductive copper regions are interconnected by waterways, which conduct electric current. Thicker waterways are used for higher currents, while thinner ones suffice for lower currents.

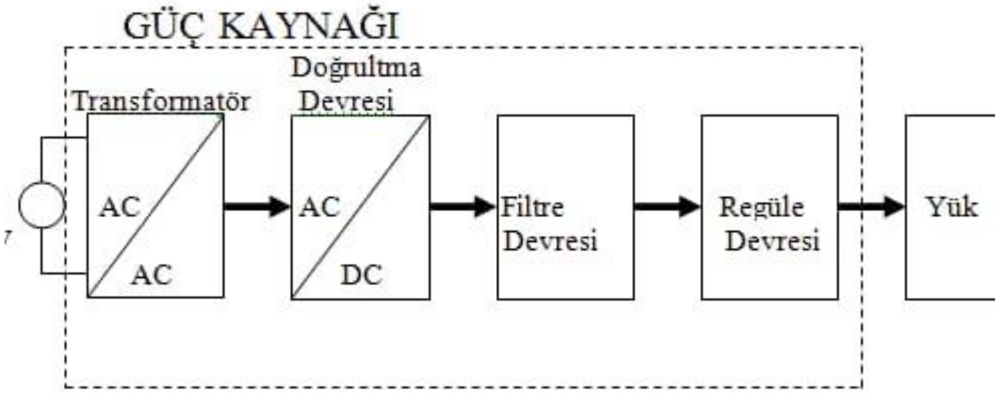
Printed Circuit Board (PCB) design is typically done using computer programs. Well-known PCB design software includes OrCad, Proteus (ISIS and ARES), Protel, and PCAD. Considerations in PCB design include trace spacing, via widths, placement of bypass capacitors, positioning of radio frequency-emitting components to minimize interference with integrated circuit elements, isolation using a Faraday cage if needed, and the separation of digital and analog ground planes.

Materials like copper-clad laminates, where copper is bonded to materials such as fiberglass, are known as copper-clad FR4. The circuit schematic is transferred onto this material in the form of a thin film. Using a resistive ink or similar substance, conductive paths are drawn on the board, outlining the desired circuitry. The board is then exposed to a specialized acid mixture that selectively removes exposed copper, leaving behind the protected traces. After washing off the remaining ink layer, the circuit board is ready for use.

2.12 POWER ELECTRONICS DEFINITION

Power electronics is a branch of science that primarily focuses on controlling the energy supplied to a load and transforming different forms of energy. It is a highly attractive and significant discipline within Electrical Engineering. Power electronics requires a fundamental understanding of Mathematics, Circuit Theory, and Electronic principles.

Power electronics is one of the most crucial branches in the rapidly expanding electronic sector. Initially confined to industrial applications, power electronics circuits and devices have now extended beyond industry boundaries, entering households, offices, and vehicles in today's world.



2.13 POWER ELECTRONICS: APPLICATIONS AND INDUSTRIAL USAGE

2.13.1 POWER ELECTRONICS SYSTEM:

The fundamental structure of a power electronics system is illustrated in block form. As depicted in the figure, a power system consists of two main sections: the power circuit and the control circuit.

2.13.2 APPLICATION AREAS OF POWER ELECTRONICS:

In Industry:

- In energy transmission and distribution.
- For motor control in various applications.
- Automation of machinery.
- Heating and cooling processes.
- In production and assembly industries.
- Power supply and control systems of various types.

In Buildings, Offices, and Homes:

- Building automation systems.
- In heating, cooling, ventilation, and security systems.
- All office equipment.
- Entertainment, sports, and gaming devices.
- Medical devices.
- Home appliances such as washing machines, dishwashers, refrigerators, air conditioners, vacuum cleaners, etc.

In Transportation Vehicles:

- Power systems in aircraft and other air vehicles.
- In railway and metro vehicles and ground systems.
- Electronic systems in heavy vehicles like buses, trucks, and tractors.
- Electrical power and control systems in automobiles.
- In vehicles such as forklifts, mobile cranes, concrete mixers, etc.

In Agriculture and Livestock:

- Automation and control in greenhouse systems.
- Open-field irrigation and product control systems.
- Automation of agricultural machinery.
- Maintenance and automation in animal farming facilities such as poultry farms and barns.
- Control of field and land cultivation, planting, and fertilization processes.
- Applications in seed cultivation and seedling growth studies.

2.13.3 INDUSTRIAL APPLICATIONS OF POWER ELECTRONICS:

The fundamental static and dynamic industrial applications of power electronics, along with other important industrial application areas, are outlined below.

Basic Static Applications:

- Uninterruptible Power Supplies (UPS).
- Switched-Mode Power Supplies (SMPS).
- Resonant Power Supplies (RMPS).
- Induction Heating (IH).
- Electronic Ballasts (EB).
- High Voltage DC Transmission (HVDC).
- Static VAR Compensation (SVC).

Basic Dynamic Applications:

- General DC Motor Control.
- General AC Motor Control.
- Control of Squirrel Cage (Short Circuit Rotor) Induction Motors.
- Control of Wound Rotor (Slip Ring Rotor) Induction Motors.
- Linear Induction Motor Control.
- Synchronous Motor Control.
- Universal Motor Control.
- Stepper Motor Control.
- Reluctance Motor Control.

Other Significant Applications:

- Lighting and Light Control Systems.
- Heating and Cooling Systems.
- Soldering and Welding Systems.
- Melting and Hardening Systems.
- Screening and Grinding Systems.
- Elevator and Crane Systems.
- Escalator and Conveyor Systems.
- Pump and Compressor Systems.
- Ventilation and Fan Systems.
- Alternative Energy Source Systems.
- Battery Charging and Energy Storage Systems.
- Electric Transportation and Electric Vehicle Systems.
- Space and Military Vehicle Systems.
- Earth Excavation and Mining Systems.

