ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
https://doi.org/10.31803/tg-20230517113905

Subject review
Received: 2023-05-17, Accepted: 2023-10-09

Automatically Guided Vehicles (AGV) in Agriculture

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Abstract: In this paper, new types of autonomous systems used in agriculture were analysed. The paper shows new self-guiding systems such as AGVs with full autonomy in degrees operation. It explains internal transport and systems of autonomous vehicles in outdoor agriculture. New autonomous systems used outside such as appliance of special navigation systems and their purpose in agriculture are present in this work. Navigation systems with GPS signal and RTK technology, vehicle guidance camera and AI machine vision for manipulation are described. Light and laser technologies for fully autonomous robotic technologies such as LiDAR system in vehicle for detection of the presence of pests and diseases are presented in this paper. The paper emphasized advantages of using AGVs as result of their autonomy, clean power sources without harmful impact on the environment. Navigation in indoor spaces that uses LTE Direct protocol is explained, whereby the Wi-Fi ceiling antenna and wireless APP for horizontal movement of AGVs is shown. The ways of using UAVs for warehouse inventory through web applications with an advanced navigation system guided by AI are given in this work.

Keywords: AI detection; automatic guided vehicles; GPS; sensors

1 INTRODUCTION

The Automatic Guided Vehicle (AGV) is used in many kinds of applications. They have done many kinds of important tasks in the field of indoor transportation [1, 2, 3], movement of outdoor goods [4, 5], as well as agricultural [6, 7] works. Automated guided vehicles are defined as vehicles with their own: operation, energy source and transshipment devices intended for the transport of materials. They can also be defined as floor transport vehicles without a driver, computer-controlled, most often electrically powered with batteries. AGV appeared in 1954 and it can be said that they represent one of the most significant developments in the automation of transport operations in industry, on assembly lines, in warehouses and in goods transport centers and terminals [8, 9, 10, 11]. Authors [12] and [13] state how AGV systems have become a key component of today's intralogistics. The technological standard and the current level of experience with this automation technology have led to the introduction of AGVs in almost all branches of industry and areas of production. According to [14], AGVs are mobile robots and come in several variants depending on the way of guidance such as wire guidence, guidance tapes, laser targets, gyroscopic guidance and guidance with camera vision. In 2019, the International Federation of Robotics categorized 41% of robots as service robots, followed by maintenance robots 39% and vacuum robots 19%. According to [9], the AGV market is growing rapidly and the number of companies adopting AGV systems is increasing [15]. In general, AGVs are driverless vehicles that are used to automatically transport materials between locations and thereby automate internal transportation [16]. Considering that AGVs are highly mobile, their networking is done wirelessly, mostly using Wi-Fi connection [17]. Authors [18, 19] observed that the use of AGV in future factories will not be able to support the current wireless communication systems therefore the next generation of systems will be implemented. According to [20] the next generation of wireless communication systems such as 5G band and Wi-Fi6 communication aim to support industrial operation. According to [21] AGVs are significantly used as part of a reliable and flexible internal transport system. Automation of logistic vehicles can also have other benefits, such as reduction of costs and working time [22, 23, 24]. Author [25] states that AGV replace 70% of human wotking time which is significant automation. In addition, the authors [26] state that multiple loading of AGV will reduce system penalty cost up to 44%.

2 TYPES OF AGVs IN INTERNAL TRANSPORT

AGV for internal transport include automatically guided platforms, forklifts with automatic guidance, AGV cargo decks and tug AGVs. Author [27] states that the most common form of platform is the industrial transport platform (Fig. 1), which is used in systems where full automation and higher flexibility in connection with other subsystems is required.

Figure 1 Industrial transport platform
(Source: https://italcarrelli.eu/agv)

Figure 2 Automatic guided forklift
(Source: https://www.agriexpo.online/prod/bogaerts/product-180911-46289.html)

Automatically guided forklifts are used in warehouses and for material handling which purpose is loading and unloading of both one load more pieces from cargo simultaneously, to different locations and at many heights which results to become one of the most commonly examples of AGV (Fig. 2). The authors [28] state that recent developments in machinery have increased production and production rates in industry resulting in the need for faster material handling systems. To meet the requirements, vehicles for handling heavy materials such as forklifts, pallet movers, electric forklifts with balanced levers are introduced in factories. For navigation of AGVs at the workspace there are many methods and they are categorized as follows: using AGVs to follow a specific route which are putted inside warehouses (guided vehicles):

1. Wired AGVs (Fig. 3) that use a wire installed into the floor to follow the intended path of AGV. The line sends a electromagnetic radiation which AGV can detect and follow like track (Fig. 4). Authors [29] state that the use of human labor has been replaced by the use of wire AGVs thus they are classified into main types based on their utility;

