DESCRIPTION OF AN INNOVATIVE METHOD FOR THE INTEGRATION OF ROBOT CELLS WITH AUTOMATED MATERIALS HANDLING SYSTEMS

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Abstract: The aim of this publication is to present a process development method that enables the integration of automated material handling systems and robotic workstations in an innovative way. Given that, in line with the spread of the Industry 4.0 concept, the robotization of production is playing an increasingly important role today, the importance of such methods is constantly increasing, which is also well illustrated by the example of a possible application discussed in the article.

Key words: Industrial robots, materials handling system, system integration method, Industry 4.0.

Opis inovativne metode integracije ćelija robota sa automatizovanim sistemima za rukovanje materijalima.

Cilj ove publikacije je predstaviti način razvoja procesa koji omogućava integraciju automatizovanih sistema za rukovanje materijalom i robotskih radnih stanica na inovativan način. S obzirom na to da, u skladu sa širenjem koncepta Industrije 4.0, robotizacija proizvodnje danas igra sve važniju ulogu, značaj takvih metoda stalno se povećava, što takođe dobro ilustruje primer moguće primene o kojoj je reč u ovom radu.

Ključne reči: Industrijski roboti, sistem za rukovanje materijalima, sistem integracije, Industrija 4.0.

1. DESCRIPTION OF THE PROPOSED INTEGRATION METHOD

Typically, it is advisable to robotize tasks that are often performed according to pre-set rules, in a standard way, are not very complex, and are not among the most critical processes for the company. These are typically the tasks that need to be performed, but their execution does not cause a particular additional motivation for employees.

Requirements for the use of industrial robots are the followings:

- return on industrial robot investment within the time horizon set by the company,
- compliance with the cycle time prescribed by the company,
- is suitable for the assigned task,
- operation in accordance with safety regulations,
- compliance with quality requirements.

With the above in mind, a six-step robot deployment process is presented below that allows robots to be effectively integrated with the company's already-existing material handling systems.

1.1 First step: Determining the range of activities that can be performed using industrial robots

As a first step in the deployment of robots, it is necessary to determine which are the processes in which the possibility of human labor being replaced by robotization arises at all. Taking into account the characteristics of human work, it can be said that within a certain time limit they are able to perform the required tasks with great precision, as the carrying capacity and fatigue of the human body must be taken into account.

At the same time, the robots do not need to rest in addition to scheduled maintenance and periodic

calibration, they are able to perform their task even in non-stop mode with high accuracy and speed.

In general, it can be said that it is expedient to implement robots in production processes where the tasks are highly repetitive, the amount of parts to be machined is large, high precision and accuracy are required to perform the task, the task is burdensome for humans, or perhaps dangerous material are present at the worksite.

1.2 Second step: Detailed analysis of activities

In the second step of the process, it is necessary to analyze our activities in order to get an objective picture of the selection process in the later steps. In addition to the time differences in the timing of human and robot work, we need to determine whether the necessary conditions can be met to implement the robotic technology required to perform the work process, whether the task can be performed using an industrial robot. It needs to be explored whether robotics can be integrated into an existing process. It must be examined whether there is sufficient space available for the conversion of the workspace and the physical needs for operating the industrial robot must be provided.

In the case of a workplace to be robotised, it must be checked that in order to perform the task:

- how much space is available,
- how much load capacity is required,
- how fast it is necessary to supply the process,
- what movements are needed,
- what gripping equipment is required,
- what tools are needed,
- the capacity of the receiving party - the equipment served (what modifications are required),
- what environment - robot connection is required.

In line with the above, this step should place particular emphasis on regulations and standards for safe working. Industrial robots have a number of risks, as they are heavy-duty equipments and have rapid movements that can cause serious injuries to workers, working in the robot's environment. The following standards should be explored before starting the process of robotization

- Standard for industrial robots: ISO 10218-1, ISO 10218-2.
- Standard for collaborative robots: ISO/TS 15066.
- Regulation on the installation of robots and robot cells: 16/2008 NFGM.

