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Robot learning through observation and measurement in production process

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Abstract. The aim of the presented research is to to verify the hypothesis of the possibility of robot's learning, through observation and measurement, to perform production tasks. At present, the role of industrial robots in majority still comes down to precise re-enacting movements in accordance with changeless, strictly defined programme. The robots' adaptivity is the next step in the pursuit of automation of manufacturing operations, ensuring the high level of safety and productivity. The development of robotics towards the adaptability and machine intelligence requires the effort to automate the processes of the identification and analysis of actions, as well as drawing conclusions concerning their outcomes and the way of their performance. Such capacities are necessary for the autonomous operation of machines, consisting in shaping and applying operation patterns in particular circumstances. Assuming that, as a result of the research, the pattern of operations allowing the machine learning in the suggested way would be elaborated, the new paths of development in the industrial robotics would emerge. The article concerns the main concept of solutions and the plan of the research leading to the definition of the principles of the process of robot learning, through observation and measurement, to perform production tasks.

1. Description of conducted research

In the process of robot's learning to perform manufacturing-related tasks, the essence is not the machine's mere repetition of actions - what matters is to analyse what and with what effect is performed, and to translate it into robot's work. It is a task-oriented approach, entailing machine intelligence and autonomy in terms of conducting a process so that the expected result of the actions is delivered. What constitutes the inspiration for the described way of machine learning is the cognitive process occurring in nature, among, inter alia humans, which is based on the observation and identification of changes in surroundings [1]. Mechanisation and automation use machines to perform tasks originally executed by a man; yet, the pursuit does not concern precise re-enacting the way in which they are performed. Despite the anthropomorphic design of manipulators, due to their measurement and executive capabilities, in robotics executive processes present different characteristics than in the case of man's work. The primary problem consists in clarifying the principles of robot's learning, that is to say, defining what needs to be monitored and how it should be done, and how to process acquired information.

1.1. Working theory

The objective of the research is to verify the hypothesis of the possibility of robot's learning, through observation and measurement, to perform production tasks. It is assumed that the process of machine's acquiring information concerning the performance of technological activities can take place in a way similar to observational learning in humans.

2. Research schedule

The work is conducted in line with the below-presented schedule. It is the listing of the major stages of the research implementation, consisting in the set of various activities. Their performance is to allow to meet the detailed research objectives, allowing the ultimate verification of the proposed hypothesis.

1. Conducting the meta-analysis of the researches the subject matter of which is similar to the examined issue, with regard to the knowledge about the possibilities of robot's learning through observation and measurement
2. Identifying problems related to the examined issue and suggesting their solutions based on the available knowledge and author's own concepts
3. Developing pattern of operation which would allow a robot to learn, through observation and measurement, to perform production operations
4. Analysing the possibilities of designing and implementing systems for the performance of activities which are necessary in the examined process of robot's learning
5. Preparing the laboratory station for conducting experiments related to the practical verification of the developed rules and procedures
6. Applying computer simulation tools for the experimental verification of the developed way of conducting the process of robot's learning
7. Applying a physically existing industrial robot on the laboratory station for the experimental verification of the developed way of conducting the process of machine learning
8. Conducting, on the basis of learnings from the experiments, the validation or the adjustment of the developed pattern of operations which would allow a robot to learn, through observation and measurement, to perform production activities
9. Recapitulating the project, drawing conclusions related to its results, and verifying the suggested hypothesis

2.1. Expected results

The deliberations on the suggested subject are intended to develop the model of the process of machine learning in the described way (if the presented hypothesis is proved to be correct) or to substantiate that the adopted conception is inadequate, and to identify the problems related to its implementation. It is presumed that, as a result of the conducted work, new knowledge in the field of artificial intelligence in industrial robotics will be acquired, constituting the foundation for conducting applied research and inspiring further concepts and scientific work.

3. Significance of research

The concept of robot's learning to perform manufacturing tasks, being the subject of the researches, concerns the development of artificial intelligence in robotics. At present, the role of industrial robots in majority still comes down to precise re-enacting movements in accordance with changeless, strictly defined programme. The robots' adaptivity is the next step in the pursuit of automation of manufacturing operations, ensuring the high level of safety and productivity. The demand for solutions enabling the facile adaptation of tools to changes in manufacturing processes is noticeable [2]. In many market sectors, the characteristics of manufacturing shifts from mass production to the unitary one, related to the exact parametrisation of a product by an ordering party, and thereby demanding more frequent modifications of the operation of machines. The concept of man and machine cooperation is also becoming increasingly popular, and the key to it lies in accurate