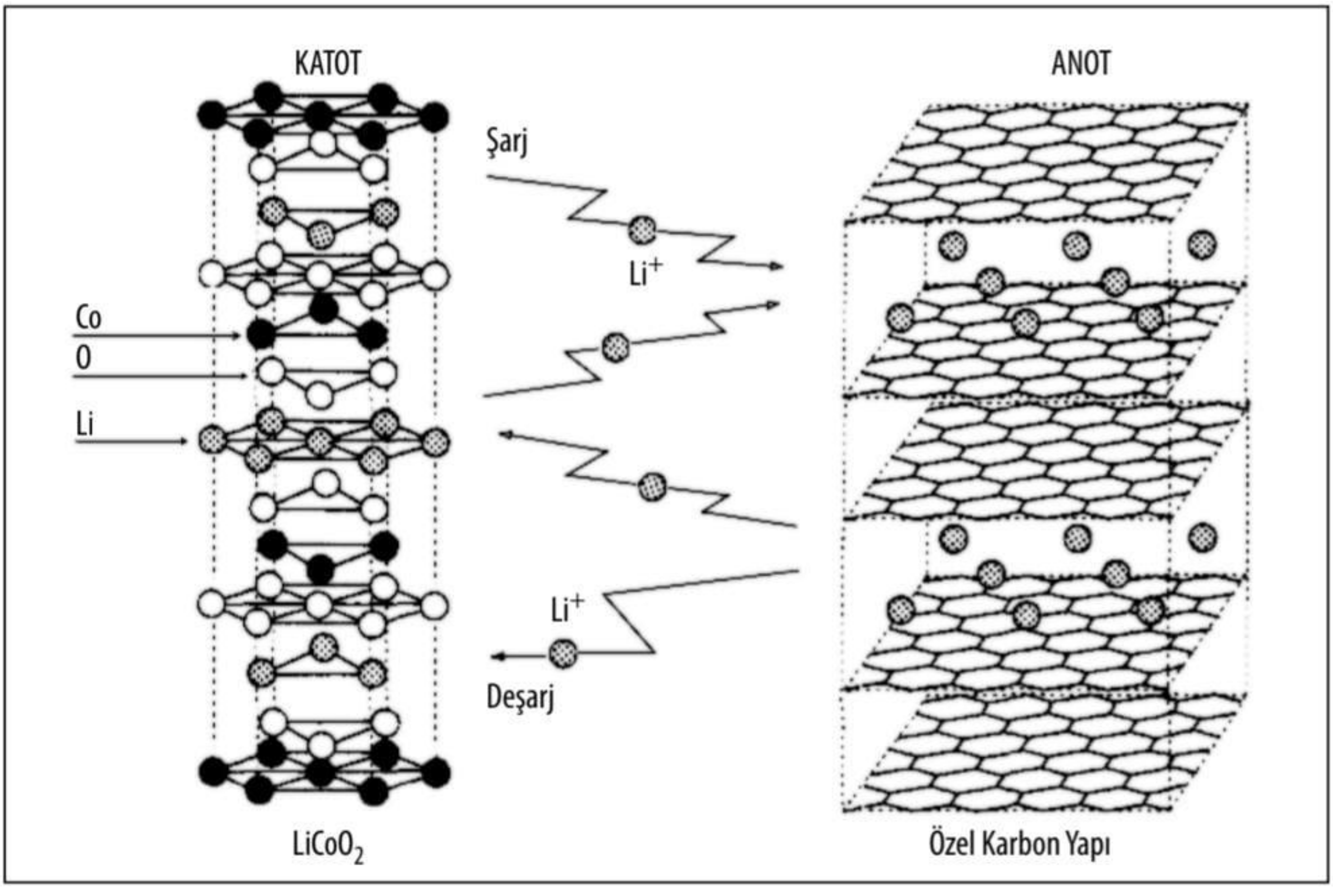
Additionally, Power Electronics is extensively integrated into interdisciplinary fields such as Industrial Automation, Mechatronics, and Robotics.

2.14 LITHIUM ION BATTERY TECHNOLOGY

Research and development activities on secondary (rechargeable) lithium-ion batteries are gaining increasing significance due to the growing demand for portable electric and electronic devices, as well as the rising importance of electric cars in the transportation sector. Lithium-ion batteries, with their high energy density and non-toxic nature, have become preferred choices for mobile phones, laptops, small household appliances, and are favored by environmentally conscious designers and consumers due to their low CO2 emission levels.

In the past, lithium-ion batteries, commonly used in portable household appliances, have seen their importance rise with the increasing need for energy storage systems amidst diminishing energy resources. This trend is expected to further escalate with the increasing production of electric cars in the near future.

This article provides a brief introduction to lithium-ion battery technology, discussing its history and the research and development efforts that have been undertaken.



2.14.1 WHAT IS LITHIUM-ION BATTERY?

Rechargeable batteries are commonly known as secondary batteries. They are electrochemical cells that can be recharged and reused after discharge. Table 1 below provides a general comparison of lithium-ion batteries with other secondary batteries such as silver-zinc, nickel-zinc, and nickel-hydrogen, highlighting their advantages and disadvantages[X].

Advantages:

- Maintenance-free due to a sealed cell design.
- Long lifespan.
- Wide operating temperature range.
- Extended shelf life.
- Rapid charging capability.
- High-power discharge capacity.
- High energy efficiency.
- High specific energy and energy density.
- Lack of memory effect.

Advantages:

- Cost.
- Degradation at high temperatures.
- Requirement for protective circuits.
- Capacity loss or thermal degradation due to overcharging.

Advantages and Disadvantages of Rechargeable Lithium-Ion Batteries

Advantages	Disadvantages
Sealed cell design, requiring no maintenance	Higher cost
Long lifespan	Degradation at high temperatures
Wide operating temperature range	Need for protective circuits
Extended shelf life	Capacity loss or thermal degradation due to overcharging
Rapid charging capability	
High-power discharge capacity	
High energy efficiency	
High specific energy and energy density	
Lack of memory effect	

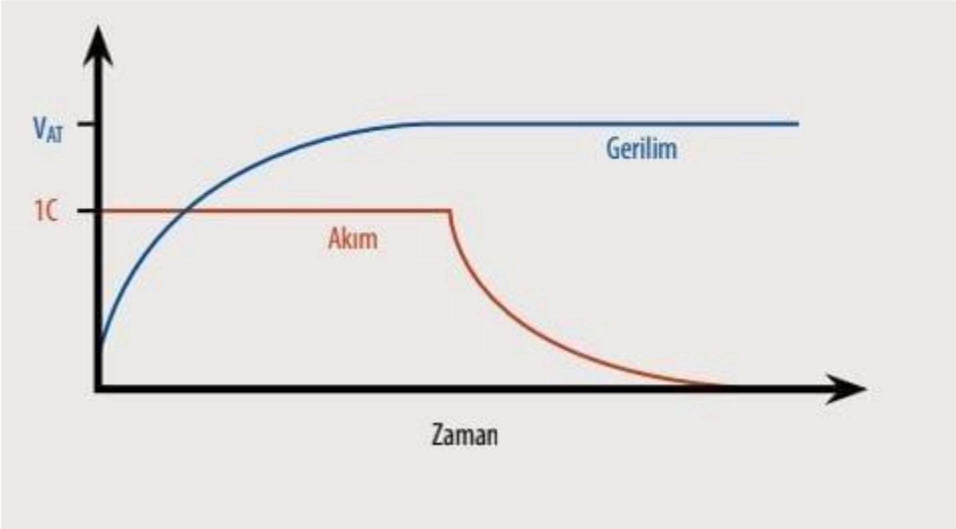
Table X: Advantages and Disadvantages of Rechargeable Lithium-Ion Batteries

2.14.2 Working Principle of Lithium-Ion Battery:

In rechargeable lithium-ion batteries, cells, responsible for generating and storing energy like in other battery systems, consist primarily of three main components: anode, cathode, and electrolyte. These components play crucial roles in the overall functionality of the battery.

The anode serves as the negative electrode, while the cathode functions as the positive electrode. Positive electrodes typically consist of metal oxides with tunnel or layered structures (LiMOx). On the other hand, negative electrode materials exhibit layered structures. These structures enable the mutual exchange of Li ions between the positive and negative electrodes during the charge and discharge of the cell/battery. This displacement is defined as a topotactic reaction.

In this reaction, the active materials in the anode and cathode host lithium, which moves as a guest from one electrode to another. Figure XI provides a schematic representation of a lithium-ion cell and the reactions occurring at the negative and positive electrodes (Table XI).



