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CENTRAL AGV NAVIGATION SYSTEM USING REAL TIME IMAGE PROCESSING.

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Abstract: Automation is the key to long-term success because a well-maintained automated system will consistently deliver the output required while keeping the same level of precision throughout the process. In addition, operating expenses are lower in all industries as compared to labor costs because an automated system is a one-time investment whereas workers must be paid on a regular basis, and labor job precision is undoubtedly lower than an automated system because there are no human errors.

The AGV (Automated Guided Vehicle) Navigation System is a warehouse sorting system that employs real-time image processing for AGV control. It is a low-cost central navigation system that is extremely helpful when applied on a big scale because the installation costs are considerably reduced.

Index Terms - AGV, Real time Image Processing, Object Tracking, Central Navigation System, Warehouse Sorting System, OpenCV, A* Algorithm, ROS.

I. Introduction

Central AGV Navigation System is a cost-efficient Navigation system for AGVs to navigate inside the arena and can be implemented for both small- and large-scale industries where the primary concern is to control the AGVs remotely and efficiently. This system makes use of a camera mounted on top of the arena to accurately locate the position of the AGV and move it to the destined position through a shortest path without any collisions with other AGVs within the arena.

The main purpose is to build an efficient algorithm for the Central Navigation System such that the AGVs can move inside the arena without collisions amongst each other and to build a cost efficient AGV which follows the commands of the Central Controlling Unit alias the Central Navigation System.

II. AUTOMATION

Automation is the key to long-term success because a well-maintained automated system will consistently deliver the output required while keeping the same level of precision throughout the process. In addition, operating expenses are lower in all industries as compared to labor costs because an automated system is a one-time investment whereas workers must be paid on a regular basis, and labor job precision is undoubtedly lower than an automated system because there are no human errors.

Automation refers to a group of technologies that reduce the need for human intervention in a task. Predefining decision criteria, sub-process relationships and related activities, and coding these pre-definitions into computers reduces human intervention.

automation can refer to anything from thermostats controlling a boiler in your home to large industrial control systems with tens of thousands of inputs and control outputs. The banking industry has also embraced automation. They range from simple on-off control to high-level multivariate algorithms in terms of control complexity.

A controller compares a measured value of a process to a desired set value and processes the resulting error signal to adjust some input to the process in order to keep the process at its set point despite disturbances in the simplest sort of automatic control loop. The use of negative feedback to a system is called closed-loop control.

Mechanical, hydraulic, pneumatic, electrical, electronic, and computer devices have all been used to automate processes, usually in combination. Complex systems, such as modern factories, airplanes, and ships, frequently employ a combination of these strategies. Labor savings, waste reduction, electricity cost savings, material cost savings, and improved quality, accuracy, and precision are all advantages of automation.

The World Bank's World Development Report 2019 reveals that the economic benefits of new technology-related companies and occupations surpass the economic costs of workers being displaced by automation.

III. AGV & NAVIGATION SYSTEM

AGVs are self-connecting trailers that can tow objects. Trailers can be used to transport raw materials or finished products. The AGV can also be used to store things in the bed. Items can be unloaded by placing them on a conveyor with motorized rollers and then reversing the rollers. Almost all industries use AGVs, including pulp, paper, metal, newspaper and general manufacturing. In hospitals, items such as food, bedding, and medicine are also transported.

A laser guided vehicle is another name for an AGV (LGV). The technology is also known as Fahrerloses Transport system (FTS) in Germany and förarlösa truckar in Sweden. Automated Guided Carts (AGCs) are lower-cost counterparts of AGVs that are usually guided by magnetic tape. The term AMR is occasionally [1] used to distinguish between mobile robots that do not rely on supplementary infrastructure in the environment for navigation (such as magnetic strips or optical markers) and those that do; the latter are referred to as AGVs.

AGCs come in a variety of variants and can be used to transfer goods across a facility or warehouse, as well as deliver loads.

Barrett Electronics of Northbrook, Illinois introduced the first AGVs in the 1950s and were essentially tow trucks that ran on wire on the floor instead of rails. This technology has spawned a new type of AGV that rides the invisible UV mark of the floor instead of being towed by a chain. The first such systems were installed to move mail through the Willis Tower (formerly Sears Tower) office in Chicago, Illinois.

The technology has advanced throughout time, and today's automated vehicles, such as LGVs, are mostly guided by lasers (Laser Guided Vehicle). LGVs are configured to communicate with other robots in an automated procedure to guarantee that merchandise moves smoothly through the warehouse, whether it is being kept for future use or transferred immediately to shipping regions. Today, the AGV is used in the construction of new factories and warehouses, safely transporting things to their proper locations.

