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Introduction of the High-Tech Logistics Laboratory installed at the Institute of Logistics of the University of Miskolc

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Abstract: In this paper, we would like to introduce the High-Tech Logistics Laboratory of the Institute of Logistics of the University of Miskolc. This system, in it’s latest iteration, was installed in 2018 and incorporates an automated, state-of the art and fully integrated material handling solution. Specifically, it contains a PLC controlled roller conveyor system, a palettizing station, an automated storage system and an AGV (automated guided vehicle). Most of these can exchange cargo with each other, either in an autonomous or semi-autonomous manner.

In the paper, first we would like to describe the previously mentioned subsystems of the laboratory, while we would also like to present the unique educational and research possibilities provided by this advanced facility. Besides, we would also like to discuss some possible future upgrades to the system, in accordance with the latest advancements of logistics automation. We believe that these insights could be useful for a wide variety of professionals who are interested in the current state of automation in the field of materials handling.

Keywords: Automated materials handling, Integrated materials handling system, Logistics research and education

1. Introduction

While the role of automation in the field of logistics and materials handling has become increasingly important in the last couple of decades, it probably had never been so important than it is today. With the increasing adoption of the Industry 4.0 principles in all industrial sectors, it became crucially important to automate the related logistics processes on an entire new level as well [3] [4]. These are the main reasons for why we think that now is an optimal time for introducing our High-Tech Logistics Laboratory, which serves both as a demonstration system of state of the art materials handling technologies, as well as a research laboratory for the testing of new solutions and also as an educational facility that helps in the training of engineering students.

In its current form, the laboratory was installed in 2018 in our Institute. While it also inherited many subsystems from the previous iterations, for example the palettizing station and multiple other elements, yet most of its components are state-of-the-art and are integrated into a modern system that makes possible the utilization of the Industry 4.0 principles.

In the followings, first the central components of the system will be introduced, which will be followed by the description of the possible future developments, the research possibilities and the educational significance of the facility. We believe that this detailed introduction of our High-Tech Logistics Laboratory can provide a unique and useful overview of the applications of modern integrated materials handling systems.

2. Description of the subsystems 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 Figure 1 on the next page:

Figure 1. The general layout of the integrated materials handling system of the laboratory (Source: created by the authors)

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

As it was previously described, the central component of the system is the closed roller conveyor belt which basically connects the other components together. The picture in Figure 2. on the next page shows a large section of this conveyor track. As it could be already seen, 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 (as the picture shows, the transmission is realized through a type of friction drive that connects the individual rollers). 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, a number of which is also visible on the picture of Figure 2:

Figure 2. A section of the rolling conveyor track with the manual tilted stand in the middle (Source: created by the authors)

Because the blocking plates, the turning tables (which will be shown in Figure 4) and the few pneumatic grippers (also see Figure 4) all need pressurized air to operate, therefore the use of a compressor is also needed for the operation of the track. This compressor can be seen on the picture in Figure 3:

Figure 3. The compressor that provides the pressurized air for the operation of the roller conveyor track (Source: created by the authors)

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 Figure 4, 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:

Figure 4. A turning table with a pneumatic gripper on the left and an RFID reader on the right (Source: created by the authors)

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).

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. The entire solution can be seen on the picture of Figure 5:

Figure 5. The storage system with the automated racking machine, together with the unloading segment of the rolling conveyor track (Source: created by the authors)

As already mentioned, 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. The palettizing station can be seen in the front of the picture of Figure 6 on the next page, together with the rolling conveyor track, the manual storage stand and the automated storage system in the background.

