9th INTERNATIONAL SCIENTIFIC CONFERENCE
ON DEFENSIVE TECHNOLOGIES
OTEH 2020
Belgrade, Serbia, 15 – 16 October 2020

ARTIFICIAL INTELLIGENCE IN RELIABILITY AND MAINTAINABILITY

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Abstract:. *At the end of 2019, the Government of the Republic of Serbia adopted the Strategy for the Development of Artificial Intelligence in the Republic of Serbia for the period 2020-2025. This was a motivation for the author of this paper to try to give an overview of the current applications of artificial intelligence applications in the field of reliability and maintenance, as well as future applications, in this paper. Some options to avoid artificial intelligence to fail are also considered.*

Keywords: *Artificial intelligence, Reliability, Maintainability, Maintenance.*

1. INTRODUCTION

The fact that the Government of the Republic of Serbia adopted the Strategy for the Development of Artificial Intelligence in the Republic of Serbia for the period 2020-2025 [14], and that the author of this paper was coauthor of a conference paper in 2003 in which posibility of improvement of jet engine diagnostic by applying neural networks was suggested [12], and the fact that the author of this paper has been working in the area of reliability and maintainability, as a professor, for more than thirty years, was a motivation to try to give an overview of the current applications of artificial intelligence (AI) applications in the field of reliability and maintenance, as well as future applications.

Because there are information that AI can also fail, the ways to avoid AI to fail have also been discussed.

The ultimate objective of this paper is to see possibilities of AI application to achieve more effective reliability and maintenance.

First, the definition of artificial intelligence (AI), then definition of reliability and maintainability is briefly discussed, and after that application of AI in area of reliability and maintainance, and finaly something about how to avoid AI to fail and maintain AI has been discussed based on the available literature. The literature review has been done using the Science Direct database search using the name of the artificial intelligence, and mostly using abstracts, and in some cases complete papers.

2. ABOUT ARTIFICIAL INTELLIGENCE

There is no generally accepted definition of Artificial Intelligence [14]. According to the Encyclopedia Britannica dictionary [17], Artificial intelligence is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. And according to the Merriam-Webster dictionary [18], AI is a branch of computer science dealing with the simulation of intelligent behavior in computers, or the capability of a machine to imitate intelligent human behavior.

In [14], the definition of AI used in [1] has been accepted: “Artificial intelligence (AI) refers to systems that display intelligent behavior by analyzing their environment and taking actions – with some degree of autonomy – to achieve specific goals.”

In [1], it has also been stated “AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications)”.

Obviously, the essential word is “intelligence“. That word has also been discussed in [1] where it is considered as “a vague concept”, studied by different research in different scientific disciplines, and that “AI researchers use mostly the notion of rationality“, which “refers to the ability to choose the best action to take in order to achieve a certain goal, given certain criteria to be optimized and the available resources”. According to that, in [1] an updated definition of AI has been proposed.

Artificial intelligence was founded as an academic discipline in the middle of fifties of the last century, and since then development has gone in different directions, being divided in sub-fields.

In the history of AI, there have been ups and downs, starting with the logic-based approach (during the 1950s and 1960s), the knowledge-based expert systems approach (1970s and 1980s), and the data-based approach (since 2000) years onwards - with periods of disappointment and reduced investment [14]. In the last decades AI is defined as the study of intelligent agents - any device that percepts its environment and takes actions (by learning or using knowledge) to achieve its goals.

The term Artificial Intelligence is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as

the ability to reason, discover meaning, generalize, or learn from past experience [17]. That is also the case in the area of reliability prognostic and maintenance management. Thus, the goal can be replacing, more or less, human reasoning with machine reasoning with less error and faster in taking dessisions.

Essentially, the use of AI is an attempt to replace human intelligence with machine intelligence. Because of that, sometimes, AI is called machine intelligence.

Progress in AI is evident in many areas, especially in the last decade. It seems that the area of reliability and maintainability is not an exception.

3. ABOUT RELIABILITY AND MAINTENANCE

Reliability is defined as the ability of an item to perform a required function under stated conditions for a stated period of time [10].

Maintenance is usually characterized with Maintainability which refers to the ability how fast and easy an item can be fixed and modified.

Quantitatively, reliability and maintainability are expressed in probability, and both are very important in reducing downtime and operational and maintenance cost of an item or system.

