AUTONOMOUS VEHICLES IN INTRALOGISTICS

DOI
https://doi.org/10.18690/um.fl.2.2026.6

ISBN
978-961-299-074-9

DARKO HERCOG,[1] PRIMOŽ BENCAK[2]

[1] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
darko.hercog@um.si
[2] University of Maribor, Faculty of Logistics, Celje, Slovenia
primoz.bencak1@um.si

Automated guided and autonomous vehicles are increasingly used in intralogistics processes to transport goods or support order picking. The publication provides a brief overview of the areas of automated and autonomous vehicles, their differences, and potential applications in intralogistics. The reader is introduced to the basic theory of the operation of autonomous mobile robots' (sub)systems (drive, sensors, localization, and navigation). For ease of understanding, web links to videos are added, which support the theory with a practical demonstration. Finally, in an example of the autonomous mobile robot MiR100, the operation of the mobile robot and its functions are presented.

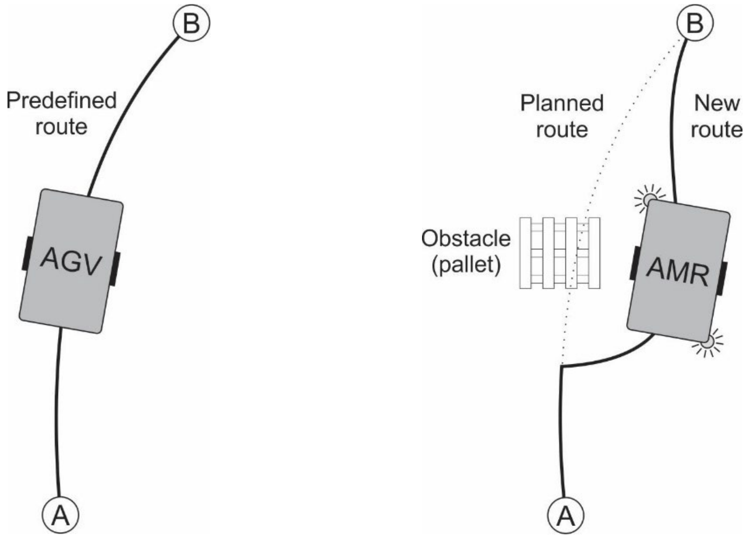
Keywords:
autonomous vehicles,
autonomous mobile robots,
AMR,
automated guided vehicles,
AGV,
intralogistics

University of Maribor Press

1 Introduction

Autonomous and automated guided vehicles enable the autonomous transport of various loads within production or logistics processes. Automated guided vehicles, for which the abbreviation AGV is used, have been present on the market for quite some time; the first such vehicle was manufactured in 1950. AGVs follow fixed and pre-marked paths (Figure 1.1-a), whereby various systems are used to mark the path, such as tracking wires or magnetic strips. The vehicle recognizes the marked path with the help of installed sensors and then follows this path with the help of a drive and control system. In addition, these vehicles also contain sensors for detecting the presence of obstacles on the marked path. In the event of a detected obstacle, the vehicle must stop and wait for the obstacle to be removed (Figure 1.1-a). AGVs represent a simple and affordable solution for autonomous internal transport, as they are based on simple detection, processing, and decision-making systems. However, these vehicles have several disadvantages, namely: (1) they follow fixed and predetermined routes, (2) in the event of an unexpected obstacle on the way, the vehicles stop, (3) the operation of the vehicles requires a change in infrastructure and later also maintenance of this infrastructure, etc. Despite the disadvantages, these vehicles are widely used in industry today, namely for less complex cargo transport from one location to another.

Less than a decade ago, newer vehicles began to appear on the market, for which the term autonomous mobile robots or the abbreviation AMR is used. These vehicles have a certain level of intelligence and can make decisions independently when they encounter new or unforeseen situations. AMRs perform localization and navigation using sensors and advanced algorithms, and a loaded map or a map of the space in which they perform transport tasks (Siegwart, Nourbakhsh, & Scaramuzza, 2011). AMRs contain numerous sensor systems, among which safety laser scanners are particularly important. As a result, they can operate near people and other dynamic obstacles, and are also able to drive through doors, corridors, and use elevators. With built-in sensors and sophisticated software and hardware, they detect objects in their immediate surroundings and, using advanced algorithms, independently calculate the optimal route to the destination. In the event of a detected obstacle on the intended route, these vehicles independently find an alternative route and continue to deliver the cargo to the target location (Figure 6.1-b). In the following, the term autonomous vehicles will also be used for AMR vehicles, and automatic vehicles for AGV vehicles.



(a) Automated guided vehicle **(b) Autonomous mobile robot**

Figure 6.1: The path of an automatically guided (left) and autonomous vehicle (right)
Source: own.

Due to their many positive attributes, sales of AMRs are growing rapidly. Annual sales currently amount to over 3 billion US dollars and are expected to grow to over 10 billion in the next five years (6.2).

