Use of Artificial Intelligence in Slovenian Manufacturing Companies

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This paper deals with the current state and research trends of artificial intelligence in manufacturing companies. The main objective of the paper is to determine the adoption of specific artificial intelligence software in manufacturing. The results are based on a subsample of 141 manufacturing companies that are located in Slovenia. The data were gathered, obtained through the 2022 European Manufacturing Survey research project. The results show that the use of artificial intelligence differs heavily in specific manufacturing areas. The paper also presents the plans of Slovenian manufacturing companies in terms of introducing artificial intelligence software solutions by the end of the year 2025.

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1 Introduction

Artificial intelligence (AI) refers to a group of scientific disciplines and techniques that seek to mimic the mental abilities of humans. Although it may seem like a relatively young discipline, research and development in this field dates back to the Second World War, when Alan Turing and Warren McCulloch laid the foundations for so-called intelligent machines. The term "artificial intelligence", dates back to 1956, when it was coined by John McCarthy at a conference at Dartmouth (Council of Europe, 2024). While the technology represented enormous potential and interest for both academia and investors as early as the 1960s, it progressed only slowly over the next few decades, due to the inadequacy of computing power. In recent years, however, computing has undergone rapid and intense changes, which have led to an increase in the computational power of computers, and, consequently, to the rapid development of AI. OpenAI was one of the first companies to offer a prototype of a chatbot called ChatGPT, which was made available to the public free of charge in November 2022. In the first week, more than one million regular users were registered, and two months later the number of users exceeded 100 million. The figures confirm that there is a very strong interest in AI among individuals, and, in academia, the rise of AI is being equated with the discovery and use of electricity.

Therefore, in this paper, we present the results of the use of AI technology in manufacturing companies. AI has entered intensively into the daily lives of companies, individuals and society as a whole over the last year and a half. We point out that the survey was carried out in the first half of 2022, just before the big boom caused by generative AI tools such as ChatGPT. Undoubtedly, over the last year and a half, companies have realized the potential of these tools, and have started to integrate them into their everyday business. In line with the above, the results presented should be interpreted with caution, but they point to the fact that manufacturing companies had already started investing in and developing AI solutions before the second half of 2022.

This paper is organized as follows: first, we will introduce the use of specific AI solutions in manufacturing companies in general. The Methodological section explains the characteristics of the European Manufacturing Survey (EMS). After that, we present the use of selected AI solutions in Slovenian manufacturing

companies. Finally, a concluding discussion is provided for the findings, where some research limitations, and directions are given for future research.

2 Artificial Intelligence in manufacturing

AI offers a unique opportunity as an enabler for industrial systems, to solve complex manufacturing problems and improve the performance of entire systems based on learning from collected data (Peres et al., 2020). AI can be used for various tasks, such as data security, planning and control, monitoring of processes, prediction and diagnosis, and also for decision- making to achieve the desired goals.

The currently most important areas of application in manufacturing are process optimization, quality control, and predictive maintenance. In process optimization, the main focus is on making manufacturing processes more profitable and sustainable. Some applications of AI include predicting energy consumption and optimization challenges (Qin et al., 2018). In quality control, early detection of defects during each production step is highly desirable. This includes automatic visual inspection of parts (Ojer et al., 2020), multi-stage quality prediction (Peres et al., 2019) and online prediction of quality (Schmitt et al., 2020). The purpose of predictive maintenance is to avoid unplanned or unexpected downtime, while increasing machine uptime. The best maintenance strategy can be created based on maintenance effectiveness, costs, resources and previous data from various sources(Yan et al., 2017).

Based on that, the technologies examined in this paper are specific software that can be upgraded with an AI component.

The first is software for production process management (Oertwig et al., 2019), which is important for planning and controlling the production process. The providers of this software are numerous, and all offer additional functions, including AI functions.

Chiarini (2020) and Poth et al. (2020) discussed quality control software in terms of product control. The software helps to check whether all the parameters of the product meet the specification. With additional AI functionality, the operator checks

the AI component and teaches it whether the product is scrap or good, to prevent good products from being thrown away in the future.

