Functionalities and Requirements of an Autonomous Shopping Vehicle for People with Reduced Mobility

António Neves[2], Daniel Campos[1], Fábio Duarte[1], Inês Domingues[1], Joana Santos[1], João Leão[1], José Xavier[1], Luís de Matos[1], Manuel Camarneiro[1], Marcelo Penas[1], Maria Miranda[1], Ricardo Silva[1] and Tiago Esteves[1]

[1]*Follow Inspiration, Portugal*

[2]*IEETA/DETI Universidade de Aveiro, Portugal*

Keywords: Robotics, Retail, Reduced Mobility, Requirements, Functionalities.

Abstract: This paper concerns a robot to assist people in retail shopping scenarios, called the wGO. The robot's behaviour is based in a vision-guided approach based on user-following. The wGO brings numerous advantages and a higher level of comfort, since the user does not need to worry about controlling the shopping cart. In addition, this paper introduces the wGOs functionalities and requirements to enable the robot to successfully perform personal assistance while the user is shopping in a safe way. A user satisfaction survey is also presented. Based on the highly encouraging results, some conclusions and guidelines towards the future full deployment of the wGO in commercial environments are drawn.

1 INTRODUCTION

This paper describes the design concerns and decisions when the company Follow Inspiration (de Matos, 2012) developing a robot to help and assist people (giving special emphasis to people with reduced mobility) in retail environments, through a *user-following* scenario.

The wGO [1] (Fig. 1) is an autonomous and self-driven shopping cart, designed to follow people with reduced mobility (elderly, people in wheelchairs, pregnant women, temporary reduced mobility, etc.) in commercial environments. With the robot, the user can control the shopping cart without the need to push it. This brings numerous advantages and a higher level of comfort, since the user does not need to worry about carrying the groceries or pushing the shopping cart.

Thanks to the sensors (RGBD cameras and LRF), wGO detects and identifies its user in less than 2 seconds, he just needs to push the "start" button and the wGO will start following him. Furthermore, distance sensors, RGBD cameras and LRF allow wGO to identify and avoid any obstacle along the way.

[1]The robot is currently patent pending.

Figure 1: wGO: Front view; Back view.

The idea for the product came from the fact that between 8% and 10% of the population has some form of disability (CRPG and ISCTE, 2007), and that in Europe alone there are about 50 million people with disabilities and 134 million people with reduced mobility. Apart from people using wheelchairs, there are other cases in which people are temporarily or permanently disabled, these include: an elderly person using a cane, or someone with a foot or leg injury who requires the use of crutches, pregnant ladies and parents with prams.

Neves, A., Campos, D., Duarte, F., Domingues, I., Santos, J., Leão, J., Xavier, J., Matos, L., Camarneiro, M., Penas, M., Miranda, M., Silva, R. and Esteves, T.
Functionalities and Requirements of an Autonomous Shopping Vehicle for People with Reduced Mobility.
DOI: 10.5220/0006385903730380
In *Proceedings of the 3rd International Conference on Vehicle Technology and Intelligent Transport Systems (VEHITS 2017)*, pages 373-380
ISBN: 978-989-758-242-4

In fact, if we add the disabled, the elderly, pregnant women, and couples with children, we find that between 30% to 40% of all Europeans could benefit from improved accessibility. In addition to those people with reduced mobility due to disability or injury, there are many people without mobility issues who could benefit from assistance in carrying heavy bags.

Shopping environments are highly heterogeneous and give rise to a high frequency of dynamic interactions that trigger various senses and emotions in humans. This often causes a high level of stress in people, and those with mobility limitations.

Some of the identified difficulties include (Australia, 2016):

- For wheelchair users:
  - no adequate forward reach at basins, counters and tables;
  - surfaces that do not provide sufficient traction (e.g. polished surfaces).
- For people who have trouble walking:
  - no seating in waiting areas, at counters and along lengthy walkways;
  - access hazards associated with doors, including the need to manipulate a handle while using a walking aid;
  - surface finishes that are not slip-resistant or are unevenly laid.

