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Safety of machinery — Relationship with ISO 12100 —

Part 5:
Implications of artificial intelligence machine learning

Sécurité des machines — En relation avec l'ISO 12100 —

Partie 5: Implications de l'intelligence artificielle pour l'apprentissage automatique

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Foreword

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This document was prepared by Technical Committee ISO/TC 199, *Safety of machinery*.

A list of all parts in the ISO/TR 22100 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The primary purpose of this document is to provide guidance for the development of artificial intelligence (AI) machine learning applications. Safety can be compromised due to the significant complexity of introducing AI machine learning to machines.

A control system can use machine learning (a technology of artificial intelligence) to improve performance of the machine or to execute tasks. The control system learns its expected behaviour through training. This involves two stages: training and inference (autonomous operation).

This document assists machinery designers to develop solutions appropriate for their particular applications. It describes how to apply the risk assessment process according to ISO 12100 to AI machine learning applications.

AI machine learning is a rapidly evolving technology and has not been a subject of machinery safety until now.

Safety of machinery — Relationship with ISO 12100 —

Part 5:
Implications of artificial intelligence machine learning

1 Scope

This document addresses how artificial intelligence machine learning can impact the safety of machinery and machinery systems.

This document describes how hazards being associated with artificial intelligence (AI) applications machine learning in machinery or machinery systems, and designed to act within specific limits, can be considered in the risk assessment process.

This document is not applicable to machinery or machinery systems with AI applications machine learning designed to act beyond specified limits that can result in unpredictable effects.

This document does not address safety systems with AI, for example, safety-related sensors and other safety-related parts of control systems.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
artificial intelligence
AI
branch of science devoted to developing data processing systems that perform functions normally associated with human intelligence, such as reasoning, learning, and self-improvement

[SOURCE: ISO/IEC 2382:2015, 2121393, modified – The word "computer" has been deleted from the definition.]

3.2
machine learning
process using algorithms rather than procedural coding that enables learning from existing data in order to predict future outcomes

[SOURCE: ISO/IEC 38505-1:2017, 3.7]

4 Use of AI in the machinery sector

4.1 General

Enterprises in the machinery sector are constantly developing AI solutions for different application processes, such as:

a) quality control;

b) process optimization;

c) condition/failure monitoring;

d) predictive maintenance.

General objectives for these applications are;

— optimization of machine performance/tasks to be performed by machinery;

— more effective use of resources;

— reduction of environmental effects;

— improvement of working conditions.

Some AI applications can have implications on the machine function and thus on machinery safety, while others do not. Whether AI can have an immediate effect on machinery safety depends on the intended optimization effect and its practical realization via the machine design.

4.2 Examples for use of AI machine learning in machine applications

4.2.1 Examples without safety implications

4.2.1.1 General

There are many examples with machinery optimizing processes without impact on safety, e.g. packaging robots optimizing pieces with randomly different sizes to load on a skid or pallet. The objective here is to get a package not exceeding certain dimensions or weight. As such, these processes are predetermined. There is no impact on safety. In these situations, AI applications do not introduce new hazards or increased risks that are not addressed by the risk reduction measures to be applied for a packaging robot without AI.

4.2.1.2 Optimization of herbicide spraying machine[1)]

Today, it is still common practice that agricultural machines treat all plants as if they have the same needs. For herbicide-spraying machines, this means broadcast-spraying (the same amount of herbicide is provided per area regardless of actual presence of weed).

An AI system that allows the identification of a greater variety of plants both crops and weeds (image recognition by deep learning) provides the necessary accuracy to make crop management decisions (precision farming) on the spot. For the application of this AI system, herbicide-spraying machines are equipped with a multitude of cameras which are interconnected with customized spraying nozzles. Based on the recognized image (crop or weed), the optimal amount of herbicide is provided by the individual spraying nozzles on the spot.

1) For example, see-and-spray machines by Blue River Technology Inc. at the following address: http://smartmachines.bluerivertechnology.com. This is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Regarding the corresponding machine function (spraying of herbicide), safe operation for this kind of spraying machines is ensured by adequate protection of the machine operator from herbicide spraying dust by means of a cab (with a filter or overpressure system) on the spraying machine itself or the agricultural tractor towing the spraying machine. The prescribed AI application in comparison to the conventional machine function does not create any additional hazards or increase the magnitude of already existing hazards. Therefore, no consideration of additional/different measures regarding machinery safety is necessary.

4.2.1.3 Optimization of the removal system for a laser cutting machine[2)]

A fully automatic laser cutting machine cuts parts from a metal sheet and removes them from the machine. These cut parts come in an almost endless assortment of shapes, sizes and thicknesses. The machine needs to remove them from the sheet in a variety of ways using suction cups and pins, otherwise the part can get jammed and stop the machine. With over 2 500 suction cups available to release parts from the scrap skeleton, part removal often succeeds at the first attempt. But, if it does not, the machine can autonomously decide to repeat its efforts, however many times are necessary. The 180 pins used to press the part out of the scrap skeleton simply try a different way of getting the job done. This method works more and more efficiently thanks to an AI solution. Whenever part removal fails at the first attempt but then subsequently succeeds, this produces data. These data are analysed and compared with data in an automated and centralized process. The results of this data comparison can then be transferred from one machine to all the other machines of the same type. This way, the other machines learn the best way to remove a similar part at the first attempt. These systems are expected to improve continuously in the future based on data from hundreds of thousands of inputs from the whole machine population.

