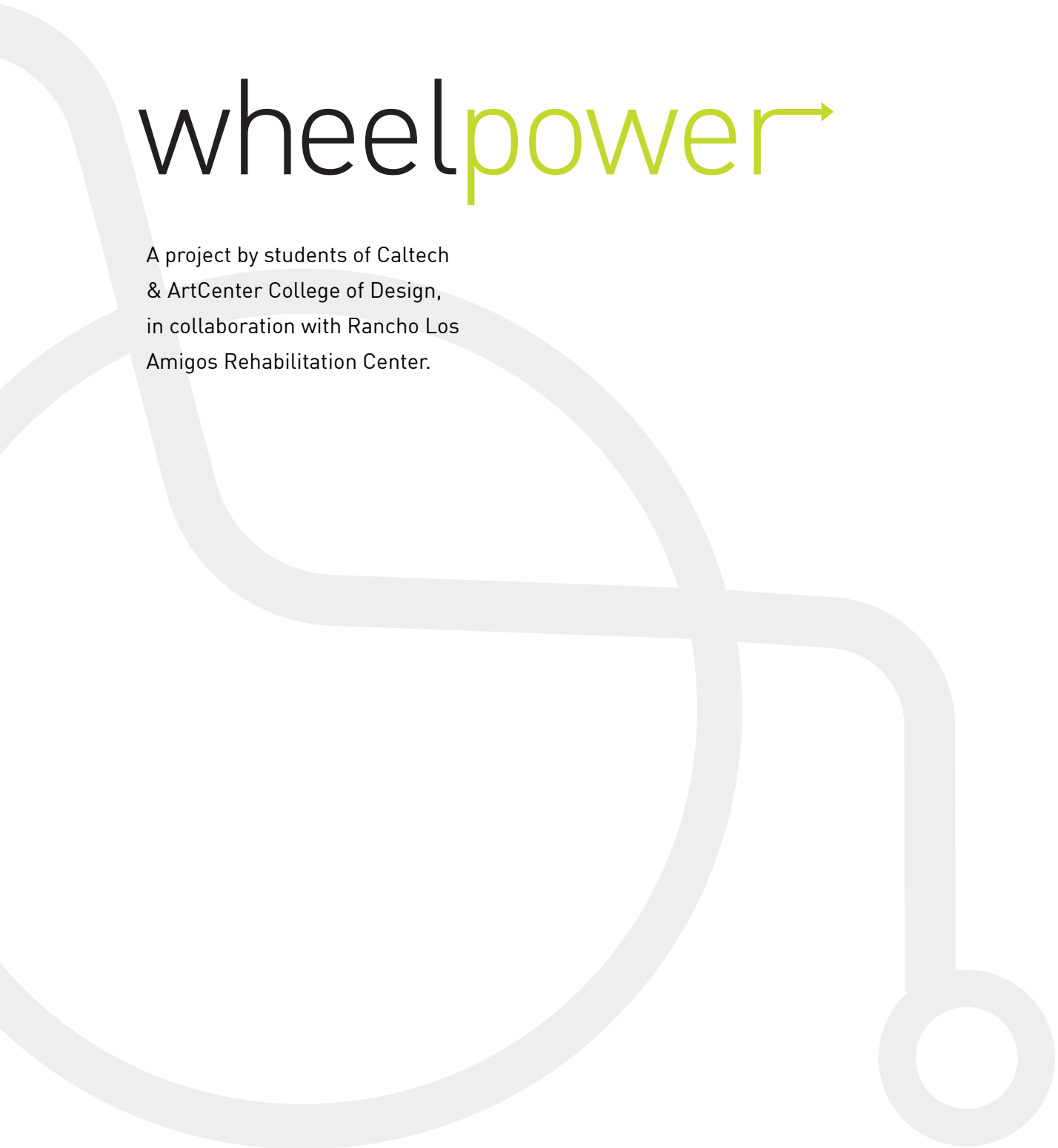
wheelpower

A project by students of Caltech
& ArtCenter College of Design,
in collaboration with Rancho Los
Amigos Rehabilitation Center.