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 Figure 6 (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 Figure 6:

Figure 6. The palettizing station in the foreground, together with the previously described systems in the background (Source: created by the authors)

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 [5], 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 automated guided vehicle (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 Mitsubishi 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. The AGV can be seen on the picture of Figure 7:

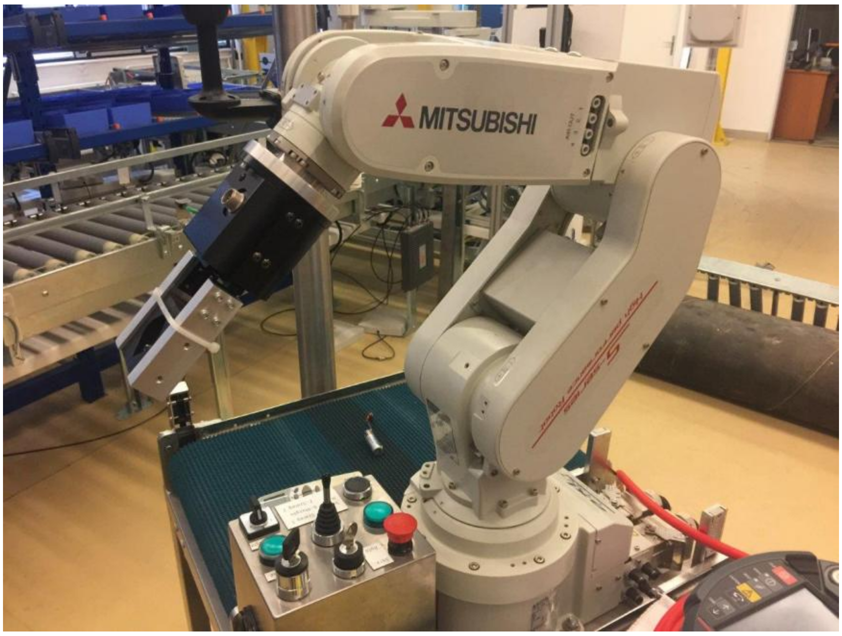

Figure 7. The automated guided vehicle (AGV) of the laboratory with its robotic arm (Source: created by the colleagues of the Institute of Logistics)

3. Possibilities of future development and research

As it could be seen from the introduction and the description of the subsystems of the laboratory, the complete integrated materials handling system is suitable to serve multiple research roles related to the Industry 4.0 concept. A typical example for that would be the use of big-data analysis techniques for processing the various information which is collected throughout the system. This information consists the data coming from the previously mentioned tracking sensors (optical sensors and RFID readers), from the PLC-based control unit, from the automated storage system, from the automatically guided vehicle and from the palettizing station. It's important to note that the control PLCs themselves also collect a large amount of data as well, for example like air pressure and drive motor status, just to name a few (in other words, a majority of the collected "low-level" data can be extracted from the PLC based control unit).

There could be several ways for the utilization of the collected and analyzed data. A typical application would be the precise forecasting of the wear out of certain machine components, most importantly the rollers in the conveyor track, as a function of the load characteristic of the rolling conveyor track. This could have impo rtant industrial applications, as the wear out of the rollers is a typical weakness in large scale conveyor systems. Besides, the measurement of the performance of the rolling conveyor track would also make possible a detailed energy efficiency analysis of the conveyor system. This is important because nowadays, energy efficiency of state of the art technological solutions is one of the key factors not only in manufacturing but also in manufacturing–related logistics and supply chain [1]. Furthermore, these types of analysis can prove to be useful in the quality management of logistics systems as well, especially as they can help in the forecasting of failures and defects in the systems [2].

Another straightforward research avenue is the further development of the automated capabilities of the AGV. Right now, the vehicle can traverse multiple preprogrammed tasks and can switch between those, depending on the situation. It can also flexibly load and unload cargo to and from the rolling conveyor system, while it’s manipulator arm can also complete preprogrammed tasks. However, there is plenty of room for development as well, especially given the latest advancements in artificial intelligence in the last few years. For example, a typical advanced capability of the robotic arm could be the automated sorting of some of the most typical cargo in the transported boxes (usually medicine packs are used as exemplary cargo), as this is a very important field of application for industrial companies (though this would probably require the installment of a machine vision system as well). Of course, the collaborative capabilities of the manipulator arm could also be enhanced in the future, as this is again a very relevant research field in Industry 4.0.

