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Note

Notes from Literature about Universal Design, Accessibility & Robots

UD-Robots

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Abstract

This document collects results from a search that was done to find out what research have been done regarding universal design and accessibility of robots. The search turned up 13 articles in this topic. Articles about universal design focused more on how an environment could be made to be universally designed for a robot. There were also several articles about how robots can be an assistive technology for people with vision impairment or hearing impairment. There were a couple of articles that raised the topic of accessibility requirements for a robot. This was further developed in a PhD thesis from earlier this year that provides a promising starting point for future work.

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1 Goal

The goal of this document is to document what has been done around robots, universal design, and accessibility. The point of the search is to know what has already been done and see if there is any previous work that we can build upon. When we started the UD-Robots project, we knew that there was little literature about universal design or accessibility for robots, but we were unsure how much there was and what the literature said. We set out to do a limited literature search in this area, document what we found, and use that as a basis for the next steps in the project.

We document details of our search method (Section 2. As part of the method, we also found the need to provide a short explanation of accessibility and universal design for information and communication technology (ICT) such as computers and robots. This explanation is important since there were different interpretations of this in the articles we collected. We then present articles that talk about robots and universal design (Section 3 followed by the articles that present robots for use as an assistive technology before discussing work that has looked at making robots accessible (Section 4. We then provide some possible next steps in the project (Section 5.

2 Method

Most of these documents were found by using Google Scholar and searching for "universal design" and "robots" or "universal design" and "accessibility". A snowball method was used. That is, we started with the known list of articles, then if an article referenced in the main article referenced other articles on the topic, they were added to the list. We were hoping to get a good overview quickly.

On the other hand, there are few articles that focus on universal design of robots or accessibility of robots. Here is the breakdown:

Universal design of robots: 4

Robot accessibility: 8

2.1 Split between accessibility and universal design

We make a distinction between *universal design* and *accessibility* for robots. Accessibility typically refers to adding additional hints and mechanisms to a technology so that it can be used by people with disabilities, this doesn't preclude making special versions that are targeted at the person (Pernice & Nielsen, 2001). Universal design refers more to the idea that one should create something that is usable by as many people as possible, without having to make special adjustments (Aslaksen et al., 1997). There are seven principles that form the foundation of universal design (Connell et al., 1997):

1. Equitable Use

2. Flexibility in Use
3. Simple and Intuitive
4. Perceptible Information
5. Tolerance for Error
6. Low Physical Effort
7. Size and Space for Approach and Use

The relation between accessibility and universal design comes down to the implementation. It is usually easier to see this split between universal design and accessibility in the physical world. For example, a building may have multiple floors and stairs are built to allow access to the different floors. However, as time goes on, it is discovered that people in wheelchairs (or things with wheels) do not have easy access to the different floors. So, to make the building more accessible, an elevator and ramps are added to the building. It might be quicker to take stairs if one can, but the elevator and ramps are there for the cases when it is needed. This is like the choices made at the school one of the authors attended growing up. Wheelchair users had access to an elevator to travel between floors, but it required you to go to one part of the building to use it, even though your destination was on the other side of the building.

Universal design would instead focus on including this need for wheelchairs or other wheeled objects at the start of the process. Instead of creating stairs at every location, they would design inclines and possibly elevators as the main way of traversing the area. Many more people could now access the building without adding additional infrastructure to the building. In addition, the ramps can be used in other contexts, such as for baby carriages or transporting heavy objects around the building. Gaining additional use from universal design measures is also called the curb-cut effect (Blackwell, 2016).

For information and communication technology (ICT), especially for things like web browsers, mobile and desktop applications, the line between accessibility and universal design is blurred. Yes, making an application accessible does mean adding some additional markup and code to an application that allows someone to use assistive technology, such as a screen reader, to read aloud the different items on the screen. This is the accessibility side. However, the people using the screen reader to access the page are using the same webpage that everyone else also uses. The upshot is that everyone uses the same apps and gets the same functionality and there aren't specially built, fragile solutions that exclude people from accessing a service. So, to achieve universal design of ICT, it is necessary to make the solution accessible, so that as many people as possible can use the same solution.