Autonomous vehicles are adaptable, as they adapt to changes in the environment. They can be programmed and adapted to perform various tasks relatively easily. Automated vehicles, on the other hand, are designed for predefined routes and tasks, and are therefore less adaptable to changes in the environment. Changing their routes or tasks requires changing the physical infrastructure. The introduction of autonomous vehicles includes mapping or creating a map of the space in which the vehicle will operate, configuring the vehicle, and programming transport tasks. The introduction of these vehicles does not require the installation of physical routes or any other interventions in the existing infrastructure. When introducing automated vehicles, however, it is necessary to adapt the environment and install tracking paths, which can be quite time-consuming and expensive. Autonomous vehicles are suitable for performing tasks in dynamic environments, such as warehouses or manufacturing plants, where vehicles move near people, equipment, and other obstacles. Automated vehicles, on the other hand, are used in transport processes, where routes are precisely defined in advance and, generally, do not change over time. Autonomous vehicles are considered more cost-effective in the long term, as they require less investment in infrastructure and can adapt to changing needs.

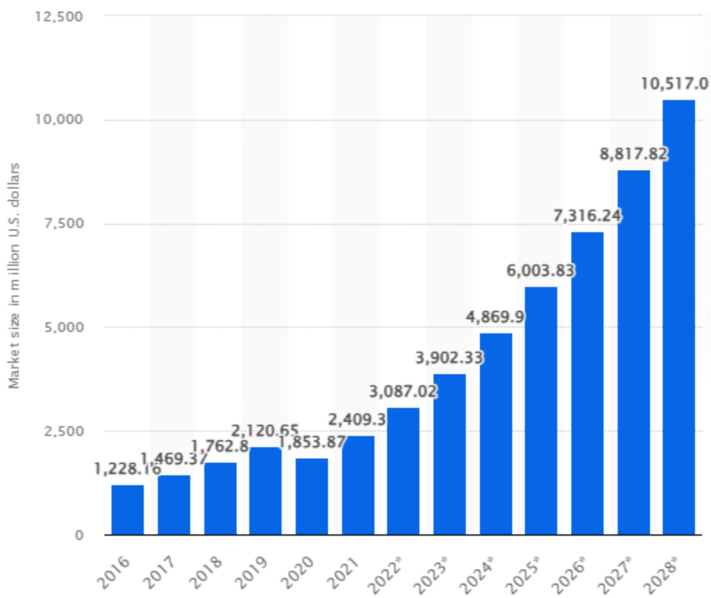


Figure 6.2: Global AMR Market Size from 2016 to 2021 with Forecast to 2028
Source: (Statista., 2023)

1.1 Vehicle types

There are many different types of autonomous and AGV on the market, including (Wikipedija, 2023)

- Pallet Trucks: These vehicles are primarily used for transporting pallets and do not contain a mechanism for automatic loading/unloading of loads. The vehicles only contain a mechanism that allows pallets to be raised and lowered within a range of a few centimeters.
- Fork Trucks: These are equipped with forks and are primarily used for the independent transport of loads on pallets. They are used in transport where there is a height difference between loading and unloading. This type of vehicle is one of the more expensive vehicles.

- Towing Trucks: These vehicles are designed to tow passive trolleys or trailers loaded with various loads. They are often used in production processes to supply assembly lines with the necessary material.
- Unit Load vehicles are designed to transport various loads, such as pallets, crates, or containers. The vehicles have a platform that includes a mechanism for lifting/lowering the load, powered/unpowered transport rollers, belt conveyors, etc.
- Light Load vehicles are vehicles with a load capacity of up to 500 kg. They are used to transport lighter objects, such as boxes, baskets, or other materials.
- Specialized Trucks: These vehicles are adapted to specific applications, such as transporting in clean rooms, hazardous substances in chemical plants, etc.

Table 6.1 summarizes links to YouTube videos showing different types of vehicles. The videos can be accessed by clicking on the YouTube icon. If the link does not work, the video can be searched on YouTube using the relevant keywords.

Table 6.1: Examples of different types of autonomous and automated guided vehicles

Type of vehicle	Video	Keywords
Pallet trucks		Nipper B.V., Nipper AGV
Fork trucks		Jungheinrich UK, AGV Forklift Trucks by Jungheinrich
Towing trucks		DF Automation, AGV towing multiple trolleys
		JD Universal, Unidirectional Towing AGV for Logistics Transportation
Unit load		Dematic, Unit Load AGV - Warehouse Automation by Egemin Automation Inc.
		IBG Automation, AGV - Automated Guided Vehicle
Light load		SSI SCHAEFER Group, Automated Guided Vehicle Weasel®, E-Commerce, Supply Chain, Hermes Fulfilment GmbH

1.2 Use of autonomous vehicles in intralogistics

AMRs are used in intralogistics and warehouses for various purposes, such as:

- supply of production workstations,
- transport of goods in warehouses and distribution centers,
- support in the picking process, etc.