Besides the difficulties brought by the shopping environment itself, conventional shopping carts, which can carry many products and which are provided with wheels so that the shoppers can push them, also have serious drawbacks. One of them being their considerable size. This is simultaneously an important asset and a significant drawback, as although shopping carts can hold large and bulky products, the increased mass complicates manoeuvrability and handling. Manoeuvrability is particularly compromised when making turns in supermarket aisles or when avoiding other carts, shelves, and indeed other shoppers (Rodriguez et al., 2014). Smaller baskets appeared on the market to overcome the traditional shopping cartś drawbacks. These baskets were developed to hold a set of items while at the same time being easy to move. They contain wheels or rolling elements incorporated into the bases which allow them to be moved when parallel to the floor or when inclined. However, even though these baskets improve manoeuvrability due to their reduced size and capacity, they also have drawbacks typical of their morphology, such as the need for the user to bend down for placing or removing items, among others. Furthermore, such baskets can have drawbacks typical of the way they are stored, since stacking them vertically can entail a problem for elderly shoppers or shoppers with any type of physical limitation (Rodriguez et al., 2014).

While the wGOs software architecture is detailed in (Neves et al., 2017), here a design point of view is adopted. The paper starts by reviewing the existing solutions for people with reduced mobility to shop (Section 2) and some of the relevant legislation related with technology equipments (Section 3). Design related requirements are given in Section 4. Next, in Section 5 the wGO design evolution and justifications for the changes made are given. Section 6 identifies the main risks related with the wGO usage in a real scenario. Section 7 analyses a user satisfaction study made in a relevant, unconstrained scenario. Conclusions and another applications of this technology are given in Section 8 and Section 9, respectively.

2 EXISTING SOLUTIONS

Looking at the commercial market, the most obvious existing solutions are those provided by shopping cart producers [2]. These providers typically have products targeted for customers in wheelchairs, but not products for other types of users with reduced mobility (e.g. pregnant women). A different type of solution is the adapted system. Some examples are the "amigo mobility" scooter [3] and adapted wheelchairs [4], etc. These products are, however, not particularly user friendly. The user needs to first move into the mobility auxiliary device and then to learn how to use it (which may be particularly hard for the scooter case). In the case of wheelchair users, the user also needs to leave their own personal chair, which may cause discomfort and unnecessary stress. Another problem with these solutions is that the user is visibly distinguishable from the other supermarket clients, which may discourage some people from using it (Iezzoni et al., 2001).

While this topic of assisted shopping using robotics has received very little attention in the academic research community, several systems exist where robots are used to help people with reduced mobility. In (Gurgel Pinheiro et al., 2015), an anticipative shared control for robotic wheelchairs, targeted at people with disabilities is presented. The same idea, of intelligent wheelchairs, is also the focus of the

[2] e.g. wanzl (www.wanzl.com)

[3] www.myamigo.com

[4] e.g. meyra (www.meyra.de), promoted by Egiro (www.egiro.pt)

work in (Faria et al., 2014a) where a data analysis system which provides an adapted command language is presented. A smart companion robot for elderly people, capable of carrying out surveillance and telepresence tasks, is described in (Pavon-Pulido et al., 2015). Also, with the aim of helping elderly people through tele-presence, a low-cost platform capable of providing augmented reality for pill dose management was developed in (Martin Rico et al., 2014). In (Faria et al., 2014b) an approach based on the Dynamical System Approach for obstacle avoidance of a Smart Walker device to help navigation of elderly people is presented.

Perhaps the closest application to the focus of this paper is presented in (Gmez-Goiri et al., 2011) where a product locator application is proposed. The application runs on heterogeneous personal mobile devices keeping the user private information safe on them, and it locates the desired products over each supermarket's map. We believe that such a system could be complementary to the wGO and could be used in combination to further improve customers' shopping experiences.

3 EXISTING LEGISLATION

In a joint effort started in 1995, the United Nations Economic Commission for Europe (UNECE) and IFR, engaged in working out a preliminary service robot definition and classification scheme, which has been absorbed by the current ISO Technical Committee 184/Subcommittee 2 resulting in a novel ISO-Standard 8373 which became effective in 2012 (for Standardization, 2 03).

