#1 Physical Design for various applications

from https://digital.csic.es/handle/10261/155313

a) Automatic Warehouse

- owned by Amazon, Kiva Systems LLC has an innovative solution to automate the material handling in Amazon warehouses.
- The main components of this system are the robotic drive units (bots), the mobile inventory shelves (pods), and the software.

b) Hospital cart transporters

- are used to move goods inside hospitals providing a safer system of work and reducing the risk of moving and handling injuries.
- it helps multiple hospital departments using specialized carts for the distribution of bulk food, medical and surgical supplies, pharmaceuticals, patient food, soiled dishes, clean and soiled linens, trash, and regulated medical waste.

c) AGV container system

- designed by VDL to transport logistic containers in the port of Rotterdam.
- The containers are automatically unloaded from the cargo ship using a crane and placed over an AGV. Then the AGV carries the container to the storage zone and another crane removes the container from the AGV automatically

- Using a centralized control system it is possible to optimize the paths and reduce the time used to load and unload container ships.

d) Helicopter and airplane tug

- There is a manufacturer called MOTOTOK that manufactures radio-controlled vehicles dedicated to move helicopters or airplanes.
- It offers to possibility to equip the tug vehicle with a camera underneath that scans a steering line painted on the production hall floor.
- Bar codes can be added near the guiding line in order to give additional information to the vehicle.

#2 Lomocation System & Actuators

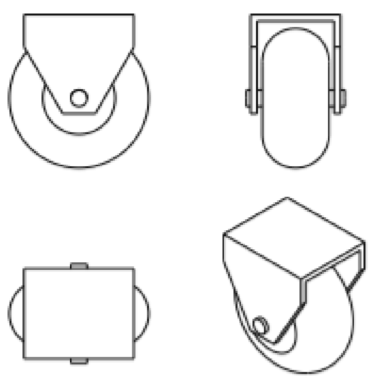
from https://digital.csic.es/handle/10261/155313

Number of wheels

Locomotion system depends on the number of wheels in AGV robot. There are four basic wheel types such as:

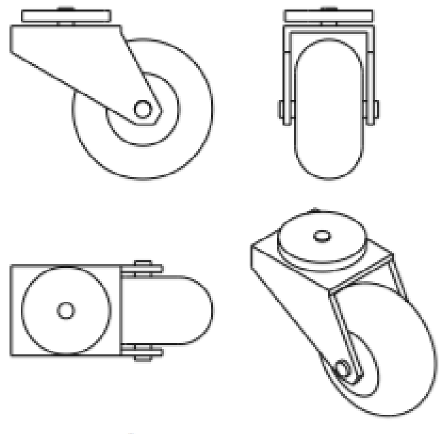
a) Standard wheel

- Two degrees of freedom; rotation around the wheel axle and rotation around the contact point.



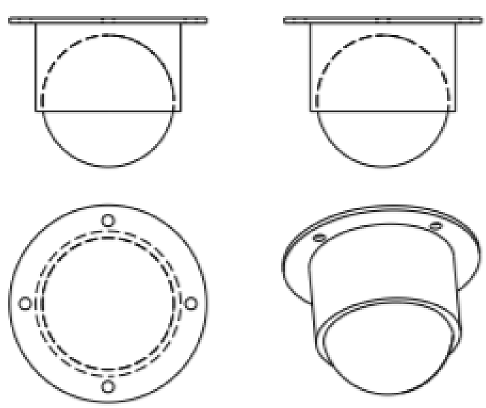
b) Castor wheel

- Two degrees of freedom; rotation around the wheel axle and rotation around an offset steering joint.



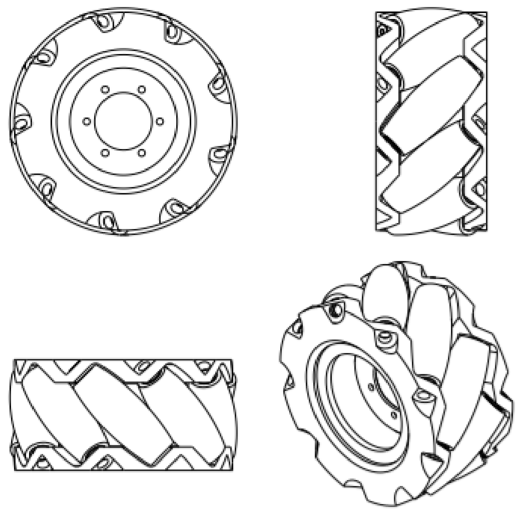
c) Spherical Wheel

- The spherical wheel has no principal axis of rotation and then it has three degrees of freedom; rotation around an axis placed parallel to the ground (2 DF) and rotation around the contact point.

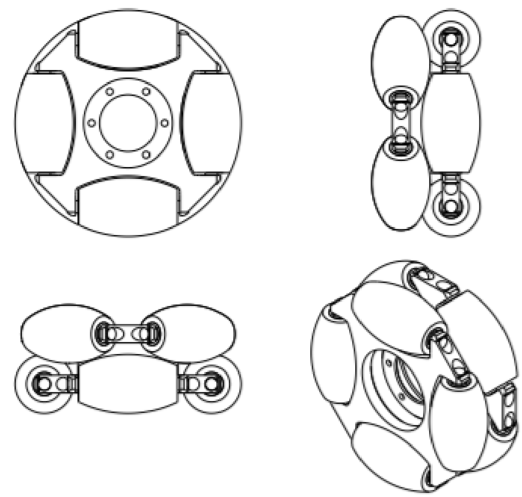


d) Swedish wheel

- Three degrees of freedom; rotation around the wheel axle, rotation around the rollers, and rotation around the contact point.



D1. 45º Swedish wheel



D3. 90º Swedish wheel

However, the spherical wheels are not used in the industrial environment because the payload per wheel is low and the design of the wheel itself is complicated. The caster wheels usually are not motorized; they are used to increase the stability of the vehicle and to distribute the load over additional contact points.

Stability

The static stability of the vehicle requires a minimum of three wheels and the centre

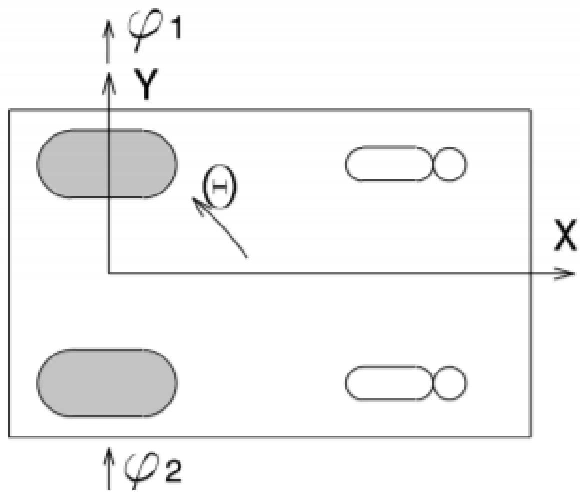
of mass inside the triangle formed by the contact points of the three wheels. Stability can be improved adding more wheels, however then the geometry will be hyperstatic

and a suspension will be required.

For manoeuvrability, Other vehicles are able to move at any time in any direction along the ground plane regardless of the orientation of the vehicle around its vertical axis. These vehicles are

omnidirectional; they can rotate from any point and translate in any direction with no constrains. Wheels with capability to move in more than one direction are required for this type of vehicles. Swedish or spherical wheels are used in omnidirectional vehicles.

