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Identification of requirements and opportunities for new types of standardized interfaces for AGV systems based on the VDA 5050 concept

Identifikation von Anforderungen und Potenzialen für neuartige standardisierte Schnittstellen für FTS auf der Basis des VDA 5050-Konzepts

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The implementation of an automated guided vehicle (AGV) or automated guided vehicle system (AGVS) is currently manufacturer-dependent. In order to achieve independence and prevent a vendor lock-in, it is useful to apply standards to control for example a heterogeneous fleet of AGVs. The VDA 5050 is a first approach to make this possible. However, further interfaces between the AGV, a master control and the surrounding periphery are not considered. The paper gathers the requirements for suitable interfaces in the AGV context of the industry from literature and practice. Based on the gaps identified in the literature and in practice, a workshop was conducted with representatives from software vendors, hardware manufacturers, and end users to confirm the assumptions and to obtain the views of the participants.

[Keywords: AGVS, AGV, Standardization, Interfaces, VDA 5050]

Die Implementierung eines fahrerlosen Transportfahrzeugs (FTF) oder fahrerlosen Transportsystems (FTS) ist derzeit herstellerabhängig. Um Unabhängigkeit zu erreichen und Hersteller Lock-In Effekte zu vermeiden, ist es sinnvoll, Standards anzuwenden, um beispielsweise eine heterogene Flotte von FTS zu steuern. Die VDA 5050 ist ein erster Ansatz, dies zu ermöglichen. Weitere Schnittstellen zwischen dem FTS, einer Leitsteuerung und der umgebenden Peripherie sind jedoch nicht berücksichtigt. Der Beitrag erhebt den Bedarf an geeigneten Schnittstellen im FTS-Kontext der Industrie aus Literatur und Praxis. Basierend auf den in der Literatur und in der Praxis identifizierten Lücken wurde ein Workshop mit Vertretern von Softwareanbietern, Hardwareherstellern und Endanwendern durchgeführt, um die Annahmen zu bestätigen und die Meinung der Teilnehmer zu sammeln.

[Schlüsselwörter: FTS, FTF, Standardisierung, Schnittstellen, VDA 5050]

1 INTRODUCTION

Industrial systems in manufacturing and warehousing environments consist of a variety of components: On the one hand, there are mobile units such as forklifts or automated guided vehicles (AGVs); on the other hand, there are stationary elements such as production systems or picking systems and stations, as well as traffic elements such as gates or elevators. The implementation of an automated guided vehicle system (AGVS) is currently associated with considerable time and adaptation efforts. Adaptations to the existing infrastructure and integration of trades or heterogeneous AGV fleets represent hurdles for the use of AGVS. As a result, the cost of deploying an AGV increases significantly, making it difficult or even impossible for small and medium-sized enterprises (SMEs) to use AGVS. This puts SMEs at a competitive disadvantage.

To keep up with the growing demands of warehousing, more and more companies are turning to autonomous systems to transport and process goods. According to Scholz-Reiter and Freitag, a system is autonomous if it is independent, makes decisions on its own without external instructions, and performs actions independently without external forces [1]. In addition, autonomous systems should become efficient and more powerful, for example, in terms of navigation capabilities or material provisioning. The main driver for autonomous systems is, among others, logistics [2]. To achieve the goal of autonomy in warehousing, different subsystems are often networked, for example, AGVs that communicate with production facilities, stationary sensors or traffic elements such as doors or elevators. However, this increasing connectivity also leads to a significantly increased integration effort, which is intensified by the fact that currently only insufficient or no standardized communication solutions exist for production and other systems with components from different manufacturers.