There, a **robot** is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks. Autonomy in this context means the ability to perform intended tasks based on current state and sensing, without human intervention.

A **service robot** is a robot that performs useful tasks for humans or equipment excluding industrial automation application.

A robot system is a system comprising robot(s), end-effector(s) and any machinery, equipment, devices, or sensors supporting the robot performing its task (of Robotics, 2017).

Being an autonomous and self-driven shopping cart, designed to follow people with or without reduced mobility in commercial surfaces, wGO follows under the **service robot** category. Thanks to the sensors (RGBD cameras and LRF) wGO detects and identifies its user in less than 2 seconds, he just needs to push the "start" button and the wGO will start following him. Furthermore, distance sensors, RGBD cameras and LRF allow wGO to identify and avoid any obstacle along the way.

The international standard IEC 60950-1 gives the general requirements for the safety of Information technology equipments (Commission, 2005). As stated, it is essential that designers understand the underlying principles of safety requirements in order that they can engineer safe equipment. Designers should take into account not only normal operating conditions but also likely fault conditions, consequential faults, foreseeable misuse and external influences.

The standard also assumes that users will not intentionally create a hazardous situation. The priorities depicted in Figure 2 should be observed in determining what design measures to adopt.

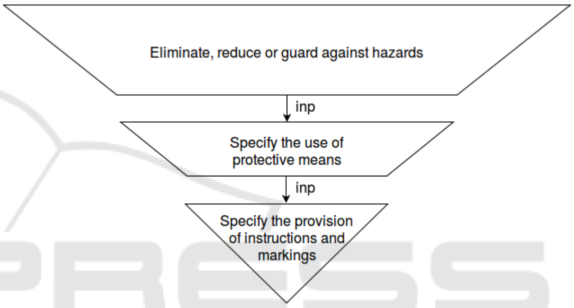

Figure 2: Priorities for design measures to adopt (Commission, 2005). inp stands for "if not possible".

The application of a safety standard is intended to reduce the risk of injury or damage due to: electric shock, energy related hazards, fire, heat related hazards, mechanical hazards, radiation or chemical hazards.

Here, we are mostly interested in the mechanical hazards, whose injuries may result from: sharp edges and corners, moving parts, equipment instability, flying particles.

Suggestions of measures to reduce risks include: rounding of sharp edges and corners, guarding, provision of safety interlocks, providing sufficient stability to free standing equipment. May also comprise selecting cathode ray tubes and high pressure lamps that are resistant to implosion and explosion respectively, and provision of markings to warn users where access is unavoidable.

Concerning Stability, the standard (Commission, 2005) states that under conditions of normal use, units and equipment shall not become physically unstable to the degree that they could become a hazard to an operator or to a service person. Compliance is checked by the following tests, where relevant. Each test is conducted separately. During the tests, containers are to hold the amount of substance within their rated capacity producing the most disadvantageous condition.

- A unit having a mass of 7 kg or more shall not fall over when tilted to an angle of 10° from its normal upright position.
- A floor-standing unit having a mass of 25 kg or more shall not fall over when a force equal to 20% of the weight of the unit, but not more than 250 N, is applied in any direction except upwards, at a height not exceeding 2 m from the floor.
- A floor-standing unit shall not fall over when a constant downward force of 800 N is applied at the point of maximum moment to any horizontal surface of at least 125 mm by at least 200 mm, at a height up to 1 m from the floor. The 800 N force is applied by means of a suitable test tool having a flat surface of approximately 125 mm by 200 mm. The downward force is applied with the complete flat surface of the test tool in contact with the Equipment Under Test (EUT); the test tool need not be in full contact with uneven surfaces (for example, corrugated or curved surfaces).

Moreover, materials and components used in the construction of equipment should be selected and arranged so that they can be expected to perform in a reliable manner for the anticipated life of the equipment.