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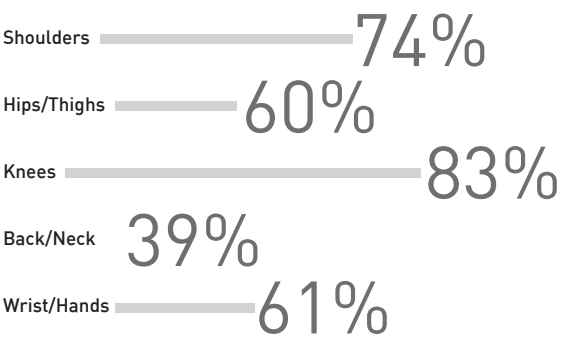
ABSTRACT

High percentages of caregivers suffer from intense pain due to the physically difficult nature of pushing clients in a wheelchair on a daily basis. Sadly, the current market lacks a viable option for an assist that benefits both patient and caregiver. Our product mitigates some of the pressure placed on caregivers while increasing carer autonomy by way of a power assist with intuitive controls that adapts to collapsible chairs. Our solution automatically supplies power to compensate for inclines and declines, allowing for smooth, easy travel with no extra user inputs required. Our concept and prototypes have been received favorably by patients and rehabilitation engineers, and have given us good insight into future progress.

PROBLEM STATEMENT

In 2015 almost 43.5 million adults provided unpaid care to an adult or a child in the United States. These caregivers spend on average 24.4 hours per week providing care, and almost a quarter of them spend 41 or more hours. Over time, caregivers who push wheelchairs are likely to experience pain due to the physically difficult nature of pushing patients. It is not uncommon for a 100 pound caregiver to be assisting a patient in a wheelchair who weighs over 200 pounds. The strain of pushing a client is especially difficult when pushing up an incline or when maintaining speed on a downwards slope. We aim to alleviate this strain on caregivers.

RESEARCH QUESTION AND BACKGROUND



* data from study conducted at the University of Dundee, UK in 2012

Needs of carers who push wheelchairs

Table I.
Percentage of pain reported by carers who experience pain with pushing wheelchairs

Our market research determined that there exists no feasible solution on the market to the medical problems faced by caregivers who push wheelchairs. There exists a wheelchair attendant powerpack by Roland Priestly which only ships within Australia; however, there are many complaints about the design of the product, especially that the product lies directly in the walking path of the caregiver.

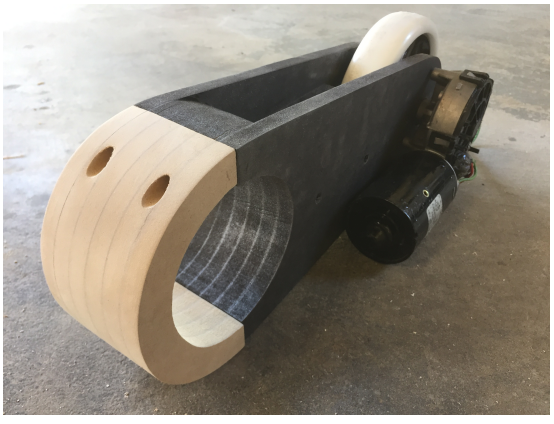
While many power assists exist for self propelling wheelchair users, there are almost no power assists for caregivers on the market. Based on the market research of pain levels of caregivers which is in that table below, there is a need for a device to ease caregivers' pain.

METHODS USED & SOLUTIONS CONSIDERED

Our initial goal with the project was to create a powered mechanism that would allow a wheelchair user to more effectively propel themselves. To get insight into viable approaches and the current state of the market, we consulted with engineers and patients at Rancho Los Amigos National Rehabilitation Center (Rancho) in Downey, CA. Physical therapists at Rancho gave us the opportunity to test out an existing mobility assist product, called the SmartDrive. Our experiences using the device, and discussions with current users, showed us that the SmartDrive was an affordable and robust solution to the problem we were trying to address.