In a differential-drive vehicle below the two motors that control the wheels must have the same velocity. The difficulty is even harder on a four-wheels 45º Swedish vehicle because all the 4 wheels must have exactly the same speed, otherwise, the vehicle will not follow a straight line.



Wheel kinematic constraints are directly related with the type of wheels and their position. The motion of the vehicle can be computed combining the motion of the individual.

wheels. Then, the wheel suffers motion only due to pure rolling and rotation about the vertical

axis. There are two constraints that must be fulfilled by all wheels; the rolling constraint

and the sliding constraint. In the following points we will see how are these equations

depending on the wheel type.

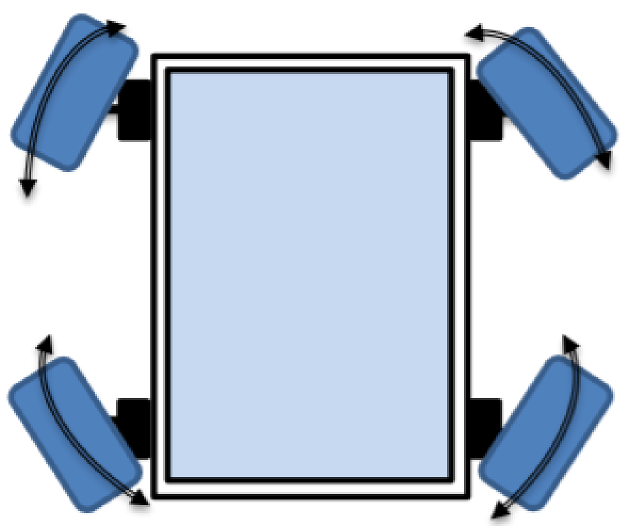
• Rolling constraint > the wheel must roll when motion takes place in the

appropriate direction.

• No sliding constraint > no lateral slippage; the wheel must not slide orthogonal to the wheel plane

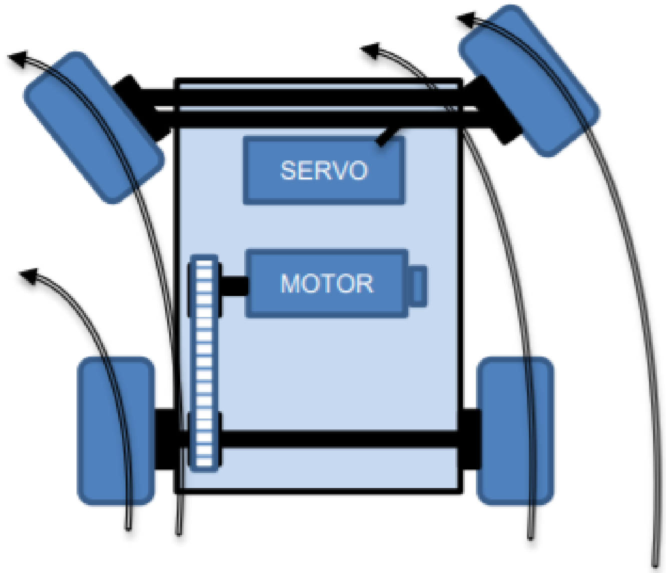
AGV DRIVE AND STEERING TECHNIQUES. [https://core.ac.uk/download/pdf/145049745.pdf]

a) Crab Steering



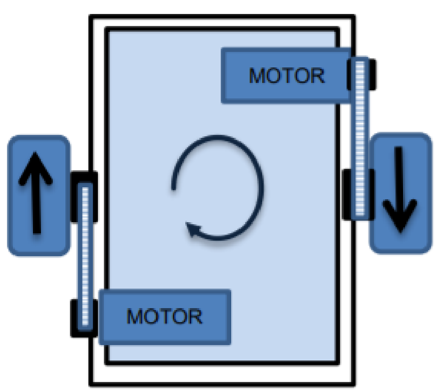
- The movement resembles that of a crab
- The driving wheels are rotated to change steering direction

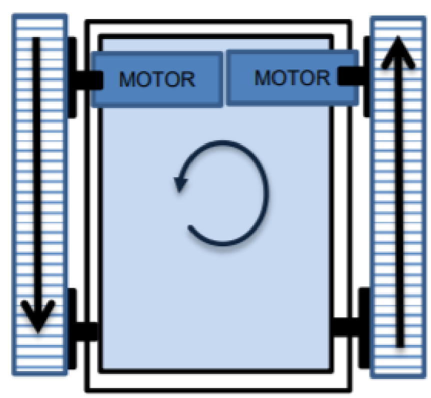
b) Single Drive Separate Steering



- This steering technique is similar to the steering of a remote control car, whereby the front wheels provide steering and the back wheels provide drive

c) Differential Steering

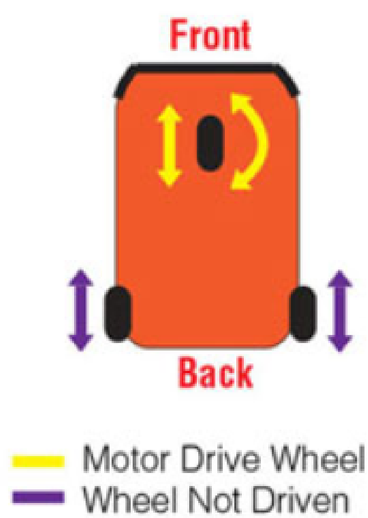




- Differential steering systems have a wheel on each side of the AGV body, whereby the movement and direction of the AGV is obtained by controlling the speed independently on each wheel

Drivetrain Design [https://www.orientalmotor.com/brushless-dc-motors-gear-motors/technology/brushless-dc-motors-agv-designs.html]

a) Tricycle Drive



- One drive wheel and 2 non-driven wheels are used in a triangular configuration.
- The sole front drive wheel is used to both steer and move the vehicle.
- One gearmotor is necessary to rotate the drive wheel, and another motor is necessary to steer.

b) Differential Drive

- It steers the vehicle using differential speed and direction of the 2 drive wheels. These include two geared motors for the drive wheels. It is extremely maneuverable since it can rotate around the center of the vehicle, but angular positioning is less precise.

c) Quad drive

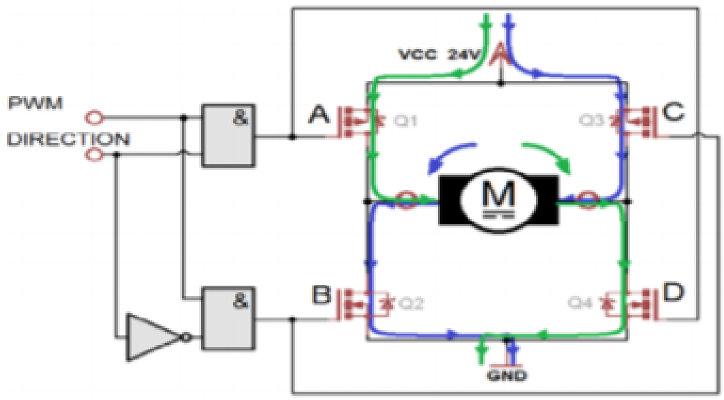
- It uses 2 steer and 2 drive motors. It is also extremely maneuverable, but more complex than other drive configurations. The vehicle can move about the center of its axis and sideways as well.

