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A survey in the design and control of automated guided vehicle systems

A. P. Vancea

Electric, Electronic and Computer Engineering, Technical University of Cluj-Napoca, North University Center Baia Mare, Baia Mare, Romania

alexvancea92@gmail.com

I. Orha

Electric, Electronic and Computer Engineering, Technical University of Cluj-Napoca, North University Center Baia Mare, Baia Mare, Romania

ioan.orha@cunbm.utcluj.ro

***Abstract* — Automatic guided vehicles (AGVs) play an important role in the small-scale industry as well as the large-scale industry in handling materials inside factories from one place to another. In the last days, the materials to be handled are more numerous and as production and demand increase, it strongly influences the transport of materials in desperate need of a vehicle to distribute, position the materials within the industry. AGVs are generally installed with wires at ground level and signals are transmitted through them to be controlled. Due to the emergence of the AGV, the workload of the human being gradually decreased and the production efficiency increased. Thus, the need for an AGV has become more technologically important in the advanced robotic world. Normally, these systems are integrated into a global production system, where is a need to make direct changes in the design and planning of the floor store to get most of them. But in the rapidly changing production system and the adaptable floor store, the implementation of AGV has become very important and difficult, because it depends on many systems, such as wires, frequency, total production, etc. Therefore, it is necessary to develop an independent AGV, which can operate on its own and make decisions based on changes in the environment.**

Keywords — AGV, industry 4.0, vehicle, algorithms, navigation, IoT;

I. INTRODUCTION

AGV is a material handling system used for horizontal movement of materials. The AGVs were introduced in 1955. The use of AGVs has increased enormously since their introduction. The number of application areas and the variation of types has increased significantly. AGVs can be used both indoors and outdoors, participating in tasks such as production, distribution, transshipment. AGVs are used to transport materials of all types related to the manufacturing process. According to Gotting, over 20,000 AGVs have been used in industrial applications. Deposits and cross docks, engineering centers are examples of distribution areas. The AGVs are used in these areas for internal transport as an example, pallets between the different departments, such as the reception, storage, sorting and dispatch areas. In transshipment systems, such as shipping containers, AGVs deal with the transport of products between different modes of transport. Getting presented an overview of the technology available for automation in container terminals. Moreover, the applicable navy-guidance systems and vehicle guidance are described in various indoor/outdoor environments. Haefner and Bieschke said that AGV systems can provide benefits to both the port and its customers by executing shipping applications between ships and inland transport, and AGVs can also be used in the process of outdoor transportation [1].

An example of such a transport system is an automated underground system with AGVs traveling in the pipes between companies and an airport [1]. In such systems, we observe a high traffic density and long tube driving times. It has even been studied whether AGVs can be used as a communication system between workstations. AGV specifications differ depending on the environment. To carry a container, the capacity of an AGV should be at least 40 tones. For a smaller capacity, it is necessary to transport pallets to warehouses. Moreover, at terminals for guided automated container vehicles, they use signs (ALVs). In this paper, we will discuss the literature concerns - the use of AGVs in manufacturing and the new fields of application, namely distribution, transshipment - maintenance and transport systems.

The most important differences between the traditional and the new application areas are the number of AGVs used, the number of transport applications, the degree of occupancy of the AGV, the distances traveled and the number of pick-up and delivery points where the transport applications become available. Panic grades are used to carry a small number of requests over short distances between selections, delivery points. Unlike reinforcement systems, a large number of AGVs have been used to perform a large number of repetitions, transport tasks to container terminals and exteriors. In previous studies, a research survey into the design and control of automated systems of guided vehicles proved to be concentrated in the literature related to the design and control of AGV systems for the manufacture, distribution, transshipment, and transshipment of port systems [2]. It was concluded that most models can be applied to design problems at teaching centers. Some of these models and new models have already proved successful. The new analytical and simulation fashion must be developed for large AGV systems to overcome the high computation times, NP complexity, congestion, bottlenecks and delays in the system and finite planning horizons [3, 4, 5]. This paper discusses the literature on different fermentation methodologies for optimizing AGV systems for two significant scheduling and routing problems in manufacturing, distribution, transshipment and port systems. We have classified methodologies into mathematical methods, simulation studies, heuristic meta-techniques and approaches based on artificial intelligence. The motivation for the classification of the programming and the routing is based on their significance in flexible manufacturing systems.

