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Study of the feasibility of sensor implementation and door automation for wheelchair accessibility in public bathrooms

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ABSTRACT

This research was carried out with the purpose of evaluating the possibility of automating the accessibility of public access to public toilets through sensors, in order to facilitate the entry and exit of wheelchair users. The importance of conducting this study stems from the fact that, currently, there are several innovations and automations on the market that increase productivity and quality in the industry, streamline processes, facilitate daily activities through automation and the use of sensors. Therefore, it appears that there is a possibility to improve the quality of life of wheelchair users, to further ease locomotion and movement in several ways ensuring safety and minimizing physical stress. In addition, an interview was conducted with wheelchair users, in order to understand their difficulties in accessing the Person with disability (PwD) public bathroom door. And it is important to highlight that the greatest difficulty is to be lack of physical space in a toilet, added to the opening doors struggle. The study portrays a method for adapting the door through automation with sensors and the costs involved in this project. The modification of the sensors provides a great automation option, by making possible that public bathroom doors to open with a better space and width. Besides, a modification like this will guarantee a decrease of some difficulties of the bathroom use by wheelchair users. While it provides safety, inclusion and a significant reduction of the daily stress aiming to a safer and independent life. This paper presents a feasibility study for the implementation of the automation mentioned above. Then, it is necessary to comprehended about the difficulties facing by wheelchairs users regarding the infrastructure found in public places to researching the civil construction standards that regulate the accessibility of public toilets. In addition, an understanding of electronic resources, technologies and costs that could enable the development of the automation. Besides, research of what the academic community is studying about it could help to lead to a better understanding of the subject.

Keywords: Automation. Public restrooms. Wheelchair

INTRODUCTION

It is not new that technology has brought innovations in our daily lives generally linked to production processes to reduce execution time, decrease costs, improve efficiency and quality through continuous and precise movement. Automation is a technology that has been bringing safety, agility and comfort to our tasks. Technology has been expanding more and more through various trends and different sectors that seek to increase its performance, improve our activities' speed, and even facilitate some type of motor or locomotive limitations.

Looking at the means of automation, it appears that there are new fields that can improve the life of a wheelchair user in society more effectively, which guarantees better accessibility. According to the Brazilian Ministry of Health, 1.3% of the Brazilian population has a physical disability. Since a good part of the population mentioned have an active life, working and/or studying, they need to move around the city. Given this scenario, the present paper aims to study the feasibility of implementing a sensor to automate doors for wheelchair accessibility in public bathrooms. (Deficientes online, 2020).

The modification of sensors that make it possible for the public bathroom doors to open is a great automation option since it is thicker and wider. The wheelchair user needs to position himself to reach the handle, pull the door, push the chair, pull the door until he can have enough space for his chair to pass, not to mention the difficulty of closing it. Because of these strains, the automation of a door that can identify the wheelchair user through sensors, which open and close the door automatically, is desirable so that the wheelchair user can have better mobility and easier access to public environments.

This paper presents a feasibility study to implement sensors and door automation for public toilets adapted for wheelchair users. Therefore, it will be necessary to evaluate the following themes: a) Researching civil construction standards that regulate accessibility in toilets; b) Assess the difficulties of the wheelchair user concerning the infrastructure commonly found in public places, such as width and weight of the door, displacement and necessary manoeuvres to access the door handle, considering the different needs of the disabled person; c) Search for electronic resources and technologies that enable the integration of knowledge in the development of a system that promotes the accessibility of the individual with special needs; d) Research what the academic community has published on the theme of accessibility for automatically opening doors; e) Prospect the costs involved in implementing a device for door automation for accessibility purposes.

According to Essence Cuidados (2018), the difficulties encountered by people with physical disabilities on a daily basis are diverse; considering this, the proposal in this study is to facilitate accessibility for wheelchair users. For that reason, the current strain of opening and closing a door will be analyzed and the cost to implement the door automation system and the benefits that disabled people would have after the implementation of the proposed system. Furthermore, the data reported and observed here can also serve as a basis for further works in the area of accessibility for the physically disabled.

To think about society is to think and work towards providing the inclusion for all individuals. Considering this scenario, technological development plays a fundamental role in the life of a person with special needs, whether visual, motor or cognitive, there is always something to be devised and designed to reduce the abyss that comes between carrying out activities on a daily basis for a disabled person.