Regarding the corresponding machine function (cutting and removal of metal parts), the safe operation for this kind of laser cutting machines is ensured by restricting the access to the cutting table by means of guards (fixed and/or movable). The prescribed AI application in comparison to the conventional machine function does not create any additional hazards or increase the magnitude of already existing hazards. Therefore, no consideration of additional/different measures regarding machinery safety is necessary.

4.2.2 Examples with safety implications

An example with safety implications is an automated guided vehicle (AGV) that operates in a space not limited by perimeter safeguards (for example, fixed guards, safety light curtains) and self-optimizes its navigation via an AI application. In this case, the AI application introduces new hazards or increases risks that are not addressed by the risk assessment of an AGV without AI operating in a space limited by perimeter safeguards.

NOTE An AGV is also known as "driverless industrial truck" (see ISO 3691-4).

An AGV without AI is travelling on predetermined routes. The routes are mostly separated from the surroundings.

For both cases (AGV without AI operating in a space limited by safeguards and autonomous AGV with AI operating in a space not limited by safeguards), the principles for risk assessment and risk reduction specified in ISO 12100 are applicable.

An autonomous AGV may take routes through the plant, which are not separated from other areas (for example, workplaces). Here, people are present at random places. An AI application calculates the preferred route and speed of the AGV to optimize the overall transportation process.

Table 1 describes the essential steps for the risk assessment and risk reduction process according to ISO 12100 for an AGV with AI in comparison to an AGV without AI.

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2) For example, see the fact sheet "Examples of artificial intelligence" at TRUMPF (https://www.trumpf.com). This is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Table 1 — Essential steps for risk assessment and risk reduction according to ISO 12100 for an AGV with AI in comparison to an AGV without AI

ISO 12100	AGV without AI	AGV with AI
Use limits	Travelling on predetermined routes.	Travelling autonomously on variable routes with variable speeds in an optimized way considering distances, known surroundings and obstacles based on AI
Space limits	Range of machine movement determined Human-machine interaction determined	Machine movement variable within a predetermined boundary Human-machine interaction within this boundary undetermined
Time limits	Abrasion of wear parts determined, predictable (for example, brakes)	Abrasion of wear parts variable, partly predictable (for example, brakes)
Other limits (vehicle limits)	Determined speed	Variable, optimized speed within predetermined limits
Hazard identification	Collision with bystanders or obstacles (shearing, crushing, etc.)	
Risk estimation (for collision)	Basic risk for an AGV without AI based on: — speed; — acceleration; — mass; — shape; — load; — braking capability; and other parameters	In comparison to the basic risks for an AGV without AI additional risks can result, for example, from: — increased speed; — increased acceleration; — sudden changes of direction of movement; — AGV movement in areas without sufficient clearance; due to effects of the AI on the AGV control system
Risk evaluation	Application of risk reduction measures	Application of risk reduction measures
Risk reduction by	Guards	Detection of bystanders via sensor-based systems to adjust the speed (up to the AGV stop), or to adjust the travel route, or a combination of both; Adjustment of detection field in relation to actual speed and position of the AGV within the predetermined boundary Restriction of energy by limitation of the AGV speed such that contacts with persons do not lead to harm
Evaluation of residual risk after risk reduction, including information of use	Adequately risk reduction achieved, information for use completed	

The risk estimation for the AGV with AI in Table 1 is referring to the collision risk only.

The main differences regarding appropriate risk reduction measures (according ISO 12100) for an AGV with AI in comparison to an AGV without AI are:

— determination of intended use and, in particular, use limits for the machine (flexibility within certain predetermined boundaries);

— risk reduction by sensor-based detection systems (versus guards) which are able to adjust/stop dangerous movements of the machine (forces, energy, speed, torque, etc.).

NOTE With ISO 3691-4 and ISO 17757, standards which address safety aspects respective for autonomous and semi-autonomous machinery, exist.

5 Conclusion

The risk(s) introduced by AI in machinery applications can be completely addressed by the methodology for risk assessment and risk reduction as prescribed in ISO 12100 where risks of the AI are addressed according to the intended use and use limits (predetermined boundaries) specified by the machine manufacturer.

Bibliography

[1] ISO/IEC 2382:2015, *Information technology — Vocabulary*

[2] ISO 3691-4, *Industrial trucks — Safety requirements and verification — Part 4: Driverless industrial trucks and their systems*

[3] ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

[4] ISO 17757, *Earth-moving machinery and mining — Autonomous and semi-autonomous machine system safety*

[5] ISO/IEC 38505-1:2017, *Information technology — Governance of IT — Governance of data — Part 1: Application of ISO/IEC 38500 to the governance of data*

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