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WheelSense: An Open-Source Smart Add-on System for Wheelchairs

The Challenge: About 2.2 million people in the United States need wheelchairs for everyday tasks and mobility. [1] Many of them are also visually impaired or have dexterity and motor challenges that make navigating the chair difficult. [2] Research indicates that between 1.4 and 2.1 million people would benefit from using a "smart" wheelchair at least part of the time. [2] Worldwide, 39 million people are blind and another 246

Photo credit: Roland Saekow, Jacobs Institute for Design Innovation, UC Berkeley

million have low vision.[3] For the 10 percent of those who use a wheelchair, independent travel is nearly impossible.[4] The smart-wheelchair projects that have emerged from robotics research are designed mainly for physical, cognitive, and neurological limitations rather than for visual impairment. Users are wary of "self-driving" wheelchairs that reduce their control and can only operate in limited environments. One such person, Tomás and Corten's friend Daniel, has both cerebral palsy and cortical vision impairment. His greatest challenge is navigating new places. He has fallen down ramps multiple times and often collides with objects even at home.

The Solution: Tomás organized some friends for a week-long "make-a-thon" at Daniel's house in Los Gatos, Calif., to identify his daily challenges and come up with practical ways to prevent injury and promote independence. After deciding that better navigation would have the greatest impact, the group hacked Daniel's wheelchair to add ramp lateral-edge detection, frontal drop-off detection, and backup assistance through auditory and haptic feedback. The chair sounds one tone when it detects a frontal drop-off such as stairs or a curb, and a different tone when it detects an obstacle while the chair is moving in reverse, and it vibrates the appropriate armrest when a wheel gets too close to the edge of a ramp. The resulting WheelSense chair that uses this novel feedback approach represents a breakthrough because it allows Daniel to remain completely in control, making independent travel more realistic. Following the make-a-thon, Tomás left the prototype with Daniel for further evaluation under the supervision of Daniel's older brother. After a couple of weeks, some of the chair's sensor mounts broke off, demonstrating the need for improvements. The wheelchair was sent to Berkeley, where Tomás recruited Corten to make WheelSense more robust. Corten developed stronger sensor mounts capable of withstanding frequent use and multiple bumps into obstacles.

Commercialization: Smart wheelchairs are considered a niche market limited to users with severe disabilities, but many more people would appreciate assists like those that WheelSense provides. Such customizations are beyond most users' means, but the components that made WheelSense possible cost only about $100, putting them well within most people's reach. Tomás and Corten believe that making their work open source and free to the public will ensure that these technologies evolve and spread to reach the widest audience possible. Commercialization prospects come from eventually licensing the technology to a wheelchair manufacturer, and Corten believes that their prototype's $100 cost will fall dramatically when mass-production techniques are introduced, making WheelSense extremely competitive with far more expensive assistant solutions on the market. The WheelSense team expects to spend six to 12 months in Phase 1, building an expanding community of active stakeholders; Phase 2, lasting a year or two, will license the add-on to manufacturers of motorized wheelchairs.

[1] "How many people use assisted devices?" Centers for Disease Control and Prevention, https://www.nichd.nih.gov/health/topics/rehabtech/conditioninfo/Pages/people.aspx

[2] Simpson, R., LoPresti, E., & Cooper, R. "How many people would benefit from a smart wheelchair?" *Journal of Rehabilitation Research & Development* (2008): 53-72. http://www.rehab.research.va.gov/jour/08/45/1/simpson.html

[3] "Visual impairment & blindness." Fact Sheet No. 282, World Health Organization (2014). http://www.who.int/mediacentre/factsheets/fs282/en/.

[4] Coughlan, J., Manduchi, R, & Shen, H. "Computer vision-based terrain sensors for blind wheelchair users," International Conference on Computers Helping People (2006). https://vision.soe.ucsc.edu/node/211