Increased Agility by Using Autonomous AGVs in Reconfigurable Factories

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Abstract. Automated Guided Vehicles (AGVs) have come up to a quite familiar picture of nowadays manufacturing sites and in general they follow some rigidly given maps of the shopfloor. Future-oriented concepts require a much more agile approach that allows AGVs to continue its logistic tasks at the shopfloor securely and safely though being confronted with recently newly aligned facilities, new barriers and boundaries without necessary reprogramming the AGV‘s environment in front.

The actual paper deals with solutions which were worked out in the research and learning factory “smartfactory@tugraz” where all relevant facilities for these research goals have been available. Additional insights and results derive from the research facility of the Center Connected Industry and its industrial application eco system. So numerous Mobile Working Stations (MWS), the latest version of a Real-Time Locating System (RTLS) and a commercially available AGV belong to the core equipment of the presented research.

As a result there could be found, that the specified requirements and new applications of future production and logistic concepts can be achieved via dynamic targets. With this development, targets can be changed locally and the AGV automatically moves to the current target position, without necessary changes in the control software.

1 Introduction

There are still topics that can drive even European Manufacturing into a competitive future. Much more than the permanent issues of quality and price, it is a customer-oriented provision of a maximum in individualization and a nearly instant availability of products and services that will make the difference. Here the magic concept of agility [1] steps in.

Agility in a pure manufacturing context means the capability to adopt all available facilities and resources of a manufacturing site so quickly that even completely new products or highly individualized products can be realized at nearly the same level of costs, precision and time as known from standard products. Despite being aware

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that this is quite a challenge, agility will save market shares and an economic sustainability as mass customization or customer co-design improves the value perception of a product [7].

First of all an agile manufacturing concept needs an adaptive and multi-skilled equipment for value adding as machine tools, presses, assembly units and the like [13]. Second, there is the requirement of an adaptive layout [15] and a performant internal logistic system which connects all these mentioned physical resources [2]. And last but not least there is the need of a powerful communication infrastructure that interlinks the system and makes all the necessary information flow targeted, fast and secure. These properties are combined in a cyber-physical system (CPS) using the 5C-architecture proposed by Lee [3].

In the following there will be described an agile conception with an innovative focus on the logistic part of such an agile system which is represented by a new prototype of the control software for an AGV. When talking about "enhanced" agility there is the statement that the performance level of agility is even increased by the use of modern AGVs as well as the usage of the newest Real-Time Locating System to address highly complex challenges of future-oriented manufacturing and logistic layouts. Dynamic programming and/or dynamic mapping of AGVs and their fleets still is not represented sufficiently in research and its related literature [14].

2 Introduction of the Research Field and its Elements

2.1 Automated Guided Vehicle (AGV)

Agility in logistics offers multiple advantages for the actual and modern production processes. Production schemes such as "just-in-time" or "just-in-sequence" for example require flawless and efficient logistic processes [9]. AGVs connected to Enterprise Resource Planning (ERP) system or Warehouse Management Systems (WMS) meet these requirements by automatically picking and delivering raw materials or components to defined destinations or in this case the later introduced Mobile Working Stations.

AGVs have a long history of development regarding both the applied technologies and the field of applications. Whereas in the 60s and 70s AGVs were wire-guided, nowadays a variety of localization and communication technologies allows a free navigation of AGVs, even in unfamiliar environments [8]. Especially using multiple technologies and make use of sensor data fusion increases the accuracy and reliability of localization systems [6].

Dynamic positioning and localization are key-factors to implement intelligent routing algorithms in the AGVS that will replace pre-defined routes as they are still used today [5].

Nonetheless, the productive usability of agile AGVs does not only depend on the chosen localization or communication technology, but far more heavily on the adequate algorithms to cope with the gathered data by the AGV hardware. This refers to both the algorithms that provide the position information of the AGV and the intelligent routing avoiding deadlocks and increasing efficiency.

2.2 Mobile Working Stations (MWS)

The physical and visible agile infrastructure of the smartfactory@tugraz is realized via so-called Mobile Working Stations (see Fig. 1). It is a development of the Institute of Production Engineering at Graz University of Technology in order to demonstrate a promising solution of realized agility. One of their major features is their autarky concerning their supply (energy, information, compressed air, etc.). So they are free of cabling what makes these facilities not only agile as for their mobility but they can easily be accessed by AGVs and other self-driving units because of their barrier free ground all around.

Fig. 1. Smartfactory@tugraz with freely accessible MWS

2.3 Real-Time Locating System (RTLS)

For an agile manufacturing infrastructure, its resources need to be equipped with preferably a Real-Time Locating System (RTLS), which provides the actual location data with an appropriate accuracy for the AGV. According to Siemens [10] a RTLS builds the basis for self-controlling processes in smart factories.

With the information about "what's where and when" from the RTLS, this system enables many valuable applications in the context of the fourth industrial revolution. For example the 3D model of the digital twin can be mapped with the real environment, new logistic concepts can be contrived and the RTLS paves the way to a dynamically changing production environment, where a reorganization and reconfiguration of the production is possible. [11].

