Review of Service Robots' Deployment and Adoption in Integrated Urban Environments

Boris Robev [1] and Ioannis Patias [1]

[1] *Faculty of Mathematics and Informatics, University of Sofia "St. Kliment Ohridski", James Bouchier blvd., Sofia, 1164, Bulgaria*

Abstract

In our days there are a lot of challenges related to robots. We see more and more services to be provided by automated intelligent systems. Service robots nowadays, have a wide distribution across various service-oriented domains in integrated urban environments (IUE), and are defined and classified by international standards. They force a closer cooperation and integration between various technologies and artificial intelligence from one side, and business models for services provision and advanced user interfaces from another. The aim of this paper is to present a short review of the applied standards, the used classification of the service robots by their different types of usage, and of the challenges in front of service providers by providing services in IUE-Labin the frame of MIRACLe project, IT technologies and robot designers. Based on the provided definitions and classifications, then the different aspect affecting the adoption of service robots are discussed. The conclusion is that a continuous and stronger cooperation between the involved stakeholders is necessary in order to achieve higher quality, and trustworthiness of the service robots.

Keywords

Service robots, automated intelligent systems, automation

1. Introduction

With the development of information technologies, technical and scientific research continue to interact more closely with business and services providers, towards automation of and aiming customer satisfaction service delivery. Such continuous change in the requirements shifts the focus from pure engineering to the fields of the development and integration with modern automated intelligent systems, including artificial intelligence (AI), sensor development, mobile services and the Internet of Things (IoT).

Information Systems & Grid Technologies: Fifteenth International Conference ISGT'2022, May 27–28, 2022, Sofia, Bulgaria
EMAIL: robev@uni-sofia.bg (B. Robev); patias@fmi.uni-sofia.bg (I. Patias)
ORCID: 0000-0002-2705-3941 (B. Robev); 0000-0003-1355-7433 (I. Patias)

Such interaction and integration between engineering, technology, and machine learning, related to service delivery to end customers, is service robotics [4,16].

Following the processes automation and optimization, service robots assigned tasks become more accurate and effective when performing repetitive tasks, performed in the past by humans. Examples for such activities are assembly parts, handling, and transporting items, performing continuous recurring jobs etc. The past decade service robots' developments indicated that service robots are constantly increasing their capabilities to process and deliver more service-oriented tasks and outcomes in more broad domains like medicine, navigation and guidance, human health care, front office operations. These services, in terms of providing them to the consumers in IUE in general, and in the frame of MIRACle project (https://miraclebg.com) IUE-Lab as concrete use cases, could be defined into three functionally independent groups: Intelligent Home Environment (IHE), Intelligent Public Environment (IPE) and Intelligent Personal Assistant (IPA).

However, deliverables, provided to service recipients and associated with more intuition, evaluation, judgment, previous experience, etc., are still could not be fully covered by robots. This means, that even with current technologies, service robots are not able completely to replace humans and provide services of the same quality as humans. On the other side, by supporting humans in delivering such services, in the contexts of future development of AI and machine learning, the human-robot boundary in terms of service providing could become more transparent and invisible.

In this paper, we provide a review of service robots by their definitions, according to the applied standards, a classification of the service robots by their different types of usage, according to IUE group's definition. A review of the challenges in front of services providers, IT technologies and robot designers in order such service robots to deliver services, comparable with humans is presented Both reviews is supposed to be used as a basis for future reviews and researches, including architecture and technologies details.

2. Robots and service robots' definitions

Toward the unification and understanding, deployment, building and maintenance of robots, some committees (i.e., Technical Committee of the International Organization for Standardization) defined a standard Robotics — Vocabulary, where all related to robotics terms and definitions are described with aim to consolidate their usage. This chapter is a short review of the main standards and definitions, according to ISO 8373:2021 and the International Federation of Robotics (IFR).

The International Organization for Standardization (ISO) defines Technical Committee (TC) ISO/TC 184 in order to manage standards in the field of automation systems and their integration, related to design, manufacture and maintenance, supply of products and related services. Areas of standardization include information systems, automation and control systems, and their integration with technologies.

According to the definition of provided in ISO 8373:2021 [1], a service robot is a robot that performs automated useful tasks, with the exception of industrial automation applications. This means that robots have a degree of autonomy, which is determined by their ability to perform one or more predefined tasks or perform tasks, considering the input information from robot-related sensors – the so-called "Adaptability". Based on that dependency, the robots could be classified as fully autonomous or partially autonomous ones [15].

