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People Following Automated Guided Vehicles - Research and Application

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Abstract—**Materials handling with Automated Guided Vehicles demonstrates a significant demand in recent years. The development of new navigation methods, that do not need a guideline, raised the flexibility of Automated Guided Vehicle Systems to a new level. Due to a clever use of modules, the vehicles have reached a quasi-standard. Successful applications and references establish a positive image of this technology. Their increasing use in all traditional and trendsettig industries prove this view.**

Conventional trucks are an alternative for the intraplant material flow. They are characterized by a high level of flexibility. However, they need one operator for every truck and shift.

With the development of a people following Automated Guided Vehicle, the benefits of automation and flexibility are targeted. Therefore, a new and interesting field for partial automation of the material flow is opened up. The approach is based on the interaction of a human and an automated vehicle. Such combined systems are especially useful where the intelligence of the worker and the economic help of mechanization are vital to the process.

Index Terms—**Automated Guided Vehicle, camera guided, order picking, people following.**

I. Introduction

It is not disputed that for many companies automation has led to well known success stories [1]. Regardless many managers stated that they wished less automation in their company because the lack of flexibility is a high risk [2]. Of course there can be a gap between automation and flexibility that stops the system from being more efficient when you have too much from one or the other [3].

In the following a system is introduced that combines the intelligence and flexibility of a person with the everlasting reliability and efficiency of an Automated Guided Vehicle, short AGV. Together the system is designed for order picking applications in non structurized surroundings where a higher level of automation is not possible or too expensive.

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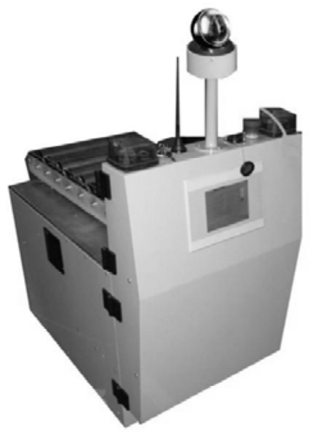


Fig. 1: Developed Automated Guided Vehicle (E&K AUTOMATION GmbH and PSLT, Germany)

Therefore, the operation company gets a low cost solution where a pricey material flow control system is not needed for the order picking process. Instead the human worker substitutes the controller and arranges the order to his best knowledge. The route is not necessarily determined and can be changed at any point. Moreover the order picker can interact flexibly and intelligently with the process.

To fulfill these requirements, it was the aim to develop an Automated Guided Vehicle that is able to follow a designated person by the means of computer vision. The innovation project was supported by the German ministry of economics and technology with the program “PRO INNO II”. The cooperation has been running by the partners “E&K AUTOMATION GmbH”, one of Europe’s leading companies for AGVS, and the “Department Planning and Controlling of Warehouse and Transport Systems”, short PSLT, of the Leibniz Universität Hannover, Germany.

During the last years an important market was developed caused by the increasing trend of transporting small and light parts. An analysis from the database “Worldwide