Risk assessment as given in ISO14121-1 (for Standardization, 2007) is depicted in Fig. 3. The first level concerns the severity of damage of injury:

- S1: Reversible, e.g. medical treatment or first aid required
- S2: Irreversible, e.g. loss or breaking of limbs

The second level describes the frequency and/or duration of exposure to hazard:

- F1: 1 day up to 2 weeks; 2 weeks up to 1 year
- F2: Less than 1 hour; 1 hour up to 1 day

The last level is the possibility of avoiding the hazard

- A1: Possible, probable
- A2: Impossible

4 wGO: DESIGN REQUIREMENTS

Several of the robot desired functionalities and requirements were taken into consideration when designing the wGO. These include:

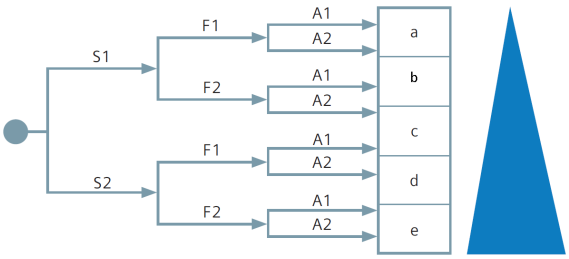

Figure 3: Risk assessment as per (for Standardization, 2007).

- The robot should not have sharp edges
- The bag should be accessible to every type of user
- Product placement in the bag should be easy
- The robot should be able to carry at least 20 Kg
- The Start/Stop button should be well identified and accessible
- The Emergency button should be well identified and accessible
- There should be redundancy in the sensors
- The robot should detect and follow people with 1.3 m height or more
- The robot should be easy to clean

Since not every type of user would be able to reach a touch screen (e.g. users in wheel chairs), a further requirement was specified that teh wGOs operation should not depend on a touch interface.

5 wGO: DESIGN EVOLUTION

The wGO is designed to have an ergonomic shape, friendly both to the target users (people with reduced mobility) and the environment (commercial retail environment).

It has, however, undergone an evolution, as can be seen in Fig. 4.

Figure 4: wGO evolution.

The design on the left of Fig. 4 was the initial proposal (v0.1). From that version to the next (v0.2) several alterations were implemented, namely:

- LRF position was changed: It was noted that the different height would make visible more of the obstacles typically present in a commercial site. Moreover, stability of the support assembly easiness was increased.
- Smaller base: A smaller increases maneuverability. It cannot, however, be too small due to stability issues which might jeopardize safety.
- Emergency button was repositioned: The emergency button needs to be visible and of easy access. It cannot, however, be positioned in a place where it can be accidentally triggered. A new location was found that complies with these requirements.
- Changes to the electronic box: Some changes to the electronic box were performed in order to increase safety. For example, the box was electrically isolated.
- Redesign of the bag holder support: Angular vertices were smoothed in order to make the product less prone to accidents.

From that version to the next (v0.3) most of the changes were related to the sensors:

Change of the LRF. Initial tests revealed that the LRF (RP Lidar) had difficulties in seeing black. A better LRF was thus chosen to minimize this problem.

Change of the Active Camera. Kinect 2 was found to be too resource demanding. A different active camera, with lower specification was tested and found to be enough for our application, at the gain of being less resources consuming.

Inclusion of a Pan and Tilt System. A pan and tilt system was included so that the active camera responsible for performing tracking would better follow the user.

Inclusion of Two Additional Active Cameras. Two active cameras were added in order to decrease the dead area and have a better obstacle avoidance performance.

Changes in the Structure. The middle main structure was redesigned in order to be thinner (a sufficiently wide diameter to allow the required cables to pass through it) and less heavy.

Reorganization of the Interior of the Base. The base was redesigned in order to accommodate two batteries and thus increase the energetic efficiency of the robot.

Head Redesign. The inclusion of the additional active cameras forced a complete redesign of the head of the robot in order to accommodate them.

6 wGO: THE RISKS

Safety is a critical characteristic for robots designed to operate in human environments. Looking back at the risk assessment as given in ISO14121-1 (for Standardization, 2007) and depicted in Fig. 3, we observe that:

- the severity of damage of injury is irreversible (e.g. breaking of limbs) - **S2**
- the frequency and duration of exposure to hazard is in the order of 30 minutes, twice a week (typical duration and frequency of a shopping experience) - **F1**
- it is impossible to avoid the hazard - **A2**

In this way, wGO is categorized in the **d** level.

