Mechanics Transport Communications

Academic journal http://www.mtc-aj.com

ISSN 1312-3823 (print)
ISSN 2367-6620 (online)
volume 14, issue 3/2, 2016
article № 1392

AUTOMATICALLY GUIDED VEHICLE SYSTEMS EVALUATION

Stanislav Glumac[1], Zoran Čekerevac[2], Jelena Maletić[3]
stanislav_glumac@yahoo.com, zoran@cekerevac.eu, jelenamaletic05@gmail.com

[1]Faculty of Business Studies, Omladinski trg 17, Vršac
[2]Faculty of Business and Industrial Management of the "Union - Nikola Tesla" University in Belgrade Knez Mihailova 33, 11000 Belgrade
[3]Polytechnic School, Kosovska 8, Kragujevac
SERBIA

Key words: *evaluation, system, automatically guided vehicles, logistics*

Abstract: *Systems for assisting drivers in driving vehicles, and even to allow automated driving of vehicles, became the focus of research in the automotive industry. But, similar systems are already in use in the production process in the automotive industry. In factories, the automatized guiding of vehicles is much easier to realize than in the road transportation conditions. In most cases, factories have well-defined transport routes, with or without crossings, and with a limited number and types of vehicles. Although it is to expect that the serial and mass production imply processes which are well defined, long lasting, and rarely changeable, automated guided vehicles (AGV) systems allow flexible routing and delivery of materials, components, and/or products.*

In the frame of this work, some of the systems for automatic guiding of vehicles used for parts transportation are presented, as well as some of the methodologies for their evaluation. Here are presented some ways of the vehicles controlling and communications, together with a brief analysis of AGV INDUMAT systems used in the FIAT factories Mirafiori, and Melfi. The methodology covers three operation criteria: the success of the mission, time, and the length of the route. The evaluation includes factors time and route length because it is quite possible that longer route can sometimes give the shorter time of transportation because the vehicles can run faster. All criteria are normalized, because of the different dispositions of working places and different AVG systems, to make comparison easier.

1 INTRODUCTION

The development of computers enabled the development of many automated and robotic systems. Automated guided vehicles systems (AGVS) are studied for more than three decades, but in recent years they become one of the main objects of research in the automotive, as well as in industry in general. Automatically guided vehicles (AGV) became very popular in use for transport where operations are repeating in the same manner and longer transport routes. AGV became an alternative for the use of forklifts, conveyors or manually powered push-pull carts. [1] In this article, here will be discussed automated guided vehicles (AGVs) in the light of definition given by the Materials Handling Institute, where AGV is considered as "a driverless vehicle equipped with an onboard automatic-guidance device (electro-optical or electromagnetic) capable of following preprogrammed paths". [2] According to this definition, AVGs can be considered as robots, but AGVs are not robots because they are not equipped with their own manipulators which can interact with their surroundings.

In industrial plants, the conditions for introduction of AGVs are much more comfortable than in the real traffic conditions outside the factories, where vehicles governing brings much more risks, and unpredictable circumstances. In the industrial plants, there are, mostly, applied a horizontal movement of material [3] and precisely defined transportation paths projected for a specific production process. In theory and practice, there can be found, also, vertical and hybrid systems, as it is analyzed in [4]

By AGVs the problem of guiding is connected with problems of assigning parts to vehicles and vehicles to paths. Numerous researchers analyzed different methods, as Random vehicle rule, the nearest vehicle rule, the Longest Idle Vehicle Rule, the Least Utilized Vehicle Rule [5]

Defining the nearest vehicle and the shortest path can be a difficult problem, [3] , but we following the deterministic approach – these problems are no so challenging. The real problem is to find the vehicle path which will give the shortest transportation time and acceptable costs. Traffic jam on some routes can appear as the problem. It will be ideal if the AGV paths can be separated, and inaccessible to pedestrians, but it is hardly feasible in reality. Because AVGSs are mostly systems incorporated in a horizontal transportation, it is real to expect pedestrians on AGV paths. In the deeper analysis and research, it is necessary to incorporate some stochastic components. To make the problem solvable, Seifert, Kay and Wilson [3] in their work have introduced some hypotheses:

