COOPERATION BETWEEN HUMAN AND AGENTS IN HOLONIC MANUFACTURING SYSTEMS

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Abstract: The current development in production is directed towards a system called socio-cyber-physical, where humans, machine facilities, materials, technologies and the environment work together. Processes in companies are enrolling in a platform called Industry 4.0. Production is more similar to a living organism where the planned dynamic in the field of logistic and production elements of the system are exchange by emergent dynamically moving fully adaptable autonomous agents. Agents are plant facilities that have software implemented with decisions rules and are not control by human. These autonomous agents communicate and interact with each other in a protocol. In the factories of the future, presence of humans is also predicted and therefore the humanization of communication and interaction between human and agents of system must be considered. The human becomes a living agent who will communicate with others and collaborate to achieve goals. In individual workplaces, agents will serve and support humans in service, production, inspection, supply etc. but also a human will do that for agents. Although production will behave Emergent it is necessary that the activity of agents support the activities of humans in the workplace and that is not possible without communication. In this point there is a need for mastering the communication between the human and the agent and this can be done through Chatbot systems. This paper is aimed at designing a potential coordination system between humans and agents in factories of the future by using Chatbot systems.

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Introduction

In the current market-based world of competition, adaptability is one of the key elements of success. The current production concepts appear in a point where production is not able to react well to market turbulence, and if so, on a limited scale. New production concepts are aimed to provide solutions that will help to respond to rapid changes from the environment. Adaptive production systems represent a new generation of systems capable of rapid response. At present there are many of these systems in the development phase: reconfigurable production systems, island of competence, Multi-Agent Systems (MAS), etc. All these new concepts are calculated with the active use of agents as the main design element. When considering agents, there is a certain form of autonomy in decision-making and self-behaviour. Such production system can be labelled as a Holonic Manufacturing System (HMS). According to Bubeník (2014), a HMS is a system where the normal centralized management is replaced by a decentralized agent. The holonic organization, also called holarchy, allows for the formation of complex systems that are highly effective. The agent can represent a robot, mobile robotic systems (MRS), Mobile automated Platforms (MAP), modular manufacturing equipment, conveyor, manufacturing buffer, buffer of tools, product, human, etc. The human remains as an important element in such systems. Other agents outside of the person have their own autonomy and create emergent behavior. Under the term, Emergence is understood the spontaneous formation of macroscopic properties and structures of complex systems, which is not easy to deduce from the properties of their components. Such properties and structures that arise from a number of relatively simple interactions are called emergent. In production, emergence occurs due to the interaction of autonomous agents that create complex systems. When a system is emergent, it is difficult or impossible to predict the future behaviour of such complex systems. A person who is a participant must have the information they need to work. This assumption according to Jánošíková (2018) is very important because Emergence bring

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chaos to managing crisis tasks. Here, appears a question if the agents are adaptable to changes from the surroundings, can the same rules be implemented to human? Because if we create a living agent, they can then interact with others. According to Wooldring (1995) a flexible agent is capable of autonomy, reactivity, proactivity and socialization. A human is capable of the first three properties in the agent environment, but socialization with other agents must be managed. In this case, there is a need for standardization in this field of communication with other agents but also there is a need for humanization in the area of displaying information (Gašová, 2017). It is important that this communication is understood by both the human and other agents at the same time. It is also necessary to resolve the way how information is received and shared with other agents. A human as a member of the system will affect the threshold sensitivity of such a system. The threshold sensitivity is change by influences from the external environment and is individual for each entity of system. A human as a member of an HMS will influence its behaviour in a significant way. Therefore, the integration of humans and other agents within the HMS must be ensured in the development of systems. Similar questions and inspirations for managing communication between agents and humans come from the automobile industry. Many new autonomous cars are independent and communication between the human and the car comes from sensors and voice commands or a touch display (Otto, 2018). The aim of presented article is the description of a possible communication between a human and a agent through Chatbot systems in HMS of the future to ensure cooperation in an emergent environment.

Multi-Agent Systems

The internal dynamics and emergence in the complex system are created by agents and by their interaction. For the management of complex manufacturing systems, it is therefore advantageous to use a Multi-Agent System. Manufacturing is nowadays more understood as a complex system on which a holonic concept can be applied, and that is why research in the field of HMS has begun. Some authors (Christensen, 2003) refer to such systems as Agent Based Manufacturing (ABM).