In industry, AMRs are mainly used to supply production workstations with the necessary materials. This supply is provided by dedicated autonomous vehicles, such as autonomous forklifts or universal autonomous vehicles, whose functionality is changed with a top module and thus adapted to specific tasks. In practice, the most common types of supply to production workstations are: (a) towing vehicles, (b) vehicles with a shelf rack, (c) with a transport system, and (d) with a lifting table.

In warehouses and distribution centers, autonomous vehicles are mainly used to support order picking. In parts-to-picker order picking, mobile racks and AMRs with a lifting mechanism are used. In the warehouse, the vehicle lifts the entire rack and transports it to the workstation where the order picker is located. When the order-picker picks the required products from the rack, the AMR transports the rack back to the warehouse. In picker-to-parts order picking, autonomous vehicles provide support to the order picker. Order pickers move along the aisles between the rack shelves and pick goods according to the order in the work order. Order pickers pick goods from the shelves and place them in boxes located on the autonomous vehicle, which transports the goods to the warehouse input/output area.

2 AMRs

AMRs contain numerous components (subsystems) that enable autonomous environmental sensing, localization, navigation, and transportation tasks. The most important ones include:

- Sensor system: This contains numerous sensors (inertial, optical, 3D cameras, ultrasonic sensors, etc.) with which the vehicle detects its surroundings. In addition to the basic sensors, some vehicles also have other sensors that are used for special tasks, such as barcode readers, radio frequency identification (RFID) readers, or environmental sensors.
- Location system: AMRs must know their exact location in the environment in which they are located. This is provided by the localization system, which, based on data obtained from various sensors, estimates the current position and orientation of the robot relative to its internal map.
- Navigation system: The navigation system is a key component for autonomous vehicle operation, as this system is responsible for route planning. Based on the initial and final locations and considering space restrictions (walls, prohibited

areas, etc.), the navigation system calculates the optimal path for the robot. In the event of a detected obstacle on the calculated path, it searches for an alternative.

- Safety system: Autonomous vehicles must not endanger the safety of people and/or equipment under any circumstances. As a result, vehicles include various safety components, such as safety laser scanners, collision detection sensors, and emergency stop buttons, which ensure safe operation of the vehicle even in the immediate vicinity of people.
- Battery management system: AMRs are usually battery-powered. The battery management system ensures optimal battery operation in order to achieve the longest possible battery life.
- Communication system: This enables communication with other systems. AMRs most often use wireless communication modules (e.g., Wi-Fi or Bluetooth).
- User interface: The user interface, which is usually accessible via a special touch screen or web interface, allows monitoring the status of the robot, manual control of the robot, display of notifications and warnings, display of an area map, programming of the robot, etc.
- Drive system: The drive system includes drive motors, gearbox, wheels, and drive motor controllers. By controlling the drive wheels appropriately, the vehicle follows a previously calculated path.
- Machine learning and artificial intelligence systems: Some advanced vehicles also include machine learning and artificial intelligence systems. These systems are used to recognize objects, optimize routes, tasks, etc.

2.1 Drive and Steering System Configurations

AMRs and AGVs contain a drive and steering system. The drive system enables the vehicle to move in the longitudinal direction, and the steering system enables the vehicle to turn. Generally speaking, there are four basic drive and steering configurations (Roboteq Inc., 2013)

1. Differential drive:
   - with four driving wheels.
   - with two driving wheels and one or more castor wheels.
2. Steer drive contains a wheel that is both drive and steer.

3. Ackerman drive. In this configuration, the rear wheels are driven and the front wheels are steered.
4. Mecanum configuration is similar to that of the differential drive with four drive wheels, but instead of regular wheels, so-called mecanum or Swedish wheels are used. By appropriately guiding these wheels, it is possible to achieve movement of the mobile robot in any direction.

In autonomous and automatically guided vehicles, the most commonly used differential drive with two drive wheels (Figure 6.3) is because this configuration is quite simple to implement and at the same time allows for sufficiently precise vehicle control. This differential drive configuration also includes one or more support wheels that prevent the vehicle from overturning. The drive wheels are mounted on the same axle, and the speed of rotation of each wheel is determined by the speed of rotation of the corresponding electric motor. If the drive wheels rotate at the same speed, the vehicle drives straight; otherwise, the vehicle turns in the direction of the wheel that rotates more slowly. A vehicle with a differential drive can also rotate in place (around the axis of rotation), namely when the wheels rotate at the same speed, with one rotating forward and the other rotating backward.

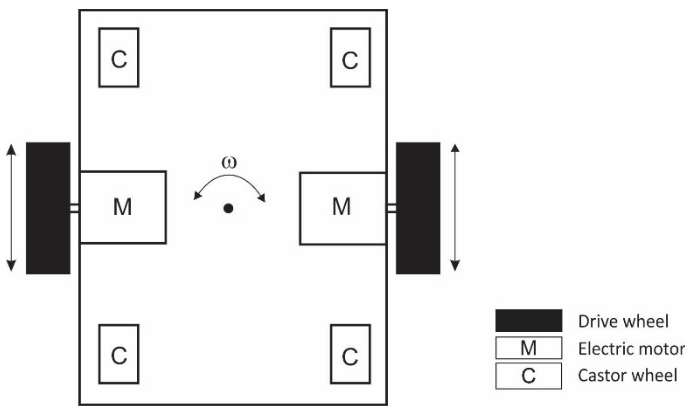


Figure 6.3: Differential drive with two drive wheels and four support (castor) wheels

Source: own.

