AGVS IN LOGISTICS SYSTEMS
STATE OF THE ART, APPLICATIONS AND NEW DEVELOPMENTS

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ABSTRACT

By now AGV-Systems are known for more than fifty years, a time in which various technical advances have been made, ranging from improved actuators and energy supplies to entirely new sensor concepts. The enormous progress of computer systems induced enhanced control strategies. This paper provides a detailed overview of the recent technologies used in the area of AGV-Systems and highlights innovative developments.

The independency of static guidance systems is subject to current AGVS research. While variations of guideline principle based on inductive or optical effects were the predominant navigation techniques for decades, nowadays laser triangulation can be considered as a standard. To establish a laser based navigation system the environment needs to be equipped with reflective markers. To overcome this disadvantage a vision based navigation system is currently developed at the PSLT. With this new technology it will become possible to establish an AGVS without any preparation of the environment in advance.

Another innovative approach of the PSLT is an AGVS with the capability to follow a specific person autonomously. An interesting perspective is a warehouse with employees focusing on picking while trolleys are following automatically. When loaded the trolleys will carry their load away. Empty replacements are provided by the central control in time.

Innovative developments like the ones described above are preparing the ground for new applications and ensure the success of AGVS in the future.

Keywords: AGVS, Guided vehicles in logisticsy

1. INTRODUCTION

One of the most important aspects of logistics systems is the material handling in industrial environments. Despite the high throughput rates realized by steady materials handling technologies such as roller or chain conveyors, the vast majority of industrial applications rely on common lifting or hauling trucks as transportation system. The reasons are manifold: Besides cost related aspects one of the main advantages is the unmatched flexibility regarding integration in an existing or changing environment.

Extending these advantages of industrial trucks by means of automation technology results in increased reliability and reduced operating costs. The outcome is the so called Automated Guided Vehicle System, abbreviated as AGVS. Automated Guided Vehicle Systems are capable of performing transportation tasks fully unattended at a low price. Applications can be found throughout all industrial branches, from the automotive, printing and pharmaceutical sectors over metal and food processing to aerospace and port facilities. The increasing interest in AGVS is reflected in the sales figures which reached a new peak in 2006 with a volume of 200 Mio. EUR according to a yearly survey among European AGVS manufacturers carried out by the PSLT.

2. TECHNICAL DEVELOPMENTS

The past years were characterized by significant technological advancements. They contributed to increased attractiveness of AGV-Systems for the users and essentially concern modularity, standardization, energy concepts, automation of standard industrial trucks, navigation systems, and safety systems [1].

2.1 Modularity and Standardization

Modularity is a common strategic production method to reduce both production costs and delivery times. Customers of AGVS can profit from an additional important advantage that the standardization of AGVS brings along: The currently inevitable commitment on lifetime to one AGVS manufacturer is abandoned, since customers can contact competitors in the context of modernizations or extensions [2, 3].

Cost reduction in the stages of development and realization of AGVS is essential for all manufacturers in order to survive in the competitive market. A common point to start from is to introduce a standardized component system. Each manufacturer would develop its own components based on this system. This will drastically reduce the variety of parts as similar components will become interchangeable between different vehicle types and manufacturers.

At the same time modularity will increase the availability of parts, simplify the logistics of replacements and reduce the capital lockup of the manufacturer.

2.2. Inductive power transfer

A technical innovation increasingly used in the field of AGVS is inductive power transfer also known as inductive coupling. This technology transfers electrical power between two circuits through a shared magnetic field. In terms of AGVS the primary circuit is a conductor embedded in the ground whereas the secondary circuit is a pickup attached to the vehicle's lower surface. By energizing the conductor a magnetic field is generated inducing a current in an inductor inside of the vehicle's pickup.

Two basic principles of inductive power transfer are to be distinguished. The first supplies the vehicle continuously at all times with energy. This requires the primary conductor to be installed on the entire driving course. The advantage is that the vehicles do not need on-board batteries. In the second case the vehicle is equipped with an on-board battery and can thus compensate an interruption of the inductive power supply. The battery of the vehicle could be charged inductively at one point, at multiple points or at a defined section of the course.

2.3 Automation of Standard Trucks

The automation of series-production trucks represents a further line of development. That concerns equally industrial trucks and motor trucks . The trucks are automated by the AGVS manufacturers. Industrial trucks are preferred in particular if both manual and automatic handling has to be realized. To increase the flexibility the AGV can be equipped with more than one load handling attachment. The automation of motor trucks has an increasing impact on the market of shuttle transportation between different buildings of one plant. The truck can be used during the daytime shift manually to increase the driving speed and in automatic mode during the rest of the time [4].

2.4 Navigation and Communication

The transportation task of AGVS requires efficient and intelligent routing. The majority of navigation systems sold currently can compute these aspects in very short time. Usually these systems are also capable of handling priorities and time schedules.

