Standing Mobility Device

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Abstract

The current world is paying more and more attention to human equality, including creating a more friendly environment for disabled people. Convenient devices appear in the public now and then. However, people rarely focus on improving the mobility and convenience of the disabled themselves. In this paper, a Standing Mobility Device is presented.

The Standing Mobility Device mainly focuses on helping people with lower body disabilities. As suggested in its name, this device enables people to get up and go around on the same plane.

The goal of the Standing Mobility Device is to make disabled people in wheelchairs able to move around more freely and let them have a more independent life while being affordable for low-income people that may use this device, such as elderly people. The whole device looks like a small-sized car that people can sit on. In this case, a pushing device is used to push the person on the device into a standing or sitting position, while wheels are attached at the bottom to move both the person and the device as a whole around the flat plane. As for the pushing device, we mainly used an electric putter for the main force input. Arduino is used to controlling the two functions, and buttons and a rocker are designed to let the person control the device. The overall structure of the Standing Mobility Device is built with Aluminum bars and Aluminum plates.

Testing experiments have been done on both the seat's rotating function and the device's moving function. For the seating, we tested its ability to ascend to the standing position and to descend to the sitting position as well as the time it takes to do so using a small voltage battery for safety considerations. For the moving function, I sat on the device and drove the device around on a flat plane and made sure it is able to move around smoothly with a person of normal weight sitting on it. Both experiments were carried out successfully, proving the feasibility of the device.

Index terms: Standing aid, Social servicing tool, Mobility, the disabled.

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1 Introduction and Goal

1.1 Introduction

Although some effort has been put into bringing convenience to the disabled nowadays the world, it is far from enough. Varying from country to country, some countries are still very poor in disabled facilities, resulting in the impossibility of disabled people moving around.

When I went back home to China last summer, I quarantined for 2 weeks in a hotel room before being able to go around freely. I had never been indoors for such a long time, and those 2 weeks were suffocating for me. Not allowed to get out of the room door, I could barely move around. I had to wait for people to distribute food to me, and I couldn’t go out to buy daily necessities.

Meanwhile, back at my home, which is an apartment in a high-rise, my grandmother stays indoors the whole time. This is because her knees were ill from aging, and moving around has become a hard task for her, let alone going outdoors. She only represents the elderly, not even the disabled group.

My mom also has knee issues worthy of attention. She often has a hard time trying to stand up and sit down.

As someone who loves the sunshine and treats outdoor activities as one of the most important things in my life, I deeply feel how heartbreaking and torturing it must be not to be able to walk freely for the rest of my life, or even my entire life. I was determined to create a device that helps these people with lower limb difficulties, hence the Standing Mobility Device.

1.2 Research Status

In the past decade, with the development of assistive technologies, many researchers have begun to focus on adding standing function to mobility devices, such as standing wheelchairs or standing frames, which are designed to enable people with mobility impairments to stand and move in an upright position, investigating their effectiveness, usability, and impact on users' quality of life. Klair's article [1] in 2020 provided an overview of the different standards and guidelines for standing wheelchairs, including safety, design, and usability considerations.

Other studies have focused on the health benefits of standing mobility devices, showing that standing can improve circulation, bone density, muscle strength, and bowel and bladder function in people with mobility impairments. Jane Goodwin's study investigated the impact of a standing frame on children with cerebral palsy[2].

Another area of research has focused on the usability and comfort of standing mobility devices. Studies have explored the different design features and adjustments that can make these devices more comfortable and functional for users. In the study about the design of a standing wheelchair by Sushant Merai [3], the developer explores user perspectives on the design of standing wheelchairs, including factors such as comfort, ease of use, and aesthetics. The authors highlight the importance of involving users in the design process to ensure that standing wheelchairs meet their needs and preferences.

Overall, the research on standing mobility devices suggests that these devices can have numerous benefits for people with mobility impairments, both in terms of physical health and quality of life.

Unfortunately, according to WHO in 2018, more than one billion people in the world need assistive technology (with 75 million people needing wheelchairs). Only about 10% have access to the assistive products they need [4]. Matters seem even worse in China. According to the data from the Second National Sample Survey on Disability in China, there are a total of 24.12 million people with physical disabilities, accounting for 29.07% of the total number of disabled people in the country[5]. Due to the largest population and economic situation, the current state of the Standing Mobility Device (SMD) market in China, is still in its early stages. The main research and development focus is on large, complex, and multifunctional standing mobility devices[6]. Therefore, prices are generally high, typically ranging from tens of thousands of Chinese yuan (2500 USD to 4000 USD) or more. This represents a significant economic burden for many disabled and elderly individuals, who are mostly the underprivileged group. According to data released by China's National Bureau of Statistics in 2022, the average disposable income per capita of Chinese residents in 2021 was 35,128 yuan, or roughly about $5,020[7]. In rural areas and underdeveloped regions, especially for disabled people who have lost their ability to work, the disposable income is much lower than this figure, making it difficult for them to afford expensive SMDs.

