Attaching a smart push support system to the Rollz Motion

Master thesis | Tim van den Ing

Master thesis

Delft University of Technology
Industrial Design Engineering
Master Integrated Product Design

Student
Tim van den Ing
4216199

Supervisory team

Chair
Prof. dr. ir. Geraedts, J.M.P.

Mentor
Kooijman, A.

Company mentor
van de Watering, H.

Client
inMarket B.V.
Binckhorstlaan 36 M017
2516 BE Den Haag

PREFACE

This report shows the graduation project about the development of a power assisted Rollz Motion. It is written to complete the Integrated Design master programme of the faculty of Industrial Design Engineering at Delft University of Technology.

I would like to thank the colleagues at inMarket and Rollz for offering the assignment, for their enthusiasm, their support and their confidence in the project.

Besides, I want to thank to the supervisory team. The meetings were highly insightful and eye-opening. The provided feedback was very useful and helped taking the project to a higher level.

EXECUTIVE SUMMARY

Rollz Motion is a mobility aid that can be transformed from a wheelchair to a rollator. Users of this Rollz Motion complain that it takes too much force to push the Rollz Motion as a wheelchair with a person inside. Especially users that live in hilly areas have these problems. This project tries to solve this problem through the creation of a power assisted push support system that can be attached to the Rollz Motion. This should lower the threshold of going for a walk and increase the range of environments that the users of the Rollz Motion can access.

Comfort

As a first step the research focussed on how the users could benefit best from such a smart system. A force analysis validated the severity of the complaints and user interviews highlighted that users can develop a fear for mobility. The smart system should comfort the user by taking away this fear and it should comfort the push attendant by lowering the use force.

Support

Some types of power assisted mobility aids have a high number of accidents. This shows that the user group is vulnerable. An analysis was done to test whether the Rollz Motion would be safe enough to motorise. Assistive supportive technology needs to be implemented in the design of the drive system to generate the necessary safety.

Perception

Mobility aids suffer from product related stigma. This creates a threshold of going for a walk, makes users insecure and can have a negative effect on the mobility of the user. For new product development the stigma needs to be redesigned to make users proud and confident about using their product.

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INTRODUCTION

As people get older or suffer from an ever-worsening disease, they have to give up on mobility, and thereby part of their freedom and independence. InMarket, a company that develops mobility aids, tries to give back this freedom to users despite their illness or old age.

A product that has been developed to fulfill this mission is the Rollz Motion (see figure 1). The Rollz Motion is a rollator that can be transformed into a wheelchair. This mobility aid should prevent the devaluation of its users' quality of life as a result of physical or mental difficulties. To do this, the Rollz Motion offers solutions for several phases over the course of a disease. The Rollz Motion can serve as a walker that offers stability for a first wobble as the starting symptom of an equilibrium disorder, and this mobility aid can be transformed into a push wheelchair in which users can rest for Parkinson's disease in an advanced stage.

The Rollz Motion can have a positive effect on the mobility of its users since the product creates a backup, in the form of a wheelchair, where users can rely on when they are tired or in pain while walking. This can take away part of the threshold of going for a walk and some fear fear of falling or the fear of getting exhausted. The Rollz Motion is designed to take away the anxiety and to make users more confident.

New technologies like small, powerful and affordable in-wheel motors and lightweight batteries provide opportunities for further developments of the Rollz Motion. Due to these technological advances, it seems to be feasible to attach the right sensors and actuators to the rollator. Electric bicycles serve as an example of a similar successful technology push. Attaching a drive system proved to offer value for people that were not able to use a non-powered bicycle anymore.

figure 1

PROBLEM

As mentioned, the Rollz Motion is a mobility aid that can be used both as a rollator and a wheelchair. The rollator can be operated by the user itself, but help is needed to move around in the wheelchair. Typically the user needs to be pushed around by someone else. This can be quite a heavy job for the person that is pushing, especially when pushing up or downhill. As a result the person that is pushing could get exhausted which will turn the trip in a negative experience. Regular wheelchairs face similar problems. As a solution, these can be equipped with push support products. Such a product generates the required force to move the wheelchair around, with the user sitting down and controlling this movement or while the person behind the wheelchair just has to give a light push. These support products are however quite expensive, heavy, and do not fit the Rollz Motion.

The goal of this assignment was to design a drive system that does fit the Rollz Motion, both physically and contextually, that makes it easy to push someone around or that allows the user to control the Rollz Motion independently. This widens the range of environments the user can access, increases the amount of independency and therefor increases the mobility of the user.

Negative effects on the use of the Rollz Motion that could arise from adding such a system needed to be avoided. One of these effects is about safety. Adding a drive system to a rollator could lead to dangerous situations for the user and its environment if the rollator cannot be controlled properly and intuitively. Having a motorised wheelchair with someone in it is required to be safe and measures need to be taken during the process to guarantee this safety. Thereby safety regulations need to be met in order to legally access public roads.

The product should not just be safe, it should also feel safe. Well-designed product behaviour needs to tackle the fear that users can have to start and to keep on moving. Feelings that users have while using these products can be a determining factor for its success. Especially new users could show apathy to a powered vehicle. While time is needed for them to gain trust and use the product confidently, the behaviour of the product will need to convince them to rely.

Another important effect could be the added weight of the system on the rollator. While the added weight results in an easier way to manoeuvre when the Rollz Motion is used as a wheelchair, the owner of the Rollz Motion would want this weight to be as low as possible so that lifting and handling is less heavy when it is used as rollator. Research is needed about the amount of weight that needs to be added to make the system work, and whether this is still acceptable for the user.

SCOPE

The analysis focussed on the application of smart systems to the Rollz Motion in general. The drive system that is mentioned in the assignment can also be seen as a smart system. Focussing on smart systems in general gave a better overview for the future development of the Rollz Motion and placed the addition of a drive system in context as a part of this future development. While the focus of the analyses is on smart systems, the main goal of the project is to create a drive system.

VISION

This vision provides the desired states which the system to be designed should fulfill. It is the result of combining the outcomes of the varying researches which will be presented later in this report. These outcomes showed that applying smart systems to the Rollz Motion has potential to take away problems on different levels that users currently face while using the Rollz Motion. The vision is divided in three parts to incorporate these levels and to gain clarity. The individual parts highlight the relationship between a smart Rollz Motion and the users (comfort), the surroundings (support) and on the society (perception). An ideal product would have to suffice perfectly to all parts.

COMFORT

Enable fear free mobility

People with medical conditions that limit their movement are likely to suffer from a fear for going out for a walk. These people could have a constant fear of falling, fear of getting lost, fear of pain or getting exhausted, even while mobility assistive devices are being used. The integration of one or multiple smart systems can help in accommodating and overcoming this fear and therefore lowering the threshold of going for a walk. As a result smart systems can comfort the user, and connect to and reassure the user's mental and physical well-being.

The push attendant experiences most discomfort when the Rollz Motion is being used as a wheelchair. In this situation a person is sitting in the Rollz Motion while a push attendant is pushing this person and the Rollz Motion forward. This can be a heavy job, especially in more hilly areas. A smart system can widen the range of accessible environments and will therefore have a positive effect on the mobility of the user.

SUPPORT

Become a reliable companion

Different roles can be distinguished when people are using the Rollz Motion, especially in the wheelchair configuration. In this configuration the push attendant can be seen as a supporter, who is concerned about the mental and physical state of the person in the Rollz Motion and who will support where possible. The person sitting in the Rollz Motion is being supported, having a large dependency on the push attendant.

In this configuration, the users rely on the push attendant to take them to a location safely. The supported user has given full responsibility to the supporting push attendant. If a product is designed that assists in the functions that the push attendant fulfils, it should also take some of this responsibility. The design of this vehicle needs to be optimised to earn the trust of both the person sitting and the person pushing.

The responsibility can only be taken if the product is aware of its suroundings. Smart systems have the power to connect the vehicle to its surroundings to take the user to their destination safely. Collecting, interpreting and responding to information from the surroundings will be of high importance in this process. The right interpretation of data can help in anticipating or preventing dangerous or unwanted situations. The system will earn the user's trust if it proves to be stable.

The hierarchical situation between the supporter and the supported will not be present in the configuration of a rollator. Still, this does not deminish the need for a reliable companion that supports the user in reaching a destination safely in this configuration.

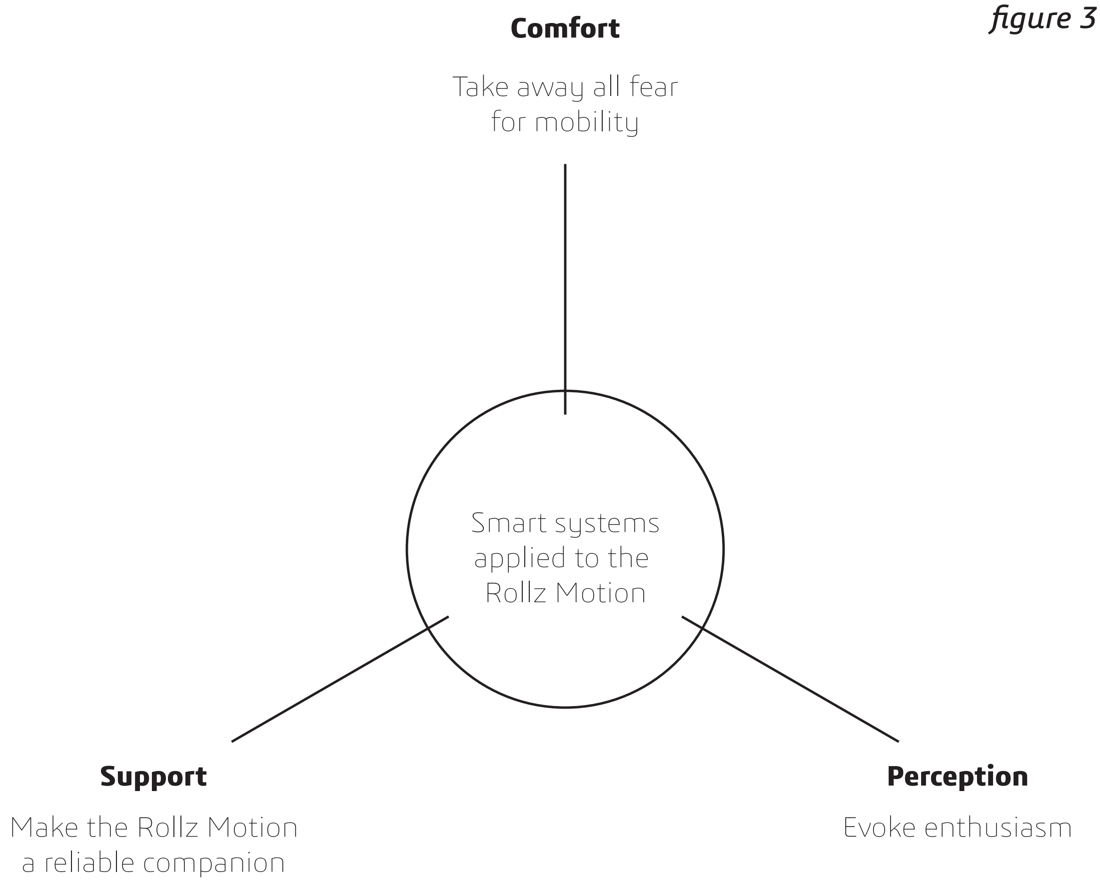
PERCEPTION

Evoke enthusiasm

The Rollz Motion is intended as mobility assistive device that surpasses the stigma better than competitive products by offering a modern looking device that can be adjusted to the needs and wants of the user. Users are positive about these features, and report that the product is perceived positively by other people. Still the users feel a large dependency and hierarchy when they are being pushed around, and some have a burden of asking a relative to do the heavy work of pushing them around. This shows that a part of the stigma is still apparent.

Some innovative products show that smart systems can transform a stigmatic mobility assistive device into a 'cool' product that provokes a 'wow factor'. These products are not just appealing to the users but also to people without mobility issues and can even amaze them. As a result, smart systems can connect the device in a positive way to the opinions of the society. Ultimately this can make the users confident and proud about their device and make their trips relaxed and stress-free.

figure 3



RESEARCH

The analyses which are presented in this chapter help defining the scope and possibilities within the described vision and can be seen as an exploration of the context. The analyses focussed on the three segments of the vision and helped in gaining a better understanding about the use of the Rollz Motion, about the problems that the users of the Rollz Motion face, about the situation of the market and the used technologies, and about the legislation for electric powered wheelchairs. The found conclusions served as input for the programme of requirements.

COMFORT

The Rollz Motion has been designed to offer comfort when the user needs it. When the user feels instable, the Rollz Motion offers stability and when the user feels tired, the Rollz Motion comforts the user with a place to sit. This analysis tested whether the use of the RM is as comfortable as it should be and searches for problems and opportunities to make the RM even more comfortable through the application of smart (drive) systems.