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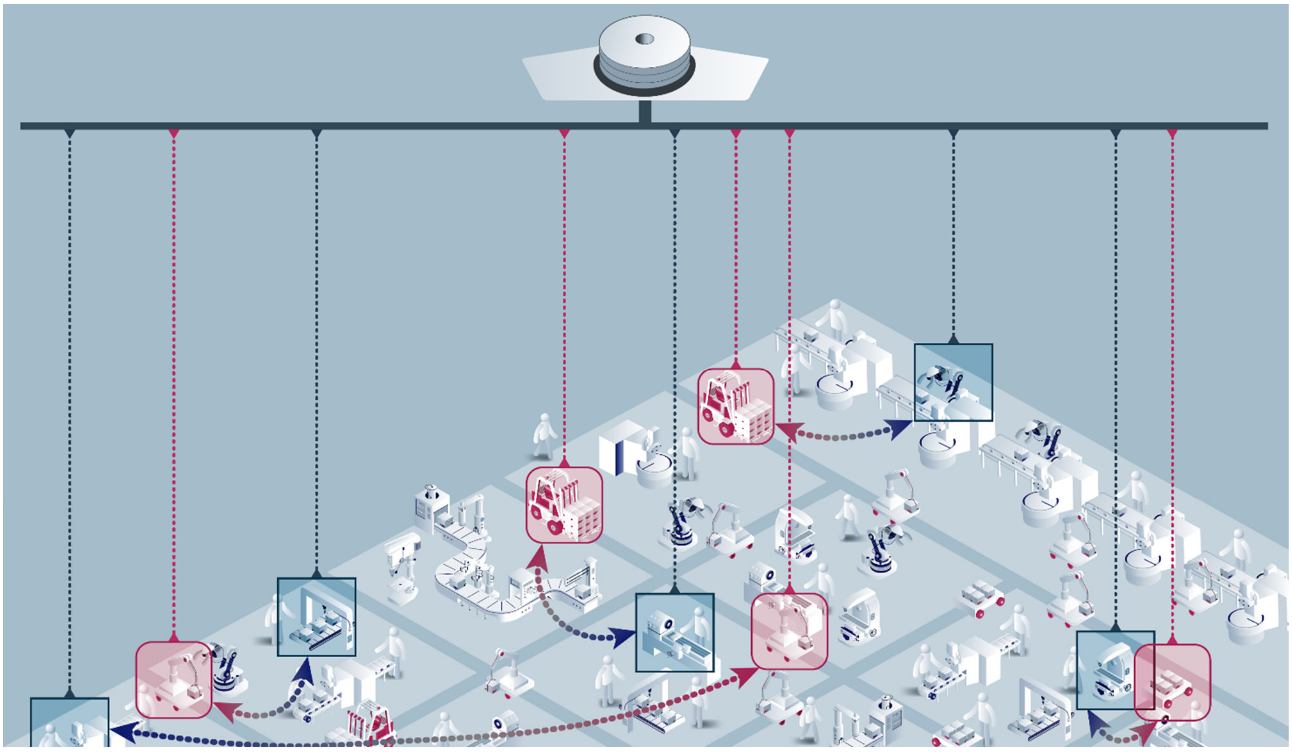

Figure 1. *Future vision of the communication between AGVS and periphery.*

Compatibility between the various manufacturer systems does not yet exist and integrating an individual solution into an overall system involves considerable additional effort.

The study Autonomous Systems [2], published by the Expert Commission for Research and Innovation, sees the further development of autonomous systems as essential to enable SMEs to master the complexity of autonomous systems and use them in their own products and services. In second and third place in the ranking of development needs for autonomous systems are the topics of self-regulation and action. A need for funding is seen for the further development of autonomous systems in small and medium-sized enterprises [2]. End users of automated (warehousing) systems will directly benefit from further development, as integration costs and robot costs will decrease due to standardized interfaces. Among other things, the cost reductions are expected to result from increased competition in the future. In 2020, less than 4 % of manufacturing SMEs used service robots in their business, compared to 12 % of larger companies [3]. Currently, the cost of robots and their integration into the production process is a major factor. Integration is mainly about time and human resources. The former can be solved by lower cost components, the latter by higher autonomy of the robots, as well as standardized interfaces. This also increases the degree of autonomy.

Standardization is a key factor in achieving Industry 4.0. Currently, there are various manufacturers in warehousing that offer complete system solutions. A later extension or a change of components is only possible with the responsible manufacturer. Interoperability is achieved by means of standardized components and interfaces. This means that different elements from different manufacturers can be used together in an uncomplicated manner, which in turn leads to greater flexibility [4].

