ADVANTAGES AND ETHICAL CONSIDERATIONS OF INDUSTRIAL IOT ARTIFICIAL INTELLIGENCE SOLUTIONS USAGE

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Abstract: The objective of this paper is to research the synergistic interaction between Industrial Internet of Things (IIoT) and the application of Artificial Intelligence (AI) in IIoT ecosystems (AIoT). For achieving this purpose, a method of integrative study of leading scientific publications on the topics 'Industrial Internet of Things' and 'Artificial Internet of Things' and the PRIZMA flow chart for filtering the list of found documents are applied. The inability of full coverage of the AIoT topic in one article has necessitated the usage of an approach for its content analysis in several thematic groups. The IIoT and AIoT concepts has been explored by various theoretical and practical aspects in many scientific papers published mainly over the past five years, but continues to arouse the interest of researchers. The novelty of the manuscript could be viewed in the attempts of systematizing the key characteristics, advantages, and risks in the practical use of these technologies in the form of smart manufacturing machines, robotic devices, autonomous vehicles, and software for predictive maintenance, and in outlining the possibility for green and sustainable AIoT platforms creation. It is concluded that a key requirement for the implementation of AIoT solutions is the consideration of the various threats and ethical aspects of their design, which contributes to the correct definition of the 'social value' of such business initiatives.

Key words: IIoT, AIoT, Industrial AI, AIoT Risks and Ethics
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Introduction

Modern IT integrates products, services, and processes in a new way and changes existing business models (Petrova et al., 2022). The quality of

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knowledge, skills and competences should be measured through the prism of the users of the personnel. (Kirilov, 2021; Kirilov, 2022). The Industrial Internet of Things (IIoT) concept ushered in the Fourth Industrial Revolution in the evolutionary development of mankind (CBS INTERACTIVE INC., 2019, p. 3), improving the productivity[2], operational efficiency and entire supply chain of today's smart enterprises. The set of technologies for Internet of things (IoT), Augmented Reality/Virtual Reality, Artificial Intelligence/Machine Learning, Robotics, Big data and analytics, Blockchain and Cybersecurity, shaping the image of the IIoT ecosystem (Kar, & Gupta, 2021), blurs the boundaries between the physical, digital and biological spheres, integrating industrial assets, machines, information systems, business processes and people (World Economic Forum, 2014). The main objective of IIoT software-hardware platforms is to share[3] data and information within a specific or several vertically integrated industrial systems through technical, syntactic and semantic connectivity standards (Joshi, et al., 2022).

The use of AI in the IIoT ecosystem is assessed as a key to creating value in the Fourth Industrial Revolution (Diab, et al., 2022, p. 7). Despite ever-growing concerns that intelligent machines can take up many jobs and redefine the way industries, businesses and the economy work (Nozari, et al., 2023, p. 806), the implementation of machine learning, deep learning and natural language processing software in industrial AI systems brings different advantages[4] to the enterprises (Haqiq, et al., 2022).

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[2] The measurement of the productivity of smart enterprises is based on a set of many cost, quality, computing, human, productivity and flexibility metrics, a detailed literature review of which is made by Kamble et al. (Kamble, Gunasekaran, Ghadge, & Raut, 2020).

[3] Sharing data, models and applications through interoperable and secure communication channels is essential to create new value chains and "unlock" the potential to offer products and services to the IIoT ecosystem from more than 350 providers. A 2021 analysis by MarketsandMarkets projects the global solutions market for Industry 4.0 to reach $165.5 billion. By 2026, the largest overall annual growth rate of 49.07% is expected for industrial AI software (MarketsandMarkets, 2021).

[4] Increasing the efficiency, reliability, safety and durability of manufactured products and creating innovative industrial items (Revathy, Raj, Selvi, & Periasamy, 2020, p. 276); improving the productivity and continuity of the production process by installing distributed production systems and industrial robots with object manipulation capabilities with almost human agility and speed (Littman, et al., 2021, p. 15); discovering new models in the collected industrial data and optimizing the functions of operational systems (Singh, Kumar, Sharma, & Rai, 2022); predictive analysis and preventive maintenance of the condition of industrial equipment (Christou, Kefalakis, Zalonis, Soldatos, & Bröchler, 2020).

The unification of two of the most important conceptual paradigms of the second decade of the 21st century in a large number of literary sources is referred to by the term Artificial Internet of Things (AIoT). The interconnections and synergies between IIoT and AIoT concepts have been described in numerous scientific publications, making the topic impossible to fully cover in one article.