These standards cover the design, installation, operation, and maintenance of an industrial robotic cell. It describes the basic hazards of these systems and sets out the requirements to avoid the risks. Prior to the robotic installation process, a risk assessment must be performed to identify the hazards in the industrial robotic cell. Then the cell should be designed and manufactured based on the results of the assessment. It is important to note that collaborative robots are subject to even stricter requirements than industrial robots.

1.3 Third step: Determining the range of industrial robots that can be used to perform this task.

As a third step in robot deployment, we need to select the group of industrial robots that can be applied to our production process by meeting the previously defined parameters. In case a suitable industrial robot is not available within the company to perform the task, it is necessary to examine the equipment offer of the robot manufacturing companies, if necessary, to use the services of the manufacturers to help select the necessary equipment for the task.

1.4 Fourth step: Selection of industrial robots that can be used to perform the tasks.

At this stage of robot deployment, the previously selected industrial robots should be evaluated depending on the shortest return on investment. During the selection, we have to determine from the possible variations the industrial robot that best fits the task to be performed at the given workplace. If necessary, the selection process can be implemented by simulation and return calculation, their joint application can be a good practice, but first it is necessary to define a decision method, the aspects of which can facilitate the selection of the appropriate industrial robot.

The decision method should be based on the following possible objective function components to be minimized:

- Payback time: Determined by formula (Static indicator).
- Space requirements for the use of an industrial robot: It can be determined by a detailed analysis of the parameters of the industrial robot and the task to be performed.
- Implementation time required: Can be determined using the steps of the current integration method.

The decision method should also take into account the following possible objective function component to be maximized:

- Maximum number of work cycles that can be performed per unit time - can be determined using simulation software.

In many cases, the objective functions are illustrated by simulation in accordance with modern Industry 4.0 principles. The use of computer software for this purpose can have a number of advantages, as certain processes and production lines, but possibly entire parts of the plant, can be virtually created, simulated and optimized with their help. One of the most important advantages of using software is that the entire production process can be completed before the start of the investment, thus eliminating losses and problems during process implementation. Such computer software includes, for example, Plant Simulation, one of the strengths of which lies in the modeling of very large scale industrial processes, e.g. the operation of manufacturing systems or warehouses.

Fig. 1. Plant Simulation (Source: [1])

Another commonly used software is Visual Components, one of the greatest strengths of which is its ability to simulate workstations and operating units in great detail. The robotic programming function included in the software provides an opportunity to precisely model and optimize the workflow of a robotic workstation.

Fig. 2. Visual Components (Source: [2])

With the help of these software, the required objective functions (the maximum number of work cycles that can be performed per unit time) and the entire robot installation process itself can be properly modeled. When examining work cycles, we use simulations to check how long the robot is able to complete a given task, which is usually faster than human cycle time. Machining accuracy, and thus the reduction in scrap, can also be modeled using software, as both frameworks include a function for exploring the possibility of errors.

1.5 Fifth step: Preparation of an implementation plan

During the preparation of the implementation plan, we have to take into account several aspects in order for the last step of the robot installation, the implementation of the industrial robot, to be realized without any problems. The implementation plan should include:

- definition of tasks,
- preparation of a schedule,
- setting deadlines,
- appointment of those responsible for tasks,
- designation of persons approving the tasks performed,
- assigning additional people to tasks (support, information provider, consultant).

1.6 Sixth step: Implementation of industrial robots

Once all the preparations for the implementation of the industrial robots have been made, the implementation of the schedule can be started using the information and instructions of the previous steps. The schedule for the implementation of the selected industrial robot is critical for the smooth operation of production processes. It is necessary to schedule properly in which period it is advantageous to implement the development, as the goal is to stop production only for the necessary time due to the installation processes, thus minimizing the production loss due to the state of the production line.