Holonic Concept

The holonic system can be seen as a system consisting of subsystems, but at the same time the system is part of a larger whole (system). A set of holons with their characteristics creates a holonic organization called holarchy, which is characterized by the tracking of common goals. According to Mičieta (2018), a holarchy allows the creation of structures and the representation of behaviour in complex systems, often referred to as social systems.

System autonomy guarantees the holonic stability and ability to efficiently resolve system turbulence. The holonic production systems according to Giret (2008) have several of the following characteristics:

- Autonomy – Each of the holon must be able to generate management (monitoring) actions and implement measures to ensure systemic stability through their own plans (strategies).
- Co-operation – The holon must communicate with each other, implement acceptable plans and transfer actions.
- Openness – The system must be able to adapt the integrations of new holons, the procurement of existing holons and the modifications of the ability of current holons.
- Reconfigurability – The ability of a holon to quickly and cost effectively change its functionality.

The HMS architecture, using Multi-Agent Systems, was designed by Bussmann (1998). A holon is basically a set of tasks that can be within different organizational units generated by agent interactions. The elemental particle of the holonic system is represented by an intelligent agent. Intelligent agents are independent and autonomous systems that carry out their nested functions. They can represent hardware and software systems. They can educate each other and work in real time at the same time. The agent consists of three main components: perception, recognition and action. The purpose of perception is to receive data inputs through sensors and provide them to the recognition module. This process can be based on filtering and priority rules (the importance of the task).

Recognition is based on the processing of inset information and decision-making rules. This process may require different methods of intelligent systems, such as the implementation of appropriate learning. The recognition mechanism must also be able to settle with unexpected situations and adapt to new situations as quickly as possible within its competence. Due to this fact, the agent must have a very dynamic and flexible structure.

Through action are realized commands (recognition), such as walking of the robot or stopping it automatically when identifying the spatial barrier. During the agent action, the signals of the environment can be changed when new information is obtained. This may be immediately perceived by another agent who registers the situation, evaluates and subsequently implements the relevant actions (Pedan et al., 2017).

Adapting Communication of Autonomous Agents to Humans

In the past, production systems were managed in a centralized method. Current and future production systems are complicated and with the increase of interaction has become more complex. However, even with the complexity of the systems, we have been able to estimate the future behaviour of the system and its elements. This means that communication in production was personal and the language of the communication and tools were known. If the worker needed a change in the behaviour of a system he consulted with the worker from a superior element, after the approval process change was implemented. Such a change could be a change in the supply route, change of workplace layout, machine settings, and so on. Such approach was granted through a centralized management system. The benefits of such system were that the worker, on demand for information, knew when the material came, how high it's stock was, what was his role and how the individual parts of the production process were moving in the space (Mleczko, 2014). The reason why there is a higher demand for new production concepts is in particular the low efficiency of such activities, failure of the information chain, local troubleshooting, non-data processing, inability to find context in data, etc. In this control of production, human interactions in the local or world language were mostly used. Newly developed concepts that used agents that are characterized by autonomy in their decision-making and interaction with other agents and it is important to include the human factor in communication.. Communication that takes place between agents is in the form of a communication protocol that is almost unreadable for the dependent worker. Agents are behaving Emergence, a worker is not able to predict the future behavior of system elements (agents). If we want to ensure the interaction between agents and humans, it is necessary to find a suitable way of communicating between them. At present, different Chatbot systems are used to communicate between humans and machines. These allow, based on simple demand, entering information into the system and retrieving information from the system, Figure 2.