The standard also provides unification of terms, rules and common understanding from all stakeholders – from analysts and designers following programmers and engineers, to end-customers. In order the meanings in the accompanying standards not to be acknowledged on a different-from-standard way, the standard gives a classification into the following categories:

- standards for mechanical structure;
- standards for motion and movements;
- standards for programming and control of movements;
- standard for usage of sensors and navigation.
- standards for modules and modularity;
- productivity standards;
- security standards.

Considering the standard and the definition of service robots described above, the following definitions of service robot activities for non-(professional (personal) or and non-professional) use, are provided additionally defined:

- Activities performed by robots intended for personal use, are those including handling or delivering items, providing guidance or guidance services or information, and activities related to food and beverage preparation, cleaning activities etc.;
- Activities performed by robots intended for professional use, are those including inspection, surveillance, handling and delivering of items, providing guidance or guidance services or information, etc.

The International Federation of Robotics (IFR) [2] applies the definitions and standards for service robots according to ISO 8373:2012. However, there are some details that according to IFR are not specifically applicable or lead to the distinction ambiguous definition of different categories of robots from the generally accepted standard. To distinguish industrial robots from service robots, IFR accepts ISO criteria determining their application in industrial automation

to non-industrial automation as sufficient to classify a robot as an industrial or service robot.

In this regard, the IFR develops its own definitions and classification of industrial robots and service robots, by defining their usage according to the areas of application [3]:

- The service robot is defined as a standalone device, programmable and moving across environment, which performs useful tasks for people or equipment, except industrial automation applications;
- In some application areas, manually operated robotic devices with limited autonomy are included. This is especially important if legal requirements prohibit full autonomy, or the application domain requires only limited autonomy;
- Customer service robot is a device designed for use by each non-professional and non-expert customer, as neither robot operation nor robot setup requires a professionally trained operator;
- Professional service robot is a device, designed for use by trained professional operators and/or preliminary trained customers.

The usefulness of using and applying standards and common definitions benefits with regulation of common understanding of definitions, sustainable quality of product and service provided and unifying of the conditions for evaluation and control of the delivered by manufacturers and used by consumers..

3. Classification of service robots

The various usages of service robots in different application and service domains, following definitions according to the 2 main standards mentioned above will be presented in this chapter. The main focus will be to go into details, by reviewing and representing on a hierarchical level categorization of service robots by their applicative, professional and non-professional utilization.

The classification approach of IFR [3] distinguishes service robots into two main categories: service robots by application criteria and service robots by type of movement criteria. Both classification categories consist of high-level classes that are summarized in groups.

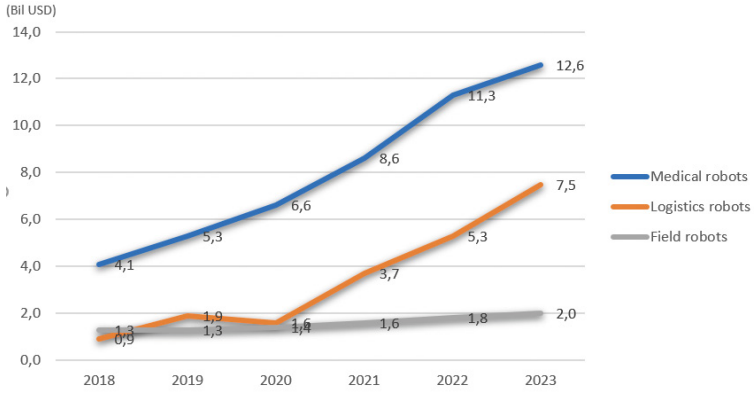

Figure 1: Service robots for professional use – turnover per application

The figure (see Figure 1) shows as well how the Covid-19 pandemic influent positively the market demand of service robots used as disinfection solutions in medicine domain and logistics solutions in warehouses and big factories as well.

3.1. Classification of service robots – movement criteria

There are four main types of movement: service robots can move on ground/hard surface, on water movement, aerial movement, exoskeleton type, and any other robots. The service robots that do not fit to any of these groups, or robots that fall into more than one of the above classes, may be classified as "Others". The full classification scheme is presented in (see Figure 2).