Robots offer an interesting intersection, since they have both a digital component and a physical component, they will have to rely more on having accessible components and software and a focus on universal design for its use. In many cases, one might not be building a robot completely from scratch and will have to look at how one can make an existing robot accessible. This offers interesting challenges. Let's see what the literature says, by first looking at articles that focus on universal design.

3 Articles focusing on universal design

Here we examine design of robots that have been built or designed with the principles of universal design in mind. They are presented in no particular order.

3.1 Universal Design with Robots for the wide use of robots - Core concept for interaction design between robots and environment - Core concept for interaction design between robots and environment

Matsuhira and colleagues (2009) presented a summary of how a research lab in Japan (Toshiba) have created their own version idea of Universal Design for robots. They have created their own set of universal design principles called UDRob that builds on the original seven principles of universal design.

1) *Equitable Use*: A robot, one of the users in this context, can use the objects. 2) *Flexibility in Use*: A robot can handle objects freely from anywhere, any posture. 3) *Simple and Intuitive*: A robot can easily get information from the environment. 4) *Perceptible Information*: A robot easily recognizes the objects it interacts with using image processing. 5) *Tolerance for Error*: A robot handles the objects safely and reliably. 6) *Low physical effort*: A robot handles the objects smoothly with simple motion, without fine tuning for positioning accuracy or dexterous motion being required. A robot handles the objects with less torque. 7) *Size and space for approach and use*: A robot approaches and handles the objects within a smaller space.

The idea is that objects and rooms in the environment that are usable by humans should also be usable by a robot. They provide examples of using geometric markers to help orient the robot in the environment or using different fasteners for things that do not require the same precision as using a bolt. Some of these ideas have been superseded by advances in technology, but they are still reasonable. The idea of only using simple words and talking loudly (likened to talking to older people) is a different comparison.

The authors also use this as an opportunity to show how these principles work with a tray table and an ApriAlpha. The tray can only be placed in a certain way.

Overall, the article presents an interesting idea, but the goal is to use UD as a basis to give the robot better access to the environment.

3.2 Universal Design of Robot Management System for Daily-Life-Supporting Robots

Another idea of Universal Design was presented at the same conference by Kim and colleagues (2009). This is another take on Universal Design applied to robots. This is more an attempt to bend universal design to make the environment work for robots (and management of the robots). The idea being that if the environment is designed to work for robots in general, then any kind of robot should be able to work on things.

The universal design principles for this context are translated as follows: 1) *Equitable use*: make the design usable for any robot. 2) *Flexibility in use*: there should be more than one way for a robot to accomplish the task. 3) *Simple and intuitive*: make sure that it is easy to get information and figure out how to use something. 4) *Perceptible information*: Present information in different ways. 5) *Tolerance for error*: Arrange elements to minimize hazards and errors and add failsafe mechanisms. 6) *Low physical effort*: The design should work without overworking the robot. 7) *Size and space for approach and use*: make it easy for the robot to approach and manipulate the objects.

These adjusted principles go into the design of a robot management system or RMS. The system has something called a Ubiquitous Function Service that contains lots of information about objects in the environment. There are also CLUE or Coded Landmark for Ubiquitous Environment markers (basically QR-codes) that the robot can scan to get information about the different objects in the environment.

Kim and colleagues give an example of the environment and how it works with a robot from Toshiba and a robotic arm that is mounted on a wheelchair. These robots are quite different in the forms, but both have arms for manipulation. Overall, Kim and colleagues provide interesting ideas about how one can build an environment that embodies their take on the universal design principles, but it also assumes a lot of additional work in data that needs to be set up for the robot.

