microMedic
2013 National Contest

KINOCOM
PROJECT REPORT

Project ID: **micro13RC276**

Team Members:

Ravi Chacko
Kendall Gretsch
Sophie Jacobson
Stephen Linderman
Inema Orukari
Will Padovano
Joshua Siegel
Avik Som

July 31, 2013

Introduction

JB was a computer programmer. One day, when he was 45 years old, he was shaving his face when he suddenly lost consciousness and fell to the floor. His wife soon found him and took him to the hospital, but by then his stroke had left him almost completely paralyzed in all four limbs and some of his neck. Several years later, we met JB in the classroom after a lecture on paralysis and treatment. In order to type, and thereby communicate, JB was using a small clicker under his right hand. JB's wife was with him, and as you might imagine, she was doing most of the speaking for him. After the presentation, a few of us went up to talk with them more. JB's wife explained that out of all the challenges JB faced, the most frustrating was the time it took him to complete a sentence on his laptop. It prevented him from participating in conversations with his friends and family.

As JB and his wife began heading home, a group of us stayed and continued talking. We felt certain that there must be more efficient and powerful ways for him communicate and control his computer. We talked about new technologies that we had seen and how a simple, flexible microcontrolled device could improve his communication. As we explored resources to help solve this patient's problem, our professor told us about the microMedic contest. Using a microcontroller and two motion sensing accelerometers, we designed an inexpensive but effective device to expand JB's methods of communication from just using a single click to controlling a computer cursor.

Beyond applications for JB, we see the potential for this technology to improve the quality of life of veterans and patients with a wide range of disabilities. The device that we created is uniquely suitable for patients with partial paralysis or missing limbs because it can be controlled by other parts of the body that are capable of movement. We call our device "kinoCOM" because it translates motion into communication.

These days, the ability to use a computer mouse is equivalent to the ability to communicate. It affords the ability to control your television, your wheelchair, your thermostat, and a range of other devices. With computer access comes access to an ever growing and improving repertoire of applications. Before his stroke, JB was a computer programmer. Restoring his ability to manipulate a cursor will improve his quality of life. As our military becomes increasingly computerized, computer interface technologies such as the kinoCOM can not only increase the quality of life of wounded veterans, but may allow them to continue to serve.

Problem Description

JB had suffered a brainstem stroke that left him almost completely paralyzed except for limited control over a few muscles in his right hand and face. Importantly, he retains roughly 30 degrees of motion in his thumb and index finger. The focus of this report up until now has been on this single patient that inspired our work, but JB's disability reflects a common limitation in our society. There are currently around 273,000 persons living with spinal cord injuries in the USA [1]. Limitations in arm mobility can be the result of neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS) as well as trauma leading to paralysis or amputation. Models estimated that around 33,000 of those disabled by 2014 will be US military veterans [2, 3].

This group of over one quarter million Americans is by no means homogenous. Of those with spinal cord injury, there are approximately 12% with complete tetraplegia, 40% with incomplete tetraplegia, 18% with complete paraplegia, and 19% with incomplete paraplegia (11% other) [1]. Even within any of those groups, the constellation of deficits varies widely across patients and, in many cases, can change drastically within a single individual in a matter of months.

There are a number of hardware and software technologies designed for or co-opted to enable the paralyzed to communicate. As a group, these are called augmentative communication devices. Most of the hardware falls in the larger category of computer interfaces. A few of the inputs used by these devices include gaze-tracking cameras, a headband with a motion sensor, and a glove (built for gaming) that allows users to tap pairs of fingers together to execute keyboard commands. The devices range in price from ~$500 (headband system [4]) to ~$10,000-$20,000 (eye gaze system [5]). In the case of JB, the eye tracking devices were unusable because he has damage to one of the nerves controlling his ocular muscles, leading to mild nystagmus (twitching of his eye). Those able to use the eye gaze system can type efficiently, but it is not adapted to enable the full functionality of a computer.

All of these technologies are innovative and useful, but they possess a common limitation. Each one co-opts a specific action (head movement, eye movement, finger touch) for the purpose of a computer interface. None of those actions are attainable for JB so these technologies do not help him. For other patients, the prohibitive cost of these technologies is the limiting factor.

