We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

5,300
Open access books available

129,000
International authors and editors

155M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Living and Interacting with Robots: Engaging Users in the Development of a Mobile Robot

Valerie Varney, Christoph Henke and Daniela Janssen

Abstract

Mobile robots such as Aldebaran's humanoid Pepper currently find their way into society. Many research projects already try to match humanoid robots with humans by letting them assist, e.g., in geriatric care or simply for purposes of keeping company or entertainment. However, many of these projects deal with acceptance issues that come with a new type of interaction between humans and robots. These issues partly originate from different types of robot locomotion, limited human-like behaviour as well as limited functionalities in general. At the same time, animal-type robots—quadrupeds such as Boston Dynamic's WildCat—and underactuated robots are on the rise and present social scientists with new challenges such as the concept of uncanny valley. The possible positive aspects of the unusual cooperations and interactions, however, are mostly pushed into the background. This paper describes an approach of a project at a research institution in Germany that aims at developing a setting of human–robot-interaction and collaboration that engages the designated users in the whole process.

Keywords: human–robot-interaction, robotics and society, mobile robotics

1. Introduction

Robots are part of many peoples' everyday life—even if only a few people are in direct contact and interaction, robots are part of production and logistic processes that affect almost all of us. However, the current increase in the development of mobile robots opens up new perspectives for human–robot-interaction processes and possibilities.

At the same time, however, those developments lead to concerns, reservations and questions of safety, ethics as well as the future of communication and society. Therefore, the sole technical development of robots is not enough. There is a high demand for interdisciplinary research in the field of social robotics that is becoming more and more relevant. Due to the sparse immediate contact between humans and robots, the research and development based on research findings is comparatively low. However, there are plenty of project calls and proposals in which robots are meant to perform certain auxiliary functions. However, many of these projects deal with acceptance issues that are due to an unfamiliar type of interaction between humans and robots. These issues partly originate from different types of robot locomotion, limitations in human-like behaviour as well as limited functionalities in general.

At the same time, animal-type robots—robotic quadrupeds such as Boston Dynamic's WildCat—and underactuated robots are on the rise and present social scientists with new challenges such as the concept of uncanny valley. However, they open up possibilities in many sectors such as in working environments of the industry as well as, e.g., health and geriatric care.

In Germany there are currently about 3.4 million people in need of care. The effects of demographic change affect the care sector in two ways: while the number of people in need of long-term care is constantly increasing, fewer and fewer newcomers to the profession are opting for long-term care; at the same time, older nursing professionals are leaving the profession early due to physical and psychological stress [1]. The majority of people in need of care (73%) are currently in outpatient care [2], 55% of whom are assigned to nursing levels 1 and 2 [3].

These developments require new innovative solutions which contribute to maintaining the independence, self-determination and quality of life of people in need of long-term care. Here, mobile robotic systems offer great potential to maintain and increase mobility as well as an independent participation in social life. However, existing mobile robotic systems show a limitation of mobility to ground-level and structured environments as well as a lack of involvement of user groups during the development process. However, this problem might be solved by a suitable mobile robot system that is developed and tested demand-oriented by including user-centered research approaches. In the following sections, a project at a research institution in Germany will be described. The project aims at developing a setting of human–robot-interaction and collaboration that engages the designated users in the whole process.

2. Shepherd: concept and design of a human–robot-interaction project for geriatric care

The overall objective of the project is the user-centric, iterative development, production and testing of a mobile robotic quadruped to promote and maintain mobility and self-care capability for outpatients of care grade 1 and 2. The system has three modes of support for care grade 1 and 2 patients: autonomous, partial autonomous and hand-guided operation (see **Figure 1**).

The autonomous operation enables the system to automatically navigate under obstacle avoidance indoors and outdoors, whereby unevenness and barriers can also be overcome automatically due to the robotic quadruped design. In semi-autonomous operation, the system can be used as a following system for following the user, e.g., when carrying goods such as groceries or as a navigator system in which
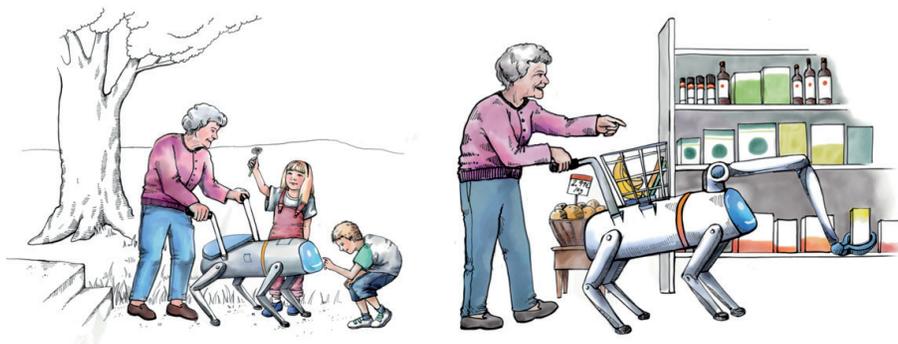
Figure 1.
Use cases for the use of the robotic quadruped for ambulatory care. Assistance in mobility and self-sufficiency of patients in need of care.

