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INTELLIGENT MOBILITY CANE FOR PEOPLE WHO ARE BLIND AND DEAF-BLIND: A MULTIDISCIPLINARY DESIGN PROJECT THAT ASSISTS PEOPLE WITH DISABILITIES

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ABSTRACT

Vision loss knows no boundaries; it can affect anyone, of any age, income level, race, or ethnic background, at any time. Regardless of the level of visual impairment, vision loss can impact a person's life and their ability to complete everyday tasks. One of the greatest challenges that a blind or deaf blind person faces is the ability to navigate safely and independently through the physical world. Traveling with little or no vision at all can be challenged and inaccessible, limiting the ability to work, go to school, take care of personal needs, or socialize with others.

The purpose of this paper is to describe and discuss a multidisciplinary project to design and build a low cost, light weight "Intelligent Mobility Cane" prototype that will aid deaf-blind and blind persons in navigating surroundings via real-time tactile and directional force feedback and guidance. The system is designed for providing information about a physical surrounding environment to a user. The solution developed by the team is a handle that attaches to a white cane and provides directional feedback to the user using a roller assembly. The roller assembly uses four bearings that rotate in one direction or another to indicate the direction the user should move to avoid obstacles. A vibration motor with different patterns of vibration is also embedded in the handle to warn about objects at upfront. The ultra-sonic sensors are used to convey the information of the environment to the handle itself. The finished cane physically resembles a conventional cane therefore allowing the user to still be able to sweep the cane, tap and feel the ground. To evaluate the performance and usability of the designed handle, the authors visited Association of Blind and Visual Impaired Association, where they formed a group of blind and deaf-blind evaluators. The result of the evaluations was positive and several suggestions were shared by the group to improve the cane.

INTRODUCTION

Assistive technology helps people with disabilities to manage and accomplish daily tasks better and assists them in many areas such as communication, education, work, and recreational activities [1]. In other words, the technology helps them be independent and enhances the overall quality of life. While many different assistive technologies are available, this project focuses on those that enhance the mobility of blind or visually challenged people.

The World Health Organization estimates that 285 million people are visually challenged worldwide: 39 million are blind and 246 million have low vision [2]. Also, a study commissioned by the Department of Education estimated that between 42,000 and 700,000 individuals have some level of both vision and hearing loss [3]. Navigating through the physical world is a tremendous challenge for those people. Blind or visually challenged people have a considerable disadvantage as they lack information for bypassing obstacles and have relatively little information about landmarks, heading, and self-velocity.

Canes and service animals offer low-technology solutions. Much research has been done worldwide on support systems for the visually challenged [4-7]. However, most of this work includes an audio interface which provides the hearing-blind person a sound feedback about the surrounding environment [7-10]. Devices relying on an audio signal for information conveyance are not well suited for noisy environments such as heavily trafficked streets where audible signals are difficult to detect and interpret. These devices are especially ill suited for deaf and blind individuals who are incapable of hearing the audio signals. This project engages advanced technology to solve the age-old problem of assisting blind and deaf-blind people as they move about in their daily lives.

The main objective of our development is to provide useful additional information without using audio interface to deaf-blind people during their mobility process. Also, our solution focuses on a low cost, lightweight prototype that will aid a deaf-blind person in navigating surroundings via real-time tactile and directional force feedback and guidance.

DESIGN PROCESS

Traditionally, the white-cane is the most popular and important assistive device for visually challenged people [4]. In this project, the handle of a standard long white cane shaft has a built-in handle with a force feedback rumble unit which guides the user away from the obstacle and object as shown in Figure 1. Also, a detection system mounts toward the tip of the cane.