JB needed an augmentative communication device personalized for the muscles that he could control. We saw the possibility for a device with the flexibility to allow the user to easily recalibrate to different ranges of motion or different motions all together. Thus, our goal was to design a low cost, customizable, and easy-to-use computer interface. The kinoCOM prototype represents the design that we felt best fits all of these criteria.

Device Design

The kinoCOM prototype has two 'control rings' that can be manipulated by the user to control a cursor. Each control ring contains an inertial measurement units (IMUs, or combined accelerometer-gyroscopes) that capture 6 degrees of freedom [6]. The IMU rings are fabricated using a 3D printer in order to accommodate the irregular shape of the IMU and the particular size of the patient's fingers. The rings were designed in CAD and printed with a desktop 3d printer using Flex EcoPLA [7]. They were designed to be worn on JB's thumb and index finger, but the material could just as easily be used to make armbands and the basic unit can be attached to and controlled by just about any part of the body.

The measurements taken by the IMUs are sampled using Arduino microcontroller. A multiplexer allows us to use multiple IMUs with the same address simultaneously. It also allows us to add additional IMUs (or other sensors) to customize the device to the patient and his needs. The Arduino uses I2C protocol to read from the IMUs. It then sends position data to a serial communications port through USB to the user's computer .

In its current prototype, the body of the code is written in Processing although it could just as well be on the Arduino. The first 5-10 seconds of data is used to calibrate a reference position. The orientation of each gyroscope is averaged while the patient is not moving and the averaged position is defined as the origin for that IMU. When the gyroscope is moved away from the origin, the cursor begins roving at a speed proportional to the angular displacement.

The code (proc_2IMU_commented.pde) could easily be converted into an Arduino.ino file, allowing the IMUs to control devices other than computers (e.g., prosthetics, robots, UAVs) in the future. We initially wrote all of the code for the microcontroller but later opted to convert it to Processing for the prototype. This allowed team members to develop the code without having the Arduino present. This also helped us quickly incorporate additional sensors such as the Xbox Kinect when prototyping the device. Processing also allowed us to use the java.awt.robot class to move the cursor, which is the only part of the current code that requires Processing. Processing and Arduino are similar languages, so if it is preferred, we can convert the code to run fully on the Arduino with ease. We hope that the judges will agree that the vast majority of the Processing code could just as easily be run on the microcontroller, making it the brains of the device.

In the 2-ring format, clicking is accomplished by holding the cursor over the desired target for 2 seconds. However, as mentioned above, we have designed the code to be modular to enable easy switching between different numbers and types of inputs. Additional modifications that we have experimented with for faster clicking include a third control ring and the ability to read in data from an Xbox Kinect through a separate CommPort.

We have met with JB and his wife to test our device and get their continued prospective. As specified by the microMedic guidelines, we have not included footage of JB using the kinoCOM. As we have expanded and improved upon our device, we have used a standardized metric of typing "Hello, how are you?" to measure and compare it's utility. Currently, in order to type, JB uses a small clicker under his right hand and software that scrolled line-by-line through an alphabet grid. For each letter, he taps when the correct column was highlighted, then tapped again for the correct row. The program uses predictive software to help JB complete words. Using his current setup, JB takes 77 seconds to type "Hello, how are you?" with the help of predictive text.

In our trial runs, typing with the kinoCOM is accomplished using a virtual keyboard without predictive text. Even without predictive text, the earliest prototypes of kinoCOM took under 77 seconds, of which 38 seconds were required for the 2-second-click method. In earlier versions, such as those demonstrated in the submission video, the velocity of the gyros above a certain threshold was used to control cursor velocity. We later moved to the current system in which gyro position (away from a calibrated origin point) controls cursor velocity. This reduced the time it takes to type a sentence considerably. Currently, we are able to type "Hello, how are you" in under 1 minute. Predictive text software would cut this time further. We have not yet speed tested with three control rings or with the Xbox Kinect. The greatest advantages of kinoCOM is seen when the patient freely uses the mouse, such as when he is surfing the internet.

If we had purchased all of the parts required to make our device at retail it would have cost us approximately $150. That number might increase with the additional input components. But we are certain that we are creating a device that is more useful and less expensive than any device available.

