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Tag - and Knowledge-based Standards Documentation

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ABSTRACT

The CE marking process is mandatory in the European Union for machines to declare conformity with all harmonized safety standards and, thus, with all relevant EU directives. The comprehensive identification of all relevant and applicable standards and laws is a major challenge, especially for smaller companies and start-ups with no previous experience in safety certification. Anecdotal experience obtained in various discussions with companies shows that the inclusion of standards and laws in product development is often neglected. Furthermore, the gap between the product and legal requirements only becomes apparent late in the development process and may cause economic damage or inhibit innovation. The authors have identified that, in addition to a lack of knowledge about safety requirements, the main reasons for this are poor accessibility of the relevant standards and the fact that they are hidden behind paywalls, which is an additional economic hurdle especially, if a detailed assessment of the standards relevance is only clarified after having bought the full standard's document. Furthermore, the titles of such standards lack consistency, and synonyms of keywords are used differently depending on their origin and their definitions are often interdependent without clear necessities and relations.

In this article, we present the concept of a tag -based description of a machine in conjunction with knowledge-based standard’s documentation to solve the aforementioned problems, in particular the identification of relevant standards in relation to a specific machine. Our solution extends the first step of risk assessment — the determination of the limits of the machine — by defining the domain, hazards and areas of application through tags. These tags have been developed in such a way that they can describe the machine unambiguously, but at the same time are general enough to keep the list reasonably short. This results in a method of describing the machine and avoids synonyms. This same list of tags is also used to categorize and assign the tags according to domain, hazard and environment of application for the standards. The relevant standards ultimately result from the combinations of the respective tags when determining the limits of the machine. This results in a dependency, and if the limits of the machine are changed, this is reflected in the relevant standards. Our approach enables that standards can explicitly reference and quote each other in a semi-formal manner. This allows further dependencies and affiliations to be investigated if required.

This tag and knowledge-based documentation enables the identification of the relevant standards for a specific machine and thus supports small and medium-sized companies in the safety certification of their machines.

1 INTRODUCTION

There is growing interest in integrating robots in public spaces which are complex ecosystems. Robots will shape our cityscape, change our understanding of work and become our interaction partners We ask ourselves the question: how can robots operate safely, sensibly and economically in this field? The authors investigate this question in the context of the rokit robot competence and interaction cluster that is funded by the Federal Ministry of Education and Research (BMBF). A competence cluster brings together interdisciplinary expertise — consisting of research institutions, companies and public administration — to help manufacturers and users integrate robots into the public-space ecosystem. rokit addresses three interlinked problems: the deployment of robots in public places, their interactions and the adaptation of existing robots to new applications. There are already many successful automation technologies for industrial and protected areas. However, a transfer to the non-industrial and especially the public sector often fails due to legal problems and human-robot-interaction issues. A first example is a mobile robot that picks up litter in a public park. A second example a collaborative robotic arm that is mounted on a mobile platform to stock shelves or assembles shopping baskets in a store. How can hazards that arise in such scenarios due to proximity to humans be assessed? What framework conditions apply to the manufacturing companies when they introduce a robot into the field? And how can the requirements be easily implemented so that they achieve an area-wide protection objective. What is needed for CE-marking?

The current process for determining the standards that apply to the respective product is that the harmonized standards must first be identified [1], [2]. To do this, each applicable product group must be selected on the European Commission's website and the list of standards must be searched by title and by testing various keywords. Once a selection of possibly-relevant standards has been identified, the table of contents and the scope of a preview of the standard must be used to determine whether the standard in question is relevant or not. If the standard is found to be relevant, it must be purchased in order to derive the complete requirements for the respective product. In addition to the harmonized standards, other standards may exist, which must be identified through further searches and evaluated using the same procedure and ultimately purchased as required. In order to answer questions such as the ones listed above for robot manufacturers or robot integrators, the authors propose a structured representation of standards.

2 PROBLEMS AND REQUIREMENTS

According to [3], the boundaries between industrial and service robot's blur. Robots can therefore be deployed in different areas, yet, the applicable standards are domain-specific, and often it remains unclear which of them apply concretely. In addition to the increasing number of stakeholders and their generally lower expertise, this also results in a complication of cross-domain safety. This is also confirmed by [4], where the authors conducted an online survey and discovered that a lack of knowledge is one of the most significant barriers to the use of collaborative robots.