IV. The AGV system has four main components.

- A vehicle used to drive a factory floor without a human operator.
- A guidance route that guides the vehicle to move along a designated travel route while avoiding obstacles.
- The control unit consists of various controllers, sensors, encoders, etc. to properly monitor the system.
- Computer Interface: Multiple AGVs interface with the main host computer and other systems such as automated warehouses and retrieval systems (AS / RS) to efficiently perform the functions found in flexible manufacturing systems.

The AGV navigation system to be implemented is a warehouse sorting system that uses real-time image processing for AGV control. A low-cost central navigation system that is extremely useful for large-scale operations because it significantly reduces installation costs.

V. EXISTING AGV

4.1. Wired

Cut a slot in soil and insert the wire about 1 inch below the surface. This slot is cut along the path that the AGV follows. Radio signals are transmitted over this line. The sensor is mounted near the ground below the AGV. Sensors monitor the relative position of the radio signal as it travels along the wire. This data is used to control the steering circuit that allows the AGV to follow the wire.

4.2. Guide tape

The guideway of the AGV (also known as an automated guided vehicle or AGC) is made of tape. Magnetic ribbons or colored ribbons are two types of ribbons that can be used. The AGV is equipped with a tracking sensor that can follow the path of the belt. If you need to change course, one of the great advantages of tape over cable management is that you can easily remove and reposition the tape. Colored tapes are cheap at first, but they do not have the advantage of being embedded in high-traffic areas that can be damaged or soiled.

A flexible magnetic rod, such as a wire, can be embedded in the ground, but it works on the same principle as magnetic tape, so it remains dead or passive. Another advantage of magnetic guide tapes is that they are reversible. Another advantage of magnetic guide tape is that it has two polarities. Pieces of magnetic tape can be placed to change the state of the AGC based on the polarity and order of the tags.

4.3. LASER

Target Navigation reflective tape attaches to buildings, poles, and permanent machines to aid navigation. In the turret, the AGV holds the laser transmitter and receiver. The same sensor sends and receives lasers. The angle and (possibly) distance to the line of sight and all reflectors within range are automatically determined. A map of the reflector placement stored in the AGV's memory is compared to this data. This allows the navigation system to triangulate the current position of the AGV. The current position is compared to the programmed path in the reflector layout map. To keep the AGV on track, the steering will change accordingly. You can then move to a specific destination using the constantly updated position

4.4. Inertial Navigation

Inertial Navigation is another type of AGV guidance. A computer control system guides the vehicle and uses inertial guidance to assign tasks to the vehicle. The transponder is embedded in the floor of the workplace. These transponders are used by the AGV to ensure that the vehicle is in track. The gyroscope can detect and correct even the slightest diversion of the vehicle to get the AGV into orbit. The inertial approach has a margin of error of 1 inch. The

inertia can be used in a variety of conditions, including narrow passages and harsh temperatures. The use of magnets embedded at the bottom of the facility that can be read and tracked by the vehicle is an example of inertial navigation.

4.5. Nature Feature Navigation

Natural Features or Natural Targeting Navigation refers to navigation that does not require a workspace upgrade. One method combines one or more distance sensors, such as: A laser rangefinder that uses a gyroscope or inertial measurement unit, and a

Monte Carlo / Markov chainization algorithm to dynamically plan the shortest course to the target while understanding where it is. Such systems have the advantage of being highly adaptable to needs-based distribution everywhere.
The AGV can design the course around broken equipment, allowing it to handle outages without interrupting all production activities. It is also easy to install and minimizes production downtime.

4.6. Vision Guidance

AGV is guided by Vision and does not require any changes to the environment or infrastructure in which it is installed. They work by recording features along the path with the camera and playing back the movement using the recorded features. dr Hans Moravec of Carnegie Mellon University designed and developed the Vision Guide AGV using evidence grid technology, a probabilistic volume sensing application. To compensate for sensor and environmental performance uncertainty, EvidenceGrid technology uses the probability of occupancy of each location in space. A custom-made stereo camera acts as the main navigation sensor. Vision-guided AGVs can create 3D maps from 360-degree photos and follow pre-programmed routes without human intervention.

4.7. Geoguide

To determine its location, the Geoguide AGV identifies its surroundings. Forklifts with geo-guidance technology detect and identify columns, shelves, and walls in warehouses without the use of infrastructure.

Table 1 shows the pros and cons of various existing popular AGVs on the basis of the guidance systems used.

