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ETHICAL COMPLIANCE OF AI TOOLS IN INDUSTRIAL MANUFACTURING– SMART 2023

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Abstract. This paper explores how to design, develop, and deploy trustworthy AI tools in industrial manufacturing. After a brief overview of existing AI ethical frameworks, the paper focuses on actioning the four AI ethical principles identified by the AI HLEG. Given the context-dependency of AI tools, these AI ethical principles are framed within the manufacturing setting. This ethics-based approach requires the operationalization of such principles to truly design, develop, and deploy trustworthy AI systems. To this end, organizational and technical measures applicable to industrial manufacturing are suggested. The focus is then placed on the role of corporate social responsibility, business ethics, and responsible research and innovation in implementing AI solutions ethically, legally, and sustainably. Finally, the paper tackles the concept of 'meaningful work', highlights its risks and propose mitigation measures to protect workers from the potential adverse effects that AI solutions might have on them.

Keywords: AI ethics, industrial manufacturing, corporate social responsibility, business ethics, responsible research and innovation, meaningful work

1 INTRODUCTION

The implementation of AI systems in industrial manufacturing brings about numerous benefits, from less machine downtime to less defects during the production process. Yet, there are considerable legal, ethical, and societal challenges to be addressed to fulfill their potential.

First, in recent years, the public sector, research institutions and private companies have issued various principles and guidelines for ethical trustworthy AI. However, as AI systems are context-dependent, these general AI ethical principles need to be adapted to the specific context

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of application to successfully imbue them into AI systems. Thus, not only technological aspects of industrial AI should be considered, but also other industrial requirements such as value creation, economic growth, human-machine interaction, and legal, ethical, and societal aspects.

Second, AI ethics in an industrial context is related to broader concepts of corporate social responsibility, business ethics and responsible business conduct, whereby companies integrate social, environmental, ethical, consumer and human rights concerns into their business strategy and operations and in their interaction with stakeholders. Furthermore, AI-enabled technologies developed by industrial companies are a result of their research and innovation activities. Therefore, responsibility of industry actors relates to a specific type of business strategy and operations, namely companies' R&I processes and outcomes.

Lastly, meaningful work in workplaces that are altered by new, automated, and digital technologies is an issue with relevance to the relationship between employers and workers. This illustrates the necessity of careful and deliberate application and operationalization of ethical principles and ultimately corporate social responsibility.

2 AI ETHICAL FRAMEWORKS IN THE INDUSTRIAL MANUFACTURING CONTEXT

In recent years, the public sector, research institutions, and private companies have issued various ethical frameworks to ensure trustworthy AI. A number of initiatives have aimed to capture this proliferation and map the landscape of such frameworks. For instance, the EU-funded project SHERPA (Shaping the Ethical Dimensions of Smart Information Systems: A European Perspective) found over 70 relevant documents [1]. AlgorithmWatch AI Ethics Guidelines Global Inventory lists more than 80 documents, including industry related guidelines developed by Google, IBM and Microsoft [2].

The IEEE (Institute of Electrical and Electronics Engineers) Global Initiative on Ethics of Autonomous and Intelligent Systems, called 'Ethically Aligned Design' was officially launched in April 2016 as a collective program of the IEEE, the world's largest technical professional organization [3]. It identified over one hundred and twenty key issues and eight founding values and principles to be applied to all types of autonomous and intelligent systems which operate in real, virtual, contextual, and mixed-reality environments [3]. Namely, (i) human rights; (ii) well-being; (iii) data agency; (iv) effectiveness; (v) transparency; (vi) accountability; (vii) awareness of misuse; and (viii) competence. There are currently 14 approved IEEE Standards development activities in the IEEE P7000 Series, incorporating transparency, data access and control, algorithmic bias, robotic nudging, and well-being.

Other remarkable initiatives on AI ethics are "The Asilomar Principles for the Future of Artificial Intelligence" [4], "The OnLife Manifesto" [5], "The Manifesto for Conscientious Design of Hybrid Online Social Systems", and "Responsible Artificial Intelligence" [6]. Stemming from these works, we can highlight several points that can be added to the IEEE principles to flesh them out: (i) the importance of explainability (or explicability) to steer clear of opaque decisions [7]; (ii) the emergence of machine ethics, or "how a machine could act ethically in an autonomous fashion" [8], and (iii) the development of bias-averse strategies to minimise negative impacts in society, avoiding the risks of harming vulnerable people.

