USAGE OF AUTOMATIC GUIDED VEHICLE SYSTEMS AND MULTI-AGENT TECHNOLOGY IN HIGHER EDUCATION

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Abstract

Today, smart manufacturing is differentiated from many other initiatives by its emphasis on human ingenuity. Human capabilities must be enhanced by intelligently designing a customized solution for a specific domain. For example, Industry 4.0 is based on collaborative robots that digitize and simplify manufacturing processes. In fact, Automatic Guided Vehicles (AGVs) are widely used in intelligent industries due to their productivity, flexibility, and versatility. They are widely considered as one of the most important tools for flexible logistics in workshops. They can move materials and products without a predefined route. Many commercially available AGVs provide a self-guided navigation system to find their way to target workstations. However, many developers and producers of industrial robots face several challenges in designing AGV systems, such as the difficulty of defining a decentralized system decision as well as the discontinuity and complexity of the design process. One of the relevant research areas related to our AGV solution is the establishment of the human-machine industrial relationship and the creation of safe operation side by side.

1 Introduction

Traditionally AGVs are considered vehicles that use conservative driving methods along a predefined path. For a while, it was the only available method of navigation for such vehicles. In recent years with the growth of technology and computational power were developed more sophisticated methods of navigation. The new methods are based on the probabilistic approach of localization and can offer dynamic path replanning [11]. These features are required by the flexible nature of Industry 4.0. Some researchers name the new generation of AGVs the autonomous mobile robots (AMR) which reflect its flexible capabilities. This work presents the development of a new "Two Wheel" autonomous robot platform for education, competition and research, based on swarm theory with machine learning for Industry 4.0 applications. The system is being developed around a popular IoT platform featured ESP32 microcontroller with wifi and bluetooth support.

2 The Automatic Guided Vehicle Systems

The Automatic Guided Vehicle Systems system are fully modular to handle small and large items such as assembly parts, various tools and even larger objects. AGV Systems are used for various industries including automotive, chemical, food industry, pharmaceutical, transportation &

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warehousing [6]. By applying automatic guided carts systems can increase productivity, reduce operating costs and improve ergonomics for nearly any company in any industry, including distribution and manufacturing. AGV carts can be used as an assembly system or to transport materials from designated pickup and drop off locations, within the laboratory, using programmable delivery routines [1][6].

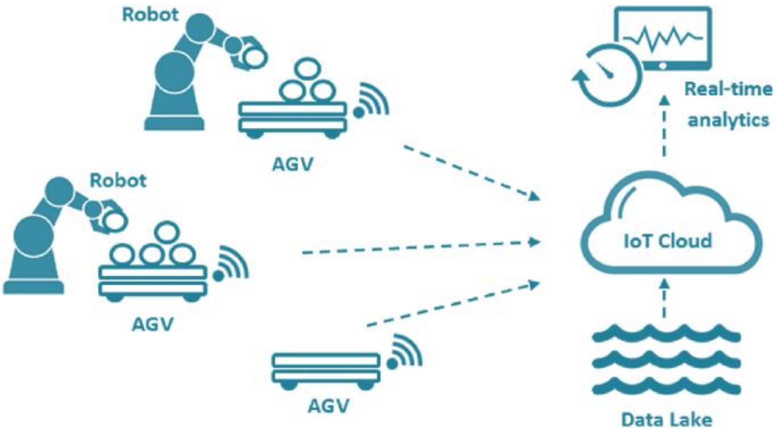

Figure 1. AGV architecture [7]

The currently existing robotic and pick and place cells can be synchronized inside the laboratory and without the need for transport mechanisms using the AGV system. AGV units transfer a work item from one position to another taking into account the current occupancy of a given cell. In this way, production is not linearly restricted, but parallel execution of procedures is possible [10]. With the application of the AGV system, applications are not restricted within one laboratory, but it is possible to transfer work items to another room by a pre-programmed path. In this way, the benefits of Industry 4.0 comes into its own maximum.

3 3D printed custom AGV

In this paper a completely 3D printed Robot with a unique shape using ESP32 as the main controller is presented. This robot can be remotely controlled using Android Dabbler app or using a web browser but also can act fully autonomously. For the chassis of the robot a 3D printing technology was used. To run the robot, a single18650 Li Ion cell 3.7V battery can be used, powering the ESP board, the camera module and motor drive with on-board USB charge option. The robot is equipped with sonar, infra and tactile sensors along with a 2MP wireless camera to detect different factors of the environment. Camera can be moved separately using the on-board pan/tilt mechanism powered by two servos [8].