Table 1 – Pros and Cons of existing AGV guidance systems

Type of guidance system	Pros	Cons
Wire guidance	Dirty environment can be handled since the wire is set in concrete floor Changing to a new route by an AGV requires laying of new guide wires throughout the shop floor, so it should not be used for a frequently changing system	Dirty environment can be handled since the wire is set in concrete floor Changing to a new route by an AGV requires laying of new guide wires throughout the shop floor, so it should not be used for a frequently changing system
Paint and chemical guidance	AGV requires laying of new guide wires throughout the shop floor, so it should not be used for a frequently changing system It requires a clean environment.	AGV requires laying of new guide wires throughout the shop floor, so it should not be used for a frequently changing system It requires a clean environment.
Laser guidance	The path must remain clear of all types of obstructions including a piece of paper	The path must remain clear of all types of obstructions including a piece of paper
Dead-reckoning guidance	New targets can be defined without much difficulty within the existing system and it allows for easy expansion of the system. The reflective targets present in the system can be easily moved without much disruption to the process It requires additional setup time as compared to other systems discussed above. Amount of programming required is also more as the AGV must be taught where the reflective targets are with respect to pick up and drop off points as well as obstacles that may be permanent fixtures on the factory/warehouse floor	New targets can be defined without much difficulty within the existing system and it allows for easy expansion of the system. The reflective targets present in the system can be easily moved without much disruption to the process It requires additional setup time as compared to other systems discussed above. Amount of programming required is also more as the AGV must be taught where the reflective targets are with respect to pick up and drop off points as well as obstacles that may be permanent fixtures on the factory/warehouse floor

VI. LITERATURE REVIEW

Saurin Sheth et al. Has developed a special machine using a color-guided vehicle system and a mechatronics system that includes computer vision, pneumatics, Arduino, and wireless Zigbee modules [1, 2, 3, 4]. This system is intended to detect vehicles entering gas stations. These gas stations are completely manual and require time and effort. In areas with low population densities, labor costs are high due to low population densities. Due to labor availability and climatic conditions, some of these gas stations are not open 24 hours a day. With these factors in mind, we have adopted a mechatronics approach to design an automated refueling system that operates 24/7 at low cost and requires the optimum amount of time to refuel with minimal effort. To do. The car must be parked in a specific area. Image processing is used to create a closed-loop system that guides the robot arm to fit the fuel tank. After the arms are aligned, the consumer must swipe the card into the machine to enter the amount of gas that fills the car. The pump will operate and the tank will begin to fill with fuel. When the input amount of fuel is poured into the car, the pump will stop supplying fuel and the arm will return to its original position. With this approach, even owners can monitor gas pumps online from anywhere in the world and overcome the idea of gas theft. This design allows you to specify the fuel flow rate for different types of vehicles depending on the capacity of the fuel tank, accelerating the process and increasing the frequency of refueling the vehicle. This can be done by coding the controller to drive the motor driver at the specific voltage required to drive the pump. As the voltage changes, so does the total flow rate, depending on the pump specifications. The process is fully automated, so no effort other than maintenance and inspection is required.

The system can be located anywhere on the highway, in less populated areas and controlled from remote stations. It is easy to use 24 hours a day, 7 days a week. The setup can be placed anywhere, as the weather does not affect the machine unless there is a natural disaster.

K.H. Pate et al. I designed a closed-loop image processing system with a mechatronics system. The closed loop system helps the robot arm orient itself in the sophisticated configuration required. [9] In this design, the fuel tank is detected using a 4-point locator or signal marker. The mark is engraved on the fuel tank, and image processing makes the match the center of the fuel tank. The center is always the same, even when viewed from an angle, and homographs can be used. Therefore, the controller easily captures the four points and uses an algorithm to find the center.

v Chauhan et al. He has developed an advanced approach for recognizing colored objects using computer vision [5] and has also contributed to improving color recognition algorithms [6]. In this system, the parts are color coded and then sorted by different colors.

After recognizing the color of the object, the robot arm automatically selects and places the object. If the color of the work does not match what was requested, it will be rejected. The complete sorting system works with image processing using MATLAB applications and PLCs that control various motors in the system. Machine vision based on the concept of color is widely used in the pharmaceutical, agricultural, and component assembly, especially in the automotive industry. Advances in both image processing technology and related software tools have enabled manufacturers to apply real-time color computer vision to factory floors. This technique can solve problems that were previously limited to manual inspection and classification. From this system, we can see that machine vision is an application of computer vision in industry and manufacturing. Two important specifications of an imaging system are sensitivity and resolution. The higher the resolution, the more limited the field of view. Sensitivity and resolution are interdependent. Increasing the sensitivity will decrease the resolution and increasing the resolution will decrease the sensitivity while keeping all other factors constant. One of the most common machine vision applications is the inspection of industrial products such as semiconductor chips, automobiles, food and pharmaceuticals. Just as human inspectors working on assembly lines visually inspect parts to assess build quality, machine vision systems use digital cameras, smart cameras, and vision software for similar inspections. To execute. The vision system is programmed to perform narrowly defined tasks such as counting objects on the conveyor, reading serial numbers, and searching for surface defects. Machine vision color began in the mid-1980s, and color cameras and image boards became commercially available.

The first application in which color machine vision was widely used was food processing, especially fast sorting of fruits. The purpose was to detect and remove defective, defective, and / or unreasonably large fruits and plant debris. In industrial applications, inspecting automotive fuse blocks using RGB color imaging to confirm the presence of the correct fuse was the first use of color imaging.