The two main risks associated with the wGO are:

- To turn due to someone hanging on it
- Collision with people

Besides the user manual and the instructions on how to use the robot properly, several of the design options had in mind the minimization of the identified risks.

Changes in the structure included in v0.3 made the robot less heavy on its top part, giving it a lower centre of gravity. The addition of one battery, besides the obvious increase in the robot autonomy, also had the side effect of adding weight to the base making the robot even more stable and harder to turn.

Collision avoidance is assured mostly by the use of redundant sensors (Ponz et al., 2016). Their existence, type and location has underwent several changes. The change in the LRF position in v0.2, for instance, made visible more of the obstacles typically present in a commercial site. The change in the LRF itself also allowed the detection of darker obstacles (people wearing a black suit for instance). The addition of two active cameras in v0.3 is another example of redundancy of sensors to detect obstacles.

Finally, there is an emergency button, clearly visible and positioned in a place with easy access for every type of user in case an unpredicted situation happens. It is important to note that this button has not yet been used in any of the internal, external, controlled or uncontrolled tests.

7 RESULTS

This section summarizes the demonstration of wGO in a relevant, unconstrained scenario (Figure 5). Two wGOs were available for the tests and only users with reduced mobility were asked to participate.

Figure 5: wGO in a relevant scenario.

Transportation of the wGOs from their production site to the destination where the demonstration (more than 1800 km) was made by truck with the robots accommodated in disposable plywood boxes.

Concerning the location description, the site had enough space for circulation, and there were no areas where the wGO did not fit. Its use was, however, restricted to days where the store was too crowded. The hypermarket had locations with several different levels of brightness and the main corridor's ceiling had big skylights.

143 clients tested the wGO during two weeks of demonstration. An average of 14 users a day used the wGO with the exception, as already mentioned, of days where the store was too crowded.

An average of 35 minutes was spent per trip, with most users being female (Fig. 6).

Figure 6: Population gender.

Most of the users had ages between 25 and 36, with the second most represented class people with 55 or more years (Fig. 7).

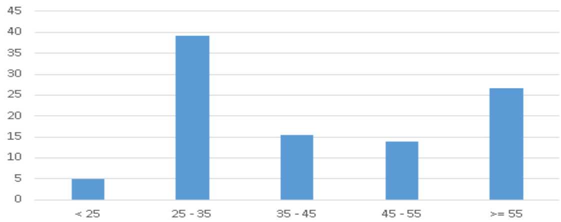

Figure 7: Population age.

The categorization of users is shown in Fig. 8. As can be seen most of the volunteers presented some type of reduced mobility. Among those, parents with a baby stroller are the most represented followed by people in wheelchair and the elderly.

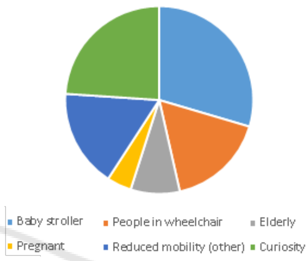

Figure 8: User's categorization.

A small questionnaire was made to the participants with the following questions:

- Do you find the wGO more agreeable than the alternatives?
- Would the wGO be a reason for you to come to this store?
- Would you reuse the wGO?
- Would you recommend the wGO?
- From a scale of 0 to 4 (being 0 not al all and 4 completely), how satisfied are you with the wGO?

Results are presented in Figs 9, 10, 11, and 12, respectively. It can be seen that the vast majority of the users find wGO better than existing alternatives. More than 64% would find it a reason to return to this particular store. More than 90% would reuse the wGO and more than 97% would recommend it. Average satisfaction was 3.5 out of 4.

7 out of the 143 have returned (within the short period of the demonstration) to use the wGO. Of these, 5 were male and 2 female.

Comments from the users included:

Detection and Identification: at times, wGO follows someone else; the wGO should have the ability to follow the customer in crowded environments; a passive bracelet or plotter should be provided so that wGO will follow one person; and the wGO should function in exterior light.

