

Accessibility and Universal Design: Motorization and improvement of a wheelchair

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03.06.2013 **Abstract**—Electric powered wheelchairs improve the mobility and autonomy of disabled patients and elders. These people have different requirements regarding steering, size, and shape of the wheelchairs. The electric power wheelchair market already offers products like wheelchairs moving with joysticks, brain control, or eye gaze control. However, to fit a specific users needs the wheelchairs often have to be customized.

In this paper, we show how to combine two existing wheelchairs, an electric power wheelchair and a non-electric buggy and show how to adapt the steering control to the needs of a specific client. Furthermore this paper informs about how to design and build a new chin control system, an universal seating system and adapt pushhandles to a redesigned electric wheelchair.

Index Terms—accessibility, chin control, electric powered wheelchair, mobility, steering systems

I. INTRODUCTION

An ELECTRIC POWERED WHEELCHAIR (EPW) can enhance the mobility of disabled individuals in daily life and reduce the dependence on human aides. EPWs are wheelchairs which are propelled by electric motors rather than by manual power. They are useful for disabled humans who cannot use their arms to power a manual wheelchair, people who do not have the upper body strength to self-propel a manual wheelchair or for people who do not want to be dependent on human support. EPW can change the life of the user significant if the input device is adjusted to the physical and mental abilities[1]. The users of electric wheelchairs increase their mobility, maneuverability and independence[2]. Often the application of EPW accompanies with very positive psychosocial effects on its users[3].



Figure 1. A) EASYS BUGGY B) COMBINED WHEELCHAIR C) POWER-PICCO

In the project ACCESSIBILITY AND UNIVERSAL DESIGN we combined a seat of a child buggy with the chassis of an ELECTRIC POWERED WHEELCHAIR in order to design a

powerchair which is adapted to the requirements of a special client who suffers of Spasticity and Dystonia. The disease makes him unable to move his legs, hands and upper body properly. Due to the small budget we received two already available wheelchairs from our customer, a physiotherapists company. In Figure 1 C) the electric wheelchair is shown. It is equipped with a motor and a joystick as a steering interface. The other wheelchair shown in Figure 1 A) is a simple child buggy. Both of these offer certain advantages and disadvantages to the client. The buggy offers a seat meeting the exigencies of the client and the electric wheelchair enables the client to move without the assistance of a person. The reason to combine these wheelchairs was that considering the physical abilities of the client the steering interface of the EPW was not appropriate. Furthermore it was better to connect seat of the buggy with the base of the EPW to one convenient wheelchair. Thereby the advantages of each wheelchair were combined.

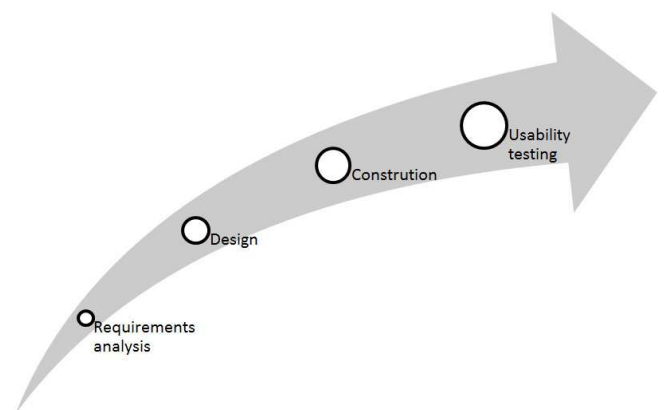


Figure 2. Project stages

In Figure 2 the process of our project is displayed. We start the project by analysing the requirements of the different stakeholders with the main focus on our client. According to our findings in the analysis we designed a universal seating system, a new steering method and came up with a new design for the communication system and the pushhandles. After the designing part the construction part followed. The final process was the usability testing of all components.

This paper is divided in five different chapters. After this introduction chapter a second chapter follows in which we consider the project background. In the third chapter the

project work is presented. We explain first the problem, present the designs for the solutions, compare costs of the component and inform about the usability of each product. The fourth chapter comes up with a conclusion and in the last chapter we propose further work.

II. PROJECT BACKGROUND

A. Client

The project is carried out for a young child which suffers of Spacidity and Dystonia. Spacidity is a feature of altered skeletal muscle performance in muscle tone involving hypertonia. Dystonia is a neurological movement disorder in which the patient cannot control his movement. Sustained muscle contractions cause twisting and repetitive movements or abnormal postures.