Hark Hwang et al. Has developed a new scheduling algorithm for automated guided vehicles (AGVs) based on the bidding concept. The given algorithm uses mathematical functions to leverage information from the AGV's WIP and travel time [7]. They first set up an event-driven model of the AGV system in the zone control framework. Next, a set of road network (route) layouts has been carefully designed for the AGV work area of the container terminal. Based on the zone control model, a traffic control strategy is proposed that separates movement conflict resolution between AGVs from routing problems. Routing algorithms are also built to minimize vehicle travel distance and travel time. Integrated design and control efficiency is demonstrated by computer simulation using a defined set of system performance metrics. They proposed a new AGV dispatching algorithm. It is developed based on an offer concept that includes relevant information, for example: B. Work in process (WIP) and AGV travel time in the workplace buffer. By computer simulation in a fictitious workshop-type automated manufacturing system. The efficiency of the algorithm is presented and compared to some known dispatching rules.

J.A Ottjes et al. We have proposed a dynamic free-range system that is superior to other models. The simulation model uses the shortest path connection approach to compare different fixed types of layouts. Collision avoidance clearly plays an important role. From this we can conclude that this approach has very high potential in terms of transport capacity [8]. The introduction of more powerful in-vehicle computers and advanced sensor technology has improved the positioning and navigation capabilities of the AGV. However, although the route is virtual, it is still fixed. The new step is to dynamically determine each path. This will take full advantage of the free space on the AGV. This white paper discusses the benefits of a dynamic free range approach. A strategy-level simulation model is presented that compares some common fixed layouts with the shortest link approach. Of course, collision avoidance plays a central role. It can be concluded that dynamic free-range agriculture has high potential in terms of the transport capacity of the resulting system. The discrete event simulation model was built using Delphi in combination with the TOMAS simulation package to compare the performance of various orbital planning strategies. This model consists of a work area with a quarry crane on one side and a stacker crane on the other side (see Figure 6). Transport operations are from quarry cranes to stacker cranes and vice versa.

For each AGV, the target is drawn from a uniform distribution. The AGV is driven at a constant speed. Except for target selection, stochastic behavior has not yet been modeled. The start and end of the orbit are discarded. Obstacles (such as hatch covers) are not modeled.

J.T. Udding et al. I have developed an AGV system using a zone control methodology. Several layouts have been designed for the AGV work area. A traffic control strategy is developed to isolate the traffic congestion problem for AGVs running on a congested network consisting of multiple AGVs. An algorithm has been formulated to address the problem of traffic congestion using zone control. The purpose is to minimize the travel and transportation times of the AGV [10]. The AGV's work area is divided into non-overlapping zones, and access to the zones is tightly controlled. This strategy facilitates collision avoidance between vehicles by requiring each zone to be occupied by up to one vehicle. Another reason it's so popular with most applications is that it's easy to install and extend.

The zone control model described below contains two components: the structure of the road network and the discrete event behavior of the vehicle as it follows a route consisting of a set of zones. The

road network consists of lanes, intersections and depots.

A. Lanes and Depots: Lanes are a finite sequence of zones. Physically, a lane is a road on which vehicles can move in the directions indicated by the order of the zones of the lane. In particular, the first and last zones of a lane are called the start zone (SZ) and end zone (EZ) of the lane, respectively.

B. Each depot is modeled as a zone that can accommodate any number of vehicles. Each depot is assigned at least one in-lane and one out-lane. On the train (or Depot Overview) is the lane in which the vehicle can move to (or from) the depot. Emphasize that the depot is not a zone in any lane. Use C to indicate each set of all zones in the system.

C. Intersections are intersections that physically connect multiple lanes. In particular, each intersection is connected to a series of in-lanes and a series of out-lanes. Intersection entrance (or exit) lanes allow vehicles to move toward (or away from) the intersection. The EZ in each lane of an intersection is called the intersection zone of the intersection. Zones that are not crossing zones are called off-crossing zones. Note that each depot is not on the lane, so it is a fallback zone. Let R and A be a set of all intersections and a set of all intersection zones, respectively.

D Adjacent Zones The concept of adjacency zones means immediate connections between zones. The set of adjacent zones for each depot contains the SZs of all its external lanes. The adjacent zone of non-EZ zone c on the lane is the adjacent zone of c on the lane with respect to the direction of the lane. The zone adjacent to the EZ in each depot's lane is the depot. Adjacent zone of EZ in the entrance lane of the intersection (that is,

Intersection zone) is the SZ of all outer lanes of the intersection. Use Yc to indicate a set of adjacent zones in zone c. (Assumption 1 shows that adjacent zones are defined for each zone of C.)