3.3 TourBot

This was a master thesis by Terrel (2009) that looked at creating a robot that could be used as a tour guide for a building on a college campus. TourBot was designed using the seven principles of universal design (Connell et al., 1997), along with an idea of Seven Principles of Efficient Human-Robot Interaction (Goodrich & Olsen, 2003). The author lays out a process for creating the robot using these principles. The process is split into 5 steps:

1. Task chart: this is a list of the tasks that the robot should do
2. Task map: A visualization of the sequence of tasks to help make sure that the task chart is complete
3. Interaction chart: a breakdown of the tasks into software and hardware components needed for each task to meet the needs of the users
4. Universal flowchart: A visualization of the previous three items. The intended sequence with the tasks, hardware and software are all put in with a check to make sure nothing was forgotten. This can be divided into the task, the universal design element, and interaction.
5. List of hardware and software: This provides the different components that are needed and the functions that need to be implemented.

There is no indication if this process is iterative or not, but since Steps 2 and 4 also are checks to see if anything is missing, it would make sense that one may run through all the steps multiple times.

The thesis only provides sketches, renderings, and simple physical prototypes of the robot in the thesis, and it is unknown if the final robot was completed (there are no follow-up articles that could be found). This software necessary for the robot to function and perform tasks in the environment is listed, but there are no prototypes that implement them.

3.4 Toward a framework for robot-inclusive environments

A different take on universal design for environments that robots are is by Tan and colleagues (2016) about how to design robot-inclusive environment. Some aspects of accessibility are included, or at least alluded to, but the article is more about exploring a framework for creating environments that are amenable to robots.

Tan and colleagues present a framework that consists mostly of axes: One axis for the level of autonomy of the robot, and one axis for the difficulty of the environment. In general, the more difficult (not necessarily complex) the environment is, the less autonomy the robot has *or* the more functionality that is required by the robot to navigate the environment.

So, the framework itself is a measure of the autonomy of the robot and the inclusiveness of the environment. These are in opposition to each other. The idea is that the sum of the two sliders need to get to over 10 to “just” satisfy the requirements. When the robot has too high autonomy it is “over-provisioned” for the environment. The function is: D=f(AUTONOMY, INCLUSIVENESS)

The article goes on to create a taxonomy of categories for different robot and environment set ups, such as a single robot in a single environment, robots working in teams in one environment, multiple robots working in one environment, and multiple robots working in multiple environments.

There are also design criteria and guidelines for designing the environments. The criteria elements are.

1. Observability
2. Accessibility
3. Manipulability
4. Activity
5. Safety

This presents an interesting way of creating environments that work for robots. It certainly provides a good argument of how robots could benefit from Universal Design.

3.5 Summary of articles focusing on universal design and robots

It seems that most of the articles that focus on universal design, focus on aspects of the environment. That is, how can an environment be designed such that a robot can go through and perform tasks without trouble. Much of the original work in universal design is focused more on environments and less so on technology. On the other hand, this could be thought of as the robot having several impairments (poor sight, mobility, and motor skills) that would benefit from environments that take limitations into account. We were more interested in what would need to be done to a robot to make it more accessible. It seems that we need to look more at making a robot accessible instead.

4 Focus on accessibility and robots

There are several articles that look at making robots accessible for people with disabilities. The literature has a split, some focus on helping with a concrete task for a specific user group. Others look at the task of creating guidelines for making sure that robots are accessible.

4.1 RFID in robot-assisted indoor navigation for the visually impaired

Kulyukin and colleagues (2004) created a prototype for creating a guide robot for people with vision impairment.

Kulyukin and colleagues posit that robots can be useful in niche locations such as airports, conference centers, hotels, or other places where guide dogs are unfamiliar of the area. Otherwise, the guide dog wins out since it is more versatile. The task is how to deploy a robot so that it is cheap and doesn't require extensive mapping of the environment. This is done with a novel (at least for 2004) the idea of using RFID tags that are distributed throughout the environment (or can be worn). The tags are passive, so they require no power.