The work published by the High-Level Expert Group on Artificial Intelligence of the European Commission (AI HLEG), "Ethics Guidelines for Trustworthy AI" [9] provides a set of ethical principles and requirements that should be embedded from the design into AI solutions to be deemed trustworthy. According to the AI HLEG there are four high-level ethical principles: i) human autonomy; ii) prevention of harms; iii) fairness; and v) explicability. These principles are turned into specific requirements for their practical implementation. These requirements are: i) human agency and oversight; ii) technical robustness and safety; iii) privacy and data governance; iv) transparency; v) diversity, non-discrimination, and fairness; vi) environmental and societal well-being; and vii) accountability.

This ethics-based approach can be used to operationalize AI ethical principles into a specific context of application -AI solutions for industrial manufacturing- which takes into account not only technological aspects of Industrial AI, but also other industrial requirements such as value creation, human-AI-interaction, ethical and regulatory aspects [10]. Moreover, such an ethics-based approach faces the challenges and limitations of a principled approach to AI Ethics (e.g., common aims and fiduciary duties, professional history and norms; proven methods to translate principles into practice, and robust legal and professional accountability mechanisms) [11].

3 FACING THE IMPLEMENTATION OF AI ETHICS IN INDUSTRIAL MANUFACTURING

This section follows the AI ethical principles established by the High-Level Expert Group on Artificial Intelligence (AI HLEG) [12], which have been adapted to the context of industrial manufacturing from an action-guiding perspective. This approach allows us to glimpse which ethical challenges may be faced in this context and recommends organizational and technical measures.

3.1 Human Autonomy

The principle of human autonomy implies that AI-enabled technologies should be designed, developed, and deployed in a way that respects and protects fundamental rights and ensures human agency and oversight.

AI-enabled technologies must ensure human dignity. In the workplace, the objectification and dehumanisation of employees should be avoided. Workers should be treated as self-determined subjects whose physical and mental health must be protected. Worker's dignity might also be undermined by the consequences that the deployment of AI systems in the workplace may have on the de-skilling of the labour force and the meaning of work.

The use of AI systems in the workplace may also lead to an advanced system of surveillance and monitoring to which employees may be subject [13]. Surveillance may cause "chilling effects" on employees and may also negatively impact their freedom, autonomy, and privacy. Therefore, legal, ethical, and social impact assessments must be conducted to strike the right balance between the intended benefits of the deployment of technology in the workplace and the possible negative consequences for employees' ethical values and fundamental rights [14].

To ensure human agency, employees should be able to make informed autonomous decisions regarding AI tools outcomes and have the skills to assess and challenge them. Therefore,

training sessions are encouraged to ensure that workers have the knowledge to understand how the system works and how to interact with it [15].

The purpose of human oversight is to prevent or minimise the potential risks of AI-enabled technologies. Meaningful human control can only be achieved if human-centric design principles and appropriate human-machine interfaces are embedded into the technologies. Additional measures should be implemented to ensure that users have the expertise, necessary competencies, and authority to exercise human control effectively, e.g., training sessions that enable the understanding of the capacity and limitations of the deployed technology, awareness of automation bias [16].

3.2 Prevention of Harms

The principle of prevention of harms means that AI-enabled technologies should not cause harm nor have detrimental consequences for individuals. In the workplace, this implies that employees' dignity must be respected, and their mental and physical integrity protected. Particular emphasis must be placed on the potential harms that technology can cause or exacerbate to workers, who are considered by the AI HLEG vulnerable people given the power imbalance and information asymmetries with employers. To minimise the impact of AI-enabled technologies on workers, a participatory approach could be adopted where workers are involved in the development and deployment of the technology [17].

The potential harms that can be caused by AI-enabled technologies also require addressing: i) the technical robustness and safety of the technology; ii) privacy and data governance concerns; and iii) societal and environmental well-being.

