DEVELOPMENT OF AN INTEGRATED STAIRCASE-LIFT FOR HOME ACCESS

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INTRODUCTION

A large portion of the general population has significant trouble with stairs. This includes children, mothers with strollers, and especially the elderly and people with a disability. The ubiquitous use of stairs in single family homes renders home accessibility as a major issue for many people in terms of safety, health, quality of life, community participation, and economy. In the United States, it is estimated that more than 90% of housing is inaccessible in some fashion to people with disabilities (Steinfeld, 1998). Marketplace solutions often have several drawbacks, most notable amongst others being usability (e.g. ease of entry and travel time), lack of inclusiveness, and reliability (e.g. use during a power failure). An innovation that addresses these and other drawbacks has the potential for major impact.

We therefore began a rehabilitation engineering design project focused on outside stair entrances to homes, e.g. a typical bungalow with several stairs at the front. Marketplace solutions include the installation of a vertical platform lift (porch lift) or ramp, often necessitating substantial home renovation. Integration of the solution with the home also poses concerns. For instance, to ascend a height served by five stairs (approximately 1 meter) a ramp of 12 to 20 meters in length is required. Such a ramp has substantial usability concerns as well as problems with installation and integration with the home and yard. A platform lift is often difficult to use (e.g. opening the door can be a challenge) and frustratingly slow, taking 15-20 seconds to traverse a height of 5 stairs. There are also issues with integration with some home designs, as well as a lack of inclusiveness and universal design principles, and potential reliability issues during a power failure.

A goal of the design project was to create an inclusive home access solution that people walking or wheeling would use. Thus we sought a design that provides a staircase and lift in the same access location and footprint. This may encourage stair use whenever possible (e.g. by seniors for exercise) as well as offer the safety and convenience of a lift when necessary (e.g. when the person is encumbered or for a wheelchair user). Another goal was to provide a lift that is substantially quicker to use than currently available solutions. A third goal was to design a device that could operate with minimal or no power, thus promoting reliability during a power outage.

Figure 1: Functional staircase-lift prototype built for a 1 meter rise.

This paper outlines the design features of our novel device, as well as the user-centric design approach that was used throughout its development. We began with an initial idea from the first author, a long time wheelchair user. Other stakeholders were soon involved, including potential users and occupational therapists (OTs). OTs with experience providing home access solutions were interviewed to solicit input on which user populations would most benefit from the device, as well as their perceived benefits and limitations of the concept. An iterative prototype design and fabrication cycle is ongoing. This entails getting feedback on the detailed design from a variety of end users, and finally presenting a fully functioning version of our solution for evaluation by various populations (e.g. wheelchair users, elderly), in comparison to conventional home access systems. Preliminary results of this design cycle are presented here.

DESIGN CONCEPT

An integrated staircase-lift (SCL) design was proposed to address our project goals. Following an ISO 9001 Quality System Process, with an assistive technology angle consistent with the HAAT model (Cook, 2007), we drafted a set of design requirements. Notable requirements that address our user-centric goals are listed in Table 1.

Table 1: Design Requirements

Inclusive design usable by all people, including those with wheelchairs and walkers
Performance characteristic: at least twice as fast a vertical platform lift
Usable for emergency descent in absence of power
Stair tread rise:run ratio of current building code
Form factor that allows aesthetic integration with North American bungalow homes
Potential for a self-powered version
Safety standards of conventional lifts
Ergonomics and entry / exit of conventional lifts

The integrated staircase-lift concept is shown in Figures 1-3. This design has two major home access characteristics: 1) it is inherently a conventional staircase (Fig. 2); and 2) each end of the staircase can operate as a platform lift, with either available at all times for use without needing to "call" the platform. Either end of the staircase has a platform large enough to accommodate two people or a wheelchair, similar in size to a conventional vertical platform lift. Each platform is hinged to the frame of the staircase in such a manner that a levered platform lift is realized, operationally analogous to a “see-saw”. The frame of the stairs, handrails, and vertical platform posts form a parallelogram linkage (Fig. 3). The entire symmetrical structure pivots around two horizontal axes placed at the centre of the stairs and handrails (red arrows in Fig. 3). The parallelogram linkage maintains each of the platforms in a horizontal orientation at all times, allowing the user to quickly raise or lower to a different level. The integrated SCL design also maintains a normal staircase for use by others when the lift is not in use, regardless of which platform is in the upper position.