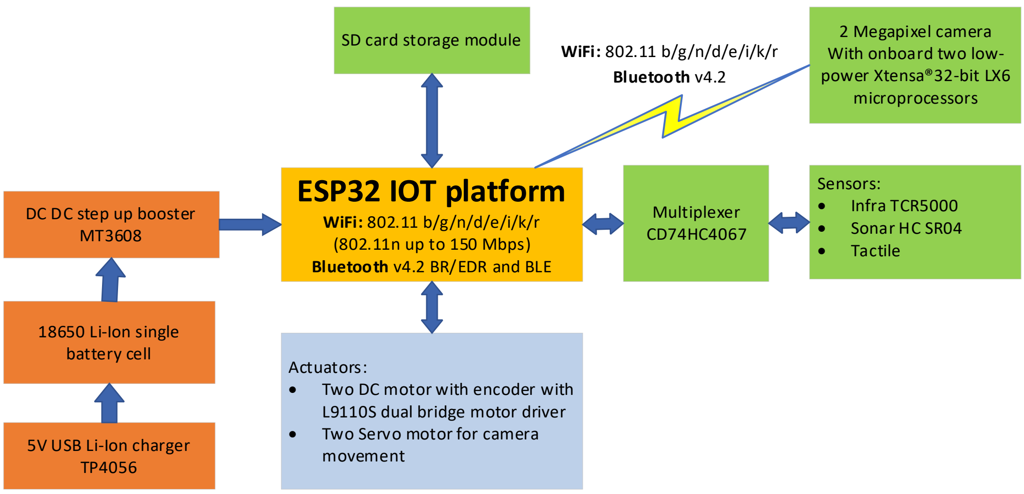

Figure 2. Developed AGV platform

The ESP32 is a popular 2.4GHz Wi-Fi and Bluetooth enabled dual core microcontroller, designed with ultra-low power 40nm technology. This chip is designed to deliver the best RF performance and performance, demonstrating flexibility, versatility and reliability in a variety of applications and profiles. ESP32 is designed for mobile, portable and Internet-of-Things (IoT) applications. The features are low-power consumption, including more CPU power and dynamic performance reduction. For example, in the low-power IOT sensor application scenario, ESP32 will wake up periodically and only when a specific condition is found [9]. Low chip duty cycle minimizes power consumption. The output of the power amplifier is also adjustable, contributing to the optimum level of communication range, data rate and power consumption.

Features:

- Power supply: Li-ion 3000 mAh 3.8V 18650 cell
- Power management: DC-DC SX1308 Step-Up 5V and 6V
- USB charger: Micro USB 5V 1A 18650 TP4056 Lithium Battery Charger
- Controller board: ESP32S
- Analog / digital I/O: CD74HC4067 16-Channel Multiplexor
- Sensors: IR Infrared Sensor Module
- Motor driver: L9110S
- Motors: DC Gear Motor
- Data storage: SD card module
- Sound: Active buzzer
- Camera: ESP32 Cam

Figure 3. 3D printed and assembled AGV`s

The vision of Industry 4.0 is that in the future, industrial enterprises will build global networks that connect their machines, factories and warehouse facilities in the form of cyber-physical systems, which are mutually intelligently controlled by sharing information that drives operations. Cyber-physical systems will take the form of smart factories, smart machines, smart warehouses and smart supply chains. The center of the Industry 4.0 vision are smart factories that will change the way production is done [2]. Production will be based on smart machines, but also on smart products. Cyber – physical systems such as smart machines will not be the only ones that are intelligent [3]. The products being assembled will also have built-in intelligence, so they can be easily identified and located at any time during the manufacturing process using AVGs. The miniaturization of radio frequency identification RFID (Radio Frequency Identification) tags allows products to be intelligent, to know what they are, when they were produced and most importantly, what their current state is and the steps needed to reach the desired state [12].