The cognitive abilities of the client can be described as capable of understanding and also giving replies by moving his head or smiling. The client is not able to talk or move his arms and legs properly. He can move them but sometimes he loses control over his movements.

Considering the consistency of his movement ability of hands, head, feet and lips we came to the conclusion, that he is capable to move his head most homogeneous. He is able to move his head in all needed direction. Further an assistive tool supports his head movement and enhances his consistency.

B. Wheelchairs



Figure 3. POWER-PICCO 1.431

POWER-PICCO 1.431: The chassis of the POWER-PICCO is made out of steel. This ensures the user to have a very stable product. Further the chassis provides a joystick interface for usage by hands, an attached engine and furthermore a battery. The availability of a chargingstation for the battery is an other advantage of this chassis.

The seating unit of the Power-Picco is very robust but doesn't offer any special features. For the client it does not fulfil the needed requirements.



Figure 4. A) EASYS BUGGY B) EASYS SEAT

EASYS BUGGY: In contrast to the POWER-PICCO the EASYS BUGGY chassis is very light. It is made out of aluminium. Additionally it is possible to fold the chassis and lock the seating unit on top.

The seating unit offers a lot of special features. It is equipped with a special balance safety system. Further it offers physiological pivots for the hip-and knee joints, lateral body guides and a breathable seat and back upholstery with reflective safety-seams. The most important features are that it provides a very easy adjustable and accessible components and a click system for fixing at the chassis. The seat meets all need of the client.

C. Project requirements

For this project and the involving tasks it is important to meet the requirements set by the stakeholders of the project. The main stakeholder of the project consist of the client, the clients family and of a physiotherapist company.

- *The client:* He needs a secure EPW which is adapted to his physical and cognitive abilities. The electric wheelchair has to be equipped with a suitable seat, footrest, backrest, front and rear wheels, motor, push handles and a steering interface.
- *The family of the client:* They want a usable electric wheelchair to enhance their mobility with our client.
- *Physiotherapists company:* They require a wheelchair which enables them to enlarge their training with the client and support his learning process. Another crucial requirement of them is to achieve the goal without any provided budget.

III. COMBINING TWO WHEELCHAIRS

This section proposes how to combine the seat of the EASYS BUGGY with the chassis of the POWER-PICCO. Furthermore this chapter presents the solution for the new steering system, a new design for the communication system and the handles.

A. Universal seating system

Specific requierements: For combining the chassis of the POWER-PICCO with the seat of the EASyS buggy it

was important to focus first on the requirements. A major requirement was that after the project it should still be possible to use complete EASyS-System. Taking this requirement into account it was mandatory to design a solution which enables the clients support to attach the seat of the EASyS BUGGY at the chassis of the POWER-PICCO and also on the chassis of the EASyS BUGGY.



Figure 5. Click System of the EASyS buggy

Design: The seating fixture has to adapt the fixing system of the seat (Figure 5). To make it possible to switch the seat on and off the electric wheelchair it was necessary to design a corresponding appliance to the base of the seat. Following these ideas we designed a seat fixture (Figure 6). Between the main bars of the chassis we added steelbars. Further we needed a system to ensure that the seat stays in the right position. Therefore we added a stop mechanism.