the system runs ahead as a navigator. In hand-held operation, the system serves as an additional support for the user. The project pursues a user-centered, participatory and iterative research approach for the development of the robotic system (see **Figure 2**). The active involvement of patients in need of care and outpatient nursing staff in the development process ensures that technical development is demand-oriented and that user acceptance of the robotic system is increased as far as possible. This enables a successful interaction between the patient and the robotic system.

The various assistance functions of the robotic system and the demonstrators to be developed will be subjected to feasibility and effectiveness studies in field trials. Through the accompanying participatory recording of user acceptance and experience, promoting factors for the use of robotic systems are empirically collected, evaluated and translated into recommendations for action using the example of the robotic quadruped. The empirical survey is based on a technographic mixed method approach, which combines quantitative with qualitative methods. Various scientific methods, such as surveys, interviews and observations, are used to provide a dense description of human–machine interaction. In the sense of a common understanding of "good care," this includes a holistic view of the human, organizational and technical levels with the aim of maintaining the health, well-being and quality of life of those in need of care [4]. The project thus aims at needs-based care and provision, strengthening the well-being of those in need of long-term care and maintaining an independent way of life in the long term. This way, the project contributes to quality care and support in the domestic and familiar living environment of those in need of care.
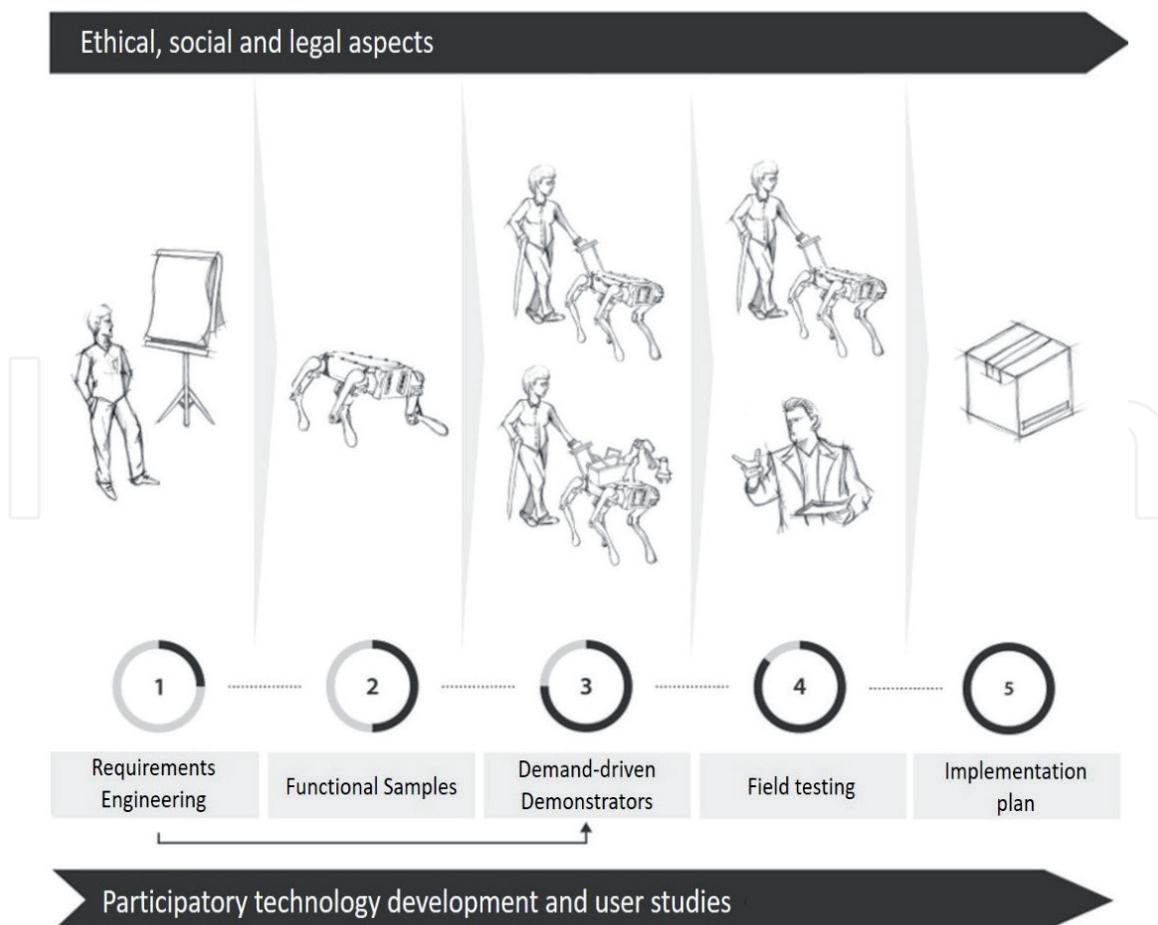
Figure 2.
Project plan of a user-centered, participatory and iterative research approach for the development of the robotic system.