Motor

file:///C:/Users/harrizazham98/Desktop/Year%204%20Sem%202/Robotic%20Hardware/AGV/Control%20Theory/PLC/ajme-1-7-38.pdf

- To drive our vehicle, we decided to choose DC motors. The motors are controlled by pulse width modulation (PWM).
- DC Motor Micromotors E192-2S.24.91 with planetary gear unit and shaft mounted two-phase Hall-effect encoder

- The principle of Hall-effect encoder is based on output voltage change of sensor in response to a change of magnetic field. The magnetic field is changed by rotation of shaft mounted permanent magnet. The magnetic field is sensed by two Hall-effect sensors which are in the phase of 90 degrees.



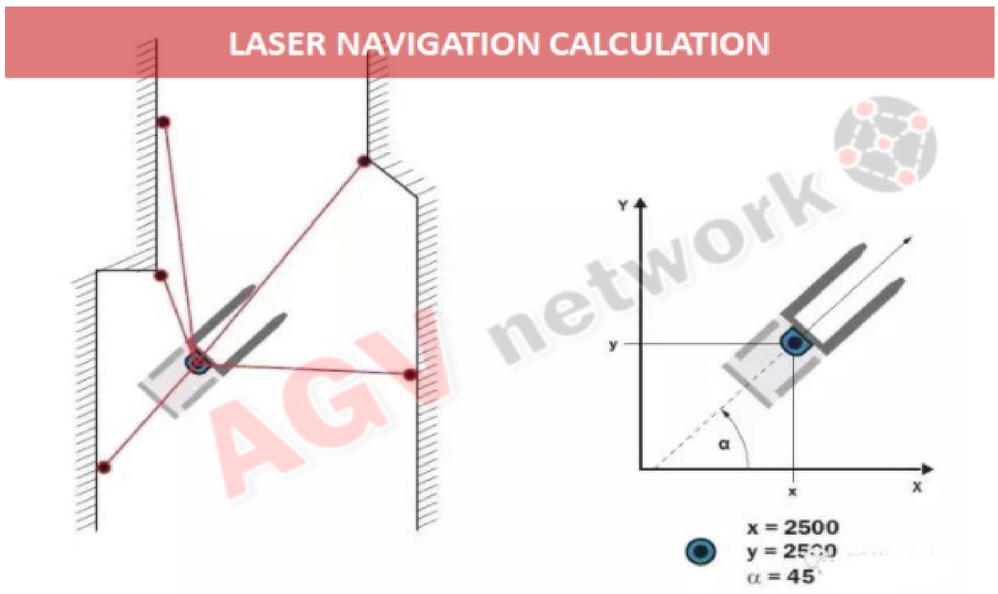
- Motor Driver Design is to control direction and rotational speed of wheels as shown in the above figure
- It is necessary to transform directioning signals to the TTL logic level first.
- PWM signals is used to control the speed of wheel rotation.
- For the upper half of H-bridge we used P-channel power MOSFET transistors IRF4905 and for lower N-channel power MOSFET transistors IRF3205.
- The logical part of H-bridge that evaluates the direction of rotation, comprisesTTL logic circuits 74HCT08quad 2-input AND gate and the 74HCT04 hexinverter.

#3 Navigation System (Sensors) & Control

a) Laser Positioning System

- A 2-dimensional Navigation Laser is set up at the top of AGV robot
- It emits a continuous fan of modulated laser light in a 360 degree pattern interacting with reflectors targets positioned in the AGV working area.
- The reflectors send back an uninterrupted reflection to the navigation device.

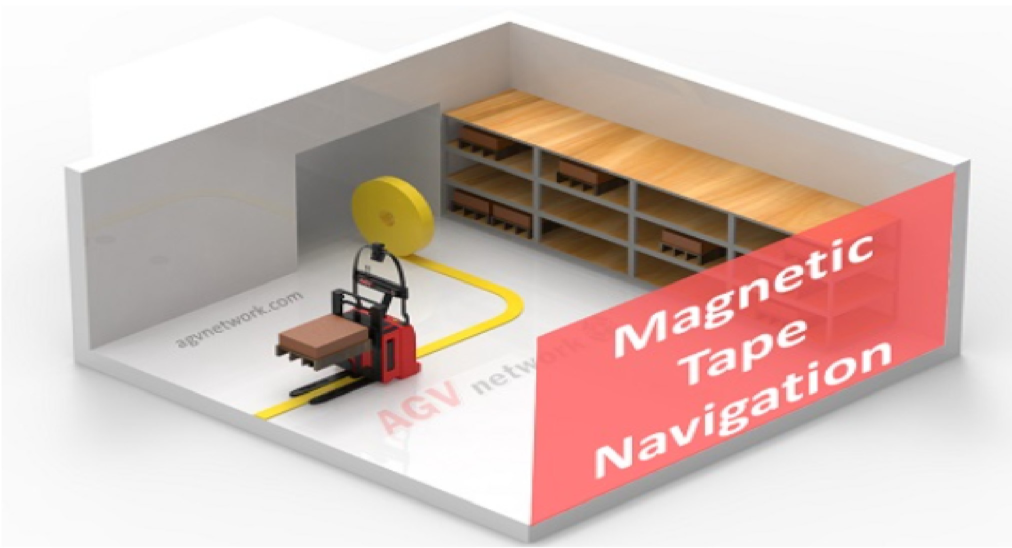
- The rotating laser angle defines a radial coordinate reference that allows to calculate the X,Y coordinates of the reflectors.
- Two examples of reflector such as Flat and Cylindrical Reflectors.



- Arrival feedback can be measured by at least three reflectors.
- It must obtain the reflector's position as a reference
- AGV matches the "seen" position of the reflector with a "theoretical" position on a 2d cad drawing.
- It is mandatory to have continuously-updated, accurate information about the vehicle's position and heading to minimize calculation errors.

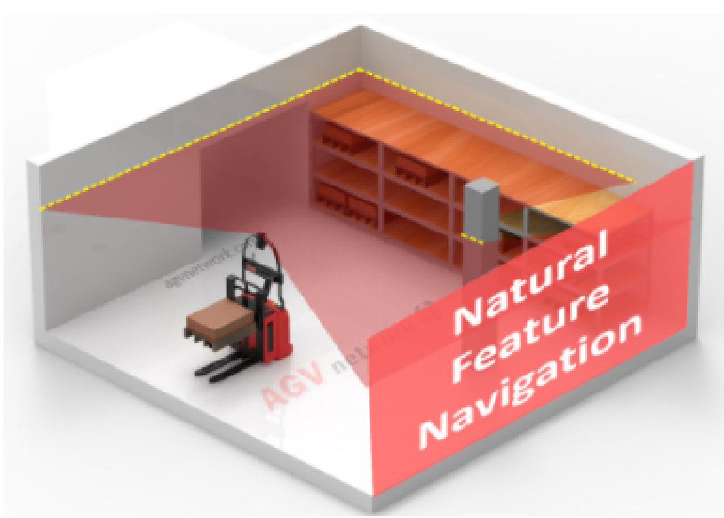
https://www.agvnetwork.com/what-is-a-laser-guided-vehicle-lgv