2.14.3 How Lithium-Ion Batteries Are Charged and Discharged?

Firstly, let's define some terms: "Capacity" indicates the maximum amount of energy a battery can store and is given in Ampere-hours (Ah); for example, a 10Ah battery can provide a current of 10 Amperes for 1 hour or 1 Ampere for 10 hours. The "state of charge" reflects how much capacity of the battery has been filled. "Nominal voltage" indicates the voltage a fully charged battery provides under normal conditions. "Terminal voltage" is the voltage the battery provides at a specific moment. A notable characteristic of lithium-ion batteries is that their state of charge is related to the terminal voltage, allowing us to estimate the state of charge by measuring the terminal voltage. Lastly, the manufacturer's specified "current constant" (C) is used as an indicator of the battery's instantaneous power, representing how quickly the battery can be discharged or the maximum instantaneous current it can deliver. For instance, a 1C battery can be discharged from full to empty in 1 hour, while the commonly available 45C batteries on the market can be discharged in approximately 1.5 minutes. A 5000mAh 45C battery can deliver a current of 225 Amperes, which is a significant power that can have serious consequences if not handled carefully.

Charging currents range from 0.5C to 2C, while the capacity of the battery and the current constant are largely independent of each other.

Understanding the state of charge from the terminal voltage makes charging lithium-ion batteries relatively straightforward. To charge the battery, a constant current of 1C is applied until the battery reaches its "maximum terminal voltage." Once this voltage is reached, the voltage is stabilized, and the current is allowed to decrease slowly until the battery is fully charged.

However, there are two crucial points to consider during charging and discharging. Firstly, fully charged and fully discharged terminal voltage values are critical. While charging, the battery is not fully charged at 4.20V terminal voltage, and if it exceeds the maximum terminal voltage allowed for these batteries, which is 4.26V, it can catch fire. Similarly, if it drops below 3V, it can be damaged beyond repair. The second point is a bit more complex: Suppose we need a battery for our laptop with a nominal voltage of 7.4V. We can achieve this by connecting two lithium-ion batteries in series. When charging and discharging these batteries, looking only at the total voltage, we can see that the battery works normally for a while, but as we charge and discharge it, it begins to deteriorate. This is because the capacities of the two batteries connected in series are not equal. As we charge and discharge the battery, the battery with lower capacity reaches its maximum terminal voltage of 4.26V earlier. Since the battery with larger capacity is still less full at that time, its terminal voltage is lower. When the total voltage reaches the maximum value of $2 \times 4.26 = 8.52V$, the battery with smaller capacity exceeds its maximum terminal voltage and gets damaged. Therefore, in applications where a high voltage is created by connecting a large number of lithium-ion batteries in series (such as electric cars), circuits are placed on each battery terminal to monitor the voltage and eliminate excess current if necessary. This may require quite complex systems, and it is one of the challenges in designing electric vehicles. There is such a device in the batteries of your mobile phone and computer, and the battery has more than two terminals to allow the phone to communicate with this device.

2.15 Software part of the AGV system

2.15.1 Collision Avoidance

The collision avoidance system implemented in the autonomous warehouse robot is a sophisticated integration of sensor technologies and dynamic trajectory adjustments. Utilizing a combination of ultrasonic and infrared sensors, the robot continuously scans its environment to detect both fixed and moving obstacles. These sensors have proven effective in various studies. When an obstacle is detected, the robot's algorithms calculate the optimal path adjustment, allowing it to either maneuver around the obstacle or come to a complete stop. This real-time response ensures the safety of the robot and the goods it transports, minimizing the risk of collisions in the dynamic warehouse setting.

2.15.2 Line Tracking Management

The robot's navigation is primarily based on a robust line tracking system. Algorithms continuously analyze the feedback from line sensors to ensure the robot stays on the designated path. In cases where the line is interrupted or deviates due to unforeseen circumstances, the robot employs advanced algorithms to autonomously re-establish the correct path. This capability enables the robot to navigate reliably even in situations where the lines may be partially obscured or distorted.

2.15.3 Dynamic Path Planning

To adapt to unforeseen obstacles or changes in the warehouse layout, the autonomous robot employs dynamic path planning algorithms. These algorithms continuously analyze the surroundings, taking into account real-time data from sensors. By calculating alternative routes, the robot can efficiently navigate around obstacles and optimize its path to reach its destination in the most time-effective manner. This adaptability is crucial for the robot's efficiency in a dynamic and evolving warehouse environment.

2.15.4 Image Processing for Parking

Upon reaching the delivery or charging point, the robot utilizes advanced image processing techniques for optimal parking. Equipped with cameras, the robot captures images of its surroundings and analyzes them to identify the most suitable parking area. This involves recognizing the available space, avoiding other objects or robots, and ensuring a secure and efficient parking maneuver. This image processing capability enhances the robot’s ability to operate seamlessly within the warehouse infrastructure.

2.15.5 Object Recognition and Waiting State

For safety during the waiting state between objects or vehicles, the robot incorporates sophisticated object recognition capabilities. These capabilities allow the robot to identify and differentiate between various objects, ensuring that it parks in a secure location. The waiting state is initiated when the robot is positioned between two objects or vehicles, providing a safe and strategic location within the warehouse. This proactive safety measure prevents potential collisions during idle periods.

2.15.6 Emergency Stop Mechanism

As a fail-safe measure, the autonomous robot is equipped with a rapid emergency stop mechanism. In the event of critical errors, system malfunctions, or unforeseen circumstances jeopardizing safety, the robot can execute an immediate emergency stop. This halts all movements, preventing potential accidents or damage to the robot, goods, or surrounding infrastructure. The emergency stop mechanism aligns with industry standards for safety in autonomous systems.

3. Emergency Stop Mechanism

In the context of our autonomous warehouse robot project, where open computing environments play a pivotal role, the inherent susceptibility to diverse security threats necessitates a comprehensive understanding of potential risks. This paper has undertaken a survey of security threats prevalent in such systems, shedding light on the challenges that can impede the seamless operation of our autonomous robot. Additionally, we have delved into an exploration of prominent protection mechanisms devised to counteract these threats. Our investigation reveals a myriad of proposed techniques; however, it is crucial to acknowledge that not all of these solutions are equally practical within the dynamic landscape of autonomous warehouse robotics. Striking a balance between robust security measures and operational feasibility poses a continual challenge in the implementation of protection mechanisms. Despite the strides made in security research, it is evident that there is still work to be done. Remaining security issues must be satisfactorily addressed to ensure the widespread acceptance and realization of the full potential of autonomous warehouse robotics. The dynamic and unpredictable nature of warehouse environments demands adaptive and resilient security solutions. As we progress with our autonomous warehouse robot project, it becomes increasingly apparent that ongoing research is imperative. Only through a commitment to innovation and continuous improvement can we fortify our system against emerging threats, ensuring not only the safety and security of the robot but also facilitating its seamless integration into warehouse operations. In this pursuit, our project aligns with the broader goal of advancing the mobile agent paradigm and contributing to the evolution of autonomous systems in open computing environments.

4 Software Requirement Specification (SRS)

4.1 Introduction

Automated Guided Vehicle (AGV) technology provides significant advantages in carrier loading, finding widespread applications in warehouses, production lines, and distribution processes. The objective of this project is to develop a reliable and effective AGV surveillance system by addressing challenges encountered in the normal navigation routes of AGVs.

4.1.1 Purpose

The fundamental purpose of this project is to enhance safety in logistics and production processes by mitigating potential risks caused by deviations in the navigation routes of AGVs. Additionally, the developed surveillance system will enable more accurate prediction of AGV movements, facilitating rapid alarm notifications in the presence of abnormal situations. This is crucial for ensuring the safety of warehouse personnel and contributing to the seamless progression of production processes.

4.1.2 Scope

This project focuses on safety and efficiency issues in logistics and production processes where AGVs are utilized. The scope of the project includes the following areas:

- Safety of AGV Trajectories: Prevention of collision risks, chaotic situations, and disruptions in production processes arising from deviations in the normal routes of AGVs.

