WEARABLE GESTURE RECOGNITION SYSTEM WITH APPLICATIONS TO AMERICAN SIGN LANGUAGE

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INTRODUCTION

American Sign Language (ASL) is the predominant sign language within deaf communities in the United States (US) and most of Anglophone Canada. According to the World Deaf Federation, there are approximately 70 million deaf people in world and about 250,000 to 500,000 native ASL speakers in the US[1].

Although deaf people communicate effectively with each other using ASL, interacting with the rest of the world remains a challenge. This is especially evident in daily activities (e.g. checkout counter at a grocery store, drive-thru at a restaurant, dealing with children or colleagues, or over the phone). And in such settings, writing or typing to communicate with a non-deaf individual may not be appropriate or practical.

The goal of this project is to develop a lightweight, wearable, and cost-effective communication system for native ASL speakers, which can translate the ASL into text or speech. The current prototype of the device is comprised of a set of extremely lightweight ring and fingernail based sensors (Figure 1). This allows input, via hand poses/gestures, to be collected as the user makes various signs. The "sign" detection offered by the current prototype is for the recognition of the ASL manual alphabet, which consist of 26 corresponding letters and signs.

In Human-Computer interaction, there are two main approaches used for gesture recognition and interpretation: vision-based approach and data glove-based approach[2]. In the vision-based approach, hand pose is reconstructed by use of a camera. And through processing techniques, such as gray-scale imaging, relevant features regarding the image can be extracted for interpretation. While, the data glove-approach employs the use of sensors attached to a glove. The sensors generate electrical signals, as a result finger flexions, which are processed to determine hand posture[2].

The appeal of the vision-based approach is the absence of a worn device and the ease of interaction with machines, especially if the user does not have much technical knowledge about the system. Still with this approach, there exists the issue of portability. Although the glove-based approach offers portability, it is not ubiquitous in daily life and so there exists the issue of mass adoption.

The system being developed for this project, is similar to a glove-based approach, but does not require a worn glove and offers more compactness. In addition, since ASL is "spoken" using both hand gesture and movement, the current system can be viewed as a precursor to a fully wearable ASL recognition system which can also take hand motions into account.

PRODUCT DESIGN

Most glove-based ASL recognition systems built are too cumbersome to use. Hence, the present system design scales down the essential portions of a "glove-based" ASL recognition system to miniaturized devices mounted on top of fingernails and rings, leaving the hand free of any haptic encumbrance[3].

At the core of the design is a fingernail mounted light transceiver device instrumented with Infrared Light Emitting Diodes (IR LEDs) and phototransistors[4]. The IR LEDs and phototransistors are placed on both the "nail facing" and "air facing" sides of the device, which is shaped like a plastic fingernail. The device is cast in smooth, transparent resin, and affixed to each fingernail using a temporary nail adhesive. In addition to the fingernail mounted light transceivers, the system also utilizes similar transceivers mounted on transparent rings worn on each finger. Thus, the current system comprises of five dual-sided fingernail sensors/transceivers, along with five transparent rings.

Changes in illumination of the IR LED are observed on each device whenever contact is made between any two fingers. The system exploits the fact that biological tissue is mostly transparent to IR. As such, it can detect contact between two finger pads, a fingernail and a finger pad, two rings, and between a finger pad and a ring. In this manner, the system can detect most hand configurations used in ASL.

Implementation of the device was performed using surface mount technology (SMT) components to build compact fingernail-sized sensors, each driven by an Arduino Pro Mini microcontroller board. This sub-unit was then mounted on a 3D CAD designed ring holder, which was integrated with a battery pack for power supply. In each sub-unit, the sensors serve as transducers, where contact between various parts of the hand are measured as electrical signals. These recorded signals are then processed for letter recognition.

The hardware development of the sensors involved the design of a flexible Printed Circuit Board (PCB), using an electronic design software called KiCad, to fabricate a small dual-sided mounted circuit. The circuit, on both sides, consisted of SMT components: phototransistor, LED, and resistor. To reduce the interference of electrical noise, the sensors were cast in a negative resin mold, the size and shape of a fingernail, using optically clear resin. The software development, for gesture detection and recognition, involved the design of a data acquisition scheme. This entailed, modulation of all 15 LEDS (2 on each fingernail sensor, 1 on each transparent ring) at different frequencies during performance of gestures by the user.