Magnetic Tape



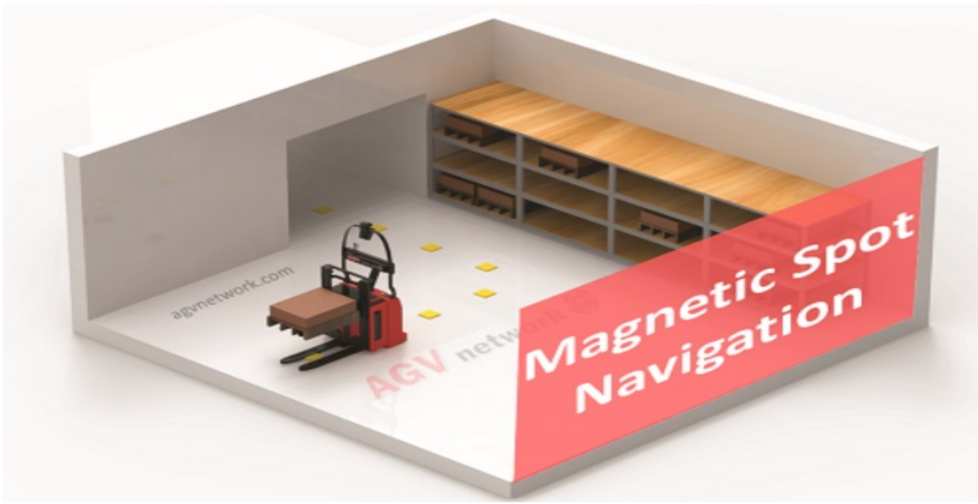
- The guided route is made by a magnetic tape that is placed on the floor surface
- AGV magnetic sensor detects the magnetic field from the tape and drives the AGV following the path.

Natural Navigation AGV - Free Navigation



- Simultaneous Localization and Mapping (SLAM). It simply means that an AGV with SLAM Navigation can map its environment and localize where it is.
- With the help of different sensors such as vision cameras, lidar sensors and lasers, AGV is able to map the environment.
- Drive the AGV manually so that AGV will map the surrounding environmentwhich creates a reference map that is used to navigate for future time at the same place.
- Map of premises of AutoCAD can be loaded into AGV management system
- All the data that the AGV acquires are combined with other data coming from odometrics, encoder, in order to improve accuracy.

Magnetic Spot Navigation

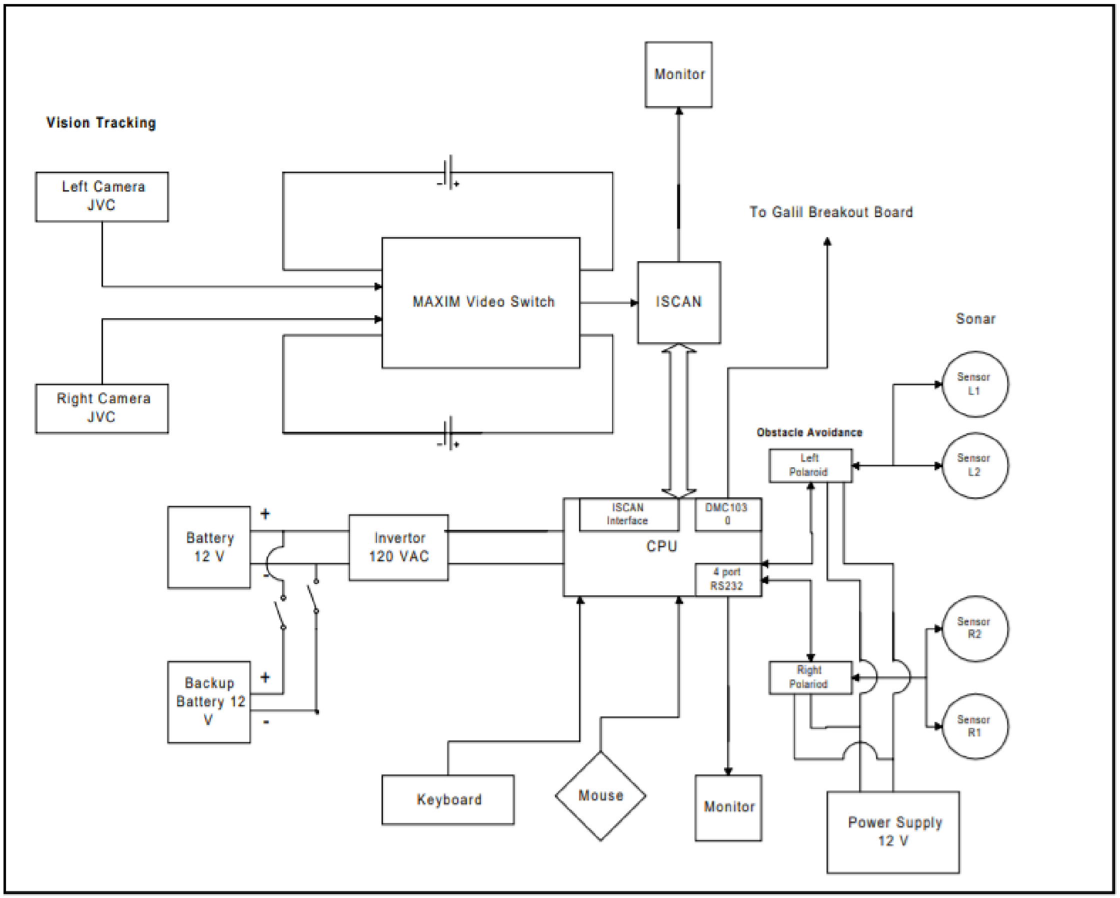


- AGVs can navigate following small cylindrical magnetic spots embedded on the floor.
- The AGVs goes from one spot to the next using sensors and controls such hall-effect sensors, encoders, counters, gyro sensor and other kinds of encoders to calibrate against steering angle errors.

Control Theory

a) Using Fuzzy Logic and PID controller [file:///C:/Users/harrizazham98/Desktop/Year%204%20Sem%202/Robotic%20Hardware/AGV/Control%20Theory/ieeesmcs.pdf]

- the use of fuzzy logic control for the high level control systems multiple types of input such as that from vision and sonar sensors as well as stored map information can be used to guide the robot. Sensor fusion can be accomplished between real time sensed information and stored information in a manner similar to a human decision maker



The University of Cincinnati Robotics Research Center has been working on improving the ability of the automated guided vehicles for several years. Based on previous experiences, a new AGV called Bearcat II is being built. This new robot features more agility, smaller size, digital control, high reliability, more intelligence. Mobile robot navigation are generally discussed on model-based approaches, sensor-based approaches, and hybrid approaches. Model-based approaches need an accurate description of the environment to generate an obstacle free path while sensor-based approaches execute control commands based on sensor data. The hybrid approaches combine model-based approaches and sensor-based approaches. It first generates a path via a model-based planner, then the path is integrated into the sensor-based controller to navigate the robot. In this way, the robot navigates along the path while avoiding obstacles unknown to the model.

Based on the above block diagram, Bearcat II is characterized by digital control, vision guidance, ultrasonic distance sensors and emergency stop. The main components of the robot include: the central CPU, Iscan and two CCD camera as vision sensor, Plariod ultrasonic sonar, two 12V batteries as motor power source, GALIL digital controller and two DC motors.

- Vision guidance system

  Two CCD cameras were used to judge the current position of the robot.

- Obstacle Avoidance System

  The sonar system reliably detected obstacles between 0.5 meter and 6 meters within an accuracy of 0.02 meter.

  The fuzzy logic controller computed correction angles.