The network-like infrastructure of the used Siemens RTLS consists of permanently installed reference components – called anchors and gateways – and transponders, which are attached to those objects whose position is of interest. The transponders send a radio signal based on the Ultra Wide Band (UWB) technology, and the reference components record those signals and transmit the captured data to the locating software, which is running on an Industrial PC (IPC). This software calculates the position of the assets and their movement, and provides the x, y, z coordinates via a standardized ISO interface for further actions [10].

On each MWS of the smartfactory@tugraz are two transponders of the type RTLS4030T installed, this in order to get calculated not only the position but also the orientation of the MWS. This transponder has an accuracy of localization of 200 mm and use the protocol type IEEE 802.15.4–2015 UWB HRP PHY [12].

3 Research Gap

Actual AGVs follow pre-defined routes and cannot cope with dynamically changing positions of their targets. As mentioned before, it is necessary to overcome this issue for realizing modern and reconfigurable production systems. Modern AGVs, which move autonomously and are connected with a Real-Time Locating System, allow to work in an environment of rapid changes and reconfigurations in a production. The relevant control software for AGVs can thus cope with changing environments and opens up completely new applications, which are exemplarily described as follows:

Maintenance. The AGV is able to bring the necessary or just recently ordered spare parts to a maintenance worker who is currently repairing any machine at a production site. In order to locate the worker, he must be equipped with a personal RTLS transponder.

Logistics. In chaotic storage systems, the use of modern AGVs and a Real-Time Locating System could decisively reduce the effort for the warehouse management software (WMS) and for the fleet management software of AGVs. Saving the positions where a certain object has been stored is no longer necessary. Even during the picking process in a logistics warehouse, the AGV could follow the worker, or it drives ahead and shows the worker the way to the next order.

Multi-Place Resource Allocation. Expensive facilities or instruments, which are required for certain production steps and some production lines only occasionally but also in different production areas could be transported to this lines with an AGV. This dramatically increases the use and cost-effectiveness of such special machines.

4 Approach of the Study

In this study a commercial available AGV of the company "incubed IT GmbH" is used. With this AGV it is possible to drive to any target position, because it moves completely autonomously in the environment and does not drive line-based, as widely known to be the state of the art. This flexibility is given by the software system it uses. It contains a central fleet management server that owns the view of the complete fleet, it acts as an interface to host systems like ERP or WMS, and it contains the configuration of the fleet. Additionally to this central control, each AGV is equipped with a software that allows localization, navigation and coordination with the rest of the fleet. By raising the capability level of each AGV as well as the fleet management server, installations differ by configuration only. In contrast to traditional AGV installations, there is no project specific programming, but configuration only.

The function of the RTLS in this concern is the steady tracking of any object that is equipped with a transponder. The always updated location information of an object either is written into a database or is communicated by a TCP/IP client.

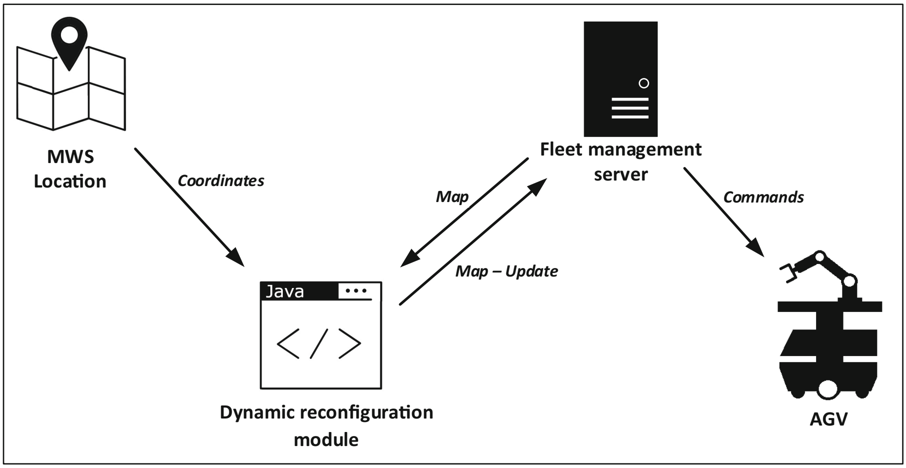

Fig. 2. Data processing of dynamic targets

As depicted in Fig. 2, the RTLS is connected to a dynamic reconfiguration module written in Java. Using a configuration file, the dynamic reconfiguration module distinguishes between relevant location information for MWS that are served by an AGV and non-relevant location information. If the location change of a relevant MWS exceeds a configured threshold, an automated update of the AGV's map is triggered. The map of the AGV contains contour information of the environment, targets (positions with specific actions like put, get or charge) and traffic regions (similar to car traffic rules). The dynamic reconfiguration module downloads the latest map by applying a RESTful (Representational State Transfer) web call, extracts the target that corresponds to the moved MWS, changes the pose of the target (x, y and orientation) and pushes the changed map back to the fleet management server. The fleet management server does a few sanity checks to make sure that AGV system is continuously operational and forwards the updated map to each AGV. Combining the updated map with the AGV's ability to navigate to arbitrary target positions results in a system that still can reach displaced MWS or any other object, because it is tracked with the RTLS.