Table 6.2 contains links to YouTube videos that demonstrate the operating principles of various propulsion and control system configurations.

Table 6.2: Examples of drive and control system configurations

Configuration	Video	Keywords
Differential drive	▶	Kollmorgen - Autonomous Mobile Solutions, AGV Vehicle Types, Differential drive
Wheel drive	▶	Kollmorgen - Autonomous Mobile Solutions, AGV Vehicle Types, Steer drive
	▶	SICK AG, Monitoring automated guided vehicles (AGV) - with Safe Motion Control from SICK
Mecanum	▶	ERobtic, ERobtic Mecanum Wheel
	▶	Torwegge GmbH & Co. KG, TORsten Mecanum Rad | Animation | TORWEGGE
	▶	KUKA - Robots & Automation, Clever Autonomy for Mobile Robots - KUKA Navigation Solution
	▶	Neobotix GmbH , Neobotix mobile Roboterplattformen

2.2 External and internal sensors

Autonomous vehicles contain many external and internal sensors. External sensors are used to sense the environment, while internal sensors are used to detect internal process variables. Combinations of data obtained from various sensors are used for environment detection, localization, and navigation. The most used sensors are:

- Inertial Measurement Units (IMUs). These are used to maintain vehicle stability and in localization and navigation algorithms. IMUs include three basic sensors, namely: (1) a 3-axis accelerometer, which measures the vehicle's acceleration in all three directions (x, y, z), (2) a 3-axis gyroscope, which measures the angular velocity or rotation rate of the vehicle around each axis, (3) a 3-axis magnetometer, which measures the strength and direction of the magnetic field in all three axes. In combination with other sensors, the data from the inertial measurement unit improves the accuracy of the robot's location estimation.
- Light Detection and Ranging (LiDAR) sensors. These sensors are a key sensor component used in AMRs for navigation, obstacle detection, mapping, and localization. LiDAR sensors use laser beams to measure distances to objects in the robot's surroundings, enabling precise mapping and navigation.
- Drive wheel sensors; these are mounted on the drive motors and thus capture the speed and position of the drive wheels. These sensors enable a rough determination of the direction and speed of the vehicle's movement. Due to various errors (random slippage of the drive wheels, geometric errors, resolution

of incremental encoders, etc.), such a system for determining the vehicle's speed is not absolutely accurate, so additional sensors (accelerometers, gyroscopes, etc.) are required to supplement the estimate of the speed of movement with more precise measurements. Drive wheel sensors provide information that helps with vehicle localization, especially in algorithms based on odometry.

- Ultrasonic Sensors emit sound waves and measure the time it takes for the emitted waves to bounce off the detected objects. They are used to detect transparent objects, such as glass doors, which are difficult or impossible for optical sensors (LiDAR, cameras) to detect.
- Camera systems are used to visually detect objects, especially those that cannot be detected by other sensors. LiDAR sensors detect objects in a plane that is a certain distance above ground (the height depends on the installation of the sensor on a mobile platform). Objects that are higher or lower than this plane are not detected by LiDAR sensors. 3D cameras are used to detect such objects, which are usually installed on the front of the vehicle.
- Radar Sensors transmit radio waves and measure the time of flight from transmission to reception. Radars use radio frequency (RF) signals, usually in the microwave band, and enable the detection of objects at relatively long distances. Compared to optical sensors such as LiDAR or cameras, radar is less affected by adverse weather conditions such as rain, fog, or snow, making it suitable for autonomous vehicles operating outdoors. However, radars generally have lower resolution than LiDAR sensors, making them less suitable for mapping areas or detecting smaller objects.
- Touch sensors; these sensors are used to detect collisions with objects. In general, contactless and contact systems are used to detect obstacles. The latter are used in automatically guided vehicles, while contactless systems are usually used in autonomous vehicles. Safety bumpers with touch sensors installed inside are used as a contact system. These sensors are activated when the vehicle comes into direct contact with an obstacle.
- Global Positioning System (GPS). Some AMRs use Global Positioning System technology to provide information about the global position of the vehicle, anywhere on the globe. This is especially useful for vehicles used outdoors, such as in agriculture or last-mile delivery. GPS signals cannot penetrate buildings, so they are not used in vehicles that operate indoors.
- Other sensors: Depending on the intended use, autonomous vehicles may also contain other sensors, such as sensors for measuring external quantities

(temperature, humidity, gas concentration), sensors for detecting barcodes, RFID tags, etc.