Lothar Schulze et al. He gave an overview of AGVS technology and provided information on recent technological advances in the field of material handling systems and research results using various methods such as statistical analysis, characteristic curves, and new approaches [11]. They recognize that one of the most important aspects of a logistic system is the processing of logistics flows in an industrial environment. Despite the high throughput rates achieved by fixed conveyor technologies such as roller conveyors and chain conveyors, the vast majority of industrial applications rely on traditional lifts or transportation vehicles as transportation systems. There are many reasons for this. In addition to cost, one of the main benefits is outstanding flexibility when integrating into existing or changing environments. AGVs can perform fully automated transportation tasks at low cost. Applications are used in everything from the automotive, printing and pharmaceutical industries to metal and food processing, aerospace and port facilities. The AGV system has been known for over 50 years, during which time various technological advances have been made, from improved actuators and power supplies to the concept of completely new sensors. Advanced Control Strategies Required for Significant Advances in Computer Systems The

AGV system basically consists of vehicles, peripherals and onsite components, and fixed control systems. Only the complete interaction of all these components guarantees the efficient operation of the system.

Vehicles: Vehicles are a central element of the AGV in performing actual transportation tasks.

Vehicles must be individually designed for the specific environmental conditions used [1]. This applies to cargo handling equipment, navigation systems, drive configurations, and other aspects.

Fixed control system: The fixed control system contains all higher-level control components. Its tasks include managing shipping orders, optimizing timetables, and communicating with other control systems through predefined interfaces. The system also handles customer interactions and often provides additional functionality such as graphic visualization and statistical evaluation.

Peripheral system components: Peripheral system components represent the various in-vehicle resources of a vehicle. Examples are battery charging stations and weight transfer devices.

Onsite System Components: The structural design aspects of the site that affect the AGV, such as floors, gates and elevators, belong to the category of onsite system components.

David Portugal et al. Announced full integration of a compact educational mobile robot platform built around an Arduino control board and a robot operating system (ROS) [12]. ROS acts as a common platform for connecting software to a variety of hardware such as controllers, sensors, and image processing software such as Open-CV. The system focuses on a compact educational mobile robot platform built around the Robot Operating System (ROS) Arduino controller board. To reduce development time, ROS creates a driver interface, provides hardware abstraction and intuitive operating modes, allowing researchers to focus on their primary research motivations. B. Search and rescue, monitoring of multiple robots or swarm robotics

VII. METHODOLOGY

Block diagram of the system in Figure 1 shows the setup of the Central AGV Navigation System. It shows the arena with pickup points along with drop points. The arena will be mapped and monitored by a camera which relays its images to the central system.

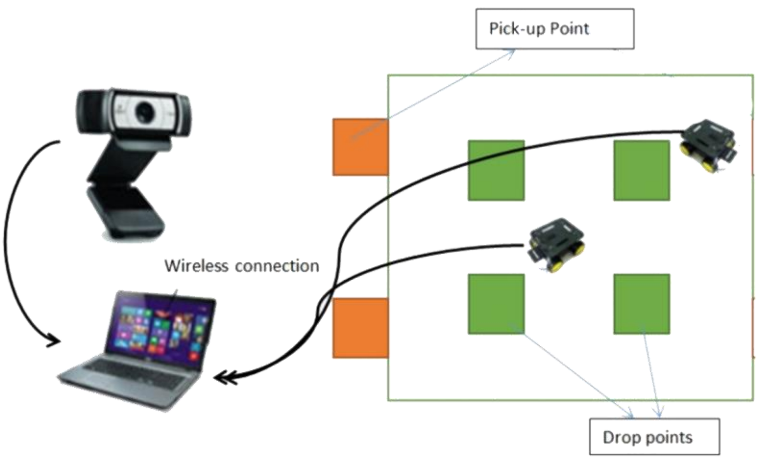

Figure.1 – Central AGV Navigation System

Below is the detailed working of the Central AGV Navigation System:

1. The camera is mounted on the top of the arena covering the entire arena with source and destination points along with the AGV on it.
2. The camera is connected to the Personal Computer or a Laptop or any Processing unit in general using a wired connection. This serves as a Central Navigation System for the entire operation of the AGV.
3. The Central Navigation System has a program written using PYTHON with an OpenCV module for Image Processing and a URLLIB module for communication with the AGV in arena.
4. ARUCO Markers are attached on the four corners of the arena to find the arena in the image obtained by the camera.
5. ARUCO Markers are binary images of a decimal number which can be decoded by a program and can be used for various purposes.
6. ARUCO Markers turns to be beneficial as the obtained imaged can be converted into a plane fitting only the arena hence enabling us to place the camera anywhere above the arena.
7. The AGV is also mounted with an ARUCO Marker on top to detect the position of AGV inside the arena.
8. Using OpenCV, the position of AGV is determined and the system waits for the task to be assigned for the AGV.
9. Each source and destination points are provided with a unique number which the user can use to assign tasks to the AGV.
10. The grid co-ordinates of all the source and destination points are initially defined for the program.
11. The user provides a task to the AGV through the PYTHON program by using the pre-assigned source and destination points of the arena.
12. The program generates a shortest path from the source to the destination which was inputted by the user.
13. As the AGV is detected using the camera along with the co-ordinates of the grid it is present in, it is compared with the next grid co-ordinates of the path generated.
14. The program decides the direction of movement of the AGV by comparing both the co-ordinates of the grid.
15. The direction of movement thus decided is sent to the ESP 32 mounted on the AGV which does the task of an ARDUINO Board with a Wi-Fi module.
16. The communication is done using the http protocol which is enabled by incorporating URLLIB module in the Python code.
17. The ESP 32 decodes the URL requested by the Central Unit and the respective operation is performed.
18. The AGV moves in the guided direction until it reaches the next grid upon which the next command is sent.
19. In this way, the AGV reaches the destination and then back to the initial source grid.
20. All this is possible if and only if the ESP 32 and the Central Navigation System are connected to a same router or hotspot, in which the data connection is not mandatory.
21. The URLs are requested to load in the network by the Central System which is done and decoded by the ESP 32 of the respective AGV as the URL requested carries the IP address of the corresponding ESP 32.

Figure 2 shows the incorporation of ESP32, L298n Motor Drivers and Motors in building of a small scale AGV.

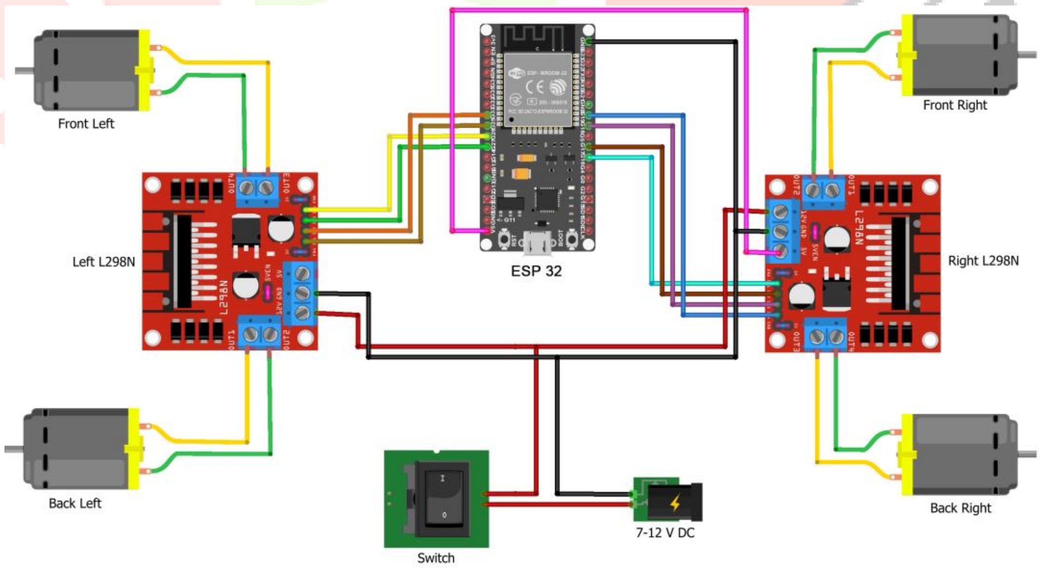

Figure.2 – Circuit Diagram for AGV

Figure 3 shows the flowchart of the Central AGV Navigation System.

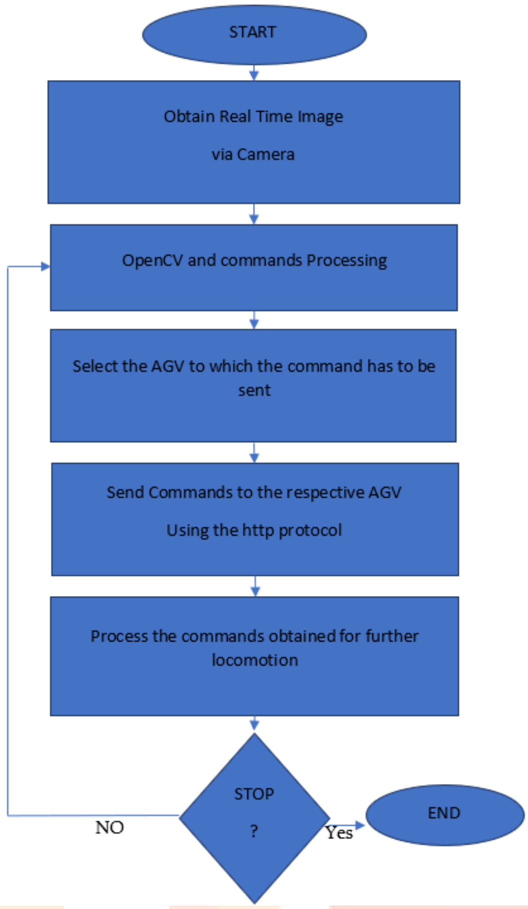

Figure.3 – Flowchart of the System

Figure 4 shows the flowchart of the Image processing algorithm implemented using PYTHON with OpenCV modules