Firstly, AI-enabled technologies must be robust, resilient, secure, safe, accurate, reliable, and reproducible. Technical robustness and resilience should be ensured to prevent the exploitation of vulnerabilities by third parties and misuse [18]. Therefore, the existence of potential security risks must be evaluated at the design, development and deployment phases, and mitigation measures must be implemented in accordance with the magnitude and likelihood of the risks. Security and safety measures should also be put in place to enhance workers safety and prevent detrimental consequences. To this end, a fallback plan can serve to ensure safety in case of a system failure. AI-enabled technologies must also be accurate. Accuracy rates should be particularly high when such systems can directly affect individuals, as is the case with workers whose integrity may be compromised. Accuracy must be monitored on an ongoing basis and procedures to mitigate and correct potential risks must be implemented. Additionally, workers need to trust the system to use it, therefore reliability and reproducibility are key aspects to ensure the adoption of the technology among workers [19].

Secondly, the prevention of harms to privacy and data protection is paramount given the potential risks that AI-enabled technologies pose to these fundamental rights through the processing of massive amounts of personal data, including the unintended collection of personal data. These rights can also be at stake because personal information can be inferred from non-personal data [20].

Respect for workers' right to privacy and data protection must be ensured by complying with the GDPR and by aligning with existing standards or widely adopted protocols. Importantly, in

IoT environments, it is particularly crucial to clarify data ownership, the roles of data controllers and processors and access to data [21]. Oversight mechanisms must also be put in place to ensure data quality (e.g., representativeness in the dataset) and integrity that minimises the risks of using biased, inaccurate, or compromised datasets. Therefore, processes and datasets must be scrutinised and documented throughout the AI system's lifecycle.

Lastly, the use of AI-enabled technologies should aim at benefitting society and the environment. AI systems must be designed, developed, and deployed with sustainability and environmental friendliness in mind. Therefore, the ecological impact of the system should be evaluated throughout the system's lifecycle and measures to reduce such impact should be encouraged. The social impact of the system should be regularly assessed both at the individual and societal level. For instance, the evaluation of the impact of the technology on workers should cover physical and mental health issues, non-discrimination, de-skilling of the workforce, among others. As for the societal considerations, the impact on the job market and the societal consequences it may entail should be addressed [15].

3.3 Fairness

The principle of fairness entails equality, diversity and the prevention of discrimination and stigmatisation against individuals and groups. Equality requires that all persons by virtue of their humanity and regardless of age, gender, sexuality, disability, ethnicity or other group or relevant personal characteristic deserve equal regard and respect.

Fairness can be achieved by i) promoting diversity, inclusion and non-discrimination; ii) fostering societal and environmental well-being while reducing potential harms; and iii) adopting accountability measures.

Firstly, diversity and non-discrimination can be enhanced with oversight processes that identify, examine, address, and test biases in the datasets and at the design and development phases [22]. From a design perspective, technology should be understandable and accessible to all workers regardless of their age, abilities, or characteristics. In this regard, the participation of relevant stakeholders with diverse backgrounds and viewpoints at the different stages is highly encouraged to ensure that diversity is embedded into the system [23].

Secondly, AI-enabled technologies should be designed to strive for social and environmental well-being. Concerning the principle of fairness, the social impact of the system on workers should be evaluated in terms of causing or exacerbating discrimination, stigmatisation, or marginalisation.

Lastly, accountability requires the implementation of appropriate technical and organisational measures to report the system's performance and provide effective remedy and redress to the extent possible. Such measures include the assessment of design processes, the underlying technology, and the data sets used, which allows for the auditability of the system. Auditability involves reporting the negative impacts of the system, identifying appropriate mitigation measures, and feeding them into the system [14]. These negative impacts can be identified and assessed through comprehensive impact assessments that must be conducted on a regular basis [24]. Accountability also includes providing explanations of the system's outcomes and the ability to seek redress.

3.4 Explicability

The principle of explicability requires transparency of the AI system – including the datasets, the inner workings of the system and the business model –which ultimately enables human oversight [14]. For systems to be transparent, traceability measures must be implemented. This implies that datasets and the technology that underlies the system should be documented, e.g., the methods used for designing and developing the system, the methods used to test and validate it and the outcomes of the system. Given that traceability allows for the identification of the reasons behind systems' outcomes, it enables explainability.

Explainability means the ability to explain the outcomes made by the system intelligibly [18]. To this end, the rationale behind a system's outcome should be understood and traced by humans. Therefore, if a system's outcomes cause harm to workers, explanations of how the system arrived at it should be provided to the worker in plain language. In this regard, communication is crucial since workers must be aware that they are interacting with an AI system in the first place in order to be able to request an explanation. Consequently, workers must be informed in a clear and understandable manner about their interaction with an AI system, how the system works and its purpose, as well as its capabilities and limitations [15].

