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Artificial Intelligence in Industry 4.0: The future that comes true: AI

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Machine Safety and Workplace Implications of Artificial Intelligence

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Abstract: *Artificial intelligence (AI) is giving an additional boost to the already rapid pace of technological progress. The rapid development of new technologies has an impact on machine safety and changes jobs. With a series of laws, directives and regulations, the EU is trying to get a grip on negative developments and use new technologies in a humane way. At the same time, industry is being called upon to acquire additional expertise in new areas of digitalisation. Established institutions around the world are working on developing new standards to facilitate the implementation of regulations. The new EU Machinery Regulation covers digitalisation and defines the use of AI or machine learning. Generative AI (GenAI) is driving prompt engineering and this technology is finding its way into machine development and other production processes. One challenge that remains is how to provide proof of safety for AI in automation technology and especially for autonomous systems.*

Keywords: *European legislation, machine regulation, artificial intelligence, AI norms, prompt engineering*

1. Introduction

Industry 4.0 has initiated the digitalization of everything from machines to the entire production process, the Internet of Things (IoT) has triggered the global networking of software, devices and machines, and now a new field of research is coming into focus: artificial intelligence. AI research reports new algorithms, models and use cases almost daily. New AI-optimized hardware architectures are also constantly being announced. With the Assisted, Augmented and Autonomous Intelligence groups, artificial intelligence is conquering all technological disciplines of Industry 4.0: from the small assembly line to AI that provides humans with supporting information for better decisions, right through to fully autonomous, AI-controlled systems.

Parallel to AI research and development, legal and normative regulations are being developed in various countries and by various institutes and associations.

Of particular importance is European Union legislation that also affects global IT companies operating in the EU market, such as the EU-AI Act (see Table 1). Table 1 lists the most important EU legislation on digitalization that relates directly to AI or has an indirect impact on AI. AI is also software that collects

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and processes data, and therefore regulations on the protection of personal data, cyber-attacks, dissemination of information, etc. are relevant.

Table 1. EU legislation on digitalisation that relates directly or indirectly to AI systems [2]

EU legislation	Content
General Data Protection 2016/679 Regulation (GDPR)	Strict rules for the collection, storage, and processing of personal data, rights of data subjects, obligations of data processors
Free Flow of Data Regulation (EU) 2018/1807 (FFoD Regulation)	Data transfer of non-personal data across national borders within the European Union, including data for (professional) users of data processing services
Public Sector Information Directive (EU) 2019/1024 (PSI Directive)	The Public Sector Information Directive regulates the use of publicly funded data for commercial and non-commercial purposes in the European Union.
Directive on Digital Content and Digital Services (EU) 2019/770 (DI Directive)	Harmonised regulatory framework for the distribution of digital content and services
Directive on measures for a high common level of cybersecurity (EU) 2022/2555 (NIS-2 Directive)	Sets requirements for cybersecurity measures and reporting for operators of essential services and digital service providers
Digital Markets Act (EU) 2022/1925 (DMA)	Targets large online platforms ("gatekeepers"), sets rules to prevent market abuse and unfair practices
Digital Services Act (EU) 2022/2065 (DSA)	Regulates handling of illegal content, liability of intermediaries, transparency of advertisements, protection of user rights in the digital space
Data Governance Act (EU) 2022/868 (DGA)	Framework for sharing data between businesses, public administrations, and citizens, considering data protection and security
Artificial Intelligence Act (EU) 2021/0106 (AI Regulation-E)	Classification of AI systems based on risk (minimal, limited, high, unacceptable) and specific requirements and obligations for the development and use of high-risk AI applications.
Cyber Resilience Act (EU) 2022/0272 (CRA-E)	Requirements for cybersecurity measures and reporting for operators of essential services and digital service providers, promoting resilience to cyberattacks.
Data Act (EU) 2022/0047 (DA-E)	Regulates fair access to and use of data generated by connected devices and machines, promoting innovation and competition
Machinery Regulation (EU) 2023/1230	Sets requirements for the safety and compliance of machinery, considers the integration of AI and autonomous systems, emphasizes the need for measures to maintain inherent machine safety

In addition to EU legislation, guidelines and standards from established institutions are particularly important for the implementation and use of AI, such as:

- ISO - International Organization for Standardization [5] ISO/IEC JTC 1/SC 42 Artificial Intelligence is a standardization subcommittee of the Joint Technical Committee ISO/IEC JTC 1 of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). To date, this subcommittee has published a total of 28 ISO norms on AI, with a further 33 under development. Table 2 lists some examples of norms that deal with security ans safety.[5]