Much of the article concerns itself with the algorithm to navigate around the areas, this involves looking at the signals received by the RFID tags and comparing them with the map of the tags to determine their location.

The robot guide or RG is a mobile platform with large RFID antennae so that it can pick up RFID tags fast enough to keep up with the speed of a moderate walk (about 0.7 m/s). The interaction is done with speech recognition or a keyboard.

A couple pilot studies were done with people with sight and people with visual impairment. The people with visual impairment were able to navigate with the robot successfully to the different locations. They complained most about the speech recognition, which is likely poor for 2003.

Although the technology used in the articles has become dated, Kulyukin and colleagues provide useful information about how one can augment a robot as an assistive technology to help guide someone in an indoor environment. A task that is still difficult. It's still worthwhile to refer to this. There is also a nice history of different tour guide robots.

4.2 Exploring the Use of a Drone to Guide Blind Runners

Al Zayer and colleagues (2016) presented an idea of using a drone as an accessibility assistant for runners with visual impairment. The main questions that Al Zayer and colleagues were concerned about are if blind people can locate the drone by the noise of its rotors and if the blind people can follow the drone in a straight line.

The experiment was run with two blind participants and had two activities. The first activity is to locate the drone as it moved between several locations. The people wore head-mounted cameras to record where they thought the drone was. In the second activity, the people were asked to follow the drone as the person walked on a walking track. They were informed that the track was unobstructed, and they could go as fast as they wanted. They were encouraged to go without their white canes and there were people walking on either side of the person just in case. The times for walking the track were recorded and the participant walked on the tracks 10 times.

The participants were able to locate the drone easily and they could follow the drone on the path. They claimed that the rotor noise was enough to know where the drone was, but they were unsure if the drone would be useful for running. The authors no participants would make any larger claims, but Al Zayer and colleagues want to experiment a bit more with it.

It was an interesting idea, but it was a bit far-fetched without more training or additional assistive technology. It could be that the participants were rightfully skeptical of the drone not finding all obstructions since it could fly over many that would get in the way of a person walking.

4.3 Using Robot Manipulation to Assist Navigation by People Who Are Blind or Low Vision

A late breaking report by Tan & Steinfeld (2017) examined using robots as an aid in providing instructions to people who are blind or have low vision. They researchers used a Baxter robot to provide guidance. They chose this robot because it is very pliant, and it doesn't have a design that can cause pinches (something to think about for accessibility).

The idea is based on a person “drawing” a map on the blind person's hand with a finger. How the robot works is that it the person grabs a hold of and the arm and then the arm makes obvious movements in a small area. This seems to work OK, but there doesn't seem to be an actual test yet.

4.4 What My Eyes Can't See, A Robot Can Show Me: Exploring the Collaboration Between Blind People and Robots

Bonani and colleagues (2018) explored how robots can assist people who are blind. The authors had three research questions:

1. How do blind people perceive and envision robots in their daily lives?
2. What are the practical benefits, in an assembly task, of a collaboration with a robot? How does the degree of active collaboration of the robot influence performance of the task?
3. How is the user perception of a robot influenced by its collaborative behaviors?

The first question was explored by focus group with 20 blind people from a local training center for blind people. All the people used screen-readers. These were divided into four groups with two researchers in each group. Each focus group lasted for about an hour.

Questions 2 and 3 were answered by creating a collaborative scenario. Participants worked with a Baxter robot to complete a Tangram puzzle. The study was within subjects and the variable was how the robot interacted with the people. In one version, the robot gave only vocal instructions (Voice-Only Assistive Robot or VOAR). The other version the robot would use its hands to guide the person to the next piece and help in putting it in the right place (Collaborative Assistive Robot or CAR). Both modes were accomplished using a Wizard of Oz technique. There was an emphasis on evaluating the robot and *not* the performance of the people. There were 12 people who participated with counterbalancing. All had some form of blindness and used screen readers. They also were interviewed.