High reliability is very important, especially in professional equipment and comprise hardware reliability, software reliability and human reliability.

Reliability prediction has been done for almost 60 years, mostly by MIL-HDBK-217, but about 30 years ago it was identified that new approaches are needed [9].

Can AI help to solve these problems, or can AI solve these problems better than people can?

Reliability is built in during design, provided in production and supported in use. It is also connected with cost. More reliable equipment is more expensive, but more reliable equipment is also cheaper for maintenance.

Reliability and Maintenance are mutually connected.

Reliability is also in connection with process of production and use or exploitation of the equipment which is designed to be reliable.

The right maintenance can save both cost and downtime, and achieve higher availability. Different maintenance strategies are in use. Basic are corrective (reactive, replace an item after it fails) and preventive (proactive, replace an item before it fails) maintenance. More used in modern equipment are predictive maintenance or condition monitoring (just in time mainetance, optimization the best of corrective and preventive maintenance, replace an item which is close to failure). Also, the combination of the mentioned has been used before. Such combination is, for example, reliability-centered maintenance.

As connectivity and data accessibility become cheaper and more widespread nowadays, many companies are looking to predictive maintenance, or condition-based, maintenance, powered by machine learning and analytics [23]. Obviously, there is a place for application of AI.

4. AI IN RELIABILITY AND MAINTENANCE

According to the available literature, studied for this work, application of artificial intelligence in reliability and maintenance started about forty years ago.

At the end of eighties of the previous century, the Rome Air Development Center (RADC) investigated so called Smart BIT - program of research of development and apply of AI techniques to effect built-in test (BIT) improvement [11] for diagnose and management of faults.

Twenty years ago, the author of this paper was involved in an attempt to propose applying intelligent system for maintenance of yet engine. In the abstract of this work [12], it has been concluded that continuous monitoring of the jet engine working process is considered to be one of the most efficient methods for engine condition assessment, and that integration of airplane and jet engine built-in information-displaying systems with nondestructive testing, spectral oil analysis and total accumulating cycle into an diagnostic system has shown to be reliable way to establish a specific form of jet engine on condition maintenance, but in spite of that, such kind of diagnostic system suffers from absence of prognostic capability that is necessary to predict future engine components behavior; so, there is a need to upgrade those systems with intelligent features that are able to recognize error patterns and make automatic decisions about engine work.

In [13], it has been stated that artificial intelligence techniques have drawn much attention in dealing with complex and challenging problems in power systems, and that reliability evaluation is a type of representative applications. In this paper some concepts on reliability evaluation based on population-based intelligent search as well as neural network enhanced Monte Carlo simulation are presented. Also, some case studies have been presented to demonstrate the effectiveness of the proposed methods. According to this paper, it appears that the intelligence based methods hold promise for reliability studies and merit further investigation.

In [13], also the conceptual basis of overall reliability evaluation process and the role of artificial intelligence methods have been examined. Also, some examples of application to the reliability analysis of hybrid systems involving conventional and alternative energy sources have been provided.

In [7], the author has found that relevant publications concerning AI applications in planning and modelling in maintenance started to appear from the mid 1980s.

A good review of AI application in maintenance management in [7] states that for over more than 2 decades (up to 2012) many attempts have been made to apply Artificial Intelligence (AI) techniques in maintenance modeling and management. The used AI

techniques are numerous, ranging from the classic expert systems that utilizes rule based reasoning to the more cumbersome optimization techniques used in Genetic Algorithms. It has been stated that in the first decade of this century there has been a shift towards developing hybrid intelligent management systems in operations that use more than one AI technique. The application areas of AI in maintenance extends widely from the intelligent maintenance optimization models to the more practical applications, such as cost budgeting of maintenance projects and selecting optimal repair methods.

This paper [7] presents an overview of the applications of AI techniques in maintenance over the two decades, identifying specific applications and extent of use of techniques and near future trends. This has been done by using the Science Direct database to carry out the literature search using the name of the AI technique, mostly using abstracts.

In [7], the author has classified Artificial Intelligence techniques into seven areas:

- Genetic Algorithms (GAs),
- Case Based Reasoning (CBR),
- Neural Networks (NNS),
- Knowledge Based Systems (KBS),
- Fuzzy Logic (FL),
- Data Mining (DM), and
- Hybrid Systems.