A first milestone in the area of standardized, manufacturer-independent communication was set with the VDA 5050 [5]. It was established in cooperation between the German Association of the Automotive Industry, the Mechanical Engineering Industry Association and other stakeholders. The VDA 5050 offers a specification of the communication between a master control and an AGV to enable the operation of a heterogeneous fleet of AGVs. However, the integration of other trades of a system is missing. On the one hand, these are stationary components such as load transfer or picking stations. On the other hand, there are traffic elements such as gates, doors, elevators or traffic zones, or even an interface for order dispatching to a master controller, or order assignment to an AGV. It is currently expensive to create a fully integrated autonomous warehousing system with components from different manufacturers. Therefore, a standardized communication layer needs to be developed for all participants of a system. The vision of a standardized communication between AGV and periphery arises as shown in Figure 1.

Advantages arise for the manufacturers of AGV as well as for integrators, who establish a connection between the individual trades and thus create product solutions. An essential point for both groups results from the development of further and larger business fields through a larger or broader market access. A faster and easier integration of systems reduces significant cost drivers such as time and personnel expenditure, which in turn reduces the cost pressure from SMEs and can therefore be assumed to lead to an increase in readiness for use. Another positive effect for manufacturers results from a higher degree of autonomy for their products. This is achieved through access to external information sources from environment and the automatic interaction of different trades via standards.

The paper is structured as follows: Section 2 presents the state of the art in AGVS standardization and the research gaps from literature and practical applications. In section 3, the identified gaps will be compared with practical experience in industry, and required interfaces will be discussed. In section 4, limitations and suggestions for further research are discussed. The paper ends with a conclusion in section 5.

2 STATE OF THE ART IN AGVS STANDARDIZATION

The following section presents the current state of the art in AGVS and robotics standardization. A distinction is made between the theoretical and practical viewpoints. Existing concepts are shown with respect to their distinguishing features.

2.1 THEORETICAL VIEW

The state of the art in warehousing is analyzed and described in detail by Fottner et al [6]. The result of the analysis is, on the one hand, that different robotic systems in warehousing act autonomously and, on the other hand, that for the establishment of efficient hybrid warehousing systems, a main development point is the exchange of information between the different system components. In the context of Industry 4.0, an important development is the integration of sensor and actuator networks with mobile robots to enable them to perform their transportation tasks efficiently. Wan et al. [7] present a system that uses robots and smart sensors to solve problems such as navigation and just-in-time material provisioning through networking. The solution is validated by simulation. The research project Industrial Indoor Localization (IIL) of the Technical University of Hamburg, has published a concept and a demonstrator for a software system called RAIL [8]. The subject of the research is an open source software standard that maps indoor industrial environments in a dynamic spatial model and thus enables localization of the deployed autonomous systems. For this purpose, the sensor and context data of the participating entities are transmitted to a uniform interface and integrated into the model. The model creates a software architecture for indoor environments and the ability to represent them [8]. Simoens et al. [9] provide an overview and discuss the benefits of integrating robots with the Internet of Things (IoT). The authors show that benefits arise from integrating robots with IoT platforms in the areas of perception, motion, manipulation, decision making, interaction, cognition, configurability, adaptability, and reliability. According to the authors, integrated solutions for robots and IoT platforms are currently limited to reading information, and no unified communication standards or processes exist.

2.2 PRACTICAL APPLICATIONS

A technical communication process between machines is called Machine to Machine (M2M) communication. According to DIN standard 43863-4, the communication process is not standardized and can take place via any communication network [10]. M2M communication protocols in warehousing are emerging and will be explained further.

The German Association of the Automotive Industry has published the VDA 5050 [5], an initial standard for communication between AGV and a master control system. The standard enables the manufacturer-independent transmission of orders to AGV and the monitoring of order execution. The MQTT (Message Queuing Telemetry Transport) communication protocol is recommended for message transmission. Information on connection, status, order, visualization and actions to be executed immediately are communicated via various channels using publish-subscribe procedures. The VDA 5050 is already in use by warehousing and logistics manufacturers and is also the subject of research by German researchers. At events such as the AGV Mesh-Up [11], the IFOY AWARD [12] and automatica [13], discussions, demonstrator applications and live tests are regularly held around the VDA 5050 standard. A team from RWTH Aachen University published a demonstrator of a digital twin of VDA 5050 in 2022, enabling automated integration of the standard into existing assembly systems [14]. Co-applicable guidelines / standards for VDA 5050 are: VDI Guideline 2510 "Automated Guided Vehicle Systems" [15], VDI Guideline 4451 Sheet 7 "Compatibility of Automated Guided Vehicle Systems (AGVS) - AGVS guidance control system" [16] and DIN EN ISO 3691-4 "Industrial trucks - Safety requirements and verification - Part 4: Driverless industrial trucks and their systems" [17]. The three listed directives / standards define the basic framework and safety-related requirements for handling AGVS. In the field of robotics, the two IEEE standards "IEEE Standard Ontologies for Robotics and Automation" [18] and "IEEE Standard for Robot Map Data Representation for Navigation" [19] provide guidance for the basic structures and navigation.