4 Structure and application of Magni mobile robots

The Magni mobile robots developed by Ubiquity Robotics are primarily for educational purposes, but they can also be used extremely versatilely to solve other, specific tasks. The robots its structure and the hardware used make it possible to carry out complicated activities and complex controls. They are suitable for indoor localization, navigation, orientation and mapping. And with the right hardware (camera) for shape recognition and more. It can also perform image processing tasks. The Raspberry PI 4 on the robot runs ROS Kinetic (Robot Operating System). A big advantage of this is that there are many libraries/modules for different sensors, making it easier to expand the robot [4]. Through ROS, we can also run complex control tasks on the robot. Open source software also provides the opportunity to optimize and customize (for a task) our system and modify our application at the lowest level.

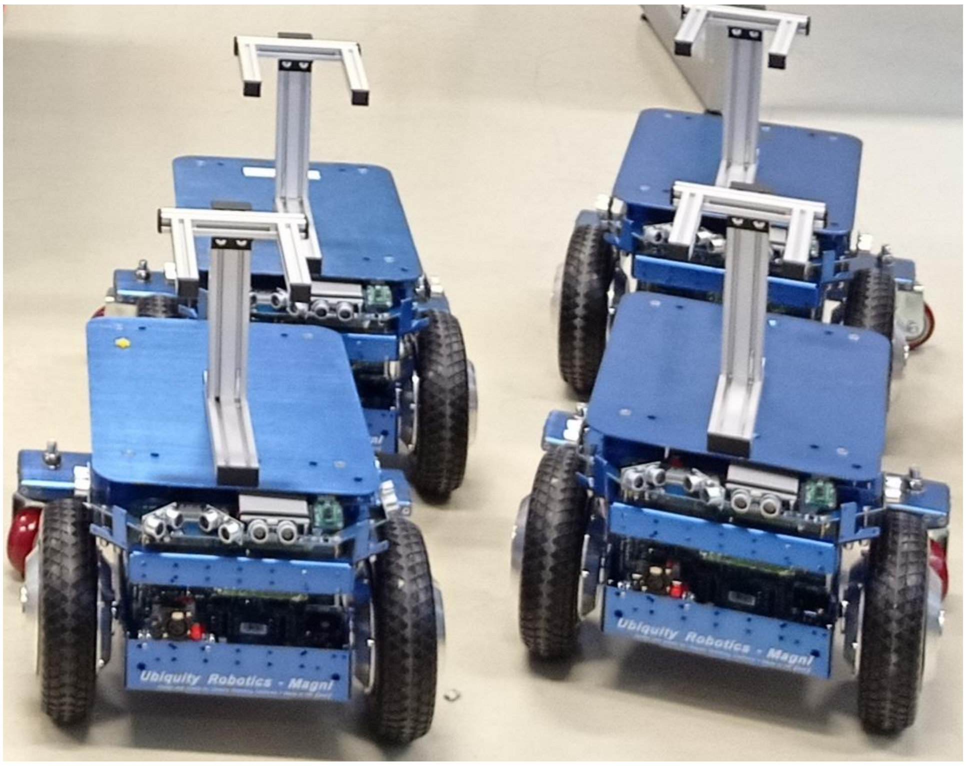

Figure 4. Magni AGV`s

Internet access is required to use the robot, a (WiFi) access point is a great solution to which it can connect. Through this, we can control the robot and start the program. It can also communicate with other devices on the network. If we have several robots, we can also think about multi-robot systems [5]. The massive robot weighs 13 kg without the batteries and has a nominal load capacity of 50 kg. We can set the size and type of battery within certain size and voltage limits. The further expansion of the robot is easy, because we have the possibility to accept different sensor holders, actuators, and other elements in several places. AGVs (Automated Guided Vehicles) can be used at the faculty for a variety of applications, such as:

- Library Automation: AGVs can be used to automate the movement of books and materials within a library. For example, AGVs can be used to transport books from a storage area to a sorting area, or from a sorting area to a pick-up location.
- Laboratory Automation: AGVs can be used to automate the movement of samples, reagents, and equipment within a laboratory. For example, AGVs can be used to transport samples to and from different instruments, or to transport equipment between different lab areas.
- Campus Transport: AGVs can be used to transport students and staff within a campus, such as between buildings or to and from parking areas.

- Food Service: AGVs can be used to transport food and supplies to and from a kitchen, or to transport trays within a dining hall.
- Maintenance: AGVs can be used to transport maintenance materials and equipment within a facility, such as to and from storage areas or between different buildings.
- Research: AGVs can be used for research applications such as testing new navigation and control algorithms, evaluating new sensors and technologies, or developing new material handling methods.