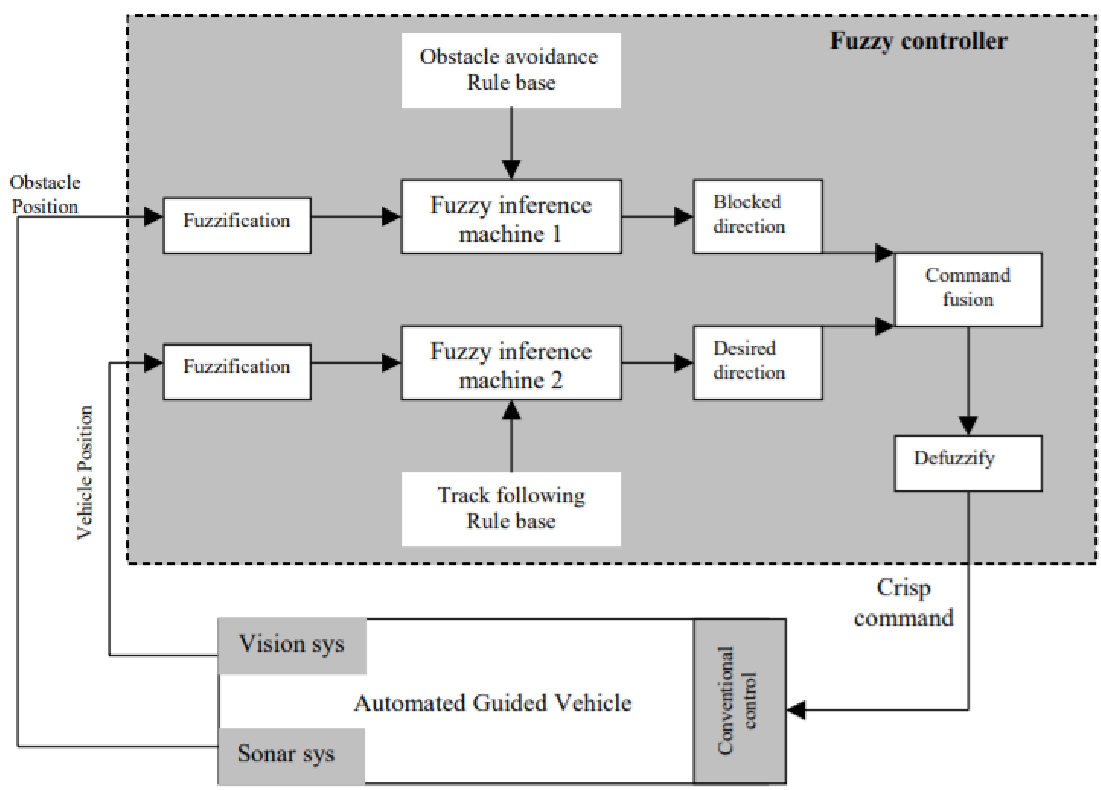
- Steering control system

  Implementing the PID controller to control two identical motors on both sides of the robot. The action of turning is achieved with the speed variations of the two motors. The working status (velocity and position) is continuously reported by encoders, built in the motor.

- Safety and Emergency Stop Braking System

When bad situdation happens, one could press the emergency stop

button or remote stop button to stop the robot immediately



we have identified the input variables as:

1. The vehicle distance from the border line Ab_i

2. The angle of the vehicle option direction to the direction of the road, Ar_i

3. The distance of the obstacle to the vehicle Db_i

4. The angle of the obstacle to the current direction of the vehicle

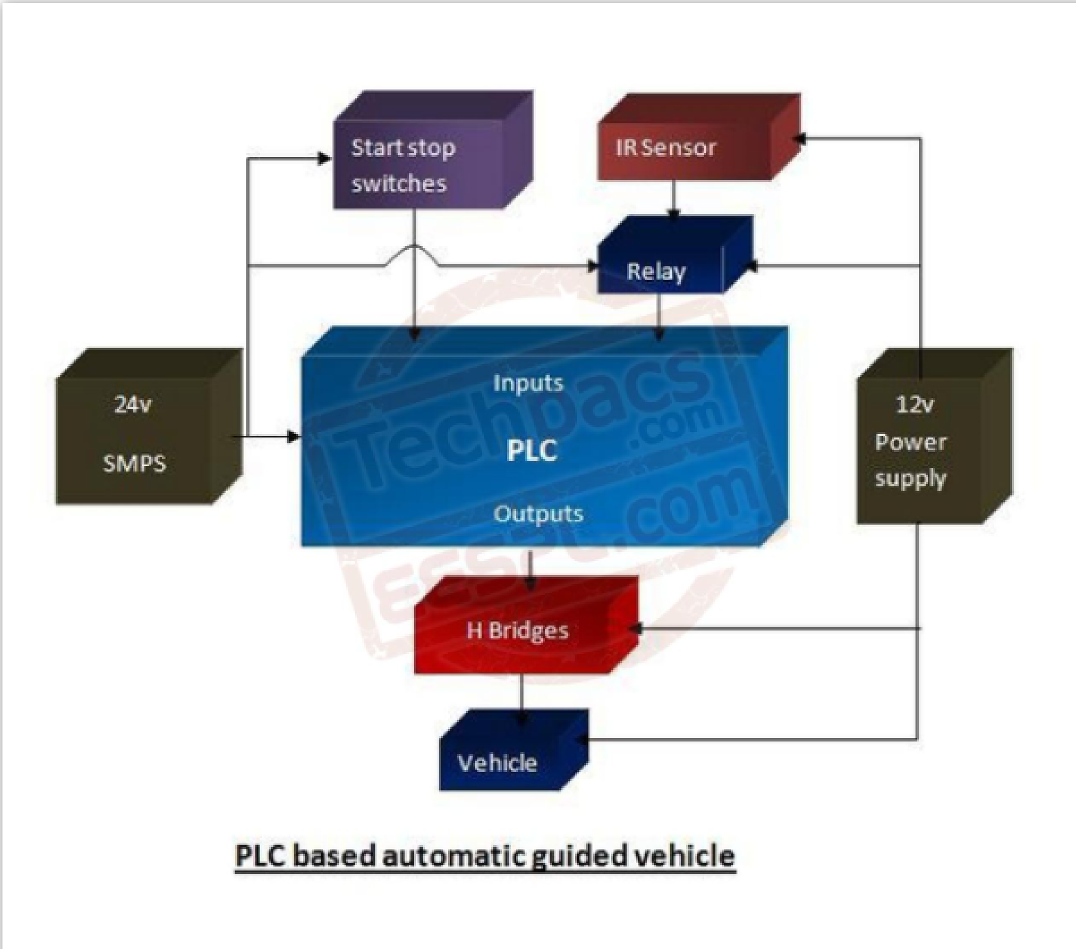
The expected output of the fuzzy controller should be

1. The direction of the next turning (-30 degrees to +30 degrees)

2. the distance from the nearest front obstacle.