3. State of the art

3.1 User-centered development, technology acceptance, user experience and ethical, legal and social aspects (ELSA)

The development of robotic systems for dependent persons requires a user-centred, iterative approach to ensure acceptance, experience and actual use by dependent persons [5]. Various qualitative and quantitative methods exist for the early involvement of users—often participatory design (PD) methods. The focus here is on the active participation of stakeholders and target groups as well as joint learning [6], the recording of the needs of the target groups and an iterative development through the step-by-step implementation and testing of functions and systems [7]. User-centered methods and techniques of human–robot interaction have already been used in research projects, e.g., in the field of "Comprehensive Geriatric Assessments" [8]. The entire user interface was derived from the requirements and wishes of the target group. A similar procedure was also used in the prototypical development of a service robot for use in geriatric care, in which critical user requirements were collected in a quantitative study and incorporated into the design of the robot [9]. The fact that an early integration of the necessary stakeholders of benefits is shown by the research of the University of Vienna on the prototype assistance robot "Hobbit." The existing acceptance problems were only eliminated by the use of an "icebreaker team" [10]. In addition, the involvement of users can also help to take into account the fears, hopes and values of future users and thus integrate them into the design phase [11]. For this purpose, a nuanced understanding of the ethical challenges is central [12]. Research in the context of a user-centered development of robotic quadrupeds does not exist yet.

3.2 Mobile robot systems based on quadrupeds

Walking robots (e.g., robotic quadrupeds—see **Figure 3**) are mobile robot systems that can realize biologically inspired gaits agile, fast and balanced by one or more legs [17]. The high degree of mobility of walking robots, in comparison to wheel-based systems, also enables them to overcome obstacles and barriers such as steps, steps or uneven ground with statically and dynamically stable gaits, whereby robotic quadrupeds stand out [18].

The development field of walking robots has experienced a strong upswing in recent years, with the first domestic applications also being presented [19]. Drivers of this development are not least the high-profile ideas of Boston Dynamics Incorporation, which has currently developed heavy-duty quadruped robots (e.g., BigDog or LS3) with a payload of up to 181 kg. The more relevant robotic quadrupeds in the domestic environment are Spot [20] and SpotMini with payloads of 14–45 kg and a dead weight of 30–75 kg. The quadruped robots are electrically and

Figure 3.
Robotic quadrupeds. (a) SpotMini [13], (b) Laikago [14], (c) ANYmal [15], (d) ANYmal and Continental [16].

hydraulically actuated and are transformed into an autonomous locomotion by the insertion of, e.g., lidar and depth cameras.

Furthermore, the ANYmal system of the Robotics System Lab (RSL) at ETH Zurich has made significant progress in recent years. With a dead weight of 30 kg and a payload of 10 kg, the system achieves a maximum speed of 1 m/s. The system can be used for a wide range of applications. The system can move autonomously in its environment thanks to the sensors used for this purpose. The Chinese company Unitree Robotics, founded in 2016, developed Laikago. With a total weight of 24 kg, it is capable of overcoming a wide range of uneven surfaces and withstanding kicks in a stable manner. What all systems have in common is that they have not yet been transferred to the area of application of care and therefore do not respond to domain-specific requirements. However, these systems impressively demonstrate the maturity of the technology. This is also underscored by the press releases of Boston Dynamics Incorporation, which is already planning to produce 100 robotic quadrupeds for sale in 2019 [21]. Subcomponents of the ANYbotics AG and Unitree Robotics systems are already available on the market, which were used for the calculation of the components.