- Routing of pedestrians is deterministic – each pedestrian will follow the shortest path to the destination.
- Pedestrians do not overtake an AGV
- If pedestrians are blocked at a node currently being traversed by an AGV, then, when the node is made available again, all waiting pedestrians are allowed to cross this node at once, prior to any other AGV;
- Pedestrians do not interact with an AGV currently undergoing load/unload processes at a node;
- Pedestrians do not interact with each other; and
- After a pedestrian reaches its current destination node, the pedestrian will stay at this location for an exponentially distributed holding time before being assigned a new destination, and start to walk to that destination.

AGVS can be organized as centralized and decentralized. They mostly possess series of sensors, onboard computation capabilities, as well as communication means. These components make them able to be autonomous, and to allow free ranging, and dynamic routing and coordination. [6]

One of the major concerns of the manufacturers is studying the performance of production systems. It allows companies to adapt to any type of change of doing business, and to ensure the smooth operation of the production system. [7] Although a serial and mass productions imply processes which are not changing in the longer period of time, AGVSs allow flexible routing and transportation of material, parts, and assemblies. Reprogramming is one of the basic characteristics of AGVS. It makes removing, if any, observed gaps, and improving the process. Together with increasing of the complexity and the volume of production, applications for AGVS become more complex, so as the evaluations of such systems. The great progress in the methodology of multi-robot system control gives a new perspective for future AGVS [8] [9].

Practice shows that self-guided AGVs based on the in floor positioned referent marks and laser guided vehicles are excellent systems, which allow defining of very complex and intertwined routes. There are in use, also, other ways of navigation (optical, odometric, inductive…), but they are less reliable and possess some other disadvantages, see [9]. Also, for AGVs communications are very important. Different methods are available, as for example IR, inductive, and RF communications, but the third is the most used method.

2 AGVS - CASE FIAT

Applying of AGVS is very popular in the automotive industry. Production processes and needs are different in each factory, and, consequently, different AGVSs are in use. In the world, there are many AGVS producers. Some of them are listed in [1]. In Europe, INDEVA modular systems are in wide use. In this paper, we'll analyze AGVs in cases of two FIAT factories: Melfi and Mirafiori.

In FIAT, there exist different AGVs and also different managing systems. What they have in common is that AVG routes are precisely defined to avoid bottlenecks. Although the AGVs are different, all of them use batteries which need to be filled by electric energy frequently. In the train composition, there can exist different number of carts, wagons (1 AGV and 6 carts in Melfi factory, and 1 AGV with 5 carts in Mirafiori factory)

Zones for the preparation of trains in both factories demand zone for manually connecting of the loaded carts, zone for unpinning of the loaded carts, zone for connecting of the empty carts, and the zone for unpinning of the empty carts.

Zones with the AGV paths must have regular, clear, smooth, floors without dust or oil stains.

2.1 AGV INDUMAT-Melfi

Figure 1 AGV INDUMAT -Melfi

Figure 3 AGV INDUMAT -Mirafiori

In the case of the **Melfi** factory, it was necessary to use small AGVs to tow logistic carts. The train is composed by dragging an AGV and pinning a logistic cart. Pinning is manually, but unpinning is automatically. Such AGVs demand wireless guiding and can drag up to 2000 kg (maximum 6 engines per AGV). Dimensions of the carts with the engines are standard (2000 x 1000 x 1000 mm) and can carry up to 1500 kg. There exist specific zones where AVGs automatically stop to be pinned or unpinned from the train.

2.2 AGV INDUMAT- Mirafiori

In the case of the **Mirafiori** factory, smaller AGV was demanded. Trains are composed by using one AGV and 5 carts loaded with assembly parts. Pinning is manually, and unpinning is automatically. As in Melfi factory, here also exist zones for automatic pinning or unpinning of carts. These AGVs demand wireless guiding and can drag up to 500 kg of weight of load together with carts. Dimensions of carts are standard (650 x 1700 x 100 mm), and each cart can be loaded by up to 80 kg.

