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An overview of current safety requirements for autonomous machines - review of standards

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Extended abstract

Background The development of automated work machine systems towards autonomous operation is proceeding rapidly in different industrial sectors. So far, automatic machines have been operating in closed areas (e.g. harbors and harbors). On the other hand, automated forklift trucks and Automated Guided Vehicles (AGV) have long been used in factories and warehouses.

Objectives The objective of the study was to obtain an overview of safety requirements for automotive non-road vehicles in different industries. The aim of the work was to explore the current situation in different industrial sectors and to study what they have in common and where there are differences.

Materials and methods VTT and Luke conducted the study on safety requirements for autonomous machines to FIMA ry. The latest information on safety requirements for the autonomous working machine systems were collected from ISO, IEC and other standards and technical reports from different industrial sectors. In addition, activities in international industry groups regarding automation and autonomy of machinery were reviewed.

Results The first safety standards or their drafts have recently been published on autonomous mobile work

equipment systems. ISO 17757: 2017 [1] defines requirements for autonomous or semi-autonomous earth moving machinery and mining machinery systems. The key point in this standard is that the requirements are defined from a system-level perspective. The draft standard ISO / DIS 18497.2 [2] defines requirements for automation of agricultural machinery and tractors. The draft ISO DIS 3691-4 [3], in turn, defines the requirements for unmanned forklifts, AGVs and associated systems.

As a summary an overall picture and status of the most interesting ISO and IEC standards on the context of autonomous machinery is given in Figure 1.

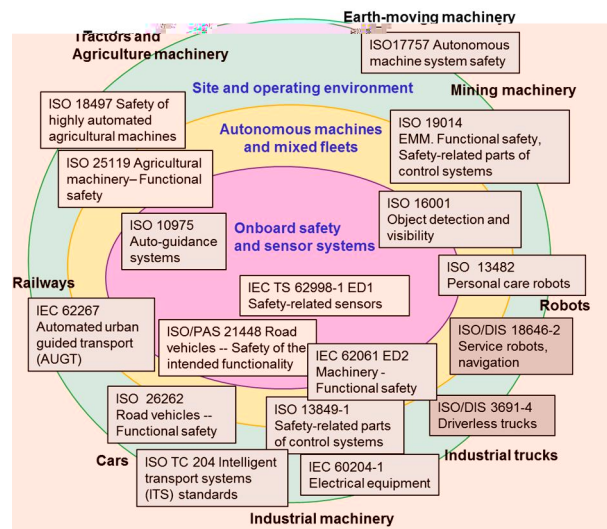


Fig. 1. An overview of the current situation in standardization on autonomous machinery.

Three approaches for safety concepts for autonomous machinery were identified in the current standardization.

The first approach aims to concepts, where machine carries a sensor system and safety system is contained within a machine. This allows non-separated working areas for humans, machines and autonomous machines to operate in the same area. These concepts are restricted to indoor applications as the sensor systems needed are only fit for indoor use.

The second approach aims to separate and isolate the autonomously operating machinery and control the access to working area and monitor other vehicles or persons in the autonomous operating area. This approach is for machines working in intensive outdoor environment.

The third approach aims to rely on monitoring by the operator. Here the concepts might include some sensing solutions to detect hazardous situations. When a problematic situation is detected, the operation could be stopped and the control is transferred to local or remote operator. The approach relies heavily on the operator's ability to understand the situation and to react correctly. The approach is suitable to working environments where there is low activity and low likelihood of hazardous situation and where there is enough time to alert the operator and transfer responsibility.

Conclusions Many of the standards related to safety requirements for autonomous machine systems are still in draft phase and the current existing standards will evolve. The standards are expected to become more precise as more is learned about the performance of the autonomous systems.

Two main problems in the standardization of safety requirements for autonomous machinery were identified. Firstly, there is a gap between the requirements set in standards and the state of the art in technology. As standards expect full compliance, there is no gradual path to develop the system. A fully functioning system is what standards expect and there is no room for trying and learning. There is problems fitting the existing designs to meet the requirements in standards. Secondly, the standards are for machine manufacturers. The worksite operators or owners are not involved. The worksite should integrate the machines not the other way round. This is also a challenge for the business case and the benefit that the machines could offer.

The systems engineering approach presented in ISO 17757 can be considered to be a good guideline to handle the management of fully autonomous or mixed fleet operation and earth moving machinery standardization is widely referenced already.

A major obstacle in the development of autonomous mobile machinery is and has been the requirements for sensor systems for detecting humans. As the machinery is heavy, collisions with the machinery pose the risk of serious injury and death, which leads to requirements for Performance Level d [4] or equal system.

Sensor fusion seems to be a good way to approach in difficult environments, since different sensors have different advantages and the sensors can compensate the weaknesses of other sensors.

References

- [1] ISO 17757:2017 Earth-moving machinery and mining -- Autonomous and semi-autonomous machine system safety.
- [2] ISO 18497:2018 Agricultural machinery and tractors — Safety of highly automated agricultural machines — Complementary element.
- [3] ISO/DIS 3691-4 Industrial trucks -- Safety requirements and verification -- Part 4: Driverless industrial trucks and their systems. Under development 2019.
- [4] ISO 13849-1:2015 Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design.