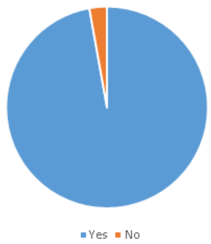

Figure 9: Do you find wGO more agreeable than the alternatives?

Figure 10: Would the wGO be a reason for you to come to this store?

Figure 11: Would you reuse the wGO?

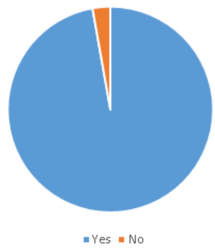

Figure 12: Would you recommend the wGO?

Visibility: to be recognizable by the customer, and more visible to others (e.g. beacon, light signal); to show when it is on or off; and increase the volume.
Capacity: larger bag; support for heavy products, such as water bottles; and hook for personal items (e.g. handbag).
Usability: to go faster and to shorten the distance between the wGO and the user.
Movement: more fluidity, especially in narrow passages and angles and reactivity in crowded environments.
Usage Restrictions: to go outside and to go to the car's trunk.
Other Features: to call a collaborator; to be able to scan products, know the price and remaining bag capacity; system for fetching products; speech recognition (dialogue with wGO); guide the customer in the store.

8 CONCLUSION

In this paper the wGOs evolution is presented. A high focus was given to security concerns and its implication the design of the robot.

A user study made with 143 volunteers was also analysed.

Several positive aspects were pointed out, such as the high interest from the customers (some came expressly to test the wGO); positive general opinion; existence of loyal customers; technical satisfaction of 87% (versus 73% on previous tests).

There were also, some points to be improved:

- During the process, the wGO should not change the user
- Difficult to move in crowded environments
- The wGO does not work outside

To attack these problems, several measures will be taken. Improvements on the identification algorithm will be made. This will both help with the first and second points to be improved. When identifying better the user, the wGO will not start following a different person and will behave better in crowded environments by, again, always following the same user.

Concerning the exterior lightning, new sensors that are able to acquire depth information in the exterior will be analysed. At the same time, new algorithms that do not make use of depth information and only the RGB will be studied.

9 OTHER APPLICATIONS

A great part of Follow Inspiration's R&D strategy is based on the wGO technology that can be applied to several scenarios, including industry, for material handling and transportation for the automative industry. As consequence, a new project were started in 2015 in order to develop a robot capable of performing tasks in an autonomous way through an industrial environment (NORTE-01-0247-FEDER-011109). New developments have been made in mapping, localization (Andry Maykol Pinto and Moreira, 2014), navigation (Costa et al., 2016) and multi-robot cooperation algorithms (Santos et al., 2015). The application of autonomous vehicles in these scenarios has several advantages in the LEAN process offering flexibility, reducing times and therefore the optimization of the operational costs.

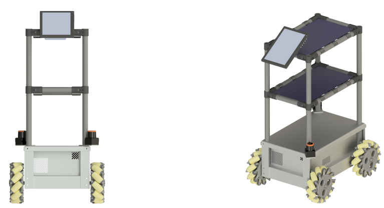

Figure 13: wGO Technology applied in an industrial scenario.

ACKNOWLEDGEMENTS

The authors would like to thank all the institutional supporters, including TIC RISCO, Portugal Capital Ventures, SGPS, S.A, CEiiA, Fundão City Hall. We would also like to thank to R&D entities including, Tente, CEiiA, Centimfe and Alma Design. These developments were undertaken under several EU cofunding programs, namely: QREN (projects: CENTRO-07-0201-FEDER-023962 and CENTRO-07-0202-FEDER-024692); Portugal 2020 (projects: PFOCI-01-0247-FEDER006398 and NORTE-01-0247-FEDER-011109).

REFERENCES

Andry Maykol Pinto, P. G. C. and Moreira, A. P. (2014). Architecture for visual motion perception of a surveillance-based autonomous robot. In *IEEE International Conference on Autonomous Robot Systems and Competitions (ICARSC)*.