Besides, due to the large population in China, supermarkets, hospitals, and homes, all have relatively small spaces, which limits the practical applications of large-sized SMDs. Based on these issues, this research aims to explore the feasibility of developing safe, flexible, and low-cost SMDs in the Chinese context so that more affordable products may become available, better serving disabled and elderly populations.

1.3 Goal

1. The main goal of this research is to develop a device that serves medical assistance purposes, and in this case, targeted at those who have lower limb difficulties
2. More importantly, the product needs to be affordable even for those who are financially difficult or have low income, which may be the majority of the target group for this product.
3. When people with lower limb difficulties, no matter their age group, and cause, use the device, the device is supposed to support them with standing up and sitting down and take them to move around if necessary. Although there are similar designs on the market nowadays, most of them have issues of being over-complicated and over-priced. This often results in hard-to-learn and use among groups of people like the elderly, and not affordable to those who are not wealthy. I wish to improve this device in order to make it functionally simple yet comprehensively useful, and cost-effective.

2 Theoretical Design

2.1 Seating

The Aluminum bars' lengths, as shown above, were calculated according to human leg lengths, and in this case, my legs, so that the person is most comfortable when sitting on the device. Since the person is sitting on the end of the upper bar, as introduced above, there needs to be an additional force to support human weight. In other words, there is torque, and we need an anti-torque force.

$$M=r*F$$

$$r1*F1=r2*F2$$

The initial design is to place two steering gears on each "joint" together with an electric putter placing force directly under the seat. The purpose of this design is to provide enough force to lift up even a person with a relatively larger weight without stalling too much to burn the circuit. Furthermore, combining the two decreases the cost of creating the device. However, The steering gears rotate the Aluminum bars based on an angle while the electric putter provides a linear lifting motion. It is extremely unlikely that the putter and the gears will align accordingly. To prove this view, we ran them together and the current stalled and burnt a board.

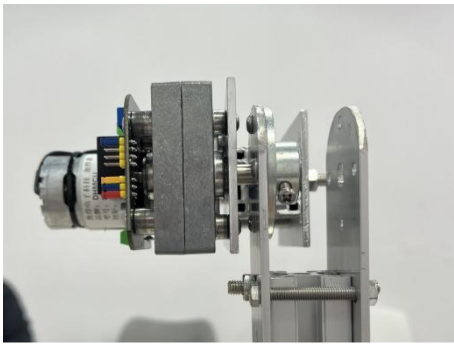


Figure 2.1(1) Figure 2.1(2)

Structure of the steering gears

The secondary design is to eliminate the electric putter and only function on steering gears because the steering gears provide a larger force. However, the steering gears are located on the “joints”, so there is insufficient distance. When the seat is in a sitting position where the bars form a right angle, the steering gears are not able to provide enough supporting force to let the seat stay at the horizontal position. Instead, it will fall.

After experiencing two failures, the cost had to be ignored to ensure success. The design is changed into a new electric putter with a larger thrust.

Finally, the seat was fixed onto the upper bars using an acrylic sheet and bolts and nuts.

2.2 Base

There was a significant height difference between the front wheels and the rear wheels, so the best installing solution is calculated to minimize the difference, and boards are added to eliminate the difference.