The inclusion of people with disabilities is guaranteed by Federal Law 13.146 sanctioned on 6 July 2015 by the Presidency of the Republic, which establishes guidelines for the acquisition and development of assistive technology, that is, it determines that some resources and services contribute to provide or expand functional abilities of people with disabilities and consequently better the individual's life, independence and inclusion.
Art. 74. Disabled persons are guaranteed access to products, resources, strategies, practices, processes, methods and services of assistive technology that maximize their autonomy, personal mobility and quality of life.
Art. 75. The State will develop a specific plan of measures, to be renewed in a period of 4 (four) years, with the purpose of:
I - Facilitate access to specialized credit, including the provision of subsidized credit lines, specific for the acquisition of assistive technology;
II - Streamline, simplify and prioritize procedures for importing assistive technology, especially issues related to customs and sanitary procedures;
III - create mechanisms to promote research and the national production of assistive technology, also through the granting of subsidized credit lines and partnerships with official research institutes;
IV - Eliminate or reduce the taxation of the productive chain and the import of assistive technology;
V - Facilitate and streamline the process of including new assistive technology resources in the list of products distributed within the scope of SUS and other government agencies. (Brazil, 2015, Art. 74)

It is essential to highlight that the technological resources that enable inclusion not only reduce the difficulties of a person with disabilities but also provide safety in the individual's daily life, such as the segment of inclusive automation, which have developed resources to adapt to different environments and facilitate actions such as opening and closing of doors and windows or simply automatically switching on and off a lamp. Piloti (2014), in his study of a home automation system that contributes to accessibility, states that "it is possible to create an Inclusive Home Automation solution with open platforms without the need for complex changes in the architecture of the home".

According to Nichelle (2010), home and edifice automation originated from industrial automation. Due to the different realities, the automation of a residential door, or even a public toilet does not involve complex systems like those used in a production line, however, the electronic principle and logical combinations are often common factors when designing an automated mechanism from a universal concept, that is, the action of opening and closing something in an automated and safe way. Given these concepts, inclusive automation has been standing out in residential and commercial environments, whether public or private.

Automation technology has proven to be the greatest ally in terms of accessibility and now, with “smart houses”, where you can control everything you need in the house with a few clicks on the controller, everything is easier. Technology has proven more and more that it has arrived to help with all kinds of problems that a disabled person may have, from new prostheses to systems that aim for better comfort.

However, there are still some “limitations” that keep people from knowing about this; the lack of access to information is one of the great technological and inclusion bottlenecks in Brazil, in addition to prejudice, lack of investments and high costs, the lack of information about accessibility tools that could make our society more just and inclusive.

The Brazilian standard ABNT NBR 9050, second edition, establishes accessibility to buildings, furniture, space and urban equipment. The internationally regulated symbol for disabled access is indicated in Figure 1. This symbol must be clearly displayed at the wheelchair accessibility location.

Figure1: International accessibility symbol
Source: Brazilian Institute for the Rights of the Disabled Person - IBDD (2014)

Therefore, the usage of a wheelchair imposes limits on the execution of tasks, as it makes it difficult to approach objects and reach elements above and below the radius of action of a seated person. In addition, the difficulty in frontal and lateral displacement of the user’s chest suggests the use of a comfort range between 0.80 m and 1.00 m for activities that require continuous manipulation. Figure 2 shows the range of motion for activities that do not require the use of force or the use of fine motor skills. In this case, the height is limited to a maximum of 1.35 m, but it is recommended not to exceed 1.20 m, using these dimensions as parameters for the activities carried out within the range of reach of the arms (0.62 m). As shows, Figures 2 and 3 on the next page.

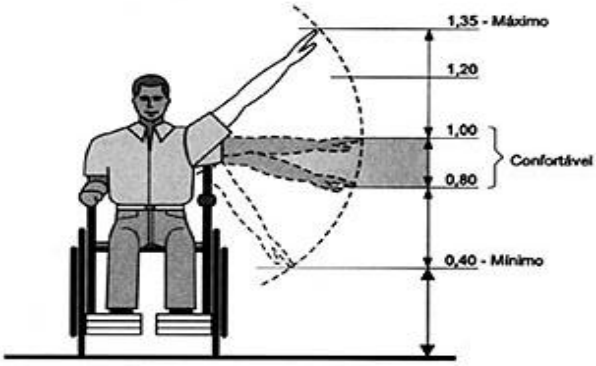

Figure 2: Average reach of motor activity.
Source: Brazilian Institute for the Rights of the Disabled Person - IBDD (2014)