Standards are drawn up, discussed and published by committees of experts [5], [6]. The fact that there exists a diverse set of committees and that some of them work independently of each other means that stylistics as well as definitions of terms can differ, making it difficult to analyse and select applicable standards. This is already clear from the way the standards are named or the form in which the standards' scopes are defined. Given that the title, scope and table of contents are particularly crucial for surveying standards, it is easy for manufacturers or integrators to miss a relevant standard.
In machine safety, standards are classified into type A, B and C standards Type A standards are basic safety standards (e.g., ISO 12100), type B standards are generic safety standards that can be used for a range of machines (e.g., ISO 13849) and type C standards provide detailed safety requirements for machine safety for specific machines. In other words, a type C standard specifies the concrete requirements of a type B standard, which in turn concretizes a type A standard. This results in a relationship between standards that also extends to other areas. For example, ISO 13482 describes the safety requirements for personal assistance robots but refers to ISO 13855 for the distance calculation. However, these dependencies, links and interconnections are not apparent in advance.

In summary, in the authors have identified three core problems, namely (1) the difficulty of selecting applicable standards, (2) the non-unique language, and (3) the links, dependencies and references between the standards. The proposed approach is intended to offer a solution to these problems and thus help stakeholders with little prior experience.

4 APPROACH

The approach pursued in this article consists of three steps: (1) definition of categories, keywords and tags, which enable the machine or application to be precisely defined, (2) filtering of the standards using these tags in the respective categories based on the scopes of the standards, and (3) interlinking between various standards. Therefore, a knowledge base must be developed which, on the one hand, enables the description of the respective machine, robot or application and, on the other hand, results in a selection of standards, data and links.

As mentioned, the aim of the tag list is to enable an unambiguous description of the scope of the machine as well as the scope of the standard. A tag is defined as a unique, understandable and clear keyword, also named as suspended hyphens. There must therefore be no synonyms or duplicates. However, tags can have subcategories and nesting. This is because the scope of the standard can have a different granularity and area of application. This becomes particularly clear regarding the different types of standards. For example, type A standards describe basic safety instructions that apply to all machines, but a type C standard is limited to a specific type of robot, such as ISO/TS 15066 for cobots. However, cobots are also machines and therefore both tags “#machinery/cobot” should apply.

The tags are classified into categories, whereby each machine must be provided with at least one tag from each category, but as many tags as necessary. The number of categories must therefore be reduced to a reasonable size and have properties that can be found for machines and in standards alike. After considering a wide variety of applications and many scopes of standards, the three category groups “Objective, Domain & Involved Users”, “Hazards and Sources of Harm” and “Environment” were determined for the description of the machines as shown in Figure 1. These categories were selected in a workshop as part of the rokit project, which was made up of an interdisciplinary team of experts from a wide range of fields. These included engineers, ethicists, lawyers, psychologists, occupational health and safety experts, management scientists and work system design specialists.

The Domain describes the type of system, such as mobile robots, as well as the users, stakeholders and other persons that must be considered for the clear classification. The description of the machine refers to the limits of the machine and, in the case of standards, the area of application and thus the scope of the standard. This specification is important because, these are standards for the industrial sector and hence restricted to the working force — people able to work and of legal age. However, public places are also occupied by children or other groups of people that require special attention which are only covered partially or not covered by these standards. The Hazard category describes obvious hazards and sources of harm. This category contains tags associated with special standards for test procedures or hazards. The last category is the Environment, to represent, among others, spatial or temporal characteristics of the robots’ operating environments. Like the domain, this may exclude areas of application. As an example, a standard that is only intended for public transport does not apply to use in public green spaces.

Just like the machines, the standards must be provided with these tags and thus described. If a new standard is added to the knowledge database that cannot be described using the existing tags, the relevant tags must be added to the list. However, this also means that the definitions of the robots must also be re-evaluated regarding the new tags, as otherwise a complete selection cannot be made. The authors have also analysed existing taxonomies, quantifications and methodologies from the literature, such as [7], [8], [8], [9], [10], and have incorporated some of the results were into the list of tags.