There is a high concentration of vision based systems, specifically Machine or Computer vision-based approaches, to ASL gesture recognition[2]. The system being developed, is unique in that it does not require input collection (gesture recognition) through the aid of camera. In addition, it does not require any extra worn device such as glove and so the user would still be able to use the system with hers/his normally. Instead, the user would wear the lightweight system on the hand for “signing” and the letters will be translated and printed on a graphical user interface (GUI) program. The interface can also identify the words and speak them out loud using existing software systems which run on smartphone and tablet devices.

The technology (hardware and software) and materials used in design of the device provide for optimization and miniaturization that will realize a feasible market-ready product. IR LED eye safety experiments were performed to ensure that the recommended IR radiation intensity, without damaging the eye, of 100W/m^ 2 was not exceeded.

BUDGET & MARKET ANALYSIS

US industry reports conducted by IBISWorld indicate market revenue for translation services at 5.4 billion, with an annual growth rate of 5.2%. As the demand for ASL interpreters continues to increase coupled with a rise in awareness of the language, a growth in ASL technologies is expected to soar as well.

The market demographic for the device consists of deaf or hard of hearing persons, “speakers” of ASL, and those interested in learning ASL. The expected sales is estimated at 100,000 units/year. At this volume, the manufacturing cost per unit is estimated at $10.57. This price reflects the materials required per unit of the device: 15 IR LEDs, phototransistor, and resistors, including a PCB board and wires. Production at this volume allows for a much lower manufacturing cost per unit, versus the expenses associated with a prototype (Table 1).

Investments in engineering will consist of about 200 hours of professional engineering services, including adapting the design for manufacturing and automated assembly. And at about $100/hour, the total cost for engineering services is roughly $20,000. Tooling, which consists primarily of injection molding, is estimated at $13,000. Thus, the total cost of production is estimated at $1,090,000.

The projected sales price is $89.99, which is very affordable compared to competitors such as MotionSavvy ($799). Since the expected revenue is $8,999,000, investment, tooling, and manufacturing costs are expected to be offset after the first year’s sales, with a gross profit margin of 87.89%.

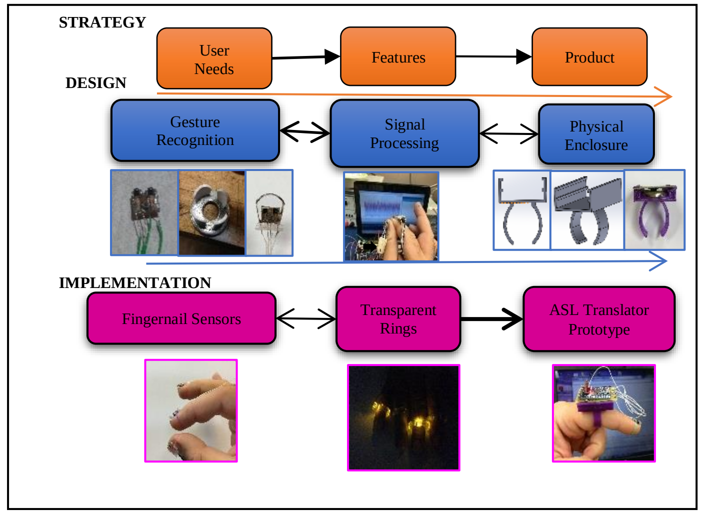

Figure 1: Functional decomposition of the ASL manual alphabet translation system.

ITEM	COST
PCB	
Equipment/parts related to the construction and modification of PCB	**66.82**
Etching	
Related to etching of the PCB (flexible & non-flexible)	**54.83**
Microcontroller assembly	
Related to building the Pro-Mini assembly	**55.48**
Casting	
Material required to make molds and cats for the fingernail sensors and transparent rings	**126.13**
Milling	
Material required fabricate PCB sensors	**26.18**
Soldering	
Material required assembly of PCB sensors	**101.75**
Total cost (Overall)	**431.19**

Table 1: Project budget for designing, building, and testing the prototype.

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REFERENCES

[1] Ross, E. M et al., *Sign Language Studies*, 6:28, 2006.
[2] Murthy, G. R. S. & Jadon, R.S, *IJITK*, 2:405-410, 2009.
[3] Yetkin, O. Ph.D. in BE, Intuitive Human Robot Interfaces for Upper Limb Prosthetics, 1-214, 2016.
[4] Yetkin, O., Ahluwalia, S., Silva, D., Kasi-Okonye, I., Volker, R., Baptist J. R., Popa, D. O., *SPIE*, 9859:1-8, 2016.