- Surveillance System Design: Design and implementation of an AGV surveillance system, incorporating forward and downward-facing cameras.

- Image Processing and Fusion Strategy: Calibration of coordinates between forward and downward-looking cameras, development of image processing, and fusion strategies.

4.2 General Description

4.2.1 Glossary

Name	Definition
Actor	Entities utilizing the automatic parking system, including users, environmental sensors, other software and hardware components, Arduino, ROS, etc.
Object Detection	The ability to recognize obstacles and lines in digital images, video feeds, and environmental sensor data.
Computer Vision	The capability to analyze visual and environmental data to comprehend surroundings and recognize objects.
YOLO Models	Deep learning algorithms used for object detection.
C	A general-purpose programming language suitable for fulfilling low-level control and processing requirements in the project.
C++	A general-purpose programming language supporting object-oriented programming, applicable for complex algorithms in the project.
ROS	Robot Operating System; an open-source software framework for developing and managing robotic applications.
Arduino	A popular microcontroller board platform for embedded system projects.

4.2.2 Functional Requirements Overview: Autonomous Warehouse Vehicle Project

In the quest to develop a state-of-the-art autonomous warehouse vehicle, functional requirements were meticulously crafted to ensure efficient cargo handling, obstacle avoidance and autonomous parking. The project includes advanced features such as line recognition, cargo collection and transportation, obstacle detection, path planning and precise autonomous parking. Below is an overview of the functional requirements:

4.2.2.1 Line Tracking and Cargo Transportation:

Line Recognition:
Computer vision techniques should be applied to accurately detect and follow designated lines in the warehouse environment.

Cargo Receiving:
Autonomous capabilities will be developed for the vehicle to approach the cargo, recognize it, and safely remove it from a specific pickup point.

Cargo Transportation:
Stability and safety during cargo transportation is ensured by using a combination of sensors and robust control algorithms.

4.2.2.2 Unblocking:

Obstacle Detection:
We used a combination of computer vision and sensor-based systems to detect obstacles in the vehicle's path**.**

Route Planning:
We applied dynamic path planning algorithms to enable the vehicle to navigate around obstacles and optimize the route to the destination.

Emergency stop:
An emergency stop mechanism will be integrated to reduce possible collisions in unforeseen situations.

4.2.2.3 Autonomous Parking:

Parking Zone Recognition:
Sensors and computer vision will be used to recognize designated parking zones within the warehouse.

Precision Parking:
Precise autonomous parking techniques will be developed to ensure correct positioning of the vehicle in designated parking areas.

Automatic Shutdown:
We will implement a system that will enable the vehicle to shut down autonomously after the parking process is successfully completed.

4.2.2.4 System Integration and Communication:

Integration with Central System:
We will establish seamless integration with a central system to receive pick-up and drop-off instructions.

Communication Protocols:
Implement reliable communication protocols for real-time data exchange between the vehicle and the central system.

4.2.2.5 Safety and security:

Emergency Protocols:
Define protocols and mechanisms for handling emergencies, including safe cargo evacuation and systematic shutdown.

Security precautions:
Implement security features to prevent unauthorized access and ensure the integrity and security of cargo during transportation.

4.2.3 General Constraints and Assumptions: Autonomous Warehouse Vehicle Project

When defining the framework for an autonomous warehouse vehicle project, we consider various constraints and make certain assumptions that guide the development process.These constraints and assumptions serve as fundamental parameters, providing clarity and context for the scope and implementation of the project.

4.2.3.1 Constraints

Hardware Realities:
This project operates within the limits of available hardware resources, including sensors, actuators, and computing capabilities.

Budget Realities:
Financial constraints shape projects and require adherence to a given budget throughout development and deployment.

Compliance:
Vehicle design and functionality must comply with existing safety and regulatory standards for autonomous systems in warehouse environments.

Temporal Pressures:
A predefined timeline dictates the project's pace, necessitating efficient development, testing, and deployment phases.

Operational Context:
Tailored for warehouse use, the autonomous vehicle's operation is constrained by the distinctive characteristics and layout of such environments.

4.2.3.2 Assumptions:

Stable Illumination:

The project assumes a consistent and sufficient level of lighting within the warehouse for the effective operation of computer vision systems.

Obstacle Variety:

Both static and dynamic obstacles are assumed to exist within the warehouse, and the vehicle is designed to adapt to diverse scenarios.

Clearly Defined Markings:

Efficient line following presupposes the presence of distinct and discernible markings on the warehouse floor.

Charging Infrastructure:

The assumption is that a reliable charging infrastructure is in place within the warehouse to meet the autonomous vehicle's periodic charging needs.

Reliable Connectivity:

Stable and uninterrupted network connectivity is assumed to enable seamless real-time communication between the autonomous vehicle and the central control system.

Navigable Pathways:

The project assumes the availability of unobstructed and navigable pathways within the warehouse for smooth cargo pickup, transportation, and delivery.

Localized Operations:

Designed for localized operations, the autonomous vehicle is limited to the defined warehouse space and doesn't consider external navigation.

Predictable Cargo Handling:

The project assumes a structured cargo handling process, with predefined pickup and drop-off points to facilitate efficient and automated operations.

Emergency Response:

The assumption is that established emergency protocols are in place, ensuring that the autonomous vehicle operates within safety parameters in unforeseen events.

4.2.4 Specific Requirements: Autonomous Warehouse Vehicle Project

The precise demands for the self-governing warehouse vehicle initiative encompass an exhaustive array of functionalities, attributes, and capacities designed to facilitate effective management of goods, seamless maneuvering around obstacles, and self-directed parking within the confines of the warehouse environment.

4.2.4.1 Route Following and Cargo Management:

Path Recognition:

The automated vehicle is expected to employ sophisticated computer vision algorithms to accurately identify and adhere to designated pathways within the warehouse, ensuring precise navigation.

Cargo Retrieval:

A sophisticated mechanism is to be devised to empower the vehicle to independently approach predefined pickup locations, recognize cargo, and securely elevate it onto the vehicle.

Cargo Conveyance:

The system will integrate robust cargo handling mechanisms, leveraging sensors and control algorithms to ensure the steadfast transportation of cargo during the vehicle's traversal within the warehouse.

4.2.4.2 Obstacle Evading:

Obstacle Identification:

A comprehensive suite of sensors, including lidar and ultrasonic sensors, is mandated to be deployed for the detection of both stationary and dynamic obstacles obstructing the vehicle's route.

Pathway Planning:

Dynamic algorithms for path planning will be implemented to enable the vehicle to adeptly navigate around obstacles, optimizing routes for the seamless transportation of cargo.

Emergency Halting:

An integrated emergency halt system will be put in place, activated by the proximity of obstacles, ensuring immediate cessation to prevent collisions and uphold warehouse safety.

4.2.4.3 Self-Directed Parking:

Recognition of Parking Zones:

The vehicle is slated to utilize a blend of sensors and computer vision for the identification and localization of designated parking areas within the warehouse.

Precision Parking:

Cutting-edge algorithms will be formulated to facilitate meticulous self-directed parking, enabling the vehicle to position itself with precision within specified parking zones.

Automated Power Down:

Upon the successful completion of parking, an autonomous shutdown procedure is to be instituted, optimizing energy consumption and ensuring operational efficiency.