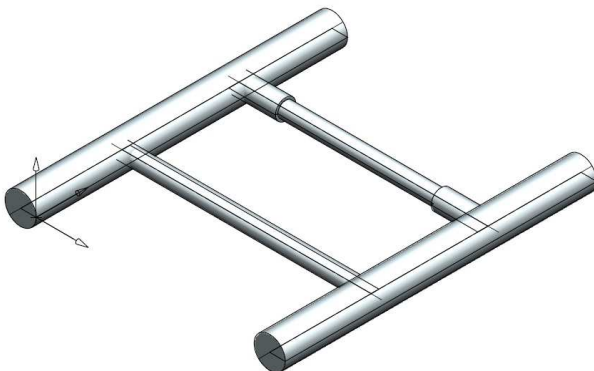


Figure 6. Design universal seating system

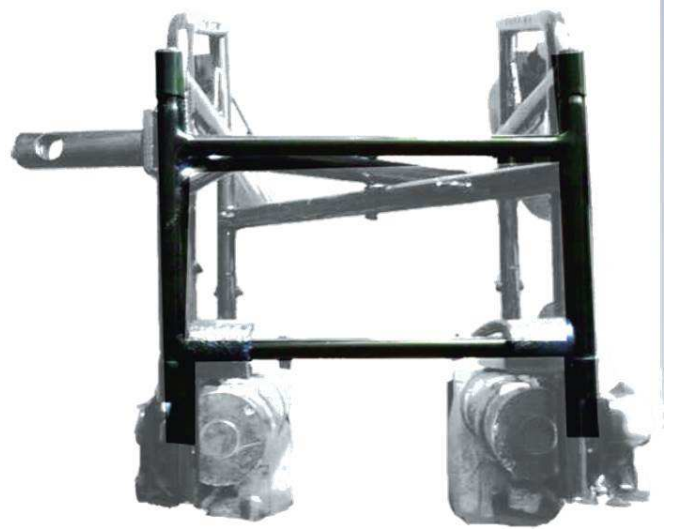


Figure 7. The constructed seat fixture

Construction: The bars shown in Figure 7 are made out of steel to ensure the stability of the fixture. The connection between the chassis and the bars was made by welding. This assures the maintenance of the product. The stop mechanism is made out of plastic due to cost issues.

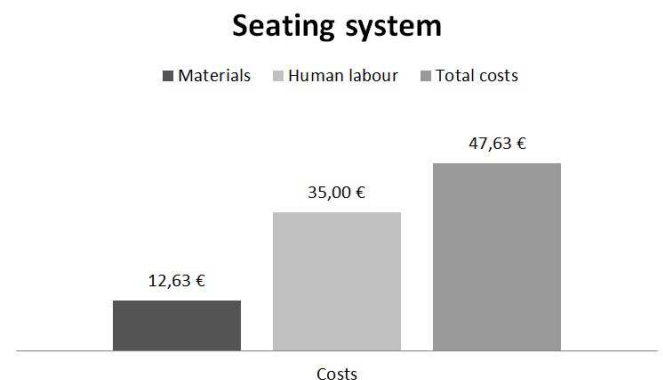


Figure 8. Costs seating system

Cost : The costs for the seat fixture are result of the purchase of two ironbars and two plastic tubes. Further employees of the university supported this task by mechanical advices and execution of welding process. Taking these costs into account the expenses sum up to 47, 63 € (Figure 8). The costs for the materials amount to 12, 63 € and the salary for the university employees accounts for 35, 00 €.

Usability: The testing process of the universal seating system proved the usability of this product. The seat can be fastend to the electric wheelchair. Also the pressure test showed that the mainenance of the system is strong enough to hold the client with his weight of about 30 kilograms.

B. Steering system

Steering approaches: The usability of a electric wheelchair depends very much on the appropriateness of the steering interface. A survey carried out in 2000 shows that

a wide majority of over 80 percent of EPW users steer their wheelchairs with a joystick and about ten percent use head or chin control for steering [4]. The state of the art approaches like eye gaze and brain control interfaces are not available at the commercial market so far. To find the best solution for the client we compared the convenience of eight different steering approaches.

Power wheelchair control interfaces used in 2000[4]	
Percents of patients using:	Average (n=46)
Joystick	81
Head or chin control	9
Sip- n- Puff	6
Other (eye gaze, tongue pad, head, hand foot switch controls)	4
Total	100

Table I

STATISTICS OF WHEELCHAIR CONTROL INTERFACE USAGE

Evaluating an appropriate steering interface: In a primary research the steering approaches joystick, chin, sip-n-puff, head, voice, tongue, eye gaze and brain control were evaluated. Table 2 lists the three best solutions for the client. It compares chin, eye gaze and head interface with the factors learning, placing, controlling, cost, usability, movement, grip, maintenance, effectiveness and safety. The factors in the table vary between two and minus two. Minus two stands for a very inappropriate solution while the score of two means that the solution is very good for the client. The score for the steering results were evaluated after an intensive research on the different approaches. The decision to implement the chin interface was taken based on the table. The most important factor to choose the chin control was that it is the most appropriate solution due to his abilities. Furthermore it is a cheap solution, that it is compared to the other steering systems very safe and that it is relatively easy to learn.