But how can the applicable standards be identified using the tags? A standard is considered applicable if, ideally, at least one tag from each category matches the description of the machine. A distinction is made between hard and soft criteria, whereby a hard criterion is exclusive, and a soft criterion is inclusive. The hazards are considered hard criteria, as consideration outside the definition has no relevance. Domain and environment, on the other hand, are regarded as soft criteria, as they are used to determine the scope of the standard, but due to a lack of available standards for specific cases, it may be useful to consider similar fields of application with related tags. These standards are also selected with some lower priority. An example of this is a mobile robot in public spaces. Such a robot resembles an Automated Guided Vehicle (AGV), but the differing, public environment renders most industrial standards inapplicable. In addition, there may be optional categories that are only optional and don't limit the selection, such as ergonomics. Since there are subcategories and nesting, the tags are organized hierarchically so that if a tag is selected, all superior tags also apply. Conversely, if only the machine is selected as a tag, subordinate and more specific tags do not apply.

Once a selection of standards has been made based on the tags used to describe the machine, further references and dependencies must be explored using the knowledge database. For example, ISO 13482 describes the inherent safety design for mobile and personal robots and refers to ISO 13855 for the safety distance.

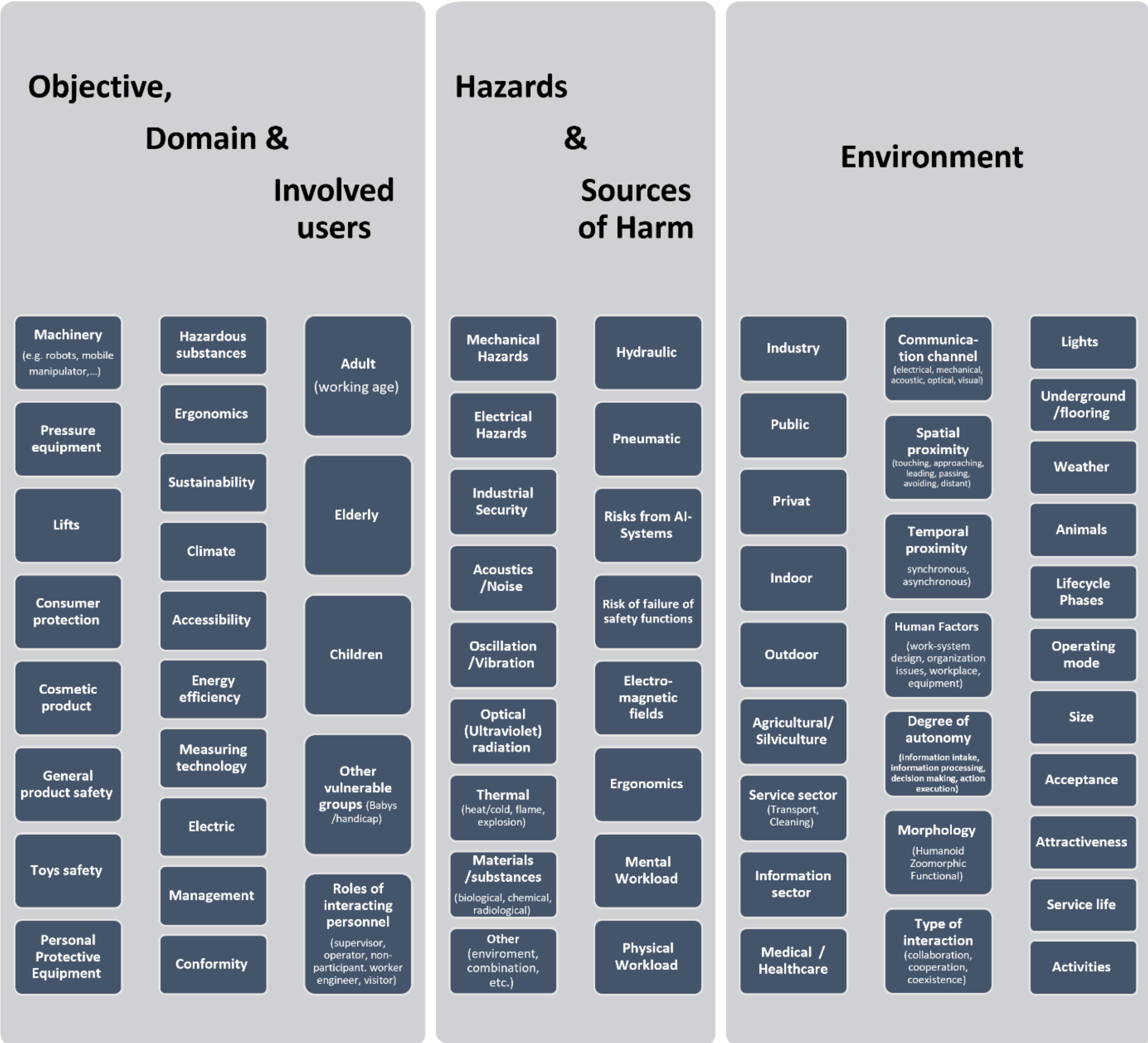

Figure 1. *List of identified tags sorted by categories. The main tags are listed first. In some cases, an excerpt of sub-tags is provided in brackets as an example.*