2.2.1 Safety laser scanners

Safety laser scanners (Figure 6.4) enable contactless detection of objects in the vicinity of a mobile robot. These sensors have a so-called safety zone and two or more warning zones, which are adjustable and intended for various support functions, such as a warning sound. If the vehicle detects an obstacle within the warning zone (yellow and orange zones) in the direction of movement, it must start normal braking. If the detected object is located within the safety zone (red zone), the vehicle must stop in an emergency using the built-in brake (Wikipedija, 2023). Modern safety laser scanners allow the configuration of multiple zones, using the associated software. AMRs usually contain two or more safety laser scanners. The most common are two, which are installed on the diagonal edges of the vehicle. Such an installation allows 360° detection of the vehicle's surroundings, which means that the AMR can also detect objects located to the side of the vehicle. This is especially important in the case of a robot turning in place.

Figure 6.4: Example of a safety laser scanner
Source: (SICK AG, 2018).

Safety laser scanners are used for non-contact detection of objects in many areas (Table 6.3) and are very often found in the field of protecting the working areas of industrial robots.

Table 6.3: Examples of the operation and use of safety laser scanners

Scope of application	Video	Keywords
Mobile robots		SICK AG, Monitoring automated guided vehicles (AGV) - with Safe Motion Control from SICK
Robotic cells		SICK Sensor Intelligence, Safe Robotics: safe sequence monitoring
		SICK AG, Safe Robotics: Palletizing application

2.3 Location and navigation systems

Autonomous and AGVs contain a location and navigation system. In the case of AGV, this is quite simple, as the vehicles only follow predetermined paths. Autonomous vehicles, on the other hand, contain a wide range of sensors and advanced navigation algorithms, which allow them to adapt to transport routes in a changing environment.

2.3.1 AGV

In AGV, inductive wires and magnetic strips are most often used to mark the route (Table 6.4). The inductive wire is the oldest system for guiding vehicles and is still used today, mainly due to its high accuracy and reliability. However, this system has one important limitation; namely, the wire must be installed in a special slot below the ground surface, approximately 1 cm deep. This means that physical intervention in the infrastructure in the area where the vehicle will perform transport tasks must be carried out. A similar intervention in the infrastructure must also be carried out whenever the route is changed. Unlike inductive wires, magnetic strips are installed on the ground surface. Their key advantage is that they can be easily attached, removed, or relocated. Magnetic strips are very robust and resistant to damage and dirt.

For path detection, so-called inertial navigation systems are also used, in which it is not necessary to mark the entire path of the vehicle, but only certain points. Inertial systems are based on measuring accelerations in all three directions (x, y, z) and angles of rotation around the longitudinal, transverse and vertical axes of the vehicle Wikipedia (2025). Based on the measured accelerations and angles of rotation, the current position of the vehicle in space is estimated using integration methods. Due to various errors (sensor errors, integration method errors, etc.), differences occur between the actual and estimated position of the vehicle, which is why additional ground markings are usually used in this type of navigation. When the vehicle crosses such a marking, the sensor detects the exact position and corrects the estimated position of the vehicle. Generally, small permanent magnets are used as markings, but there are also solutions using RFID or QR tags.

2.3.2 Autonomous vehicles

In autonomous vehicles, two methods are often used for localization and navigation, namely 2D laser scanning and Simultaneous Localization and Mapping (SLAM).

2D laser scanning works on the principle of measuring the reflection of a laser beam from fixed reflectors in space. Based on the reflection of laser beams from different reflectors, the current position of the vehicle is determined using triangulation. Laser technology provides high resistance to false reflections and high accuracy of position determination. This technology is usually used on slightly higher platforms, for example, in forklifts, because in these cases the laser is mounted quite high and, as a result, the laser beams are not interrupted when people are present.

Table 6.4: Examples of how different location-based navigation systems work

Location and navigation system	Video	Keywords
Inductive wire		Jungheinrich AG, Jungheinrich Inductive Guidance for Forklift Trucks
		Götting KG, Götting FTF Spurführungstechnologien / AGV Track Guidance Technologies
Magnetic strips		Götting KG, Götting FTF Spurführungstechnologien / AGV Track Guidance Technologies
		Roboteq, Magnetic track following Mobile Robot demonstrator
Inertial system		DS AUTOMOTION, Magnetic Navigation by DS AUTOMOTION GmbH - Automated Guided Vehicle (AGV)
2D laser		Götting KG, Götting FTF Spurführungstechnologien / AGV Track Guidance Technologies
		DS AUTOMOTION, Laser navigation by DS AUTOMOTION GmbH - Automated Guided Vehicle (AGV)
SLAM		cygbot lab, 2D/3D Dual SLAM Robot using ROS and LiDAR with Raspberry Pi

When using SLAM algorithms, a vehicle builds a consistent map of the area it is in, and at the same time determines its current location on this map. SLAM often involves sensor fusion, in which data from multiple sensors is combined to improve the accuracy of mapping and localization. SLAM algorithms are classified based on the sensors they primarily use. LiDAR SLAM prioritizes LiDAR for sensing the environment, while Visual SLAM uses a machine vision system or camera as the primary sensor. SLAM is suitable for unknown or dynamic environments, where the layout of facilities can change over time. SLAM algorithms are computationally very expensive and consequently require a lot of processing power and memory. SLAM depends on the quality and accuracy of sensors, so sensor calibration is crucial.

