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Development Possibilities of the High-tech Logistics Laboratory Established at the Institute of Logistics of the University of Miskolc

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Authors' contributions

This work was carried out in collaboration among all authors. Author PT designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors RS, TB and ÁC created the visual elements and their description. Authors ST, PV, ÁC, IH and RS managed the analyses of the study. Authors TB, ST, PT and PV managed the literature searches. Authors PT and BI supervised the whole process. All authors read and approved the final manuscript.

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ABSTRACT

The Institute of Logistics of the University of Miskolc started training logistics in Hungarian higher education for the first time in the early 1990s. In recent decades, the training structure and laboratory infrastructure of the institute have changed significantly, relying on the relevant educational and research connections in Germany. The publication presents one of the institute's laboratories, the High-tech Integrated Logistics Laboratory, which contains a number of material handling equipment (pallet handling cell, AGV, automated warehousing system, etc.), which provides an opportunity for fulfillment of high-quality teaching and research tasks. In addition to a brief presentation of the laboratory, the researchers present their future ideas about the laboratory in different areas of development, which can also serve as a useful guide for other professionals involved in logistics education and research.

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1. INTRODUCTION

With the strengthening of digitalisation and networking in recent decades, it is becoming increasingly possible to implement individual mass production at low unit cost and high service quality [1]. This requires a high level of automation, real-time data collection and processing of the examined system, and the application of algorithms supporting predefined operation [2]. Furthermore, it is essential that companies use a wide variety of process development methods [3,4]. The Institute of Logistics of the University of Miskolc has implemented a laboratory in which most of the material handling equipment (e.g.: AGV, automated warehousing system, roller conveyor system, etc.) often used in production and warehousing processes can be found. With the development of the system, it becomes possible to train and research the operation of these equipment and their integration possibilities. In addition to the installation of material handling equipment, a simulation investigational system has also been developed, which basically performs educational tasks. These type of laboratories can be found in several places (e. g. the Fraunhofer Institute [5], NTNU [6], FH Joanneum University of Applied Sciences [7]), but at the same time it can be said to be unique in its appearance and complexity. Based on the knowledge acquired in the laboratory, more than 50 students become able to perform logistics system design tasks each year. We plan to ensure the long-term development of the laboratory with the help of equipment and tender grants provided by companies. Students entering the lab receive accident prevention training, and a number of sensors and sensors ensure accident-free use. In addition to training, we also provide consulting services for the equipment in the laboratory, if required.

After a short presentation, the paper presents the development directions of the following period in the following fields:

- Optimization possibilities for object layout.
- Operational optimization possibilities.
- Possibilities of developing a product tracking system.
- Development opportunities of the robotic area.
- Development opportunities for material handling equipments.

2. INTRODUCTION OF THE HIGH-TECH LOGISTICS LABORATORY

The central part of the High-Tech Logistics Laboratory of the Institute of Logistics is an integrated materials handling system which contains the following main components: a PLC controlled roller conveyor track which acts as the backbone of the complete system; a palettizing station; and an automated storage system. The general layout of these components can be seen on the picture of Fig. 1.

It is important to note that while it is not present on the picture of Fig. 1, yet the system is also complemented by an automated guided vehicle (AGV). This unit will be also described later, after the introduction of the main components.

As it was previously mentioned, the central component of the system is the closed roller conveyor belt which basically connects the other components together. The conveyor track surrounds a manually operated tilted stand which provides a secondary option for storage and the possibility to examine the combined operation of the automated system together with human operators.

The conveyor track is made up of multiple modules, with each module having its own drive system. The modules are also equipped with pneumatically operated blocking plates which provide separation between the carried boxes. For the properly timed operation of the former plates, the detection of boxes on the track also has to be realized. This is implemented through the use of optical sensors. Because the blocking plates, the turning tables at corners of the track and the few pneumatic grippers all need pressurized air to operate, therefore the use of a compressor is also needed for the operation of the conveyor system.