The MassRobotics Autonomous Mobile Robots Interoperability Working Group has developed a standard for interoperability of mobile robots in industry [20]. Currently, this only allows mobile robots to publish state information in a vendor-independent format between each other. Here, in contrast to VDA 5050, the vehicles' communications take place between the master controller. Status information includes information about the location, speed, direction of travel, state, tasks / availability, and other

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performance characteristics. The MassRobotics Interoperability Standard, as well as VDA 5050, thus focus on the vertical integration of mobile robots.

Another working group worth mentioning is ISO/TC 299 Robotics, which has now published 26 ISO standards [21]. These relate to basic definitions and safety aspects in the context of robotics. These include, for example, DIN EN ISO 10218-2 [22]. In practice, the standard is applied by the Robotic Industries Association by means of a technical report, which was implemented for the US-American market [23].

In addition to existing robotics and AGVS standards, concepts that standardize the identity of an object or entity also need to be listed. For this purpose, the German Federal Ministry for Economic Affairs and Energy presented the white paper Asset Administrative Shells (AAS) in practice in the context of the reference architecture model Industry 4.0 (RAMI 4.0) [24]. Physical and virtual assets are considered as objects of the AAS. The AAS is a digital representation of an asset which could be a real object or process. The AAS consists of different submodels, each of which represents certain features of the real object or process. The submodels can, for example, contain information about the identification of the object or process, its state or its documentation. The AAS enables different systems to communicate with each other and exchange information via step-by-step expansion stages, with communication being enabled in the final expansion stages. It serves as an interface between the real world and the digital world. No specific communication protocol is prescribed for implementation. The white paper does not have a standardizing purpose, but develops suggestions for existing concepts. The concept of the AAS is realized by the open source middleware Eclipse BaSyx [25] for production systems with a digital twin. This allows an AAS to be implemented digitally and in production. Tasks such as documentation or predictive maintenance can be managed digitally. BaSyx provides real-time data analytics, data processing pipelines and data monitoring through the AAS.

In parallel to RAMI 4.0, the Industrial Internet Reference Architecture (IIRA) [26] exists on an international level. The IIRA is a concept developed by the Industrial Internet Consortium (IIC) to provide a standardized architecture for the Industrial Internet of Things (IIoT). The IIRA defines an architecture that encompasses the various aspects of the IIoT, including device networking, data collection and processing, security and privacy, data analysis, and integration with existing business processes. It establishes guidelines, best practices and standards to support the development and implementation of IIoT solutions. The IIRA consists of several layers that organize the IIoT architecture hierarchically. The layers include the device layer, the connectivity layer, the analytics layer, the application layer, and the business and ecosystem layer. Each layer performs specific tasks and provides interfaces for communication and data exchange between the different components [26].

Another open source project is FIWARE [27], which provides a platform for developing smart applications and managing data in a networked environment. It was originally launched by the European Commission to support the development of smart cities and the IoT. FIWARE provides a set of standard components, interfaces and tools to help developers create applications that can access connected devices, process data and be interoperable. It operates in mainly in the domains agri-food, cities, energy, industry and water. FIWARE provides an architecture platform for the users. The platform also provides various services, including data management, context awareness, access control, device management and more. A central concept of FIWARE is the so-called NGSI (Next Generation Service Interfaces) data model, which provides a unified and standardized way to model, retrieve and exchange data from various sources.