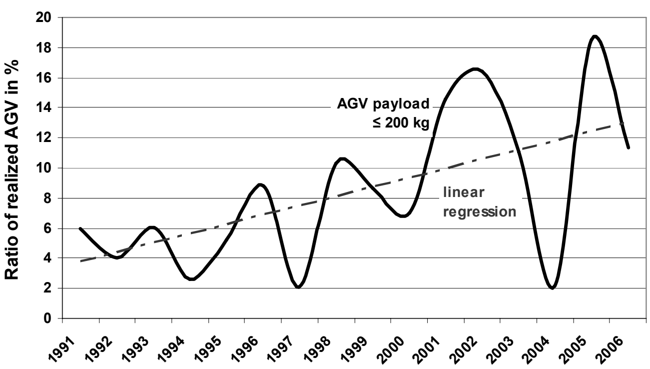


Fig. 2: AGV with less than 200 kg payload

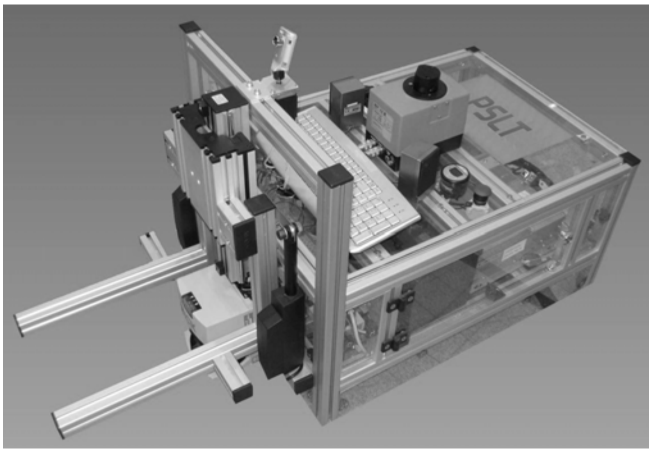


Fig. 3: Test vehicle at the PSLT

AGV-Systems of European Producers” by the PSLT shows that light transport goods up to 200 kg have significantly increased its ratio.

The presented concept supports the ongoing trend of modern transport control to arrange multiple transport patches with lesser volume and weight. For the same total amount of transport goods more vehicles are needed that carry fewer articles each. Conditions for this concept are low priced and small vehicles.

For the project the conceptual development of an AGV with the specifications for the application order picking was in the focus point. After completion of the theoretical planning the project was transferred to construction design. The test vehicle on the way to the final design was used to improve and validate the progress. Both the technical functionality in all relevant situations and the implementation into the logistic chain were targeted.

II. Field of Order Picking

As a consequence of the multifaceted tasks and trends of order picking the materials flow systems are characterized by a vast quantity of solutions due to the interaction of humans, machines, organization and information. Quality, productivity and flexibility are the main topics [4].

For the related time rates, consisting of base, transition, delay and picking time, potential technical and ergonomic improvements can be derived in regard to the intended task. The order related base time covers tasks like receipt handling, preparing of the loading equipment, return of the load units and record taking. The transition time includes one- to three-dimensional movement of the order picker either by walking or driving. The delay time results from the needs to read and handle the patch receipt, search, identification and counting of the next item as well as the confirmation. Times for the actual picking operation are summed up to the picking time. The total order picking time is:

$$t_{Kom} = t_{Ba} + t_{Tr} + t_{De} + t_{Pi} \tag{1}$$

t_{Kom} *total order picking time*
t_{Ba} *base time*
t_{Tr} *transition time*
t_{De} *delay time*
t_{Pi} *picking time*

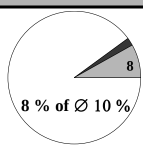
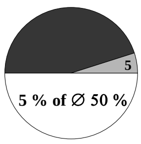
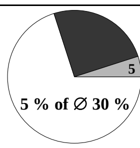
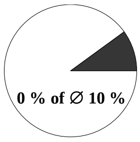
Table I: Total order picking times for the man to goods principle

Ratio of total order picking time in %		
Time period	According to Gudehus [5]	According to Malton [6]
Base time	5 % … 10 %	≤ 5 %
Transition time	40 % … 60 %	≤ 60 %
Delay time	20 % … 30 %	≤ 20 %
Picking time	15 % … 35 %	≤ 25 %

Two general principles of order picking systems are differentiated. In the man to goods principle the items are stationary while the picker does the relative movement. Transition time and picking time are sequential. To overlay these two times in the goods to man principle the items are dynamically accessed and moved by a materials flow system when needed. While the order picker is currently working on one order the next patch can already be on the way to the workstation. This however requires a high grade of automation level and standardized units as found in an automated small-parts warehouse.

This project is targeted at the order picking field with a man to goods principle. Nevertheless a significant amount of the related times are being carried out simultaneously by the aid of an AGV. The biggest cut is the reduction of base time since the preparations do not necessarily have to be done by the order picker. Of course there is also a considerable reduction of transition time as the AGV provides load units and carries out completed orders autonomously. Moreover the delay time and picking quality is improved because the worker doesn’t have to control the vehicle and can concentrate on the job. An overall possible reduction of 18 % of the total picking time has been calculated.