The aforementioned turning tables connect the perpendicular track segments at the corners. They are equipped with short conveyor belts for moving the boxes. One of these turning tables can be seen on the picture of Fig. 2, together with a small pneumatic gripper on its left side (the latter serves for fixing a box in a given position). Also note the electric motor that drives the conveyor belt of the table. Finally, an RFID reader is also visible on the right side of the picture of Fig. 2.

It is worth noting that the track is equipped with multiple RFID readers (and writers) in multiple locations, therefore the traffic on the system can be precisely followed not just by one, but by two tracking solutions simultaneously (the other one being the utilization of the previously mentioned optical sensors).

Fig. 1. The general layout of the integrated materials handling system of the laboratory (the palettizing station is in the foreground, while the conveyor track and the automated storage system are in the background)
(Source: created by the authors)

Fig. 2. A turning table with a pneumatic gripper on the left and an RFID reader on the right
(Source: created by the authors)

The rolling conveyor track is connected to an automatic storage system at the back of the laboratory. This system is serviced by an automatic racking machine that “knows” (through pre-programming) the exact locations of each storage space in the racking stand. Again, the measurement of distances is solved through optical sensors in this case as well. The conveyor track can directly move boxes onto the table of the racking machine through an open track segment specifically designed for unloading.

As already introduced, the third component of the integrated materials handling system is a palettizing station at the “front” of the rolling conveyor track. This station combines multiple typical solutions for materials handling, such as two lifts which move the boxes horizontally, inductive sensors for palette tracking, a “gravitational” lane, blocking devices and a special pushing mechanism for the vertical movement of the cargo. The main purpose of the station is to demonstrate the operation of these more specialized materials handling methods, but it can also be operated together with the rolling conveyor system.

It is important to note that while the previously described components can be automatically operated together by a PLC-based control unit, each subsystem can also operate independently as well. Furthermore, the individual track segments can also be operated manually, just as the racking machine.

The PLC-based control unit can be seen on the right side of the picture of Fig. 1 (the cabinet with the industrial monitor). The manual operation of the track segments can also be realized through the display of this unit, specifically through the HMI (human machine interface) that is implemented on the touch screen. The manual operation of the automated storage system can be realized through the control box that can be seen on the left side of the picture of Fig. 1.

While manual operation is an option, of course the real strength of the system is that it can operate autonomously in an integrated manner. What this means is that the described components can exchange boxes between each other without human intervention (of course, except the manual storage stand in the middle), while the system can also implement complex materials handling strategies. This is made possible by the intensive utilization of sensors throughout the entire system. Here, it is also important to note that Industry 4.0 solutions are based on intelligent sensors and sensor networks and have a great impact on the performance, reliability and efficiency of cyber-physical systems [2], such as in the case of our materials handling system. Furthermore, in our case the PLC-based control unit can be linked to a traditional SCADA (Supervisory Control and Data Acquisition) system and also to a state-of-the-art MES (Manufacturing Execution System) as well, thereby allowing the implementation of higher level control strategies for the complete system.

As it was mentioned before, the system is also complemented by an AGV that provides an even more flexible way of moving around individual boxes in the laboratory. This vehicle is equipped with a laser radar, a modern and frequently used solution for providing localization data for autonomous vehicles. The machine also has a WLAN-port, therefore it can be ordered to fulfill a new task at any given time. However, what makes this AGV really unique is that it is also equipped with a compact robotic arm, therefore it can also manipulate the cargo in the transported boxes, according to the predefined task. Of course, the achievable level of automation in this latter area is the focus of ongoing research.

3. OPTIMIZATION POSSIBILITIES OF STORAGE TECHNIQUES IN THE HIGH-TECH LABORATORY

Among the devices installed in the High-tech laboratory, the storage function plays a primary role. There are three installed storage devices, which can be seen on the picture of Fig. 1:

1. The warehouse stacker and the high-bay storage shelf to simulate long-term storage.
2. Ergonomically designed gravity storage shelf for short-term storage.
3. A roller conveyor arrangement also suitable for storage on a material handling device, which is capable of temporary store goods by moving around.