For the focus groups, there were some standard concerns that is found among the general public about robots. For example, that robots are used in factories and that there were concerns for them taking a job, the robot attacking you (accidentally or intentionally), wanting control over the robot, etc. As for what they thought the robot could do. Items were around:

- Navigation (especially local navigation on foot).
- Housekeeping tasks and chores such as vacuuming and washing dishes, assembling furniture, laundry.
- Helping educate (sighted) children (especially in sighted things blind parents cannot help as much with such as handwriting or color).
- Social companion
- Servant (doing whatever is needed)
- Substitute for vision, identify and find objects

In the collaborative scenario, the participants had a general preference for the robot that used its hands. All the participants were able to complete the puzzle with the CAR versus only 2 with the VOAR. They were also able to complete the assignment quicker with CAR. Participants also thought that the puzzle was easier when working with the CAR (the puzzle was essentially the same between robots).

The ROSAS questionnaire (Carpinella et al., 2017) used and there was a statistically significant difference between the Warmth and Perceived Competence of the CAR versus the VOAR, with participants preferring the CAR. There was no difference between discomfort for the robots.

The blind participants in the experiment noted that they did like the noise the robot made because it helped them to understand that it was moving and what it was trying to do. Also, almost all thought that the robot helped in the task and would find it useful in day-to-day life.

From the focus group, there was a desire for safe navigation as a potential use for people with low vision. The blind people were more interested in ground navigation. It also seems that having the robot work with and provide touch can also be helpful and add something beyond the standard text-to-speech interfaces. This also leads back to some complaints about the interface for the RFID-based robot (Kulyukin et al., 2004).

4.5 Nothing About Us Without Us: a participatory design for an Inclusive Signing Tiago Robot

This article from Antonioni and colleagues (2022) proposes the use of robots for specific subgroups of populations, such as deaf people and those using sign language. The article sheds light on the importance of recognizing specific characteristics of sign language and cultural norms in sign language.

The paper focuses on the Italian deaf community, where Antonioni and colleagues used a participatory design approach. The context was the 2021 Smart City Robotics Challenge where people ordered coffee from a robot at a coffee shop. Participants in the coffee shop were from the deaf community. Experts from the deaf community helped in collecting a dataset of signs to build an algorithm for signing and then choosing the set of signs that could be done with the robot.

The aim of the paper was to explore new possibilities of automated sign language, through the inclusion of robots. Specifically, the research robot platform from Pal Robotics, TIAGo was included in this project. The study has included a one-arm TIAGo that executed sign language. Since only one arm was used for TIAGo, the signs to be configured were categorized in simple signs (one configuration), composed signs (two configurations) and phrases (three or more configurations). The TIAGo could generate signs and recognize signs that people signed to it.

Overall, the involvement of the deaf community was very helpful in making the sign language from the robot more understandable. The deaf community also felt that they were included in the design process. This can be a good model to consider for involvement of other people with disabilities when creating robots.

4.6 Accessibility Guidelines for Tactile Displays in Human-Robot Interaction. A Comparative Study and Proposal

This article by Qbilat and Iglesias (2018) tries to lay the groundwork for creating a set of accessibility guidelines for robots, especially with a tactile display. Although the article claims to present guidelines. There are no guidelines presented in the actual paper, instead it presents a methodology of how these guidelines were researched.

4.6.1 Methodology

The methodology has six parts.

1. Study main accessibility standards, guidelines and recommendations for web sites, web applications, and software applications. None of these focus on HRI, but it provides a starting point.
2. Study the main interaction characteristics of tactile displays in HRI based on literature rivet and authors' expertise.
3. Compare the differences between accessibility standards and guidelines.

4. Analysis of documentation of the characteristics of tactile displays to HRI.
5. Analysis of how much the different guidelines overlap
6. Requirement classification based on WCAG v2: perception, understanding and interaction.