Static routing is a well established standard in navigation. This routing technology is based on fixed course sections. AGV-Systems with static routing are similar to the railway system with course sections corresponding to tracks and the central navigation system relating to the railway control center. Sections are marked as occupied whenever a vehicle is entering and remain blocked until the vehicle has left again. This behavior can result in deadlocks, e.g. two vehicles trying to enter the same section on both endings at the same time.

With laser navigation flexible paths become feasible. Vehicles can leave their assigned path to perform evasive movements in order to solve deadlocks or avoid collisions. Other proven navigation systems utilize either magnetic or radio transponders embedded in the ground. This allows vehicle movements from point to point. To achieve guideline-free characteristics transponders can be spread evenly throughout the AGVS's operational area.

2.5 Sensor and Safety Systems

A new promising approach is to equip an AGV and other vehicles with a collision avoidance system. This system will determine each vehicle's position and instantaneously broadcast it to other vehicles in order to forewarn drivers or the central navigation system to avoid collisions at an early time. This will significantly reduce the number of collisions between Automated Guided Vehicles and manual trucks.

Laser range scanners have proven an indispensible potential as security equipment and laser navigation technology. It is only a question of time when the currently well-established two dimensional planar scanning will be extended by the third dimension to provide the necessary data for radically enhanced precision and accuracy.

An important step considering laser navigation is to achieve independence of reflection markers. Besides reduced installation costs this will allow to overcome the limitations of the current triangulation laser navigation method, developed more than ten years ago.

3. ACHIEVEMENTS IN RESEARCH

The PSLT is currently performing research in various interesting areas of AGVS. Topics to be pointed out are a visual navigation system and a people tracking vehicle.

3.1 Visual Navigation

The PSLT is currently developing a new navigation system for AGVS which will perceive the vehicle’s environment by optical sensors such as CCD or CMOS cameras. In contrast to the common navigation procedures used currently for AGVS the new navigation system will be independent of infrastructural restrictions such as metalliferous grounds or undercuts of walls. All necessary sensors and image processing equipment will be installed on board the vehicle. Additional auxiliaries as for example reflectors, magnets or guiding wires are not necessary. In this respect the new navigation system is clearly superior to technologies used at present like laser, guiding wire or magnet point navigation. One big advantage is the elimination of static driving courses. This provides the appealing possibility to dynamically circumnavigate obstacles or solve blockings.

The challenge is to determine the vehicle’s position relatively to its environment exclusively on the basis of information available in the images recorded by the on-board camera. A first solution to this task, also known as the localization problem, exploits the fact that AGVS are generally used in an industrial environment. This legitimates the assumption that the vehicles environment is at least partially known beforehand and remains invariable up to a certain level. Thus it is possible to generate a map in advance and commit it in a suitable form to the vehicle.

The PSLT is currently analyzing various approaches on their suitability to the localization problem. On this basis sophisticated algorithms are developed to extract perspective information from the recorded camera data. By means of a combination of different procedures a spatial image interpretation is generated which is then compared to the generated environment data.

3.2 People Tracking AGV-System

Another new development at the PSLT is an AGV with the capability to follow a specific person autonomously. The people tracking AGV can identify its designated user by the means of computer vision. A practical application is given in warehouses with order picking functions. By automatically following the order picker it can be insured that the person's focus is on its main task. Once the order is completed the AGV can transport the load units to their intended disposition place without the assistance of a driver. Therefore the manpower can be used on more profitable tasks. After the picker has fully loaded one AGV he will move to a transmission station where an empty AGV for the next order already awaits him. In low cost areas the order list can be a paper version that the AGV brings along with the empty box or pallet. When a computerized system exists it is more convenient to use headsets for pick-to-voice applications. Figure 1 shows a scenario of a people tracking AGVS in a warehouse. It will be possible to have several pickers working in the same workspace without vehicles colliding or blocking their ways.