PRODUCT

The smart drive system that will be designed needs to fit the Rollz Motion. A product analysis was made to determine how the drive system could be useful and what problems it could solve. Since the assignment states that the smart drive system has to be (partially) integrated and/or (partially) attached to the Rollz Motion, the best way to fit the smart system to the Rollz Motion was researched to find out to what extent the Rollz Motion is suitable for the system to be installed without obstructing comfortable use.

Use configurations

The use configurations of the Rollz Motion need to be defined to understand how the Rollz Motion is intended to be used and to determine in what situations the implementation of the smart systems can lead to a more comfortable use of the Rollz

figure 4: the configurations of the Rollz Motion; Folded (left), Rollator (centre), wheelchair (right)

Motion. Ideally the use should become comfortable for each of the configurations for all involved stakeholders.

Basically the Rollz Motion is designed to be used as an assistive mobility device in two different configurations. One of these configurations is as a four wheeled walker. In this configuration the user is walking behind the Motion and pushing it forward to move. The Rollz Motion is supporting the stability of the user like a regular rollator.

In the other configuration the Rollz Motion is being used as a wheelchair. The user that was walking behind the Rollz Motion in the rollator configuration is now sitting in the seat of the Rollz Motion. A push attendant is now standing behind the vehicle to push both the Rollz Motion and the user in it forwards. To transform the Rollz Motion from a rollator to a wheelchair the user or an attendant needs to unfold a backrest, place foot support pads and twist the handles. All can be done in less than 30 seconds. Figure 4 shows the two configurations in which the Rollz Motion can be used.

Force analysis

For each of the specified configurations the forces are determined that are required to use the Rollz Motion. Based on these forces an assessment was made that showed whether the force is comfortable or not. In ergonomics literature no solid definition of comfort is given. It is regularly defined as the absence of discomfort. In terms of force, it proved to be difficult to specify comfortable force limits. Different studies show different comfortable force limits and the test procedure seems to influence the result. While force limits can be found in literature, it is advised not to blindly follow these guidelines and to use tests to fine tune the necessary force exertion for each individual project. (The occupational ergonomics handbook). For this reason the conclusions are based both on the findings from literature and on interviews with users.

"Comfort is described as the absence of discomfort"

Using the Rollz Motion in the configuration of a rollator seems to fit the found force limits (Dined, n.d.). Tests show that the required force to push the Rollz Motion around with 14 kg of added weight (which could resemble groceries) on different hardened terrains does not surpass 18 N. 18 N is similar to 20% of the maximum two hand push force of the fifth percentile of woman who are older than 80 years (Dined, n.d.).

The force it takes for a push attendant to push the Rollz Motion uphill with a person in it can become quite high. The total required force is depending on the slope of the hill and the type of surface. The maximum allowable slope as specified in the applicable standard requires dynamic movement on a slope of 6 degrees. Other powered wheelchairs even provide a safe slope angle of around 10 degrees. The total force it takes to push the wheelchair on an asphalted hill with such a slope can exceed 220 N depending on the weight of the person sitting in the RM. This force is higher than 50% of the maximum force that an average male older than sixty of the fifth percentile can deliver. Table 1 shows that quite a lot of male elderly are unable to deliver the required force. And approximately half of all elderly woman reach their force limits while trying to climb such a slope. This finding is corresponding with the claim that some users make, that it takes too much force for them to push someone around for a day in the Rollz Motion. A model can be found in appendix A.1.6.

Dutch elderly (age)	2 hands pushing force (N) male (P5)	2 hands pushing force (N) female (P50)
60-64	279	288
65-69	226	250
70-74	239	230
75-80	180	219
80+	152	165

table 1

Concluding, it can be claimed that the use of a motor can be most beneficial in the configuration where the Rollz Motion is being used as a wheelchair. The forces that need to be delivered in this situation could be higher than the forces that push attendants can constantly deliver. While one could argue that the hill where the forces are higher than the push attendant can handle would be avoided by the users of the Rollz Motion. The motorisation could encourage the users to start climbing this hill which enlarges the range of environments of the Rollz Motion and their users.

"The use of a smart drive system can be most beneficial in the configuration where the Rollz Motion is being used as a wheelchair"

USER

Mobility

Worldwide populations are getting older, resulting in more elderly. In total 20% of the population is expected to have past the age of 60 in 2050, compared to 10% nowadays (Manini, 2014). Aging is correlated with cognitive, locomotive and sensory impairments that become more severe when people age. (Tinetti, 1986). These impairments may have a negative effect on the mobility of elderly. 24% of the elderly (aged over 65 years) have mobility problems. Since decreasing mobility is correlated with aging as well, it will get harder and harder for aging people to have an active lifestyle without adaptations and/or assistance.

The views on this growing group of elderly are diverse. Some see the growing aging society as a problem and point out the potentially high impact on social and healthcare cost as a result of the physical and mental problems of this group. While other views focus more on the opportunities that are provided for this group and focus on aging healthy to postpone the decline of abilities. Mobility is mentioned as one of the topics that can help in postponing this deterioration (McInnes, 2011).

A decline in mobility can have numerous reasons that can have physical, mental and/or environmental causes. These causes can be linked; environmental causes can for example lead to physical or mental problems. The mobility decline can have a gradual character, which can give a person time to adapt to the situation, but can also get more extreme, e.g. when a person falls and fractures one or more bones. The large variation in causes and decline extremity results in complexity in the creation of an evidence based system that prevents or treats mobility impairment (Manini, 2014).

“Mobility: you either use it, or lose it”

Manini

Research shows that mobility is an important factor in aging healthy and a restriction in mobility can have severe consequences (Ettinger, 1997). Mobility problems can result in social restrictions and limits accessibility to public buildings and shops. It can even lead to social isolation and be a predictor of mortality. To prevent these negative consequences of passivity the mobility of elderly needs to be maintained or trained. Even when people have been diagnosed with diseases such as osteoporosis or COPD, they can positively influence their health by exercising (Ettinger, 1997).

Mobility behaviour research of people with mobility assistive devices shows that travelling distances are generally small. Reasons for travelling are mainly groceries and leisure (figure 5 & 6).

Interviews with users show that they value their mobility (see appendix A.3.2). Multiple users say that they think their health is important and that they constantly try to maintain it by having an active lifestyle. The Rollz Motion is a product that enables the users to go out for a walk, even when environmental factors, or their physical or mental state are not ideal. These findings correspond with findings in literature. One study shows that the use of wheeled walkers increase the user’s walking distance, walking speed and cadence (Mahoney, 1992). Another study shows that users are satisfied with their mobility assistive device and think that the device enables them to have an independent and socially active life (Brandt, 2003).

Concluding, the Rollz Motion can already be seen as a product that can help in maintaining and training the mobility of users. Therefore the use of the Rollz Motion (RM) can prevent discomfort through the positive influence of exercising on the user’s well-being. It decreases the threshold for people to start walking. The interviews showed that many users are aware of this function and find their personal health important.

Fear

Users can have multiple reasons to get restricted in their mobility as previously described. One of these reasons has a mental nature. (Elder) people can develop fear of movement. This is shown in literature (Leonhardt, 2010) and was something that the users pointed out in the interviews as well (Appendix A.3.2). This fear can make the task to motivate them to start and keep on moving quite difficult.

The fear of falling is a well known fear that has been researched quite extensively. Numerous papers have been written about the fear of falling that elderly can have. It has even been suggested that the fear to fall increases the chance on falling (Kleinfield, 2003), since this fear can have large consequences. It could for example lead to depression, which will be treated with medication. This medication can make people more liable to fall.

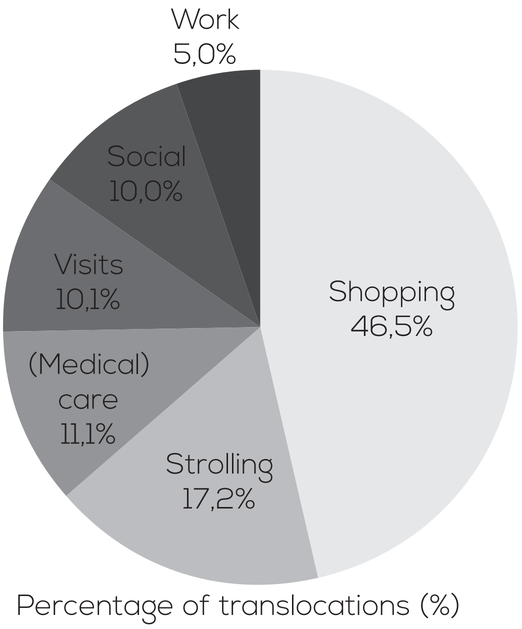


figure 5

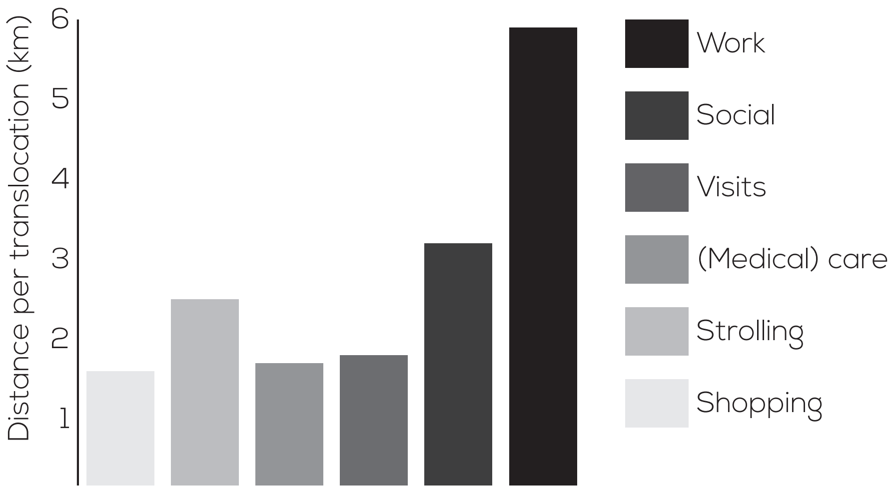


figure 6

"Eventually you get paranoid. You're afraid to do anything"

Kleinfield, 2003

Other mental factors that can play a role in the restriction of one's mobility are a fear of pain and lack of self-efficacy (Leonhardt, 2010). Doing movements that have caused pain previously can provoke anxiety (Martin, 2005). In such a situation people tend to find alternatives for the movements that cause the pain.

Apart from the general types of fear that are prevalent for elderly, other types of fear exist can be linked to specific diseases. For example patients with Alzheimer's disease or dementia can develop a fear of getting lost. And persons that suffer from Parkinson's disease have a fear of freezing: standing still without being able to move anymore.

Not just elderly (patients) can develop fear disorders. Caregivers or relatives can have anxiety that the person they care for ends up in an unwanted uncomfortable situation. This fear can restrict the elderly (patients) even more since the caregiver can have power to restrain them in their activities.

"Mobility assistive devices make people cope with their fears, but do not take them away"

Assistive products generally try to offer solutions for the fear that people experience. Rollators, for example, offer stability to make people cope with the fear of falling. In the case of the Rollz Motion some users still experience part of this fear of falling and/or other fears (like a fear of getting stuck somewhere or losing sense of direction) while walking with the rollator. During interviews these users specifically mentioned that they are anxious to overlook a bump and lose their balance, and that they scan every inch of the pavement to prevent this from happening. This indicates that the Rollz Motion needs to be further improved to completely cope with the user's fears. Equipping smart systems to assistive mobility aids can help in making users overcome their fears.

Persona

To gain a better understanding of the potential users of the smart Rollz Motion a persona was made based on the outcomes of the analyses. This persona does not just focus on the owner of the Rollz Motion, but also on the push attendant since he/she is at the moment also involved in the configuration where the motor will be of best use.

The persons displayed in the persona are a representation of the people met during the interviews. In general the found characteristics for people who asked for a motor in the Rollz Motion were similar for most people: An elderly couple of which one of the partners has a chronic disease (mainly the woman). His or her partner is able to take care for his/her relative, but has problems with pushing the Rollz Motion with his/her relative in it.

These couples do desire to have an active lifestyle, as mentioned during the interview at Rollz International (see appendix A.3.1). They like to go out and do not want their physical limitations to be obstacles for the activities they undertake. Some users even took the Rollz Motion on vacation. They book flights for trips overseas, roll aboard the Trans-Siberian Express, and even find ways to hike towards Machu Picchu.

“Users like to go out and do not want their physical limitations to be obstacles for the activities they undertake”

Scenarios

The persona gave an idea about the users and allowed to write detailed scenarios. These scenarios are written around the two characters as described on the next page. They are partly based on user interviews and stories about users collected during interviews with Rollz employees, and are partly fictional.