The review in [7] shows that over the two decades, up to June 2012, many AI techniques have been applied in maintenance management and modelling with next conclusion:

- The most popular of the AI techniques applied in maintenance was GAs (due to its nature which offers powerful optimization tools that can deal with complex maintenance planning problems),
- Both KBS and FL have received moderate interest in maintenance applications.
- Few applications have been found on CBR and NNs in maintenance but none using DM (with expectation that DM will be used in future).
- Few hybrid systems have been developed in the maintenance area, but the number of publications with FL and hybrid systems increased.

In [5], which is included in review in [7], to improve the efficiency of reliability-centered maintenance (RCM) analysis, case-based reasoning (CBR), as a kind of artificial intelligence (AI) technology, has been successfully introduced into RCM analysis process, and a framework for intelligent RCM analysis (IRCMA) has been studied.

Now, as an addition to review from [7], some examples from sources after 2012, also using the Science Direct database and name artificial intelligence, are given.

In [19], it is written about an example which comes from Lufthansa Airlines, which maintains more than 1,000 planes and is using machine learning in real-time data collection and decision making, and that recommended failure-avoidance actions come as a result of error messages and sensor data, among other things.

In [24], it has been concluded that emerging technologies such as the Internet of Things (IoT), Big Data, analytics, and cloud data storage are enabling more equipment to share condition-based data with a centralized server, making fault detection easier, more practical, and more direct.

In [4], it has been stated that AI Techniques for Reliability Prediction for Electronic Components provides emerging research exploring the theoretical and practical aspects of prediction methods using artificial intelligence and machine learning in the manufacturing field.

As it has been said before, the production process is also important for reliability. Bad production process can degrade reliability built in during design phase. In [2], it has been studied how machine learning models can fit reliability estimation function in comparison to the traditional approaches (e.g. Weibull distribution), because the reliability estimation of engineered components is fundamental for many optimization policies in a production process. Four diverse machine learning approaches are implemented: artificial neural networks, support vector machines, random forest, and soft computing methods.

A new method for hull structural plate corrosion damage detection and recognition based on artificial intelligence using convolutional neural network (CNN) has been proposed in [15], which makes up for the research gap of applying deep learning into corrosion damage detection in the field of naval architecture and ocean engineering.

In [16], data driven-based and knowledge driven-based fault detection and diagnosis (FDD) methods for building energy systems have been reviewed, and strengths and shortcomings of the existing artificial intelligence-based methods have been analysed.

In [8], the AI-based algorithms (data-driven modeling approach) for predictive maintenance have been presented and applied to monitor two critical machine tool system elements: the cutting tool and the spindle motor.

Everyday life shows that faults of elements and systems are inevitable. But, are near-zero-failure systems possible? In [6], it has been found that the results obtained in 12 international companies demonstrate a possible global standardization of operative processes, leading to the design of a near-zero-failure intelligent system that is able to learn and upgrade itself, which is exploitable in any context of Society 5.0, thus reducing the risk factors at all management levels and ensuring quality and sustainability.

5. RELIABILITY OF AI

Everything can fail, and an AI is not an exception. If AI is an attempt to replace human intelligence with machine intelligence, and human reasoning can sometimes fail, so AI can fail in a similar way. So, is the reason of erroneous reasoning (erroneous concluding, decisioning) in wrong learning? Or can we raise the question about reliability of AI, or how to avoid AI fails?

In [26], it has been discussed why deep learnig AIs are so easy to fool. An example is in self-driving car application in real situation. But it has been said that it can also happen in case of sabotage.

In [25], under the headline "Enhanching the reliabiliy of artificial intelligence", it has been stated "Computers that learn for themselves are with us now. As they become more common in 'high-stakes' applications like robotic surgery, terrorism detection and driverless cars, researchers ask what can be done to make sure we can trust them. " So, are they reliable? Or, can they fail?

There are examples of erroneous AI. Some examples can be found in [3]: AI failure from IBM, Microsoft, Apple and Amazon. Example from IBM happend in 2013, when IBM partnered with The University of Texas MD Anderson Cancer Center developed a new "Oncology Expert Advisor" system with the goal to cure cancer. In July 2018, StatNews reviewed internal IBM documents and found that IBM's Watson was making erroneous, downright dangerous cancer treatment advice. In [3], it has been concluded that, probably, the reason is because the software is trained on a small number of hypothetical cancer patients, rather than real patient data.