5 IMPLEMENTATION

A knowledge platform for standards documentation has been set up. The tool Obsidian is used, it is a software for creating and organizing notes with Markdown syntax. The tool also provides a graphical representation of the notes, so that patterns and relationships between such notes can be quickly recognized and navigated. Templates have been created for the various document types such as laws and standards. Other types, such as literature, test protocols, etc., can be added. It is also possible to add tags to the notes and create links.

The notes are structured as follows (Figure 2 a). Basic properties are specified in the first section. The properties include the working status, the issue date, the harmonization status, the validity, as well as the availability in German or English and whether a freely available version exists. This is followed by the full name, the committee or scope, the document type and, if applicable, the source. Document types are standards (A, B1, B2, C), preliminary standard (CWA, TS, TR), EU directive/regulation or national law. Further types can be added such as state regulation, accident prevention regulation, rules or principles of occupational organizations or technical information, governmental technical rules, technical information of the federal states, guidelines, test protocols or literature. The second section contains the "Scope", which provides a brief description of the document. In the third section, tags are listed according to domain, hazards and environment of application. This is followed in the fourth section by the "Normative references" or "Relevant regulations", which creates a link between various notes. "Further information" can be listed in the last section. This is where all project partners can post links to information, guidelines or further reading. This part adds a lot of value for the users as it links and makes transparent publicly accessible content concerning the standards topic. An overview of the relationship between some of the individual entries is shown in Figure 2 b as an illustrative example.

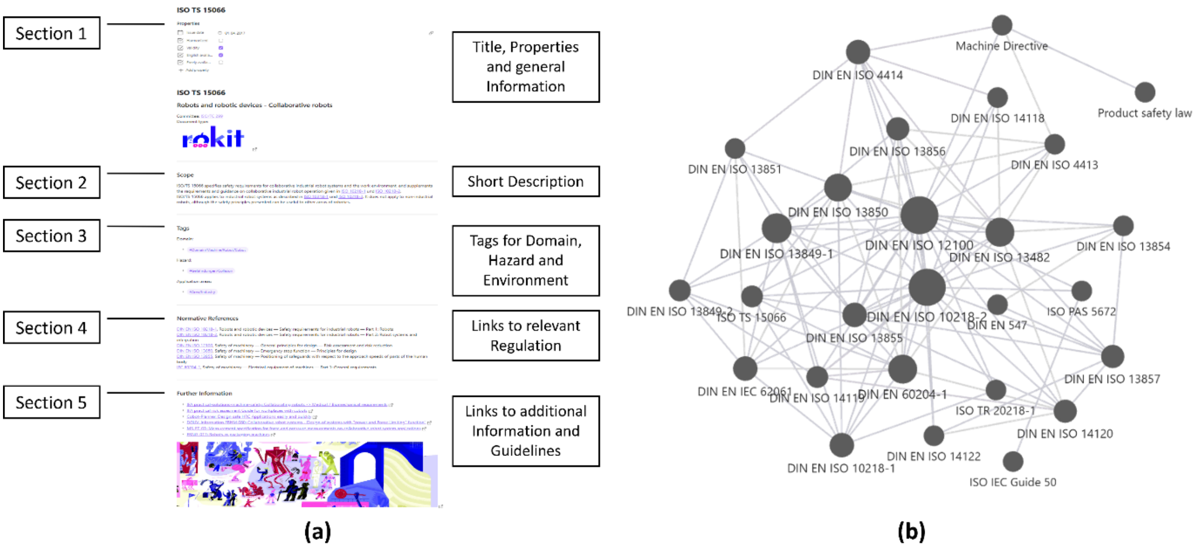

Figure 2. *(a) structure of a note with five sections and its visualization in the tool interface; (b) example of an animation of the relationships between different standards.*

As all notes are tagged in Section 3, it is possible to create a list of applicable standards for an application that contains this tag. The list can be used as a starting point for a review of relevant documents that may apply to the application. In addition, a graphical representation can be created for each tag, showing all documents tagged with it. Finally, a GitHub directory is used to make the tool accessible.