b) PLC Controlled [

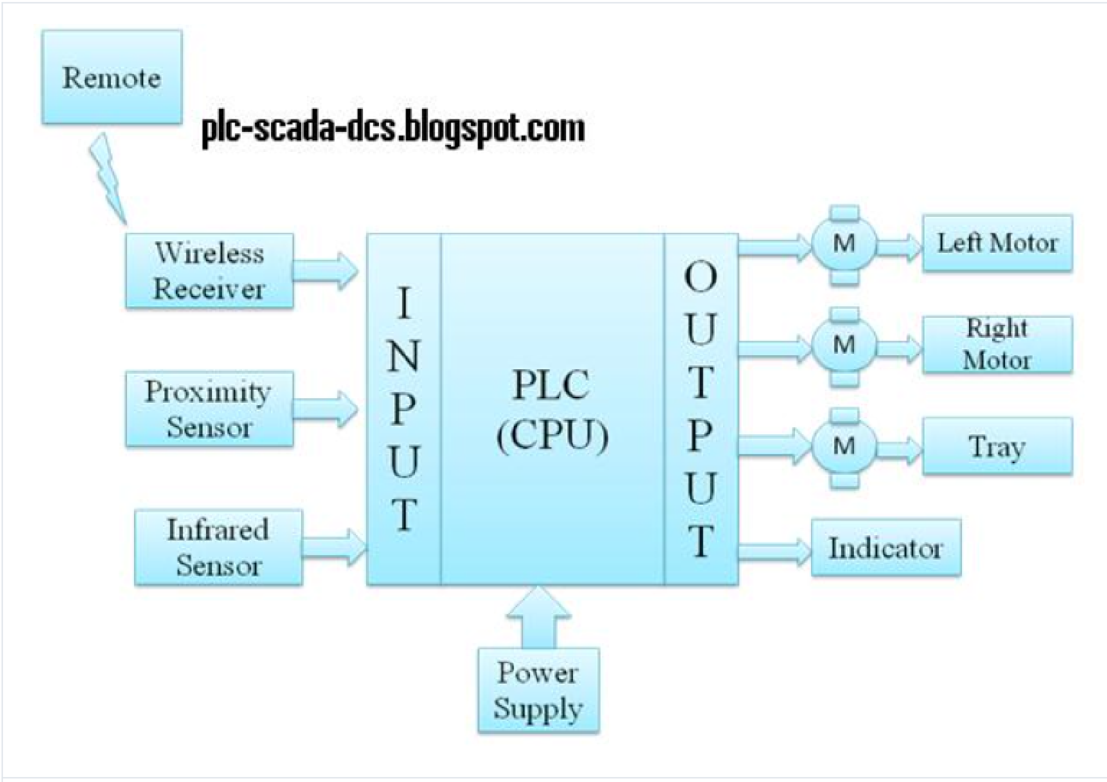
https://www.techpacs.com/category/Project/10-18-37/PLC-Based-Smart-vehicle-path-control-and-navigation-system-for-automated-guided-vehicle]



PLC Control [

https://www.plctutorialpoint.com/2013/09/plc-based-automated-guided-vehicle.

html]



- The remote control, proximity sensor and infrared sensor are connected at input & power supply connected to programmable logic control.
- At output we connected three motors with encoder

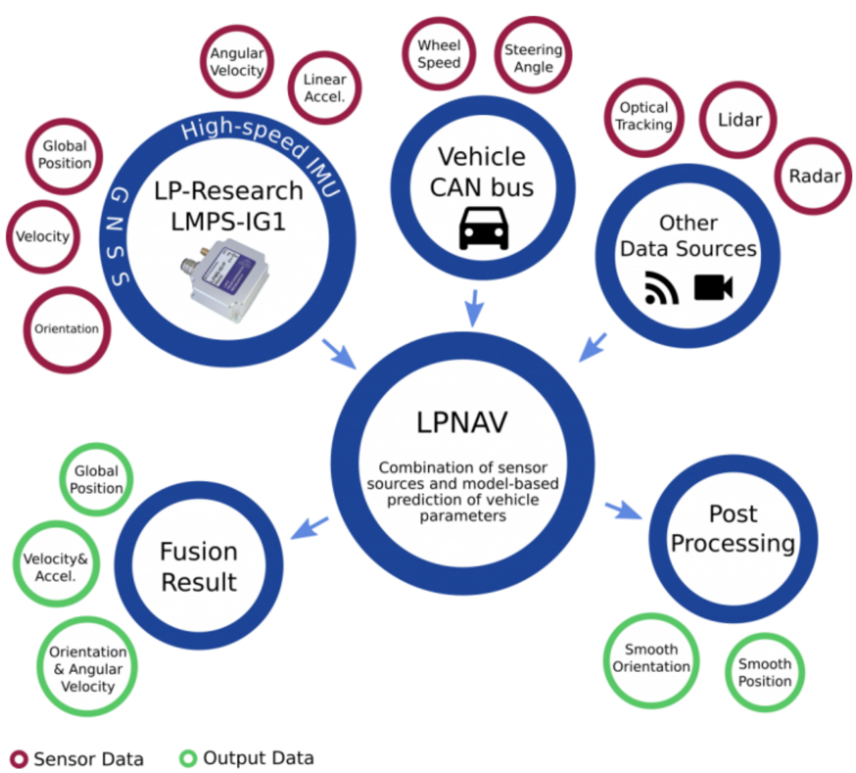
Industrial PC Computer for AGV Robot

1) https://www.syslogic.de/eng/fahrerlose-transportsysteme-fts-91156.shtml

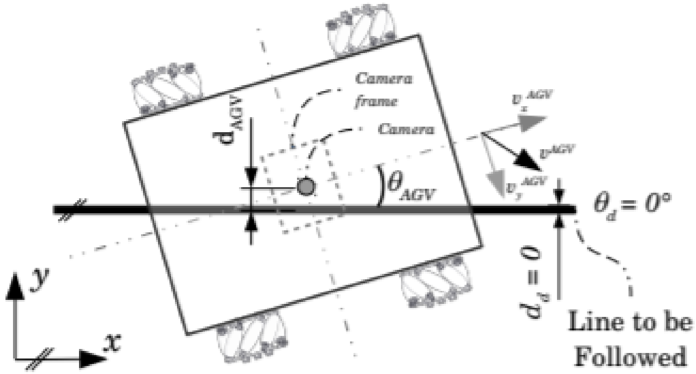
#4 Data Collection

a) Calculate accurate position information [https://lp-research.com/automatic-guided-vehicle-navigation-system-lpnav/]

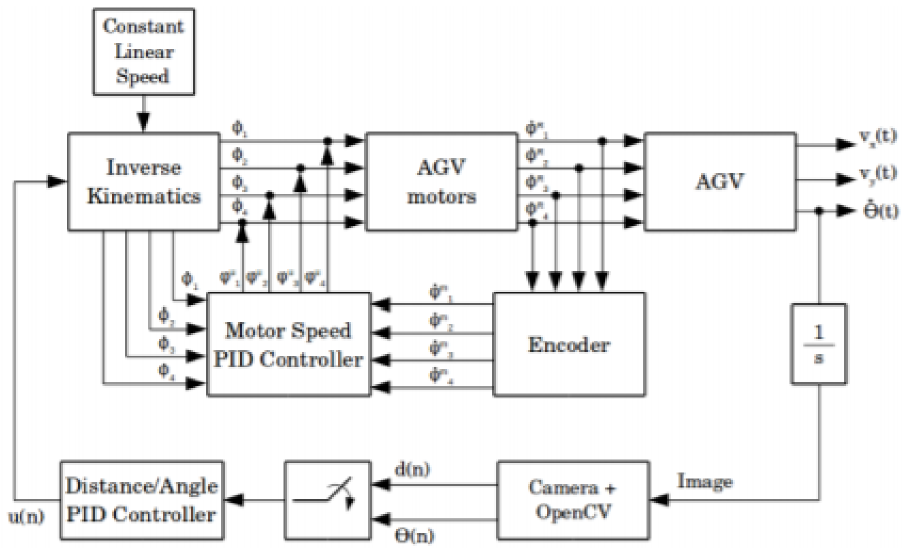
- A combination between IMU (Inertial Measurement Units), optical, GNSS (Global Navigation Satellite System) and odometry data. This allows the fusion of various signal sources to calculate accurate and reliable position information.
- In outdoor environments, GPS can be used to determine location with sub-meter accuracy. In indoor environments the GPS signal is not available and other measures to acquire position information need to be used such as tracking beacons or optical markers.