There are authors who ask questions about potential risks, such as whether AI will pose an existential threat to humanity, or whether AI technology will be concentrated in the hands of the few [3], but I think that it is not a question of AI application in the area of reliability and maintainability, at least not in the near future.

Also, a question that AI can fail to function as expected has been raised, and the reason is because of the nature of the machine-learning algorithms on which modern AI are commonly built. These algorithms are capable of learning from massive amounts of data, and once the data are internalized, they are capable of making decisions experientially or intuitively like humans. This means that, for the first time, computers are no longer merely executing detailed pre-written instructions but are capable of arriving at dynamic solutions to problems based on patterns in data that humans may not even be able to perceive. This new approach comes at a price, because many of these algorithms can be black boxes, even to their creators [3]. But, in the area of maintenance the problem that arises more often is that we have no enough data.

One of the important questions is if AI can work on small number of data, for example number of failures. In [21], it has been concluded that a model's predictive accuracy depends on the relevancy, sufficiency, and quality of the training and test data. Two questions are commonly asked with regard to failure history data: (1) How many failure events are required to train a model? (2) How many records is considered as "enough"? [21].

5. MAINTAINING AI

An AI system also needs maintenance, not only because AI can fail. In [20], AI is compared to a car's engine in a way that maintaining AI can be as easy as replacing the cabin air filter, or as complicated as rebuilding the transmission, and that is considered as a reason why it is important to understand some basic AI maintenance best practices.

So, just like some other product, an AI requires maintenance to remain robust and valuable, and as a car, an AI can experience a sudden, catastrophic failure if it has not been kept up-to-date.

To build a successful AI there is a need to be familiar with cases when AI initiatives fail in order not to make the same mistakes. Also, there is a need to be familiar with data science.

6. CONCLUSION

It seems that progress in AI is inevitable, so it is important to understand its potentials for application in reliability and maintenance and also its possible pitfalls.

Review of available literature shows that AI is more applied in maintenance than reliability. Kobbacy's paper gives a good review of AI application in maintenance management during the end of the last century and beginning of this century. It shows that the most popular technique in maintenance was Genetic Algorithms, then Knowledge Based Systems (or expert systems) and Fuzzy Logic with moderate interest, and Case Based Reasoning, Neural Networks and Hybrid Systems with only a few applications. Nowadays, much more interest is in machine learning (as a subset of AI), deep learning (as a subset of machine learning), and intelligent agents. It seems that machine learning and intelligent agents can be more applied in reliability and predictive maintenance in future.

Artificial intelligence can be applied in reliability and maintenance. In both cases the problem is data. The problem is how to cope with a huge amount of data on the one hand, and with very small amount of data on the other hand, because both can be the case in reliability and maintenance.

Everything can fail, and an AI is not an exception. So, an AI system also needs maintenance. Also important question is how to avoid failure of AI.

References

[1] A definition of AI: Main capabilities and scientific disciplines. Independent High-Level Expert Group on Artificial Intelligence set up by the European Commission, 8 April 2019. (Available at: https://ec.europa.eu/digital-single-market/en/news/definition-artificial-intelligence-main-capabilities-and-scientific-disciplines) Accessed: 20.04.2020.

[2] Alsina, E., Chica, M., Trawinski, K., Regattieri, A., "On the use of machine learning methods to predict component reliability from data-driven industrial case studies", *The International Journal of Advanced Manufacturing Technology.* Vol. 94, pp. 2419–2433, 2018

[3] Bathaee, Y., "The Artificial Intelligence Black Box and the Failure of Intent and Causation", *Harvard Journal of Law & Technology*. Volume 31, Number

2, Spring 2018

[4] Bhargava, C., *AI Techniques for Reliability Prediction for Electronic Components*, IGI Global, 2019. Available at: https://www.researchgate.net/publication/336770768_AI_Techniques_for_Reliability_Prediction_for_Electronic_Components Accessed: 20.06.2020.