Existing systems, however, were developed less along specific user requirements than along technical feasibility. Furthermore, experience shows that, despite press announcements, it remains to be seen whether these systems are actually mature enough to be launched on the market in the near future. In addition, the participatory development of the system along the High-Tech Strategy 2025 enables the Federal Government to both strengthen the competencies of Germany as a science location and contribute to the active shaping of highly innovative systems.

The biologically inspired locomotion of robotic quadrupeds has been the subject of interdisciplinary research for many years [22]. In this area, remarkable successes have been achieved in recent years in stability against external influences (e.g., kicks and jolts by persons) [23], adaptivity on uneven surfaces [24], and safe interaction with humans through the transition from stiff, position-controlled to active, passive and hybrid compliant actuators [25]. Besides the integration of further sensors for environment detection and recognition and the derived motion planning and generation [26], these and other control engineering approaches of whole-body control for the direct adaptation of the system to a changing, uneven terrain are applied [27].

Furthermore, the field of mobile robotic systems with tyres has already produced initial approaches for following persons [28] with medium numbers of persons as well as following systems, e.g., in supermarkets [29], which have so far only been evaluated on a small scale and which have not yet included the aforementioned challenges of robotic quadrupeds. In addition to the technical implementation, the navigation of mobile robot systems outdoors has been the subject of interdisciplinary research for several years [30]. Challenges here are the recognition and classification of passable paths [31], changing lighting situations during the day [32], dynamic obstacles such as people, cyclists or pets [33], intersections and road crossings [34].

4. Scientific and technical objectives of the project

4.1 Requirements analysis and scenario development of robotic quadrupeds

Since the project goal contains a user-centered and demand-oriented development of the demonstrators, the specific requirements of the stakeholders of the care sector—persons in need of care, carers as well as relatives—are collected

in design thinking workshops. On the basis of these user-specific requirements, concrete scenarios and functions for technical implementation are defined, such as, for example, a required seating area on the system or a shopping basket for weekly purchases. The following research questions are addressed within the workshops:

- What requirements do people in need of care, carers and relatives have for mobile robotic systems to maintain and promote the mobility of people in need of care?

- What functionalities must such a system have?

- Which specific application scenarios result from this?

4.2 Participative technology development and user studies accompanied by ELSA

The technical development and implementation of the robotic system follows an iterative, participatory research approach. Together with the users, the project team will develop prototype functions of the system in creativity workshops. In addition, the attitude, usability, user experience and technology acceptance will be recorded in a pre–post design of participative user studies following a technographic mixed-method approach. This approach enables a detailed description of the human–robot interaction for the derivation of scientific and user-oriented findings, which are directly applied in further technical development. The final evaluation of the demonstrators takes place in the context of field tests, which are meant to raise and analyze the effectiveness of the functions in domestic and public environments. The following research questions will be answered:

- How do mobile robotic systems affect technology acceptance and user experience?

- What influence does the user's attitude have on the handling of robotic systems?

4.3 Development, production and testing of the robotic quadruped

Within the scope of the project, two identical demonstrators will be developed, manufactured and tested in field tests as basic systems of the robotic quadrupeds. A modular approach is chosen, which allows different structures to be determined according to requirements through workshops and surveys on the basic system. The basic system refers to the basic body of the robotic quadruped, which is designed to meet the requirements in terms of load, running speed, motion dynamics and total weight. Further superstructures are used, for example, to carry goods or designate handholds for hand-guided operation. Since the system is used indoors and outdoors, a robust construction and resistance to external influences are taken into account. Lightweight materials are selected to reduce the weight of the platform and maximize the load capacity. The design and selection of suitable drives, battery systems and sensor and computing hardware is based on the components available on the market. In addition to the design and manufacture, the development of the drive controllers and the kinematics of the robotic quadrupeds for the implementation of dynamic and stable gaits takes place.