3 EVALUATION

As well as by creating an AGVS, one of the basic challenges is to define the criteria for the evaluation. Processes are very complex. To make the evaluation easier, it is useful to divide AGV systems into classes and groups. Classification can make the influences of some alternatives to control demands clearer. Formalized schema of AGVS classification is presented in Peters, Smith, & Venkatesh's work [10], and will not be discussed here, but it helps us to make differences among complexity and the compromises of the performances. For example, comparing to the one-way path, two-way path gives shorter transportation distances, and it is to expect to give shorter transportation time. But, it is also to expect more sophisticated traffic control in that case. Similarly, bigger AGVs and carts can bring to the efficiency, but bigger loads mean also bigger challenges in organization and realization of transport.

3.1 Methodology

In this part of the article, there will be presented some aspects of the AGVS evaluation methodology proposed by Berman, Schechtman, and Edan in their work [11] It can be used for material handling. The evaluation process is interactive and results gained in one segment evaluation can influence to the evaluation of the other parts of the AGVS.

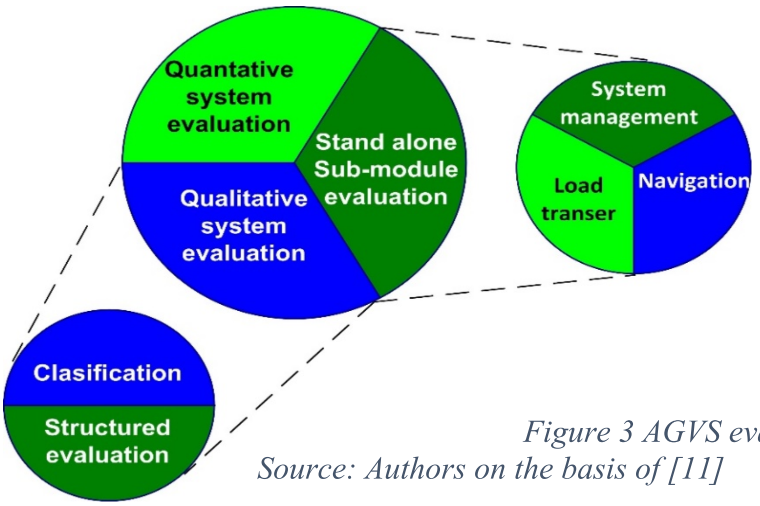

Figure 3 AGVS evaluation process
Source: Authors on the basis of [11]

Stand-alone sub-module evaluation; AGVS are very complex. In the engineering practice, if possible, sub-models are evaluated in a stand-alone mode, because it is cheaper and more comfortable. Therefore, Koff [12] divided AGVS functionality into three main submodules: system management, navigation, and load transfer. These sub-modules reduce complexity considerably, allowing detailed statistical analysis of each sub-module. Evaluation can be conducted using both, simulation and hardware implementation where appropriate. It is very convenient when the simulations can be based on real values gained by the hardware implementation. It increases the reliability of the simulations results and allows modules to be checked and corrected.

Quantitative system evaluation —When a sub-module is evaluated separately, due to the system complexity, some influences of the system are not visible. Therefore, it is important to evaluate sub-modules when the whole system is active. But, frequently, this stage is difficult to implement. The system hardware implementation is expensive, and obtaining of statistically significant results sometimes may be impossible. On the other hand, it is valuable in proving the concept, and in correcting approaches to the interrelationships between the modules.

Qualitative system evaluation — Some system attributes can't be quantified. In such cases, the qualitative system evaluation may help to underline system quality. Debates about the quantitative and qualitative evaluation methodologies last for many years [13], but these two approaches are now complementary rather than competitive. They only represent different points of view to the same problem, as Hoepfl, [14] stated.