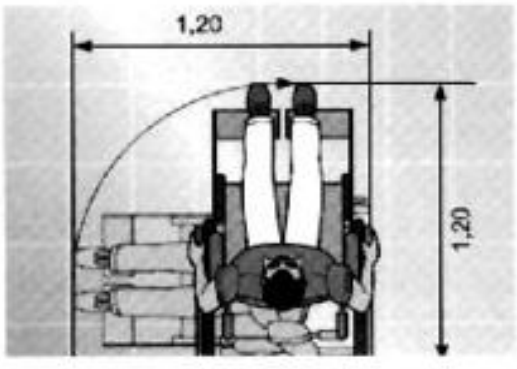

Figure 3: Rotation maneuver without frontal displacement.
Source: Brazilian Institute for the Rights of the Disabled Person - IBDD (2014)

In rotation maneuvers without displacement, the minimum required areas are: 1.20 m by 1.20 m for 90º rotation (Figure 3). And 1.50 m by 1.20 m for 180º rotation (Figure 4). Another maneuver to be considered is the movement within a 1.50 m diameter circle for 360 º rotation (Figure 5).

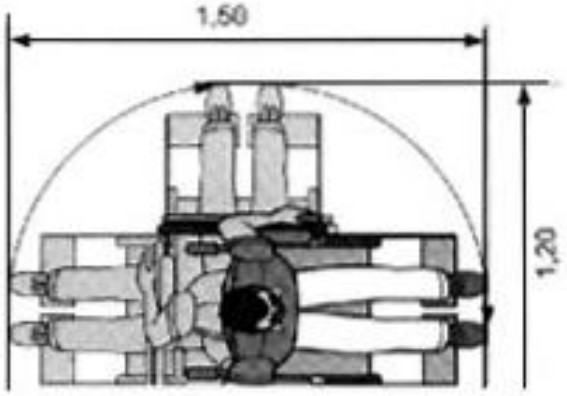

Figure 4: Rotation maneuver without lateral displacement.
Source: Brazilian Institute for the Rights of the Disabled Person - IBDD (2014)

Rotation maneuver with displacement is the ideal area defined according to the radius required to perform the rotation, allowing passage through different dimension aisles.

For doors, it is standard that they have a free span of at least 0.80 m (including elevators); no effort greater than 35.61 N to pull or push it, opening in one movement, lever handles; coating resistant to impacts caused by walking sticks, crutches and wheelchairs (from its lower part up to a minimum height of 0.40 m).

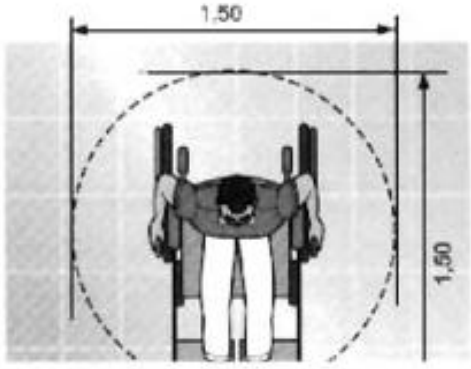

Figure 5: 360º Rotation Maneuver.
Source: Brazilian Institute for the Rights of the Disabled Person - IBDD (2014)

MATERIALS

Through the observation of the accessibility difficulties of wheelchair users, this paper proposes to evaluate the feasibility of implementing an automated door opening system. To this end, a small survey was conducted with open questions to understand the difficulty in opening a door. According to Freitas and Prodanov (2013) open questions are more difficult to assess, but they allow the informant to freely express his opinion.

The questionnaire was sent by e-mail randomly on blogs towards people with physical disabilities, three people participated, two men and one woman, all wheelchair users, one of whom has a complete loss of the function in one of his hands. The questions asked were: a) Do you have any difficulty accessing the bathroom in relation to opening and closing the door, how do you do it currently? b) Were there an automatic system to open and close that door, would it make it easier? c) What are the most common difficulties encountered in opening the door? To visualize the conceived system, computational resources were used through the Microsoft 3D Builder® software combined with the guidelines established by the civil construction standards related to accessibility.