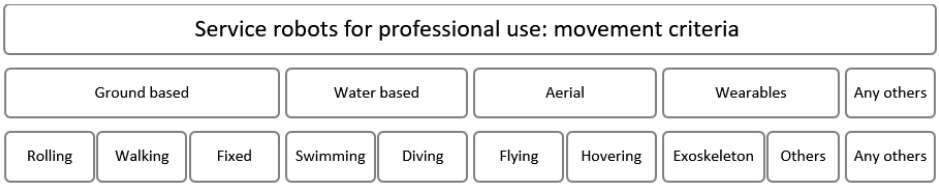

Figure 2: Service robots for professional use: movement criteria

The classification covers almost all service robots use cases of MIRACle project. Of course, the usage of water and aerial based service robots in Intelligent home environment is limited due to the space and other environmental factors. From the other side, wearable service robots' usage have a wide application as personal assistant, by helping and supporting disabled consumers.

3.2. Classification of user/consumer service robots – application criteria

The classification of service robots in regards of the respective application criteria is presented (see Figure 3). According to the provisions it has two separate categories: consumer-oriented robots presented in Chart 3short in this section and professional service robots, presented in next section. In the class of customer-oriented service robots, three main groups of applications are defined: service robots for domestic tasks, social interaction service robots, and home health care assistants.

The second application group is an example that justifies the deviation from the criteria of ISO 8373:2021 for commercial versus non-commercial use for the categorization of service robots [2], as was reviewed in Section 2 discussed above. The criterion for consideration as a consumer robot in the third group is the possibility of using the robot by non-specialist users.

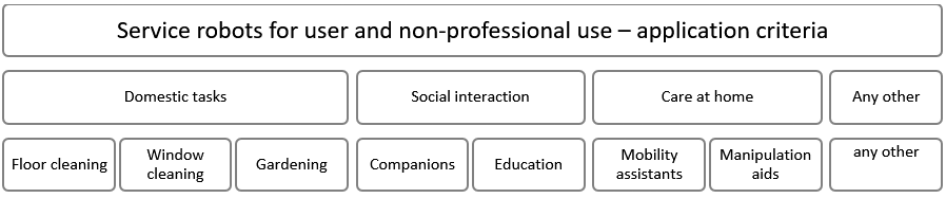

Figure 3: Service robots for user and non-professional use: application criteria

This classification applies generally to Intelligent Home environment functional group in MIRACle project IUE-Lab. The different layers of classification represents use cases of services for home and/or building automation (light, electricity, heating) and generally almost all home equipment, that could use sensors and wireless communications with remote management, cleaning and security.

3.3. Classification of professional service robots – application criteria

The professional service robot applications category uses eight different groups of applications plus an additional group called “Other” professional service robots. In the ninth group are considered all service robots that do not fit into any of the above groups and classes.

All types of agricultural applications are grouped together in first group. Professional cleaning robots are divided by analogy with home cleaning robots, considering the professional or trained operator usage and maintenance. Professional inspection and maintenance robots are classified according to the site where they are intended to be used. In this case it was accepted big buildings and other construction for public use. The applied fourth group covers robots for construction

and demolition usage. Group 5 includes various logistics and transport robots in different use cases. Robots grouped in medicine are used not only for diagnostics and surgical operations (semi- or fully autonomous), but also for medical scientific analysis, research and clinical trials [13].

Detailed graphical representation of professional service robots' classification by application criteria is given (see Figure 4).

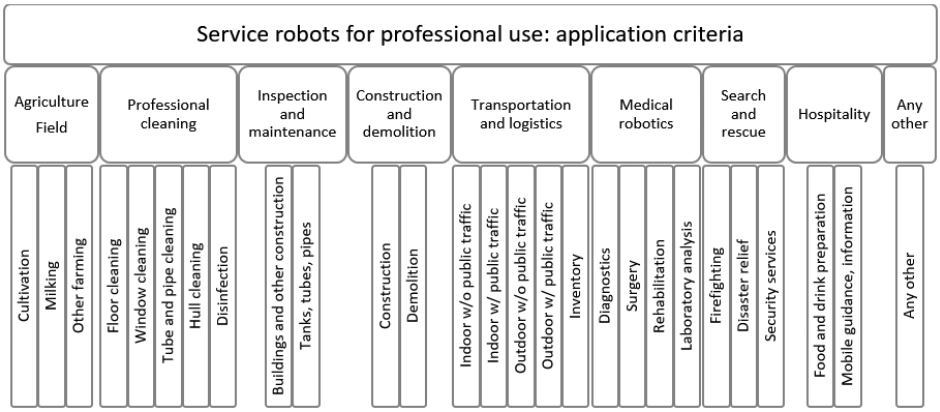

Figure 4: Service robots for user and professional use: application criteria

Apart of the pure home or domestic usage, as mentioned in previous section, the classification of service robots for professional usage have a broad usage and are able to provide services in wide applicative domains. Here, Intelligent public environments group applies, as it covers not only the so-called "smart cities", but also industrial applications in closed environment. Examples are Intelligent transportation, Smart buildings, Smart government, Smart security, and of course their service sustainability.