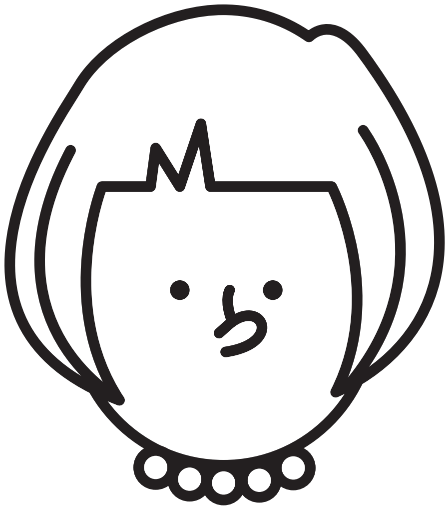
These scenarios helped in defining the steps that the users could take in specific situations that could occur and how a powered Rollz Motion could help in these situations. It showed large differences between a push support solution and a self-controllable solution. Studying these scenarios created a list of desired functionalities and potential uses of smart systems applied to the Rollz Motion. The complete scenarios can be found in appendix A.3.5.

One of the main outcomes of these scenarios is that a push-support solution, where a second person is helping out, will be most comfortable for the person sitting in the Rollz Motion in numerous situations. Another outcome of the scenarios is that a push-support solution will result in a more simplistic design since the push attendant can provide necessary functionalities that would otherwise need to be fulfilled by the system.

In the situation, for example, where a user in a self-controllable Rollz Motion needs to climb a curb to get on the pavement with a height of 7cm or higher, the user has to get out of the wheelchair. Where other manual powered wheelchairs (with large 24” rear wheels) can just back up and climb the curb backwards, this will be impossible for the Rollz Motion due to the smaller 12” wheels. If no additional systems will be designed that can support the user in climbing the curb, the user of a self controllable wheelchair would have to get out of the wheelchair and lift the Motion onto the curb from a standing position.

If a push-support solution will be chosen for this scenario, the person sitting in the Rollz Motion can hold his/her position, while the push-attendant could make the vehicle climb the curb, potentially with additional power provided by the push support system. There will be no need for other curb climbing devices in this situation.

figure 7



name	**Johann Egger**	**Martha Egger - Steuben**
age	76	71
height	1.80m	1.57m
occupation	retired salesman	
health	in excellent condition for his age	suffering from Multiple Sclerose

Johann does not want to let the physical condition of his wife become a restriction to travel. He likes to visit other European cities by plane

He likes to assist his wife where possible. He provides all the needed care for her

He enjoys going out with Martha and with his grandchildren

Is not physically able to push the Rollz Motion continuously with Martha inside in the hilly area where they live.

Lives together with Johann in a small village in Switzerland and is the proud owner of a Rollz Motion

She wants to maintain an active lifestyle and values her mobility and her health

Focussing on the beautiful moments she still can experience helps her to remain positive despite her disease

SUPPORT

The smart Rollz Motion needs to support the user in reaching the destination safely and confidently. This analysis tries to answer which measures have to be taken to make the vehicle supportive and how the Rollz Motion can become a trusted partner.

PRODUCT

Tests were done to predict whether the powered Rollz Motion shows potential meet the requirements as stated in the standards that apply to powered wheelchairs, whether a powered vehicle would be safe enough to use in its context and if and how smart (drive) systems will be needed to improve safety and reliability.

Safety

Numbers about the amount of accidents with powered assistive mobility devices are shockingly high. In 2015 in the Netherlands, 2700 people needed medical treatment after being involved in an accident with a mobility scooter (Kleijne, 2016). Especially for mobility scooters numerous fatal accidents occur annually.

The high rate of accidents may have several causes. In 20% of the cases tipping was the cause of the accident. In 15% the cause was related to the mobility scooter driving into an obstacle and in 14% the drive gave incorrect input. One of the reasons behind the causes is the disability of drivers to respond adequate to potential dangerous situations due to decreased sensory capabilities and/or long reaction times. Interviews with mobility experts (see appendix A.3.4) highlighted that some of the drivers have problems with assessing their speed and the consequences of their input, which results in tipping and (too) long braking distances. These findings show that the user group of assistive mobility devices is vulnerable and that additional safety measures need to be taken to ensure a vehicle that will not cause harm to the users or their surroundings.

"The requirements based on legislation and standards are not strict enough to create sufficient safety"

Legislation

To legally access the roads the design of the powered wheelchairs needs to be adjusted to fit the applicable legislations and standards. The requirements that are specified in these laws and standards create a minimally acceptable level of quality, safety and performance.

The standard that describes most of the requirements for motorised wheelchairs is the standard NEN-EN 12184-2011 (see appendix A.6.1). This standard specifies the minimum performance demands for the different types of powered wheelchairs. The smart Rollz Motion will therefore need to suffice to this standard. The maximum speed is key in the classification of the powered wheelchair. If the maximum velocity is lower than 6km/h, the vehicle will not have to apply to European regulations (168/2013) and the requirements that are stated in these regulations (see appendix A.6.2).

The design of the power assisted Rollz Motion will have influence on the applicable regulations. If a self-controllable solution will be chosen, the vehicle will be seen and classified as a powered wheelchair and apply to the legislation for vehicles like mobility scooters. These regulations require additional lights, reflectors and even insurance. For push support solutions these additional regulations do not apply.

Designing a vehicle in compliance with the legislation and standards will provide a good first step in designing a vehicle that is safe to use, but can still have flaws that may cause harm for the users and/or the environment. Looking at the number of accidents with powered assistive mobility vehicles - which are in compliance with legislation - shows that the requirements based on legislation and standards are not strict enough to create sufficient safety.

Stability

Tipping has been mentioned as one of the main reasons for accidents with mobility assistive devices (Kleijne, 2016). The chances of tipping for a motorised Rollz Motion have been researched to show what measures need to be taken to prevent this from happening.

“The tip-over of a wheelchair is one of the most dangerous motions that threaten the safety of a user”

Oh, 2015

The Rollz Motion was initially not designed with motorisation or smartification in mind. In other words, parameters like the wheelbase, the location of the centre of gravity (see appendix A.1.5 for an estimation of the location of the centre of gravity) and the wheel distance are not optimised for the additional forces that are generated by (an) added motor(s). This raised questions about the stability of the Rollz Motion.

A created mathematical model (appendix A.1.8) shows that the Rollz Motion can be statically stable up to a slope of 15 degrees. In this model it has been assumed that the user is sitting in the Rollz Motion as intended.

While this 15 degrees slope may be critical, it is not found too often in context. Ramps are usually not steeper than 10 degrees (see appendix A.2.1), and most European hills or mountains could be climbed without surpassing the 15 degree limit.

For dynamic stability, the maximum rates of acceleration are dependent on the steepness of the slope the Rollz Motion is on. These rates are presented in figure 8. This graph shows that the maximum rate of acceleration on a 6 degree slope is just higher than 1.5 m/s2. This rate of acceleration surpasses the requirement in the standard NEN-EN 12184 that states that the vehicle needs to be able to accelerate up to 2km/h from standstill on a 6 degree slope within 5m. With the maximum rate of acceleration of 1.54 m/s2 this distance is only 0.90m.

“The motors need to be controlled to accelerate and decelerate depending on the steepness of the slope the Rollz Motion is on”

The deceleration requirements state that the vehicle needs to be able to decelerate from the maximum speed to standstill on a slope of 6 degrees within 2m. With the maximum deceleration rate - which leads to a stopping distance similar to the acceleration distance (0.90m) - this should just be possible. These findings show that the Rollz Motion will be stable enough to meet the stability requirements as stated in standard NEN-EN 12184.

While the model shows that the vehicle can accelerate and decelerate with high rates when standing on a horizontal and sloped plane, the limits could be reached when

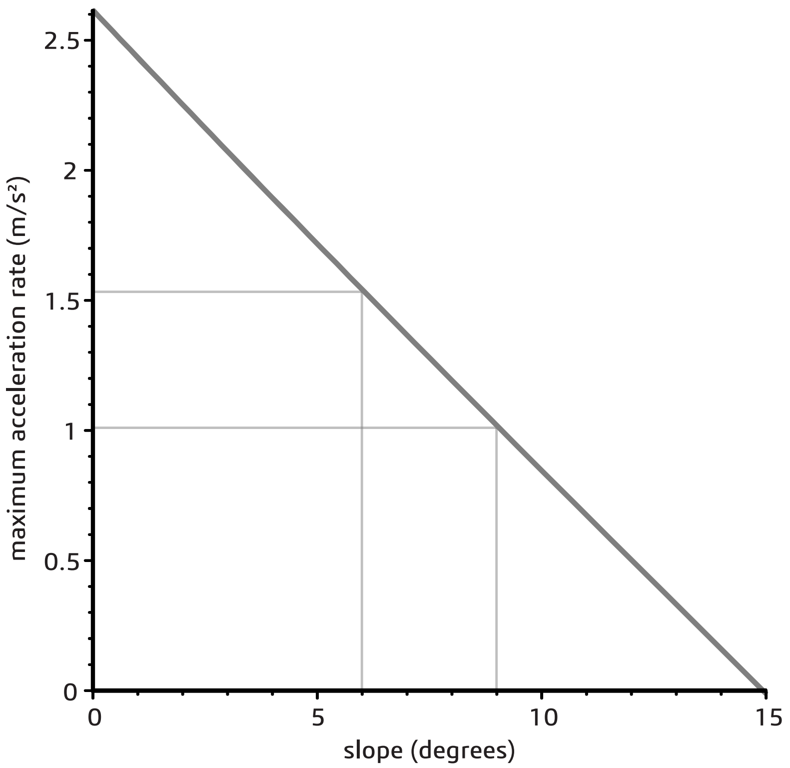


figure 8

standing on steeper planes. This urges for solutions that prevent the Rollz Motion from tipping when the motors generate acceleration. Basically the motors need to be controlled to accelerate and decelerate depending on the steepness of the slope the Rollz Motion is on. The control system needs to be smart enough to detect the slope and provide the right acceleration or deceleration.

Obstacles

Driving around with the Rollz Motion and listening to users showed that obstacle climbing is a problem for most rollators and wheelchairs. Besides, colliding with obstacles is one of the main reasons for accidents with mobility scooters. While using the Rollz Motion users actively search for bumps which might cause inbalances and some users even mentioned to be launched from the seat of the RM when encountering a bump. Testing also showed this incapability of the Rollz Motion to climb obstacles (see appendix A.2.1).

The size of the front wheels is too small and the normal force that is acting on them too high to easily climb obstacles that are higher than 18mm. This results in sudden stops when the Rollz Motion encounters such an obstacle. Depending on the speed of the RM at the moment before impact, a user that is sitting in the RM could be launched and a user that is walking behind the RM could lose balance.

Research about obstacle avoidance systems for wheelchairs has already reached a further stadium that has lead to (semi-)autonomous wheelchairs. These wheelchairs can reach a destination without user input while driving and without colliding. These systems still are too expensive and not safe enough to be implemented in products (Ruíz-Serrano, 2014). More simplistic obstacle detection methods involve the use of ultrasonic sensors. Using these sensors shows potential to create the desired safety by detecting obstacles.

While obstacle detection and obstacle avoidance systems are too expensive and not safe enough to be applied onto wheelchairs, collision detection has already been fitted onto powered wheelchairs. Instead of preventing a collision, these systems make the vehicle stop moving when a sudden drop in velocity is noticed. While such a system cannot prevent harm caused by the collision, it will prevent the situation from becoming even worse.

USER

Human machine interaction

Power assisted wheelchairs try to make The design of the human machine interface in power assisted wheelchairs is intended to feel natural and intuitive.Electric wheelchairs are being controlled in varying ways. Especially self-controllable wheelchairs for paralysed or quadriplegic users show a varyity of input solutions that try to improve comfortness, safety and maneuvrability. Research suggests that some of the available solutions are inconvenient, inaccurate and/or inappropriate for specific situations (Han, 2003). This highlights the importance of selecting the right human machine interface.

Numerous examples of the powered devices show that counterintuitive interface solutions can create dangerous situations. One of these examples can be found in the powered rollator beactive+e. This rollator speeds up to a set speed where the user has to keep up with the walker. If the user is using a specific grip, he/she needs to release one of the handles when he/she wants to stop. As a result the user can get in a situation where the speed is higher than the user can handle while holding the rollator with just one hand.

While these systems need to create support and safety for the users, they create danger instead. These findings show that interface systems are needed where the users can rely on. For the Rollz Motion these systems need to be tested with users in a safe environment and optimised before bringing the product to the market to verify that these systems support the user and that the user can trust them.

TECHNOLOGY

Power assisted wheelchairs face similar control problems as a power assisted Rollz Motion would face. These wheelchairs are optimised to transform the input of a user to controlled motion in a safe and stable way. The users of these power assisted wheelchairs can have decreased muscular force, motor skills and/or reaction time. Still, the control algorithms in these power assisted wheelchairs are able to assist these impaired users intelligently. Optimising the control system creates the needed safety, enlarges the range of accessible environments and increases the group of users that can operate the vehicle (Wang, 2009).

