Digit: A low-cost, open-source, universal, biometric HID for ALS care

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Abstract

Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease that reduces an individual's control of voluntary muscles, leading to eventual paralysis. There are no known cures for ALS, but symptoms can be managed using assistive technology. Assistive technology often has extremely high cost due to the customization of input devices. For example, wheelchair control mechanisms need to be adapted to each individual depending on their unique progression, driving prices up by orders of magnitude.

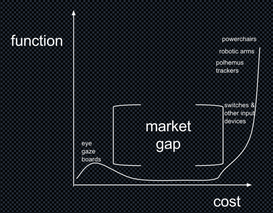
To solve this, we have developed Digit, a low-cost (under 10 USD) and adaptable human interface device (HID). Its applications currently include controlling a cursor on a computer screen and recognizing gestures for language output; however it is a general input device that has the potential for applications in the control of other assistive technologies, such as wheelchairs and robot arms.

In addition to its role as a universal input device, Digit is unique in that it serves as a platform for future development. It passively measures muscle deterioration, allowing for future informatics research regarding the progression of neuromuscular diseases. Additionally, it is completely open-source and modular, allowing for development of new applications for use by regular patients.

In comparison to contemporary assistive technology, Digit is uniquely cost-effective due to its simple mechanical design. Its ergonomic generality helps eliminate the gap between users and assistive technology providers.

Introduction

- ALS is a progressive neurodegenerative disease
- Patients experience degradation in the strength and control of voluntary muscles, until complete paralysis
- For more than 90 percent of cases, the cause is unknown
- There is no known cure, and the only existing treatment extends life expectancy by a mere two months
- Most treatment is in the form of symptom management based on assistive technologies
- Most assistive technologies involve regaining the ability for normal life, centered on concepts like robotic arms
- The cost of implementation of these technologies is generally in the range of 50,000 USD
- The high cost of modern assistive technologies is due largely to the difficulty of necessary customization to a specific user
- ALS affects people in highly varied manners, and as a result assistive technologies need to be designed specifically for individual patients, resulting in extremely high costs

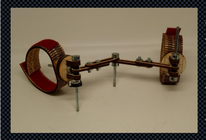


- Adaptability can also be difficult due the lack of data collected about the progression of a disease in an individual
- There are currently few devices which passively track muscle motion, or otherwise collect metrics to inform users
- Additionally, there are no universal metrics specifically designed to track the progression of ALS
- Measurements to classify the severity of cases of ALS are general metrics, with ambiguous significances in relation to ALS, and their analyses are limited to clinical settings
- Research and development in ALS has been relatively stagnant due to a lack of readily available data

Product Overview

Version 1 (under 10 USD)

- Digit is essentially a wearable, modular, and adaptable joystick – a simple mechanism
- It extrapolates motion based on two potentiometers, measuring the angles of a joint
- The analog potentiometer signals are interpreted by a PSoC 5LP microcontroller, which can be used as output for a USB HID Mouse or any other device.
- The majority of components were laser cut, in order to minimize cost
- All other construction materials are readily available for a minimal cost
- The cost of Digit is under 10 USD. With efficient production, it will be under 5 USD.

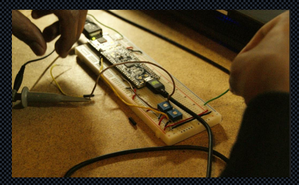


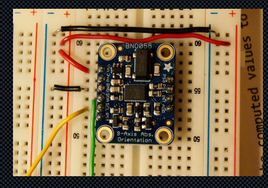
List of Materials

- 32-bit ARM® Cortex®-M3 PSoC® 5LP
- (2) Potentiometers
- 1/8" Birch Plywood
- 1/8" Square Metal Shafts
- Assorted Machine Screws, Nuts, Collars, Washers, and Spacers
- Velcro Straps

Version 2 (in development)

- Digit V2 uses two 9DOF Inertial Measurement Unit Sensors (one on each side of a joint)
- V2 should be compatible with V1, allowing for modularity and expansion
- V2 adds precision to Digit, allowing for applications such as biometrics
- V2 adds multiple axes to Digit, allowing it to record more movement for applications such as 6DOF robotic arms
- V2 adds ergonomic comfortability and low visibility, allowing it to be placed almost anywhere on the body
- The price of V2 is already under 100 USD as a prototype. This price can reduce easily with component reduction and efficient production.