4.4 Development and testing of locomotion, assistance functions and autonomous navigation

The system has three assistive functions (follow-on, navigator and manual operation) and is able to navigate autonomously indoors and outdoors. The follow-on function allows for the user to be detected and tracked by quadruped sensor systems. This enables the quadruped to be used, for example, as a load carrier. Through the navigator function, it can serve as a "guide" for users to achieve a defined goal. The assistance function for manual operation makes it possible to use the system as a support and control it intuitively. As interaction components, intelligent spacer textiles integrated in the handle of the quadruped are used, which record the user input by means of high-resolution pressure and shear sensors. For this purpose, spacer fabrics are designed with integrated conductive yarns, manufactured on industrial knitting machines and tested for their sensitivity and service life. In autonomous navigation, the system is able to automatically detect its environment, locate itself in it and navigate under collision avoidance, as well as overcome barriers. In order to increase the safety of the user, a contactless connection of the user to the quadruped is established by means of intelligent arm cuffs. The textile-integrated MEMS acceleration sensors and RFID antennas in the cuffs enable the detection of falls, the localization of the affected person and, if necessary, the emission of an emergency signal.

4.5 Social, ethical and legal support for user-centered, iterative development

The responsibility and accountability of technical development and research play a core role in the project. Therefore, the user-centered conception, implementation and testing of the quadruped will be accompanied throughout the entire course of the project, taking social and ethical issues into account. Within the framework of workshops with the project team, ELSA aspects are sensitized and integrated into the technical conception and implementation. Accompanying the technical realization is a first analysis regarding ethical questions towards autonomy and support of autonomy. In addition, the user studies will be carried out and evaluated taking ELSA into account, e.g., in the context of addressing the test persons and data evaluation. Legal challenges, in particular outdoor safety in traffic, data security as well as safety-related aspects are dealt with and analyzed accordingly by subcontracting a lawyer.

5. Conclusions, discussion and outlook

The paper describes the concept and design of a user-centered approach of developing a mobile robot to assist people in need of care. To date, interdisciplinary research on the subject of human–robot interaction is still a field where there is a lack of convincing research methods and results. However, robots are continuously finding their way into our everyday lives and are already indispensable today. Therefore, researchers from the field of humanities as well as robotics and general engineering need to work closer together and develop convincing technologies that are not just functioning on a level of technology but also allow for acceptance and collaboration between robots and humans. One decisive element in this process is that those teams need to work closely together and actively engage the designated users through the whole of the development process.

In order to pursue that goal, a team of researchers from both robotics and humanities has put together a concept and design of a project for the development

of mobile robots that are supposed to assist humans in need of care. The concept shows that not only the technology has to be carefully thought through in order to provide a secure service and show no gap between the robot's appearance and its actions. The social aspects and requirements of people in need of care, the nursing staff as well as relatives need to be taken into consideration and carefully used to develop the technologies. The research questions that have been raised include both human and technology factors that are crucial for the acceptance and success of future interactions between robots and humans.

However, this paper only marks the starting point of the project. It will be subject to further research and publications to show results of the studies and analyses in order to give recommendations on the process of developing social robots of the future. Since technology is continuously developing rapidly, it will not be sufficient to engage the users in just one design process. Rather, interdisciplinarity and user involvement need to become standard requirements in the process of designing technologies that are meant to work at the interface between humans and machines.

Author details

Valerie Varney*, Christoph Henke and Daniela Janssen
Cybernetics Lab of RWTH Aachen University, Aachen, Germany

*Address all correspondence to: valerie.varney@ima-ifu.rwth-aachen.de

References

[1] Bendel O. Pflegeroboter. 2018. DOI: 10.1007/978-3-658-22698-5

[2] Statistisches Bundesamt. Pflegestatistik 2015. Pflege im Rahmen der Pflegeversicherung. Wiesbaden: Deutschlander-gebnisse; 2017

[3] https://www.bundesge sundheitsministerium.de/fileadmin/ Dateien/3_Downloads/Statistiken/ Pflegeversicherung/Zahlen_und_ Fakten/Zahlen_und_Fakten.pdf

[4] https://www.zqp.de/wp-content/ uploads/ZQP_Ratgeber_ GutePflegeerkennen.pdf

[5] Krishnaswamy K, Moorthy S, Oates T. Survey data analysis for repositioning, transferring, and personal care robots. In: Proceedings of the 10th International Conference on Pervasive Technologies Related to Assistive Environments (PETRA '17); New York, NY, USA: ACM; 2017. pp. 45-51

[6] Lee HR et al. Steps toward participatory design of social robots: Mutual learning with older adults with depression. In: Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction (HRI '17); New York, NY, USA: ACM; 2017. pp. 244-253