Future Timeline

We see several logical updates to improve the kinoCOM prototype's capabilities. Instead of controlling a keyboard, which was intentionally designed to slow typing speeds on typewriters, we could design software with more efficiently organized and spaced letters for faster cursor-based typing. Predictive text software can drastically improve typing speed by allowing a user to confirm a whole word or phrase instead of typing letter by letter. A better system to select/click would also greatly speed up operations.

While the current prototype relies on wires to connect the IMU rings to the Arduino and the microcontroller to the computer, we would like to make the entire system wireless. This would eliminate the wires over the user's hand and make it easier to move the gyros with more distant muscle groups. Wireless microcontroller-to-computer connections could also be more functional for some applications, and improve device portability.

On/off gestures are another potential modification that could help eliminate unintentional movement of the cursor or typing by the user. Interfaces with wheelchairs or other daily tools would expand the patient's control beyond a computer and facilitate movement in addition to communication. In JB's case, he could take control of his own wheelchair instead of requiring his wife to control the joystick for him. The modular setup will allow these changes to be easily incorporated into kinoCOM.

Further Applications

In addition to the functions described above, we envision several modifications that can augment the kinoCOM's functionality. Different inputs, such as pressure readings, electromyography (EMG), or eye tracking can be added to the device depending on an individual patient's abilities. Combining multiple inputs also expands the degrees of control over the system if a patient intends to control multiple outputs simultaneously. In addition to controlling computers, we could harness kinoCOM technology to control prosthetics or robots.

IMUs and other sensors can also be powerful tools of control outside of healthcare applications. The gaming community is already starting to use motion sensors to augment gameplay. Surgeons could use a glove with several IMUs for exquisite control over robotic surgery tools such as the DaVinci Robot. Military applications might include controlling unmanned vehicles, exoskeletons, or drones. The great advantage of kinoCOM is that its modular design allows it to be adapted to new technologies and purposes.

Conclusion

The ability to easily build and use microcontrollers has opened up tremendous possibilities for improving healthcare. As we sat there after JB left, we talked about how communication tools around us are changing so rapidly and yet the tool he uses to reach the outside world are decades out of date. Our focus from that point onward has been to design a device that is flexible enough to help any potential patient no matter the extent of their impairment. The modular setup of kinoCOM enables flexibility to use a wide variety of inputs to robustly control devices. The gap between what is, and what can be, inspired us. We believe this is also what inspired Parallax to create the microMedic competition. We are very grateful to Parallax and the microMedic 2013 National Contest for providing us with this exciting opportunity to learn, explore, and try to help our military and community.

References

[1] National Spinal Cord Injury Statistical Center and University of Alabama at Birmingham, “Spinal cord injury facts and figures at a glance.,” *The Journal of Spinal Cord Medicine*, vol. 36, no. 2, pp. 170–1, Mar. 2013.

[2] J. E. Lasfargues, D. Custis, F. Morrone, J. Carswell, and T. Nguyen, “A model for estimating spinal cord injury prevalence in the United States.,” *Paraplegia*, vol. 33, no. 2, pp. 62–8, Mar. 1995.

[3] M. J. DeVivo, “Epidemiology of Spinal Cord Injury,” in in *Spinal Cord Medicine: Principles and Practice*, 2nd ed., C. M. Bono, D. D. Cardenas, F. S. Frost, M. C. Hammond, L. B. Lindblom, I. Perkash, S. A. Stiens, and R. M. Woolsey, Eds. New York, NY: Demos Medical Publishing, 2010, pp. 78–84.

[4] Natural Point, “SmartNav 4:AT,” 2013. [Online]. Available: http://www.naturalpoint.com/smartnav/products/4-at.

[5] The ALS Association, “Augmentative Communication,” 2010. [Online]. Available: http://www.alsa.org/als-care/augmentative-communication/.

[6] Sparkfun Electronics, “IMU Digital Combo Board.” [Online]. Available: https://www.sparkfun.com/products/10121.

[7] “Flex EcoPLA,” *MakerGeeks*. [Online]. Available: http://www.makergeeks.com/flecna1.html.