6 CONCLUSION

While still incomplete, the developed knowledge database has already proven beneficial during an initial conformity assessment in the rokit project [11]. Here, the company Angsa Robotics develops a robot that supports waste management companies by automatically vacuuming up the smallest pieces of waste such as cigarettes or bottle caps from green fields. Due to the new field of application, the start-up was faced with a problem when selecting the appropriate standards. The concept of the tag-based knowledge database presented in this article was a very helpful first starting point for the certification process of the robot. The staff at Ansa Robotics was initially unsure about which standards apply to the safety requirements for their specific application in a public park. ISO 3691-4 was initially identified, which describes the requirements for driverless industrial trucks, but is limited to industrial applications. However, the knowledge database identified further references to ISO 13856 for pressure-sensitive protective devices and EN 61496 for electro-sensitive protective equipment. In addition, ISO 13482 was identified for personal assistance robots, as this will serve as the basis for service robotics. Of course, general A and B standards, such as ISO 12100 and ISO 13849, which apply to all machines, have also been identified. Without the knowledge database, identification had been more difficult and presumably not thriving without expert knowledge.

The initial focus was on machine safety and the associated standards, but the authors are planning to add further areas to expand the knowledge database in the future. Furthermore, the use case of searching and researching standards can also be extended to the correct application of those standards and thus provide additional assistance. As a further outlook, the developed methodology can also serve as a basis for the emerging research field of digital risk assessment. The results will be added to the rokit competence cluster and made available via the project's website.

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8 REFERENCES

[1] “Searching for standards - KAN.” Accessed: May 08, 2024. [Online]. Available: https://www.kan.de/en/standardization/searching-for-standards

[2] “Harmonised Standards - European Commission.” Accessed: May 08, 2024. [Online]. Available: https://single-market-economy.ec.europa.eu/single-market/european-standards/harmonised-standards_en

[3] J. Saenz *et al.*, “COVR Toolkit – Supporting safety of interactive robotics applications,” in *2021 IEEE 2nd International Conference on Human-Machine Systems (ICHMS)*, Magdeburg, Germany: IEEE, Sep. 2021, pp. 1–6. doi: 10.1109/ICHMS53169.2021.9582659.

[4] I. Aaltonen and T. Salmi, “Experiences and expectations of collaborative robots in industry and academia: barriers and development needs,” *Procedia Manuf.*, vol. 38, pp. 1151–1158, 2019, doi: 10.1016/j.promfg.2020.01.204.

[5] “KANelot - the game - KAN.” Accessed: May 08, 2024. [Online]. Available: https://www.kan.de/en/publications/kanelot-the-game

[6] “Principles of standardization - KAN.” Accessed: May 08, 2024. [Online]. Available: https://www.kan.de/en/standardization/principles-of-standardization

[7] L. Onnasch, X. Maier, and T. Jürgensohn, “Mensch-Roboter-Interaktion - Eine Taxonomie für alle Anwendungsfälle,” 2016, doi: 10.21934/BAUA:FOKUS20160630.

[8] B. Matthias, S. Oberer-Treitz, H. Staab, E. Schuller, and S. Peldschus, “Injury Risk Quantification for Industrial Robots in Collaborative Operation with Humans”.

[9] P. Nickel *et al.*, “Work System Design in Machine and System Safety with a Focus on Human-System Interaction,” in *Proceedings of the 21st Congress of the International Ergonomics Association (IEA 2021)*, vol. 222, N. L. Black, W. P. Neumann, and I. Noy, Eds., in Lecture Notes in Networks and Systems, vol. 222. , Cham: Springer International Publishing, 2021, pp. 154–160. doi: 10.1007/978-3-030-74611-7_21.

[10] I. Aaltonen, T. Salmi, and I. Marstio, “Refining levels of collaboration to support the design and evaluation of human-robot interaction in the manufacturing industry,” *Procedia CIRP*, vol. 72, pp. 93–98, 2018, doi: 10.1016/j.procir.2018.03.214.

[11] “Startseite - Angsa Robotics.” Accessed: May 13, 2024. [Online]. Available: https://angsa-robotics.com/