Altough numerous similarities can be found between the power assisted wheelchairs and the Rollz Motion, differences are apparent as well. Many of the researched wheelchairs are being used by severely disabled people that could suffer from multiple disabilities. The users of the Rollz Motion generally do not suffer from these severe conditions. Especially push attendants can be completely vital people who are able to assess the safety of a specific situation correctly and respond on this situation in a safe way. The neccesity of an advanced control system can be questioned for these users. Still the situation could occur where a user with impairities, decreased muscular force and/or motor skills will be using the system. For these users an advanced control system will be needed to create a safe means of transportation.

Wheelchair control systems

The control system that will be fit to the Rollz Motion needs to convert user input into controlled motion. Large differences can be found in the intelligence of these control systems in commercially available products. Some drive systems of electric powered wheelchairs possess the desired levels of intelligence, which creates functionality and comfort. These systems have been designed to be human friendly, have integrated sensor technology and can even be seen as systems that control the vehicle together with the user (Chen, 2009). The involved algorithms guard the vehicle against contextual disturbances (Oh, 2008) and raise the robustness of the stability and maneuvrability (Wang, 2009).

When an intelligent control system is absent within a power assited wheelchair, this directly negatively influences the comfortability and safety of the vehicle (Ding, 2005). Non-intelligent systems do not match the needs of elder and/or disabled users and need improvements in order to cope with difficult drive conditions, enlarge the population that is able to control the vehicle and guarantee safety.

While intelligent control algorithms can robustly convert the user input into controlled motion, the user can still have moments of unstability or uncontrollability due to their disabilities. These moments can cause harm to the user, the vehicle and/or the surroundings. For this reason, additional control systems need to be included to make the vehicle respond safely to unstable user input as well.

Oh (2014) proposed such an integrated system that fuses the available sensor data to detect the environmental conditions and the status of the vehicle. Based on the collected data the response of the wheelchair on user input is determined. This creates a system that becomes aware of its context and adapt to it to ensure stability and operatability and to reduce the chance on accidents. As a result this system can safely respond to unstable user input and it even has the power to completely ignore the input of a user if this is the only way to ensure stability. The complete schematic of this system can be found in figure 9.

The schematic consists of four main blocks. In the Operation State Observer the available sensor data is being collected. This includes data that is being used to determine the state of the vehicle. Detecting the (change in) position of the vehicle, the (rotational) speed and delivered torque is required to properly observe the state. Sensors like an accelerometer and gyrocscope, motor current sensor and motor speed sensor are necessary components in fulfilling these tasks. Furthermore the state of the system is being checked to spot any errors that could cause problems.

The collected data is analysed further at the Fuzzy Operation Condition Detection. At this block the system tries to determine the conditions in which the vehicle is operating. It detects the surface on which the vehicle is driving, the weather conditions and the intentions of the user based on the data that has been collected at the state observer.

Subsequently, the fused sensor data is used at the Assistive Control Algorithm to

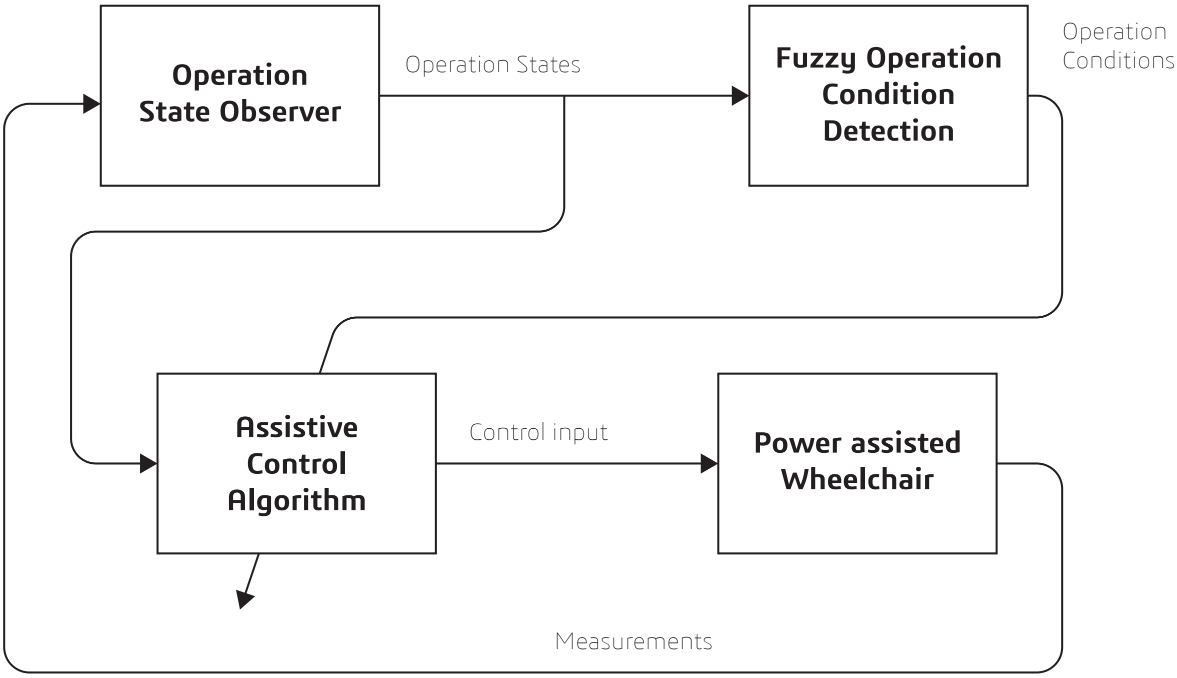


figure 9

determine the required actions that need to be taken to properly control the wheelchair. These actions can include but are not restricted to limiting the acceleration to maintain stability or to automatically brake when the maximum speed on a downhill slope is being reached. More in depth information about the control algorithms that can be implemented to assistively control the vehicle can be found in the next paragraph.

The power assisted wheelchair is then controlled based on the decisions made by the control algorithms. These actions influence the state of the vehicle again, requiring new measurements, new state observance and condition detection to constantly ensure a proper functionality.

This presented control system can fit the Rollz Motion perfectly since this system provides solutions for the challenges in controlling the powered Rollz Motion. Oh showed that stability control can be implemented in the presented system which can prevent tipping. Furthermore the system can be used to detect specific situations, for example when the push attendant wants to perform a wheelie. When this situation is detected the system can cut off the motor power to ensure safety and reliability. These features exactly fit the functionality that a powered Rollz Motion would require.

Another reason why this system fits the power assisted Rollz Motion so well is because the Rollz Motion can be used in different configurations. This leads to different use states. It is important to have a system that can detect the (changes in) states. The system needs to detect whether or not a person is sitting in the Rollz Motion and for each situation it should respond naturally on the input of users, while the contextual factors could be completely different. Constantly detecting the state and condition of the system and the environment shows potential in providing a natural and reliable output for any given situation.

Specific control algorithms

Instead of focussing on the entire control system, most of the available literature about power assised wheelchair control focusses on the specific types of drive control systems that are integrated in the complete control system. Main research topics include velocity control, stability control, traction control, and suspension control. Not all of these control systems are apparent in commercially available electric powered wheelchairs. Velocity and stability control have been and are being researched and applied extensively in powered wheelchairs. Traction control and suspension control are less frequently found in wheelchair control systems and are mainly used in other industries such as the automobile industry. However, research about traction and suspension control is showing benefits for use in electric powered wheelchairs. Below each of these control systems are described in more detail.

Velocity control

Since the speed and direction of electric powered wheelchairs are the most commonly controlled variables, velocity control systems can be found in almost all electric powered wheelchairs. Being able to control the speed of the motor(s) is one of the main technologies where powered wheelchairs are built on. Based on the input of the user a motor controller sends the required voltage and current towards the motor(s) that enable the desired movement. Typical velocity control systems are closed loop, meaning that sensors are used to detect the speed of the powered wheels. The difference between the detected speed and the desired speed can then be determined and this differentce minimised by changing the voltage and current that is provided to the wheels (see figure 10). A closed loop system can make vehicles drive at a same speed uphill and downhill and on varying terrains.

Numerous control algorithms are being used and researched. Research shows that the widely used Proportional Integral controller does provide some level of control results for velocity control of power assisted wheelchairs (Ou, 2010 & Wang, 2009 & Solea, 2015). Such a control system constantly minimises the difference between the desired input speed and the actual speed of the motor. By tuning the PI controller with the right parameters a rigid control system can be obtained (van Gerven, 2006). Still these controllers are sensitive to disturbances and variations in loads (Wang, 2009). This raises questions to what extent these controllers can be used for the power assisted Rollz Motion. Real time model based control algorithms show to be more robust, but may require higher levels of complexity (Wang, 2009).

Stability control

Users may have problems in assessing the dangers of their current speed and loss of stability while driving in the vehicle. This can result in unsafe control choices that might result in unwanted or harmful situations and make the complete system less reliable (Boladzjiev & Stefanov, 2002). Control algorithms can prevent these

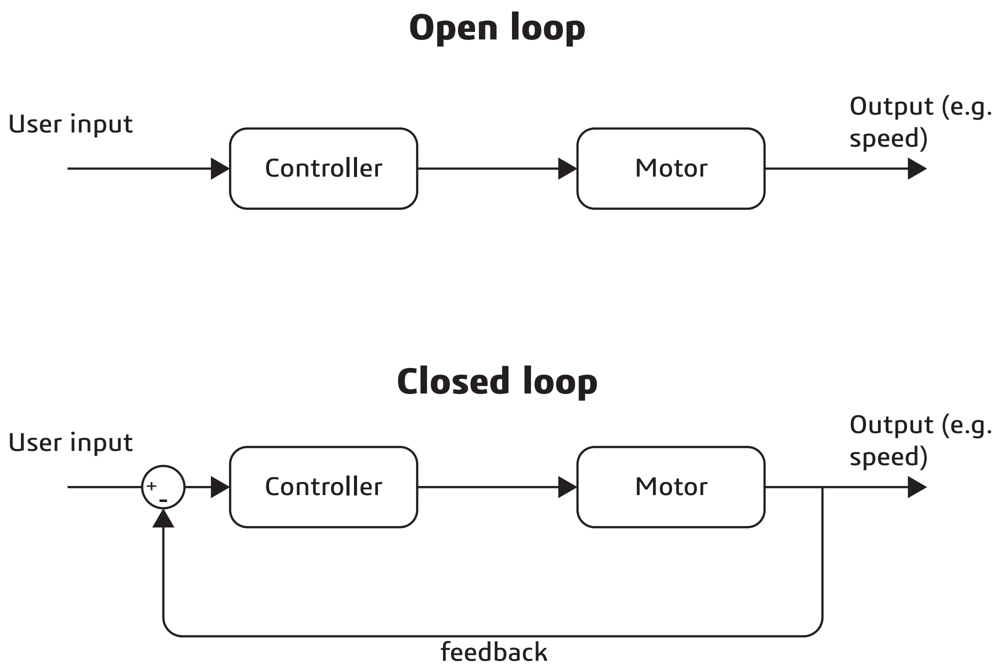


figure 10

harmful situations due to unsafe control choices. Stability control systems need to foresee potential loss of stability and alter the control signal in such a way that stability is maintained.

Boladzjiev and Stefanov generated a stability control system that can account for dangerous user input by performing a real time analysis of the dynamic model. Within this system, equilibrium is constantly being analysed and dynamic reaction on the input of the user predicted. The signal that controls the motors is changed as a result of the analysis to maintain stability. Based on the analysis the system can even reject a command of the user.

Traction control

Traction control is mainly used for all terrain electric powered wheelchairs (Ding, 2005). This wheelchair type has to deal with varying surfaces and needs to control the speed of the motors. No research has been found on traction control systems for two wheel controlled electric powered wheelchairs.

Suspension control

Suspension control systems are rare in electric powered wheelchairs. Research shows potential benefits in overcoming obstacles easier and eliminating vibration better. Currently only some automotive concepts are apparent. The investment costs required to develop and manufacture these actively suspended wheels seemed to be too high to continue the design process.

Wheelchair model

A wheelchair has been modeled in Matlab/Simulink to test the findings about the control algorithms. The complete model can be found in appendix A.7.1. The model mainly focussed on the velocity and torque control of the system since this is the main technology that is needed to make the system work. This does not mean that the other control algorithms, like stability control are of minor importance.

The model showed that a PI controller can be indeed effective in controlling a wheelchair motor. The model showed that such a system can be tuned to make the motor reach a set speed at a decent acceleration. However, as mentioned in literature (Wang, 2009), changing loads in different scenarios within this model highlighted the incapability of PI controlled systems to robustly handle disturbances. This is visualised in appendix A.7.1. The model shows a difference in response when a slope is encountered for different weights of the users in the wheelchair. In other words, a tuned PI controlled system might work correctly for a 120 kg person when encountering a bump or a slope, while this system can give undesireable and unstable responses for a 75 kg person. Retuning the parameters of the PI system for a specific situation would be necessary to provide robust control.