Figure 2: Communication scheme via Chatbot system

Source: Gregor, Gregor (2015)

There are now many solutions to ensure translation of demand on request. Some examples which are applicable in the industrial environment are:

- NADiA – Network Neural virtual agent for human and Machine communication (Neurally Animated Dialog agent), according to Wu et al. (2018) it is a conversational agent that relies on a neural network that can understand, recognize, and generate verbal phrases. It allows verbal input of the user as well as capturing human facial expressions and responding to them through a meaningful way. Its advantage is that it needs only limited computing power. This enables it to be deployed in small-size phones and devices, as well as in robotic systems. It can create a machine communication protocol from human verbal input and, after answering, translate this machine protocol into a person-intelligible language.
- KNADIA – KNowledge assisted DIALOGue Systems, according to Singh et al. (2018) is a system of assisted dialogue using deep learning that allows hundreds of demands per day. It allows enterprise employees to obtain information or knowledge stored in a database. These can be released based on demand. It is currently being used by Tata Consultancy Services.
- syra Bigdatachat – This is not a software as such, but the service offered by ThirdEye. It provides a BIGDATA mining design tailored for a company. It is a cloud-based service, which on demand can search for the necessary data and also interpret demands (ThirdEye, 2019).

For each Chatbot system it is important to have a normal language translated into the machine demand language; only so it will be guaranteed that the user not only receives the information but also shares it. In order to avoid incompatibility of the displaying and communication tools, the communications processes between the workers, agents and the agents themselves must be standardized. This will ensure that there is no longer any incompatibility between the individual manufacturers of the agent systems in the production itself.

Interaction of Human and Autonomous Agents

“Interaction” means how the worker enters and receives information from the Chatbot system. The chatbot system can be or not be placed in the communication hardware. A Chatbot system is only needed to communicate with the hardware. Under the term “hardware” are tools for human Chatbot software interaction. The user interface is an important element of communication. Information can be presented through:

- Digital display – This interprets the information in visual form or sound form (static display, SMART watch etc.).
- HMD – Glasses for augmented realities can display information on the protection glass field or directly on the eye retina.
- Headphone Device – In this case, the information is not visualized but only given in audio form.

- In the future, there will be an important role in displaying information by holograms. Their research is, however, at a stage where their more extensive use in industry for the present is costly. Connection between humans and agents can be seen in the following Figure 3.

Figure 3: Communication human – agent via Chatbot system

Source: Authors

Figure 4: Chatbot system as a part of MAS but also as data input for the Distributed control system

Source: Authors and Gregor, Haluška, Grznár (2018)

A person communicates with a Chatbot system through a hardware device that serves as a user interface to input and output information. The Chatbot behaves as an agent and communicates with other agents via IoT to fulfil its role, which is the demand for information in the system or its transaction to the system. The Chatbot can use the AI service as a cloud service for this role, it can search for correlate using Big Data and demand for other information (Özçekiç, 2017). Based on all data interference mechanisms, the information obtained is interpreted by the user through a hardware device.

The architecture of Human-Agent Cooperation

In holonic manufacturing systems, elements of manufacturing systems do tasks autonomy through cooperation/negotiation with other elements because they want to achieve common goals. These common goals can be common for the worker or for any non-living agent-based machine. Once the non-living agent-based machine and worker have a common goal there is a need to transfer information between them. The primary use of the design architecture is to outline future connectivity between agents and humans. Intelligent monitoring and control system architecture is common for all non-living agents, but final behaviour of the agent depends on the tasks. The Chatbot system is also part of MAS and can obtain information through the architecture but the Chatbot system is also a data input for the Distributed control system controlled by a human Figure 4. With the Chatbot system, a human is connected through hardware. After an inquiry, a human obtains information which was mined based on the index after the chatbot system translates the speech to the keyword index.

Conclusion

Humans will play an important role in the Holonic Manufacturing Systems of the future. In emergent systems, a significant problem is to predict the behaviour of such complex systems. In factories of the future, most factories will be complex systems and will use agents. In such systems it is very difficult for humans to do task without information from system. Current manufacturing is from a point of view that communication a coordination is without problems because machines do not have self-control and are control by humans and behaviour in such systems is predictable. But new emergent manufacturing systems will work with agents. Human places do not replace fully robotic equipment, but the human will carry out activities that will cooperate with other elements of the system (agents) in order to achieve their common goal. Agents are kept emergent, which complicates the work of humans in such systems. It is necessary to find ways to fully implement a person into new manufacturing systems to be able communicate with the other agents in order to increase the effectiveness of the activities. Chatbot systems are shown as being suitable for dealing with communications between humans and various agents. They can be based on certain mechanisms and provide a clear presentation of information. At the same time, they allow a human to import information into a system that helps autonomous robots to make their own decision.

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