Collaboration Possibilities for Autonomous Industrial Transport Vehicles

Gábor Bohács¹, András Máté Horváth¹

¹ Department of Material Handling and Logistic Systems,
Faculty of Transportation Engineering and Vehicle Engineering,
Budapest University of Technology and Economics

Corresponding author: gabor.bohacs@logisztika.bme.hu

Abstract

Autonomous industrial transport vehicles are already in operation in the industry, but the area is very rich in further development topics. Collaboration among these vehicles makes up a special problem. First, this paper surveys the current area in detail. There is not only collaboration among the same type of vehicles like platooning discussed, but also the special tasks that are necessary for material handling operations. Second, proper conclusions are drawn for the elaborated concept of our former research regarding the possibilities of enhancement towards vehicle collaboration and its conditions.

Keywords: autonomous transport vehicles, forklifts, material handling

1 Introduction

Autonomous transport systems are very common in the industry. Their main use is to increase the material handling capacity at companies. This is also an essential development to counter the lack of forklift drivers. As acting like integrated components of the whole production system their application largely increases overall efficiency. Currently, the most applied type of equipment in the autonomous transport system segment is the automated guided vehicles (AGVs). These machines operate adequately safely due to their detailed standardization [1]. Despite these are already in operation for more than 50 years their popularity is still ongoing. The most important feature of them is that these are following a well-defined route without inbuilt intelligence to avoid for example unexpected obstacles. Due to the novel requirements of Industry 4.0 systems regarding increased complexity, in some systems, the applicability of the AGVs is not sufficient. This market gap is filled by the autonomous mobile robots, which main characteristics compared to AGVs is described in [2]. We can point out here that the main advantage of AMRs (autonomous mobile robots) is that these can also operate together with people unrestricted. This has however come with a cost, AMRs are more limited in capacity and speed compared to AGVs.

Despite the long history of autonomous systems in operation, there is still active research in this area (see [3] and [4]). Actual research approaches are for example the fusion of AGVs and collaborative robots; the use of machine-to-machine communication to integrate AGVs and the manufacturing environment and AI-driven analytics focused on the data produced and consumed by AGVs [5].

The current paper focuses on an actual topic that is also very relevant for the praxis. The area of optimizing a single autonomous mobile robot in a factory environment is already a well-researched area. Besides, there are many papers like [6] where a swarm of same-type robots are optimized. The researched systems are no longer restricted to indoor applications, there are papers focusing on outdoor use that are relevant as well [7]. Our focus is to assess the various types of collaborations among different vehicle types, used during industrial transport tasks. Finally based on the findings we set up a concept based on our former research.

2 Vehicle collaboration for industrial transport vehicles

However the collaboration possibilities among various types of autonomous vehicles and mobile robots are almost unlimited, there are typical applications that have both scientific and practical relevance. The first application is the collaboration among the same type of vehicles. We don’t mention here the most obvious task of...
avoiding each other in order to fulfil the transport requirements. An interesting approach however is the direct, physical and informatic connection of vehicles from the same type to achieve the handling ability of greater loads. Authors of paper [8] present a new class of Intelligent and Autonomous Vehicles (IAVs), from the Intelligent Transport in Dynamic Environments (InTraDE) project. This type of vehicle is technologically superior in many respects to existing automated guided vehicles. They offer greater flexibility and intelligence to manoeuvre in confined spaces where logistics operations take place. This includes the ability to pair/disassemble, allowing 1-TEU (20-foot equivalent unit) IAVs to dynamically mate, transport containers of any size between 1-TEU and 1-FFE (40-foot equivalent unit), and disassemble again. The deployment of IAVs helps port operators to efficiently cope with the ever-increasing container traffic in ports and avoid the need to deploy multiple 40-foot transport vehicles in very confined port areas.

There is also an increasing number of applications for the collaboration of different vehicle types. In industrial transport, the most obvious task is to automate the loading and unloading of transport vehicles using forklift type machines. In most cases the carrier vehicle is not automated, it is like a conventional, human-driven truck [9]. In this case, collaboration is also needed between machine and human in order to enable the start and finish of automated loading. A good example is presented in [10] in which the loading forklift AGV autonomously operates together with a truck. It should be underlined that in this case, the autonomous vehicle is not a special design, it is based on the transformation of a conventional forklift truck, upgraded by intelligent components (see Fig. 2.).

An interesting collaboration concept is presented in [11] in which a mobile robot, with the use of its sensors and robotic arm, moves a conventional pallet jack, which is also operated by a human. The worker carries out the loading and unloading operations, while the robot executes pallet transport. This is again an example of human-robot collaboration in material handling using the same transport equipment.

Finally a well-researched are should be mentioned: platooning. This has particular significance in road transport where closely driven interconnected trucks can achieve saving on fuel. The authors of the paper [12] focus on a different area – constructional site traffic – where the platooned manner improves safety, security and efficiency, control overall traffic flow and reduces resource usage.

As a summary, we concluded that practical applications in the discussed area can have very different structures. The use of already existing machines is common, thus human collaboration can more easily be achieved.
3 Description of the concept

In our former research [13] a low-cost vision-based towing truck has been developed and tested for factory site material transport operations. The towing truck had formerly been tested during the development in the ZalaZONE proving ground. Formerly we have also researched methods for material loading and unloading [14] using a forklift. From these and from the results of the literature analysis a new concept for autonomous vehicles’ collaboration has been worked out. Here following principles have been identified:

- The solution should be cost-effective because today it is the most decisive factor regarding implementations. That means for us primary that we would place intelligent and costly units only where it is necessary.
- As vehicles we intend to use high-capacity, industrial class products for development basis.

The elaborated concept is depicted in Fig. 3. High capacity is secured using a towing truck and trailers. The towing truck will be equipped only with the necessary, basic navigation functionality, which is supplemented by basic safety features. Besides the towing truck can implement platooning function. This is the so-called “strong” component of the system. Its capacity can be multiplied by using double tugger trains following each other.

Another part of the system is an automated forklift, which is the “smart” component. It is equipped with a more intelligent navigational component, a more capable safety system and also a teleoperating capability. The solution has a single disadvantage: the intelligent forklift travels together with the towing truck. However, it is countered by the multiple advantages, which are as follows. There is no need to duplicate the forklift unit at the material source and drain stations, therefore a single unit is enough. Using this travelling loading machine, mid-stops can be easily implemented, making the to be implemented tasks more versatile. By having a teleoperation capability the forklift can be assisted during loading, unloading and travelling as well.

4 Conclusion

In this paper, a novel vehicle collaboration concept has been presented using the literature analysis and applying rational principles. The concept’s main novelty is the separation of the system components into high-capacity and smart units, which enables several advantages. Future research will be aimed to assess applicability details and exact definition of necessary functionalities. There is also an ambition to test the functionality using real vehicles. For this purpose existing vehicles using the ZalaZONE infrastructure would be ideal. In this case a manually driven vehicle can be the leader and the follower can be an already automated towing truck.

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