4.2.4.4 Integration with Central System and Communication:

Incorporation with the Central System:

The autonomous vehicle is required to seamlessly integrate with a central control system, facilitating efficient communication and coordination of tasks related to pickup, transportation, and delivery.

Real-time Data Exchange:

Implementing reliable and low-latency communication protocols is imperative to facilitate real-time data exchange between the autonomous vehicle and the central control system.

4.2.5 Safety and Security Measures:

Emergency Procedures:

A comprehensive set of emergency procedures will be articulated and implemented to guarantee the safety of both the vehicle and the warehouse environment in unforeseen or emergency scenarios.

Controlled Access:

He system is mandated to integrate robust access control measures, preventing unauthorized access to the vehicle's control systems and cargo, thereby ensuring the security of operations.

4.2.6 User Interface Design:

Remote Surveillance:

A user-friendly interface is to be devised for remote surveillance, empowering users to monitor the vehicle's status, oversee cargo, and receive real-time updates on operational parameters.

Manual Override Option:

The system is to incorporate an alternative for manual override, granting operators the capacity to assume control in situations necessitating manual intervention, thus ensuring adaptability and flexibility.

4.3 Use Case Scenarios for the Autonomous Warehouse Vehicle Project

4.3.1 Cargo Pickup and Delivery:

Objective: The vehicle picks up cargo from a designated pickup point and securely delivers it to a specified drop-off point.

Scenarios:

- The central control system initiates a cargo pickup request, specifying the pickup and delivery points.
- The vehicle autonomously navigates to the pickup point, adapting its speed to environmental variables such as traffic.
- Utilizing various sensors, the vehicle accurately identifies and picks up the cargo securely.
- During transit, the vehicle dynamically adjusts its route based on real-time environmental conditions.
- Upon reaching the delivery point, the vehicle safely unloads the cargo and completes the task.

4.3.2 Line Following:

Objective: The vehicle accurately navigates by following designated lines within the warehouse.

Scenarios:

- The vehicle starts its operation and initializes the line-following algorithm.
- Using line-following sensors and cameras, the vehicle continuously tracks and adjusts its position relative to designated lines.
- In cases of poor line quality, the vehicle employs image processing algorithms to enhance line detection and maintain precise navigation.
- The vehicle responds to sudden line deviations or changes, ensuring continuous and accurate line following.

4.3.3 Obstacle Avoidance:

Objective: The vehicle navigates safely within the warehouse, avoiding both static and dynamic obstacles.

Scenarios:

- The vehicle's sensors constantly scan the surroundings for obstacles, including both static structures and moving entities.
- Upon detecting an obstacle, the vehicle evaluates its position and motion to create a dynamic obstacle map.
- Using path planning algorithms, the vehicle devises an alternative route to circumvent obstacles efficiently.
- In critical situations where collision risk is high, the emergency stop system activates, bringing the vehicle to an immediate halt.

4.3.4 Autonomous Parking:

Objective: The vehicle autonomously parks in designated areas within the warehouse.

Scenarios:

- The vehicle identifies available parking zones using a combination of sensors and image processing techniques.
- Utilizing precise maneuvering algorithms, the vehicle navigates to the designated parking area.
- During the parking process, the vehicle continuously monitors its surroundings, adjusting its position for optimal parking.
- Upon successful parking, the system updates the vehicle's status, optimizing energy usage, and automatically shutting down.

4.3.5 System Integration and Communication:

Objective: The vehicle seamlessly communicates and integrates with the central control system.

Scenarios:

- The central control system issues real-time commands to the vehicle, such as initiating tasks or updating routes.
- The vehicle acknowledges received commands and provides constant updates on its status, location, and environmental conditions.
- In the event of communication disruption, the vehicle activates failsafe protocols, ensuring safe operation or stopping when necessary.

4.3.5 Safety and Security:

Objective: The vehicle is prepared for any security threat and operates safely.

Scenarios:

- The vehicle is equipped with a comprehensive set of security protocols to handle emergencies or unforeseen circumstances.
- If a system error or security vulnerability is detected, the vehicle enters a safe mode, ceasing autonomous operations.
- Emergency buttons or manual control options are available for operators to swiftly intervene in critical situations.
- Continuous surveillance of the vehicle's surroundings ensures prompt threat assessment and avoidance.

4.4 Conclusion

To The development of the Autonomous Warehouse Vehicle Project has been guided by a comprehensive set of software requirements, encapsulating the diverse functionalities necessary for seamless cargo handling, obstacle navigation, and autonomous parking within a warehouse environment. The meticulous consideration of these requirements serves as the foundation for creating a robust and intelligent autonomous system.

4.4.1 Achievements

Throughout the specification process, the team has achieved a clear understanding of the project's scope, objectives, and critical functionalities. The definition of user roles, identification of system actors, and detailed requirements for object detection, computer vision, and motion planning lay the groundwork for the successful implementation of the autonomous vehicle.

4.4.2 Object Detection and Computer Vision

The integration of Object Detection, leveraging advanced computer vision techniques and YOLO models, empowers the vehicle to accurately identify objects, navigate designated paths using line recognition, and interact with its environment dynamically. The fusion of forward and downward-looking cameras, coupled with innovative QR code recognition through the downward camera, enhances the precision of pose estimation and ensures reliable navigation.

4.4.3 Motion Planning and Navigation

The autonomous vehicle's ability to navigate dynamically within the warehouse, avoiding obstacles and following marked paths, is a testament to the well-defined requirements in the realm of motion planning. The implementation of obstacle avoidance, path planning, and emergency stop protocols contributes to a robust navigation system that prioritizes safety and efficiency.

4.4.4 Autonomous Parking

The project's focus on autonomous parking is underscored by the development of precise parking algorithms, recognition of parking zones, and an automated shutdown procedure upon successful parking. These features not only optimize energy consumption but also enhance the vehicle's overall operational efficiency within the warehouse environment.

4.4.5 Future Considerations

While the current set of software requirements provides a solid foundation, continuous refinement and iteration will be essential to address emerging challenges and technological advancements. Future considerations may include the incorporation of additional sensors, optimization of image processing algorithms, and enhancements to the user interface for more intuitive control and monitoring.

4.4.6 Conclusion Statement

In conclusion, the Software Requirement Specification for the Autonomous Warehouse Vehicle Project serves as a comprehensive guide for the development team. The delineation of user characteristics, functional requirements, and system constraints ensures a systematic and well-informed approach to building an autonomous vehicle that excels in cargo handling, obstacle navigation, and parking within a warehouse setting.

5 Software Design Description(SDD)

5.1 Purpose

This document is created to elaborate on the software design of the Autonomous Warehouse Vehicle Project and define the software structures, algorithms, and components that will be used in the development stage of the project. The primary objective of our project is to optimize warehouse management processes and make material movement within the warehouse more efficient and reliable

5.2 Project Description

The Autonomous Warehouse Vehicle Project aims to automate cargo transportation and placement processes in warehouse environments. The starting point of this project is to reduce manual handling operations in the warehouse, optimize warehouse management, and strategically redirect human resources to more strategic tasks. The vehicle should be able to follow specified lines, detect obstacles, and park safely in a designated storage area.

5.3 Objectives

The main objectives of our project are as follows:

- Line Following: The vehicle should be able to follow a specific line drawn on the floor, allowing it to move along designated routes within the warehouse.
- Obstacle Avoidance: The vehicle should be capable of detecting obstacles in its surroundings using sensors and navigate around them safely or choose an alternative route.
- Autonomous Parking: The vehicle should be able to park safely in a designated storage area. This process should be accomplished through precise sensors and algorithms.
- Safety and Efficiency: The software should adhere to safety standards while executing the vehicle's movements and tasks. Additionally, it should operate efficiently to maximize material movement within the warehouse.