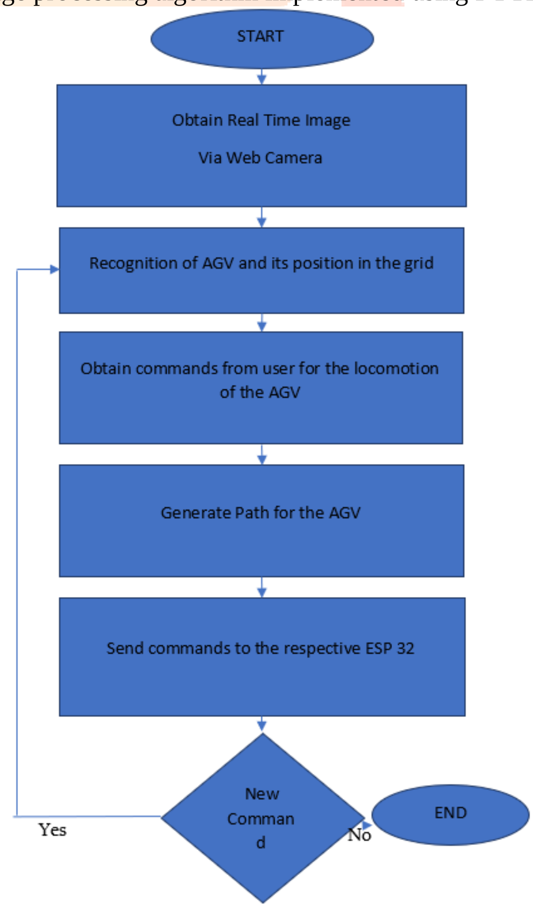

Figure.4– Flowchart of OpenCV – Python Program

Figure 5 shows flowchart of the Arduino code written for the ESP 32 to follow the commands received from the Python program over an http protocol.

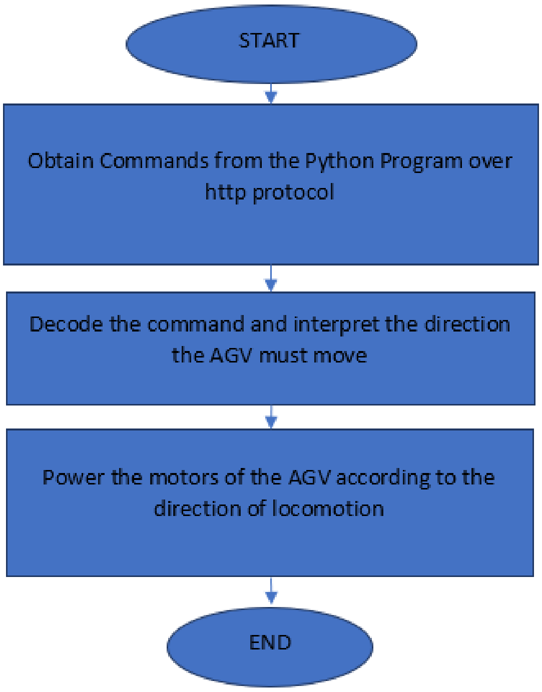

Figure.5– Flowchart for ESP32 Arduino Program

The arena has 4 aruco markers placed on the 4 edges for getting a precise arena detection and plane formation for Image processing.
Figure 6 shows a picture of the arena as viewed by the camera mounted over it.

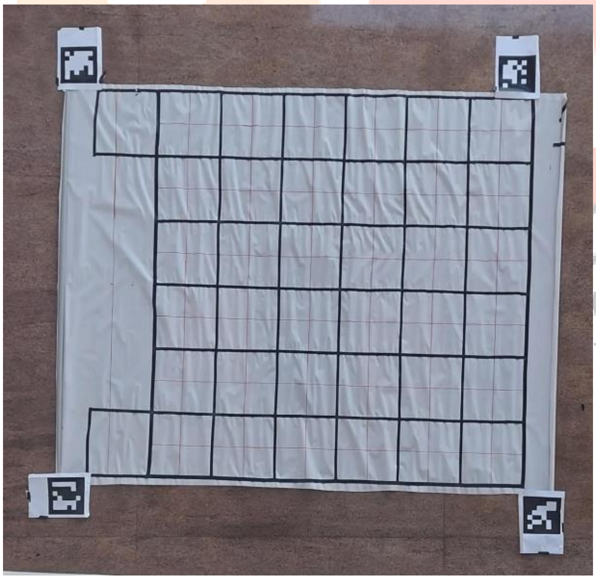

Figure.6 – Arena as viewed from the camera

A rigid model of AGV constructed using ESP32 and L298n motor drivers to control the Mecanum wheels for it to navigate around the arena is shown below.