[5] Cheng, Z., Jia, X., Gao, P., Wu, B., Wang, J., "A framework for intelligent reliability centered maintenance analysis", *Reliability Engineering & System Safety* 93(6):806-814, 2008. Available at: https://www.researchgate.net/publication/223777201_A_framework_for_intelligent_reliability_centered_maintenance_analysis Accessed: 20.05.2020.

[6] Foresti, R., Rossi, S., Magnani, M., Lo Bianco, G. C., Delmonte, N., "Smart Society and Artificial Intelligence: Big Data Scheduling and the Global Standard Method Applied to Smart Maintenance", *Engineering*, January 2020

[7] Kobbacy, A H K. "Application of Artificial Intelligence in Maintenance Modelling and Management", *2nd IFAC Workshop on Advanced Maintenance Engineering, Services and Technology*. Universidad de Sevilla, Sevilla, Spain. November 22-23, 2012

[8] Lee, J. W., Wu, H., Yun, H., Kim, H., Sutherland, W. J., "Predictive Maintenance of Machine Tool Systems Using Artificial Intelligence Techniques Applied to Machine Condition Data", *Procedia CIRP*, Vol. 80, 2019, pp. 506-511

[9] Pokorni, S., "Reliability prediction of electronic equipment: problems and experience", *7th International Scientific Conference on Defensive Technologies OTEH 2016*, Belgrade, 6-7 October 2016, pp 695-700

[10] Pokorni, S., "Reliability of Internet of Things", *8th International Scientific Conference on Defensive Technologies OTEH 2018*, Belgrade, 11-12 October 2018, pp 567-570

[11] Richards W.D., Smart BIT: A plan for intelligent built-in test. *IEEE Aerospace and Electronic Systems Magazine*. Vol. 4/1, 1989

[12] Siladić, M., Pokorni, S., Rašuo, B., "Possibility of improvement of jet engine diagnostic by applying neural networks", Proc. *XLVII ETRAN Conference*, June 8-13, 2003, Vol. I (in Serbian)

[13] Singh, C., Wang, L., "Role of Artificial Intelligence in the Reliability Evaluation of Electric Power Systems". *Turkish Journal of Electrical Engineering and Computer Science*, Vol.16, No.3, 2008. Available at: http://journals.tubitak.gov.tr/elektrik/issues/elk-08-16-3/elk-16-3-2-0808-7.pdf Accessed: 20.04.2020.

[14] Strategy for the Development of Artificial Intelligence in the Republic of Serbia for the period 2020-2025 years. The Government of the Republic of Serbia, December 26, 2019 (in Serbian)

[15] Yao, Y., Yang, Y., Wang, Y., Zhao, X., "Artificial intelligence-based hull structural plate corrosion damage detection and recognition using convolutional neural network", *Applied Ocean Research*, Vol. 90, September 2019

[16] Zhao, Y., Li, T., Zhang, X., Zhang, C., "Artificial intelligence-based fault detection and diagnosis methods for building energy systems: Advantages, challenges and the future", *Renewable and Sustainable Energy Reviews*. Vol. 109, July 2019, pp 85-101

[17] https://www.britannica.com/technology/artificial-intelligence Accessed: 20.04.2020.

[18] https://www.merriam-webster.com/dictionary/artificial%20intelligence Accessed: 20.04.2020.

[19] https://www.efficientplantmag.com/2017/11/ai-reliability-much-fast/ Accessed: 20.04.2020.

[20] https://www.lexalytics.com/lexablog/ai-maintenance-critical Accessed: 20.04.2020.

[21] https://docs.microsoft.com/en-us/azure/machine-learning/team-data-science-process/predictive-maintenance-playbook Accessed: 20.05.2020.

[22] https://www.lexalytics.com/lexablog/stories-ai-failure-avoid-ai-fails-2020 Accessed: 20.04.2020.

[23] https://www.uptake.com/blog/how-ai-is-making-predictive-maintenance-a-reality-for-the-industrial-iot Accessed: 20.05.2020.

[24] https://www.aerospacemanufacturinganddesign.com/article/artificial-intelligence-for-predictive-maintenance/ Accessed: 20.04.2020.

[25] https://phys.org/news/2016-10-reliability-artificial-intelligence.html Accessed: 20.06.2020.

[26] https://www.nature.com/articles/d41586-019-03013-5 Accessed: 20.06.2020.