After this discovery, we modified our goal to focus on addressing the needs of caregivers-propelled chairs. The advantage of this choice was that we were freed to approach a problem not yet addressed by industry; at the same time, the design insights we received from Rancho patients about sizing, aesthetics, control, and safety were still applicable as we began prototyping.

Our goals for initial prototyping were to assess how much power the assist needs, and how it might attach to the wheelchair. We designed our first attachment prototype to emulate the SmartDrive mechanically: the wheel's housing was fastened around the center bar of the wheelchair with a clamped collar. We selected an appropriate motor and battery to allow the wheel to spin. To ensure that the wheel contacted the ground at all times, we constructed a suspension system that braced the attachment against the wheelchair's front bar with a compressed spring.



With a propulsion mechanism in place, we had the opportunity to test basic caregiver control over the wheelchair's movement. Our first prototype was a handle attached to the back of the wheelchair that the caregiver could grasp: by turning the handle, the user could control the amount of assist (in a full range from zero to 100 percent power). This control was implemented with an Arduino unit running code to adjust the power delivered to the motor.

Our prototyping gave us insight into two key issues that would define our final design. The first is that, as most caregivers push collapsible wheelchairs as opposed to fixed-bar wheelchairs, our power assist attachment would have to rely on a different attachment system to that of the SmartDrive. Second, we found an opportunity to implement a much more sophisticated control algorithm, one that could tackle the problem of compensating for inclines and declines and apply to **all** power assists.

We next prototyped a new attachment system, in which we substituted the wheelchair's front casters with omnidirectional wheels. These wheels offer advantages over conventional casters in that they allow for a full range of motion without getting in the way of the patient's feet. Testing of these wheels revealed that the wheelchair's motion was unimpaired. This inspired to us to look towards motorized "omni wheel modules" as a compact propulsion system for collapsible wheelchairs.

DESCRIPTION OF FINAL APPROACH & DESIGN

The final approach and design focuses on an intuitive, input-free and human-centered approach to controls. Our product is designed to make all terrain feel like flat ground to a caregiver pushing their client. Pushing a client on flat ground is usually quite easy for a caregiver, while pushing a wheelchair uphill or controlling a wheelchair downhill can be extremely difficult and quite dangerous. Depending on the angle of a ramp, our product provides sufficient assistance for the ramp to feel flat. Thus, if the

caregiver needs to stop on a ramp while pushing a client, the wheelchair will not roll away, giving the caregiver peace of mind. The orientation of the wheelchair is discerned using a control system that utilizes both an accelerometers and a gyroscope. This is all controlled by a PID loop that maintains wheelchair position. On an uphill slope, the system provides enough power to the motor module to feel like flat ground, and on downhill slope and in electronic brake mode, the system back-drives the motor on a fast pulse to smoothly keep the chair from rolling away. Caregivers who desire more control can still control WheelPower by twisting the handle of the wheelchair

OUTCOME (RESULTS OF TESTING)

We tested our product on several inclines, and the gyroscope is able to accurately detect a slope and turn on during an incline or decline and turn off when on flat ground. Our future plans involve increasing accuracy of our slope angle readings, using digital filtering.

We worked very closely with Rancho Los Amigos Rehabilitation Center medical officers, physical therapists, and clients. Gilbert Salinas, Diego Rodriguez, Jan Furumasu, and Renee Alvarez were four Rancho staff members with whom we worked. Gilbert is the chief clinical officer at Rancho and a user of the SmartDrive. He really enjoyed using the SmartDrive but gave use his feedback on where its design can improve. Diego Rodriguez is a wheelchair-using engineer at Rancho who explained the difficulty of pushing a wheelchair up a hill or on uneven ground. Jan and Rene are physical therapists at Rancho who gave us information from their experience with different power assists and allowed us to try out the SmartDrive.