4.6.2 Results

The guidelines that were used included:

1. WCAG v2.0
2. BBC Accessibility Standards and Guidelines
3. Funka Nu Mobile Guidelines

The paper then compares each guideline. Unsurprisingly, there are blind spots in each of the guidelines. This can be expected since each guideline covers slightly different areas (WCAG mostly Web, BBC content for its media on web, mobile, and TV, and Funka Nu on mobile apps). Unfortunately, some of the guidelines (such as the BBC guidelines) have disappeared since the article was published, so it is difficult to explore these blind spots.

Otherwise, they set up that they will continue to work with this further. They claimed they would be doing this with a robot named CLARC (Ting et al., 2017).

4.7 A Proposal of Accessibility Guidelines for Human-Robot Interaction

Qbilat and colleagues (2021) created a basic sketch for accessibility requirements for HRI in this article. The requirements were based on some initial work by the authors from the tactile display article above (Qbilat & Iglesias, 2018) and has been extended to HRI in general.

The accessibility guidelines are based on multiple other guidelines:

- WCAG
- WAI-ARIA
- BBC content guidelines
- Funka Nu Mobile guidelines
- IBM hardware guidelines
- PUX recommendations (from GPII)

Qbliat and colleagues have read these documents and created a new set of guidelines that is a combination of these other guidelines. To verify these new guidelines, Qbliat and colleagues surveyed some designers to get their opinions. The designers seemed to like the guidelines and felt the guidelines could be useful. The guidelines themselves are available on GitHub[1]. A much longer exploration of the work involved and some work at applying them is detailed in the next section.

4.8 Accessibility Requirements for Human-Robot Interaction for Socially Assistive Robots

This is a PhD thesis from Al-Qbliat (2022), one of the co-authors of the previous two papers. The goal of the thesis was to create accessibility guidelines for human-robot interaction. The thesis itself can be used for looking at things like Universal Design of robots. The most useful parts in this regard are appendices E and F, which are the updated guidelines (even better than the ones on GitHub) and a re-arrangement of the same guidelines with a focus on disabilities. That is, the guidelines are the same, but they are split by disability.

Here is an outline of the relevant chapters from the thesis:

Chapter 2 Literature Review

This is a literature review that looks at different socially assistive robots that have been used for assistive tasks for people with and without disabilities. There also is an examination of different accessibility laws, regulations, guidelines, and standards for human-computer interaction and HRI. This is mostly things that I am aware of through work in UD. Although there is a new standard (ISO/IEC 30071-1 2019) that talks about creating accessible ICT and how to build up a culture around it. Naturally, there is nothing that addresses robots and HRI dirrectly. It also looks at different methods for evaluating HRI, although it seems to neglect ROSAS.

Chapter 3 Analysis and Classification of Robot's Interaction Components

This chapter walks through a good selection of robots that have been used as SAR and tries to come up with a list of components that could have an effect on accessibility. This includes both hardware and software components. This includes an article about classification by Tzafestas (2016). This classification is a set of different components that can be used for interaction with a robot. Al-Qbliat identifies which of these components one needs to consider (reproduced in Figure 1).

[1] https://github.com/Malak-Qbilat/HRI-Accessibility-/blob/main/Guidelines%20for%20accessibility%20requirements%20in%20Human-Robot%20Interaction.pdf

