Towards more autonomy on flight experience: a new concept for the aisle wheelchair developed through design thinking

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INTRODUCTION

Traveling with limited mobility can be a very difficult task, especially if it involves being within the restricted space of an airplane. Aircrafts have physical constraints that create difficulties for accessibility. For this reason, passengers that are faced with limited mobility or disability have often a challenging journey throughout the entire flight experience [1, 2, 3]. Even though this is a notable issue, there are still few studies dealing with the experience of people with disabilities regarding the air transport [1]. Other existing studies are focused on accessible products, especially those designed for the elderly and people with disabilities. However, these products do not necessarily correlate with possible use in air transport [4].

Darcy [2] divides the flight experience in six stages (pretravel planning, boarding and disembarking, seat allocation, onboard personal care issues, equipment handling and customer service), pointing out the main difficulties faced by people with disabilities. Some of these issues have been explored by researches, such as: a new solution to improve the usage of an aircraft lavatory (onboard personal care stage), which allows easier access by a wheelchair on board [5]; improvements in the control of the personal entreteinment system, supported by the use of an accessible device integrated with the existing controls in an aircraft for functions such as reading light, flight attendant call and ventilation (onboard personal care stage) [6]; improvements on airport logistics concerning wheelchair storage and security (equipment handling stage) [7].

This paper focuses on the boarding and disembarking and seating allocation flight experience stages. Due to the narrow aisles of aircrafts, not fitting a standard wheelchair, wheelchair users must frequently be transferred from their wheelchair onto an aisle chair before boarding. The aisle chairs are significantly smaller and narrower than a standard wheelchair, making it uncomfortable for passengers [1,2]. However, comfort is not the only problem of the aisle chair. It also lacks the means of self-propulsion, resulting in implications for passengers' independence [2]. When passengers reach their seat, they may have to perform another transfer between the aisle wheelchair and the seat. Only specific more recent aircrafts and rows of seats have armrests that rotate up and allow an unhindered transfer. If it is not possible, the crew may have to lift the person over the arm of the seat. This is a risk process for both: the passenger, and the crew member [2]. During the flight, if any wheelchair user passenger wants to use the lavatory, they must do this process again, and it can be even worse since some aircrafts do not carry the aisle chair onboard [4,5].

Almeida et al. [7] proposed a redesign of an aisle chair that improves the transfer process, using either the lateral or frontal transfer options. That project was focused on people with sufficient strength in the trunk and upper limbs to support sitting and perform a transfer between seats. Tests performed with a functional prototype showed that the frontal transfer option, used to transfer from passenger's wheelchairs to the aisle chair, often leave a small gap between chairs which makes this transfer difficult for people with disability [8].

Despite recent improvements in aisle chairs design, existing solutions do not yet allow for independent movement within aircraft, requiring the support of a crew member in several movements. In this context, the objective of the research project presented in this paper is to develop a motorized aisle chair that allows people with disabilities to move independently throughout the aircraft, to access their seat on board, to move to the lavatory, and to disembark autonomously. The paper aims to present the concept design of the motorized aisle wheelchair proposed as a partial result of this research project. The paper also discusses the lessons learned during the design process. The paper is organized in three additional sections: Methodology, which describes the design approach adopted; Results, which presents the main findings of each design cycle; and Discussion and Conclusion, which presents the discussion of the results and lessons learned, draws the concluding remarks and outlines the next steps of the research project.

METHODOLOGY

The methodology followed to achieve the concept design for the motorized aisle chair presented in this paper was based on the Design Thinking approach. The Design Thinking is a human-centered approach to solve complex problems and to develop innovative solutions in a way to meet users' desirability, technical feasibility and economic viability [9]. This approach is applied through an iterative process that comprehends tasks related with user empath, problem definition, ideation, prototyping and testing, developing the solution in a series of design cycles. In this project, three design cycles were carried out: needfinding, benchmarking and critical function prototype. In the needfinding phase, the team sought to understand user needs through interviews and secondary data analysis. From this step, a list of requirements, constraints, and functions for the prototype was raised. During the benchmarking cycle, the team searched for existing solutions in the market to understand how effective they are in solving the needs of the user and at solving functional problems. In the Critical Function Prototype (CFP) phase, the team identified the most crucial functionality-based feature and developed ideas for that, complementing the Working Structure. The most promising idea (in the lens of desirability, feasibility and viability) was selected, prototyped and tested, providing the backbone to the concept design.

RESULTS

This section is organized according to the design process phases, summarizing the most relevant results of each design phase.

Needfinding

In this phase, three people with disabilities were interviewed. All of them had experienced flights and faced the challenges of using an aisle chair. Furthermore, two visits were organized to a mockup of an aircraft available at the university. They were essential to take measures and experience the environment. Another important source of information for the needfinding phase was interviewing members of previous projects focused on aisle chair design by the same research group [7, 10]. The reports of these projects were also analyzed, including seven interviews with wheelchair users, two interviews with experts from the aeronautics industry, and four interviews with crew members.