The aim of the study is to outline the application opportunities, potential risks, and challenges of the emerging Artificial Intelligence of Things (AIoT) paradigm and its synergistic interaction with the Industrial Internet of Things. As a contribution to the researches in this scientific area, the conducted review of the selected publications attempts to assess the ‘social value of AIoT platforms.

Paper’s tasks are through an integrative study of various literature on the topics ‘Industrial Internet of Things’ and ‘Industrial Artificial Intelligence’ systematizing the key characteristics, advantages and risks in the use of both paradigms and outlining the possibility for creating ethical, green, sustainable, and socially significant AIoT platforms.

Methodology

This study uses the method of integrative literature review on the topics 'Industrial Internet of Things' and 'Industrial Artificial Intelligence'. The purpose of this kind of literature reviews is not to cover all publications on the problems studied, but to combine, critically analyse and synthesize viewpoints and insights from different scientific fields or research traditions (Snyder, 2019, p. 336). Focusing on the identification and analysis of terms, patterns and trends within key topics allows for a deeper understanding of the concepts, theories and problems in an area of study, identifying gaps in studies, outlining areas of consensus or disagreement, and marking directions for future work on the subject (Bibri & Jagatheesaperumal, 2023, p. 2409). On this methodological basis, a bibliographical review of major scientific publications (articles, books, book chapters, conference proceedings) has been carried out in the paper in the following sequence of activities:

1. Definition of the aim, tasks and scope of the study.

2. Selecting the key topics of the study ('Industrial Internet of Things' and 'Industrial Artificial Intelligence') and summarizing them in the keyword 'Industrial IoT Artificial Intelligence'.

3. In-depth search of documents on the selected keyword in literature sources indexed in three scientific databases as of September 19, 2023. The search by text string 'Industrial IoT Artificial Intelligence' generates a list of a total of 31, 332 electronic documents - 302 pcs. in Scopus, 20,800 pcs. in Google Scholar, 9,517 pcs. in ScienceDirect and 713 pcs. in Emerald Insight.

4. Selection of the documents. The results obtained from the above electronic databases are further filtered according to the criteria available on their sites up to 330 titles as follows:

- Scopus:
  - ✓ Publication period - from 1 January 2019 to 19 September 2023
  - ✓ Scientific field - Computer Science; Engineering; Decision Sciences; Business, Management and Accounting; Social Sciences; Economics, Econometrics and Finance
  - ✓ Publication Status – Final
  - ✓ Type of access – completely free access
- Google Scholar:
  - ✓ Publication period - from 1 January 2019 to 19 September 2023
  - ✓ Types of articles – All types
- ScienceDirect:
  - ✓ Publication period - from 1 January 2019 to 19 September 2023
  - ✓ Category of titles – Internet of Things
  - ✓ Scientific field – Computer Science; Engineering
  - ✓ Type of access – Open Access & Open Archive
- Emerald Insight:
  - ✓ Publication period - from 1 January 2019 to 19 September 2023
  - ✓ Type of access – publications with free access only

For the implementation of activities 3 and 4 of the methodology, the PRISMA approach (Figure 1) has been applied, through which the filtered list of documents is reduced to 41 publications:

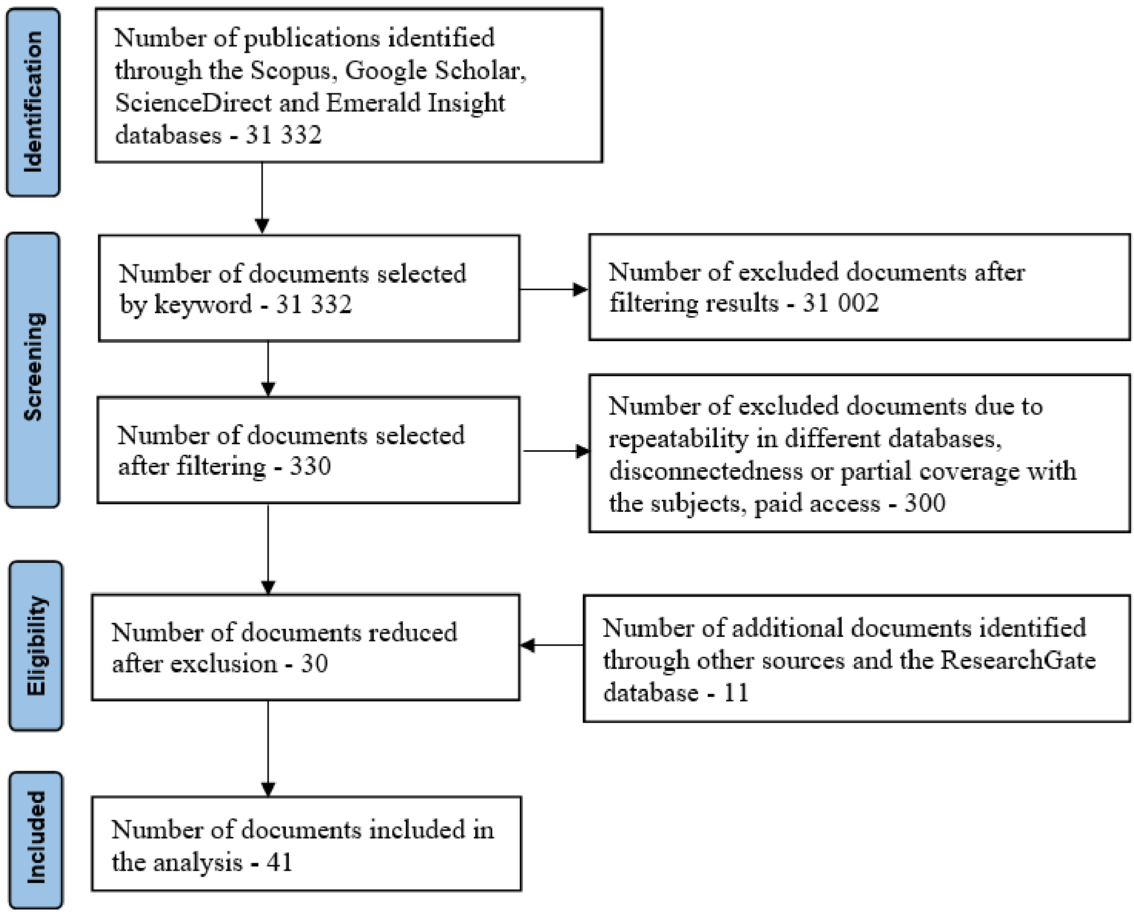

Figure 1. PRISMA flow chart for bibliographic search and selection.
Adapted by: (Moher, et al., 2009, p. 3.)

5. Data extraction and synthesis. The selected publications have been reviewed for the purpose of extracting repetitive text analytical units in the form of keywords ('IIoT', 'AIoT', 'I4.0', 'Industrial AI', 'AI Ethics'), phrases ('AIoT architectures AND frameworks', 'AIoT advantages AND risks, 'sustainable AND green AIoT') and judgments corresponding to the aim of the study.

6. Integration of identified concepts, phrases and judgments in the 'AIoT frameworks', 'AIoT architectures', 'AIoT risks', 'AIoT ethical considerations' thematic groups.

7. Content analysis of categorized thematic groups in the aspect of detecting recurring patterns, opportunities and risks of using AIoT.

8. Discussion. The results of the analysis are discussed in the direction of outlining the possibilities for assessing the social value of AIoT platforms.

9. Conclusion. Conclusions are made about the state, trends and prospects for the application of Artificial Intelligence technology in the ecosystem of the Industrial Internet of Things.

Results

The versatility and interdisciplinarity of the scientific field of Artificial Intelligence require the study of the technological, economic and social aspects of its application in the field of Industry. The content analysis of the terms and ideas in the analysed literature sources synthesizes several **thematic groups** presented below.

Reference Frameworks for the Artificial Internet of Things

The development, implementation and operation of AIoT systems require the application of information and industry standards for safety, sustainability and reliability, approved by the International Standardization Organization (ISO) and the International Electrotechnical Commission (IEC). The creation, analysis and maintenance of system architectures and conceptual architectural models described in the ISO/IEC/IEEE 42010:2011 standard underlies the following architectural AIoT frameworks:

1) Reference Architectural Model for Industry 4.0 (Trakadas, et al., 2020) consisting of eight layers (Asset, Integration, Communication, Information, Functional, Business, Human-in-The-Loop, and Federated Intelligence layers).

2) The Industrial Internet Reference Architecture (Lin, et al., 2022) describing architectural problems, constructions and approaches for conceptual development, documentation and communication between IIoT systems.

3) Industrial IoT Artificial Intelligence Framework (Diab, et al., 2022, p. 7) reflecting the business, usage, functional and implementation aspect of AIoT systems.

4) AIDA (Chahed, et al., 2023) – a holistic architectural framework for AIoT application implementation.

5) Edge MLOps (Raj, et al., 2021) – a framework for a fully automated and scalable process for training, deploying and monitoring AIoT data and

operations in peripheral nodes in real time, implemented in two layers - Cloud Orchestration layer and Edge Inference layer.