2. INTRODUCING AN EXPERIMENTAL USE CASE

We believe that the High-tech logistics laboratory at the Institute of Logistics of the University of Miskolc provides an excellent opportunity for the experimental application of the presented integration procedure, which includes several advanced material handling systems, thus offering various possibilities for a possible robot integration.

Another reason for why the above-mentioned laboratory provides an excellent opportunity to test the method is that because the institute also purchased a KUKA KR 5 Sixx R650 industrial robot in 2006, which was originally put into operation in the Integrated Product Identification laboratory of the Institute's (then known as the Department of Material Handling and Logistics). Recently, however, due to the transformation of the laboratory infrastructure at our institute, it has become necessary to examine how this robot could be integrated with the automated material handling system of the previously mentioned High-tech logistics laboratory, so the problem naturally arises essentially due to the recent organizational transformations.

The KR 5 Sixx R650 is a classic light-duty industrial robot designed primarily for moving and machining workpieces in a dry room. The machine has 6 articulated shafts, the location of which is shown in the schematic diagram of the equipment (Figure 3) [3]

The robot has a load capacity of 5 kg, an unladen weight of 127 kg, a horizontal projection of 650 mm and a repeatability of ± 0.02 mm [3]. The main characteristics of the movements along the axes are summarized in Table 1. [3]

Fig. 3. Location of the 6 axes (Source: [3])

Axis	Movement speed	Roll
A1	375 °/s (6.54 rad/s)	$\pm 170^\circ$
A2	300 °/s (5.24 rad/s)	$+45^\circ - 190^\circ$
A3	375 °/s (6.54 rad/s)	$+165^\circ - 119^\circ$
A4	410 °/s (7.16 rad/s)	$\pm 190^\circ$
A5	410 °/s (7.16 rad/s)	$\pm 120^\circ$
A6	660 °/s (11.52 rad/s)	$\pm 358^\circ$

Table 1. Main characteristics of axial movements (Source: [3])

The High-tech logistics laboratory itself 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 [4].

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.

Fig 4. The palettizing station in the foreground, together with the mentioned systems in the background (Source: created by the authors)

It is important to note that while it is not present on the picture of Figure 4, yet the system is also

complemented by an automated guided vehicle (AGV). 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.

Fig 5. The automated guided vehicle (AGV) of the laboratory with its robotic arm (Source: created by the colleagues of the Institute of Logistics)

As it can be seen from the previous descriptions of the Kuka KR 5 Sixx series industrial robot and our High-tech logistics laboratory, there are multiple options for integrating the robotic arm with the material handling systems of the laboratory. For example, the robot could be integrated either with the palettizing station, or with the rolling conveyor system, or perhaps with both. In this latter case, the robot could facilitate automated cargo transfer between the two subsystems, which would open up a wide range of new materials handling strategies that can be tested in the laboratory.

Of course, it would also be a very interesting research area to examine how this particular robot 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 case of both machines as well.

As soon as the circumstances allow it, we hope that we can implement the integration process according to the previously described method, which would result in a significant advancement in the capabilities of the laboratory. Besides, it would also validate the applicability of the method, thereby opening up the possibility of using it in industrial projects as well.

3. SUMMARY

Within the framework of this publication, we presented an integration method for robotic workstations which includes the detailing of the

requirements for the use of industrial robots, the most important objective functions of the implementation of robots in the production process, the evaluation of the advantages, difficulties and limitations of the implementation and the preparation and execution of the implementation plan.

In the following, we would like to examine the implementation of industrial robots in production processes through a practical example, using the method we have defined. The integration of the automated material handling system installed in our laboratory and the presented Kuka KR 5 Sixx industrial robot can provide a good opportunity for this, as on the one hand it can validate the application of the method in practice and on the other hand open the way for further practical applications. We think that as the Industry 4.0 principle induces the robotization of manufacturing at a continuously increasing pace, likewise the application possibilities of the presented method will going to be increasingly wider as well.

4. REFERENCES

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