[7] Kwon M, Jung MF, Knepper RA. Human expectations of social robots. In: The Eleventh ACM/IEEE International Conference on Human Robot Interaction (HRI '16); Piscataway, NJ, USA: IEEE Press; 2016. pp. 463-464

[8] Ting KLH et al. Integrating the users in the design of a robot for making comprehensive geriatic assessments (CGA) to elderly people in care centers. In: 2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN); Lisbon; 2017. pp. 483-488

[9] Lin X, Chen T. A qualitative approach for the elderly's needs in service robots design. In: Proceedings of the 2018 International Conference on Service Robotics Technologies (ICSRT '18); New York, USA: ACM; 2018. pp. 67-72

[10] Fischinger D et al. Hobbit, a care robot supporting independent living at home: First prototype and lessons learned. Robotics and Autonomous Systems. 2016;**75**:60-78

[11] van Wynsberghe A. Designing robots for care: Care centered value-sensitive design. Science and Engineering Ethics. 2013;**19**:407. DOI: 10.1007/s11948-011-9343-6

[12] Sharkey N, Sharkey A. Granny and the robots: Ethical issues in robot care for the elderly. Ethics and Information Technology. 2010;**14**(1):27-40

[13] https://robots.ieee.org/robots/ spotmini/

[14] https://bit.ly/2X6xAHl

[15] http://www.industrytap.com/ anymal-robot-knows-take- elevator/44199

[16] https://www.anybotics.com/ 2019/01/31/robotic-package- delivery-with-anymal/

[17] Raibert MH. Legged Robots that Balance. Cambridge, MA, USA: Massachusetts Institute of Technology; 1986

[18] https://robotrabbi.com/2017/11/ 20/4legs/

[19] https://www.youtube.com/ watch?v=tf7IEVTDjng

[20] https://spectrum.ieee.org/ automaton/robotics/robotics-hardware/

spot-is-boston-dynamics-nimble-new-quadruped-robot

[21] https://techcrunch.com/2018/05/11/boston-dynamics-will-start-selling-its-dog-like-spotmini-robot-in-2019/

[22] Silva M, José TM. A historical perspective of legged robots. Journal of Vibration and Control. 2007;**13**:1447-1486. DOI: 10.1177/1077546307078276

[23] Sparrow R. Kicking a robot dog. In: 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI); Christchurch; 2016. pp. 229-229

[24] Bellicoso CD et al. Advances in real-world applications for legged robots. Journal of Field Robotics. 2018;**35**:1311-1326. DOI: 10.1002/rob.21839

[25] Buchli J et al. Compliant quadruped locomotion over rough terrain. In: 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems; St. Louis, MO; 2009. pp. 814-820

[26] Fankhauser P et al. Robust rough-terrain locomotion with a quadrupedal robot. In: 2018 IEEE International Conference on Robotics and Automation (ICRA); Brisbane, QLD; 2018. pp. 1-8

[27] Kalakrishnan M et al. Fast, robust quadruped locomotion over challenging terrain. In: 2010 IEEE International Conference on Robotics and Automation; Anchorage, AK; 2010. pp. 2665-2670

[28] Repiso E et al. On-line adaptive side-by-side human robot companion in dynamic urban environments. In: 2017 IEEE/RSJ International Conference on Intelligent Robots Bend Systems (IROS); Vancouver, BC; 2017. pp. 872-877

[29] Göller M et al. Sharing of control between an interactive shopping robot and it's user in collaborative tasks. In: 19th International Symposium

in Robot and Human Interactive Communication; Viareggio; 2010. pp. 626-631

[30] Kümmerle R et al. Autonomous robot navigation in highly populated pedestrian zones. Journal of Field Robotics. 2015;**32**:565-589. DOI: 10.1002/rob.21534

[31] Schilling F et al. Geometric and visual terrain classification for autonomous mobile navigation. In: 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS); Vancouver, BC; 2017. pp. 2678-2684

[32] Upcroft B et al. Lighting invariant urban street classification. In: 2014 IEEE International Conference on Robotics and Automation (ICRA); Hong Kong; 2014. pp. 1712-1718

[33] Ferrer G, Sanfeliu A. Behavior estimation for a complete framework for human motion prediction in crowded environments. In: 2014 IEEE International Conference on Robotics and Automation (ICRA); Hong Kong; 2014. pp. 5940-5945

[34] Radwan N et al. Why did the robot cross the road?—Learning from multi-modal sensor data for autonomous road crossing. In: 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS); Vancouver, BC; 2017. pp. 4737-4742