In this section we are focusing on the first point. The high-bay-like storage system is almost equivalent to an automated storage form of a modern company, with the difference that it is tailored to fitted inside a room, so it’s much smaller than the real system and unfortunately, we only have one row. The 140-space shelf is otherwise capable of simulating storage strategies of large companies and experimenting with newer principles, since the horizontal and vertical movement speeds can be varied independently within large limits. Thus, no matter how high or wide a warehouse is, we are capable of producing similar conditions. The system can test most commonly used storage techniques [8] for head storage layouts, which can be:

- Completely random placement,
- The nearest empty place compared to the entry point,
- Storage in the empty space closest to the next removal point,
- Storage according to ABC / XYZ analysis

With the help of the automatic storage system, we can examine four important properties of the storage system and the associated storage strategy and thus determine the properties to be optimized:

- Storage system stability: above a certain saturation, the intake/removal time increases significantly, or the entire system can be blocked,
- Speed of storing, which largely depends on our storage strategy and size of the warehouse,
- The rotation of the stored goods, which largely depends on the speed of storing and size of the warehouse,
- The number of storage locations and the dimensions of the storage system

For most companies, the speed of storing and stability are the primary goals, but energy consumption can be reduced along with these. The primary source of this is that stackers use much more energy for lifting, than for horizontal movement. The optimization tasks listed so far can be performed by the laboratory, in some cases together with additional sensors.

4. OPTIMATIZATION POSSIBILITIES IN VIEW OF OPERATION

The integrated logistics laboratory offers a wide range of scenarios, where the optimization of operation strategies of materials handling systems can be developed, analyzed, and evaluated. These tasks include the layout design, the optimization of loading unit building processes, the evaluations of various algorithm of routing problems, the scheduling of materials handling operations and the optimization of different picking strategies in storages and warehouses [9].

Routing problems represents significant problems in in-plant supply solutions, where the optimal routing of material handling and transportation machines, like automated guided vehicles or unmanned aerial vehicles can increase the efficiency of the logistic processes. In the integrated logistics laboratory, the automated guided vehicle, two Robotino mobile robots offer opportunities to demonstrate the impact of routing algorithm on the efficiency of the whole system. Our future plan is to integrate some drones into the system. The integration of the unmanned aerial vehicles and the AGV makes it possible to develop and demonstrate new algorithms for routing problems of cooperating vehicles. The design of multi-level loading unit building processes can be realized with the use of various boxes. The scheduling of material handling processes can be taken into consideration as an integrated approach, but we can apply various solutions for each part of the integrated laboratory. The storage makes it possible to develop various layout designs in the storage and analyze their impact on the operation of the automatic racking machine.

5. PRODUCT IDENTIFICATION SYSTEM DESIGNING POSSIBILITIES

With the help of a good identification and tracking system, the principle from raw material to customer can be implemented even in the case of usually complex supply chains. The transparency of the system and its processes can be greatly increased, the special needs of customers and partners can be more easily met, customer dissatisfaction can be minimized, and we can react much faster to quality problems.

It is advisable to use internationally widely accepted standards as the basis for the identification system. The GS1 company's Global Traceability Standard can be a great way to describe unified processes, that can be applied to the entire system, providing answers and solutions to almost any needs that arise. This solution enables connection between different identification systems along the entire length of the supply chain, thus establishing the possibility of testing, implementing, and training for many modern solutions.

The main pillars of the implementation of the identification system are the standard identification keys, data-storing symbols and the electronic data interchange (EDI). These require IT upgrades, but may also require hardware expansion, e.g. scanners, RFID readers, tags. The first step of the development process is a thorough overview of the current equipment park, finding possibilities in the current system, and then creating the model of the processes. This is followed by the design and development of the identification system on both the software and hardware side. To achieve this a master database of the products must be created, the ERP system must be developed, the standard solutions of EDI must be introduced, and the technical tools of the laboratory must be expanded in parallel with all the necessary measurements.