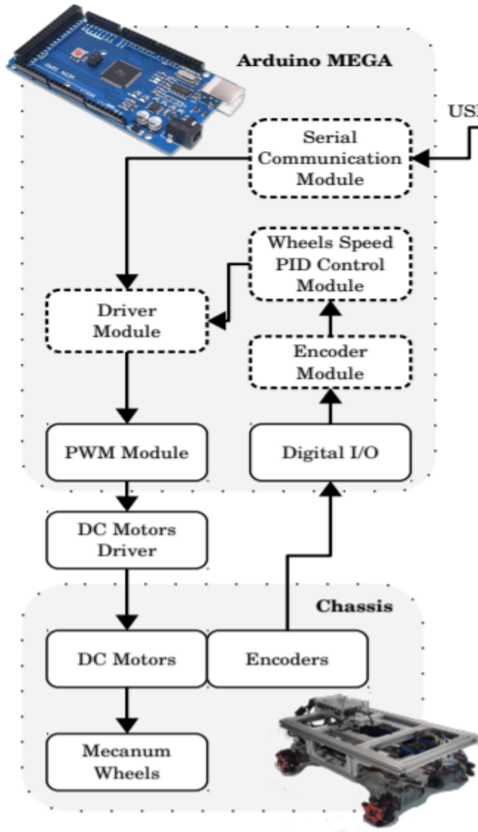
b) Guidance system – path planning [sensors-19-04111]



- It shows an AGV with a visual guidance system scheme. The camera—whose center matches the AGV center—acquires an image frame capturing the passive guideline position related to the AGV. An image processing algorithm measures the AGV angle θ_{AGV} and distance d_{AGV} from the line. The desired angle θ_d between the AGV center and the guideline to be followed is equal to zero. In the same way, d_d denotes the desired distance from the AGV center to the line, which is also equal to zero. Thus, the problem is with manipulating the wheels' direction and speed, therefore manipulating v_{AGV}, so θ_{AGV} and d_{AGV} tend to zero.



The figure shows the proposed control loop for the line-following problem described. As AGV output signals, we have x and y-axis velocities, $v_x(t)$ and $v_y(t)$, and the angle deviation $\dot{\theta}(t)$. A camera acquires an image and, after processing, it is possible to measure the angle θ_{AGV} and the distance d_{AGV}. The PID controller block has one of these two values as input and outputs a control signal. As desired values are both zero, that is, the set-point is zero, then the measured value is the system error.

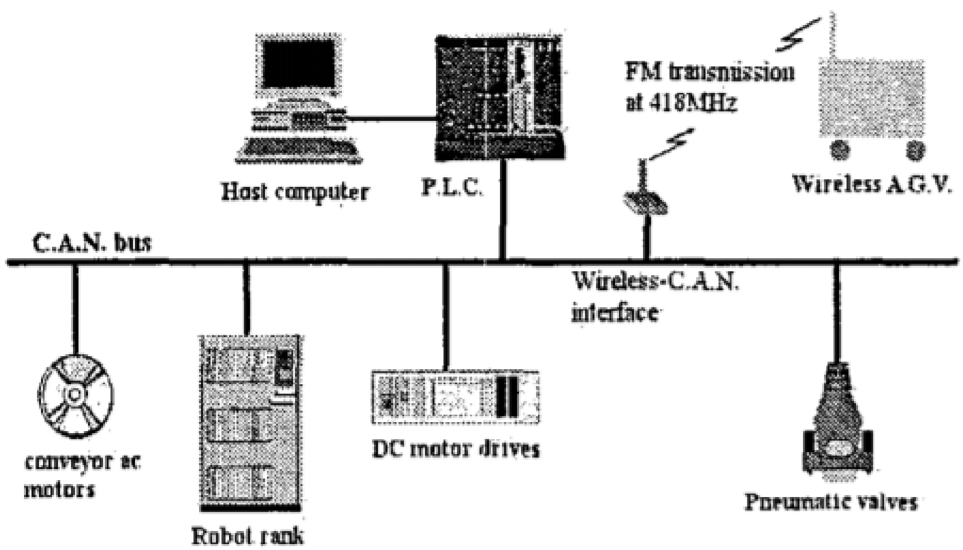


The figure shows the higher processor is a portable computer. It performed image acquisition and image processing loops, and the PID controller calculation for deviations on distance and angle from the guide. The lower-level processor is an Arduino Mega 2560, based on the ATmega 2560. It received the linear speed command from the higher-level processor and sent the specific commands for each motor through the DC motor driver. The Arduino is also responsible for reading the encoders and control the individual DC motor speed using a PID strategy. The Arduino board communicates with the higher-level processor by a USB cable and a serial communication protocol.

#5 Data transmission

a) Wireless communication between A.G.V.'s (Autonomous Guided Vehicle) and the industrial network C.A.N. (Controller Area Network).

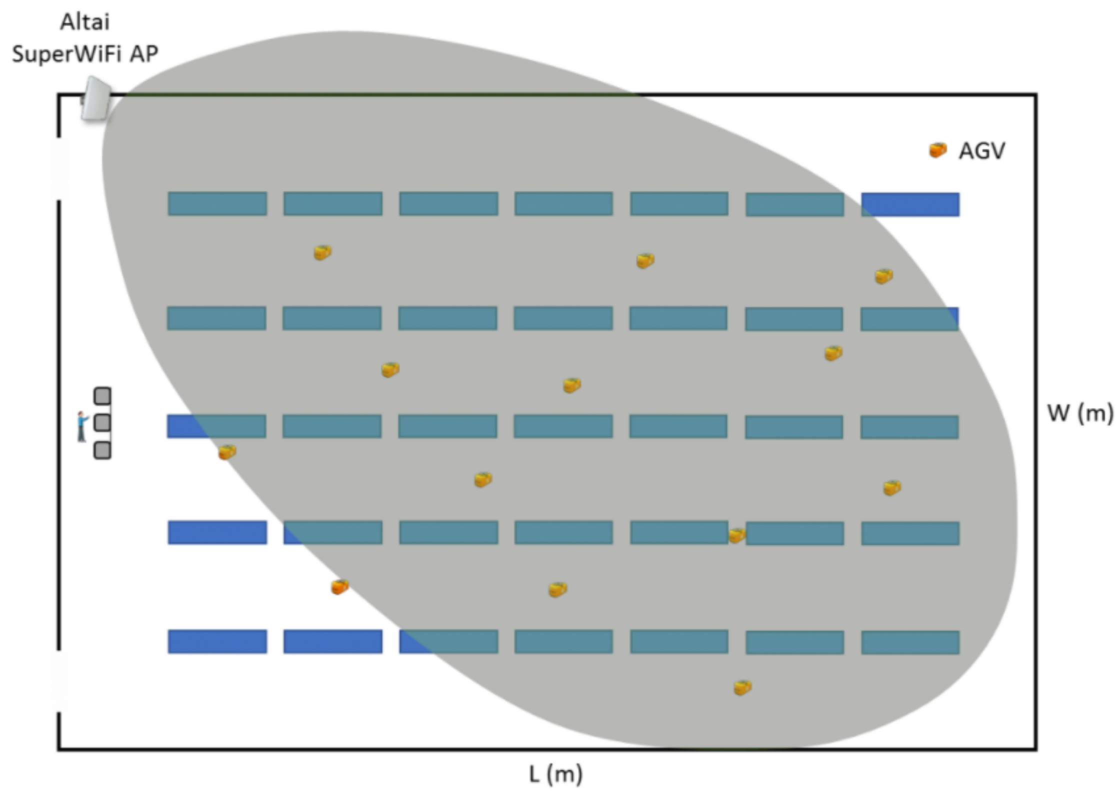
- the wireless integration of A.G.V.'s to the global industrial network makes them programmable from any terminal controller at any time.



