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Innovative assistance system to prevent accidents on sliding table saws

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ABSTRACT

In 2019, the Institute for Occupational Safety and Health (IFA) conducted a proof of concept of a camera-based assistance system designed by a saw manufacturer. The camera system is designed to trigger a safe state when a hand approaches the hazardous area in a dangerous way. To detect a hand and track its movement, software is used that employs artificial intelligence (AI) to examine camera images for the presence of human hands. There are currently no suitable standards for the assessment of vision-based protective devices using AI technology. Due to the AI component the system was therefore not assessed as a protective device, but as an assistance system. Assistance systems can help to gain experience with the use of AI technology The examination of the AI component therefore followed four basic principles for risk mitigation of AI-systems.

1 WHY IST THE INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (IFA) CONCERNED WITH THE PROTECTION OF SLIDING TABLE SAWS?

Serious accidents occur time and again on sliding table saws and circular table saws in general, as operators typically work with their hands very close to the saw blade. The safety guard required by standards on such saws is the safety hood. On the one hand, this hood serves as protection against sawdust and wood dust, which are extracted from underneath. It also shields the saw blade above the material to be sawn from contact with the operator. Unfortunately, this protective device is often not adjusted correctly, resulting in serious injuries to the hands. According to the German Social Accident Insurance Institution for the woodworking and metalworking industries (BGHM), a total of 177 accidents occurred on circular table saws in the commercial sector between 2014 and 2017 in Germany [1].

2 HOW CAN A SLIDING TABLE SAW BE ADDITIONALLY SAFEGUARDED?

Since there is a high accident rate despite compliance with the normative requirements, but at the same time modern systems, e.g. those that pursue an AI-based approach, are not available at the safety level of a protective device, the aim is to further reduce the accident rate by means of additional technical equipment, so-called assistance systems. This approach does not replace safety functions required by standards, but instead uses an additional function that does not currently contribute to risk reduction in accordance with DIN EN ISO 12100. This article explains the classification of an AI-based camera system as an assistance system as well as the function and testing of such systems using the example of the sliding table saw.

3 WHAT IS AN ASSISTANCE SYSTEM?

With the GS-BAU-70 "Principles for the testing and certification of safety-relevant assistance systems on machinery and commercial vehicles" [2], German test bodies of the DGUV Test network, including the IFA, have developed a test principle for assistance systems. This test principle describes the following definition of an assistance system:
"An assistance system is a support system for users of stationary and mobile machinery that provides an assistive function for operating tasks or is intended to counteract errors and misconduct in operating tasks."

As not all assistance systems have the same objective, the following classes of assistance systems are defined:

- Class A assistance system
  A class A assistance system is an information system with an indirect effect.
- Class B assistance system
  A class B assistance system is a warning system with an indirect effect, which delivers a warning with particular emphasis..
- Class C assistance system
  A class C assistance system is an assistance system with a direct effect that can be overridden by the user if required by the application. Such a system actively intervenes in a minimizing/limiting manner, makes a suggestion for action to the user if necessary and is not part of the risk reduction strategy.
- Class D assistance system
  A class D assistance system is a semi-automated system with a direct effect that can be overridden by the user if required by the application. Such a system actively intervenes in a minimizing/limiting manner, is part of the risk reduction strategy and can, for example, take over part of the operating task.
- Class E assistance system
  A class E assistance system is a fully-automated system with a direct effect that cannot be overridden by the user.

The AI-based assistance system presented below as an example can be assigned to class C. It has a direct effect, initiates a safe state when activated, but at the same time makes no contribution to risk reduction. The protective device required by the standard, the protective hood, is still present. This system therefore does not replace the existing protective device but provides additional protection for the operator.