Table II: Possible reductions of time periods

Influence of the people following system on the order picking time		
Time period	Reduction in %	Reasons
Base time		1) Preperations are not done by the order picker.
Transition time		2) Transportation from and to the picking area is automated. 3) Shorter distances from the pick position to the container.
Delay time		4) No time for the control and use of the picker trolley is required. 5) Shorter time to identify the pick position needed.
Picking time		6) No change.

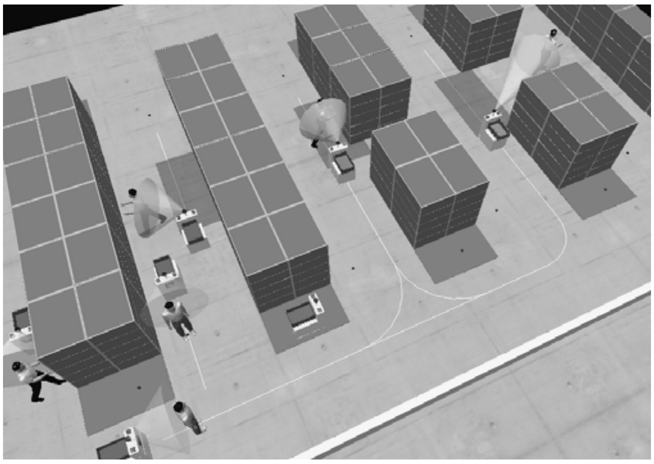


Fig. 4: Application overview for order picking

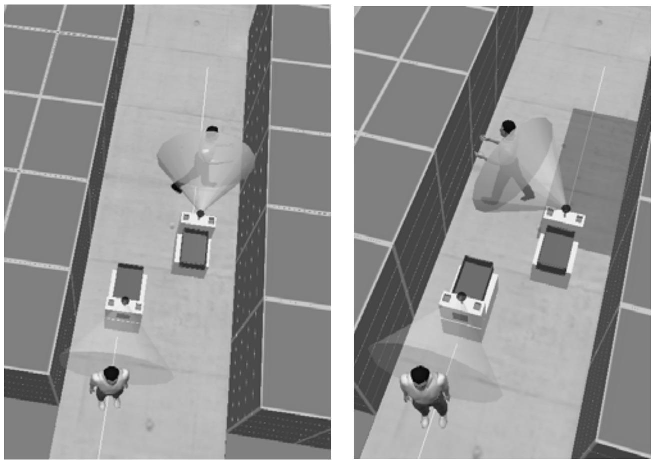


Fig. 5: Alignment to the right within aisles

III. Project Overview

The main scenario of this project is an industrial warehouse whereas the location of the items does not necessarily have to be known to the system, while the order picker knows the way the AGV will “follow the leader”. Therefore a structural integrity of the storage is not fundamental because the human can be used as the natural and superior navigation system.

In conventional systems the load vehicles are passive. That means the operator has to move the vehicle himself with a certain level of distraction and danger potential. While the AGV will follow autonomously, the order picker can concentrate on his job of picking. Once an item is selected, it can be placed in the box on the AGV that is already in position. Then again the order picker can concentrate on the next patch.

To start the process chain, the AGV will pick up an empty box and carry it to a waiting point autonomously by means of regular navigation technology, e.g. ground markers. These waiting points can be the face side of a shelf or along a hallway where the navigation method can be switched from autonomous to following.

Once the order picker is logged into the system he will get a tag that will enable the vehicle to identify him. At the waiting point the operator and the vehicle can join to start the process. From that point, the AGV will track and follow its designated operator within a certain safety distance. With a remote control the operator can manually pause the following mode to avoid unnecessary movement. That can be the case when the order picker will return to a position in a short time or to avoid entering a one way aisle.

When the following mode is activated inside an aisle, the AGV will align to the right continuing alongside the shelves. This prevents on the one hand the vehicle to meander from left to right when the order picker selects items from both sides of the aisle. On the other hand and even more important, opposing vehicles will not get in each others way.

Another feature is the recognition of the end of a shelf. When the vehicle detects a discontinuation in the laser scanner data a short distance will be bypassed whereas a greater gap will make the vehicle wait for a signal from the order picker. This option may be necessary in some structures when one way or narrow aisles cannot be entered.