Artificial Internet of Things Platform

The topological variations of modern AIoT solutions found in the scientific works of different authors are based on the reference frameworks cited above and on an architectural platform consisting of the following three abstract layers:

1) Front-end devices collecting real-time data from the environment, interacting with it to make decisions at the local level and sending sensor data to the other two layers. As such, ordinary IoT devices and intelligent AIoT objects with the ability to integrate complex deep learning algorithms and direct and indirect machine communication with certain activators or other IoT devices are used. Detailed analysis on hardware (MCUs, MEMS/NEMS sensors, wireless access media), software (operating systems, protocol communication stack) and middleware (deep learning frameworks for AI application development over premises or cloud servers) components on the current AIoT devices is made by Hou and others (Hou, et al., 2023).

2) Edge/fog computing devices controlling, collecting, storing and analysing in real time sensor data from front-end devices and communicating with the other two layers. The approach of using edge/fog components, bringing the capabilities of processing the received sensor data near to their sources, reduces traffic to cloud data centres, solves latency and flickering problems in the transmission of information, and accelerates the response to time-critical tasks (Debauche, et al., 2020). As a central component in the AIoT platform, 'edge agents' (Carvalho, et al., 2019, p. 278) interact with other software-based solutions and control industrial machines through standard communication protocols. Edge agents may play the role of intelligent 'cognitive assistants' (Angulo, et al., 2023) mediating human-machine interaction in an AIoT cyber-physical system.

3) Back-end devices for cloud computing performing deep analysis and long-term storage of production data, on the basis of which long-term management decisions can be made. In the layer of cloud components, the large volume of structured (numbers, symbols, tables), semi-structured (graphics, XML documents) and unstructured (logs, audio, video, and images) information is cleared, integrated, arranged and summarized for the purpose of creating new knowledge using AI classification techniques

(Caiazzo, et al., 2023). An example of an applied solution for digitization of processes on autonomous industrial monitoring of thermal anomalies in an aluminium production plant through a set of edge, fog and cloud components is presented by Ghazal et al. (Ghazal, et al., 2020).

Risks in the Use of the Artificial Internet of Things

The successful operation of real-time connected smart industrial devices depends on several factors and is subject to risks of different nature. A systematization of the different requirements for the security of IIoT solutions in the form of an interactive mind-map, based on a literature review of more than 200 publications in the period 2011-2019, was made by Tange et al. (Tange, et al., 2020). A classification of threats to IoT technology into three groups of attacks – hardware (hardware trojan, side channel attack, tampering, DoS, DDoS), software (botnet, spoofing, DoS) and data transit attacks (eavesdropping/sniffing, replay attack, traffic analysis, man in the middle attack) - was made by Williams et al. (Williams, et al., 2022). At the same time, research is being conducted on the potential of IoT for the needs of Risk Management and IoT solutions for managing various types of risks (Popova, Marinova, & Popov, 2023).

The performance of AIoT systems is most often judged by the characteristics of safety, security, confidentiality, reliability and resilience to environmental disturbances, human errors, system errors and attacks (Diab, et al., 2022, p. 15). Ensuring their secure functioning is based on the application of commonly valid IT and operational system safety principles, standards, and good practices (such as ISO/IEC 2700028 and IEC 6244329 families of standards) and the consideration of AI-specific hazards - instability and vulnerability of AI models and algorithms, protection against attacks on AI cyber-physical systems, prevention of manipulation of data used in AI applications, etc. The multifaceted relationship and interdependence between AI technology and the entire set of threats to its cybersecurity is detailed in a report by the European Union Agency for Cybersecurity of 15.12.2020 (ENISA, 2020).

Protection of information generated by AIoT platforms from cybercriminals is most often achieved through machine learning algorithms. A performance comparison of Logistic Regression, Support Vector Machine, Decision Tree, Random Forest and Artificial Neural Network methods in an experiment to predict attacks and detect anomalies in IoT systems was made by Hasan et al. (Hasan, et al., 2019). Patil et al. are investigating the integration of Physically Unclonable Functions (PUFs) software chains of bits to implement an authentication linking of AIoT objects to a server machine (Patil, et al., 2020).

Ethical Considerations in the Application of the AI Technology

The Fourth Industrial Revolution extends ethical concerns from previous ones beyond questions of future workforce employment towards "what it means to be human" issue (Peckham, 2021). In another paper (Peckham, 2021), the author defines several aspects of humanity that are influenced and can be violated by the technology of Artificial Intelligence (cognitive acuity, ability to relate to others, freedom and privacy, moral agency, loss of work, what is real, the value of life, life expectancy, morality) as well as a three-phase framework of actions to assess the impact of AI applications on the individual and the ways to preserve human virtues and rights in the cyber-physical systems:

1) Analysing of the impact of AI application on personality using AI Taxonomy. A taxonomic categorization of terms and technologies for managing systems with artificial knowledge, systematized from various literature sources, is made by Radanliev et al. (Radanliev, et al., 2021).