Once the developments are complete, it will be possible to track and identify events related to products moving along the supply chain at both physically and virtually, from the raw materials through manufacturing processes to the customers. Products passing through RFID gates can only proceed after reading their ID (faulty IDs will be detectable). Depending on the code sequence scanned, various events may be induced, such as the start of the next material handling process or the creation of an automatically generated electronic invoice that can be send to the customer immediately. In accordance with the predefined system of rules we can automatically generate the followings: the arrival of incoming raw materials, their ID, storage place in the warehouse, ID for collection boxes created during the simulation of the production process, LOT numbers, creating load units and with logistic ID labels. All transactions are recorded in the ERP database. As part of the digital communication, an automatic or even real-time exchange of master data between the parties may appear, completed by electronic delivery papers and invoices generated according to the EDI rules without human intervention.

The Institute of Logistics of the University of Miskolc plans to launch two new training courses (logistics simulation engineer and Industry 4.0 process development engineer), where a dedicated subject will be focused on identification and tracking technology. The High-Tech Logistics Laboratory provides an excellent opportunity for the practical application of theoretical knowledge. With the continuous technological development of the laboratory, students can gain a wider spectrum and more up-to-date knowledge of this topic.

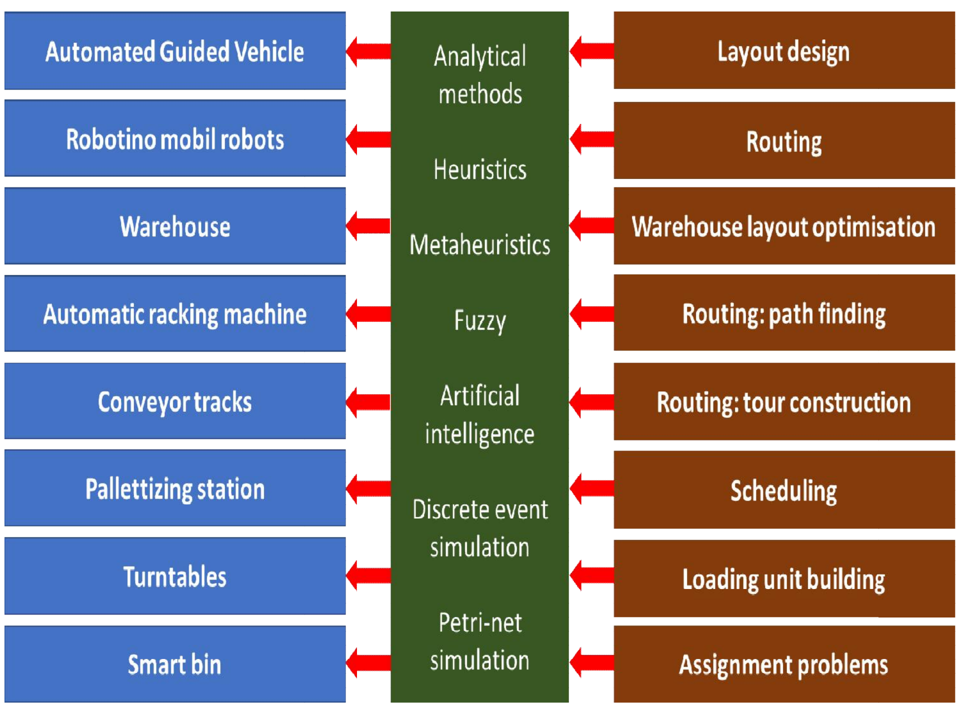


Fig. 3. Optimization tasks in the integrated logistics laboratory

6. DEVELOPMENT POTENTIAL IN THE FIELD OF ROBOTICS

In the High-Tech Laboratory there is an AGV, which can be seen in the Fig. 4a. This AGV was built in 2009 as a prototype. This vehicle is an automated carrier vehicle, which can be regarded as mobile robot [10]. To automated functions the AGV uses LIDAR navigation sensor, safety sensors, PC and PLC for controlling, and motors for moving [11]. On the AGV there are installed also two conveyor belts (see Fig. 4a). These belts can hold for instance a box, but due to its motorized function it can also pick and place the box. This AGV is part of automated material handling system, it can pick and place different materials from an input storage to an output storage and vice versa. The development possibility is in the optimization of its path and trajectory planning and adding new ways and goals for the remaining tasks.