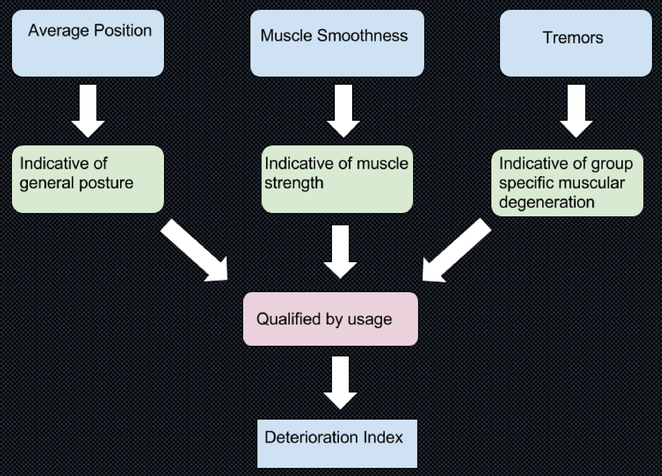
Application: Metric Analysis

One of Digit's most unique aspects is its ability to passively record and analyze information regarding muscle deterioration. This characteristic allows both users and researchers to understand the capabilities of degrading muscles.

- Digit's metric analysis software extrapolates as many valuable metrics as possible from potentiometer angle values
- Each of these metrics can be used to monitor and classify the deterioration of muscles and muscle groups
- The magnitude of deterioration metrics are adjusted for the amount the muscles are used during the measured time frame
- These metrics are incorporated in a single summary value of deterioration index
- The deterioration index represents a rate of muscle degradation measured on a daily basis, useful to caregivers, clinicians, and researchers in finding progression patterns

Metric	Calculated by…
Average Position	Finding modal data points
Muscle Smoothness	Determining average angular acceleration excluding points when at rest
Tremors	Identifying patterns of opposite accelerations at constant intervals of between 8-12 Hz.

- Precision of metrics, especially tremor detection, can be greatly increased with the use of modular inertial measurement units
- Depending on the hardware used, the metrics can have varying levels of specificity, as required by the patient

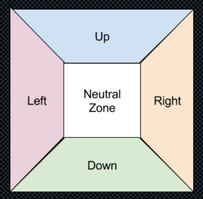


Application: Language Output

Digit can be applied to several domains of assistive technology. Its universality allows it to fill many market gaps.

- One of the largest assistive technology market gaps is that of efficient communication methods
- There is a distinct lack of low-cost digital communication
- Digit can overcome this by serving as device for language output through an "air-writing" method
- Each letter is condensed into an intuitive set of three sequential directions
- The user inputs three movements beyond a defined neutral zone, and the directions and their order denote a character
- This is more efficient than gaze boards, while only slightly increasing cost
- The precision required is small enough that it can be used even with the basic potentiometer setup

An example of the three direction composition of a letter



A diagram of the direction zones for character input

Evaluation

Potential Benefits

- Digit is uniquely cost effective, with production costs significantly lower than any current market options
- This is because it is based on the simplest possible model, with only enough functionality as necessary
- Additionally, Digit has the advantage of extreme adaptability
- While most current options require customization from assisted technology providers, Digit can be optimized for use with minimal technologic proficiency
- Digit is also unique due to its passive metric capabilities, allowing caregivers to be informed
- The accumulation of metrics will allow for further development of technology and informatics research

Limitations

- The current prototype (V1) is limited to use in parts of the body compatible with the straps
- V1 is a significant obstruction to certain activities, and is not very comfortable to wear
- The current prototypes are relatively fragile
- The task of identifying causes, and potential solutions of deterioration currently falls on the user
- Tremor detection has not been tested in realistic settings
- Digit measures the deterioration of one specific region of the body, which may not be representative of total progression

Future Direction

- Automated adaptability: Digit collects data that would allow it to adapt to user inputs over time, interpreting whether the location of Digit's components should be moved
- Increased functionality: we could use multiple modes (to allow for more than simply 2-D motion)
- The IMUs will be developed into an ergonomically suitable, and modularly-attached system, allowing the user to completely optimize the functionality of Digit
- The language output method could be incorporated into a user-friendly software that allows customization
- The language output method could expanded from three directional characters to interpret true handwriting
- The language output method could use live audio speech generation for conversation
- Modularity of analysis: allowing variable analysis functions depending on the level of progression of the patient would be highly beneficial and possible with the data collected

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