Control device	Chin	Eye Gaze	Head
Learning	1	-1	1
Placing	1	2	1
Controlling	-1	2	1
Cost	2	-1	1
Usability	2	1	1
Movement	-1	1	-1
Grip	-1	1	-1
Maintenance	1	-1	-1
Effectiveness	2	-1	1
Safety	2	1	-2
Endscore	8	4	1

Table II

CONVENIENCE RESEARCH ON STEERING APPROACHES FOR THE CLIENT

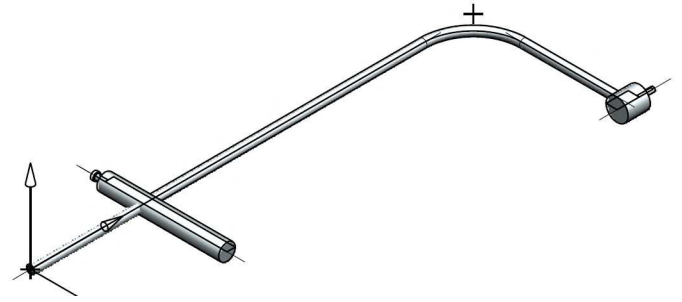


Figure 9. Design chin control system

Design of the chin control system: Although the decision for the chin control system was done, there are different solutions on the commercial chin control market. One approach is to put the chin control at a special holding around the neck. This establishes the opportunity to move the upper part of the body while steering because the system moves with the user. Another approach is to attach the chin control system to the wheelchair. Due to this solution the user is able to move his body more independent. Following the second solution we came up with a design for the chin control interface.

Focussing on the usability of the steering system it was necessary to take into consideration the shape of the interface, the materials and the accessibility of the steering system.

The design of chin interface is built up of a joystick and a control in the shape of a ball. The ball is made out of soft plastic, which enables the client to steer the wheelchair smoothly. It is a burling ball and the covering is a bit sticky whereby the chin of the client doesn't slip of the ball while steering.

The system which provides the steering interface is shown in Figure 9. On the top of the bended bar is a box for the joystick. The cables for the joystick pass through the bended bar and are connected with the controlbox of the former steering box. The big pipe crossing the bended bar is attached to the chassis of the POWER-PICCO. A screw at the end of the pipe makes it possible to adjust the steering interface into the right position for the client, because the bendend bar can be moved until it is bended down by the screw. This improves the accessibility of the steering system a lot. Although when the client grows it is easy to adapt the system to his size.

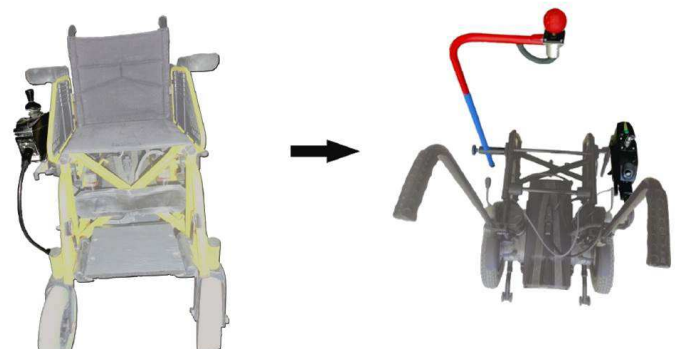


Figure 10. Change of steering interface: A) Joystick control B) Chin control

Construction: In order to build the steering system it was necessary to build at the upper part a box for placing the joystick, further a bar to hold the steering interface and a construction for mounting the system at the chassis of the POWER-PICCO. The bar holding the steering interface was bend and the box of the chin control was welded onto the bar. Additionally the mounting system was welded to the chassis.

The electrical construction part included changing the joystick to a chin control. Therefore the joystick of the original controlbox (Figure 10 A)) was removed and enlarged by a cable to use the joystick as a chin control. For making it possible to switch the steering system off and on a plug was added at the cable and the old steeringbox, which still contains the microcontroller as seen in Figure 10 B).

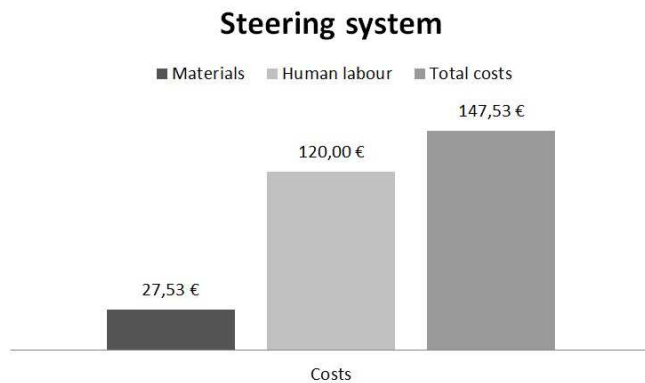


Figure 11. Costs steering system

Costs: Figure 11 shows the costs for the steering system. Analysing the materialcosts for the steering system the following components had to be considered the purchase of a connection bar, an attaching system, a base board, a steering-ball, a black shrink, AlphaWire industrial cable, a PVC tube, an electrical plug, a cylindrical knurled knob and different metalsprays. All these materials sum up to a price of 27, 53 €. The university employees supported the task by executing the production processes welding and bending and also by mechanical and electrical support. In total the expenses for human support amount to 120, 00 €. In total the costs for this product account for 147, 53 €.