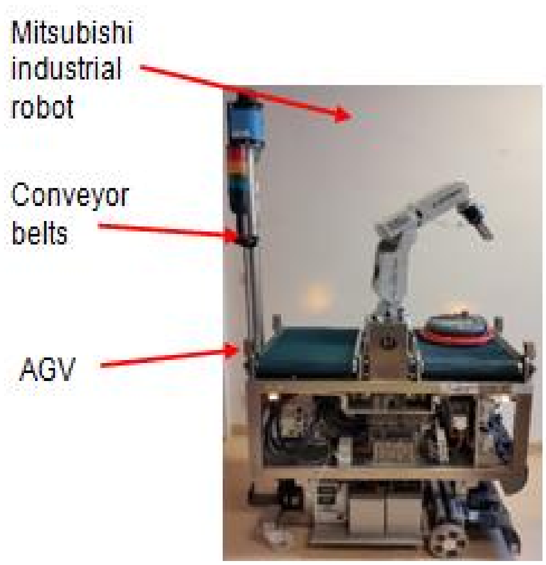
On the AGV there is mounted also a Mitsubishi RV-2SDB industrial robot among two conveyor belts (see Fig. 4a). This robot can handle the parts, which the belts cannot pick and place, or can pick and place from one conveyor belt to the other belt. With development it could perform also other task, for instance assembly, disassembly.

In the laboratory in center part of the automated material handling system there was mounted a Mitsubishi Scara-type industrial robot. However, this robot had to go away due to an ownership problem. In the future, the Institute of Logistics would like to buy a similar, but moderner Scara-type industrial robot to perform the tasks there. The robot performed the material handling between the roller-track and vertical placing device.

The Institute of Logistics has another industrial robot, but in other building. This robot is a Kuka KR5 Sixx (see Fig. 4b), this was the fastest robot in its new age. The plan is to move this robot to the High-Tech Laboratory and use as a part of the automated system.

7. DEVELOPMENT OPPORTUNITIES FOR MATERIAL HANDLING MACHINES

One direction for the development of roller tracks is the grouping of conveyed products. The accumulation conveyor is an integral piece in the design of today's modern distribution systems. This conveyor allows for the buffering of work between various processes as the rate of production can often vary from the rate of consumption.



(a) AGV with Mitsubishi industrial robot, (b) KUKA KR5 Sixx industrial robot

Fig. 4. AGV and industrial robots available in the Institute of Logistics

Fig. 5. Accumulating roller conveyor
(Source: GEBHARDT Fördertechnik)

To achieve this the PLC controlled roller conveyor track should be equipped with an accumulation conveyor track. The accumulation conveyors have the ability to remove drive in segments or zones to allow conveyed products to stop or collect at will. These conveyors are used to hold or buffer products into areas such as merges, sortation, or palletizers.

In this case we could be able to simulate a real product process, where the collect of the transferred boxes or pallets are needed.

Another development option is to expand the function of the Scara robot by increasing the number of replaceable manipulators. The robot is still suitable for automatic manipulator replacement. If equipped with manipulators capable of performing additional functions, so manipulators can be positioning, pre-assembly, lubricant or adhesive applicator, or many other tasks. This significantly expands the functionality of the system. It also provides an opportunity to practice programming tasks for diverse tasks.

8. CONCLUSION

In order to overcome the logistics challenges present in the 4th Industrial Revolution, the performance of educational and research tasks with the development and operation of modern laboratory systems is becoming more and more important. Due to the training of suitable specialists for companies and the realization of industrial research tasks, a High-tech Integrated Logistics Laboratory was established in 2018 at the Institute of Logistics of the University of Miskolc. The paper presented the structure, operation and development guidelines of this laboratory. In our opinion, these ideas can serve as useful guidelines for logistics education and research professionals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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