When the order is completed, the picker will switch the vehicle to the automatic navigation method again to enable the system to bring the box to its destination. Therefore the operator does not need to use costly time for simple delivery labor and can go to the next empty vehicle waiting. This is one of the main reasons that make this new system more profitable over conventional manual order picking.

Following specifications are required for an automated order picking process applying the man to goods principle:

1) Identification of the designated person to allow more than one vehicle in the system.
2) Localization of the adequate position in short time and over certain distance.
3) Following procedure in unstructured areas with safety clearance.
4) Ability to change aisles.
5) Automatic or manual pause mode for one way aisles.
6) Alignment behavior in narrow aisles to avoid oncoming traffic.
7) Error and obstacle tolerance.
8) Control to start, execute and end picking orders.
9) Monitoring the patch at least at the end of the task.

IV. Person Identification Method

One focus of this project was the development of a person identification method that is error tolerant but also process safe. It is significant that the designated person and the relative position to the vehicle can be found in any relevant handling situation. Also the functionality has to be proven with multiple vehicles and order pickers in the same room.

Out of many sensors that have been evaluated a camera with a self-developed computer vision software has been found the most rewarding for the identification process. Theories for people tracking based on laser scanners have been taken into consideration and also shown good results as long as the subjects have a minimum distance between each other [7]. For the distinct identification of the person, however the camera sensor is predominant.

The developed software enables the vehicle to distinguish between multiple workers by recognizing their assigned identification tags. The detection is based on a two level algorithm combining the necessary information from shape and color of the tag.

Once the designated tag is identified the color of the clothing becomes the main target so that the position of the worker can be followed by the camera software. Most of the relevant situations can be tracked without further information. When the system notices another worker in the region of interest and cannot optically follow the pathway a new identification is conducted. Therefore it is well possible that many pickers can share the same work area.

As the essential component, the computer vision software is responsible for gathering the required information from the picture at a certain speed. On the foundation of C++, the routines of the library “OpenCV” have been found to be fast and potent. For performance reasons the hsv-format with certain threshold levels is being used.

In the second step a continuously adaptive mean shift algorithm is used on the filtered color of interest in the picture. The camera orientation is controlled to rotate towards the center of the color balance point. Therefore, the system will track and instantly follow the movement of the targeted person automatically.

An important influence on the identification process has the distance from the camera to the tag. Due to the resolution and the noise of the sensor, the tag can only be detected within a determined range. Considering the aspired maximum physical distance for following over only two or three meters, the resolution can be rather low. If the pathway is blocked, of course, the distance can increase to a point where the designated person can not be identified anymore [8].

Fig. 6: Computer vision software with tracking marker

Fig. 7: Information screen during identification process

Due to obvious laws of physics, a rather critical factor for the camera sensor is the illumination level of the person and the surrounding. Little or pointed light as well as backlighting, e. g. from bright windows or beamers, can disturb the tracking algorithm significantly. Since colors are degenerating in dark zones, the computer vision is especially disordered by larger shadows. For the given reasons, an adequate and constant light is fundamental for the reliability of the sensor software. Generally speaking, the illumination level is more decisive than the cost of the camera or an intelligent software.

With support of the camera sensor the laser scanner can well determine the distance to the designated worker. Using a characteristic hysteresis curve, the speed of the vehicle is optimally matched to the worker. Due to safety reasons, the vehicle uses the same laser scanner as a protective device as demanded by law [9].

For the realization two individual software modules on independent hardware were established. The people tracking module evaluates the environment information obtained by the camera. The resulting angle of the currently tracked person and a rough estimation of its distance are forwarded to the path planning which refines the distance information by data from the laser scanner.

In the next step, a feasible path is generated which is eventually transformed in commands that are passed on to the vehicle and motor controllers. The resulting movement enables the vehicle to follow the desired target. In addition the laser scanner data is also evaluated by the path planning module and the vehicle controllers for obstacle avoidance and security reasons respectively.