3 Autonomous vehicle MiR100

The MiR100 (Mobile Industrial Robots., 2023) is an autonomous vehicle with a payload of up to 100 kg, manufactured by Mobile Industrial Robots. It can be used exclusively in closed production areas, warehouses, or other industrial facilities. The MiR100 (Figure 6.5) has two built-in safety laser scanners (Figure 6.6), which are mounted on the diagonal edges of the robot, enabling scanning of the entire area around it. The vehicle also contains ultrasonic sensors and a 3D camera. As a result, the MiR100 can operate near people and other dynamic obstacles and is able to drive through narrow corridors or doors. The MiR100 operates on a differential drive, namely, it has two drive wheels and four support wheels (Castor wheels). The vehicle can be manually operated via a built-in web interface, but it is primarily intended for autonomously performing various transport tasks. The robot performs localization and navigation via a map that can be imported or created at the first start.

Figure 6.5: MiR100
Source: own.

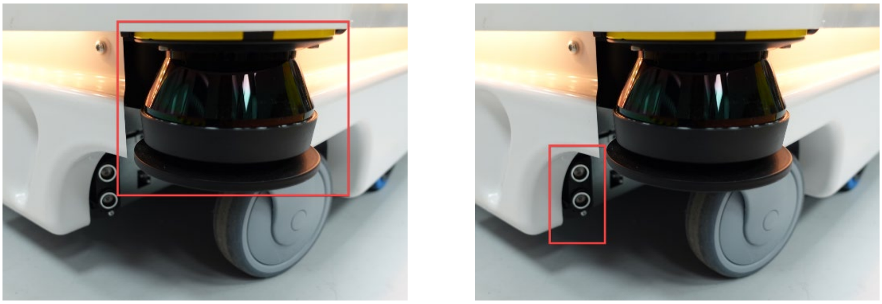


Figure 6.6: Safety laser scanner (left) and ultrasonic sensor (right)
Source: own.

The MiR100 is a basic mobile platform on which various Top Modules can be fitted to modify the functionality of the vehicle (Figure 6.7). For example, the MiR Hook 100 top module turns the MiR100 into a towing vehicle, allowing the towing of loads on attached trolleys. Examples of some of the modules added above to the MiR100 are given in Table 6.5 below.

Table 6.5: Examples of the top modules for the MiR100

Top module	Video	Keywords
Roller, belt		Omni Automation, MiR 100 Robot - Top Module Roller Conveyor
		Mobile Industrial Robots, Mir100 hos SAXE på Elmia Automation 2016
CLAMP		Robotcenter, Clamp top module for MiR100/MiR200
Towing		Mobile Industrial Robots, MiR 100 Hooking a Trailer Automatically
With a collaborative robotic arm		Mobile Industrial Robots, MiR100 with UR cobot arm at SGIMRI

Figure 6.7: Example of a top locking module
Source: own.

3.1 User interface

MiR robots have a built-in Wi-Fi access point, through which it is possible to access the robot's user interface. The user interface, designed in the form of a web page, allows: (1) creating dashboards, (2) mapping the space, (3) creating missions, (4) monitoring the current state of the robot, (5) managing users, (6) manually controlling the robot, (7) updating the software, etc.

Dashboards allow direct access to individual key functions of the robot and are primarily intended for different groups of users. Each dashboard consists of visual widgets that represent system features, such as a specific mission, a map, the current queue of missions, etc. Dashboards can be created and edited using the built-in dashboard designer. An example of a dashboard is shown in the figure below (Figure 6.8).

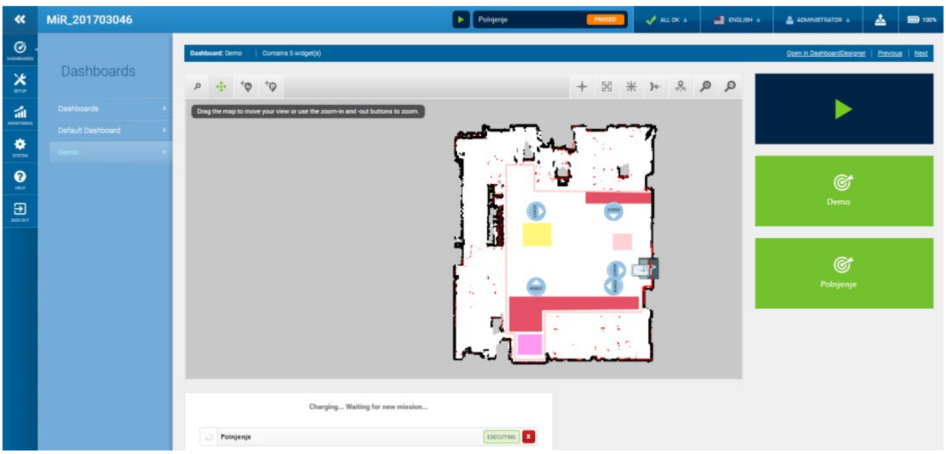


Figure 6.8: Example of a built-in dashboard

Source: own.