4 CORPORATE SOCIAL RESPONSIBILITY, BUSINESS ETHICS AND RESPONSIBLE RESEARCH AND INNOVATION

For manufacturing companies, innovative AI solutions are needed to achieve competitive advantages in the current market environment. Innovation does, however, not only have positive effects, but can have negative effects as well. Innovative new processes can contribute, for example, not only to the creation but to the destruction of jobs. New AI systems can lead to an invasion of privacy, to reinforcing biases, discrimination, and stereotypes. Therefore, ethical concerns in the context of industrial manufacturing also relate to the broader concepts of corporate social responsibility (CSR), business ethics and responsible business conduct, as well as responsible research and innovation (RRI). These concepts have in common that they try to integrate ethical, social, environmental, consumer and human rights concerns into a company's business strategy, processes, and operations. Nowadays, increasingly while engaging with all stakeholders involved.

4.1 Corporate Social Responsibility (CSR)

CSR is a management concept to integrate social and environmental concerns in a company's business operations and interactions with its stakeholders. It is a way for a company to achieve a balance of economic, environment and social imperatives (the so-called Triple-Bottom-Line-Approach).

Tools of CSR include hard law and soft law instruments. Hard law instruments are binding laws and international contracts, that are enacted by regulators or signed by nation states, and which a company must adhere to in developing and using AI systems. Examples, related to human rights, are the Universal Declaration on Human Rights, Charter of Fundamental Rights of the European Union, and the European Convention on Human Rights. Soft law instruments

have mainly a voluntary and self-regulatory character and include standards, principles, codes of conduct, and reporting initiatives to provide quantitative data on non-financial (societal and environmental) responsibility performances. Soft law instruments relevant for embedding AI ethical principles involve, for instance, the AI ethical principles established by the AI HLEG [12] and by the IEEE [3]. They stress that AI systems need to address human autonomy, prevention of harms, fairness, explicability, awareness of misuse and competence. Further ethical principles can be extracted from soft law instruments such as the United Nation's Guiding Principles on Business and Human Rights (2011) [25] and ISO 26000 Guidance Standard on Social Responsibility (ISO 26000) [26]. The ethical corporate responsibility and social principles can include carrying out human rights due diligence, to be accountable, be transparent, behave ethically, respect stakeholders' interest, respect the rule of law and comply with the international framework of human rights.

A company can also enact its own voluntary CSR program. Such CSR programs can take on a variety of forms and serve different goals. Being voluntary in nature, instead of being required by public policy or contractual obligations, they can have positive effects on the company's brand value and can help with employee retention. In the context of AI in manufacturing, companies can think of CSR programs to bridge the digital divide, upskill workers, or fight the reinforcement of biases and discrimination.

4.2 Business Ethics and Responsible Business Conduct

Business ethics is the application of ethical values to business behaviour and can provide a framework for balancing different perspectives, values, and interests at stake. Thought-through and operationalised business ethics is essential for companies, especially if they develop and implement AI systems. It is relevant to both the conduct of individuals of the company and to the conduct of the company itself. Responsible business conduct can include confidentiality, fair dealing, protection and proper use of company's assets, compliance with laws and regulations, and encouraging reporting of any possible illegal or unethical behaviour. In the context of AI in manufacturing, it is elemental that companies adhere to existing laws and regulations, ensuring the protection of workers' rights and privacy, and creating channels for workers to address critical issues.

4.3 Responsible Research and Innovation (RRI)

AI systems developed for industrial manufacturing are results of research and innovation (R&I) activities. The concept of responsible research and innovation (RRI) stresses that these R&I activities should be structured in such a way that they enable the development of products and services that are ethically acceptable, socially desirable and respond to the needs and expectations of people and society. It is a "way of thinking that balances commercial and other goals with those concerned with wider wellbeing" [27]. RRI has been horizontally integrated into the European Commission's Horizon Europe program, as well as previously in the Horizon 2020 program, and is therefore especially important for R&I activities in the EU and in EU-funded projects. A key part of RRI is people's engagement and participation in the research process.