In this section was presented a classification overview of service robots, covering their usage by professional and non-professional operators and customers. The mentioned classification of service robots in different categories and application domains, based on IFR approach, is indicative and obviously covers most of the service domain areas, which could be automated. We also described the significant grow in usage of service robots during the recent years and indicative statistics were shown at the beginning of the section.

4. Service robots' adoption

According to the standard approach of providing customer services, peoples must manage such services. As mentioned at the beginning, with advanced AI [14], Internet of Things (IoT) and IT technologies, service robots are gradually

displacing service providers with intelligent robotic operators, mitigating or fully avoiding the need of direct contact between user and service provider [7, 8]. For example, in many places (publicly accessible buildings and institutions like airports, hotels, restaurants, hospitals, big shopping centers, governance institutions, etc.) there are installed terminal devices in order to limit contact between people and service providers, by providing the consumers with a new, interactive services.

Although, the so-called service robots have fairly high-tech computing resources, their functionalities in terms of autonomy level, which depends on the limited AI required. This implies the provision and use by the consumer of only a limited range of services. The theory specifies four intelligences required for service tasks: mechanical, analytical, intuitive, and empathetic, and lays out the way service providers should decide between humans and machines for accomplishing those tasks [8]. Mechanical intelligence corresponds to mostly algorithmic tasks that are often repetitive and require consistency and accuracy, such as order-taking machines in restaurants or robots used in manufacturing assembly processes [17]. These are essentially advanced forms of mechanical machines of the past. Analytical intelligence corresponds to less routine tasks largely classification in nature (e.g., credit application determinations, market segmentation, revenue predictions, etc.). AI is rapidly establishing its effectiveness at this level of analytical intelligence/tasks as more training data becomes available [18]. Empathy, intuition, and creativity are believed to be directly related to human consciousness [19].

However, this is not so clear in the service robots, as they still cannot fully cover the intuition and empathy of people [8]. Therefore, there is still a clear limit of the activities defined by the service provider to be performed by people (activities with more intuition, evaluation, judgment, previous experience, etc.) versus robots. This means, that even with today's technology, service robots cannot completely replace humans and provide services of the same quality as humans.

On the other hand, the increasing prevalence of service robots, as discussed in the previous section is quite positively perceived by consumers as an innovation and mitigation of risks arising by the interaction with the human factor. Therefor there is an increase in confidence and trustworthy of service robots [10]. Additional value as well, is the increasingly human-friendly appearance of robots (where applicable). This could be considered as first aspect regarding the appropriate adoption of service robots.

A second dimension of this adoption are the respective business models. Based on that, the challenge for business owners is open. There is a necessity to determine the definition of the user-friendliest interface of the service robot (including appearance). This can provide with ways to upgrade existing services provided, to increase the level of service delivery, with all of their advantages and

disadvantages. For the purpose research, based on surveys, feedback, analysis and other appropriate tools are required.

The third aspect for the successful adoption of service robots, is the consumer attitude. We need to determine what are/would be the customer expectations and what is the level of customer satisfaction. The comparison should be done according to the delivery of services from service robots today. Such comparison must take into account the limitations of technology and AI, today and in the near future, assuming a positive trend in their development).

Undoubtedly, the introduction of a wider range of service robots is a challenge for both the users and the service providers, and solutions should be provided by business models and user interface designers. The challenge is also to change the concept of service delivery with higher quality, consistent of consumer needs, with increased trustworthiness and security.

5. Conclusion

Service robots have been introduced in many areas and there is strong evidence that these robots can be adapted to specific needs in terms of tasks and functions.

In this paper a review of standardized definitions of service robots were analyzed and presented. The classification and usage per different principles, applications, and domains were represented and graphically visualized. A study of the interaction between service robots and customers, in terms of service provision and delivery was explored, with outcome about the need of closest collaboration between service providers, technology, designers and service robots' manufacturers.