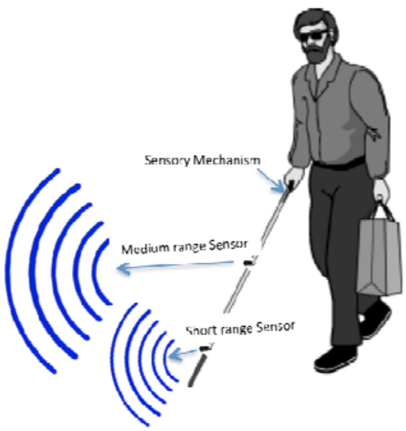


Figure 1. Overview of Mobility cane Architecture

The cane handle consists of an integrated directional force feedback unit. This unit will rotate when the cane detects an obstacle, thereby signaling the user. The object detection system uses four ultrasonic wave sensors, which when combined, create optimal potential for interpretation of the physical environment (representation). A small embedded microcontroller with general-purpose I/O interface will be used to collect data from the detection system, compute the optimal interpretation of the physical environment, and control the sensitive tactile pad based on the physical environment. The microcontroller (μC) integrates inside of the Intelligent Mobility Cane and is operated by a light-weight battery. As the user encounters an obstacle, the force feedback rumble unit guides the user away from the obstacle.

Handle [11]

The design objective of this project is a dramatically improved handle for a mobility cane that provides haptic feedback. This feedback will quickly respond to signals from a detection system. The cane handle is designed to visually and physically resemble a conventional handle and intuitive enough to be used with minimal training. Since the cane would be in constant use throughout a day, comfortability is a significant factor of the design. The grip diameter and weight of the handle was seen as a part of this specification.

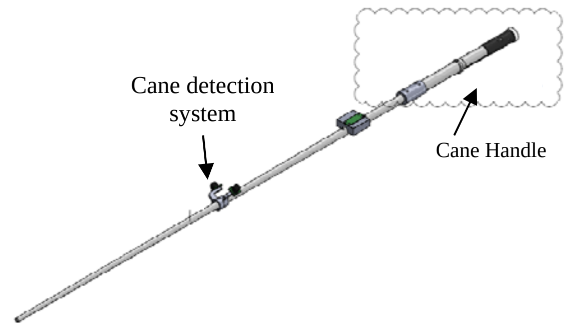


Figure 2. Schematic of the Mobility cane (Handle and the detection system).

The team designed and manufactured a handle that attaches to a white cane and provides directional feedback to the user using a roller system (Figure 2). This system contains ball bearings (Figure 3) that will roll beneath the palm, allowing the user to feel the direction of rotation. For example, if the rollers rotate to the right, it indicates that there is an obstacle to the left and that the user should travel to the right.

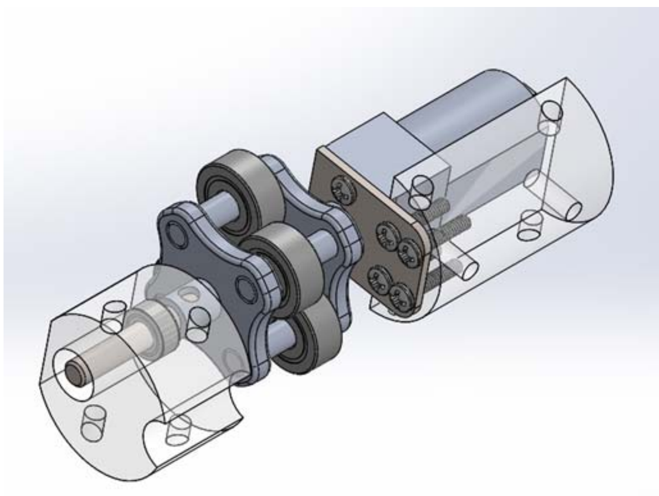
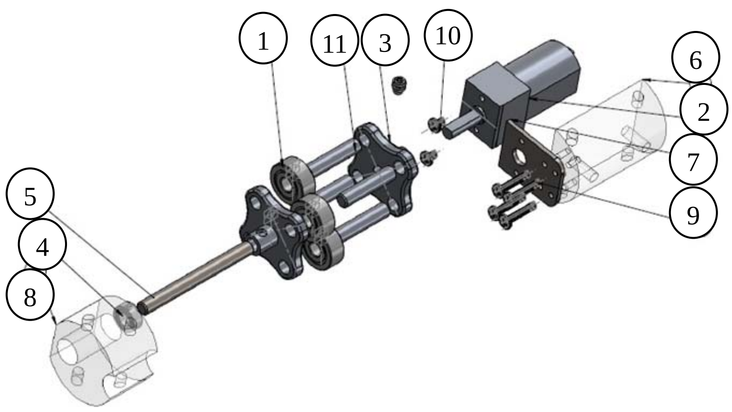