Structuring of the process of qualitative evaluation helps to keep focusing and makes systems comparison. Process of the qualitative evaluation can be divided into two phases:

– classification of the system according to its attributes; and
– qualitative evaluation of the system by using its formalized structures. [15]

Classification is important because it represents a level of the system complexity and gives a better overview of its capabilities. The classification can be made from different points of view, but two approaches are mostly used: one from the multi-robot field, and the other from the field of AGVS. Considering the system from both aspects gives a better overview of the system and its future development perspective. [15] These two approaches are in fact complemental, more than concurrent because they shed the light on the different aspects of research or evaluation.

3.2 Performance measure

3.2.1 System management

For AGVS management evaluating it is good to choose measures that encompass all aspects which are in conjunction with the module operation. Also, these measures should be decoupled, as much as possible, from other influences on the manufacturing system. The proposed measures are [11]: the number of deadlock situations; dispatching rate (the number of dispatches per hour); the average waiting time of ready parts; the average orders queue length; AGV empty travel rate (empty/loaded travel time) and AGV idle time. For more details, see the named source.

3.2.2 Navigation

For an evaluation of the navigation module Berman, Edan and Jamshidi [16] suggest three operation measures: mission success (S), time factor (Ft), and path length factor (F_l).

Mission success (S) is defined as:

$$S(i)=\begin{cases}\mathbf{1} & \text{If AGVi reached its target without colliding}\\ \mathbf{0} & \text{Otherwise}\end{cases}$$

The time factor (F_t) is defined: $$F_t(i)=\frac{T_i^{st}}{D_i^{st}/v_{\max}}$$

where: T_i^{st} – the time that AGV_i took to reach its target, $v_{\max}$ – maximum speed of AGV_i, D_i^{st} – the optimal path length of each run

Path length factor (F_l) is defined by: $$F_l(i)=\frac{L_i^{st}}{D_i^{st}}$$

where L_i^{st} is the measured path length for AGV_i.

Measures of both, conclusion time and path length need to be included, because AGVs may take longer paths but be faster, as it is shown in [17]. All measures need to be normalized to facilitate comparisons over different layouts and different AGVSs. The optimal path length D_i^{st} of each run can be computed according to the a priori shortest path found and the run-time rerouting points (points in which the AGV had to choose alternative paths) [15]

4 CONCLUSIONS

Implementation of AGVs is one of the most important steps in the automatization of transport operations in production, storage, terminals… It is very important when choosing of performances for system management evaluation, to include full influential spectra of work of modules, and also, as much as possible, to separate measures from other parameters that influence the production system. For the evaluation of the navigation three operation measures: mission success, time factor, and path length factor can be used.

REFERENCES

[1] n.d., "Automatic Guided Vehicle Manufacturers," 2015. [Online]. Available: www.automaticguidedvehicles.com.

[2] B. Benhabib, Manufacturing: Design, Production, Automation, and Integration, New York - Basel: Marcel Drekker Inc, 2003.

[3] R. W. Seifert, M. G. Kay and J. R. Wilson, "Evaluation of AGV routing strategies using hierarchical simulation," in *Proceedings of the 1995 Winter Simulation Conference*, 1995.

[4] S. J. O. Hoshino, A. Shinozaki and H. Hashimoto, "Optimal Design, Evaluation, and Analysis of AGV Transportation Systems Based on Various Transportation Demands," in *Proceedings of the 2005 IEEE International Conference on Robotics and Automation*, 2005.

[5] N. Viswanadham and Y. Narahari, Performance modeling o automated manufacturing systems, Englewood Cliffs, New Jersey: Prentice Hall, 1992.

[6] G. Rigatos, Intelligent Industrial Systems: Modeling, automation and adaptive behavior, Hershey - New York: Information Science Reference, 2010.

[7] S. Dhib, M. Elleuch and A. Frikha, "Evaluation of AGV system in flexible production system: A simulation study," in *International Conference on Advanced Logistics and Transport (ICALT)*, Sousse, 2013.