AGVs can provide significant benefits in higher education by improving efficiency, reducing costs, and increasing safety. However, it is important to note that AGV systems can be complex and costly to implement, and it is essential to carefully evaluate the potential benefits and costs before deciding to implement an AGV system.

5 The use of AGV in higher education

In engineering education, students study programming as a foundational subject over several semesters. The programming language used is C/C++, and during further studies, based on the acquired foundations, the students also learn C#, JAVA, and Python. The mentioned programming languages also form a good basis for programming AGV systems.

One of the most important roles in navigation applications is location determination and position estimation. These applications are characterized by the fact that several types of sensors provide information about the environment. Unfortunately, in most cases, the measured information is saturated with noise to such an extent that it is not possible to precisely estimate the position on them. Algorithms based on Kalman filters offer an alternative to this, which try to reduce the estimation error to a minimum based on an a priori system model. At the same time, by using them, the information received from several sources can be utilized at the same time.

Figure 5. Teaching AGV theoretical background for students

AGV systems can act independently of an external controller and perform for example a Simultaneous Localization And Mapping (SLAM) algorithm. Their programming is guided by the goal of reacting to external influences in some way. The more advanced ones use a stereo vision system: spatial perception is ensured by two cameras and image recognition software for the localization and classification of objects. They can also use microphones and smell sensors to analyze the environment. Some, such as vacuum cleaners and lawnmowers, which have already appeared in everyday life, only operate in familiar, well-defined areas, while others also analyze unknown, difficult terrains and adapt to them by associating certain terrain patterns with certain actions. But there is also an alternative design concept based on randomness: if a problem arises, the robot will experiment until one of its attempts is successful.

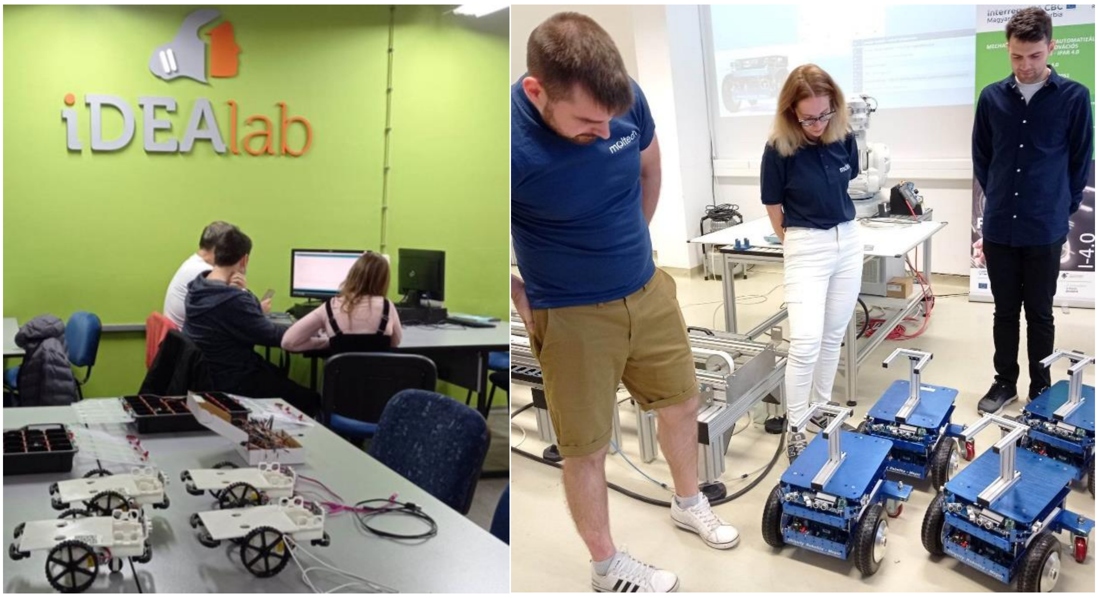

Figure 6. Students working with AGVs

SLAM is an algorithm that enables a mobile robot to build a map of an unknown environment while simultaneously determining its own location within that environment. SLAM algorithms can be used in both indoor and outdoor environments, and are often used in applications such as autonomous navigation, robot mapping, and augmented reality. The basic idea behind SLAM is to have the robot move around the environment while collecting sensor data, such as laser rangefinding, image data, or odometry information. This sensor data is then used to estimate the robot's position and orientation, as well as the locations of objects and features in the environment. There are two main approaches to SLAM:

- EKF-SLAM (Extended Kalman Filter SLAM): This approach uses a Kalman filter to estimate the robot's pose and map. The filter combines the robot's odometry information with sensor data to estimate the robot's position and orientation, and to build a map of the environment.
- Graph-based SLAM: This approach uses a graph to represent the robot's trajectory and the features in the environment. The graph is constructed incrementally as the robot moves, and the robot's pose and the features' locations are estimated by solving an optimization problem on the graph.