2. Guidance tape – a magnetic tape (Fig. 5) or a colored tape is used that is set along the intended path of the AGV which the vehicle follows [30, 31], also the main disadvantages are magnetic tape maintenance, magnetic tape cost and not suitable for complex paths [32];

3. AGVs that have transmitter and receiver have possibility to collect and spot lasers. According to [33] lasers are classified either by the US Performance Standard (21 CFR 1040) of the Center for Devices and Radiological Health (CDRH) or the International Code (IEC 60825-1). Classification is based on the level of hazard of the laser beam during normal operation and includes factors such as wavelength, power output, accessible emission level, and emission duration. The following classes are defined: Class 1 and 1M, Class 2 and 2M, Class 3R (formerly 3a) and 3b, Class 4.

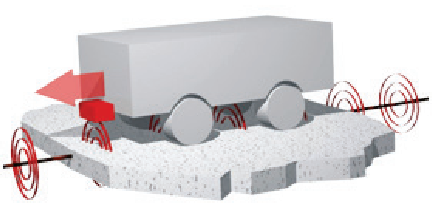

Figure 3 Wire guidance system
(Source: www.goetting-agv.com/components/inductive/introduction)

Figure 4 Scheme of induction guidance
(Source https://hy-tek.com/resources/whats-the-difference-between-amr-and-agv/)

Figure 5 Magnetic tape for guidance
(Source: https://www.roboteq.com/applications)

If AGVs want to have navigation through laser orientation then it is needed to put refelctive tapes on surface, also to have adequate technique AGVs to calculate their location related to the map stored in their memory when laser light is reflected from the tape. AGVs have laser transceivers on a rotating dome that automatically calculate the angle and distance to any reflecting tape in the line of sight (Fig. 6). According to [34] LGVs (laser-guided vehicles) are a kind of AGV that use floor-mounted reflective tape and laser sensors (as opposed to markers, wires, and magnet crumb trails) to triangulate position and navigate the warehouse. The disadvantage of navigation use of laser light are higher costs and more system maintenance requirement [35];

4. Inertial navigation – Inertial guidance where the current position of AGV is found by last information about position of the warehouse technique and their speed. AGVs are equipped with many types of sensors: accelerometer, gyroscopes and magnetometers. AGVs with current position can not be fully autonomous – they need it to have communication with a transponder that is usually installed in the floor. According to authors [36] automated guided vehicle (AGV) system has a central unit which takes control of scheduling, routing, and dispatching decisions for all AGVs, AMRs can communicate and negotiate independently with other resources like machines and systems and thus decentralize the decision-making process (Fig. 7).

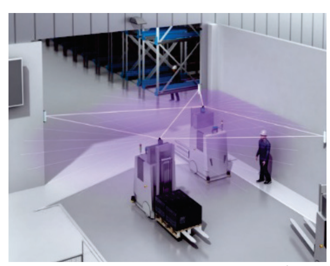

Figure 6 Laser determination of position in space
(Source: https://www.sick.com/es/en/end-of-line-packaging/automated)

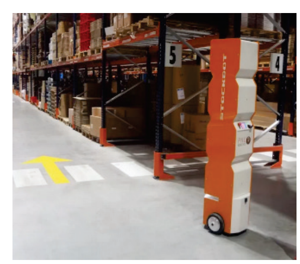

Figure 7 Stockbot for automating inventory-taking
(Source: https://blog.pal-robotics.com/advanced-factories-autonomous-mobile-robots/

According to [37] one of the ways of using UAVs for warehouse inventory through web applications is the application of modern drones with an advanced navigation system guided by artificial intelligence. Skydio is a fully automated solution. After we mapping sophisticated drones fly the routes using AI-driven navigation system to capture images of bar codes, LPNs (Fig. 8) and then drone returns to its dock, where all the data can be securely uploaded to warehouse or yard management system.

Figure 8 Drone capturing code and LPN
(Source: https://www.inboundlogistics.com)

3 MECHANISMS FOR MOVEMENT

Mechanisms for movement allow the robot to have abillty to motion and perform under low constraints. These mechanisms are modeled after movements in nature such as walking, running, rolling, sliding and jumping [27]. Mainly, robots can operate with two type of moving: on wheels (Fig. 9) and with articulated legs. The mechanism on the wheels is the simplest, in contrast to the legs, which require greater degrees of freedom with a high level of complexity [38]. Mechanisms with legs (Fig. 10) are more suitable for rough terrain where irregularities prevent the use of wheels because they need a larger contact surface. Their energy consummation of foot style is more higher compared to style with wheels on solid and flat areas. If the area is getting softer then energy consummation is higher. The foot style of robot hase dot contact with the area it becomse more effective on light terrain. The inclusion of machine vision in agriculture is increasingly used especially in agricultural vehicles (autonomous and non-autonomous) and can be used for various agricultural operations, including row detection (Fig. 11), special application, identification and monitoring. With progress, the machine vision is becoming an imperative in autonomous vehicles [39, 40, 41, 42].