5.4 Definitions

Name	Definition
Autonomous Warehouse Vehicle	A vehicle that automates cargo transportation and placement tasks within a warehouse.
Line Tracking	The process of detecting and following lines drawn on the floor to enable the vehicle to move along specific routes within the warehouse.
Obstacle Avoidance	The capability of the vehicle to detect obstacles within the warehouse using sensors and avoid them safely.
Autonomous Parking	The ability of the vehicle to park safely in a designated storage area. This process is accomplished through precise sensors and algorithms.
Computer Vision	A subfield of Artificial Intelligence focused on recognizing and understanding objects using visual inputs.
YOLO Models	YOLO (You Only Look Once) Models are a family of object detection algorithms used in real-time computer vision applications.
Sensors	Hardware components on the vehicle used to collect environmental data for line tracking, obstacle avoidance, and autonomous parking processes.
Control Algorithms	Software algorithms that guide the vehicle's movements and coordinate tasks.
Database	An organized collection of structured data storing user settings, camera configurations, and statistical data for local processing in Insightio.
UI (User Interface)	The graphical or text-based interface facilitating interaction between the user and the application.
C and C++	General-purpose programming languages used for various applications, ranging from low-level operations to high-level applications.
Arduino	An electronic platform and programming language used for embedded systems and prototyping.
Jetson Nano	An embedded system and artificial intelligence computing platform produced by NVIDIA. Designed for high-performance computing and deep learning applications.

5.5 System Overview

5.5.1 Project Objectives

The Autonomous Warehouse Vehicle Project encompasses an automation system designed to perform cargo transportation and placement tasks within a warehouse. The primary objectives are as follows:

- Achieving autonomous pickup and delivery of cargo.
- Integrating line tracking, obstacle avoidance, and autonomous parking capabilities.
- Enhancing material movement within the warehouse to optimize operational efficiency.

5.5.2 System Architecture

The autonomous warehouse vehicle includes a set of integrated systems and components. The key components are as follows:

- Line Tracking Module: Detects lines drawn on the floor to enable the vehicle to move along specific routes.
- Obstacle Detection Module: Utilizes sensors to detect obstacles around the vehicle and develops strategies to safely avoid these obstacles.
- Autonomous Parking Module: Employs algorithms and precision sensors to park the vehicle safely in a designated storage area.
- Control Algorithms: Software algorithms coordinating various tasks and directing the vehicle's movements.

5.5.3 Software and Programming Languages

The project will utilize C and C++ programming languages, offering features suitable for general-purpose programming and embedded systems. Additionally, the Arduino and Jetson Nano platforms will be integrated into the project.

5.5.4 External Libraries and Frameworks

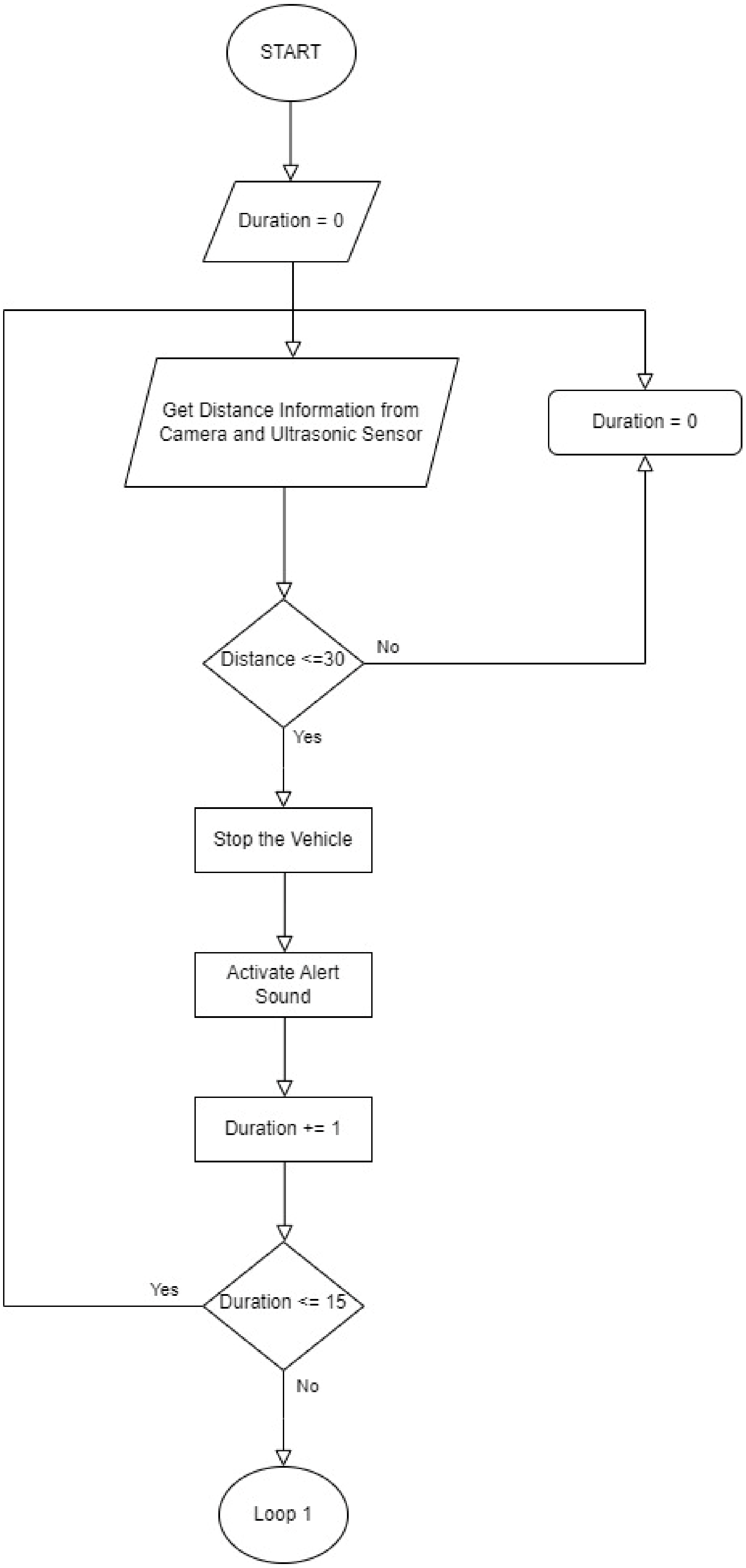
The External libraries such as OpenCV for line tracking and object detection and frameworks like YOLO (You Only Look Once) will be used in the project.

5.5.5 System Integration

The integration of the autonomous warehouse vehicle system involves the interaction of various components and modules. Line tracking, obstacle avoidance, and autonomous parking modules are integrated by control algorithms, and an interface is provided.