3 Structural Design

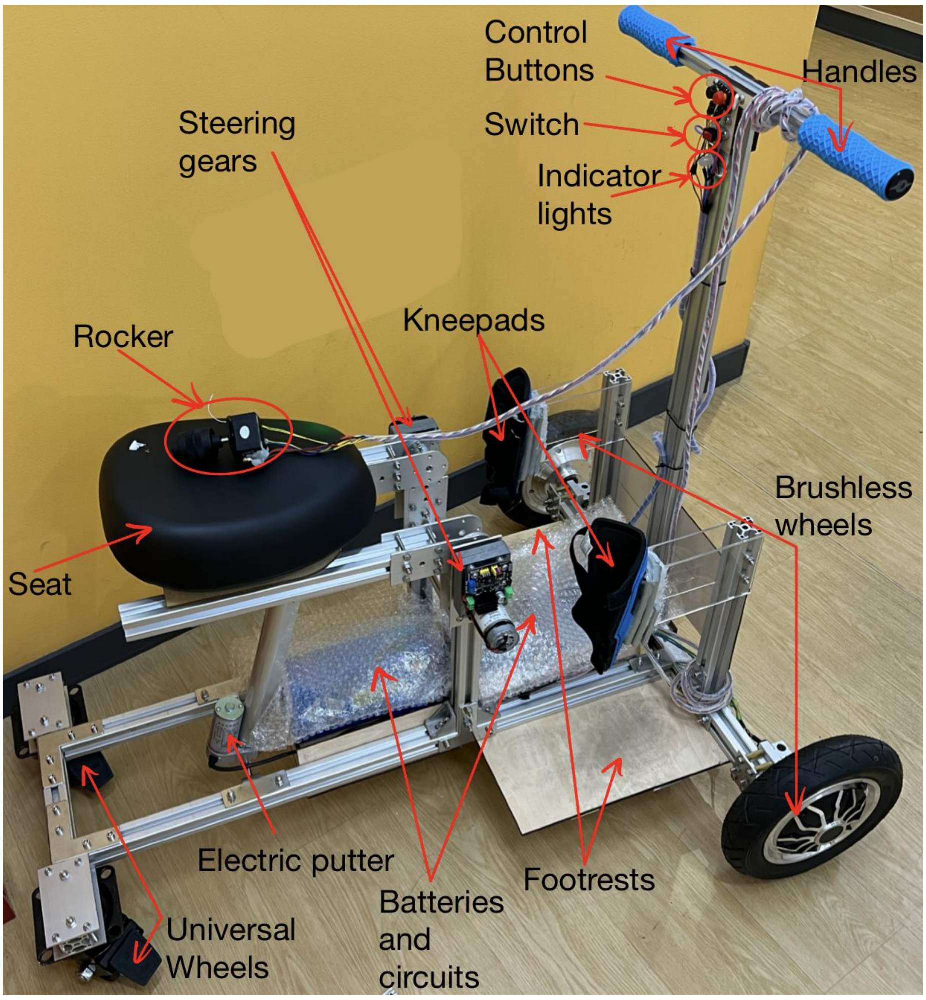


Figure 3
General Description

In general, the device is made up of the base, which includes wheels, footrests, and a base structure made of Aluminum bars; the seating area, which includes a seat for people to sit on and its supportings; the steering and supporting front area, which includes an armrest and buttons and a rocker to control the whole device.

3.1 Base Structure

The base structure is in general a triangular shape, which increases the stability.

There are four wheels in total, with two regular wheels in the front and two universal wheels at the back. The footrest has an Aluminum base and wooden boards on top for comfort.

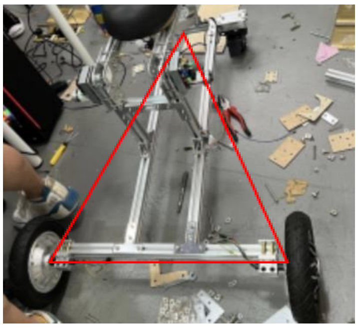


Figure 3.1
Base

3.2 Seating

The seating must apply to both the sitting and standing position of the person. Therefore, the supporting bars of the seat are designed to function similarly to human legs, containing two bars representing thighs and calves and a joint. The seat is located at the back of the top bar, where the human bottom is supposed to be. When the person is in a sitting position, the two bars form a right angle with the seat facing upwards for the person to sit on. When the device is to lift the person into a standing position, the angle slowly widens, finally reaching approximately the flat angle.

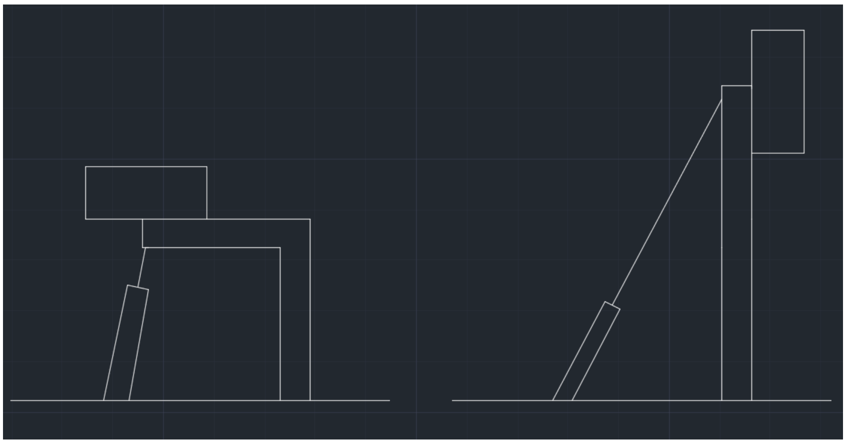


Figure 3.2(1)
Working mechanism

Figure 3.2(2) Figure 3.2(3)