In the US market, the Semiconductor Equipment and Materials Institute (SEMI) has published the E82 standard [28]. SEMI E82 is a standard specifically designed for factory automation, such as semiconductor or flat panel display factories. It specifies requirements and standards for transporting equipment within and between transport systems. The standard defines how devices should be viewed and behave from a central control computer (host). SEMI E82 facilitates the integration of devices into an automated factory by defining a standardized interface and the operational behavior of the devices. However, there are other topics that fall within the scope of the standard, such as traffic management, parallel carrier transfer interface, and transport system controller architecture [28]. In order to identify resources and objects in a uniform manner, the Internet standard RFC 4122 (Request for Comments 4122) [29] was published. The standard defines uniform resource naming schemes for UUIDs (Universally Unique IDentifier) or GUIDs (Globally Unique IDentifier), which have a length of 128 bits and guarantee uniqueness over space and time. They are used for a variety of purposes because no central registration is required and generation can be automated. The specification supports very high assignment rates and is well suited for sorting, hashing and for storage in databases. Since UUIDs are unique and persistent, they are well suited as resource naming schemes with low cost of creation [29]. The concept of UUIDs is also recommended by VDA 5050 in the unique ID identification of actions and their association with status [5].

Another standard for vendor-independent localization of objects in industry is omlox [30], published by the PROFIBUS & PROFINET International industry association. The location data of the devices are unified and represented in one interface. The standard supports UWB, RFID, Wi-Fi, GPS, BLE and 5G technologies. This enables vendor-independent real-time location of a wide variety of devices in an industrial context. The omlox standard is not an open source solution and is only implemented with certified partners.

When using a fleet of AGVs, it is necessary to use a master controller or fleet manager. Several providers already exist on the market that offer vendor-independent systems. With these systems, a basic use for the realization of AGVS is possible without own development work. However, each extension (e. g. an interface to a warehouse management system (WMS) or other periphery) is a customized solution and not standardized, as such solutions can only be integrated with considerable effort. Exemplary products for a manufacturer-neutral control system are openTCS (Open Transport Control System) [31], KINEXON Fleet Manager [32], incubed IT Fleet Management Server [33] or SYNAOS Mobile Robot Fleet Management [34]. These control systems already have an interface to VDA 5050 and therefore support the standard. The above solutions use the MQTT protocol for communication with the AGVs. The advantage of the protocol is that the clients only require a resource-saving code and the function is guaranteed with limited networks with low bandwidth [35]. Besides MQTT, other protocols exist, such as Zero MQ, Websockets, RosBridge, DDS, AMQP, WebRTC, HTTP/2, ROS1, ROS2, UDP. OPC UA, CoAP and XMPP. Among the different protocols, the most appropriate one should be used depending on the context and use case.

3 REQUIREMENTS FROM INDUSTRY

Based on the concepts and systems presented in section 2, it can be seen that there are a number of efforts to enable multi-vendor applications. However, these solutions are often customized and require a high level of implementation effort. SMEs in particular are usually not able to implement the solutions because they lack the expertise, capacity and financial resources. Therefore, customization is currently required for implementation. A completely free open source solution that addresses the standardization of AGV interfaces such as peripherals or order creation is not yet available. This is because existing concepts such as FIWARE, Basyx or RAMI 4.0 cannot be easily applied to the industrial AGV context. To confirm the identified research gap from the literature and available applications, a workshop was conducted with industry participants. The goal was to gather the requirements of the participants and confirm the need for a standard for peripherals and other elements in the warehouse in an AGV context. Elements from a warehouse may include a WMS, enterprise resource planning (ERP), human-machine interactions or the periphery like picking stations, lifts, and more. From the needs and experience reports of the participants, a ranking of the addressed interfaces was created as an initial requirements identification for a standard. The motivation of the standard is inspired on the framework of the VDA 5050 and the success behind it. The standard cannot provide small implementation details but defines a comprehensive communication layer for the AGV sector. In addition to the interfaces themselves, the challenges, goals and use cases were also discussed in the workshop.

3.1 WORKSHOP FOR INTERFACE DEFINITION

The workshop included two participants from AGV software enterprises, three hardware manufacturers and one end-user from warehousing. Of the six participating companies, two belong to SMEs. The workshop was held in spring 2023. Based on the deficits identified in practice and in the literature, the most useful interfaces for AGVS were to be defined together with the participants. The following key questions were discussed:

- How can different elements of a warehousing system automatically recognize each other and communicate with each other?
- How can different AGVs in a warehousing system automatically use the functions of other elements?
- How can AGVs act holistically and autonomously across different areas?