Such an adaptively tuned PI controlled system, combined with the other control systems will be too complex to be developed within the scope of this assignment and will for that reason not be further elaborated within this project. Still their desired functionalities will be described and some of the algorithms will be used to control a working prototype.

PERCEPTION

The Rollz Motion has been designed to be perceived positively compared to competitive mobility assistive devices. This analysis researches whether the RM is actually perceived this way and shows how this perception can be improved even further through the use of smart (drive) systems.

"Stigma free assistive devices can enhance one's well-being and result in an increased self-esteem"

STIGMA

Product related stigma can be defined as social unease that people feel while using or perceiving a product. (Medical) assistive mobility devices, such as the Rollz Motion, can elicit these negative emotional responses from their users and society. While assistive mobility devices possess the desired functionality, they usually fail to address the user's social needs and wants and do not appeal to their emotional demands (Vaes, 2012). Product related stigma can result in stress and reduces the self-esteem of the user, resulting in a negative use experience. On the other hand, assistive mobility products that are designed to be stigma free can enhance one's well-being resulting in an increased self-esteem (Rosenfield, 1997). These research conclusions show that the product attached stigma is of high influence on the perception and experience of the product and that new assistive mobility products should not contain stigmatizing features to create a positive user experience.

Stigma in the Rollz Motion

Users mention that they like how the Rollz Motion looks and feels, and that they get quite a lot of positive reactions from other people (see appendix A.3.2). Still some stigmatizing features can be discovered within the design of the Rollz Motion. Especially the use in the configuration of the wheelchair is perceived as stigmatizing. Owning a product that can be used as a wheelchair makes users realize that they are disabled, and they feel that society perceive them as disabled as well. Users claim to feel dependent on their push attendant and they feel a hierarchy when they are sitting in the RM without having any form of control. They also claim that they find it difficult to ask someone for the heavy job of pushing as shown in Appendix A.1.6.

Re-shaping product related stigma

Multiple design strategies to overcome stigma can be found in literature. One of those is about re-shaping the socio-societal context. This strategy focuses on creating awareness and changing the attitude of society towards the stigmatized product. This can be done by (marketing) campaigns and could involve influential persons (Vaes, 2012).

Another strategy is about re-shaping the meaning of the product. This strategy has been used in the design of the Rollz Flex. This assistive device has been designed as a shopping cart, that will also provide more stability for the user. It can be seen as a walker in disguise. Designing the Rollz Flex in this way hides the stigmatizing features. Another solution that would fit this strategy is about diversing the attention away from stigmatizing features. Personalisation is an example of this solution.

A third strategy is about empowering the product user against stigma. Within this strategy the product could create additional benefits or it could give the impaired user qualities that outperform the qualities of abled persons. This way the product will be accepted better by society.

MARKET

The market of mobility assistive devices can be seen as conservative. Most of the available products have stigmatizing features and most innovation is limited to incremental steps. The Rollz Motion has been designed to outperform the competition and to look different than other products in the market. This way the product stigma that is attached to wheelchairs and rollators was intended to be bypassed. The products of Rollz can be seen as very innovative. (Appendix A.4.3)
As a result of this design strategy, the Rollz Motion became too innovative to be understandable for users and resellers. They were not able to understand the design philosophy behind the Rollz Motion, which led to low sales numbers. While the innovativity and uniqueness of the Rollz Motion can be seen as a strength it also causes problems in marketing and sales.

While they are rare, assistive products and technologies do exist that do cope better with the stigmatizing effects of mobility assistive devices. More and more concepts and products are being developed that posess features that help overcoming the stigma. The Twizzler is an example of such a product (see figure 11). This is a self balancing

figure 11 (Impact Presentations, 2017)

wheelchair that gives the user more ability than abled users and therefore re-shapes the stigma. Due to this added feature other people percieve the wheelchair in a more positive way and it empowers the user. This does show that the found design strategies to overcome stigma can work.

“The created concepts and products show a shift towards smart healthcare and smart mobility”

At the moment the use of these technologies is not found throughout the entire market. The large majority of mobility assistive devices is non-electric, but the created concepts and products show a shift towards smart healthcare and smart mobility. These concepts show potential in addressing the problems of the users and in lowering healthcare costs. A next innovation step is needed to make the products of Rollz fit for this shift and to keep the innovative position that Rollz possesses at the moment.

This innovation step cannot be too large. This can result in a similar situation compared to the launch of the Rollz Motion, where the product was too innovative for the market. The first innovation step towards a smart Rollz Motion needs to be small enough to be understandable for the users. This finding would justify a choice for a push-support solution as a drive system for the Rollz Motion. For such a solution a (smart) system helps a push attendant in pushing the Rollz Motion as a wheelchair. A push-support solution fits the wants of the users directly and can be a good first step into making the Rollz Motion intelligent.

CONCLUSION

The conducted research highlighted multiple problems that can be solved or improved through the use of smart (drive) systems. Solving these problems should result in a vehicle that is comfortable for the user(s) and the push attendants, supportive enough to be safe and reliable in context, and perceived well by both users and society. The analysis displays that the Rollz Motion shows potential to be stably motorised in its current design state if the right control system will be implemented.

SCOPE

A push-supportive drive system for the Rollz Motion proves to fit this vision best and shows potential to solve most of the problems. A push-support system suits the wants and needs of users and their relatives directly and such a solution will therefore be logical and understandable. Besides, a system like that will fit the way in which the product owners are using the Rollz Motion at the moment and applies to the vision of the Rollz Motion to make its users do more activities together.

A self-controllable solution could result in more indepency for the user, and therefore can be perceived as less stigmatic and more practical since no push attendant is needed. While this is true, the absence of a push attendant will be the cause of more problems as well. Obstacle climbing is one of these problems. For a push support solution the push attendant can overcome an obstacle easily, but for a self-controllable solution an additional system should be designed to help climbing this obstacle. The independency of a self controllable system will lead to a large dependency on the system. Choosing for a push support solution will therefore fit a first innovation step better, with lower investments and lower the overall risks.

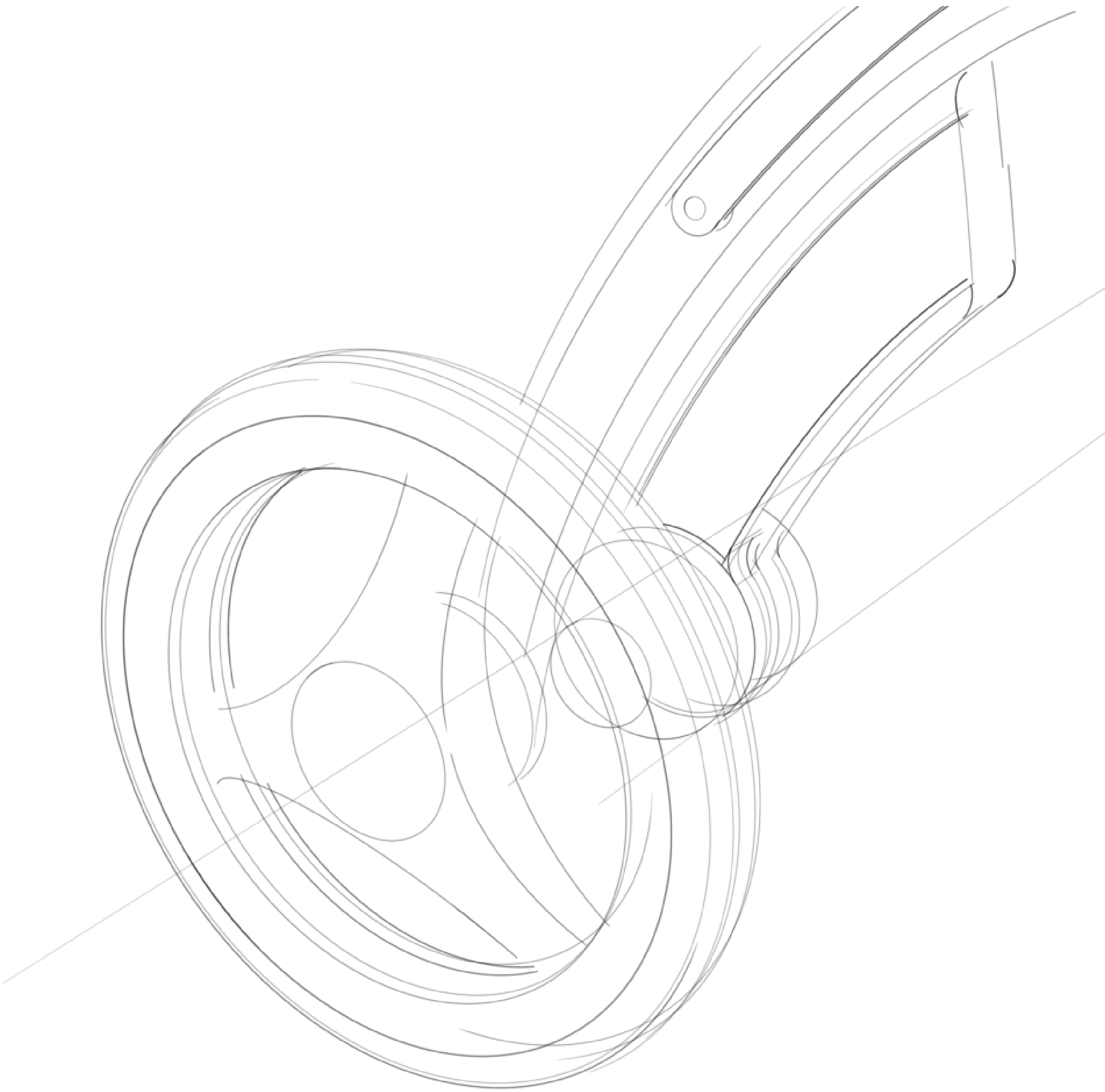
This push support solution needs to be fit for the future. Other solutions might be favourable for later innovation steps. A system that can be adapted to meet the requirements and allow these innovation steps will be beneficial.

PROGRAM OF REQUIREMENTS

All analyses resulted in requirements for this product that is described in the scope. These requirements concetize how this product can lead to the description in the vision. Each of the requirements is linked to one of the segments of the vision. The entire program of requirements can be found in the appendix (Appendix B.1).

CONCEPT DESIGN

This chapter focuses on the creation of ideas and the transformation of these ideas into feasible concepts. Three design strategies have been used to fit each of the components of the vision (figure 12). These different strategies have been merged afterwards to create the concepts.



The comfort component of the vision can be fulfilled when the product will have the correct functionalities. Especially the function of generating power to support the push attendant will relieve the push attendant and create comfort. This process started with the definition of functions that the product to be designed should fulfil. For each of these functions principle solutions were created.

The support component of the vision is about trusting the product. This is dealing with the interaction that users have with the product. In order to trust the product, users will constantly need to feel safe while using it. To satisfy to this part of the vision a prototype is used. Ideas on controlling and interacting with the product have been prototyped and tested. Based on the outcomes of these tests the ideas have been developed further.

For the third component of the vision, perception, an approach found in literature has been followed. Vaes (2014) created an approach of redesigning product related stigma within a product. Along with this approach 17 ways to do this were distinguished within his work. These 17 ways formed the starting point for an ideation process where the stigma related features of a power assisted mobility aid were being redesigned.

The outcomes of the three methods served as input of the concept designs. These outcomes have been merged together where possible to create unique and functional concepts.