4 FUNCTION OF THE AI-BASED ASSISTANCE SYSTEM

The camera system presented as an example can initiate a safe state when a hand approaches the danger zone. To detect a hand, the manufacturer has developed software that uses artificial intelligence (AI) to examine camera images for the presence of human hands. As soon as the AI recognizes a hand in the camera image that is moving towards the saw blade and thus diagnoses a dangerous situation, the saw blade is lowered under the work table in a fraction of a second to prevent contact between humans and the saw blade. From this safe state, the machine can be returned to working condition within a short time and work can continue without damaging the sliding table saw or the material being processed.

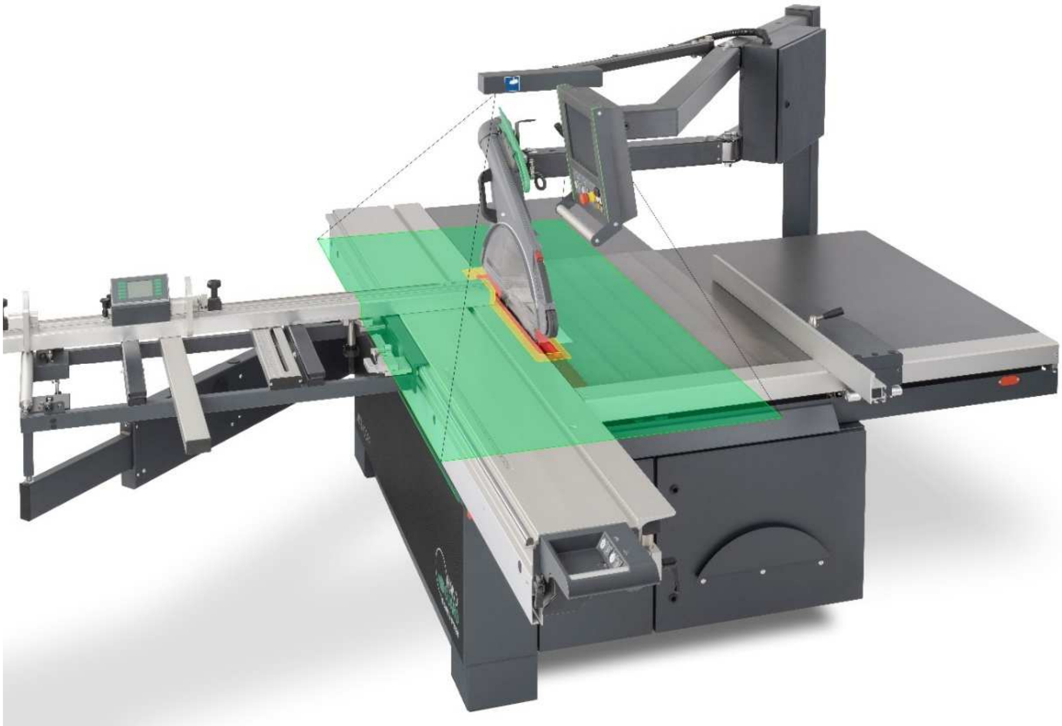

***Figure 1**. Illustration of an AI-based assistance system on a sliding table saw. © Andreas Metzner Fotografie*

In operational practice, a so-called start-up test, among other measures, ensures that the system functions reliably. After starting the machine, it must recognize both hands of the operator, otherwise the machine's saw blade cannot be started.
As the system can also recognize more than two hands in one image, a second operator is also protected. However, to ensure that the additional person can work safely, they should first test themselves manually on the system. The hand detection tests are only used to check whether the operator's hands can be recognized at this time. There is no teach-in or online-learning of the system at runtime.

5 REQUIREMENTS FOR AN AI-BASED ASSISTANCE SYSTEM

To ensure that the individual assistance systems function correctly and to ensure a high level of protection for the operating personnel, the IFA works with the responsible accident insurance institution to develop the requirements for such non-normatively defined systems in these cases.
If the system has an AI component, the possibility of new hazards arising from the use of this technology must be ruled out. In order to achieve this, AI-specific aspects are relevant, which can influence the reliability and robustness of the AI system and therefore have a direct impact on the safety of the system.
Robustness is a new challenge in connection with AI systems, as these systems are used for very complex tasks in complex usage environments that involve a certain degree of uncertainty. Deep neural networks pose a particularly difficult challenge as they are both hard to explain and sometimes exhibit unexpected behavior. Based on the current technical, regulatory and normative characteristics, four basic principles for risk mitigation can be derived for AI systems, each of which is associated with corresponding measures.