RESULTS AND DISCUSSION

For a better understanding of the real need of wheelchair users when in need of opening and closing a door, the following are the answers given by three people who participated in the survey on the subject:

a) Matheus Alencar, 25, Curitiba resident, quadriplegic (he has lost movement in one of his hands). “The biggest difficulty is in relation to the length of the door, the latch that cannot be thick and plump, to be able to fit the hand, because as my hand does not function it is much more difficult, to get in I put my hand on the latch and pull it down to open the door, move the chair forward, pull the door back, turn the chair over again and finish closing the door. An automatic system would be of great assistance, it would facilitate entry and exit, also regarding the issue of hygiene”.

b) Marinês Buchelt Romanoski, 38, resident of Londrina, wheelchair user. The participant did not answer whether she has any other motor impairments, in addition to the lack of movement of her legs. “Nowadays, after the projects that make access to bathrooms and other public places feasible, it is easier to get around, although some older buildings still make it difficult, however regarding the opening of doors, there are places that do not provide space to maneuver the chair properly. This makes it a little difficult. If there was an automated system for opening doors, it would greatly facilitate accessibility, for sure. Talking to wheelchair friends and asking for a suggestion, they told me about a sliding door to make it easier”.

c) Rafael Ferreira Correa, 42, resident of Porto Alegre, wheelchair user, has lost movement of his legs due to a spinal cord injury. “At the moment, I have no difficulty with residential doors, they are all wide doors and some are sliding doors that make it easy to open and close. In my case, I don't see any advantage in automation, I have already used it in airports and I was unsure with it as a system. I am a wheelchair user, T6 spinal cord injury with no leg movements. I see no difficulties. Except for bank doors with high pressure on the springs, these are the most difficult to open. Not having enough space for the door and chair, doors with springs to close on their own, are usually difficult to open. Small doors too”.

Using Microsoft 3D Builder® software, the automation of the toilet door was conceived and built virtually as shown below. In Figure 6, in blue, the electronic system is shown, its sensors and cables

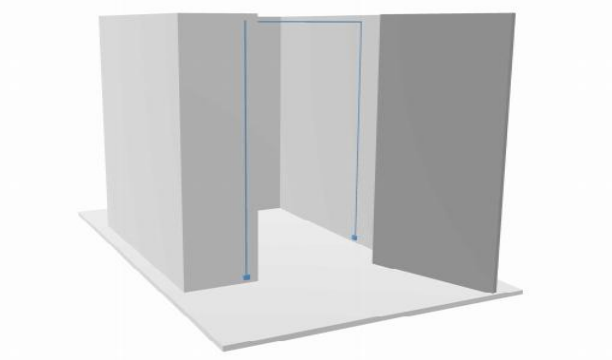

Figure 6: Front view of the bathroom. Source: own authorship

Figure 7 shows the front view of the PwD bathroom with emphasis on the external sensor. In blue, it shows the electronic system as already mentioned and, in green, the toilet ware and the equipment that every bathroom for a wheelchair requires.

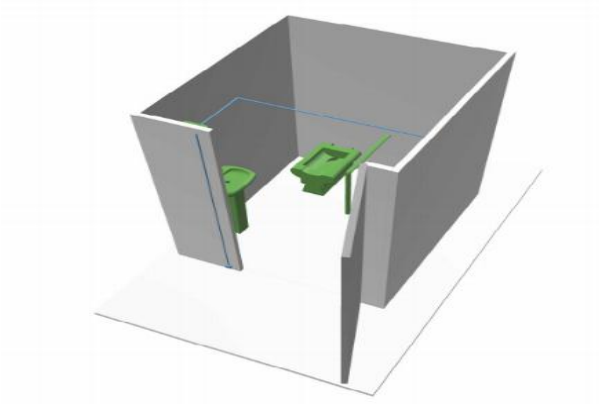

Figure 7: Tilted top view of the bathroom along with the electronic system.
Source: own authorship

Figure 8, shows the front / top view of the bathroom. Figure 9, on the other hand, shows the top view, portraying all the components of a standard public bathroom, emphasizing the electronic system.

