

# CHAPTER 20

## VANDERBILT UNIVERSITY

School of Engineering  
Department of Biomedical Engineering  
Vanderbilt University,  
VU Station B 351631  
Nashville, TN 37235-1631

### Principal Investigators:

*Paul H. King*

(615) 322-2201

[paul.h.king@vanderbilt.edu](mailto:paul.h.king@vanderbilt.edu)

*Mark Richter*

(615) 731-1869

[mark@max-mobility.com](mailto:mark@max-mobility.com)

# WHEELCHAIR PROPULSION MONITOR

*Designers: William Emfinger*

*Client Coordinator: William Mark Richter, PhD.*

*Supervising Professor: William Mark Richter, PhD.*

*Department of Electrical Engineering and Computer Science*

*Vanderbilt University, Nashville, TN 37235*

## INTRODUCTION

Over half of the manual wheelchair user population has developed an upper limb overuse injury. Wheelchair propulsion is likely one of the contributing factors in the development of these injuries. As such, clinicians are training users to change the way they push their wheelchairs. With users pushing an estimated 2,500 times each day, they are being encouraged to make every push count. By using long, smooth push strokes, users can decrease how often they push and thereby decrease their overall number of pushes taken each day. By providing propulsion biofeedback, the Propulsion monitor project will hopefully reduce the number of users developing shoulder and wrist problems.

## SUMMARY OF IMPACT

Understanding the biomechanics of manual wheelchair propulsion is integral to providing accurate, beneficial biofeedback to the users. The focus of the project is to design, prototype, fabricate, and program a sensor and feedback device to record and analyze propulsion data from the wheel. From these data are gleaned the push starts and stops, as well as the speed, distance and acceleration of the wheel. These data, covering both activity and cadence, provide beneficial feedback for propulsion training and research.

## TECHNICAL DESCRIPTION

A proof of concept Propulsion monitor was developed which is shown in Fig. 20.1. The prototype is designed to evaluate the ability to detect push starts and stops with an angular rate gyro, as well as to assess the potential of various proposed components. The prototype is a custom printed circuit board with: 1) a high contrast organic LED screen (OLED), 2) a 4-way mini joystick with center click, 3) an ultra-thin 3.7V 3.4Wh Lithium Ion rechargeable battery, 4) an altimeter, 5) a 4GB

removable micro SD memory card, 6) a mini-USB and wireless Bluetooth chipset, 7) a tri-color LED and 8) an ATME162L microcontroller. Code was written in C and uploaded to the microcontroller to integrate the components, identify push starts and stops, calculate propulsion outcomes, display results to the screen, receive input commands from the joystick, write data to the SD card, monitor battery charge, and facilitate wired and wireless data transfer to a laptop. After a series of circuit debugging and re-design iterations, the prototype achieved full functionality. The OLED screen is an excellent display choice with high visibility even in direct sunlight. Use of white text on a black background maximizes visibility as well as minimizes power consumption. The joystick enables menus to be navigated and selections to be made. The tri-color LED changes from green to yellow and finally pulsing red as battery reached a critical level. The prototype is mounted onto an instrumented wheel and used to push through several propulsion environments, including an undulating path around a parking lot, a straight path on low-pile height carpet and on a research treadmill set to a two degree incline. The Propulsion monitor results are found to be very comparable to those from the Instrumented wheel. Total number of pushes identified was the same for the treadmill and carpet but short by one push on the parking lot surface. The unidentified push was a small corrective push with unperceivable wheel acceleration. Push start and stop events are found to be within 10 ms of those identified by the Instrumented wheel. As a result, calculated outcomes of cadence, contact angle and distance travelled per push differ slightly from the Instrumented wheel results. Differences are found to be less than 5% between the two instruments. The high level of agreement between the Propulsion monitor prototype and the Instrumented wheel validates the Propulsion monitor prototype.