5 Case Study for Validation

The networking of the RTLS with the newly developed control software of the AGV was tested in the research environment of the smartfactory@tugraz. A reconfigurable assembly line consisting of four Mobile Working Stations (MWS) formed the test setup.

In the first case, the production line was adapted for product A (see Fig. 3), where the MWS 3, which is also the target station for the AGV, was located at the right end of the line. In the second case, the production was reconfigured for assembling product B. In this layout, the target station MWS 3 was located on the left side of the line and has additionally changed its orientation.

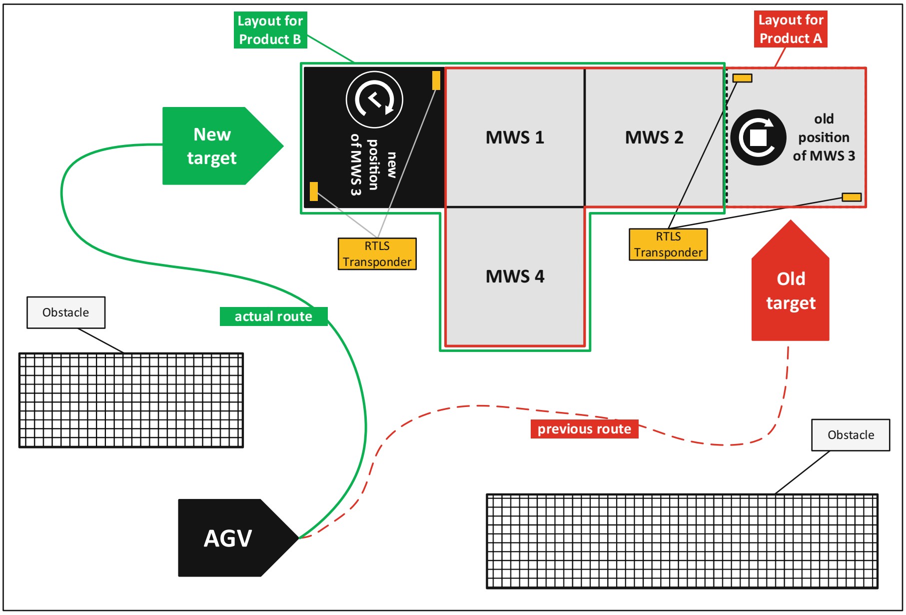

Fig. 3. Re-Routing to the actual position of the MWS 3

The test runs of the AGV started always at the same starting point, only the position of the particular target has been changed physically. The coordinates and orientation of the MWS 3, transmitted by the RTLS, were used for pre-positioning the AGV in front of the target with a defined offset and correct orientation to the target. The fine positioning was done by means of the AGV's laser scanners. So the changes in the software was done automatically by the entire system itself.

The results of the five final test runs showed that the inaccuracy of the RTLS (± 200 mm) affected the calculated target for the AGV and finally the test duration. Table 1 shows the deviations (orientation and coordinates) from the ideal target and the individual test durations.

Due to the deviations of the current target from the ideal target, the AGV needed in the worst case 4 s more time for the fine positioning with their laser scanners in front of the target MWS as in the best case. In all test runs the desired results could be achieved. So the successful interaction of the RTLS and the control system of the

Table 1. Results of the test runs

Test-Nr	Deviation of the correct orientation	Deviation of the goal coordinates x/y	Test duration
1	−4,72°	−4,5 mm / 5,0 mm	31 s
2	−3,37°	1,5 mm / 7,5 mm	30 s
3	8,25°	5,0 mm / 10,0 mm	33 s
4	1,76°	2,5 mm / 0,0 mm	29 s
5	−0,77°	-3,0 mm / 3,0 mm	29 s

AGV could be confirmed and another milestone for creating agile production systems has been accomplished.

6 Conclusion and Outlook

Within the framework of this research work, the approach to dynamically changing targets has been successfully implemented. This new milestone in the development of intralogistics will enable new applications with the effect of increased productivity and cost-effectiveness. The successful networking of the RTLS with the control software of the AGV revolutionizes the use of AGVs, in particular changes of targets in the map. From now on, target changes no longer have to be made by an expert of the control software, because the actual target coordinates are permanently provided by the RTLS and leads to a steadily updated map. This entire development is an important enabler for automatically reconfigurations of a modular and really agile production lines.

For future work, it is already planned to power up the wireless communication of the described setup. The actual WiFi communication will be replaced with the newest communication standard 5G. This will guarantee the necessary bandwidth and latency. The first step will be to substitute the currently used WiFi devices with 5G-capable equipment so that the existing 5G network of the smartfactory@tugraz can be used. Especially in terms of safety-features of AGVs, 5G can be compared to WiFi quite well considering the maximum latency of the system. Studies at Center Connected Industry have shown that the follow-up of an AGV receiving safety signals of an infrastructure ESPE is significantly shorter when using 5G instead of WiFi. Additionally, 5G as a communication technology paves the way for real time cloud or edge computing with its high data rates and low latency [4].

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