Australia, G. o. W. (2016). Section five access and inclusion. Disability access and inclusion plan - training package, Disability Services Comission. Accessed: 2016-11-18.

Commission, I. E. (2005). Part 1: General requirements. *Information technology equipment Safety*.

Costa, P., Moreira, N., and Campos, D. (2016). Localization and navigation of an omnidirectional mobile robot: The robot@factory case study. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, pages 1–9.

CRPG and ISCTE (2007). Elementos de caracterizaccão das pessoas com deficiências e incapacidades em portugal. In *Programa Operacional de Assistência Técnica ao QCA III: eixo FSE.*

de Matos, L. (2012).

Faria, B., Reis, L., and Lau, N. (2014a). User modeling and command language adapted for driving an intelligent wheelchair. In *IEEE International Conference on Autonomous Robot Systems and Competitions*, pages 158–163.

Faria, V., Silva, J., Martins, M., and Santos, C. (2014b). Dynamical system approach for obstacle avoidance in a smart walker device. In *IEEE International Conference on Autonomous Robot Systems and Competitions*, pages 261–266.

for Standardization, I. O. (2007). Safety of machinery – risk assessment – part 1: Principles. Standard, ISO.

for Standardization, I. O. (2012-03). Robots and robotic devices – vocabulary. Standard, ISO.

Gmez-Goiri, A., Castillejo, E., Ordua, P., Laiseca, X., Lpez-de-Ipia, D., and Fnez, S. (2011). Easing the mobility of disabled people in supermarkets using a distributed solution. In Bravo, J., Hervs, R., and Villarreal, V., editors, *Ambient Assisted Living*, number 6693 in Lecture Notes in Computer Science, pages 41–48. Springer Berlin Heidelberg.

Gurgel Pinheiro, P., Cardozo, E., and Gurgel Pinheiro, C. (2015). Anticipative shared control for robotic wheelchairs used by people with disabilities. In *IEEE International Conference on Autonomous Robot Systems and Competitions*, pages 91–96.

Iezzoni, L. I., McCarthy, E. P., Davis, R. B., and Siebens, H. (2001). Mobility difficulties are not only a problem of old age. *Journal of General Internal Medicine*, 16(4):235–243.

Martin Rico, F., Rodriguez Lera, F., and Matellan Olivera, V. (2014). Myrabot+: A feasible robotic system for interaction challenges. In *IEEE International Conference on Autonomous Robot Systems and Competitions*, pages 273–278.

Neves, A., Campos, D., Domingues, I., Santos, J., Leo, J., Xavier, J., de Matos, L., Camarneiro, M., Penas, M., Miranda, M., Morais, R., Silva, R., and Esteves, T. (SUBMITTED 2017). *A personal robot as an improvement to the customers in-store experience*. In-Tech.

of Robotics, I. F. (2017). Definition of service robots. http://www.ifr.org/service-robots/. Accessed: 2017-01-23.

Pavon-Pulido, N., Lopez-Riquelme, J., Pinuaga-Cascales, J., Ferruz-Melero, J., and Morais Dos Santos, R. (2015). Cybi: A smart companion robot for elderly people: Improving teleoperation and telepresence skills by combining cloud computing technologies and fuzzy logic. In *IEEE International Conference on Autonomous Robot Systems and Competitions*, pages 198–203.

Ponz, A., Rodrguez-Garavito, C. H., Garca, F., Lenz, P., Stiller, C., and Armingol, J. M. (2016). Automatic obstacle classification using laser and camera fusion. In *International Conference on Vehicle Technology and Intelligent Transport Systems*.

Rodriguez, V. J. L., Fernandez, L. M., Hansen, M. M., Modrego, C. E., Peligero, F. J. A., Torijano, J. L., Guallar, E. E., Cornudella, B. S., and Verdejo, I. G. (2014). Shopping cart. Justia Patent.

Santos, J., Costa, P., Rocha, L., Moreira, A., and Veiga, G. (2015). Time enhanced a*: Towards the development of a new approach for multi-robot coordination. *IEEE International Conference on Industrial Technology (ICIT)*.