As result of the needfinding phase, a list of requirements, constraints and functions was systematized: (1) to provide more autonomy and independence for passenger on boarding, disembarking and on the way to the lavatory; (2) to avoid unsafe and uncomfortable transfers; (3) to allow the wheels to lock to avoid accidents during transfer and in case of turbulence; (4) to be comfortable, to avoid injuries for seating for long periods of time; (5) to quickly move inside the aircraft; (6) to prevent feet from being dragged while moving; (7) to keep the user's feet secure while moving the wheelchair; (8) to have an intuitive and accessible control system that allows full control of its movement by users; (9) to allow for maneuvering inside tight spaces; (10) to be narrow, considering that the average aircraft aisle width is about 19,75in; (11) to be light, considering that the average weight of an aisle chair is around 35 lbs; (12) to be compact, to facilitate its storage onboard; (13) to be inconspicuous; (14) to withstand passenger weight, considering 150kg a reasonable maximum load; (15) to withstand 6 G's, if onboard; (16) to withstand 16 G's during takeo□ and landing, if occupied by the passenger; (17) to be made with materials allowed to have onboard and approaved by aircraft regulators; (18) to allow for proper hygienization and maintenance.

Benchmarking

In this phase, the requirements, constraints, and function raised in the needfinding phase were used as input for benchmarking. Sixty-three solutions were identified, including patents of assistive technology of aisle chair and seat mechanisms for air transport, existing aisle chairs, new concepts for aisle chair, manual wheelchair, motorized wheelchairs, a concept for an omni-directional motorized wheelchair, scooters, power add-on units that converts a manual wheelchair into the powerchair, electric bicycle conversion kits and body lifts.

As results of this phase, two benchmarks are highlighted. The first one is the patent entitled "Mobile aircraft seat-wheelchair for disabled passengers and people requiring assistance" [11], describing a motorized aisle chair that enables passengers with disabilities to remain in the same seat during the flight since it is locked on the aircraft cabin floor. However, the design proposed in this patent has implications in terms of the space required for wheelchair mobility inside the aircraft and the locking mechanism of the aisle chair on the cabin floor is not fully described [4]. The mobility issue is apparently solved in the second benchmark, the aisle chair concept named Air Access [12], which is composed of two elements: a detachable wheelchair by which passengers can be transported onto and off of the plane, and a fixed-frame aisle seat on the aircraft into which the wheelchair is mated to create a regular seat. However, in this concept there is a lack of independence of the passenger in driving the aisle chair.

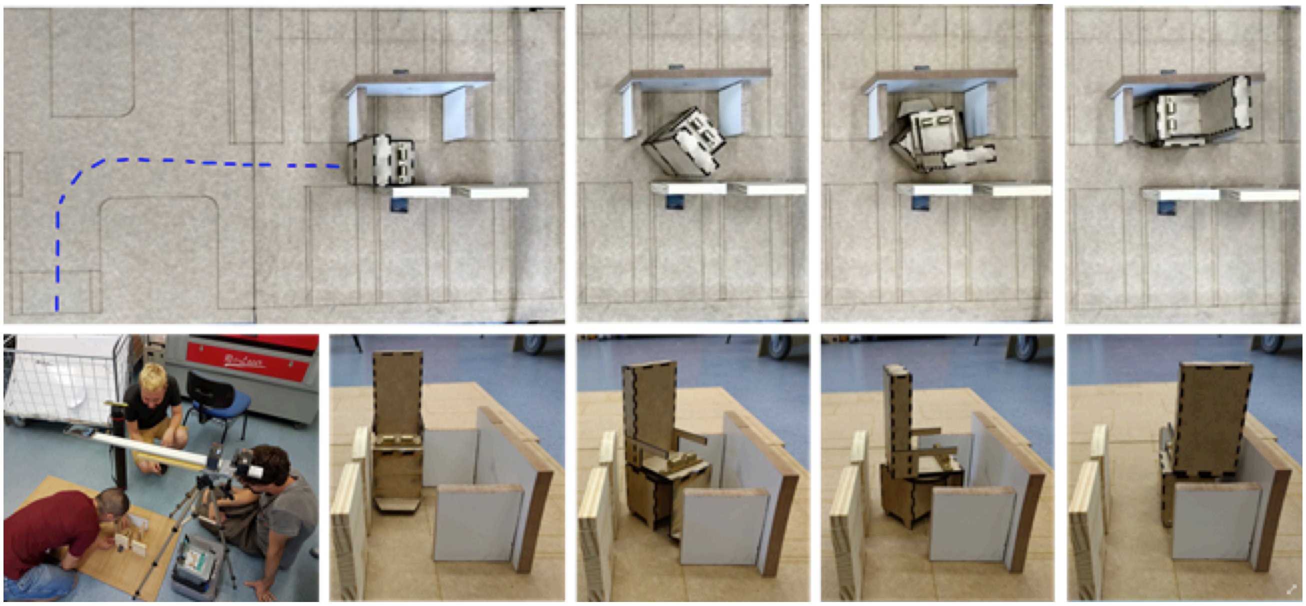
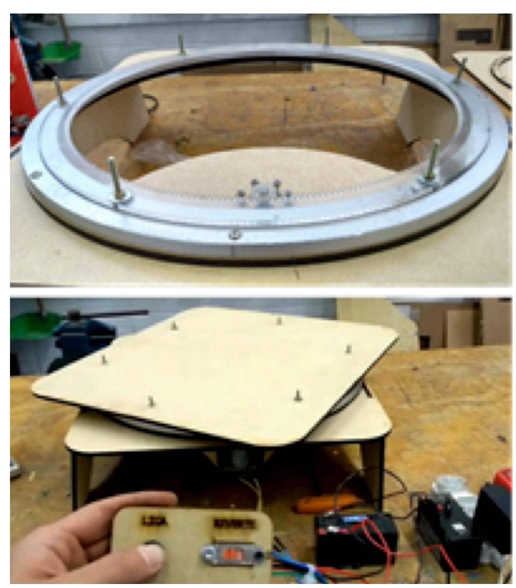