II. WHAT IS AN AGV?

AGV is the acronym for Automated Guided Vehicles [6]. Such vehicles are used in warehouses to transport the goods. The AGVs look like little cars that can move controlled in a warehouse. Controlled travel is ensured by special software. With the help of this software, AGVs know what to do, orient themselves in the warehouse and avoid collisions both with each other and with other static objects [7]. There are several types of automatic vehicles produced by several companies. Each of these can be used for moving pallets or even for lifting operations. Some of these automatic vehicles can move shelves with products to be arranged. The AGV's central processing system issues the steering control as well as the speed of movement. For the predefined manufacturing environment, the map is saved in the AGV memory.

A general AGV system consists essentially of peripherals vehicle on-site components, stationary control system. The main components of the AGV system are THE VEHICLE, ORIENTAL WAY SYSTEM, TRAFFIC CONTROL, and MANAGEMENT SYSTEM. The flawless interaction of these components ensuring the efficiency of the work installation. AGV will guarantee a safe performance, as well as the load and the surroundings.

A. VEHICLE

The vehicle is the central element of the AGV because it fulfills the real transport task [8]. The vehicle is individual depending on the design, purpose and activity environment. They are used in several scenarios such as AGV designed to improve the health care system, AGV developed as a hotel service robot. Amazon has implemented the KWIA robot for automatic storage and retrieval of products in the system. The most common uses of these automatic vehicles are in the production area when supplying the workstations with raw materials. Also, they are used when picking up finished or semi-finished products and bringing them to the storage area. Automatic forklifts can be considered AGVs, however, the common perception is that AGVs are the kind of cars that come under the pallet and pick it up [9]. As I said at the moment, they are used in production environments due to the high costs of purchasing the systems.

In Fig.1 is presented an example of automatic pallet truck.

Fig. 1. Automatic pallet truck

In Fig.2 is presented an example of automatic conveyor.

Fig. 2. Automatic conveyor

The pallet truck is used to move palletized loads on a predefined route, and the Carrier is used to move a unit load from one station to another. It is suitable for the automatic loading and unloading of pallets with mechanized lifting platform

B. ORIENTAL WAY SYSTEM

The vehicle guidance system is the method by which AGVs are defined and the vehicles are controlled following predefined paths. The AGV system uses the guide path, it chooses a path based on the programmed path [10]. It uses the data provided by the sensors and is compared with the value offered by the programmer. When AGV approaches a decision point, it only has to decide whether to follow the path.

The most used guidance technologies in AGV are:

a. Landmark-based navigation

b. Behavior-based navigation

c. Vision-based navigation

a. Landmark-based navigation

The markup-based navigation technique is based on their identification and subsequent recognition, distinct features of an object in the environment that may be previously known or dynamically extracted. The various technologies used in navigation based on land marking are incorporated into a guided wire and tape type system (line tracking robot). In the wire-guided method, the wires are placed in a small channel inside the workspace floor. AGV senses the low-frequency current in the 1-15 kHz range for guidance vehicle. The guide band or the next AGV line are robots that operate with the vehicle that detects and follows a predefined line drawn on the work floor. To track the line drawn on the floor, the robot used an array sensor that sends the signal to the robot's control system. According to the input signal, the central system manipulates the robot to remain in operation while constantly correcting the wrong movements of the robot through a feedback mechanism thus forming a simple system of efficient loops. MA Rahman described in his work an AGV is driven by a sensor-driven actuator and its position, controlled by 3 infrared sensors connected to a PIC-16F877A microcontroller, and that the system is automatically using the inertial sensor the AGV is capable of collision avoidance.