The next software is the machine and equipment maintenance software (Lee et al., 2019; Cardoso and Ferreira, 2020). The software includes a maintenance plan to determine which repairs are carried out according to the plan. The AI functionality, equipped with sensors, checks for tool wear, and reports a possible failure with minimal downtime, saving the company money. The main goal of AI is to improve plant efficiency by minimizing downtime in production (Antosz et al., 2020).

The fourth software is used to manage internal logistics, and is usually used for mapping (e.g. transport, warehouse). Mathematical models and linear programming are usually used to find an optimal system for internal logistics (Knoll et al., 2019). However, by using sensors to track traffic and generate data that is fed into an AI algorithm, further dynamic changes and optimizations can be made, which, in turn, reduces costs for the company.

Halhoul et al (2021) conducted an extensive literature review on AI-based software for saving energy while maintaining optimal heating/cooling conditions. Their research shows that significant energy savings have been achieved at sites where such systems have been used.

The last software we included in our research is used to improve and innovate production processes. According to Machado et al. (2019), not much can be done to improve and innovate production processes without big data. In this case, sensors need to be placed in strategic locations to collect data, and big data cannot be analyzed with conventional software, but requires AI enhancements.

3 Methodology

The research data were collected using the EMS, coordinated by the Fraunhofer Institute for Systems and Innovation Research – ISI, the largest European survey of manufacturing activities. The survey's questions deal with manufacturing strategies, the application of innovative organizational and technological concepts in production, cooperation issues, production offshoring and backshoring, servitization, and questions of personnel deployment and qualification. Data on

performance indicators such as productivity, flexibility, quality, and returns are collected in addition. In our last EMS research round, we added questions on digital elements of products, new business models, artificial intelligence, the circular economy, etc. The survey takes place every three years. In most countries, EMS is organized as a paper-based survey at the company level (the core questionnaire has six pages). The persons contacted to fill in the questionnaires are the production manager or the CEO of the manufacturing companies. The responding companies present a cross-section of the main manufacturing industries. Included are producers of rubber and plastics, metal works, mechanical engineering, and electrical engineering.

The survey is conducted among manufacturing companies (NACE Revision 2 codes from 22 to 32) having at least 20 employees. The main objectives of the EMS project are to find out more about the use of production and information technologies, new organizational approaches in manufacturing, and the implementation of best management practices. Our research is based on EMS data from a Slovenian subsample from the year 2022 round. We received 141 responses – a 16% response rate. We classified manufacturing companies into three classes, based on the number of employees. The largest share of respondents was from medium-sized companies (around 49%), followed by small companies (31%) and large companies (20%).

4 Results

The use of AI was firstly explored through a question which pertained to the areas of application of specialized software, and if that software also uses any elements of self-learning, or, more specifically, AI. We were interested in the following areas in the manufacturing companies:

- production process management,
- quality control,
- machinery and equipment maintenance,
- internal logistics management,
- energy management,
- and improvements or innovations in products or production processes.

The general use of specialized software and AI-based software was explored and presented in Table 1. We have observed the incorporation of specialized software and AI functionalities in different operational areas of manufacturing companies. Firstly, we have observed the use of general software solutions in previously described areas (column "Have SW"). The proportion of companies using such solutions is significant, but varies by the examined areas. Unsurprisingly, two thirds of companies use manufacturing process management software, which is in line with the share of manufacturing companies that have integrated (ERP) or partial (MES) IT solutions in production. In addition, we wanted to know whether these software solutions already include self-learning algorithms or AI functionality. The column "SW+AI (all)" presents the total share of Slovenian manufacturing companies that use software solutions that already include self-learning algorithms or AI functionality. The column "SW+AI (SW owners)" presents the share of Slovenian manufacturing companies that use general software solutions, but include self-learning algorithms or AI functionality in these software solutions.