Both EKF-SLAM and Graph-based SLAM have their own advantages and disadvantages, and the choice of algorithm depends on the specific application and the type of sensor data available. SLAM is a fundamental technique in robotics, and its implementation can be complex, involving multiple sensors, motion models, and data association techniques. SLAM is an active area of research and new algorithms and techniques are being proposed and developed. Programmable AGV systems can be used at different age and skill levels of education. Excellent tools for learning programming and increasing motivation. They provide an opportunity for the practical implementation of the theoretical knowledge already acquired like swarm-based multi-agent distributed architecture. With their use, it is possible to try different programming languages and programming environments in life-like situations. They can become auxiliary tools for different subjects, and they can be new opportunities to achieve the goal. They can conquer countless areas in the near future. They can become important tools for research in communication, artificial intelligence, image processing, algorithm theory, shape recognition, game theory, and swarm intelligence. The application of the mobile robot in education seems justified. Due to its favorable price, you can buy several packages or develop your own solution, so the whole group does not rely on one device. It can also be used to teach group work. When issuing a more complex task, when breaking it down into subtasks, tasks that can be divided into individuals in each group are given. The students learn to cooperate, help each other during the completion of the task and are very well motivated. The acquired knowledge can be used well later when working in the industrial field.

The Magni robot by Ubiquity Robotics and the 3D printed custom AGV are both mobile robots designed for educational and research purposes. However, they have some key differences in terms of features and capabilities. The Magni robot is a small, tracked mobile robot that is designed for research and education in areas such as robotics, AI, and computer vision. It is equipped with a variety of sensors and actuators, including a stereo camera, a 6-axis IMU, a LIDAR sensor, and a RGB-D sensor. It also features a powerful onboard computer, which allows for real-time control and data processing. The 3D printed custom AGV is a versatile robot that is designed for educational use in areas such as electronics, robotics, and programming. It is equipped with a variety of sensors and actuators, including a range finder, a camera, and a variety of infrared sensors. It also features an onboard microcontroller, which allows for real-time control and data processing. In terms of performance, the Magni robot is more advanced than the 3D printed custom AGV, as it is equipped with a wider range of sensors and more powerful onboard computer. It is also more versatile and can be used for a wider range of applications such as computer vision and AI. On the other hand, the 3D printed custom AGV is more affordable and simpler to use, making it a good choice for educational use and for beginners in robotics. In summary, while both robots are designed for educational and research use, the Magni robot by Ubiquity Robotics is more advanced and versatile, while the 3D printed custom AGV is more affordable and simpler to use, making it a good choice for educational use and for beginners in robotics.

6 Conclusion

A manufacturing industry that uses the most modern technologies, equipment, processes and work methods based on Industry 4.0 is a de facto standard. It brings great benefits to businesses such as increased productivity, competitiveness and profits. Existing production systems generally do not yet apply all Industry 4.0 concepts, which should change in the near future. That gap, which was discovered by the research, should be filled with a higher percentage of satisfaction of the concept of Industry 4.0. The programmable production system is the closest to the production system required by Industry 4.0. In order to achieve all the principles of Industry 4.0, it is necessary to focus on the concepts, in relation to which the existing production systems deviate the most from Industry 4.0, such as self-configuration, self-optimization, early adoption and predictive maintenance. Institutions of higher education must train future engineers who are capable of implementing such systems. One such competence is working with AGV systems. The fundamental trend of the future is artificial intelligence. This trend also emphasizes the capabilities of software embedded in AGV systems. Smarter robots can learn to perform tasks that previously proved difficult or impossible without costly and time-consuming coding. Today, advanced AGV systems use artificial intelligence to provide capabilities such as more accurate object identification or information-based traffic for safe maneuvering in crowded and dynamically changing environments, all while using less energy. The autonomous behavior of AGV systems, which move from one point to another without knowing what is happening around them, will continue to improve.

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