In Bajastani's [11] work described using a robot that follows the line that describes a cheap and simple navigation technique using ATMEGA 16 microcontroller completely automatically in the environment. This gives the robot the ability to perform 90-degree curves, the ability to capture and count the junctions. It uses LEDs with adjustable intensity and light sensors for navigation, thus improving the robot's performance in low light conditions.

In Fig.3 is presented an example of a robot that follows a line that describes a cheap and simple navigation technique based on landmark navigation;

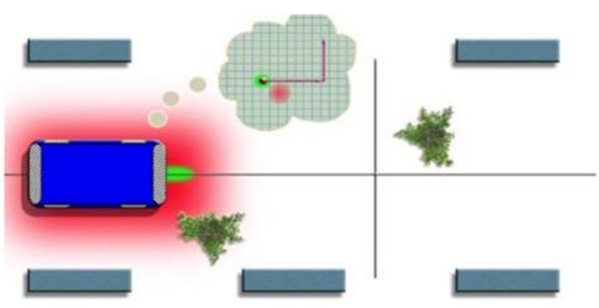

Fig. 3. Landmark-based navigation

b. Behavior-based navigation

This type of paradigm has been accredited and suitable for a suitable unstructured environment, as it can incorporate with a large number of sensors. Behaviors for the best navigation techniques also require a high level of computing power, neural network, genetic algorithm [12] and more combinations thereof. The behavioral navigation system uses laser beam navigation technology for mobility. Laser beam navigation technology is used to determine vehicle position and navigation in the system. In LOTHER's work, we discussed the technique of scanning the workspace to improve the accuracy of the AGV. An important step considering the laser navigation is the independence of the reflection marker technique, which have a low installation cost and which will allow overcoming the limitation of the currently used triangle system, a system developed more than ten years ago.

c. Vision-based navigation

It is the latest guidance technology, which works without continuously defining the path. Uses the reconnaissance navigation system providing the position and angular speed of an autonomous mobile robot [13]. Simion has defined the mobile robot as the device that can move in the environment with a certain degree of autonomy. Then the navigation associated with the external sensor that captures information from the workspace by measuring proximity and visual image. Malhotra and Al's research discussed the design of a mobile robot for a dynamic environment [14]. A brain-focused design for the autonomous robot by integrating the central system as well as the sensor system was used to detect obstacles in the warehouse. Ramos discussed the algorithm for the vision base system using the neural network.
K.Kishor (2010) discussed the smooth motion of the robot in the workspace.

In Fig.4 is presented an AGV that used a navigation technique based on vision navigation;

Fig. 4. Vision-based navigation

The conventional robot loses a lot of time in tracking the guideline, and the speed is restricted and the robot oscillates a lot, so more time is used to navigate the route. The controller calculated its current position, then calculated the error from the target position when the error is raised the engine will make a high turn if the error will decrease the engine will make a low turn so that the magnitude of the turn is proportional to the error [15]. Derivatives control is implemented to mitigate the actual swing hours.

The basic idea of the algorithm is:

Error = Target Position - Current Position;
P = error × K_p;
D = error - previous error; stores changes from error to deflected;
Correction = P+D;
K_p = constant proportional to the time error;

The correction term is applied for left and right engine speeds. The constant in the algorithm has been adjusted to minimize oscillation and exceedance at the highest possible speed by adjusting, proportional constant

C. TRAFFIC CONTROL AND MANAGEMENT SYSTEM

To function efficiently and increase AGV productivity, the vehicle should be well managed and minimize waiting time at the loading/unloading station. Traffic control managed by AGV using on-board vehicle detection and zone control [16]. Kumanan describes the multiple objective programming of AGV in a flexible manufacturing environment, using optimization algorithms. He described the algorithm for controlling traffic in the workspace. The genetic algorithm is the algorithm based on the search for the natural selection process. The ACO algorithm is used to find the combination near-optimal program that satisfies both the load balancing between the AGV, depending on the travel time and the minimization of time. For efficient control, two types of the control system are used inside the workplace:

1. Stationary control system
2. Peripheral control system

The stationary control system covers all the superior control components. It maintains the administration of the transport control, the optimization of the communication of the program with another control system through a predefined interface. It is also responsible for consumer interaction and provides ancillary functions such as graphical visualization and statistical analysis [17]. The peripheral control systems manage various equipment onboard the vehicle such as the battery charging system and load transfer mechanism.

The mathematical model can describe the AVG operation in the factory/warehouse unit. The efficiency of the AGV can be measured by the effective actuation time of the AGV from loading to unloading cycle. For this mathematical model, we can suppose that AGV moves at a constant speed throughout the environment and ignores the effect of the deceleration of the acceleration and other speed differences [18]. The time for a typical delivery cycle is described as the AGV system:

1. Upload to the pickup station
2. Travel time to the teaching station
3. Unloading at the output station
4. Empty travel time

In Fig.5 is presented the route of an AGV from the loading moment until the unloading moment known as delivery time;

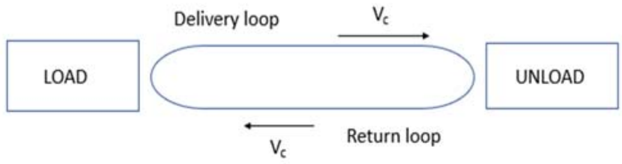

Fig. 5. The route of an AGV

To calculate the delivery time of the vehicle in an environment we use the equation:

$$T_e = T_l + L_d / v + T_u + L_e / v \quad (1)$$

Where:
T_e = delivery time (min / delivery)
T_l = loading time (min)
L_d = remote load loading until unloading
v = speed of the carrier
T_u = the download time of the station
L_e = the distance of movement of the vehicle until the start of the next delivery station.

To find the number of vehicles in an environment we use the equation:

$$n = \frac{WL}{AT} \quad (2)$$

Where:

n = vehicle number
WL = working load (min)
AT = time available (min)

To find total workload time or the total amount of work express in term of time we have the expression:

$$WL = R_f T_a \quad (3)$$

Where:
R_f = total constant hourly delivery for the system
T_a = is defined by the time available per hour per vehicle

Using the above equation we can find how many AGV can fit in certain workspace. It calculate the time require for completing a task.

III. APPLICATION

Autonomy is the key factor for using AVG in different fields. It will achieve a high degree of accuracy and accuracy which will result in a complete reduction of system errors and improvement time. Flexibility is the key factor that will help AGV become popular in other material handling systems

[19]. The AGVs are used inside the factories, but they also expand their spaces in other service sectors:

1. *Material handling*: used in extremely large car and electronic factories, at the unloading station;
2. *Warehouse*: used in the electronic commerce warehouse for the transport of the material;
3. *Commercial*: luggage transport to the airport, supermarket, mall, floor treatment, such as washing, exchange;
4. *Energy and defense*: transportation of high-risk substances, mapping of bombs and mines, recovery and elimination of nuclear and steam generator inspection, pipeline inspection;
5. *The medical service*: delivers water and food medicine, administrative reports, handling of hazardous materials, and disposal of biological waste [20];
6. *Personal care*: Assistance for persons with disabilities and early assistance with personal hygiene;

IV. CURRENT STAGE

Automated Guided Vehicles (AGVs) are also known by other names, such as LGV (Laser-Guided Vehicles), Mobile Robots, SGVs (Autoguided Vehicles), Guided Cars, Autonomous Vehicles, Driverless Vehicles and other names within the context. Industry 4.0;

Regardless of the vehicle structure (forklift, tractor, trolley, etc.), several AGV guidance systems drive the AGV and announce the management system with the positioning of the AGV within the chosen framework. The AGV guidance system allows the AGV to follow a defined route and to announce the Management System with its real-time positioning. Choosing the right AGV navigation technology is essential, as it will influence the overall cost of the AGV system.