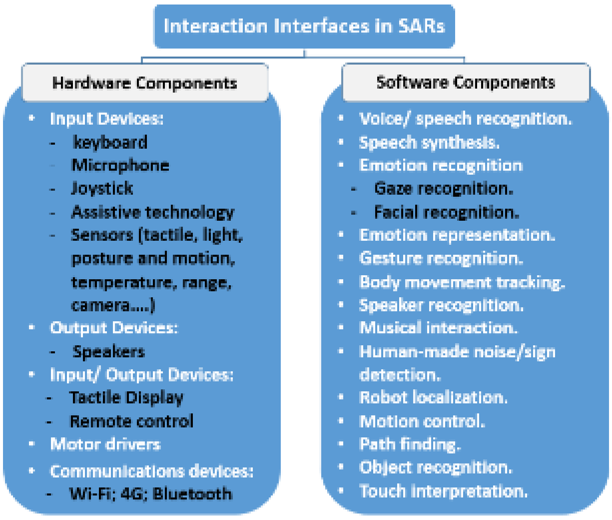

Figure 1. Interaction interfaces in socially assistive robotics. The items listed in black are interfaces that one needs to consider (Al-Qbilat, 2022, p. 70).

Chapter 4 Study of Accessibility Barriers in Human-Robot Interaction

This chapter looks at different methodology for evaluating accessibility barriers for HRI. Of course, there is none, really, until they propose one. The basic version is:

1. Define the evaluation scope
2. Explore the target robotic application (software and hardware)
3. Audit the robot application: check all initial interaction components and check all complete processes
4. Report the results (the elicited accessibility barriers)

There is also an examination of ways to define disabilities. This examination is unfortunately rooted in the medical model, but the work still is useful. There is a final mapping of disabilities to different components that might be helpful. Section 5.4 of the thesis has an actual use case with NAOTherapist and discusses the process with creating personas, scenarios, and observations. This process could be useful for other projects.

Chapter 5 Proposal of Accessibility Guidelines for Human-Robot Interaction

This chapter documents the reviewing of the different guidelines introduced in Qbilat and colleague (2021) (Section 4.7) and synthesizing them into guidelines that can be used for HRI. This is a representation of the work done presented in the previous section of this document.

Chapter 6 Evaluation

This is an application of the guidelines used to evaluate the guidelines. First, with groups of designers and then with the case of the ROSI robot in its Town Crier and Telepresence roles. The group of designers agree that the guidelines could be helpful, but some wanted a graphical representation and others wanted it targeted by disability. The evaluation of the ROSI robot was interesting and they did indeed find issues that could be fixed and make them better. It seems the process works well. Finally, there is an update to include new WCAG 2.1 and adjustments based on these results. This is what is in the appendix.

Chapter 7 Conclusion

This is mostly the conclusion. One recommendation is to also try the methods with different types of robots.

Appendices E and F are useful for further work. In general, the Appendix is sufficient and follows more a standard for universal design.

4.9 Summary of articles about accessibility

The beginning set of articles looks at how one can instrument a robot to help people with vision impairment in ways of navigation or manipulation. The final set of articles comes from a group of researchers that are essentially working in the same area that we are: they also want a set of guidelines that can be used to build accessible robots and determine if they are indeed accessible. This looks like an area for further collaboration.

5 Conclusion and next steps

There have been different attempts at creating universally designed environments for robots and creating robots that can assist people with different disabilities (mostly people who are blind). Of course, there have also been socially assistive robots (Matarić & Scassellati, 2016) that have been designed to assist in social training, such as for children with autism (Schulz et al., 2020), but we did not include specific points from them in this document.

The work by Al-Qbilat (2022) to apply the WCAG guidelines to robots is a good starting point for assessing if a robot *is* universally designed. That is, it can be used for seeing if the minimum requirements are there before attempting to test the robot with people with different disabilities. The next step would be to try and use these updated guidelines from Appendix E of her thesis on several different robots and see if it can identify accessibility issues.

It also seems that the context for the use of the robot is important as well. It appears that most robots still aren't made to work everywhere. They have limits on where they can work and what they can do. So, this will also need to be kept in mind.

We have been in contact with Al-Qbilat and her supervisor, Iglesias. They were very happy to provide a copy of Al-Qbilat's PhD thesis, and they would be interested in working on future areas for seeing how to make a robot accessible. We must find a way to cooperate in future research. One of the most obvious ways would be to see how the additions to the updated WCAG 2.2 guidelines can be adjusted to include robots.

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