The staff at Rancho has suggested that our product, whose controls are currently more intuitive and well-mapped than other marketed products, can be used in markets beyond caregivers propelled chairs. We see application in other settings such

as hospitals, airports, or any other wheelchair-accessible location with long distance pushing required. This is especially useful at inpatient hospitals where nurses and volunteers might need to assist patients on wheelchairs for several months at a time.

COST BREAKDOWN / FEASIBILITY

Central to the success of WheelPower is the affordability and feasibility of the product. As such, we designed the entire product around optimizing its manufacture so to reduce cost. One chief methodology in this effort was sourcing COTS (Components Off The Shelf) wherever possible. By adapting existing components purchased in wholesale quantities and minimizing the need for custom-tooled parts, we open up possibilities for short-run production, enabling the testing that is needed in a product in this category. Where custom-tooled parts are necessary, we've designed for simple two-part polycarbonate molds with no undercuts or significant changes in wall thickness.

The result of these efforts is that we have been able to bring the cost of production for WheelPower units to what we estimate will be below $400. We have sourced appropriately sized omni wheels for $14 ($28/unit). The lithium-ion battery used in the device is sold, along with a charging dock, wholesale for $52/unit. The applicable brushless motors and their controllers are purchasable at bulk prices of $90/unit. Based on component costs and added cost buffer for PCB manufacturing and assembly, we estimate the cost of electronics in the unit to be approximately $30/unit. After soliciting a rough quotation, we believe the additional polycarbonate parts necessary, including the bevel gears, outer casing and handlebar can feasibly be manufactured for $150/unit in initial single-cavity-mold small batches, and for under $100/unit produced at scale.

It is valuable to compare these estimates to the retail cost of the SmartDrive, $5,990.00. We cannot ascertain the cost of manufacture for SmartDrive's product. However, through simple changes to the mechanical design of our own, we have been able to bring costs low enough to project a retail value of approximately $850. Through interviews we conducted with patients at Rancho Los Amigos, we found that to break the most significant barrier to adoption, we would need to produce a unit for under $1000. Though our numbers are far from concrete, we believe with confidence that we can do so.

SIGNIFICANCE OF PRODUCT

The SmartDrive has had great success within the wheelchair-using community because it alleviates arm, shoulder, and back pain. Our product goes further, providing nearly limitless applications for assistance with wheelchair users as well as people who aid them. There is currently no product to help caregivers, both paid and unpaid, who work with clients using collapsible wheelchairs and who suffer from significant pain and damage due to the constant pushing of the wheelchair. We will be able to help the 83% of caregivers who deal with consistent pain on a daily basis.

We believe that our product has a wide reach beyond the use of caregivers. The system we have developed can be installed onto nearly any type of manual wheelchair in under 15 minutes. Based on early testing, we have also found that it works on certain types of walkers. Our future work involves continuing to bring our system into the hands of people who can benefit from it, looping user feedback into our process, and allowing us to iron out any bugs that exist mechanically or in our software.
We are passionate about bringing a low-cost, human-centered product to market and are grateful to our friends at Rancho Los Amigos who have helped make that possible.

ACKNOWLEDGEMENTS

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Our collaborators at Rancho Los Amigos National Rehabilitation Center provided invaluable experience and guidance to our design process. We would like to thank a few individuals who were particularly instrumental in aiding our project. Diego Rodriguez and Gilbert Salinas familiarized us with engineering, financial, and user experience challenges related to motorized wheelchair assists, and shared their experiences using the SmartDrive. Jan and Rene, physical therapists at Rancho, shared their experiences working with patients using the SmartDrive, and allowed us to test the device. Andy Lin has provided incredible support in connecting us with the Rancho team.

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