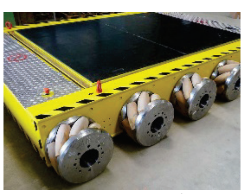

Figure 9 Transport platform with wheels (Source: www.arbeitsbuehnen-weiss.de)

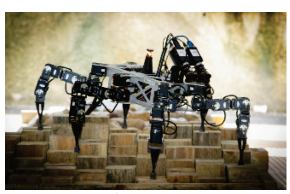

Figure 10 Complex movement mechanism for overcoming difficult terrains (Source: Kottege, 2017)

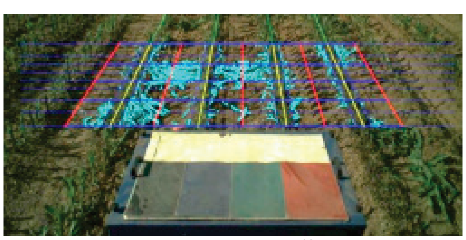

Figure 11 Detection rows with machine vision (Source: Pajares et al., 2016)

The same authors [38] state that image sensors are used for numerous tasks in agriculture such as guidance, weed detection or phenotyping analysis. Crop row detection and identification are the most common tasks in agriculture when image processing techniques are used for obstacle detection or environment mapping. Newer technological advances allow vision systems to be connected to unmanned aerial vehicles (UAV), which are also considered autonomous vehicles. The positioning of sensors on a vehicle requires a geometric relationship between the sensor, the vehicle, and the field of view that the sensor uses for guidance information. A commonly used machine vision system is AutoTrac Vision, which uses the technology and methods to extract information from an image on an automated basis to follow the machine in crop rows. Using new technology, it can generally to make less crop destruction due to machine wheel passes throughout the time of certain operations (Fig. 12) [43].

Figure 12 Camera locations in AutoTrac Vision system
(Source: https://www.heavyquipmag.com)

Autonomous vehicles for successful driving and filling of transport vehicles during harvesting often use the John Deere Active Fill Control system, which consists of dual cameras for having 3D real time checking and management of the refilling of transport trailers throughout the time of autonomous driving and harvest (Fig. 13). The Case IH AFS autonomous steering system is a navigation technology, which can be used with the Precision Land Management laser guidance navigation for crops (Fig. 14). Also in plant production often can be used navigation system SmartSteering for laser detecion of crops that uses an IR camera system during driving for the technology and methods to extract information from an image on an automated basis to follow the machine and to have opportunity to see and to control of trailer load level [44]

Figure 13 Active monitoring of trailer loading (Source:www.deere.com).

Figure 14 CAM PILOT 3D camera (Source: docplayer.org/53262082)

There are two types of attachment control for successful autonomous control of agricultural equipment: an active control system (uses GPS signal or a vision sensor) and a passive system that has a location detection sensor [45].

During the movement of autonomous vehicle on production fields, there is a negative impact because of the surface inhomogeneity, which affects the deviation from the planned path. Because of the mentioned, specialized guidance of attachement that can be adapted to different types of autonomous vehicles is increasingly being used. An autonomous vehicle is a part of an autonomous system that includes an autonomous attachement and a control unit (main controller for precise vehicle control) [46]. Autonomous vehicles use numerous systems to correct the accuracy of the attachement, which are installed on autonomous vehicles such as the ProTrakker 500DB, which has the ability of 2.54 cm accuracy. The ProTrakker 500DB (Fig. 15) is compatible with numerous attachment control options from GPS signal to ultrasonic sensors [47]. A similar alignment system for the autonomous attachement is the use of a Dynatrac drawbar (Fig. 16) with a GPS guidance camera along with RTK signal to reduce the attachement drift [48].