reading of man's movements and reacting to them, so that the cooperation is possible and runs in a safe way [3]. The development of robotics towards the adaptability and machine intelligence requires the effort to automate the processes of the identification and analysis of actions, as well as drawing conclusions concerning their outcomes and the way of their performance. Such capacities are necessary for the autonomous operation of machines, consisting in shaping and applying operation patterns in particular circumstances [4, 5]. Conducting the presented research is to result in the identification of the correlations and procedures concerning the described process of robot's learning, which could constitute a foundation for subsequent implementation work. At the further stages of considerations there will be searched the possibilities of the technical implementation of a robotic system for the performance of assumed tasks. It concerns, among others, ensuring the appropriate levels of accuracy and speed of measurements and calculations, permitting the entire system to work properly. In the long term, the acquired knowledge could serve in order to apply robot's learning through observation and measurement in specific manufacturing processes.

3.1. Current state of the art

Scientific resources describe the methods of learning typical for living creatures. Generally, the standard, man-supporting mechanics and control engineering systems differ in their construction and way of operation from natural patterns, which is often caused by technical constraints. Thus, it is necessary to prospect for and examine conceptions allowing the implementation of certain phenomena – learning, in this case – into the operation of machines. For engineers, nature constitutes great inspiration; and the inclination to recreate particular processes with the help of devices contributes to new discoveries and elaborating increasingly advanced technical solutions. In the field of robotics-related considerations, the methods of functioning of men and machines overlap, for instance due to the issue of their cooperation, constantly gaining in popularity. The emphasis is put on the operation of robots in the task-oriented mode, in which what is strictly defined is not the way of performing some tasks but what their result is supposed to be. In the examined case, the problem consists in determining the type and way of implementing actions thanks to which the robot, based on observation and measurement, would acquire information on the course and result of given actions, learn how to achieve the result and could refine its work. It is necessary to determine the principles concerning the observation of elements in robot's surroundings, the type of measurements and accuracy with which they would have to be performed, the priorities during the monitoring of individual parameters and creating all correlations necessary for the efficient conducing of the described process of machine learning. The methods of all operations being the components of the presented robot operating mode have to be closely adjusted the specific conditions and requirements related to the performance of manufacturing tasks. In various application areas there exist certain solutions of the problems similar to those related to the presented issue. At the further stage of work, these solutions shall be verified with regard to their suitability in the examined circumstances and, if necessary, their modifications will need to be put forward, so that it would be possible to apply them in the pursuit of the assumed objectives.

3.2. Impact of research project on development of science

Th exploration of the issue of robot's learning, through observation and measurement, to perform manufacturing tasks is to lead to the development of the new way of operating industrial robots. Instead of the textual programming of actions the robot is to perform, their demonstration appears in the assumed robot's working practice. As in the case of human learning, the machine would record events composing the performance of a given task, and, based on the collected information, it would determine what should be done and how to do it in certain situations in order to achieve a desired outcome. This is the way in which formulating the commands to be executed by the robot would take place. The development and, afterwards, the implementation of such a mode of robot's work would be an innovative achievement, which would have the potential to change the way of functioning of these machines in industrial conditions. The observation of the behaviour of objects

within the robot's surrounding would be the source of information concerning the necessity of taking specified actions in given circumstances. The process of learning would permit to develop movement patterns, ensuring the avoidance of collisions and other hazards. It would extend the possibilities of sharing the workplace by men and machines in situations in which today physical barriers are still used due to safety issues. Similarly to a man improving his capabilities through the experience in the performance of work and the analysis of its results, the robot would also be able to verify its movements and trajectories on an ongoing basis in order to advance them. The development of robotics in this direction could result in the situation where industrial robots would automatically adopt their actions to changes in the environment (caused by, for instance, the activity of men or other machines in their working area), since they would learn how to react to changes so as to maintain the high level of security and efficiency.