The vehicle can be manually controlled using a virtual joystick, which is an integral part of the user interface. The user interface allows the creation of multiple user accounts with different permissions, which allows controlled access to individual robot functions. The user interface also allows monitoring of the status of the robot (its location on the map, battery status, error and warning messages, etc.).

3.2 Mapping and editing maps

Mapping or creating area maps is the most important process that allows the vehicle to operate independently in a selected space. Creating a map is done in two steps. In the first step, a CAD file of an existing map of the space is loaded onto the robot, or the map is created by manually guiding the robot. In the second step, the map is edited using the built-in editor. The built-in mapping functionality allows you to create a map by manually moving the robot around the space using the built-in virtual joystick. During movement, data is captured from safety laser scanners, and based on this, the robot creates a map of the space. After capturing the map, editing follows. In addition to fixed objects (e.g. walls), the creation process also captures so-called dynamic objects (people, forklifts, carts, chairs, pallets, etc.), which are located in the vehicle's surroundings at the time of capture. These objects must be removed, otherwise they may extend the length of the vehicle's path. Scanning can also cause errors in detecting stationary objects (e.g. walls) and, as a result, objects appear as broken lines on the map. In this case, such objects must be corrected or drawn additionally using the built-in tools on the map.

On the edited map, using additional tools, it is possible to determine: (1) Preferred zones, (2) Unpreferred zones, (3) Forbidden zones, (4) Critical zones, (5) Speed zones, (6) Blink zones, Beep zones, etc.

The individual zones have the following meaning:

- Preferred zones: The robot always tries to drive in this zone.
- Unpreferred zones: The robot tries to avoid this area, but if there is no other option, it can also drive through this area.
- Forbidden zones: the robot must never enter this area.
- Critical zones: obstacles detected by installed cameras or scanners are ignored in these areas. This allows the robot to approach obstacles without triggering the safety stop system. When the robot leaves this area, the protective functions are reactivated. This area is useful, for example, in narrow passages, doors, etc.
- Directional zones: determine the direction of the robot's movement. The robot can only move in the selected direction in this area.
- Speed zones: In these areas, the vehicle's speed can be increased or decreased. For example, speed reduction is used if the vehicle is in an area with a lot of

people. The default robot speed is 1 m/s, the minimum is 0.1 m/s, and the maximum is 1.5 m/s.

– Blink zones, Beep zones: while driving in this area, the robot can play a selected sound and/or signal appropriately with the built-in LED light strip. Signaling is primarily used to alert people to the presence of the robot.
– I/O module area: When entering this area, the robot activates the Input/Output module.

Figure 6.9 shows an example of an edited map with special areas added.

Before creating transport tasks (missions), position points (markers) must be defined on the created map; these are points in space to which the robot can drive. Each point contains a name, X and Y coordinates of the point in meters, and the orientation of the vehicle in degrees.

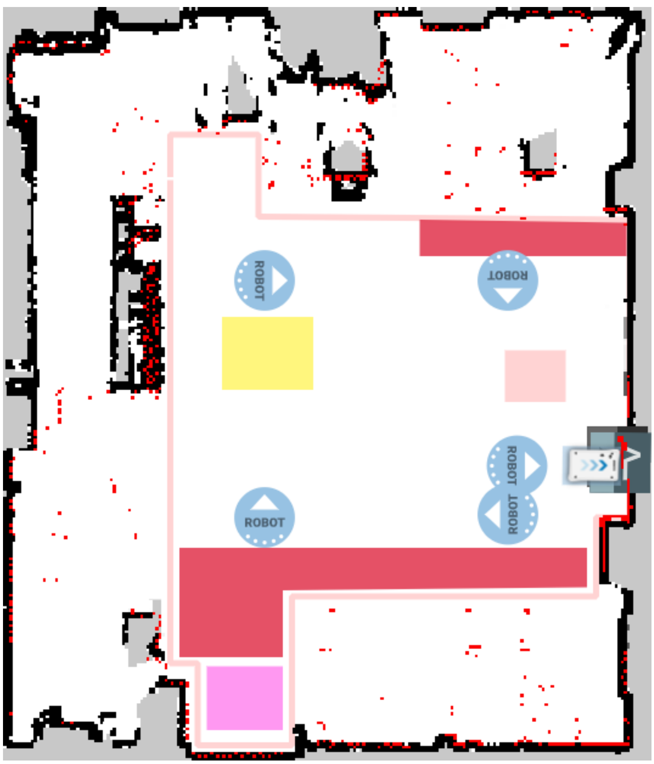


Figure 6.9: Example of an edited map with special areas added

Source: own.