The data in Table 1 highlight a predominant reliance on specialized software in the management of production processes, with a 62% adoption rate; however, AI integration in this area is still at 8%. In the quality control, 43% of companies utilize specialized software, with 12% leveraging AI functionalities. Meanwhile, maintenance of machinery experiences a 37% adoption rate for specialized software, followed by management of internal logistics at 31% adoption rate. Only 8% of companies leverage AI functionalities for maintenance and 6% for internal logistics. The last two areas are Improvement or innovation of production processes and Energy management, with 26% and 23% adoption rates respectively. Similarly, as before, only 8% of companies leverage AI functionalities in the area of improvement and innovation of production processes, and only 6% of companies leverage AI in energy management. Even though there are companies that use specialized software, there are only a few who actually use software with AI.

In general, around 20-30% of companies that use a software solution for a specific domain include AI functionality in their software solutions. The overall share of Slovenian manufacturing companies using AI-enabled software is between 5% and 12%.

Table 1: Adoption of AI-based software in Slovenian manufacturing companies

Software (SW)	Have SW	SW+AI (all)	SW+AI (SW owners)
Software for Management of production processes	61,7%	7,8%	12,6%
Software for Quality control	43,3%	12,1%	27,9%
Software for Maintenance of machinery and equipment	36,9%	7,8%	21,2%
Software for Management of internal logistics	30,5%	5,7%	18,6%
Software for Energy management	23,4%	5,7%	24,2%
Software for Improvement or innovation of production processes	26,2%	7,8%	29,7%

Table 2: Planned use of AI-based software in Slovenian manufacturing companies by 2025

Software (SW)	Plan to use AI by 2025
Software for Management of production processes	20,4%
Software for Quality control	21,3%
Software for Maintenance of machinery and equipment	12,4%
Software for Management of internal logistics	8,2%
Software for Energy management	7,4%
Software for Improvement or innovation of production processes	10,6%

Table 2 shows the share of companies that are not yet using AI solutions, but plan to deploy them by 2025. It is important to reiterate that, at the time of the survey, companies were not yet aware of the potential of generative AI, so it can be assumed that, if they were not, these shares of planned use would be much higher.

5 Discussion and conclusion

This paper explores the current trends and applications of AI in manufacturing companies. Six major areas of AI application are provided: production process management, quality control, machinery and equipment maintenance, internal logistics management, energy management, and improvements or innovations in products or production processes. In order to gain insights into the actual use of AI and current areas of application in manufacturing companies, the data were used from the newest round of EMS 2022. Our results show that the share of companies using software solutions in these areas varies by the examined areas in terms of general use of software solutions, and in terms of software solutions with built-in AI functionality. The most frequently used software with AI functionality is in the field of Quality Control, where, especially, Computer Vision and Machine Learning Solutions are becoming an important role in manufacturing companies.

In our 2018 survey, only 5% of the surveyed population of manufacturing companies used AI in their processes. As we can see, the proportion of manufacturing companies using specific solutions based on self-learning algorithms / AI has increased significantly. Combining all 6 possible types of AI-based software, 20% of Slovenian manufacturing companies use at least one of these six types.

As is the case with all research, some limitations must be taken into account when considering the reliability, significance, and general use of the obtained results. Firstly, once again we must point out that our survey was conducted few months before the arrival of AI solutions that became generally more accessible in companies and society in general. Second, the data from Slovenia contain 141 companies in the EMS 2022 round. Although the sample is not small, further research should go in the direction of a larger sample of more countries.

In the future we will also make a more in-depth analysis regarding the use of AI, where we will consider company size, the technological intensity of the industry they belong to, and their status as the final producer or supplier. We will also look into the relationship between the introduced AI solutions and the use of specific digital technologies.

In 2025, we will conduct a new survey to put even more emphasis on AI issues. We can expect a significant increase in the share of manufacturing companies deploying and using AI capabilities in different ways. Tools such as ChatGPT and a range of similar tools and their derivatives have accelerated the use of AI enormously in the last year and a half. Businesses are realizing the huge potential of this technology, and, in particular, are discovering areas where AI technology can help them. These are often areas where, less than two years ago, manufacturing companies could not even imagine the potential benefits of AI.

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