Assuming that, as a result of the implementation of the further research work, the precise pattern of operations allowing the machine to learn in the suggested way will be elaborated, the new paths of development in the industrial robotics may emerge. The suggested solution would constitute the foundation for creating new, more simply to use interfaces of robot control. The considerations are to concern the automation of the procedures of gathering information related to given activities and translating them into the operation of the robot which would perform those activities. It would allow to apply robots in the areas where, at present, the difficulties in robot's reprogramming due to frequently changing work cycle and conditions constitute the contradictions. The described manner of industrial robot's learning would bring machine methods of receiving and processing information closer to those used by people, which would facilitate substantially handling the machines and addressing commands to it. The learning would consist in the demonstration of activities to be performed by the robot; thus, in its nature, it would resemble training an employee [6]. The technical capacities of registering and processing data would condition the rapidity and effectiveness of machine's analysing examples, creating, on the basis of them, the expected operation logic and perfecting the robotised manufacturing processes. It cannot be ruled out that those actions would be performed in shorter time and would provide a better outcome in comparison to when people perform them. The robot, automatically learning through observation and measurement, would allow its quick and easy adaptation to the performance of various production tasks, to the cooperation with a man or another machine or else to replacing a man in those situations where a risk to health or safety is posed. What plays a significant role in the functioning of the analysed robotic system is monitoring the surroundings and the automatic control of activities, which are supposed to reduce the risk of errors and accidents [7]. Hazardous situations are often caused by the unpredictability of certain phenomena at the stage of programming a robot using popular, traditional methods. Nevertheless, if the robot has a possibility of learning, its database of procedures is enlarged with each and every new registered occurrence, which increases the possibility of its correct reaction in the given circumstances.

4. Result of to date research work

From the preliminary analysis, conducted while developing the generic concept of the described issue, there emerges the existence of a tendency to develop robotics in the presented direction [6]. The possibilities of machines' automatic adaptation to the requirements of implemented processes are increasing. This phenomenon plays a crucial role in the correct functioning of, growing more and more popular, human-robot cooperation, the area of which is constantly expanding. Various measurement methods are being implemented and perfected in order to enable the efficient registration of occurrences within the robot's working area. Owing to artificial intelligence, the machines are starting to work autonomously, they have the capability of learning how to react adequately to miscellaneous external factors, and their operation is being simplified [8]. All indications are that elaborating the issue of robot's learning in the suggested way constitutes the next stage of the development of product robotisation. Solutions which may prove helpful in materialising the followed idea of robot's learning concern mostly the non-industrial application. On the basis

of the conducted analysis, it was assumed that it would be possible to make those solutions accommodated to the requirements concerning the manufacturing operations which entail high precision and efficiency, with the safety being maintained at the same time [3]. Observation and measurement, which are crucial in the examined process, are to take place entirely in a contact-free way. Contemporary robotics is familiar with the machine learning methods related to the mechanical transmission of information. The examples include defining the movement pattern of a manipulator by guiding its arms manually, or demonstrating a movement in a haptic glove [2]. Yet, there exist vision and sensor tools which enable contact-free gathering of information concerning the geometry, location and dislocation of objects within the monitored area. The studies of their capacities show that they allow the registration of data being indispensable in the process of learning through observation and measurement [3]. Conclusively, the gathered knowledge provides ground to claim that the selected direction of research is pertinent and the presumed outcome is achievable.

4.1. Model of examined process

In the first, heretofore carried out phase of the research, the theoretical considerations were conducted considering the structure and principles of the operation of the system allowing machine learning of the performance of manufacture tasks through observation and measurement. The preliminary analysis shows the general adopted pattern of the robot's operation in the described process, as shown in the figure 1.