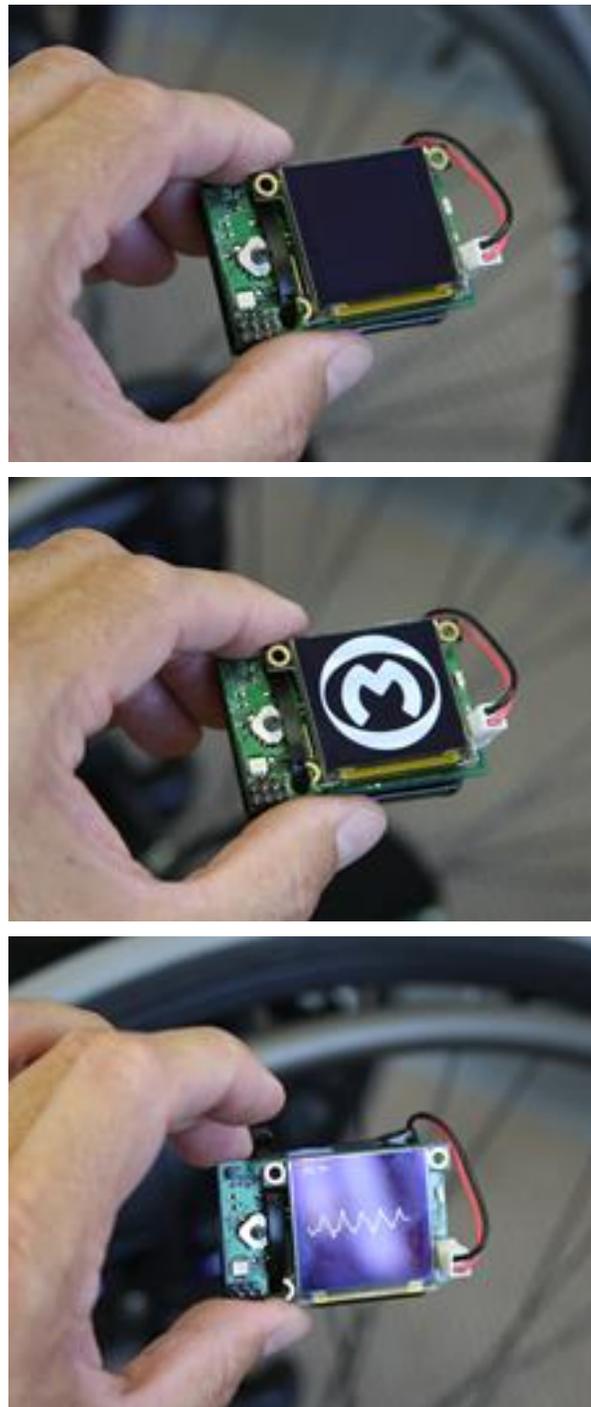


Fig. 20.1. The Propulsion monitor prototype has an OLED screen that is visible even in bright sunlight.

# WHEELCHAIR DYNAMIC CENTER OF GRAVITY (D-COG)

*Designers: A. Lossing, K. Mobley, G. Spiegel*  
*Supervising Professors: W. Mark Richter and Paul H. King*  
*Department of Biomedical Engineering*  
*Vanderbilt University, Nashville TN 37235-1631*

## INTRODUCTION

There are over two million manual wheelchair users in the United States. "Active" manual wheelchairs are used by disabled people who still maintain independence and are seeking products and upgrades that will increase that independence. Over the past decade this push for independence has led to the promotion of "tippiness", which is defined as "a compromise between the risk of rearward instability and the ability to propel and maneuver easily". A wheelchair is tippy when a minimum of 80% of the user's weight rests on the rear wheels. The user accepts additional instability, in the form of higher likelihood of tipping over backwards, in order to gain significant advantages in maneuverability and propulsion. The purpose of this work was to design a wheelchair that allows users to receive all the benefits and independence that accompany the use of a tippy wheelchair while minimizing the disadvantage suffered while traveling up a hill. The design must add as little weight as possible to the wheelchair and be easy for the user to actuate during normal motion.

## SUMMARY OF IMPACT

By allowing weight to be shifted forward during the climbing of hills, the user is spared the need to lean forward to minimize the possibility of tip-over during normal hill climbing, and is in a more

comfortable propulsion position. The D-COG wheelchair gives the user a more comfortable and efficient way to climb hills, while allowing all the benefits of a tippy wheelchair, and does not add significant weight to the wheelchair. The final prototype moves the center of gravity from 83% to 64% of weight on the rear wheels by moving the seat 3.18 inches forward.

## TECHNICAL DESCRIPTION

The final design is comprised of four main features including a two piece frame, concave wheels and their housing, brakes, and an initiation switch. The upper frame comprises the seat, footrest, and back rest, the lower frame is attached to the standard wheel assembly. The concave wheels link the two sections and allow them to move relative to each other when the brakes are disengaged. There are the two main positions of the wheelchair; the tippy setting for general use and the forward position for climbing hills. The forward position, for climbing hills, is set at a seat position three to four inches in front of the chair's normal position. This hill climbing setting is achieved by releasing the brakes with the initiation switch and "scooting" forward to a stop position and resetting the brakes. Upon reaching a level position, this process is reversed to reset the desired "tippy" setting. Approximate costs include \$1,150 for hardware and \$500 for machining and labor.



Fig. 20.2. The completed prototype in the tippy position.



Fig. 20.3. The completed prototype in the hill climbing position.