Table 2. *Examples of published AI norms* [5]

Norm Reference	Topic
ISO/IEC 22989:2022	Information technology — Artificial intelligence — Artificial intelligence concepts and terminology
ISO/IEC TR 17903:2024	Information technology — Artificial intelligence — Overview of machine learning computing devices
ISO/IEC 23894:2023	Information technology — Artificial intelligence — Guidance on risk management
ISO/IEC TR 5469:2024	Artificial intelligence — Functional safety and AI systems
ISO/IEC 5338:2023	Information technology — Artificial intelligence — AI system life cycle processes
ISO/IEC TR 24028:2020	Information technology — Artificial intelligence — Overview of trustworthiness in artificial intelligence
ISO/IEC TR 24030:2024	Information technology — Artificial intelligence (AI) — Use cases

This is an example of a technical norm developed by ISO in cooperation with the International Electrotechnical Commission (IEC):
International norm ISO/IEC 42001, which is currently undergoing the EN standard process, defines the requirements for the introduction, implementation and continuous improvement of an AI management system in organisations that offer or use AI-based products or services. The standard addresses challenges such as ethics, transparency and continuous learning. The standard provides a structured approach to the management of AI projects, from risk assessment to risk management. [adapted 6]

- IEEE SA - Institute of Electrical and Electronics Engineers Standards Association: The Ethics Certification Program for Autonomous and Intelligent Systems (ECPAIS) has the goal to create specifications for certification and marking processes that advance transparency, accountability, and reduction in algorithmic bias in autonomous and intelligent systems. ECPAIS intends to offer a process and define a series of marks by which organizations can seek certifications for their processes around the A/IS products, systems, and services they provide. [9]
- DIN Deutsches Institut für Normung e.V. is the independent platform for standardization in Germany and worldwide. It uses norms and standards to describe what is technically possible, economically viable and proven in practice. [1]
- VDA Association of the German Automotive Industry, which deals with the safeguarding of AI, i.e. how the use of AI in vehicles can be proven to be safe. [1]

2. EU Machinery Regulation

The new Machinery Directive 2023/1230 will come into force in all member states of the European Union on 20 January 2027. This means that the essential health and safety requirements and conformity assessment procedures in particular must be applied uniformly for all stakeholders in the EU and there is no scope for divergent implementation, as is currently the case with the Machinery Directives. The Machinery Directive 2006/42/EC [4] applies to the manufacture of machinery and will remain in force until 19 January 2027.

The new Machinery Regulation also takes into account new risks arising from the integration and connection of digital technologies with machinery, such as the implementation of software that utilises machine learning or software that ensures safety functions.

The new Machinery Regulation defines that if the machine is connected: [3]

- to the Internet;
- to a device (data carrier, e.g. USB stick or other devices);
- with remote devices, i.e. via the Internet;

this must not lead to dangerous situations.

Software that fulfils a safety function of the machine and is placed on the market separately is considered a safety component and is subject to the certification procedure for safety components.

The risk assessment of a machine in accordance with the new regulation must also take the following points into account: [3]

- effects of software updates on the safety of the machine;
- future updates to the software installed in the machine;
- use of artificial intelligence in the execution of a safety function;
- Training the AI with training data on the machine

If the AI controls a machine function that may affect the safety of the machine, the AI is monitored by the Safety Monitoring System. This system continuously monitors the operating parameters and the results of the AI and intervenes if the defined safety limits are exceeded in order to put the machine in a safe state. In the event of a machine stop triggered by the safety monitoring system, the reason that led to the stop should be displayed. An Explainable AI is to be integrated for this purpose in order to transparently display the reasons for the machine stop. One example of an AI function in an industrial robot is the optimisation of robot movements within a defined range. If the defined range is exceeded, the safety monitoring system must stop the machine. However, the certification of an AI for use in the area of functional safety is still a field of research at the current state of the art.

The new Machinery Regulation provides for a type examination of machinery by a notified body if [amended after 4].

- Safety components whose behaviour is wholly or partly self-developed by machine learning techniques and which guarantee safety functions.
- Machinery with embedded systems whose behaviour is wholly or partly self-developed through the application of machine learning techniques and which ensure the safety functions and which are not placed on the market separately but only together with the embedded system.

When AI is used in autonomous machines, e.g. autonomous mobile robots with automatically determined routes, the system must be designed in such a way that it does not cause

- machines or associated products to act beyond their defined task and range of movement;[4].
  This means that the limit values defined for the machine must not be exceeded and that monitoring of the limit values must be provided.
- The record of the data relating to the safety-related decision-making process to demonstrate the conformity of the machinery must be kept at the reasoned request of a competent national authority;[4].
  This means that the conformity of the machinery can also be subsequently withdrawn due to the negative influence of further developed or no longer safe artificial intelligence. In this case, the

machinery must be decommissioned until a new conformity procedure has been carried out.