Four dimensions of RRI have been deemed central and are relevant for AI ethics: inclusion (also called engagement or involvement of society), anticipation (assessment at an early stage of benefits and risks), reflexivity (reflecting on values and beliefs during R&I) and responsiveness (the ability to change routines, structures, and systems to adapt to changing circumstances and new insights).

Anticipation takes a central role in developing new AI systems. AI systems can have vast negative consequences for the work force, for example by discriminating workers, and thereby also for the business operation and the reputation of the company. Therefore, it is essential to think of an appropriate design of an AI system early in its life cycle to mitigate the risks of the AI system being biased or unexplainable. This, furthermore, can help with the adaption of the AI systems by the workforce, as it increases the trust of the workforce in the AI systems.

5 MEANINGFUL WORK IN INDUSTRIAL MANUFACTURING

There is no unanimous definition of the concept of meaningful work. For many years, it has been a source of multidisciplinary inquiry, and there is still an ongoing academic discussion on its meaning, scope, and actual implications. Nevertheless, in general terms, meaningful work can be understood as work that facilitates "…the development and exercise of capabilities, especially insofar as the exercise of realized capabilities meets with recognition that supports self-esteem", the exercise of virtues, purposiveness, and integrates elements of workers lives including personal relationships [28]. As such, meaningful work empowers the workers to flourish and occupy their time meaningfully and productively in an engaging and reasonably challenging way.

Technological improvement—especially the implementation of AI solutions—in the industrial manufacturing sector pursues the optimization of production, cost reduction, and, ultimately, increasing benefits. Therefore, it aims at having a direct impact on the productive processes, which inevitably leads to a transformation of the workplace. It implies that the design, development, and deployment of AI tools in industrial manufacturing have implications for workers' experiences of meaning in the workplace due to the changing nature of tasks and how they are executed. Notwithstanding the advantages inherent to the implementation of AI solutions, both for the workers and the production process, several authors have raised potential negative effects and threats on the worker's feelings on their daily working tasks.

Among the wide range of potential negative effects that AI tools might have on workers, we can highlight: (i) a diminishing feeling of purpose at work; (ii) less social interaction between workers; (iii) increasing isolation and feelings of meaningless; (iv) unfeasible upskilling to deal with machine-control tasks; (v) de-skilling labour and reducing worker's motivation; (vi) enhancing job polarisation; (vii) losing job social recognition; (viii) data driven-technologies might lead to worker performance monitoring which can undermine worker autonomy; (ix) a reduction of the workers' understanding of their job, and thus of their autonomy, caused by the opacity of the machine-learning algorithm [7, 29, 30, 31].

The design of ethical monitoring strategies is key to lessen the impact of these negative side-effects. Hence, the incorporation of AI solutions into industrial manufacturing must be conducted together with the adoption of adequate mitigation measures. These measures must

seek to ensure that the concept of meaningful work irradiates the entire range of AI solutions set in place. Some measures that can be outlined include: (i) implementing mechanisms to reduce negative impacts on employees regarding re-skilling issues that might arise when using AI tools; (ii) the need to obtain feedback from operators to determine more precisely any consequences caused by AI tools; and (iii) the importance of providing adequate training to operators before using AI tools.

6 CONCLUSIONS

AI systems in industrial manufacturing do not only lead to positive impacts but have risks associated with it of negative effects on the workforce, on the environment, on the company's reputation and broader society. Turning AI ethics principles into practice requires the implementation of technical and organizational measures aimed at ensuring the design and development of trustworthy AI systems. Thereby, empowering workers, enhancing social inclusion and informing up-skilling training programs. In sum, adopting AI technologies in the shopfloor that are beneficial to humans individually, organizationally and societally.

Likewise, companies should refer to concepts of corporate social responsibility, business ethics and responsible business conduct, as well as responsible research and innovation to identify, address, and mitigate potential negative impacts. These concepts help to integrate ethical, social, environmental, consumer and human rights concerns into a company's business strategy, processes, and operations.

Perceptions on meaningful work might be altered by the implementation of AI technologies in the shopfloor. Therefore, careful operationalization of the AI ethical principles and application of corporate social responsibility and business ethics principles is paramount.

This paper is a first attempt to put AI ethical principles into practice in industrial AI. It provides a starting point for the discussion on how the effective operationalization of AI ethical principles can be achieved in manufacturing.

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