3.3 Creating missions

After creating the map, the vehicle is programmed, or the so-called missions are created. A mission consists of various actions, such as: (1) moving the vehicle, (2) turning the digital signal on/off, (3) connecting/disconnecting the cart, etc. Individual actions represent the basic building blocks for creating missions, and they can also be used within other missions. Most actions have adjustable parameters.

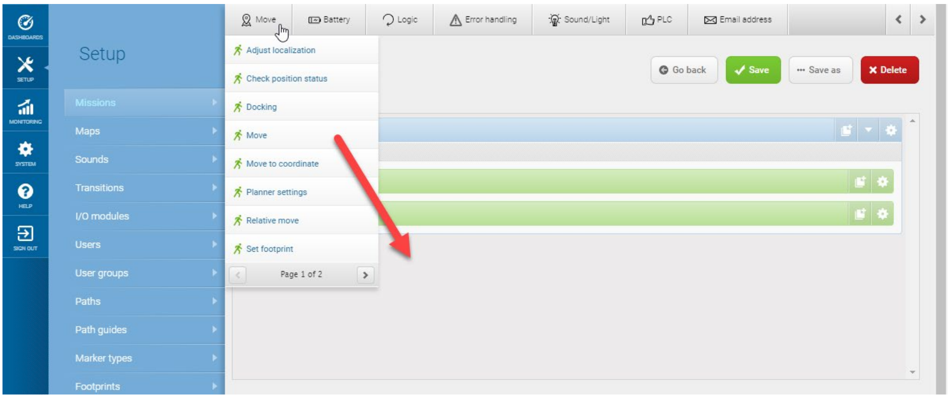


Figure 6.10: Mission Editor
Source: own.

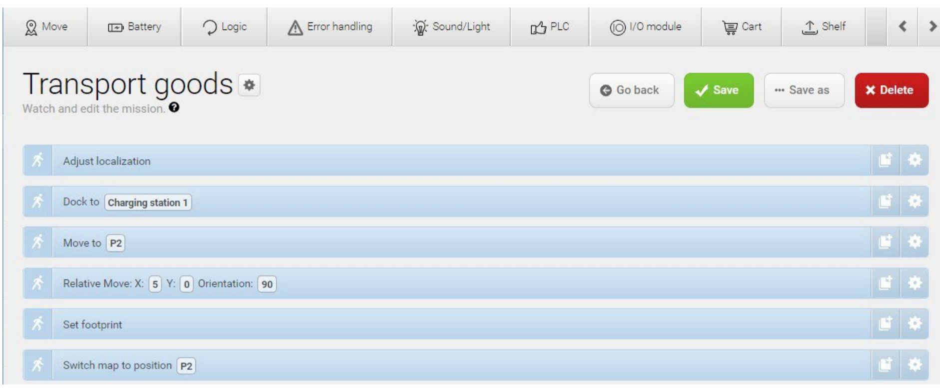


Figure 6.11: Example of a created mission
Source: own.

A mission consists of individual actions or commands that can be selected in the Mission Editor menus (Figure 6.10). The commands are grouped into submenus: Move, Battery, Logic, etc. A command is added to a mission by dragging it to the bottom of the editor (Figure 6.10). The commands are executed in sequence, from top to bottom. The parameters of the selected command can be changed by selecting the icon (gear) located on the far-right side of each command (Figure 6.11).

4 Conclusion

The chapter provides the reader with basic information on the operation of automated guided and autonomous vehicles and describes practical application examples. In a brief overview of the field of automated guided and autonomous vehicles, it can be observed that one and the other use different sensor systems to detect the surroundings and obstacles. Different actuators are used to achieve different modes of motion and, consequently, different vehicle kinematic and dynamic properties. The main difference between automated and autonomous vehicles lies in the decision-making systems directly linked to the sensing systems. A practical example of an autonomous mobile robot, MiR 100, illustrates the user interface and the basic functions for operation in intralogistics applications. It can be concluded that the MiR 100 is a basic autonomous platform but needs additional modules for more advanced applications. We foresee that the use of autonomous mobile robots will increase in the future, mainly due to the upgrading of existing automated guided vehicles and the automation of manual processes.

References

Mobile Industrial Robots. (2023). MiR100 User guide. Retrieved from https://www.mobile-industrial-robots.com/

Roboteq Inc. (2013). Building a Magnetic Track Guided AGV, Application Note AN1326. Retrieved from https://www.roboteq.com/index.php/applications/100-how-to/278-building-a-magnetic-track-guided-agv

SICK AG. (2018). SICK Web Site. Retrieved from https://www.sick.com

Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D. (2011). *Introduction to autonomous mobile robots*: MIT press.

Statista. (2023). Global autonomous mobile robot market size 2016-2028. Retrieved from https://www.statista.com/statistics/1285835/worldwide-autonomous-robots-market-size

Wikipedia. (2025). Inertial navigation system. Retrieved from https://en.wikipedia.org/wiki/Inertial_navigation_system

Wikipedija. (2023). Automated Guided Vehicle. Retrieved from https://en.wikipedia.org/wiki/Automated_guided_vehicle