Figure 15 ProTrakker 500DB system (Source: https://www.protrakker.com)

Figure 16 DynaTrac® system (Source: www.laforgegroup.com)

The application of autonomous vehicles in agriculture is often reflected in the use of a robot-electromechanical machine that can move, perform operations using limbs, feel external stimulation and physically influence its environment while using modern navigation systems [49]. Autonomous agricultural robots and autonomous vehicles have the potential to improve the efficiency of agricultural production and reduce resource consumption [50, 51]. An example of an autonomous vehicle for crop health monitoring is the LadyBird. Ladybird (Figure 17) is used for autonomous crop monitoring, where crop condition assessment is performed using hyperspectral cameras, thermal and infrared detection systems, also panoramic and stereo vision cameras, LiDAR and GPS guidance [52]. According to [53] main advantages of using LiDAR are: data can be collected quickly and with high accuracy, surface data has a higher sample density, can be used day and night, can be used to map inaccessible and featureless areas, also has minimum human dependence. Disadvantages of LiDAR: high operating costs in some applications, degraded at high sun angles and reflections, the laser beams may affect the human eye in cases where the beam is powerful.

The use of the LadyBird autonomous vehicle enables detection of the presence of pests and diseases [54]. Authors [55] state that nowadays autonomous vehicles and robots are increasingly used as a fleet of vehicles. The impact of fleet coordination automation on commercial agriculture is huge. Future systems will require a high degree of autonomy and the potential to operate as a fleet because of concerns about the availability and operation cost on family farms [56, 57]. Authors [58] state four main sensors in vehicles, which are in the autonomous vehicle fleet: inertial measurement unit (IMU), camera, RTK-GPS receiver and LiDAR system.

Figure 17 Ladybird autonomous vehicle (Source: https://www.abc.net.)

4 NAVIGATION IN INDOOR SPACES

LTE Direct is the autonomous long-distance D2D (Device to Device) protocol. This communication protocol will exploit direct communication between nearby LTE devices. LTE direct technology is used for data transmission over long distances (Fig. 18), i.e. for the use of AGV devices via IoT in protected areas [59]. According to [60], a ceiling antenna connected to a wireless APP is often used to move the AGV in the horizontal plane and send commands (Fig. 19.). According to [62] in greenhouses, warehouses and indoor environments often are used AGV equipped with RFID sensors for RFID localization tags and environmental mappig (Fig. 19).

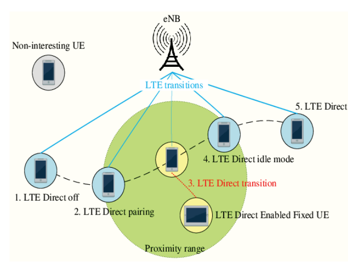

Figure 18 Communication between nearby LTE devices (Source: [61])

Figure 19 AGVs operating on floor level with Wi-Fi network (Source: [60])

RFID read/write devices can detect tags at ranges of up to 2 m (depending on the transponder used). This means that pallets or trolleys can be identified during the AGV's approach (Fig. 20). Once read, the tag data is verified via the warehouse management system, supporting consistent traceability of goods flows.

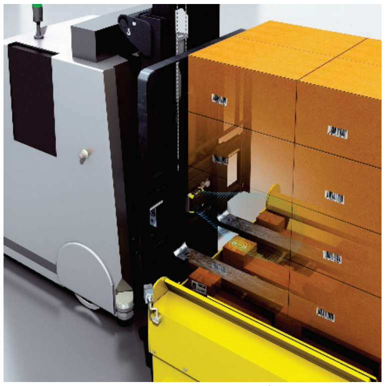

Figure 20 RFID on AGV
(Source: https://www.sick.com/ag/en/industries/logistics)

5 CONCLUSIONS

The advantages of AGVs are manifested in the adequate replacement of human resources/operators, high efficiency, the possibility of 24-hour work, lower labor costs compared to human labor in the long term. AGVs are equipped with numerous systems for avoiding objects, thus minimizing damage to products, machines and infrastructure. They have safety sensors and under high-frequency operation they remain in their work zones without endangering the environment. They can be programmed to handle different products with a certain degree of finesse as required, thus reducing the potential level of damage during handling. In processes that may include conveyor belts for sorting and serial collecting it is needed to have warehouse software to manage and command the best time for using a fleet of AGVs, also to schedule the input of stock. The result is maximum use of working time. AGVs can operate under low changes so they become a machines with better manipulation unlike conveyor belts or flow racks, AGVs can operate with minimal changes to the existing layout of the workspace or warehouse. Initial costs when purchasing an AGV can be significant due to the high purchase price and maintenance costs of the charging station, however, in the long run they are easier and more predictable than the human sector of workers because they do not require compensation for shift work, holidays or need for a day off. For the successful operation of AGV, it is necessary to provide quality markings for the successful operation of the sensors and to familiarize the staff of the work area or warehouse. AGVs are autonomous vehicles that are at the top of the niche in the automation ecosystem due to their autonomy and the use of clean power sources without harmful impact on the environment.

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