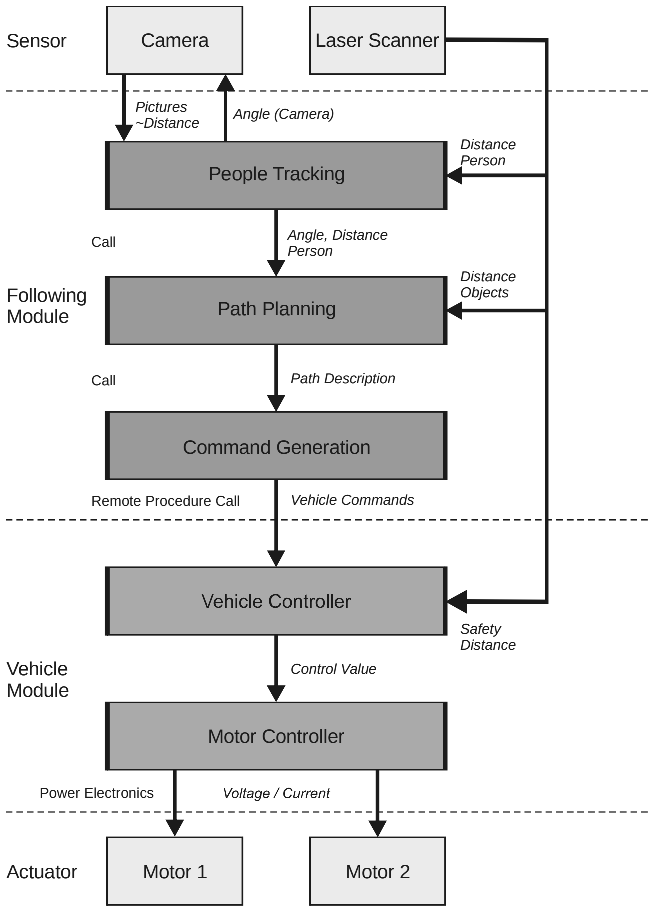


Fig. 8: Interaction of modules

Fig. 9: Conventional order picking vehicle (Jungheinrich AG, Germany)

V. Targeted Applications

The application of order picking is immensely diverse. Conventionally, order picking is a personnel-intensive procedure with high input. Despite all efforts, the human flexibility often cannot be replaced by automation solutions. To raise the effectiveness of the process and to minimize mistakes the picker is often supported by technical assistance like pick-by-light, pick-by-voice or handhelds [10].

With the use of horizontal or vertical order picking trucks, the transit times are reduced. By doing so the picker has to apply the needed accuracy and concentration for operating a materials handling truck during his entire working time. Especially for short distances from one picking position to the next, the handling of the truck is less a help and more an unwanted interception of the movement.

Logistic operations like order picking would immensely profit from the function of an autonomously following AGV. The overall completion time for one patch can significantly be reduced by allowing the worker to concentrate on the picking task only. Even more time will be saved when the AGV will carry the completed unit to its destination without human support. Empty replacements are provided by the central control in time.

Another outstanding application for a people following AGV is an assembly plant with mobile workstations. In prospective to this system, there will be non-linear workstations that move freely with the cooperating worker. This approach will come into consideration for many companies with highly individualized products or diversified work steps.

Apart from industrial solutions, the following module system can also be used for personal information terminals. Application areas are for example museums, galleries, sales- and showrooms or airports where the AGV accompanies the visitor interactively with a multimedia display or audible information that corresponds to the objects on location.

On top of that, the vehicles can be used as personalized bag carriers especially at airports, train stations or supermarkets. The transport of luggage or bags could be accomplished without manual support to the great benefit and comfort of the owner. More interesting fields of applications and interfaces are possible and underline the interesting diversity of this topic [11].

VI. Practicable Perspective

The cooperation project has shown the feasibility of the people following AGV. In many applications the functional teamwork between workers and machines is needed when a complete automation can not economically be realized. If the interaction can reliably be established, benefits for the operator as well as the process will occur. It was shown that a people following algorithm based on a camera sensor can contribute to the human machine interaction. Advantages for the logistics are improved efficiency, more comfort and an additional benefit due to connected applications.

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