Figure 2 was used to visualize the idea of the missing connection between master control and interfaces. Impulses like the differentiation of the interface specification into periphery, sources, sinks, loading stations and order generation should give first ideas for the upcoming discussion. The narrative of VDA 5050 was used as a model, and the interface between the master controller and the element should be similar to this. Since VDA 5050 uses the master control to connect different AGVs, it is possible to use this approach as well and create standardized interfaces e. g. between AGVs and periphery. The idea should strengthen the interoperability of the AGVS. An exemplary implementation can be done via the master controller. An interface between the master controller and other elements of a warehouse is also conceivable. In Figure 2, the possible interfaces are shown as the gray area.

After the introduction of the general idea and Figure 2, the workshop was conducted in five discussion rounds: 1. feedback on the idea, 2. presentation of conceivable interfaces, 3. voting on prioritization of interfaces and definition of new interfaces not yet considered, 4. challenges and goals of interfaces in comparison between is and should state, and 5. use cases.

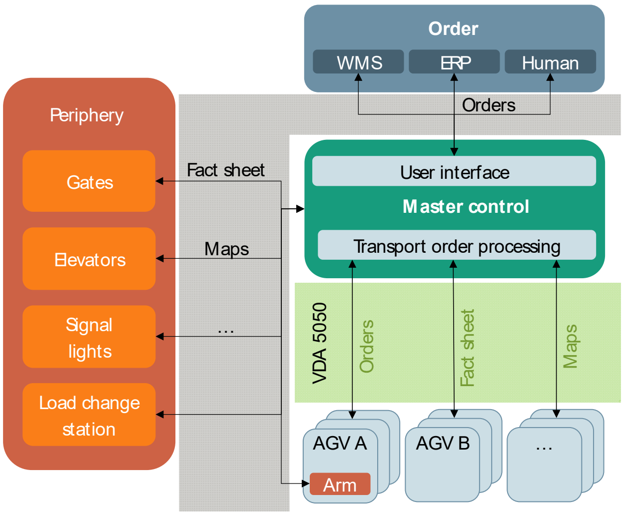

Figure 2. *Concept of possible connections of interfaces between master control and periphery and orders.*

3.2 RESULTS OF THE WORKSHOP

In the first workshop round all participants agreed on the relevance of the general idea and shared the views of the previous introduction. Further exchange took place in the basic framework conditions regarding communication logic, privacy and security requirements.

In the second round of the workshop, the preferred conceivable interfaces were explained. A total of six interfaces was identified from preliminary discussions and practical experience. These include order creation, load change and picking stations, loaders, doors, signal lights / traffic lights and lifts. Order creation is an interface between master control or AGV and ERP or WMS. The goal is to enable the master control, AGV or other devices to independently initiate or confirm orders in the system. Simple order creation at the push of a button is also feasible. The interface of the load changing and picking station should allow the station an independent management to permit an AGV to enter and exit. If the necessary peripherals are available, automatic loading and unloading by the AGV itself or by the station, for example with a robotic arm, is enabled. At the charger interface, AGVs should be able to charge themselves or have the battery changed by the station. Doors are often a component of warehouses. When interacting with the AGVS, a proprietary interface currently has to be created. This can be solved with standardization. The interface between the AGV and the door should allow the door to open and close independently for cross area movement. The interfaces to signal lights, traffic lights and other lamps should include e.g., a status display or the consideration of traffic rules by light signals. The last presented interface of the elevators shall allow the AGVs to travel alone in an elevator. This includes requesting the elevator, entering and exiting, and reaching the correct floor. Queues in front of the elevator must also be considered.

After all the interfaces were presented, the third step of the workshop was to ask the participants if they could identify other interfaces. The only newly defined interface was AGV to AGV. This means that AGVs can communicate with each other and exchange status information. The rest of the predefined interfaces could already cover most of the participants requirements. To prioritize the need to work on the interfaces, a vote was carried out. The basis for the ranking was, among other things, the frequency of occurrence in reality or the effort required for implementation. The selection of relevant factors for the vote was left up to the participants. The voting resulted in the following order of priority: (1) Load change station / picking station, (2) Elevators, (3) Doors, (4) Order creation, (5) Chargers, (6) Signal lights / traffic lights / lights, (7) AGV to AGV.