Figure 1. CFP to test maneuver trajectory

Critical Function Prototype

Based on the findings from previews phases, one function was assumed as the critical one: allows for manoeuvring inside tight spaces. This decision ware influenced by the gap highlighted on the mobile aircraft seat-wheelchair patent [11]. After deciding the critical function, a brainstorming session was held to generate ideas for a new concept to fit this gap. Some ideas have arisen, and the one considered most promising was materialized in the critical function prototype (CFP): a motorized aisle chair that rotates on its axis allowing the manoeuvring from the aisle to the seat location. This prototype brought to the team a good understanding of the maneuver, in a quick and cheap way, using a 1:7 scale model analyzed through a stop-motion video. Figure 1 presents the first CFP in four different stages of the manoeuvre, from two different perspectives. The blue line illustrates part of the trajectory, and the picture at the left bottom corner shows the team recording the stop-motion video.

To build it, first the blueprint of an aircraft was engraved in a MDF board, and wood was used as physical barriers, representing the regular seats. Then, a scale model of the aisle chair was built in MDF, to test if the rotation mechanism would help in the manoeuvre. For the prototype of the rotative aisle chair, conservative outline dimensions were assumed, based on existing aisle chairs raised on the benchmarking phase. The detailed design of the chair was not considered essential for this prototype, as the main objective of the CFP was to assess the concept for the critical function. Aircraft measures were collected from the visits to the airplane mockup during the needfinding phase and based on publicly available datasheets and information.



The first test brought new concerns to this concept. Will the users be troubled by the narrow distance between their legs and the fixed seats? Will the user accept an autonomous manoeuvring, considering that it would request precise movements challenging to be done an inexperienced user using the joystick? To test this hypothesis, a new CFP was built in order to prototype the rotation mechanism. Once this mechanism is ready, testing the manoeuvre with end users through a real scale aisle chair will be enabled. For this prototype, an axial ball bearing was used attached to pair of gears made with acrylics in a laser cutter, moved by a DC motor. To control the motors, a switch was constructed allowing the mechanism to rotate in both directions. The mechanism was tested to check if it was withstanding the weight of the user and the seat. Figure 2 shows the rotation mechanism and testing procedure.

DISCUSSION AND CONCLUSION

The study presented in this paper is part of a research project that aims to develop a motorized aisle chair that will allow people with disabilities to move with autonomy inside an aircraft. In this context, the objective of this paper was to present the concept design of this solution. The concept created is aligned with state of the art identified in the benchmarking [11,12], with incremental innovations to fill their gaps and provide more independence for the passenger, eliminating the requirement of significant crew aid.

The prototypes and tests presented here addressed only one function of the product, to allow for manoeuvring inside tight spaces, considered a critical function. Some technical aspects of this function have been validated. However, tests with users still must be performed to verify their feelings regarding the proposed concept. In this way, the next prototype should have the structure of an aisle chair equipped if the rotation mechanism, to allow the users experience the manoeuvre. Therefore, prototype motors are not yet required, because the movement can be done manually by the design team. After the approval of users in this checkpoint, the park assist function (autonomous manoeuvring) should be prototyped and tested. Besides the manoeuvre function, other critical functions emerged with the concept created, as the need to lock the aisle chair on the aircraft cabin floor while flying. The project approach based on design thinking lead to working in short design cycles in close contact with users, to minimize risks. Moreover, the team becomes more confident in making design decisions. The use of physical prototypes was relevant to improve team confidence and team communication.

Finally, despite the ongoing stage of the project, the preliminary results presented here may already support discussion. The main contributions of the paper are threefold: (1) the identification of requirements, constraints and functions for the aisle chair; (2) proposing a new concept to solve the design problem; (3) detailing the application of the design thinking process for assistive technology development. Next steps in this research stream include detailed solution design and extensive user testing.

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