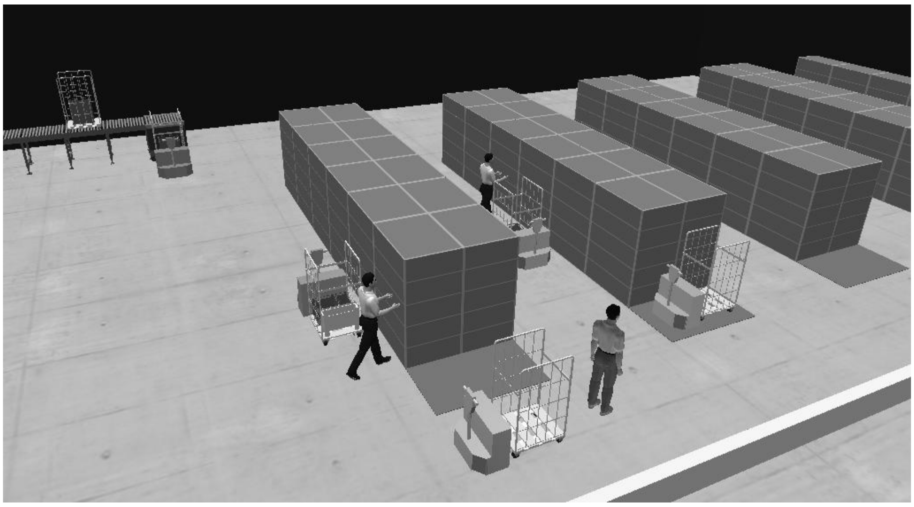

Fig. 1: Scenario of people tracking AGVS in order picking application

The basic requirement for human-robot interaction is the system's ability to distinguish between a person and its surroundings and moreover to identify this person. At the PSLT this is achieved by using a digital camera and software which was especially developed for this project. The main focus is centered on computer vision and its practical integration into an AGV-System for people tracking. The path planning and tracking algorithms are currently optimized. Experimental results proved good performance. In 2006 the system was presented at the AGV Conference which is conducted by the PSLT at the Leibniz University Hannover every two years.

At this point the people tracking AGV has already found the interest of AGVS manufacturers and users. For further research on this topic the PSLT is cooperating with E&K Automation, a leading AGVS manufacturer, with support of the German research program

"Pro Inno II". The target is to have a commercial product for a variety of applications by the end of this year.

4. WORLDWIDE INSTALLATIONS OF AGVS

The trends of the different markets and thus the development of the AGVS manufacturers are also of particular importance for investment decisions of customers. Customers have to ensure that the acquired technology is future-oriented and that the manufacturer will be available at the market segment of AGVS in the long term [5]. The selected AGVS manufacturer should be available for service and support of the system as well as for spare part supply for a long time.

A substantial indicator for the market tendency for AGV-Systems is the annual number of AGVS put into operation. They are ascertained for the European AGVS manufactures by the PSLT. The data is based on the information of the AGVS manufacturers.

In comparison to the year 2000 about a quarter of the AGVS manufacturers are on the one hand "new" vendors. On the other hand the "old" vendors offer new and different achievement profiles today. Both aspects point out the dynamics on the vendor side, which offers with more than twenty-five European AGVS manufacturers a large variety.

The number of AGVS put into operation world-wide by European AGVS manufacturers sums up to over 3.300 new systems with about 27.500 Automated Guided Vehicles in total. After an intermediate flattening related to the number of the Automated Guided Vehicles and AGVS put into operation a significant growth can be registered from 1996 until 2006. Thus in the three-annual average the level rose in the mean-time over 110 new systems per year. In 2006 a new peak with 169 AGV-Systems was reached.

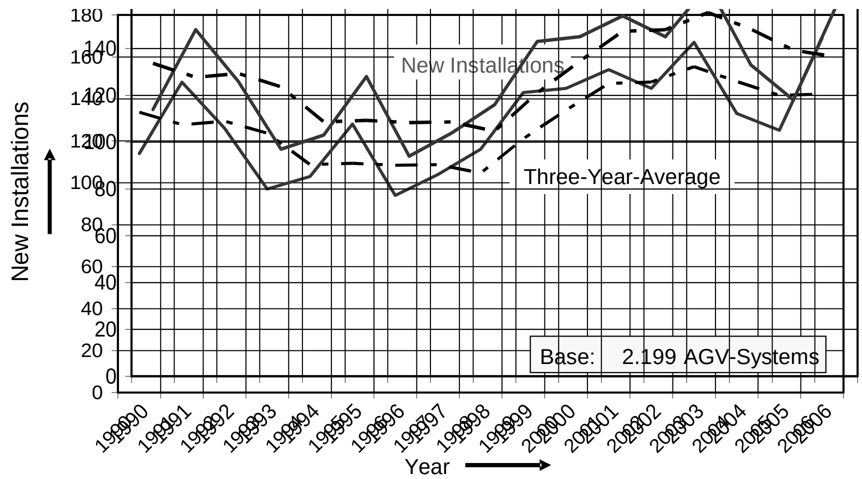

Fig. 2: AGV-Systems in openings of European AGVS manufacturers [6]

A similar process is determined for the number of Automated Guided Vehicles put into operation. It is also a trend that the average system size measured in vehicles per system rises. The average number of vehicles per system amounts now again over six vehicles. As the complexity of systems increases, the requirements on planning, engineering, project management, realization and putting into operation rise. This trend is also pointed out by the fact that the average equipment price allocated on the vehicles increased.

In 2006 a considerable number of about 6 % among all AGVS in Europe was realized within the outdoor sector. These applications of AGVS within port facilities for the containerization and as shuttle transportation already proved their fitness to practice.

5. CONCLUSIONS

Significant technological advancements contributed to increase the attractiveness of Automated Guided Vehicle Systems for the users. They essentially concern the modularity, the standardization, the navigation system, the energy concept, the automation of series vehicles and the safety system. New approaches in research will extend the application of AGVS to new areas in the future. For manufacturers of AGVS increasing size and complexity of systems means new challenges but also new opportunities to establish their position in the global competition. The rising number of new installations over the last years points out that European manufactures have noticed this new challenge and have reacted well by constant improvement of their products.

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