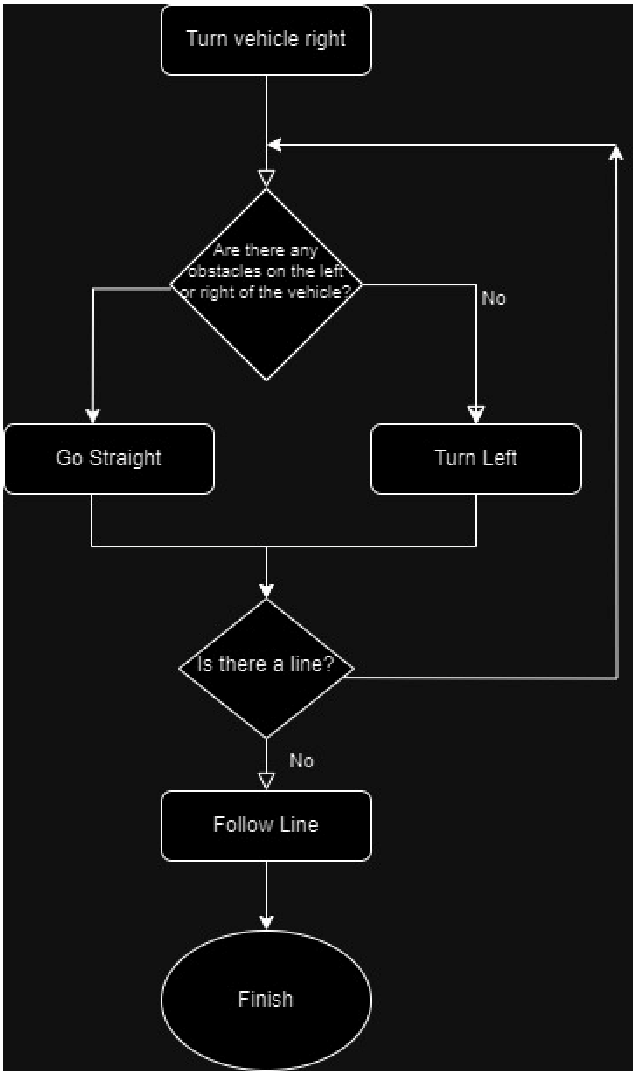
5.5.6 Algorithms

5.5.6.1 Obstacle Detection and Avoidance Algorithm:

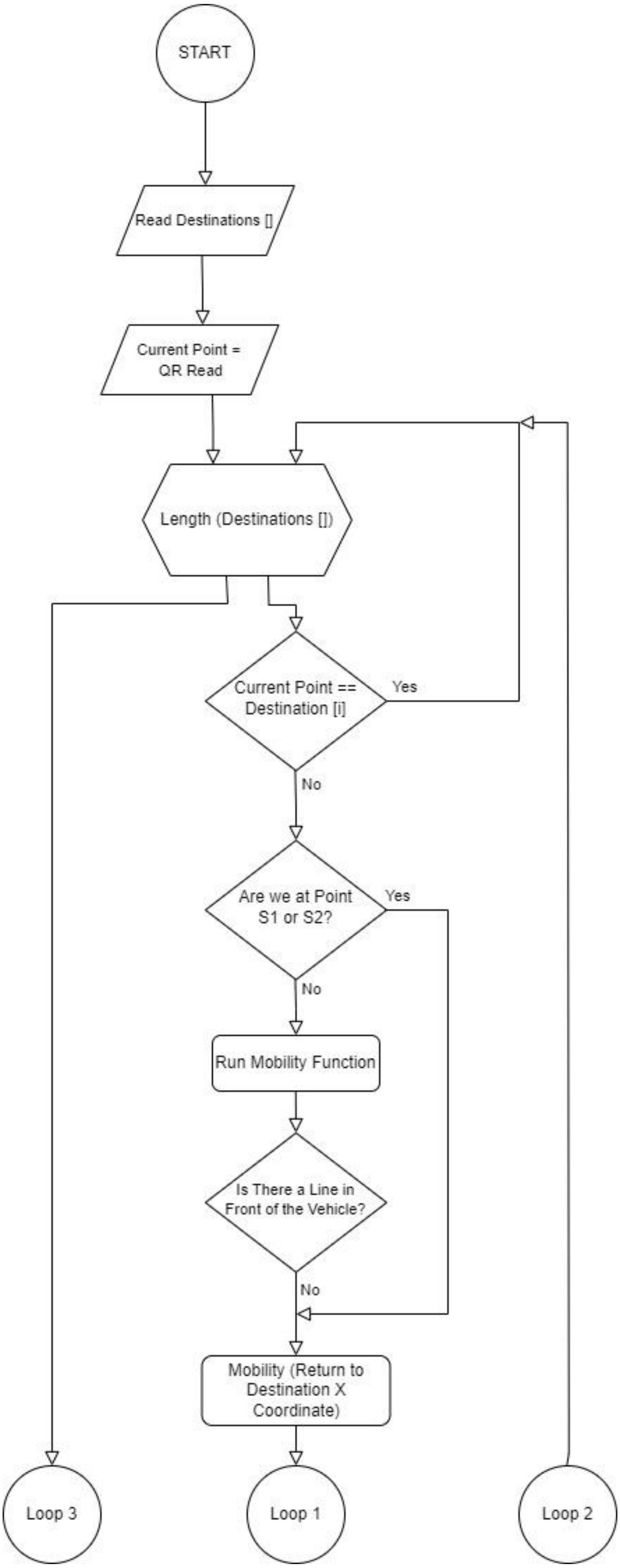


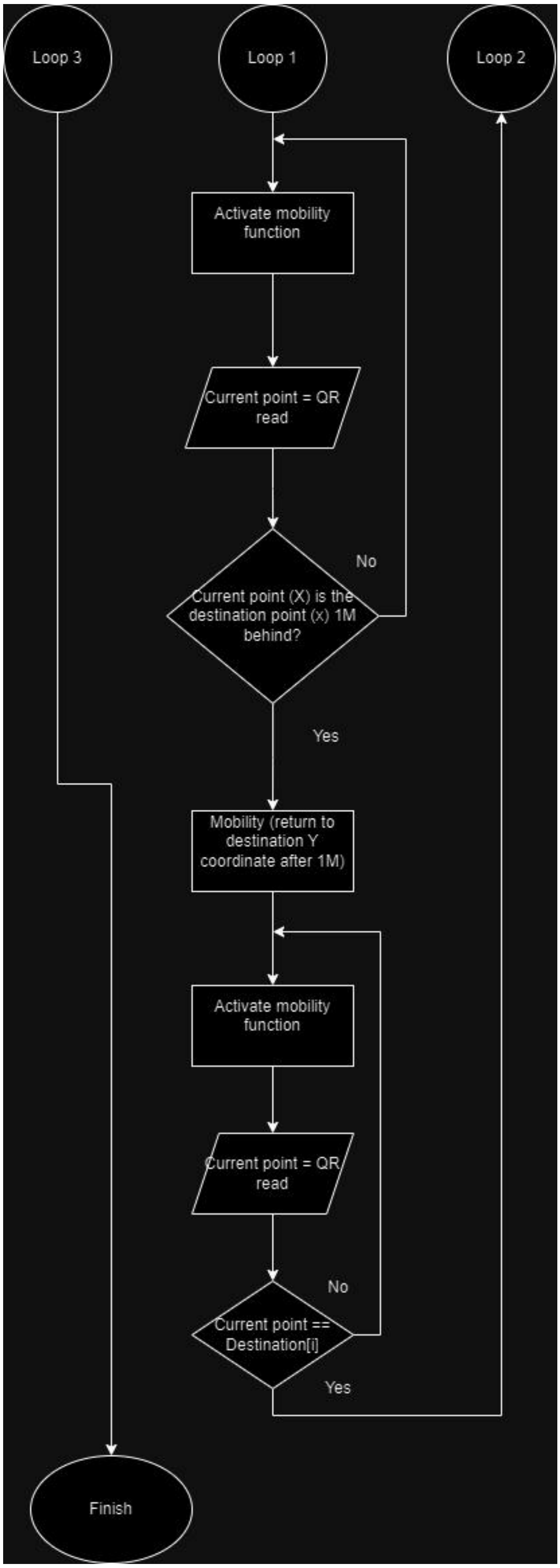
Algorithms are used to calculate the shortest possible route by considering the surroundings and the distribution obtained from the ultrasonic sensor.