2) Assessing the influence of this impact on human virtues. Ethical and social concerns about the application of AI technology in different spheres of human life require the design of solutions with such functionality to comply with the following set of principles:

- Human, societal, and environmental wellbeing.
- Human-centred values (human rights, diversity, individuals' autonomy).
- Fairness - AI solutions should not show algorithmic biases toward individuals, communities, or groups.
- Privacy protection and security of human's rights and data.
- Reliability and safety way of operation.
- Transparency and explainability - people must be informed if they interact or are being impacted by any AI technology.
- Contestability – in a case of an AI solutions' impact people should be provided with the opportunity to challenge the use or outcomes of the AI system.

- Accountability – designers of AI solutions should be identifiable and accountable for the outcomes of their works.

3) Preventing potentially dangerous influences by creating standard AI regulations. A global list of frameworks and regulatory principles for ethical deployment of AI systems can be found at https://algorithmwatch.org/en/ai-ethics-guidelines-global-inventory/.

Discussion

The aim of the author's review of the selected scientific publications is to make an attempt to assess the 'social value of AIoT platforms. Such an approach requires taking into account both the benefits and improvements this technology brings to individuals, organisations and society, as well as the costs (need for significant financial investment and organisational changes) and the concerns associated with it (Leszkiewicz, et al., 2022). The most frequently cited risks in AIoT are fairness, transparency, and understandability of the AI algorithms, privacy concerns and need of AI regulations, algorithmic bias). However, most publications are dominated by optimistic opinions that the convergence of AI with other information and operational technologies (IoT, digital twins, edge, 5G[5], brain-computer interfaces, quantum computing, etc.) can create a new generation of customized and real time interacting highly distributed human-machine systems, capable of digitally transforming almost any industrial sector.

According to Zhang and Tao, moving AI's computing capabilities close to data-generating production assets makes their behaviour intelligent and autonomous and facilitates the multimodal execution of faster, more efficient, more secure, and greener operations (Zhang & Tao, 2020). The trend towards "greening" of IoT technology (G-IoT) is usually achieved by implementing simple programmable low-energy consumption controllers or more complex hardware components such as DSPs, SOCs, CPUs, FPGAs, CPLDs, GPUs, and ASICs (Fraga-Lamas, et al., 2021). Furthermore, the application capabilities of sustainable AIoT extend beyond the peripheral layer, covering the entire supply chain (Ghahremani-Nahr, et al., 2021).

Another open issue on this theme is the inclusion of datasets collected by AIoT devices in environmental, social and governance (ESG) metrics,

[5] Systematization of literature summarizing the fields of application of AI methods for service management, network and cloud resources management, and radio management in 5G systems is made by Varga et al. (Varga P, et al., 2020).

through which business executives and investors assess the level of sustainability of an organization. A literature review of publications exploring the deployment of AI technologies to assess the impact of ESG indicators on firm performance is made by Saxena et al. (Saxena, et al., 2023). In the more general aspect of the sustainability framework called the triple bottom line (TBL), the fundamental influence of AIoT on the profits of organizations, people and planet Earth has been studied by Bronner, Gebauer, Lamprecht and Wortmann (Bronner, et al., 2021).

Conclusion

The application of artificial intelligence technologies in industry in the form of smart manufacturing machines, robotic devices, autonomous vehicles and software for predictive maintenance is considered as a major contributor to value creation in the Fourth Industrial Revolution. The Artificial Internet of Things platforms have the potential to create a new generation of highly distributed human-machine systems and to digitally transform industrial enterprises by helping them to better understand gathered data sets.

Analysing the collected sensor and operational data from the implemented business processes through machine learning software, deep learning algorithms and natural language processing tools enables the application of techniques for intelligent optimization of industrial operations, increasing company productivity and quality of manufactured products, reducing energy and material consumption, increasing production flexibility and creating new business value. A guarantee for the effectiveness of this analysis is the implementation of measures to maintain a high level of safety, reliability, sustainability, security and confidentiality of data in the AIoT platform.

The rich palette of risks to which artificial intelligence systems are generally exposed requires a systematic approach in their management in a specific industrial environment. This is the safest way to design and deploy reliable, sustainable and socially valuable AIoT platforms.

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