Standing Position *Sitting Position*

3.3 Front Area

There's a handle in the front for people's hands to hold on to for stability. Knee pads are attached to fix calves. In addition, the two buttons control the lifting of the seat. The top button on the rocker is responsible for changing between seat adjusting mode and moving mode, while the rocker controls the moving directions.

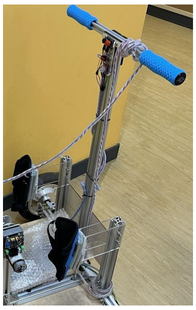
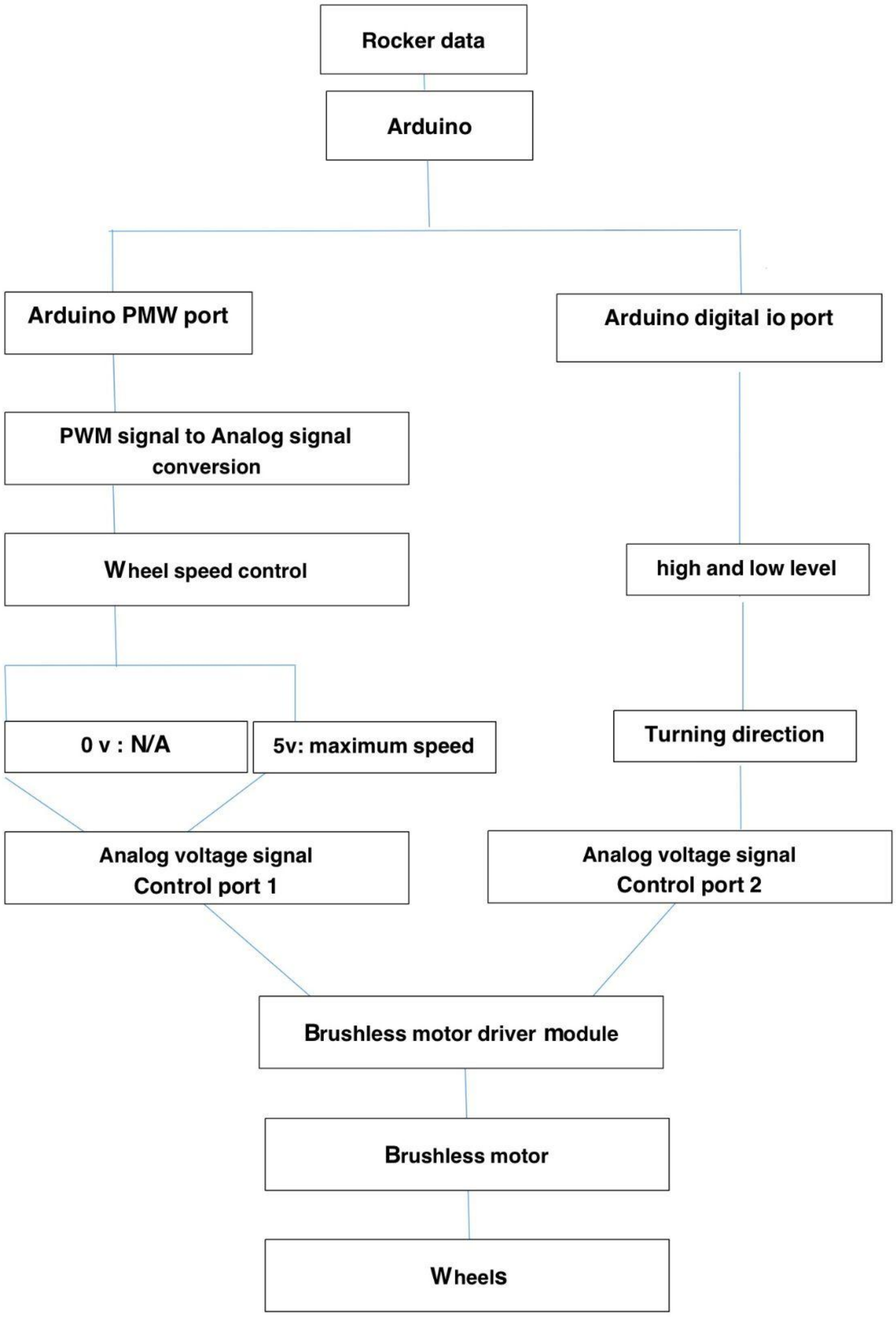