Usability: The first usability test proved that the chin control interface was the right decision for this special client. He showed while the test that he is able to understand the steering of the chin control interface and also was able to move the EPW on his own. Also the client was able to move on his own due to safety issues human supervision is still recommended.

C. Adjustment of the pushhandles

Specific Requirements: Due to the design of the seat fixture and the added seat to the electric wheelchair the volume of the upper part of the wheelchair increased. The original pushhandles of the wheelchair did not fit into the intended place at the chassis of the POWER-PICCO anymore. In order not to cut any part of the EASYS seat it was mandatory to

change the fixture position of the handles and also enlarge them.

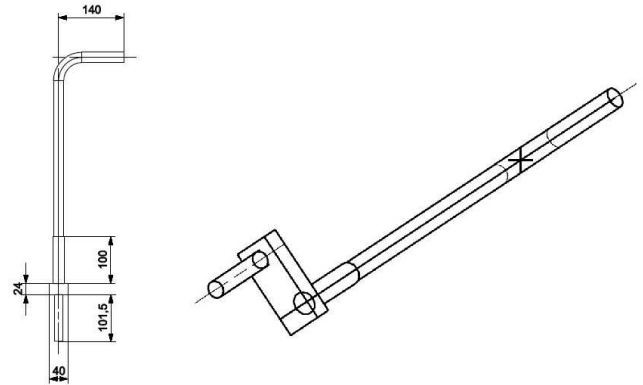


Figure 12. Design pushhandles

Design: To cope with this problem we designed a new fixture to mount the handles on. The design shown in Figure 12 consists of three parts. The original handles at the top part of the sketch. Beneath a further pipe, which enlarges the whole handle. Under the enlarging pipe we designed a metalblock as a connector between the old space for the handles and the new one.

Construction: The steelbars and aluminumblock were custom-tailored for the pushhandles. Into the aluminiumblock two holes were drilled with the corresponding diameter for the bars. The bars were fixed with a special glue to provide maintenance.

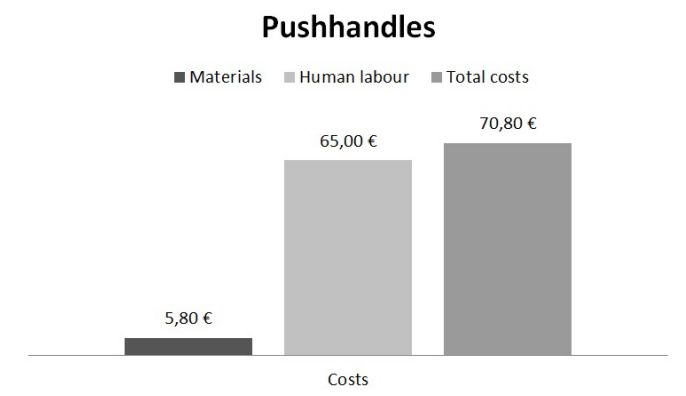


Figure 13. Costs pushhandles

Costs: Building the pushhandles a budget of 70, 80 € was necessary. Costs for the materials sum up to 5, 80 € and the expenses for the mechanical support and the execution of the welding process expenses with the amount of 65, 00 € occurred (Figure 13).

Usability: Testing the usability of the pushhandles proved the stability of the handles. Moreover by changing the position of the handles it is now possible to mount the EASYS seat on the chassis of the POWER-PICCO without taking the handles off. This makes the system very usable and less time

The final conclusion for this project is, that it is possible to achieve very helpful and assistive tools also with low costs. For the projectgroup it was a very good experience to work on this real life product and succeeding by improving the life of a special client.

V. FUTURE WORK

For following European Project Semester groups we propose to set up new projects about this topic. To cope with the issue of safety could be a very interesting and important as a project in upcoming semesters. As a solution we recommend attaching for instance distance sensors to the wheelchair which communicate with the engine and ensure that the EPW stops in case of danger. After this adjustments it will be possible to enlarge the environment from indoor to outdoor environment and also from always needing a caretaker to total autonomy.

Futhermore we propose to implement our design regarding the arms of the communication system in order to increase the mobility and maneuverability.

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