[8] S. Berman and Y. Edan, "Decentralized autonomous AGV system for material handling," *Int J Prod Res,* vol. 40, no. 15, p. 3995–4006, 2002.

[9] FIAT Group, Logistic Standard Book: LOGbook FGA Logistic Standard & Guidelines, Rev. 2. EN, FIAT, 2008.

[10] B. A. Peters, J. S. Smith, and S. Venkatesh, "A control classification of automated guided vehicle system," *International Journal of Industrial Engineering,* vol. 3, no. 1, p. 29–39, 1996.

[11] S. Berman, E. Schechtman, and Y. Edan, "Evaluation of automatic guided vehicle system," *Robotic and Computer-Integrated Manufacturing,* p. 7, 2008.

[12] G. A. Koff, "Automatic guided vehicle systems: applications, control and planning," *Material Flow,* no. 4, pp. 3-16, 1987.

[13] M. Patton, Qualitative evaluation and research methods, CA: Sage Publication Inc., 1990.

[14] M. C. Hoepfl, "Choosing qualitative research: a primer for technology education researchers," *J Technol,* no. 9, pp. 12-39, 1997.

[15] S. Berman, E. Schechtman, and Y. Edan, "Evaluation of automatic guided vehicle systems," *Robotics and Computer-Integrated Manufacturing,* vol. 25, no. 3, pp. 522-528, 30 Jun 2009.

[16] S. Berman, Y. Edan and M. Jamshidi, "Decentralized autonomous automatic guided vehicles in material handling," *IEEE Trans Robotics Autom,* vol. 19, no. 4, pp. 743-9, 2003.

[17] E. Gat, "Towards principled experimental study of autonomous mobile robots," *Autonomous Robots,* vol. 2, no. 3, p. 1573–7527, 1995.

ОЦЕНКА НА СИСТЕМИТЕ ЗА АВТОМАТИЧНО УПРАВЛЕНИЕ НА ПРЕВОЗНИТЕ СРЕДСТВА

Stanislav Glumac[1], Zoran Čekerevac[2], Jelena Maletić[3]
stanislav_glumac@yahoo.com, zoran@cekerevac.eu, jelenamaletic05@gmail.com

[1]Faculty of Business Studies, Omladinski trg 17, Vršac
[2]Faculty of Business and Industrial Management of the "Union - Nikola Tesla" University in Belgrade Knez Mihailova 33, 11000 Belgrade
[3]Polytechnic School, Kosovska 8, Kragujevac
SERBIA

Ключови думи: *оценка, система, автоматично управлявани превозни средства, логистика*

Резюме: *През последните години системите за автоматично управление на превозните средства се превръщат в обект на изследване в автомобилната индустрия. Подобни системи вече се използват при производствените процеси в автомобилната индустрия. Разбира се в заводите автоматично управление на превозните средства е далеч по-лесно изпълнимо, отколкото при реалните пътни условия. В повечето случаи, заводите разполагат с добре определени маршрути за движение на превозните средства, с или без кръстовища, както и ограничен брой на автомобилите по пътните платна. Серийното и масово производство предполага добре определено, дългосрочно и рядко променящо се производство на системи за автоматично задвижване на автомобилите, които да позволяват гъвкаво определяне на маршрутите на движение и доставка на товарите.*

В рамките на изследването са представени някои от системите за автоматично управление на превозните средства, както и методологията за тяхната оценка. Засегнати са също така някои от способите за контрол на превозните средства, като е направен картък анализ на системата AGV INDUMAT, използвана в заводите Мирафиори и Мелфи на ФИАТ. Методологията на изследването засяга три критерия: доставка, време и дължина на маршрута. Самата оценка включва показателите „време" и „дължина на маршрута", тъй като в някои случаи е възможно по-дългия маршрут да позволи транспортния процес да се осъществи за по-кратко време, поради по-висока скорост на движение на автомобила. Поради различното разположение на работните места и разнообразието на автоматични системи за управление на превозните средства, всички критерии за оценка са приравнени и сравними по между си.