Possible additional functions of sorting, decision making, data transfer, data collection, weighing of goods, organization, procedures, warehouse administration, administration of storage sites, product recognition, mastering various models, finding pallets, loading-trucks, security intelligence, intelligent situational responses (fire alarm switch, various modes of implementation), faster and more complex work during shutdown periods (night recharge). The traceability of logistics processes is extremely up to date. Each movement is performed and recorded reliably. This creates an end-to-end process, generating a history that is useful and necessary for internal audits.

In summary, it can be said that AGV is a powerful and necessary tool for modern logistics in all branches of industry, including in the pharmaceutical and food industries [21].

A. Industry 4.0

Industry 4.0 is the subset of the fourth industrial revolution concerning the industry. The fourth industrial revolution encompasses areas that are not normally classified as an industry, such as smart cities, for example. Although the terms "industry 4.0" and "fourth industrial revolution" are often used interchangeably, "industry 4.0" refers to the concept of factories where machines are augmented with connectivity and wireless sensors, connected to a system that can visualize the entire line of production and makes decisions on its own [22]. Essentially, Industry 4.0 describes the trend towards automation and data exchange in technologies and manufacturing processes that include cyber-physical systems (CPS), the Internet of Things (IoT), the Industrial Internet of Things (IIOT), cloud computing cognitive computing and artificial intelligence.

The concept includes:

- Smart manufacturing
- Smart factory
- Industrial Internet of Things also called Internet of Things (IoT) for manufacturing

Industry 4.0 favors what has been called a "smart factory". Within modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions [23]. On the Internet of Things, cyber-physical systems communicate and cooperate and with people in real-time, both internally and through the organizational services offered and used by participants in the value chain.

The term "Industry 4.0", shortened to I4.0 or simply I4, was born in 2011 from a project of the high technology strategy of the German government, which promotes computerization of production. The term "Industry 4.0" was publicly introduced in the same year at the Hannover Fair. In October 2012, the Industry 4.0 Working Group presented a set of Industry 4.0 implementation recommendations to the German Federal Government. The members and partners of the Industry 4.0 working group are recognized as the founding parents and the driving force behind Industry 4.0. On April 8, 2013, at the Hannover Fair, the final report of the Industry 4.0 working group was presented. This working group was led by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann (German Academy of Sciences and Engineering).

Because the principles of Industry 4.0 have been applied by companies, they have sometimes been re-branded, for example, aerospace parts manufacturer Meggitt PLC has marked its own M4 Industry 4.0 research project. , will affect the labor market discussed in Germany under the theme "Work 4.0".

Industry 1.0 refers to the first industrial revolution. It is marked by a transition from manual production methods to machines using steam and water. The implementation of new technologies has been around for a long time, so the period to which it refers is between 1760 and 1820, or 1840 in Europe and the USA. Its effects had consequences on textile manufacturing, which for the first time adopted such changes, as well as the iron, agriculture and mining industry, although it had an impact on the increasingly powerful middle-class society. It also affected on the British industry at that time.

Industry 2.0; the second industrial revolution or better known as the technological revolution is the period between 1870 and 1914. It was possible with the extensive rail networks and with the telegraph that allowed the faster transfer of people and ideas. It is also marked by the increasingly present electricity, which allowed the electrification of the factory and the modern production line. It is also a period of great economic growth, with an increase in productivity. However, this has led to an increase in unemployment, as many workers have been replaced by factory cars.