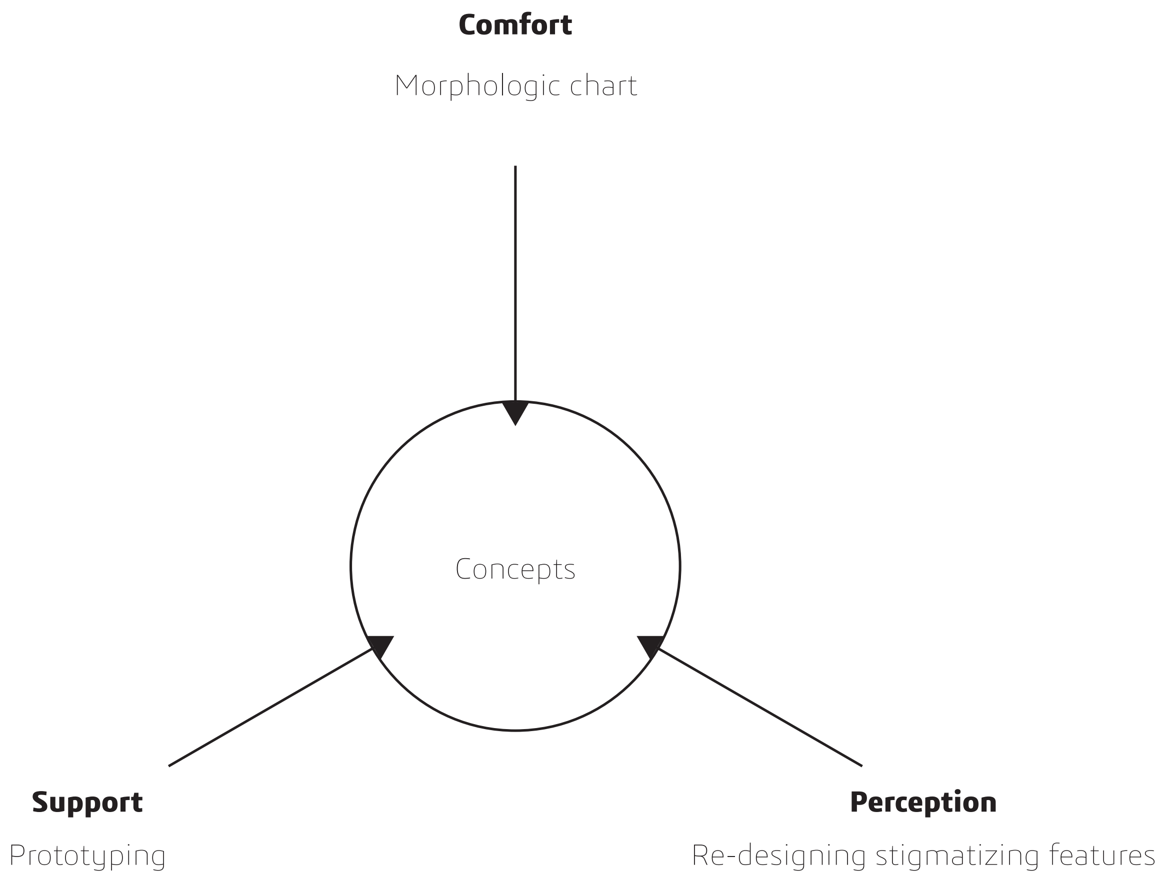

Comfort
Morphologic chart
Concepts
Support
Prototyping
Perception
Re-designing stigmatizing features

figure 12

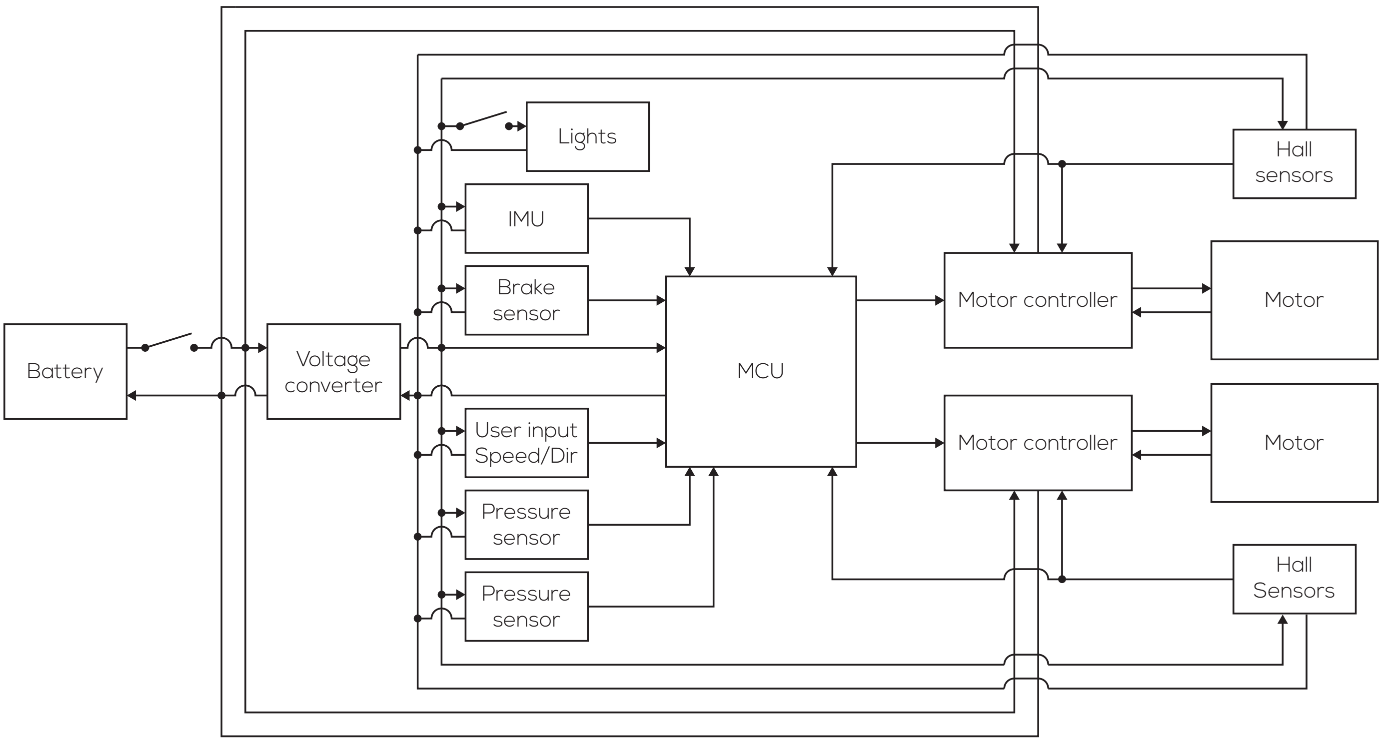
IDEA GENERATION: COMFORT

As a starting point for this ideation strategy a schematic overview of the required components within the system has been created. This schematic was based on the programme of requirements which clearly mentioned the components and their functionalities. Appendix A.5.3 shows the process of the formation of this schematic. This schematic can be found in figure 13.

Having this overview allowed to start applying all components to the Rollz Motion. To structure this process a morphological chart has been used. Figure 14 shows this morphological chart that has been used for this ideation session. It basically shows alternative ways to fit the required components to the Rollz Motion.

One of the outcomes of this method was that some of the solutions do not interfere. For example, the choice for a specific user input system does only have marginal consequences for the other components since these are probably placed on different parts of the Rollz Motion.

figure 13



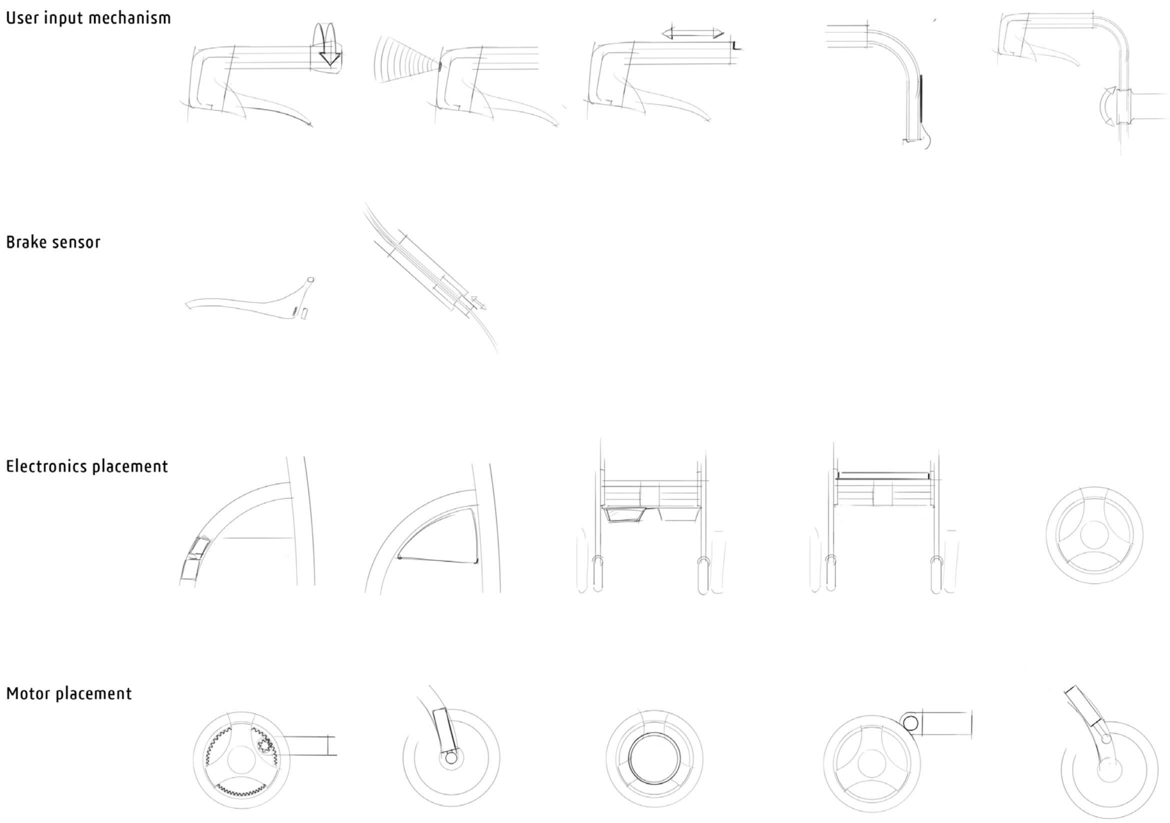

User input mechanism
Brake sensor
Electronics placement
Motor placement

figure 14

IDEA ITERATION: SUPPORT

While the system overview and the ideas that are presented in the morphologic chart showed first potential in fulfilling the necessary functions, these methods lack in depth data on the effectiveness of each of the proposed solutions. This effectiveness has a large influence on the product interaction and the relationship between the user and the product. A prototype has been built as an elaboration of some of the proposed principal solutions (figure 15). This gave a first indication whether the solutions could match the formulated criteria regarding the support component of the vision.

The use of the prototype can be seen as an evaluating approach, and in some ways it was indeed used to evaluate the ideas, but based on this evaluation new ideas emerged. Basically the control principles have been tested and one or multiple design iterations followed afterwards until a sufficient level of support was reached.

The design of the used prototype can be seen as modular in a way. This means that is was relatively easy to change and improve solutions. The prototype used two 12" wheel with integrated HUB motors. These motors were controlled using an Arduino and two motor controllers. Different types of sensors served as input for the Arduino. More information about the prototype and the used components can be found in appendix C.2.1 and C.2.2.

figure 15

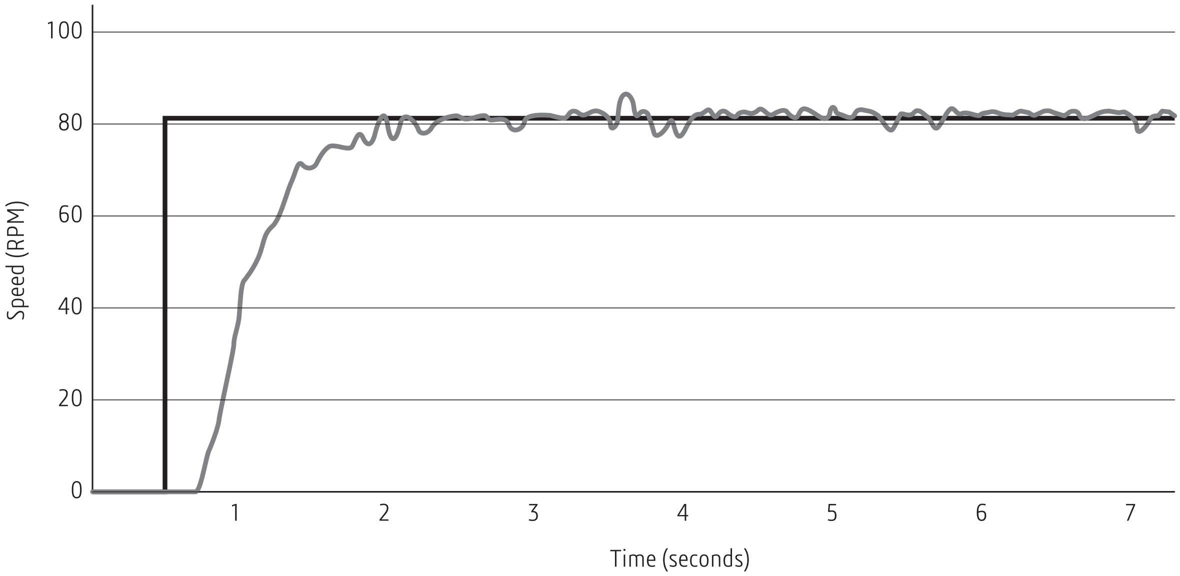


figure 16

Motor control

The prototype allowed to start testing a proper way of controlling the motors. In the previous chapters some control algorithms have been shown and some even were proposed to be included within the design. While these proposals still were theoretical, the prototype allowed get more insight in the effectiveness of these control algorithms. Furthermore it provided user feedback about the types of velocity control.