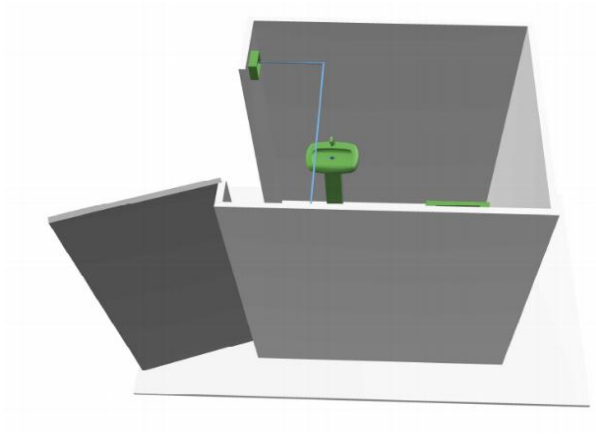

Figure 8: Front/top view of the bathroom.
Source: own authorship

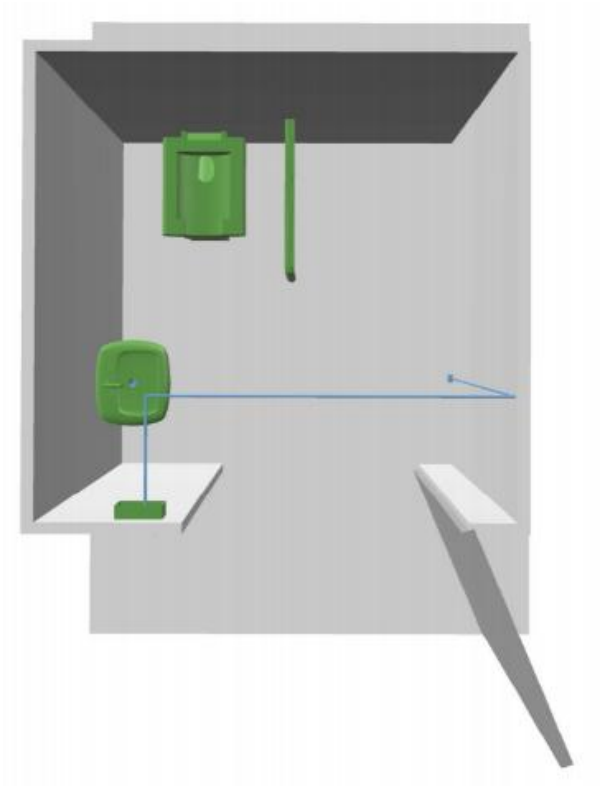

Figure 9: Top view of the bathroom along with the electronic system.
Source: own authorship

The system was designed so that after the distance sensor detects the chair at a distance of 18 cm, for 4 seconds, it will automatically send the information to the Arduino® board, opening the door by means of an electric motor connected to the system.

After the wheelchair user enters the bathroom, another sensor is installed on the right wall that will carry out the command so that the door is closed again. When using the bathroom, the wheelchair will again position itself next to the internal sensor for 4 seconds to open the door.

In the event of a power failure, the system has a 1000 mAh battery so that it continues to function normally until power is up again. In addition, electrical sizing was based on the condition that the board has a minimum voltage of 3.7 volts and a current of 45 mAh. With these improvements, wheelchair access to the bathroom will become easier and require less physical effort to open the door, which is heavy.

The price of the electronic components needed for the automation system of a door used is shown in Table I. The average cost is in US dollars, considering the currency exchange rate on 4 July 2021 from Brazilian Real (BRL) to US dollars (USD) as 1 BRL = 0,19 USD.

This table presents the individual components conceived in the assembly of the automation system; the door and labor costs are not included. It is important to emphasize that knowledge on electronics is necessary to assemble the system.

Table 1: Components budget (Baú da Eletrônica; Techmakers; Usinainfo, 2020)

COMPONENT	FUNCTION	AVERAGE COST (USD)
Presence Detector	Detect movement through the heat emitted by the body	US$ 3,31
On/Off Switch	Responsible for turning the system on and off	US$ 0,77
Battery	Operation in case of power outage	US$ 9,71
Dc 5v Motor	Perform the mechanical movement of the door	US$ 13,14
Cables And Wires	Transmit information, voltage and current	US$ 10,65
Distance Detector	Activate the door mechanism through proximity detection	US$ 2,89
Arduino Uno R3 Board	Board in which electronic and programmed components will be introduced	US$ 14,17
Grand Total		US$ 57,52

CONCLUSION

Evaluating accessibility has always been a great challenge for those who have healthy physical and cognitive skills, but it is necessary in a society that seeks to integrate people and reduce differences. A major barrier has already been overcome given the enactment of laws aimed at the physically disabled, as they determine minimum conditions of accessibility and rights, and consequently provide some strength and voice to those who seek said rights. Given this perspective, we sought to put forward a door automation system for public toilets that would guarantee better autonomy for a wheelchair user. Through assessing the reports of wheelchair users, it was possible to identify that opening a door is not the greatest difficulty; the bigger issue seems to be the lack of physical space in a toilet which is often more evident than the weight of the door or the type of door handle. However, it is necessary to discuss the topic so that improvements can be identified and implemented.

As a suggestion for future research, it is recommended to evaluate the costs of assembly and maintenance of the door automation system, the influence of the door weight in relation to the system as well as the already known costs of adapting so that public agencies of each region can assess the economic viability of the implementation.

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CONFLICT OF INTEREST:

The authors declare no conflict of interest.

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