The third industrial revolution or Industry 3.0 took place at the end of the twentieth century, after the end of the two great wars, as a result of the slowing down of industrialization and technological advancement compared to previous periods. It's also called the digital revolution. The global crisis of 1929 was one of the negative economic developments that have occurred in many industrialized countries since the first two revolutions. The production of Z1 (electrically operated mechanical computer) was the beginning of more advanced digital developments. This continued with the following significant advances in the development of supercomputer communication technologies. In this process, where there was extensive use of computing and communication technologies in the production process. Cars have begun to abolish the need for human power in life.

"Industry 4.0" is an abstract and complex term consisting of several components when we analyze our society and current digital trends closely. To understand how extensive these components are, here are some digital technologies that contribute as examples:

- Mobile devices
- Internet of Things (IoT) platforms
- Location detection technologies
- Advanced human-machine interfaces
- Authentication and fraud detection
- 3D Printing
- Smart sensors
- Big data analysis and advanced algorithms
- Multi-level customer interaction and customer profiling
- Augmented / portable reality
- Fog, Edge and Cloud computing
- View the data and start the training "in real-time"

Mainly, these technologies can be summarized in four major components, defining the term "Industry 4.0" or "smart factory":

- Cyber-physical systems
- Internet of objects
- Cloud computing
- Cognitive calculation

With the help of cyber-physical systems that monitor physical processes, a virtual copy of the physical world can be designed [24]. Thus, these systems can make decentralized decisions on their own and achieve a high degree of autonomy (for more information, see "Characteristics of Industry 4.0). As a result, Industry 4.0 networked a wide range of new technologies to create value.

B. Software-level navigation techniques implemented to facilitate AGV maneuverability

As the number of AGV systems increases in partial flow systems, routing problems have increased the complexity of AGV system management. AGV routing problems are one of the basic problems in AGV systems. Each AGV should be guided by efficient, collision-free routing algorithms [25] to perform their tasks. The routing algorithm should be fast. That is, an AGV system can have dozens of AGVs running simultaneously if the algorithm's calculation costs a long time, other AGVs can be blocked. Algorithms should be able to solve deadlocks. For example, an AGV with a fork may need to lower a load to the position that could block other AGVs. This can be solved by enlarging the corridor which can be difficult to do if the system is running.

The chosen path of the vehicle should be that it does not affect the existing active travel schedule. Maxwell and Colab developed a two-way AGV management system that calculated the minimum number of AGVs in a time-dependent environment to maximize efficiency with ignored time and the collision problem is not solved. Gaskins and Tochoco developed a time-dependent model for solving the unidirectional AGV route optimization solution by minimizing the total travel distance with poor robustness (the algorithm can easily run in dead blocks). Broadbent and Colab invented the concept of a short conflict-free route.

An array was generated by applying the Dijkstra algorithm that describes the time taken by a vehicle to a node. Conflicts at a node or recovery conflicts can be resolved by slowing down the vehicle, which is still scheduled [26]. The procedure can be applied to any type of path, namely unidirectional and bidirectional models and introduce the concept of virtual tunnel for the bi-directional path consisting of several segments of multi-directional paths. This concept allows multiple AGVs that cross at the same time at an intersection.

Egbelu is one of the first researchers in AGV bi-directional route planning issues and has discussed various types of bi-directional AGV travel problems. Egbelu also compared unidirectional AGV systems and two-way AGV systems in the same environment. The solution seemed effective in simple models, but in large-scale maps, deadlocks can be easily reached. Dowland focused on collision-free problems using Petri-net to find possible collisions in a given node [27]. The solution is composed of delays and deviations while Endo used the same mesh with the genetic algorithm. Both solutions are only effective in small area problems, but when dealing with large/complex maps, the algorithm is not able to respond to real-time requests.

AGV routing algorithms can be classified into 2 categories: AGV routing algorithms through wires and wireless AGV routing algorithms [28]. The first algorithms are normally modeled by graph theory, and the latter is modeled by field, space analysis.