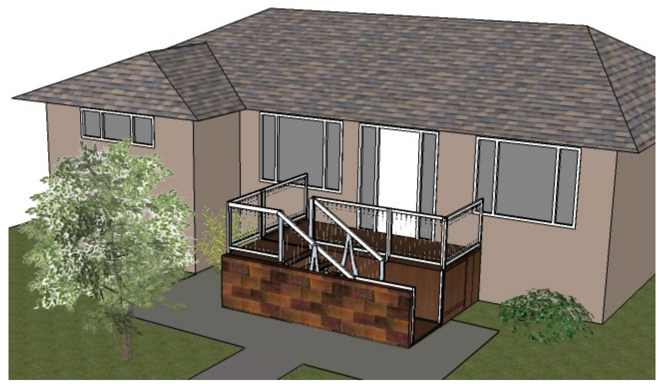

Figure 2: Staircase-lift model integrated into front porch of a bungalow home.

DESIGN RESULTS

A fully functional prototype of the SCL design has been built (Fig. 1) to elevate approximately 3 feet (5 stairs).

To prevent falls, especially by the elderly, stair-riser heights and tread lengths should conform to specific asymmetrical geometries (e.g. a rise:run ratio of ~7:11; Irvine, 1990; Roys, 2001). In order to maintain proper stair geometry when the SCL swaps positions, a pivoting mechanism that links each stair riser to a third parallel linkage (blue arrow in Fig. 3) to pivot each stair was designed and validated for feasibility. This design has the added benefit that the entire structure can accommodate changes in elevation of several inches, or until another step needs to be added to the staircase, providing flexibility for various heights of entry levels.

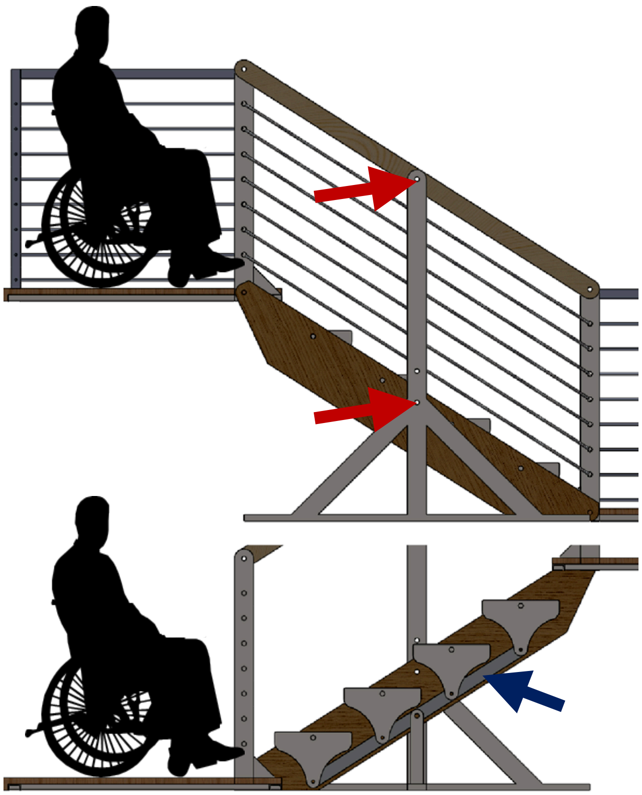

Figure 3: The integrated SCL design. The entire structure moves about two pivot axes (red arrows), providing the pivoting lift action. The bottom cutaway model shows the internal linkage (blue arrow) of the staircase treads.