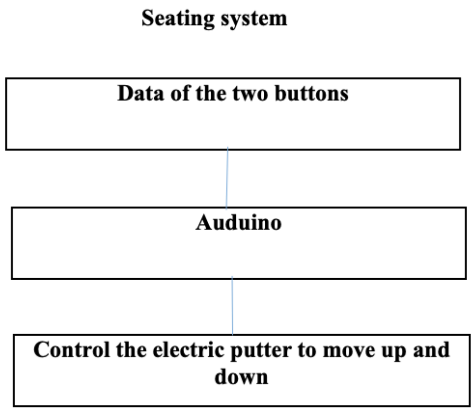
Figure 3.3
Front Area

4 Electrical Circuit Design

4.1 System 1: Moving System



4.2 System 2: Seating System



5 Transforming Modes

This is a dual-system device that includes two kinds of functions.

The first mode is the seat adjustment mode. Under this mode, there are two buttons on the front area. One button rises the seat to a standing position and the other descends the seat to a sitting position.

If the top button on the rocker is pressed, the device switches into the second mode, moving mode. Under this mode, the device can be moved around in all directions by controlling the rocker.

If the top button on the rocker is pressed again, the mode changes back to the seat adjustment mode.

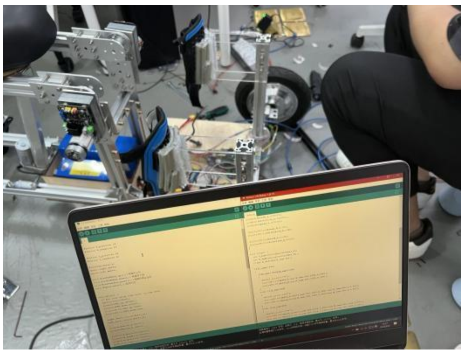


Figure 5
Dual-system programming

6 Testing Experiments

6.1 Seating Area Experiment

Purpose of the experiment: to test the seat's ability to ascend and descend to the designated position smoothly and the speed to do so.

Method of the experiment: A person (I) control the device and lets the device perform ascending motion and descending motion.

Procedures:

1. Examine every part of the device to make sure that everything is in the proper position to ensure the prerequisite of developing the experiment.
2. Turn on the main power switch.
3. Use the button on top of the rocker to make sure the device is in seating mode, then control the device with the two buttons responsible for ascending and descending to make the seat do the corresponding motion.
4. Film the whole moving process.

Experiment result:

Figure 6.1
Experiment Result

Discussion: The seat works smoothly at a slow speed that ensures the user's safety. In the experiment, we used a lower voltage battery than designated, therefore its speed should be approximately two times faster than it was in the experiment. After calculation, the regular speed for either ascending or descending the seat from the two extreme positions should be around a little less than 15 seconds.

6.2 Moving Experiment

Purpose of the experiment: to test the device's ability to be driven around on a flat plane, including its fluency, stability, speed, load-bearing, and steering function.

Method of the experiment: A person (I) sits on the device and uses the rocker to drive the device on a relatively flat plane.

Procedures:

1. Examine every part of the device to make sure that everything is in the proper position to ensure the prerequisite of developing the experiment.
2. Turn on the main power switch.
3. Use the button on top of the rocker to make sure the device is in moving mode, then drive the device with the rocker that's responsible for changes in directions as well as the speed of the device.
4. Film the whole moving process.

Experiment result:

Figure 6.2
Experiment Result

Discussion: The device moves smoothly at a speed controlled by the user. It can change directions and stop as the user wishes. It is also effortless to hold a human (me) of around 53 kilograms on top of the device, and it is estimated that it can hold up to 80 to 90 kilograms. The average speed is approximately 15 km/hr.

7 Results

The device was tested out using both a 24V battery for the electric putter and a

36V battery for the wheels. The seating functions well to hold me up and down while I'm sitting on it, and I'm able to drive the car on a relatively flat plane.

Figure 6
Final product

8 Discussion

It is a great success that the device is able to work in both functions at the cost of around 200-250 USD when the products' prices now seen in the market on average are at least 10 times the number.