Algorithms implemented for navigation**:**

- Wire-Guided AGV routing algorithms
- Dijkstra Algorithm
- Floyd-Washal Algorithm
- Minimum-spanning-tree

- Time-dependent algorithms
- Genetic Algorithm in shortest path searching
- Wireless-Guided AGV routing algorithms
- A* Algorithm
- Bezier Curve with Genetic Algorithms (BCGA) in AGV route optimization
- Artificial Potential Field Algorithm (APF) in AGV routing problem
- Fuzzy logic approach in wireless-AGV path finding
- Particle Swarm Optimization (PSO)
- Neural Network approach

From the algorithm tests, the Bezier Curve solution is the most unstable algorithm because it is very related to the complexity of the maps, the particle density, the size of the curve, the number of AGVs, It is not recommended for complex maps or multi-AGV systems, but it can be used as under the control of AGV positions (that is, if we have solved the route through other efficient algorithms, we can use Bezier Curves as a precise method of motion control to guide AGV).

Fuzzy logic is one of the easiest algorithms in programming, accuracy is extremely high and is dependent on the structure and parameters of the algorithm [29]. The potential artificial field algorithm showed the adaptability of complex maps and multi-AGV systems. If proper heuristic methods are used, he is capable of jumping from blockages. GA and PSO behaved a little harder in tests, especially when the facilities are complex. The reason for this phenomenon is that the algorithms are not as accurate as of the Dijkstra algorithm. Meanwhile, due to the different heuristic methods and the initialization of the algorithms, the results might be different.

C. An example of a custom AGV. Development of a self-guided tracking vehicle using a carrier wave detection method

In order to develop the self-tracking of the carrier with an AGV in an unlimited workspace, a dynamic distance measurement was adopted, a system that uses the speed variation between a radio wave and an ultrasonic wave that propagates in the air. Microchip PIC 18F452 is used as a control core. To facilitate the targeted functions, the interaction in combination with high-quality sensors plays an essential role [30].

By using a wireless radio transmitter and an ultrasonic transmitter at the waist of the user inclined towards the sensors in front of the AGV, the distance between the user and the AGV can be calculated. To avoid collision with an obstacle, an ultrasound transmitter is installed on both sides of the AGV. Subsequently, a controller based on Fuzzy Thinking will operate the motor movement allowing it to track and avoid obstacles.

Fig.6 shows how the distance between the person and the robot is calculated;

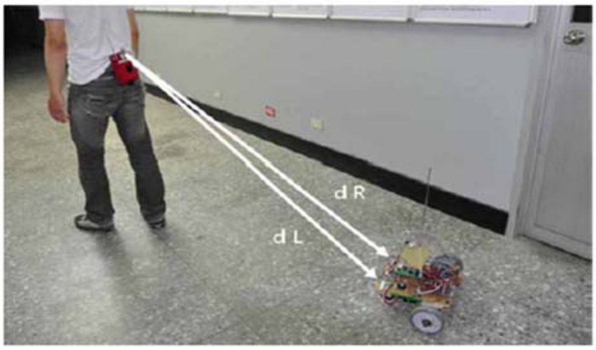

Fig. 6. The distance between receiver and transmitter

a. The principle of distance calculation

As shown in Fig. 6, the distance between the user and the ultrasound receivers will be calculated using the varied wave characteristic of radio and sonic rays. The speed of a radio beam propagation with a light wave is much higher than the propagation of an ultrasonic ray with a sound wave. As shown in Fig. 7, two ray signals (a radio beam and an ultrasonic beam) are transmitted from the transmitter attached by the user. Timers (left / right) (ultrasound receivers) will be operated when the radio wave is detected. The meters will start to calculate the time until the ultrasonic rays arrive [31].