- In parallel it has been developed an A.G.V. to demonstrate, among others, a 2-way wireless communication protocol that allows it to exchange data with a base computer.
- The base transmits the commands. The vehicle on command reception responses back to the base to acknowledge the success or the failure of the command execution.

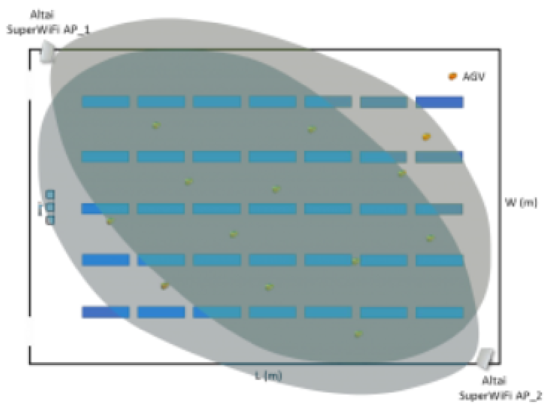
[https://powertecwifi.com.au/wifi-solution-for-automated-warehouses/]

- WiFi, due to its technical maturity, unlicensed spectrum, and abundant terminals/cards available, has become the most common choice of the wireless network for automated warehouses.
- Altai Technologies is the world-leading large-coverage outdoor WiFi solution provider.
- Altai Super WiFi APs have super large coverage. In line-of-sight (LOS) condition, A8-Ein(ac) base station can provide coverage up to 1.7km to normal clients (laptops, smartphones, etc.), and A3-Ei AP can also cover up to 1km. Thanks to such super coverage capability, by installing a single such AP at a high place at one of the corners of the warehouse, blanket WiFi coverage can be provided in the warehouse without any blind spot. See below figure for the illustration.



- One of the major reasons that Altai Super WiFi APs have such great coverage capability is the high-gain wide-beam antenna.
- Automated Warehouses have heavy workload, which poses high requirement on the stability of the system. As the communication platform for AGVs and the backend control system, the WiFi network must be able to provide quality service persistently. Therefore, coverage (or AP) redundancy has become one of the important requirements for the WiFi network of an automated warehouse. Since Altai Super WiFi APs have super large coverage, the redundancy solution is direct and simple. As illustrated in the below figure, we just need to install another AP at the diagonal location of the initial AP. Both APs could provide full coverage

of the warehouse individually. When one of them fails, all the AGVs could be served by the other one.



PROVIDER: https://pintobrasil.com/agvrobot/#300

#6 Power Management

Types of battery for AGV robot: from [https://www.agvnetwork.com/agv-types-of-battery]

- It depends on the battery charging strategy of your automated guided vehicle system that defines the best technical and economical solution.
- It has:
    - Sealed GEL
    - AGM Pure-Lead
    - Lithium Batteries
    - Flooded Lead Acid

Specification	GEL	PURE-LEAD	LITHIUM	FLA
Online Charging				
Depth of Discharge				
Fast Charging				
Battery Life				
Gas emission				

Need of maintenance				
Need Vehicle modification				
Battery Price				

1) AGM and GEL batteries

- sealed and non-spillable batteries.
- maintenance-free.
- "Deep cycle" batteries. It means that the battery can be discharged down up to 80% (so when it only remains 20% capacity in the battery).
- low self-discharge rate.
- low gas emissions or not emissions at all.
- recharging time is around 5 hours.
- Two or three shifts AGV systems having battery swap strategy. In this case, a second battery is needed.

2) Pure-lead Batteries

- advanced AGM batteries having pure-lead thin plates rather than standard lead-calcium plates.
- excellence battery life, near 1200 cycles with 60% depth of discharge.
- maintenance free and sealed batteries with very low gas emissions.

3) Lithium batteries for Automated Guided Vehicles

- Contactless charging technology reaches near 95% efficiency and needs batteries able to receive a big amount of energy in fast charging cycles.
- For a given depth of discharge (DOD), Lithium batteries grant more recharging cycles so more life.

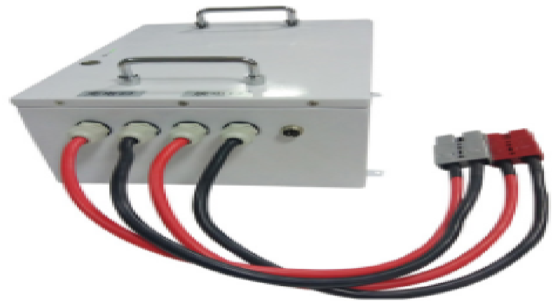
CYCLE LIFE (capacity ≥ 80% of nominal)	
80% DoD	2500 cycles
70% DoD	3000 cycles
50% DoD	5000 cycles

- Lithium batteries can handle DOD of 80% maintaining excellent battery life (still close to 2500 cycles).

- Lithium batteries are more efficient. If you charge 1 kwatt, a lithium battery losses around 50 watts (you really get 950 watts).
- With Lithium batteries you should only need 10% of AGV time for charging, it means that your AGVs are available more time for performing missions and transporting materials.
- same weight and more power.
- Lithium batteries are instable. They need protection against overcharging.

24V 60Ah Lithium Battery Pack For AGV, Electric Robot, Automated Guided Vehicles from https://www.lithium-battery-factory.com/product/agv-lithium-batteries-24v-60ah/#:~:text=High%20Power%2C%20Fast%20Charge%2C%2024Volt,autonomous%20to%20accomplish%20their%20mission.

- High Power, Fast Charge, 24Volt, Lithium Ion Batteries Designed for AGVs And The Material Handling Industry
- environmental improvements over the traditional lead acid batteries.
- outstanding qualities of AGV power lithium ion battery with high safety, lightweight, long life span, environmental applicability, fast charge



Nominal Voltage	**24V**
Nominal Capacity	60Ah
Energy	1440 WH
Dimensions (L x W x H)	**324*232*200MM**
Weight	21KG
Case Material	ABS/Iron case
Certifications	**CE/ISO/UN38.3/MSDS**
Efficiency	99%
Self Discharge	<1% per Month
Series & Parallel Application	max. 4 series or 4 parallel connected application
Peak Discharge Current	60 A
Continus Discharge Current	30 A
Operation Temperature Range	-20~60℃
Voltage at end of Discharge	24 V
Working Voltage	24-25.6V
Discharge Temperature	-4 to 140 ºF (-20 to 60 ºC)
Charge Temperature	32 to 113 ºF (0 to 45 ºC)
Storage Temperature	23 to 95 ºF (-5 to 35 ºC)
Cycle Life	**> 2000 cycles**
Self-Discharge Rate	Residual capacity: ≤3%/month; ≤15%/years
	Reversible capacity: ≤1.5%/month; ≤8%/years
Storage Temperature & Humidity Range	Less than 1 month: -20℃~35℃, 45%RH~75%RH
	Less than 3 months: -10℃~35℃, 45%RH~75%RH
	Recommended storage environment: 15℃~35℃, 45%RH~75%RH