The Proportional Integral control algorithm that is used widely in power assisted wheelchairs proved to be effective in precisely controlling the motors sufficiently to control the motors in the prototype. This can be seen in figure 16. This graph shows a step response function of the desired speed (black line) and the actual motor speed in RPM (red line). It shows that a properly tuned system slowly and gradually accelerates to the desired speed.

Users that tested the prototype that was equipped with this control algorithm liked an acceleration where the actual motor speed gradually rises to the desired speed. This gave the user the feeling of a controlled acceleration. The users disliked when the acceleration was faster and when the speed overshoot the desired speed for a brief moment. The high acceleration rate made the vehicle drive away from the push attendant. This made the participant brake again. Such a system created an ongoing cycle of stopping and accelerating.

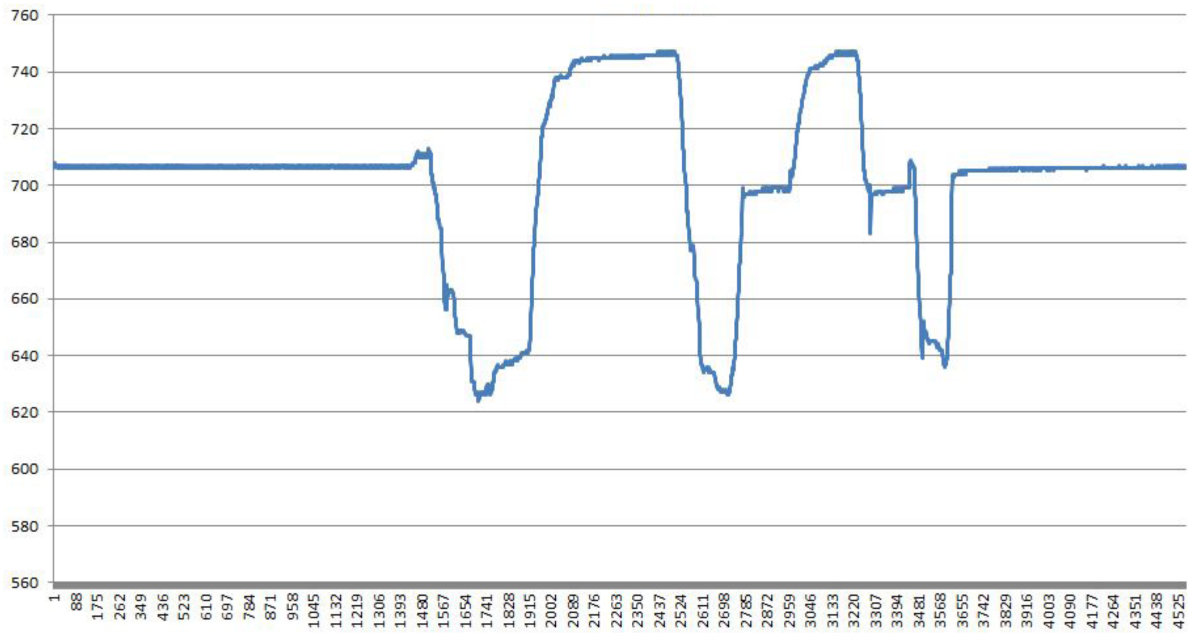
Human machine interaction

The ideas regarding the human machine interaction that are shown in the morphologic chart are approached from the perspective of the user. These ideas focus on proper ergonomic positioning and acceptable movements to control the power assisted Rollz Motion.

The angle of approach for the prototype was rather technology based than user based. Sensors that could detect the intentions of the users were selected and tested on the prototype. These tested sensors/ components included:

Ultrasonic proximity sensor
Joystick
Thumb throttle/Potentiometer
Inductive sensor

figure 17



IDEA GENERATION: SUPPORT

The third component of the vision is about redesigning the stigma that is attached to assistive mobility devices. Vaes (2014) proposed 17 design strategies to do this. Multiple brainstorm sessions has been held to find ideas for the application of each strategy to the Rollz Motion. The outcomes of these sessions can be found in Appendix C1.1.

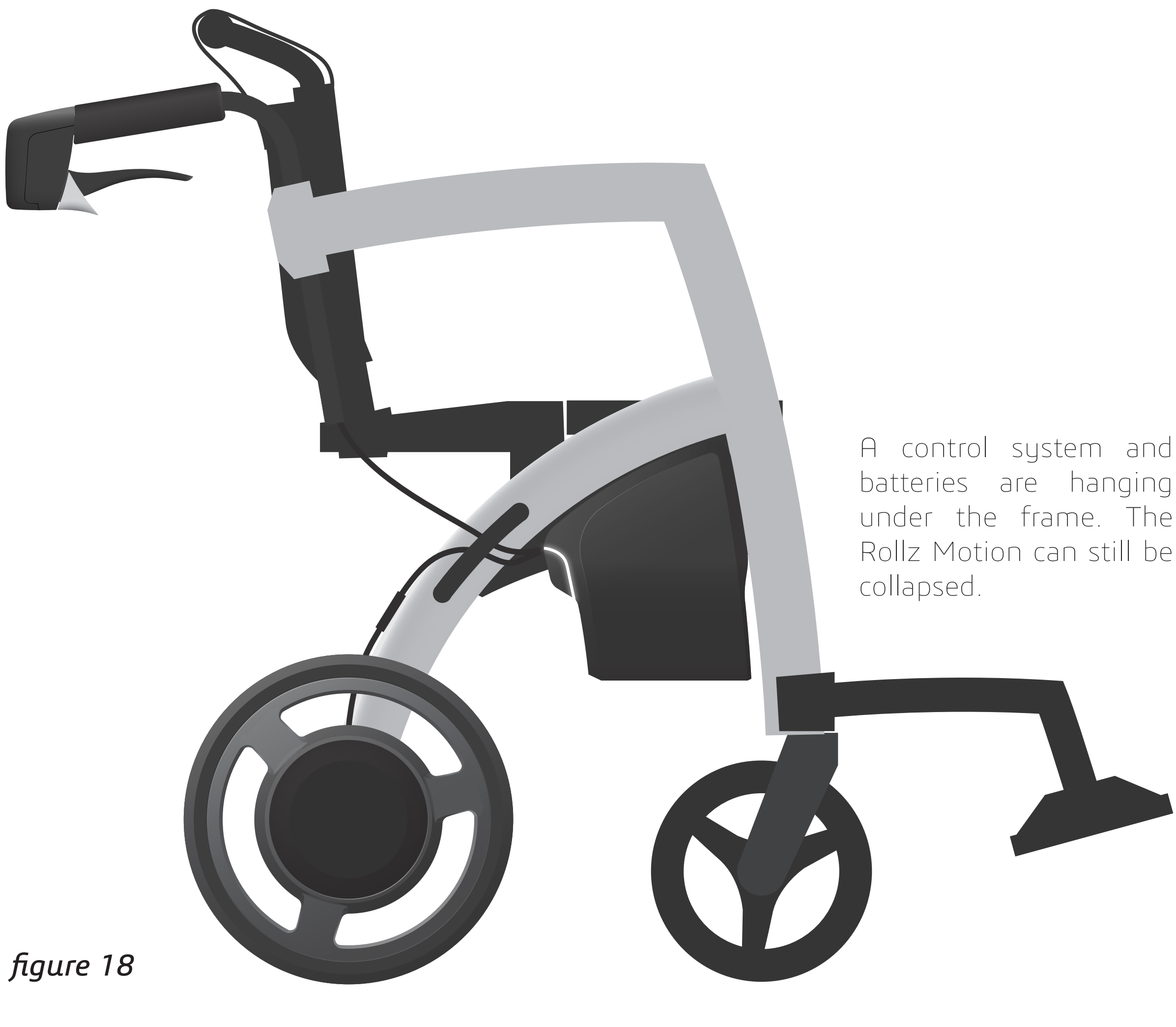
Some strategies turned out to be more relevant than other strategies. Strategies like camouflaging or disguising stigma sensitive features and strategies about giving the vehicle extra abilities were easy to generate ideas for and showed potential for redesigning the stigma. While other strategies like focusing on the ultimate product goal did not match the scope of the assignment.

CONCEPTS

Merging the outcomes of the three idea generation strategies into concepts was the logical next step within this process and resulted in four concepts. Each of the concepts is presented below. The concepts are presented in more detail in appendices C.3.1, C.3.2, C.3.3 and C.3.4.

Concept 1: Future proof distraction

The solutions for this concept have been chosen based on quick installation. The system can easily be attached to the Rollz Motion without having to replace or change structural components.



A control system and batteries are hanging under the frame. The Rollz Motion can still be collapsed.

figure 18

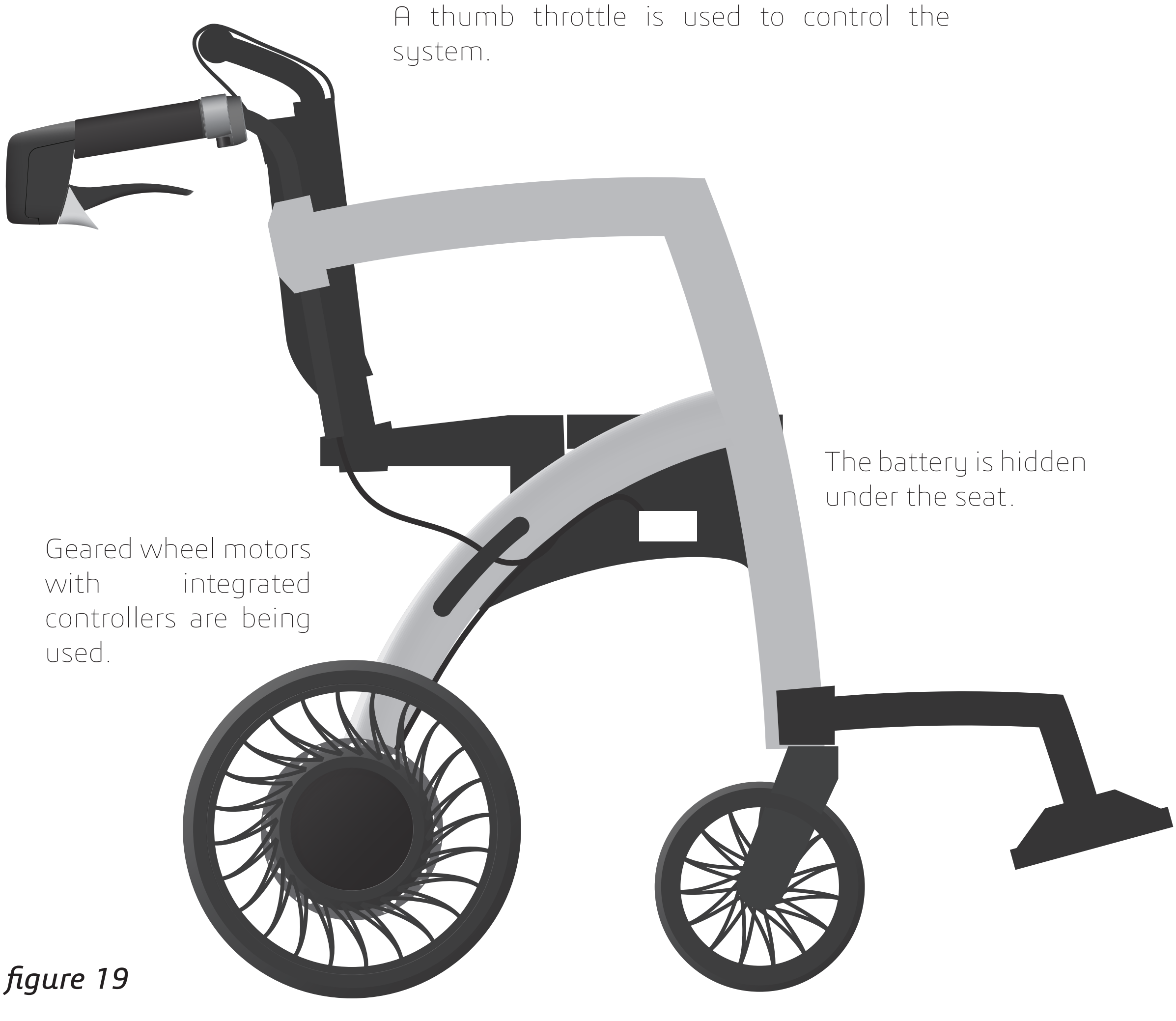
Concept 2: Lightweight cruising

Concept 1 lowered the total lifting weight by making parts detachable, while concept 2 lowers the overall component size and weight. This creates a system that looks lightweight and that is partially hidden inside the Rollz Motion.

The user can control the Rollz Motion through a thumb throttle, which has a cruise control function that keeps the distance between the push attendant and the Rollz Motion constant. When the cruise control mode is enabled the Rollz Motion is basically following the movement of the push attendant.