Fig.7 shows how the distance between the person and the robot is calculated by using the speed difference of the radio beam and the ultrasound beam;

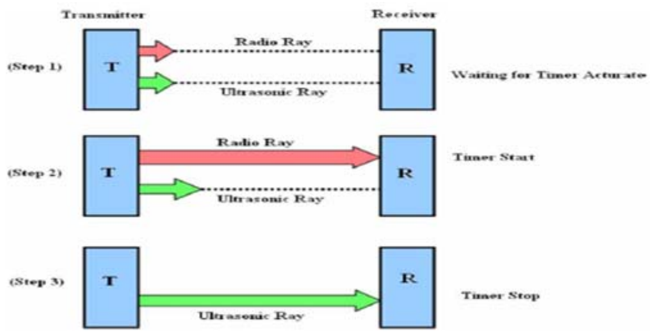

Fig. 7. Detection of distance using the speed difference of the radio beam and the ultrasound beam

b. Self-tracking system

As shown in Fig. 8, to control the movement of the robot [32] ,which will keep an adequate distance behind the user, a strategy based on Fussy rule, related to the detection of distance (dR and dL) is adopted to control the rotation of the motors [33]. The Fussy rule used in the robotic system is as follows:

Rule 1: if d R, d L <110 (cm), then the engines stop;

Rule 2: if 110 (cm) ≤ d R, d L <120 (cm) then the engines slow down;
Rule 3: If 120 (cm) ≤ d R, d L then the engines start;

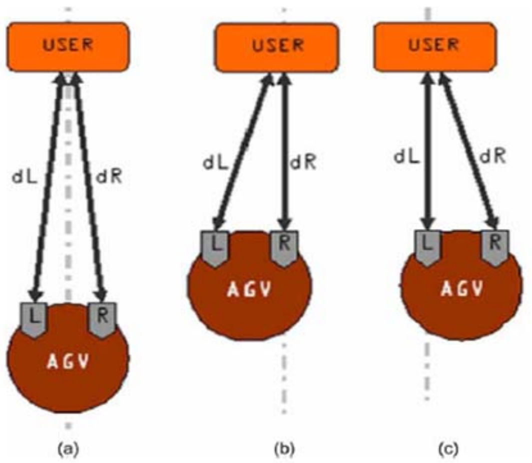

Fig. 8. Position of the AGV in relation to the left / right ultrasound received from the transmitter;

c. Kinetic control of the robot

For the robot to be able to follow the user's direction, control is crucial [34].To act properly the direction of the AGV, four cases of movement are classified:

Case 1: The signal for the right/left receivers disappears
Case 2: the signal for the receiver on the right side disappears; the signal for the receiver on the left is detected.
Case 3: the signal for the receiver on the right side is detected; the signal for the receiver on the left disappears.
Case 4: Signals for right/left receivers are detected.

For the status of case 1, there are three types of events possible:

(a) An obstacle in front of the robot;
(b) The distance is too close;
(c) The distance is too far to be effective.

In this situation, the robot will wait for the signals to be received at the left / right receivers**.**

For the condition of case 2, the robot is behind the user. In this situation, dL detected is above the user's detectable range; therefore, the robot will be positioned to the left until both signals can be detected; Similarly, for the state in case 3, the robot must be on the left and behind the user, so that d R detected is beyond the user's detectable range; This is why the AGV will turn right until both (right/left) receiving signals can be detected.

For the condition in case 4, both dR and dL can be detected. This means that the distance between the AGV and the user is within a detectable range. In this situation, it is essential to keep the AGV directly behind and in the center of the user.

V. CONCLUSIONS

There are several possible directions for further research.

We can improve the type of AGV guided tape using a better navigation technique [35].

Any environment and cheap among autonomous robots can be adopted.

There is a significant amount of difference between the theoretical and practical time value of the work cycle being optimized by adopting a different methodology [36].

Besides, one can think of a relaxation of the symbol holding requirements in the traffic control system, so that more vehicles can leave different crossing zones simultaneously and, therefore, the performance of the AGV system can be improved [37].

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