Up till now, The construction of the main structure has been completed, and this product has achieved the successful operation of both functions.

It is easy to learn and easy to use using only two buttons and a rocker to control all functions, specially designed for the elderly group, as complicated methods of control can be hard for them to master.

As mentioned, the cost of producing this research project is less than one-tenth of the price of similar devices in the current market. If we are able to improve the device by eliminating some useless parts and afterward realize mass production, we are able to produce this product at an astoundingly low price that elderly people and people with financial difficulties can afford.

For future work, I believe we can further improve this research project in the following aspects:

Using an electrical putter is the most straightforward way to realize the function of ascendable and descendable seats. Although it is already very stable, the stability of using an electric putter for a considerable number of years is still a question. Therefore, for future improvements, the electric putter can be changed into a linkage mechanism for further stability. In the current design, the seat belt that the person should be wearing while using the device, the knee pads, and the handrails are all designed out of stability and safety considerations.

In addition, with two universal wheels in use, it is likely that the device is going to drift a little before moving in the desired direction. In the future, only one universal wheel should be used, and the wheel should be of a spherical shape instead of the ones that change direction as the motion goes on.

When the person controls the device to stop moving, the front wheels stop, as desired, but I firmly believe that adding a brake system to the device is necessary, in case of emergency.

Finally, the final product put onto the market cannot look like such a steel skeleton, hence beautification and packaging of the device are essential.

9 Conclusion

I would proudly say that this research, conducted up till now, is an overall success compared to both the current market and myself. It is important to see the potential of this family cost-effective project bears, as it is designed out of practical considerations. So far, it’s not a complete device to be put onto the market, but after improvements, this will be the exact device people are looking for.

I believe that this research project is very meaningful both socially and economically. Bearing the goal of developing a human well-being assistance device, it can benefit the disabled group that suffers from social inequalities tremendously. What’s more important is that this device is realistically affordable to them as well as easy to control, specially designed for the elderly group who are mainly retired, and the disabled group who may suffer from low incomes because of job inequalities. It also frees disabled people so that they are able to live independently on a daily basis without having to bother their family members all the time.

10 References

1. Klair Bayley, Stephanie Parkinson et al. “Benefits of powered standing wheelchair devices for adolescents with Duchenne muscular dystrophy in the first year of use” Journal of Paediatrics and child health, vol. 56, Sep. 2020, pp. 1419-1425

https://doi.org/10.1111/jpc.14963

2. Jane Goodwin etc. “Standing frames for children with cerebral palsy: a mixed-methods feasibility study.” Health Technol Assess, Sep. 2018. PMID: 30234480

3. Sushant Merai etc. “A study and design of standing wheelchair.” Materials today: proceedings 2022, pp 3787-3792

4. World Health Organization. Assistive technology. 18 May 2018. Available from https://www.who.int/news-room/fact-sheets/detail/assistive-technology. Accessed 20 July. 2022

5. 第二次全国残疾人抽样调查办公室. 第二次全国残疾人抽样调查主要数据手册[M]. 北京: 中国统计出版社, 2007.

6. 狄梦洁,闫 媚,谭 军,罗龙军,廖友峰,卜宏伟,张小年. 一种适用于偏瘫患者的新型转移辅助轮椅设计 Design of a New Transfer Assisted Wheelchair for Hemiplegic Patients[J]. 设计, 2021, 06(02): 13-17. https://doi.org/10.12677/Design.2021.62003

7. National Bureau of Statistics. Statistical Bulletin on National Economic and Social Development 2021. 28 Feb, 2022 [国家统计局. 中华人民共和国2021年国民经济和社会发展统计公报. 2022-02-28] http://www.gov.cn/xinwen/2022-02/28/content_5676015.htm Accessed 2 July, 2022.

8. United Spinal Association: The Wheelchair reviews. https://unitedspinal.org/wheelchair-reviews-views/ . Accessed 20 July. 2022.

9. Levo - The Experts in Standing. https://levousa.com/ . Accessed 22 July. 2022.

10. Permobil-Powerwheelchairs. https://www.permobil.com/en-us/products. Accessed 2 Aug. 2022.

11. Masiya A Marufu and A Van Der Merwe. “Using service-dominant logic to build empathy for design thinking in a health service delivery environment”. Third International Congress on Information and Communication Technology, 2019 , pp. 499–515.

12. Hobbs D, Walker S, Layton N, et al. “Appropriate assistive technology co-design: from problem identification through to device commercialisation.” Global Perspectives On Assistive Technology. Vol. B. 2019. pp. 342–358.