Yet another avenue of development could be the further robotization of the laboratory. This is an especially straightforward direction, given that our institute already has a Kuka KR 5 Sixx series industrial robot which is currently under relocation. This robotic arm could be integrated either with the palettizing station, or with the rolling conveyor system (or with perhaps both). Of course, it would also be a very interesting research area to examine how this particular machine could cooperate with our existing AGV, especially with the manipulator arm of the latter. Joint collaborative tasks could be for example the loading and unloading of the boxes with cargo, which would naturally incorporate sorting tasks as well. Of course, such advanced capabilities would probably also require the utilization of further sensors in this case as well.

The previously described possibilities are just a handful of the multiple Industry 4.0 research fields that could be examined with the help of the introduced materials handling system. We hope that as the field of Industry 4.0 develops further, we will too have a continuously growing number of research opportunities which could be elaborated in the future through the aid of the presented laboratory.

The potential of the laboratory is also well illustrated by the level of interest which it generates in the relevant professional fields. For example, in the picture of Figure 8 on the next page, the capabilities of the materials handling system is demonstrated to the Hungarian

State Secretary of Higher Education (first on the left) and to the Director of the Institute for Computer Science and Control of the Hungarian Academy of Sciences (second on the left):

Figure 8. The capabilities of the laboratory is demonstrated to the Hungarian State Secretary of Higher Education (first on the left) and to the Director of the Institute for Computer Science and Control of the Hungarian Academy of Sciences (second on the left) (Source: created by the colleagues of the Institute of Logistics)

4. Educational applications

It is needless to say that the presented laboratory and its integrated materials handling system provides many educational opportunities as well. By becoming familiar with the different technologies and solutions which can be found in the laboratory, the students can also gain valuable knowledge in a wide range of different areas. Primarily, they gain relevant knowledge in logistics system design, based on Industry 4.0 principles. They can also study and witness the realization of various materials handling strategies in a real system, for example the implementation of the SMED (Single-minute exchange of die) method, which is a typical strategic tool in lean manufacturing and logistics [6]. Here, it must be also noted that the examination of various logistics strategies in the real system can be conducted together with the creation and running of a virtual simulation of the system, also called a “digital twin” in Industry 4.0 terminology [6].

Furthermore, the students can also familiarize themselves with the majority of the logistics solutions which are also utilized in real life materials handling systems. Besides, they can gain practical knowledge in multiple areas related directly to automated materials handling as well, such as certain fields of applied information science (namely robot and PLC programming), certain fields of automation, some subfields of electrical engineering and also of mechatronics.

Here, it is also important to note that our Institute runs multiple educational programs in which the laboratory plays an important role. These include our BSc and MSc logistics engineering educational programs and also or lean process engineering training program, not to mention our planned Industry 4.0 process engineering program. Finally, the laboratory naturally plays an important role in the training and research activities of our PhD students as well.

5. Summary and conclusions

In the paper, we provided a detailed overview of the High-Tech Logistics Laboratory of the Institute of Logistics at the University of Miskolc. The purpose of this overview was to demonstrate the wide variety of applications of a state of the art materials handling system, especially from the aspect of the Industry 4.0 concept.

As it was shown during the descriptions of the different subsystems, the possible applications range from the examination of big data based predictive maintenance approaches to the development of collaborative robotic solutions for cargo sorting and other tasks. The integrated materials handling system also proves to be a good basis for the education of future engineers, while it also provides various research opportunities for young researchers. Overall, the introduction of our laboratory provides a comprehensive picture of various industry 4.0 solutions, together with their implementation in a realistic and highly automated materials handling system. This can serve as a useful starting point for any researcher or professional who is interested in the development of Industry 4.0 based materials handling solutions and applications.

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