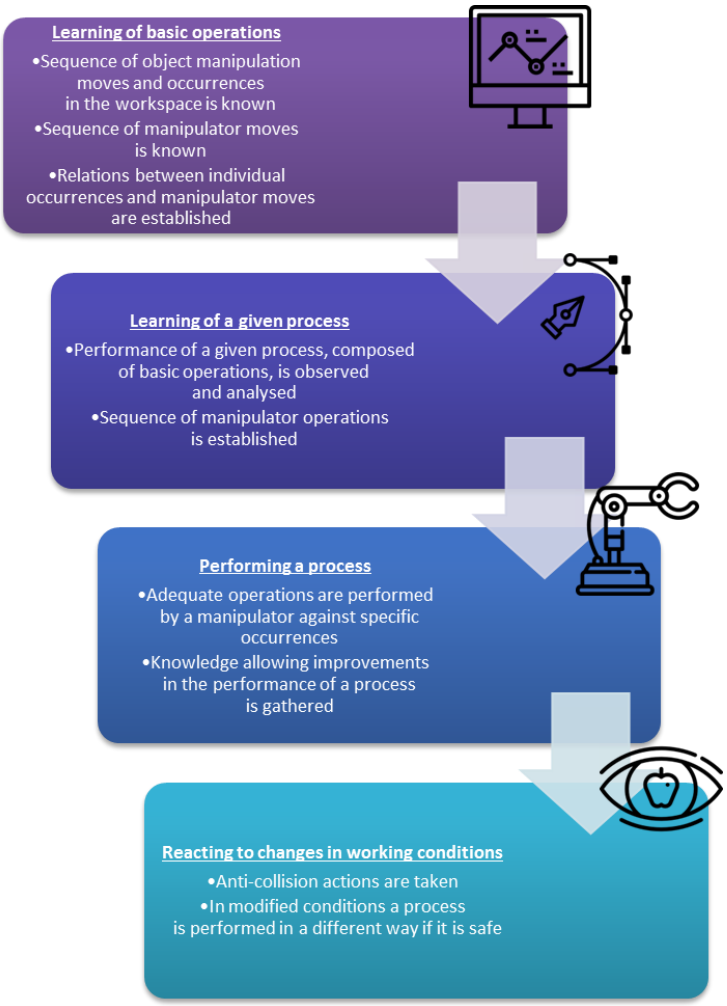

Figure 1. Diagram of learning process and performing actions in considered system.

The diagram as presented in the figure 1 refers to the situations in which an industrial manipulator learns to perform production tasks, being composed of a sequence of basic operations identified by the robot. Materials which will be examined in this part of the project are scientific publications regarding the application of machine learning in robotics, artificial intelligence and surroundings monitoring techniques. Conducting the analysis of the outcomes of the researches the subject matter of which is close to the presented issue allowed to verify and adjust the assumptions regarding the way of executing individual operations within the process of machine learning to perform production tasks with the application of methods being taken into consideration. It provided a basis not only for the elaboration of the generic rules according to which the process should take place, but also for the pre-definition of the procedures which are necessary in order to achieve the desired results. This knowledge is indispensable so as to execute further actions, as listed in the presented framework of the research.

4.2. Concepts of systems in examined process

The preliminary configuration of the robotic system was adopted allowing to run the considered process in line with the principles set forth in the first phase of the research. The subject matter of the further considerations shall, among others, consist in the way of the efficient performance of the observations of the surroundings and the measurement of relevant parameters, as well as of creating an artificial intelligence system operating in an expected way, all with the application of available tools. It is reasonable to clarify the guidelines regarding the technical aspects of functioning of the examined robot's operation mode in the industrial conditions. On the basis of the hitherto analysis, it was determined what elements should form the examined robotic system. Figure 2 presents the particular components of the described system.

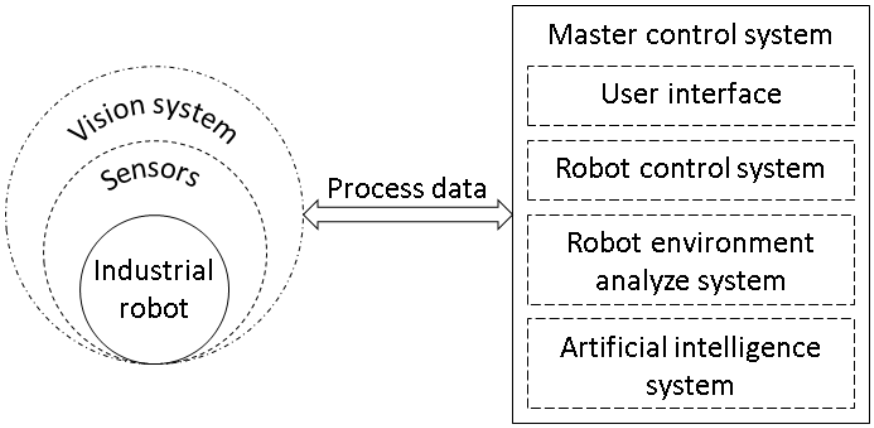

Figure 2. Diagram of considered robot learning system.

It was initially assumed what kind of measurements could make it possible to acquire information about the robot's surroundings necessary so as to the examined process of machine learning is conducted efficiently. These are the measurements of the distance between the robot and the elements which surround it, the vision registration of the surroundings and the 3D scanning of the area of work. Their role has been symbolically depicted in figure 3.

