Bridging the Normative Gap: Standardization for Sidewalk Robots in a World of Self-Driving Cars, Personal Robots and Automated Industrial Vehicles

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***Abstract*—Sidewalks are increasingly being shared by autonomous mobile robots, creating a safety-sensitive environment that lacks explicit safety-focused standards. Establishing such standards is an essential prerequisite for progressing these vehicles from the laboratory to lager-scale, widespread use. This ongoing research presented here aims to fill this gap by exploring standards in related areas, assessing their applicability, and examining possible derived specifications adapted to mobile robots operating on sidewalks and similar traffic environments. As part of our methodology, we draw upon findings from the development of two delivery robot prototype vehicles and a literature review. By establishing a foundation for the design and assessment of future standard drafts, our research supports the broader adoption of mobile robots and contributes to safer urban sidewalks.**

***Index Terms*—autonomous mobile robots, sidewalk operation, safety, standards, last-mile delivery**

I. Introduction

Sidewalk-based mobile robots, depending on context also referred to as Sidewalk Autonomous Delivery Robots (SADR) [1] or Public Mobile Robots (PMR) [2], hold great potential to automate various aspects of public life, including last-mile transportation, food delivery, and cleaning tasks [3]–[5]. These robots navigate sidewalks, pedestrian zones, and public squares, effectively operating within public spaces and on public roads. As such, they occupy a unique position: On one hand, they resemble automated robots widely employed for industrial indoor transportation tasks such as automated guided vehicles (AGV) and autonomous mobile robots (AMR); on the other, their application environment resembles the conditions encountered by autonomous passenger cars. Furthermore, their proximity to people reveals distinct parallels to service robots and personal care robots.

Given these complexities, the use of sidewalk robots requires stringent safety measures for the vehicles, their operation, and their development processes, including verification and validation. Standards frequently serve to harmonize the representation of state-of-the-art practices across various domains [6]. This holds true for safety-related subjects as well, making such standards essential for the future widespread deployment of robots in public spaces, both from the perspectives of manufacturers as well as regulatory authorities. In addition, the establishment of clear standards would also benefit research institutions seeking to evaluate robot systems within real-world environments.

To date, only a few publications have addressed the topic of safety standards for mobile robots operating on sidewalks. Salvini, Paez-Granados, and Billard [7] examine hazards from mobile robots, providing crucial groundwork for developing necessary safety specifications. In our own previous work [8], we briefly discuss the application of automotive standards to a mobile delivery robot operating on sidewalks in Germany. Again Salvini, Paez-Granados, and Billard [9] addressed a related question by examining the extent to which the ISO 13482 [10] standard for personal care robots sufficiently covers safety for bystanders and in public spaces and suggests the need for extensions in this area. Beyond that, efforts are

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Standard	Subject	Topics relevant to sidewalk robots
EN 61508 [11]–[18]	Functional safety of safety-related systems	Basic standard for safety of E/E/PE systems
ISO 12100 [19]	Safety of machinery – General principles	Risk assessment and risk reduction
IEC 62061 [20]	Safety of machinery - E/E/PE control systems	Requirements for design and verification
ISO 13849 [21], [22]	Safety of machinery – Control systems	Design guidelines and validation approaches
ISO 3691 [23]	Industrial trucks - Safety	Requirements and verification for AGV
ISO 19649 [24]	Mobile robots - Vocabulary	Definitions for industrial and service robots
ISO 18646 [25], [26]	Criteria and test methods for service robots	Performance evaluation (**not safety**)
ISO 13482 [10]	Safety requirements for personal care robots	Requirements, validation, user information
ISO 23482 [27], [28]	Robotics - Application of ISO 13482	Test methods and application guidelines
ISO 26262 [29]–[38]	Road vehicles (RV) - Functional safety	Automotive-specific approach to safety
ISO 21448 [39]	RV - Safety of the intended functionality	Safety beyond failures; complements 26262
ISO 21434 [40]	RV - Cybersecurity engineering	Cybersecurity for E/E systems in RV
ISO 22737 [41]	Low-speed automated driving systems (LSAD)	Specific requirements for LSAD $\leq$ 32 km/h

TABLE I: Selection of existing standards for autonomous robots and cars that may be applicable to sidewalk robots.

underway to develop a standard for sidewalk vehicles that encompasses not only space management but also a part on safety considerations (ISO 4448 [42]). However, as the standard remains in the development stage, detailed information concerning the specific safety topics it addresses is not yet accessible to the public.

As a result, it is important to determine the extent to which sidewalk robots are already covered by existing standards and identify areas where further standardization may be required. Additionally, it is crucial to determine the specific adaptations or novel requirements that would be advisable for these vehicles. In the context of this contribution, we aim to offer a preliminary overview of our work on this subject, focusing on identifying standardization gaps and highlighting similarities or comparable existing regulations.

II. Methods

The preliminary findings originate from two sources: a practical case study [43] and a literature review. The case study centered on the development of two delivery robot prototypes for deployment in public spaces in Germany. A technical inspection association was consulted during this process to provide guidance on the development and validation stages, utilizing automotive standards deemed most appropriate for the task at hand. An evaluation of our results presented here through expert interviews is yet to be conducted.

III. Preliminary Results and Discussion

Standards primarily target safety-related electrical, electronic, and programmable electronic (E/E/PE) systems. Table I provides an overview of existing standards that may be relevant to sidewalk robots. These include a basic standard that promotes safety by defining general processes and work products (EN 61508 with a safety life-cycle and risk-based approaches to assess hazards and evaluate safety measures), standards that adapt this to specific domains such as AGVs (ISO 3691-4) or series-production road vehicles (ISO 26262) but also standards featuring specific requirements for narrowly defined applications (e.g. ISO 22737 with functional and performance requirements on low-speed automated driving).

However, even for domain standards that primarily cover processes without specific requirements, differences in context can pose challenges when directly adopting them for mobile sidewalk robots. This is especially crucial when accounting for safety scenarios in distinct operating environments.

While existing standards addressing the safety of E/E/PE systems in mobile industrial robots (AGV/AMRs) provide a solid foundation for tackling safety concerns, they do not specifically cater to robots operating in traffic or pedestrian environments. Concurrently, automotive-focused standards cover functional safety throughout the vehicle life cycle, as well as cybersecurity and safety of the intended functionality, emphasizing autonomous driving features in road traffic. Here a critical examination is warranted to determine if the focus on road vehicles, which can be significantly larger and faster, is appropriately suited for compact robots operating at pedestrian speeds. Furthermore, initial standards explicitly addressing service and personal care robots fall short in adequately considering the unique context of sidewalks, where robots interact with pedestrians and other road users.

IV. Summary and Outlook

It becomes evident that sidewalk mobile robots are not sufficiently addressed by current safety standards for autonomous robots or cars. The distinct application context of compact robots operating in close proximity to people and navigating within public traffic areas is not considered. Nevertheless, general methodologies for development processes and specific requirements can be derived from standards in related fields. These approaches should be incorporated into ongoing standardization efforts or employed as evaluation criteria for assessing draft standards.

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