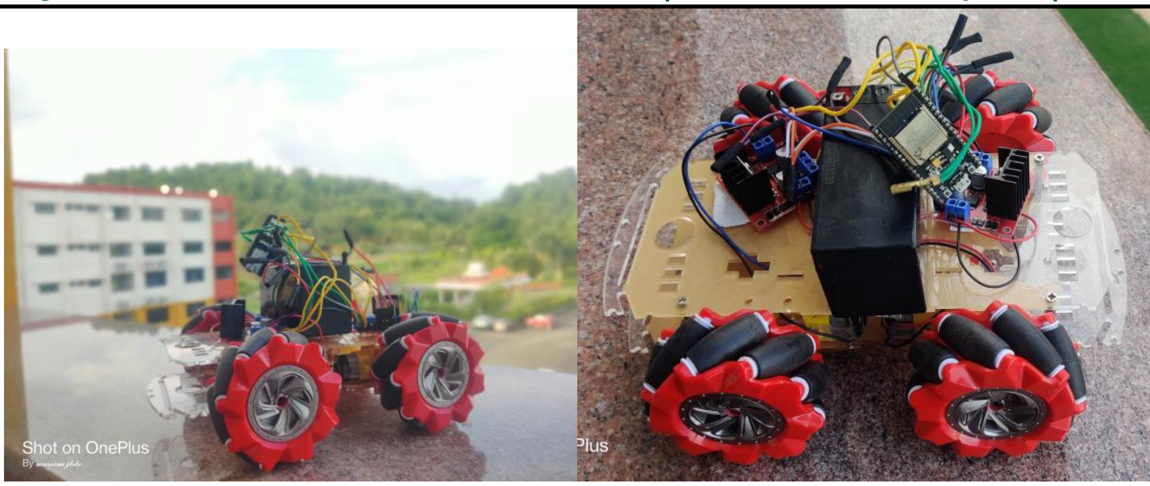

Figure.7 – The AGV Model for Image Processing

The Python Program generates a shortest path between two grids when the grid coordinates are given as an input to program. Along with the coordinates, the camera view is given as an input to program so as to show the shortest path the AGV is supposed to take.
Figure 8 shows the shortest path (shown in blue) which is supposed to be followed by the AGV.

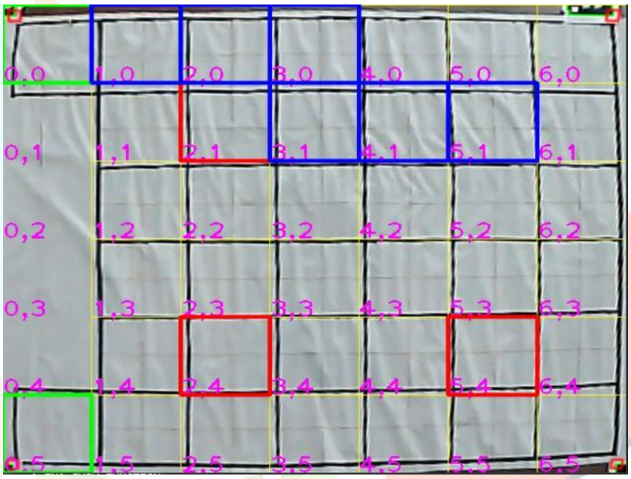

Figure.8 – Shortest path generated for an AGV

VIII. CONCLUSION

The model of AGV developed for its control using Image Processing is cost efficient when compared to an ideal AGV as shown below in Table 2.

Table 2 – Cost Analysis of this AGV and a Typical AGV

Component	**Price in INR**	**For AGV with Image Processing**	**For AGV without Image Processing**
ESP 32	400	Yes	No
Other Microcomputers	2700	No	Yes
L298n driver * 2	600	Yes	Yes
Mecanum Wheel * 4	1000	Yes	Yes
Battery	900	Yes	Yes
Proximity Sensor	300	No	Yes
Other Sensors and Guidance systems	5000	No	Yes
	TOTAL	2900	11,600
	For 5 AGVs	14,500	58,000

Workspaces using such AGVs for moving parts will already have cameras which will be used by authorities to monitor the processes. The same camera feed can be given as an input to the Image Processing System which will reduce the cost of operation drastically. Controlling an AGV remotely using Image Processing with an efficient model of AGV will be widely preferred by the industries and warehouses world-wide. This method of navigation of AGV can also be implemented on a large scale by incorporating multiple cameras combining to produce a single image and then feeding it to the program.

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