- At the starting point, the algorithm places a starting marker.
- The algorithm continuously analyzes the surroundings and the distribution obtained from the ultrasonic sensor.
- Based on the information about the surroundings and the distribution obtained from the ultrasonic sensor, the algorithm calculates the nearest safe route.
- To follow the safe route, the algorithm sends instructions to the vehicle's control panel.
- The vehicle follows these instructions and tracks the designated route.
- The algorithm continues to calculate and send instructions to the control panel to target the shortest route. An important part of the algorithm is to stop the vehicle when it reaches a distribution of less than approximately 30 centimeters. In this case, an alert directive is sent to stop the vehicle and activate the warning system. If this situation persists for 15 seconds or less, the alert system remains active.

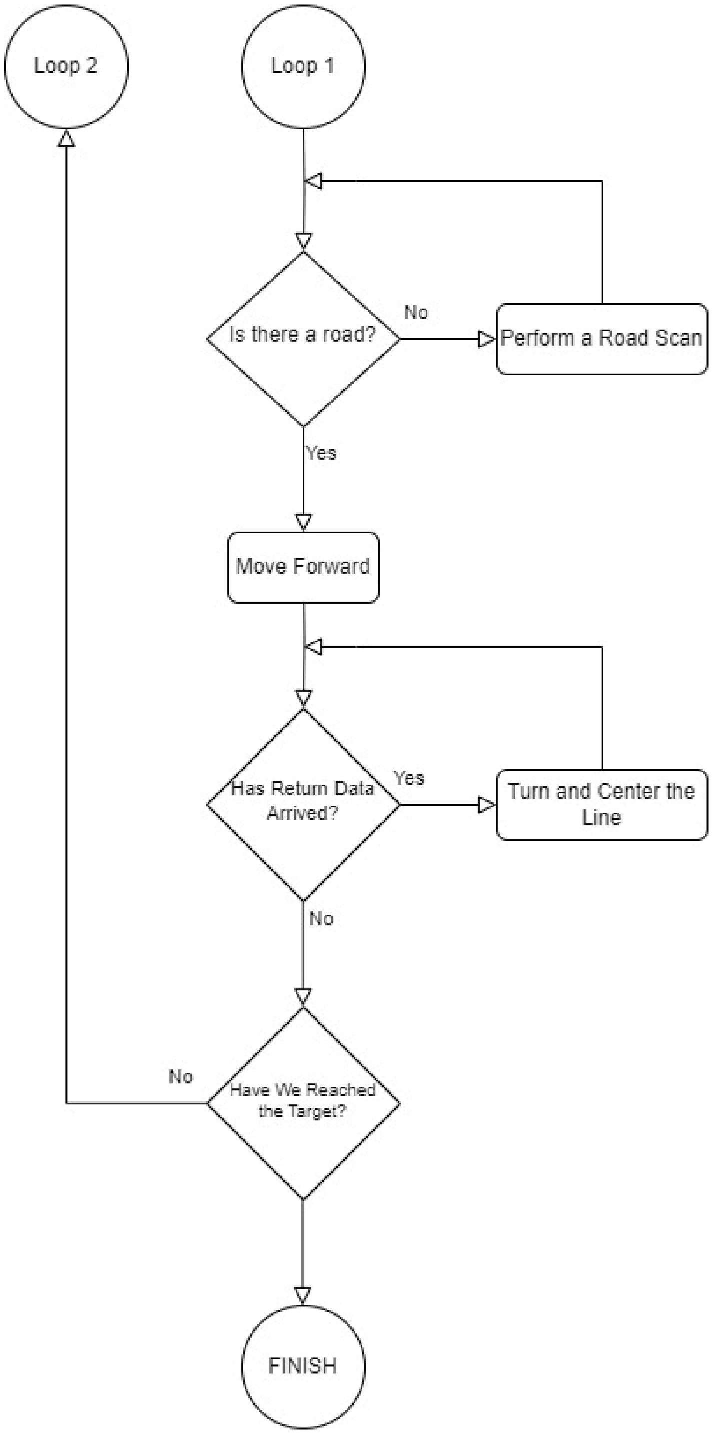


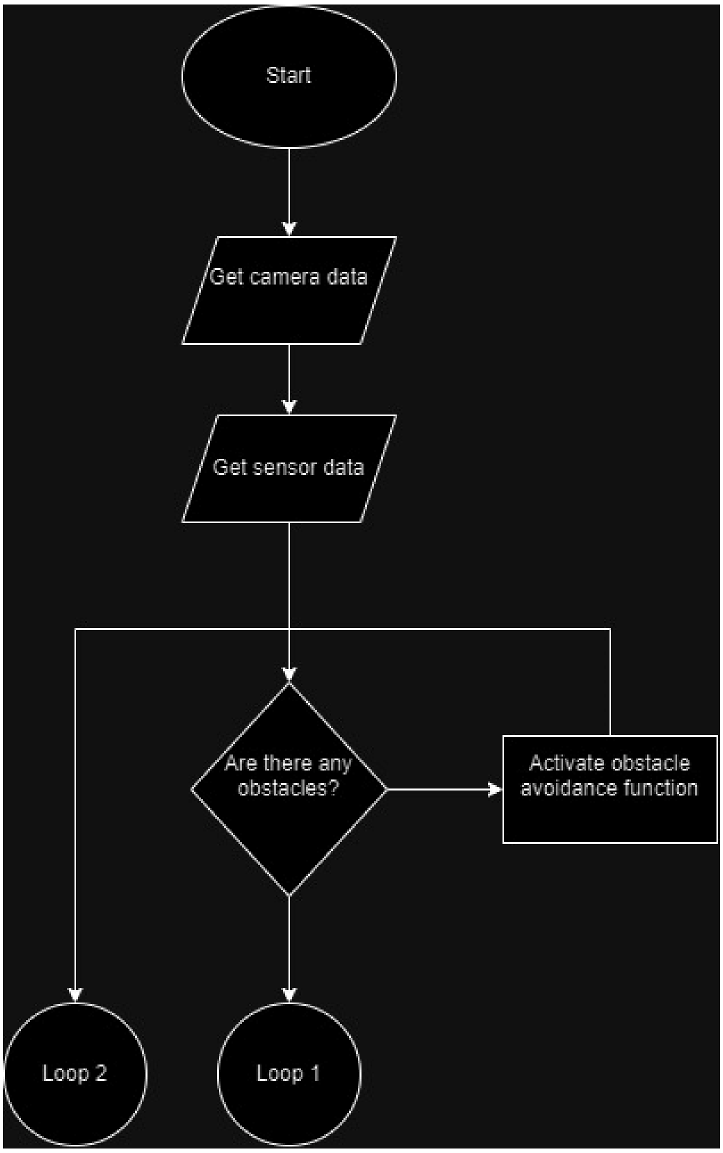
5.5.6.2 Navigation Algorithm





5.5.6.3 Mobility Algorithm





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