Continuous and stronger integration between all of the above-mentioned stakeholders, will evolve the further development of automation systems and services in many sectors and will support the focus to become more services oriented with even higher quality, customer satisfaction and trustworthy.

With appropriate scientific and mathematical modeling, based on a known localization and positioning algorithms, integration of autonomous intelligent systems, i.e., service robots in particular service domains navigating and providing guidance to consumers could be achieved.

Thereafter the author's interests are focused on future researches and deployments of service models for:

- integrated infrastructure, based on intelligent sensors and management devices;
- data management including data modelling;
- define service optimizations and delivery to the end consumers, based on the above models.

6. Acknowledgements

This paper is prepared with the support of MIRACle: Mechatronics, Innovation, Robotics, Automation, Clean technologies – Establishment and development of a Center for Competence in Mechatronics and Clean Technologies – Laboratory Intelligent Urban Environment, funded by the Operational Program Science and Education for smart growth 2014-2020, Project BG 05M2OP001-1.002-0011.

7. References

[1] International Organization for Standardization, Robotics — Application of ISO 8373:2021, 2021, URL: https://www.iso.org/obp/ui/#iso:std:75539:en.

[2] International Federation of Robotics, URL: https://ifr.org.

[3] Chapter 1 reviews definitions and classifications of service robots, World Robotics 2021 Service Robots, 2021, URL: https://ifr.org/service-robots.

[4] euRobotics aisbl (Association Internationale Sans But Lucratif) Strategic Research Agenda, updated version 2018, accessed 2022, URL: https://www.eu-robotics.net.

[5] Sonja Zillner, Michela Milano, Edward Curry, et al. Strategic Research, Innovation and Deployment Agenda AI, Data and Robotics Partnership, Third release, September 2020, accessed January 2022, URL: https://ai-data-robotics-partnership.eu.

[6] Stefanie Paluch, Jochen Wirtz, and Werner H. Kunz, The Service Robot Revolution, 2022, URL://www.academia.edu.

[7] Hrynowski Z., Increased use of low-contact services may prove permanent. Gallup, 2020, URL: https://news.gallup.com/poll/309203/increased-low-contact-services-may-prove-permanent.aspx.

[8] Huang M, Rust R., Artificial intelligence in service. J Serv Res 21(2): 155–172, 2018.

[9] Laowattana, D. Service robots head to pandemic's frontlines. Meet FACO: new breed of AI powered, multi-tasking service robots. Asian Robotic Review, 2020, URL: https://asianroboticsreview.com/home341-html.

[10] Talk B, Lew E., Pandemic and the smarter world: a future of robots? Columbia Business School, Ideas and Insights, 2022. URL: https://www8.gsb.columbia.edu/articles/brand-talk/pandemic-and-smarter-world, future-robots.

[11] Chang Ai, Trimi C. Impacts of service robots on service quality, 2020.

[12] Leventi, N., Vodenitcharova, A., & Popova, K. (2020). Ethical aspects of the use of innovative information technologies in clinical trials. Proceedings of CBU in Medicine and Pharmacy, 1, 66–70. URL: https://doi.org/10.12955/pmp.v1.100.

[13] SERVICE ROBOTS Record: Sales Worldwide Up 32%, IFR, URL: https://ifr.org/downloads/press2018/Presentation_Service_Robots_2020_Report.pdf.
[14] M. Nisheva, D. Shishkov, Artificial Intelligence, ISBN: 954-8643-11, Integral, 1995, Bulgaria.
[15] Vasil Georgiev, Ioannis Patias, Hristo Hristov, Autonomous Systems: Platforms, Applications, Perspectives – ISBN: 978-954-07-5033-0, University publishing house "St. Kliment Ohridski", Bulgaria, 2020.
[16] Ioannis Patias, Vasil Georgiev, Design of Robotic Systems, ISBN: 978-954-07-4207-6, University Publishing House "St. Kliment Ohridski", 2017.
[17] Colby, C. L., Mithas, S., & Parasuraman, A., Service Robots: How Ready are Consumers to Adopt and What Drives Acceptance?, Frontiers in Service Conference, 2016.
[18] Wedel, M., & Kannan, P., Marketing analytics for data-rich environments. Journal of Marketing, 80(6), 97–121, 2016.
[19] McGilchrist, I., The master and his emissary: The divided brain and the making of the western world: Yale University Press, 2019.