The rims of the wheels work like a suspension system. Each of the spokes can be seen as a damper that can smoothen the motion of the vehicle. This can further inrease the cruise controlled experience.

A thumb throttle is used to control the system.



The battery is hidden under the seat.

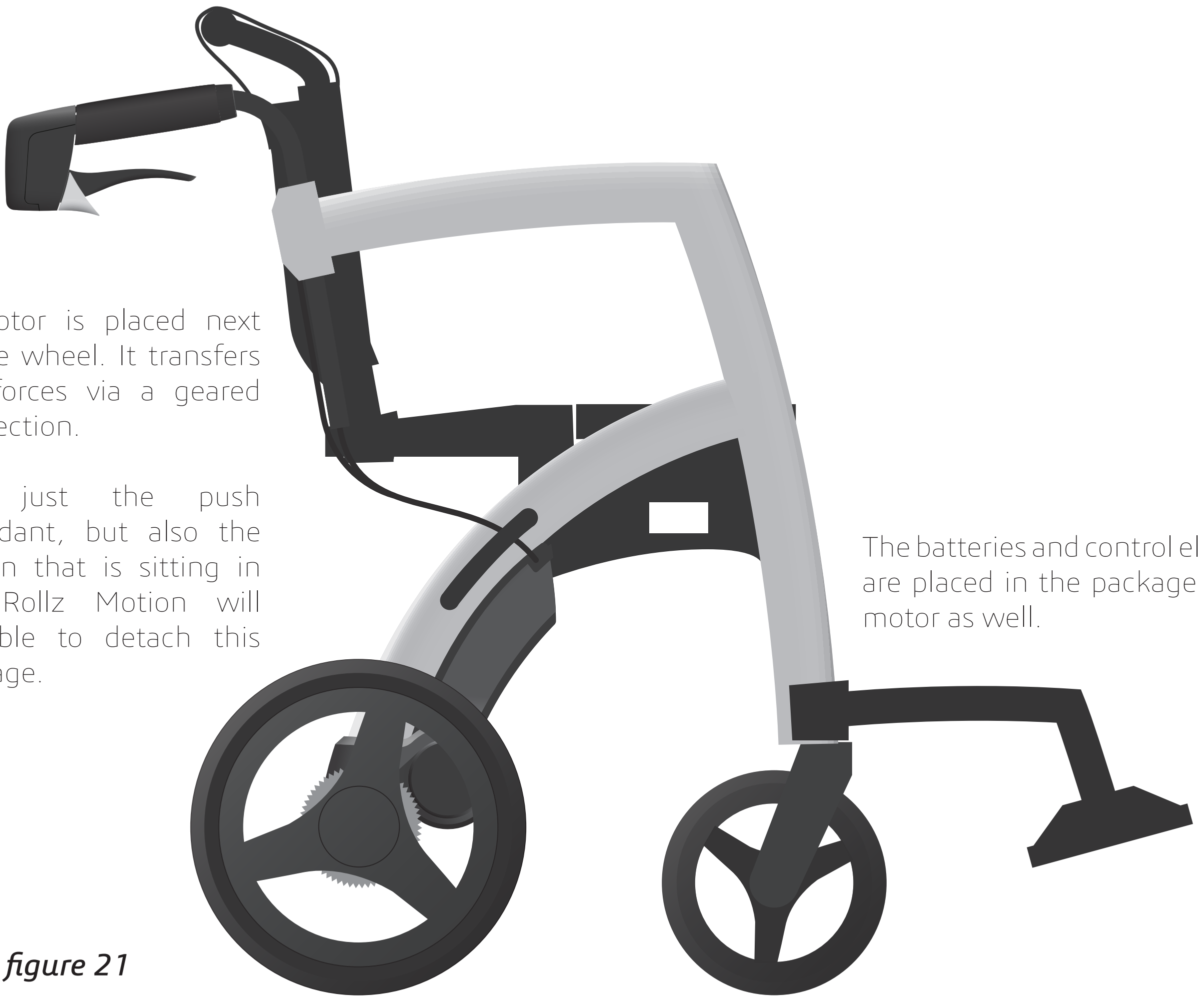
Geared wheel motors with integrated controllers are being used.

figure 19

Concept 3: Attached & Together
The motor package can be placed on a gear that is fitted the rims of the rear wheels. This solution limits the additional width of the vehicle. The other concepts all get wider, something which would not be useful when someone is walking next to the vehicle to control it.

A motor is placed next to the wheel. It transfers the forces via a geared connection.

Not just the push attendant, but also the person that is sitting in the Rollz Motion will be able to detach this package.



The batteries and control electronics are placed in the package near the motor as well.

figure 21

VALIDATION

The last step of the design process was a validating step that analysed whether the system sufficed to the vision. Each of the criteria has been validated seperately and the results can be found in appendix D.2.1. Below some interesting results are being presented.

Performance

The performance of the prototype and the user input control algorithm has been evaluated for different drive conditions. This quantified the results and gave an indication of the effectivity of the system.

A first test was run to see whether the system could reach a constant speed of 5 km/h for a specific situation. If this passed the acceleration rate was tested. This acceleration test was performed to get an indication of the robustness of the system. During user tests the system needs to provide stable control for numerous different scenarios.

This acceleration test started from standstill on a specific type of surface and with or without a determined load. A smartphone was used to send a signal that enabled to the system to accelerate to 5 km/h. Without pushing the Rollz Motion forward the researchers made the system accelerate. While doing this the speed data was being recorded.

The recorded data can be found presented in graphs (figure 22). These represent different testing situations and conditions. The tests show that the system is capable of giving a desired response as mentioned in the ideation phase on page 51.

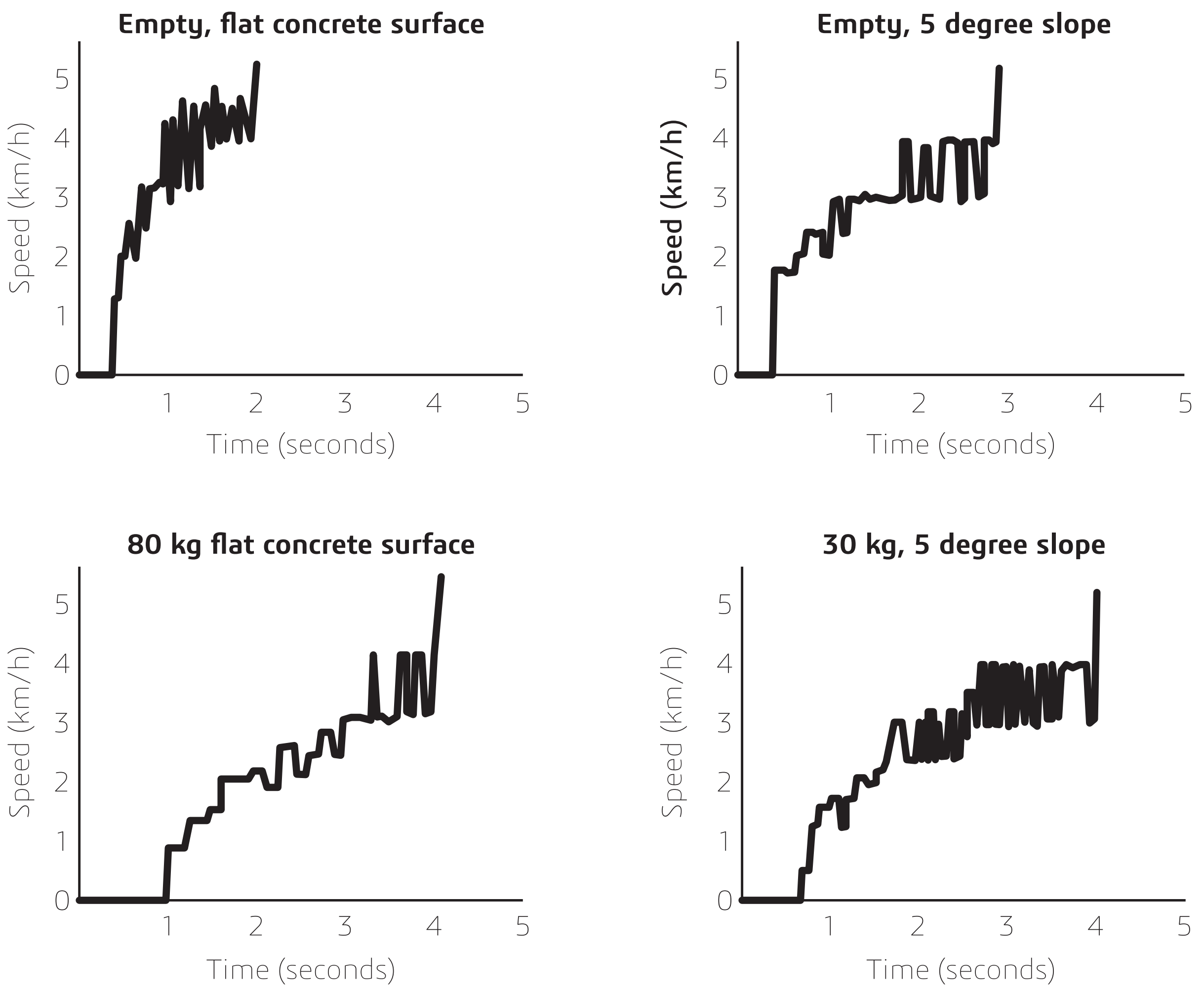


figure 22

While the PI control algorithm was sufficient to fulfill most of the tests that proved the effectivity of the concept, this control algorithm as implemented in the prototype will fail to create the desired levels of support within the product. As mentioned this algorithm needs to be improved further, or changed for another speed control system to create the desired levels of support.

User tests
The working prototype allowed to start testing with users. These tests tried to determine whether the system would work intuitively and effectively and whether users were able to trust the system. The full tests can be found in appendix D.4.1.

These tests showed that users need some time to start trusting the electric Rollz Motion. The results improved a lot after the users got instructed to just start walking. Still some moments of fear could be distinguished, but these faded away after some minutes. All participants were able to use the system as intended. Users mentioned that they liked using the system and found the movement very natural.

“When I was sitting in the Rollz Motion I did not feel whether the motors or the push attendant were delivering the force”
Joris, participant (for the performance test)

Approximately half of the user tests took place inside a building. The responses of the users of these tests inside were more negative than the tests that took place on and outside location and the users were more cautious before using the Rollz Motion inside. While participants of the user tests that took place outside found it easier to start walking. The rate of acceleration of the prototype fitted the context with more than enough space to start moving best. Some users mentioned that they found the system too sensitive and the acceleration rate too high. Inside, or in other narrow areas users wanted to have little acceleration speed and more control. This finding strenghtens the belief that the numerous speed modes are necessary.

“The movement feels completely natural”
Ben, participant

CONCLUSION

To conclude, lets go back to the vision. This vision clearly mentioned that a smart solution that would be fit to a mobility assistive device should offer comfort, support and should minimise product related stigma. Having the presented push support system allows to see to what extent this vision has been implemented in the system.

Comfort

When an unpowered Rollz Motion with a 125 kg person in it faces a 8 degree slope it will cost the push attendant 220 N of pushing force to climb the hill. When the motor packages are added, together with force sensing handles, this pushing force can be as low as 10 N, while still being able to climb the hill. For this ultimate situation, 22 times less force is required to get the same result. This decrease in push force improves the comfort of the push attendant. This will allow the users to extend their range and increases the range of environments that can be accessed easily.

While adding the push support system will not directly have a positive effect on the physical comfort levels of the person in the Rollz Motion, the system can apply to the mental well being of the user. These users do not have to worry about the push attendants getting tired and they do not have to feel guilty about having to give a push attendant a heavy task of pushing.

The prototype shows potential for a push support system to be of good use in a rollator configuration as well. The motors can help in climbing obstacles and lower the required pushing force when a load (e.g. groceries) are placed in the Rollz Motion. Further research is needed to define the true potential in the rollator configuration.

Support

The proposed control system can eliminate some of the causes of accidents with mobility assistive devices. It can intelligently determine the state of the system and detect the condition to maintain stability and properly transform the input of a user to controlled motion.

As mentioned in the vision, the push attendant can be seen as a supporter, who is supporting the person in the Rollz Motion. The push support system makes an addition to this relationship. Where the push attendant still supports the person in the Rollz Motion, the system is supporting the push attendant as well. The system supports the push attendant in creating safe, controllable and reliable means of transport. This increases the group of users that will be able to use the system.

Perception

The system provides a next step in the development towards a stigma free product. The prototype tests indicated that the added motors worked appealing to push attendants. They seemed to enjoy and have fun while pushing the Rollz Motion around.

Still, due to the low impact character of the concept, the additional packages will blend in the design of the overall Rollz Motion. For this reason the destigmatising effect of this will be limited. The added package will not have the power to completely reshape the stigma. The person inside the Rollz Motion will still feel a dependency on the push attendant and hierarchy. Further innovation steps will be required to solve these issues.

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