1. Good engineering and data science practice
   To ensure an adequate level of quality for an AI system, a development must be guided by established basic practices. This includes adhering to a consistent process that covers all phases of the development of an AI system. In addition to ensuring a good development process, basic practices also include the application of data quality standards and the use of programming guidelines.
2. Application / interpretation of existing functional safety standards
   Depending on the complexity of the chosen model, individual methods for avoiding and reducing systematic errors during software development can be interpreted from the existing standards (see, for example, [3], Annex A.2).
3. Mitigation of AI-specific risks through further measures
   If hazards arise from specific risk categories within the planned application of the AI system, various specialized methods should be used preventively during development in order to minimize these AI-specific risks. Examples here would be robust training or explainability methods. Often, the risk minimization achieved is not yet sufficient or can only be quantified to a limited extent, which is why the application of these methods alone does not currently meet the requirements for rigorous proof of safety.
4. Overall system protection and runtime monitoring
   Even after applying certain measures during development to reduce AI-specific risks, AI systems typically still exhibit certain amounts of uncertainty in their predictions. If this uncertainty is measured and quantified during runtime, a measure of reliability can be determined for an AI system. In addition to model-related uncertainties, environmental conditions can also contribute to the predictions of a model not being reliable. For example, a camera-based system for detecting people in the absence of sufficient lighting will predict with high confidence that there is no person in its field of vision. The safeguarding of such an AI system should therefore be considered on a system-wide level. In the example mentioned, a classic brightness sensor could be used to check the credibility of the model with regard to this particular possible error. If the overall uncertainty of the AI system is high, the principle of safe failure should be applied. To do so, the system could fall back on a classic decision-maker, for example, or switch to the safe state first and request a further check by a human.

6 FUNCTIONAL TESTS OF THE OVERALL SYSTEM

A further consideration in the evaluation of such assistance systems is functional testing, so-called black box tests. In such tests, the system is exposed to various initial situations that are relevant in the application of operational practice and compliance with the expected system behaviour is checked. In the case of imaging AI-based systems, the different factors influencing detection must be covered in the initial situations. With regard to hand detection on a sliding table saw, for example, skin colour, skin soiling, tattoos, lighting and the various possible hand positions are factors influencing detection. The above list is only a selection of influencing factors and is not a representation of the complete test scenarios.

Figure 1. *Factors influencing an AI-based hand detection*

7 RESULTS AND USE

A system with an AI component can already be considered as a suitable assistance system. In order to be classified or assessed as a protective device, a system for sliding table saws, for example, would require proof that all hands – including those with large tattoos, for example – are detected with a very high probability in all working situations. At the same time, proof would have to be provided that situations in which the output of the AI is highly uncertain are recognized so that the system can also switch to the safe state in these cases. According to the current state of expert discussion and standardisation, it is not yet possible to provide sufficient proof for a single image-based system when using artificial intelligence and machine learning. To further improve occupational health and safety, it makes sense to classify such system as assistance systems and thus provide additional protection for the operating personnel.

8 OUTLOOK

An adaptation of the system presented here as an example on a sliding table saw to other machine types and applications is certainly conceivable. However, when transferring the system to other applications, e.g. other saw types, attention must be paid to the changed framework conditions and influencing factors. The different environmental conditions and machine characteristics have a major influence on detection and must be re-evaluated.

9 AWARDS

The system presented has been awarded the German Occupational Safety Award 2021 in the "Operational" category. In November 2023, the International Social Security Association (ISSA) presented the manufacturer of the system with the triennial Safety Award.

10 REFERENCES

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