- A correction of the machine or the associated product to maintain the inherent safety is possible at any time. [4]
  In the case of autonomous robots, it must be possible to intervene in the machine control system at any time in order to change or overwrite the results of the AI. This can be done automatically by an external safety monitoring system or manually by an operator, for example. If manual correction of the AI results is planned, this requires that the operating personnel are trained for this workstation and are familiar with the machine, the process and the application of the AI.

3. Promting Engineering

As prompt engineering is being learnt through its current use in search engines and through the use of generative artificial intelligence (GenAI), it is to be expected that this technology will also be widely used in the development of automation solutions. The ambiguity of human language, which often leads to undesirable results in generative AI when prompting, is clearer in mechanical and electrical engineering - not least due to pronounced legal and normative regulations - and is therefore more suitable for AI in technical applications. Prompts are already being used today in the use of technical documentation and in the creation of control programmes. It is therefore conceivable that the prompting technology used today will be integrated into the further life cycles of automation in an adapted form.
Prompt engineering can be used from the creation of the layout of a machine through to complete production in a factory. However, the definition of prompt engineering "is the process by which solutions are controlled with generative artificial intelligence (generative AI) to achieve the desired results" [8] must be adapted for reasons of safety and technical feasibility in the automation technology of a production, e.g: Prompt engineering in automation technology is the process in which solutions for the automation of a production are controlled with artificial intelligence in such a way that they achieve the desired results according to the state of the art.
The development of prompt engineering for the design of automation systems is about precise input and an AI with training data that can rule out incorrect input from the outset.
What applies to ChatGPT "*Express yourself precisely and give context*" [7] would apply to automation technology: "*Enter precise information with sufficient parameters.*"
Such a prompt during layout creation in automation technology could contain the following information:

- System consisting of the system elements (machine types, incomplete machine, sensors, protective elements, etc.)
- Process description with process parameters and automation corner points
- Workpieces and tools with their parameters
- Limits of the respective system element (e.g. machine with work area, performance, control system, etc.)
- Environmental parameters and internal company standards for defined machines and processes

Software tools for design, layout creation and simulation are particularly suitable for generating variants and therefore data that can be used for training AI.
In CAD or simulation tools, it is possible to generate models or initial layouts using prompts. In a CAD tool, such a prompt could look like this:
"Create an articulated arm robot on an area of 10 x 20 m: payload 25 kg, range 1800 mm, which picks up the workpieces: round blanks with a weight of 2 kg and the dimensions WxL 20 x 250 mm from a table height 730 mm with a work surface of 1 x 2 m with a gripper and positions them in the CNC machine".

The result should be a layout of a system in which the following system parts are drawn in a hall: an industrial robot with a gripper, a table in front of it and a CNC machine to the side, a protective grid with a door around it and a control cabinet for the robot and a control cabinet for the CNC machine outside the protective grid. Based on this layout, the technical draughtsman can then move or change each element and use the design for the meeting and then make further adjustments and changes.
For a simulation, the basic control programme of the robot, the CNC machine and the higher-level PLC, including the control panel with start and stop buttons, could be created automatically. The networking between the robot, CNC and PLC should also be created. In the safety part of the PLC, the emergency stop button and the safety switches on the safety gate should be integrated into the control programme.
The following applies to generative AI: "*Avoid bias in the prompts, as the results will usually contain bias.*" [7] should be avoided in engineering for reasons of machine and occupational safety. Therefore, one challenge for the future is to develop an AI for automation systems in such a way that it can intercept such and similar incorrect inputs as "*Create a layout with a CNC machine for welding sheet metal on a 1 x 2 m table*", as a CNC machine is not intended for welding.
It is also important that only trained automation technicians work with these tools and that the evaluation of the results of AI in automation may only be carried out by experienced automation technicians.

3. Conclusion

In recent years, the European Union has responded to the rapid development of digitalization with new regulations to define the impact on people, the economy and society as a whole. The new regulations also lead to a burden on the economy, not just the European economy, but also have an impact on globally operating corporations. The new EU Machinery Regulation takes digitalization and AI into account. However, how the safety of AI can be proven is still the subject of research. A solution is currently being sought in which the behavior of the AI is monitored externally. Generative AI is changing engineering through the introduction of prompt engineering. In particular, software tools with integrated prompts in design, simulation and programming make work easier and increase efficiency.

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