In the fourth round, the challenges and target states of the individual interfaces were discussed. The load change station / picking station interface is a challenge that includes a wide range of protocols, both proprietary and standardized. The stations are divided into active and passive variants and exhibit a variety of degrees of complication, ranging from simple run-in processes to complicated sequences. One mentioned aspect of a participant is an interface problem of the heterogeneity of communication technologies. These range from redundant and safety-oriented approaches to communication using mechanical components. In addition, established interfaces such as optical data sensors and simple programmable logic controllers are often used, which can be based on different technologies such as Profinet, Ethernet, WLAN or other methods. These range from point-to-point communication to radio links and contact-based interfaces that must provide different levels of security and information flow. In the target state, different mechanisms should be covered, such as active or passive load change. In addition, a generic description of the interactions for different systems should be provided. The implementation should be reliable and simple. It should be noted here that a future standard that is to be developed cannot address the breakdown at the sensor and actuator level. Such an implementation must be realized on a different layer. The challenges of the door interface range from the simple connection of inputs and outputs to the integration in programmable logic controllers, depending on the individual connection of the shop floor. This interface is currently subject to variability depending on the manufacturer. In addition, automatic doors and airlocks must be considered. For the target state, a standardized communication between the door and the AGV must be created. For this purpose, individual door elements can be connected to the system with IoT modules. Standardized communication protocols for the doors can be used to create processes for opening and closing them. The challenge with the elevator interface is the diversity of manufacturers. They use different connections to the system and different control systems. The goal is to standardize control and feedback signals. A variety of systems is also used in practice for order creation. These range from ERP systems to simple custom programmable logic controllers. For the target state it can be helpful to create a simple consideration for small programmable logic controllers and for large established systems. AGV to AGV, charging stations and lamps, current solutions range from no existing communication to individual integration via the control system. Unified interfaces can allow easy integration.

In the fifth round, the following use cases were identified. There are different scenarios for load changing and picking stations. Here, the load is transferred from the AGV to, for example, a stacker crane or a roller conveyor. This interaction requires precise communication and coordination, as well as feedback to the AGV to enable movement once the operation is complete. In addition, there may be stations that use simple occupancy queries to inform the entry process. In other scenarios, the pallet transfer is performed using a lift from the AGV. Stations with entry requests and position determination require precise maneuvering of the AGV. Buffer stations use load balancing for efficient order processing and distribution. Another approach is to have stations with their own queue to optimize throughput. There are also AGVs with arms to unload the carrier into the station. Regarding doors, different types of gates and doors are addressed. For the future vision, fire doors and gates are connected via input and output interfaces. It is desirable to have an independent opening and closing of the doors. High-speed doors and airlocks are integrated into the system using programmable logic controllers. Airlocks have a mutual door interlock and a central standby position. Automatic doors are part of the interfaces that allow smooth passage in automated environments. The integration of elevators into automated operations results in a variety of application scenarios. Elevators may be shared by people and vehicles, resulting in mixed use. Grouping and selection of elevators allows equal use of multiple elevators. Elevator availability is dispatched in real time, considering travel times and alternative uses, such as for people. Elevator occupancy is monitored using technologies such as cameras and floor sensors. Interfaces for AGV to AGV or to charging stations and lamps also include many use cases. Charging stations and AGVs can turn on the charger and communicate status information such as readiness and charging. AGV to AGV transfers allow cargo to be shared between different types of vehicles, such as between an automatic forklift and a carrier. Light signals, including traffic lights and intersections, optimize traffic flow. The lights are activated autonomously by the AGV, allowing AGVs using optical image processing to operate in dark environments.

4 LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

With captured the impressions and requirements of the industry, the next step is to launch a possible project. For example, an implementation with a large consortium can be realized independently in a suitable funding program.

The results do not claim to be complete. The roundtable discussions are intended to stimulate further research activities, which are supported with the relevance of the voices of industry. Further structured interviews with partners from different industries can bring in other perspectives. A detailed requirements survey and a large-scale survey to prioritize the interfaces to be implemented provide a good starting point. During implementation, privacy and security standards must be maintained at all times.

5 CONCLUSION

The results of the workshop as well as the literature and practical experience show that there is a need for action. A standardized interface extension in the field of AGVS is the next step towards automated and autonomous systems. The success story of VDA 5050, which was able to establish an independent standard, can serve as a conceptual model. The support and willingness of the industry shows that progress must be made together and that further standardization is necessary.

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