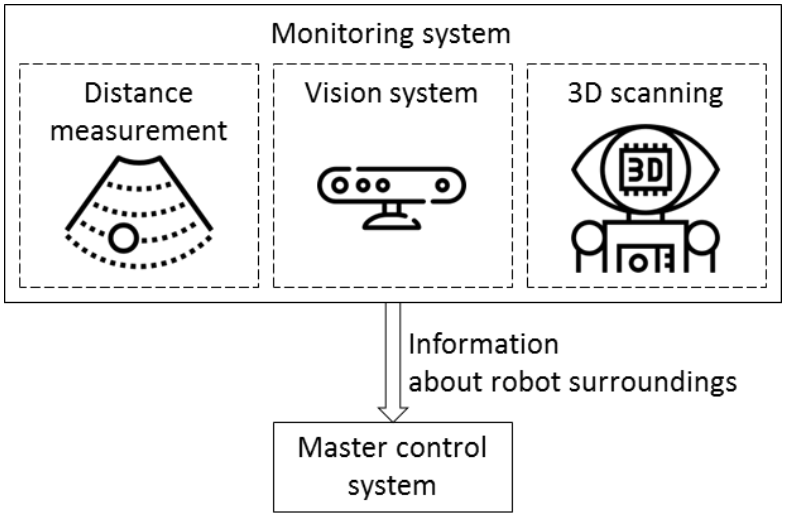

Figure 3. Diagram of monitoring system.

Using figure 4 the preliminary adopted structure of the information flow and creating correlations in the artificial intelligence system, which would be an element of the described robotics system, was presented.

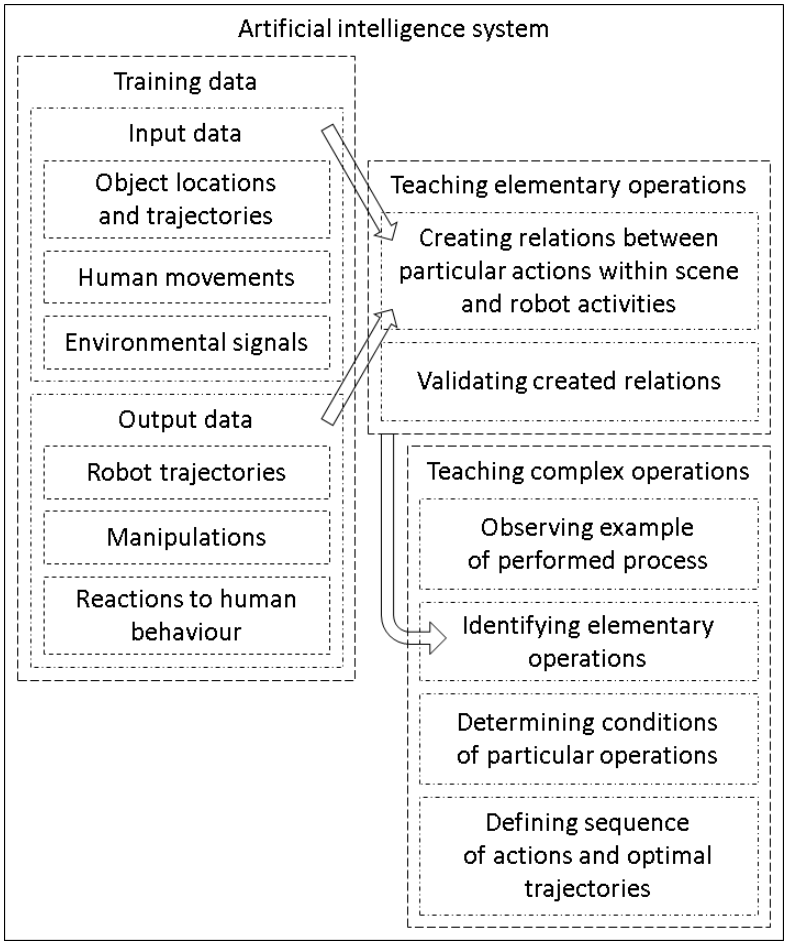

Figure 4. Diagram of artificial intelligence system.

It is planned to create computer programmes for processing registered data and implementing the process of machine learning and robot control with the use of the artificial intelligence systems.

5. Conclusions

The presented general assumptions, concerning the solutions which are to allow to conduct the examined process, shall be verified and specified at the further stages of the research. It shall permit to shape the guidelines concerning the technical aspects of creating and configuring the system of devices allowing performing individual actions of the process of machine learning through observation and measurement. The data is essential to conduct the experimental phase of the research, in which the theoretically determined rules shall be assessed in practice. The trials of the industrial robot's functioning in the assumed way are to be conducted, with the application of the elaborated tools. Based on the results of the tests, it will be possible to determine the effectiveness of these solutions and, in the case of discrepancies between facts and expectations, the aspects on which incorrect assumptions have been made will be reconsidered. The solutions which are to be the result of the presented research constitute the innovation and, in order to be able to describe them meticulously, it is indispensable to articulate reliable learnings, strengthened with relevant experiments.

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