The levered lifting action of the SCL lends itself to possible benefits from counter-balancing. When balanced (e.g. person on one side and equivalent weight on the opposite platform), it requires very little effort (i.e. simply needing to overcome frictional forces in the pivots) to manually move from one position to the other. As an alternative counter-balancing mechanism, we have added gas springs to our prototype and demonstrated self-powered operation. Using an ad-hoc lever mechanism, the platforms can easily be moved the entire vertical distance, in a very smooth and quick manner (~3 seconds from bottom to top). Similarly, a user is able to raise the platform by providing about 10 pounds of force on a hand crank attached to a chain and sprockets. Further work in this regard is ongoing, for possible use as a low cost alternative to a powered version both in North America and potentially in low resource settings (Borisoff, 2012). At this time an automated power mechanism has not yet been assembled.

Regarding home integration, the SCL requires a landing (e.g. front porch, Fig. 2) the length of the device. For an elevation served by 5 stairs, the SCL requires a landing of about 4m in length. However the landing size only grows about 30cm per additional stair: e.g. for 10 stairs the landing is about 5.4m long. This footprint compares very favorably to ramps, while only adding about twice the footprint of a platform lift over the existing staircase size.

STAKEHOLDER PERSPECTIVES

In order solicit stakeholder feedback on the SCL design, eight OTs with between four and fifteen years of experience practicing in community care were interviewed by Masters of Occupational Therapy (MOT) students. Their experiences in prescribing accessibility solutions for clients living in single family homes were explored, along with their perceptions of the SCL concept after viewing pictures and animation of the concept.

Several key factors emerged from an analysis of the interviews. Foremost, OTs emphasized the leadership role played by the client in choosing appropriate assistive technology solutions, with the therapist acting more as a consultant.

Study participants, without exception, identified cost as the most common concern cited by their clients. In order for the SCL to be a viable solution it was noted that the cost must be within a manageable price range or the device must become eligible for funding. Safety (i.e. the need for safety features such as gates, railings, emergency stop, etc.) is also paramount.

The importance of an access solution "fitting" the house was noted. The height of the entry, landscaping issues, size of the landing necessary, and footprint in comparison to porch lifts were of concern. It was noted that the footprint of the SCL compares very favorably to ramps.

The therapists also claimed that aesthetics were important to their clients. Clients want the front of their home to look nice, and they are looking for more subtle and unobtrusive solutions that don’t create a stigma often associated with disability related products. Comments included: "some people don’t like things coming down their stairs so it looks like they are disabled". As well, there were concerns that obvious home access devices may attract criminal activity by showcasing that residents may be vulnerable due to mobility issues, saying "it’s like an advertisement". One OT commented that the SCL design doesn’t "scream out disability", while another stated that it looked "more normalizing". It was also stated that the SCL embraces universal design.

The client's condition and prognosis must also be considered. OTs consider both the client’s current and future physical and cognitive abilities, and the potential presence of a caregiver. Participants noted that the SCL would be particularly well suited for people who have energy issues (MS, chronic fatigue, elderly), or for people who vary or may decline in mobility over time (e.g. walking now but need a wheelchair down the road).

Other factors brought up in the interviews included the ease of installation and the ability to remove the access solution if the house is sold. One OT suggested that the SCL would be great if it was available "in a box" and could be assembled without stairs or railings needing to be taken out. Others stressed the importance of being able to take it down easily when it wasn’t needed anymore. We are exploring the ability to construct a simple removable porch landing over an existing staircase for installation of the SCL. The possibility that the SCL could be self-powered, or at least operational for emergency egress, was considered to be a benefit as it was noted that people like something that doesn’t necessarily rely on power.

As a next step in the design process, the team is working to solicit feedback from potential clients from a range of different disability groups. To this end, two MOT students will soon conduct four focus groups with end users about the SCL design.

For the final step aimed at getting end user feedback, a mixed methods approach will be used to evaluate the SCL against other home access technologies. For this evaluation, participants will be asked to use various access methods including a fully functioning SCL, a ramp, a platform lift, and a staircase with a stair lift installed. Evaluation tools will include direct observation, semi-structured interviews, and standardized outcome measures.

CONCLUSIONS

Our novel integrated staircase-lift shows promise for use by various different populations. The solution has potential to provide inclusive home access to all users as well as address shortcomings of existing home access solutions. Exploring the stakeholder perspectives may enhance knowledge translation and facilitate adoption of this device at the completion of the design process.

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