Figure 3. Roller system modeled using Solidworks.

The fabrication and assembly of all components was performed in house at our college's machine shop. There were a total of 16 parts that were fabricated either from ABS plastic or aluminum. The roller system assembly was secured onto the handle bottom plate with machine screws. Figure 4 shows a detailed drawing of the roller system.



1	Ball bearing	7	Motor mount
2	Screw	8	Motor mount plate
3	Shaft ball bearing	9	Shaft mount
4	Round shaft	10	Screw
5	Motor	11	Dowl pin
6	Rolle holder		

Figure 4. Roller system modeled using Solid Works.

In order to integrate the handle with the detection system, two battery clips were epoxied onto the handle bottom plate. Wires that interface the microcontroller and power management system were fed through the hollow adapter and cane and connected with plugs inside the handle to complete the assembly. Mounts for the microcontroller and sensors are also epoxied to the cane with wired being fed through the hollow fiberglass cane as necessary. The Printed Circuit Board (PCB) is secured on the handle between two PCB holders that are glued on the handle next to the batteries. To complete the handle assembly, two covers are placed over the bottom plate and secured with two collars.

The Detection System

The initial overview of the detection system architecture is shown in Figure 5.

The system consists of ultrasonic distant sensors, which are short and medium range sensors, and a microcontroller. The short-range sensor is used to detect any immediate obstacle or object and fulfills any immediate action requirements for the cane. The microcontroller receives an input from the sensor and processes it immediately to determine the instruction for the cane handle. A medium range sensor is also used to detect any obstacle or object at further range and is used for the warning purpose of the cane.

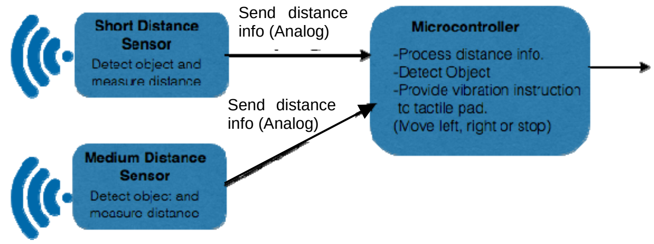


Figure 5. Overview of the detection system architecture.

The microcontroller is considered the thinking part of the Intelligent Mobility cane. The responsibilities of the microcontroller are listed below:

- Accept the distance analog information from sensors and convert to digital information.
- Process the digital information from short range sensor and determine an immediate action for the rumble device.
- Process the digital information from medium range sensor and prepare a possible action in new future state. The information will be used to determine the complexity of the surrounding.

Microcontroller for the Detection System

The microcontroller selected for this project is part of MSP430 family from Texas Instruments. A 32-bit ARM Cortex-M4 architecture was chosen because of its higher performance, small footprint, low-cost, and low-power-consumption.

This device is responsible for processing the sensor readings, modulating feedback; and serving as an ‘interpreter’ between the user and physical environment. The ARM microcontroller switches between active/sleep modes on demand to conserve as much battery life as possible. The microcontroller is flexible enough to accommodate overall design including sensors, feedback devices, wireless modules, and user input devices.

Integration

The purpose of integration is to connect the detection system (sensors), the cane handle (directional force feedback unit) and the microcontroller device (circuit board) together. The detection system consists of sensors mounted on the cane. The sensors, the microcontroller, the bi-directional haptic force feedback devices, the vibrator and various other components are powered by the power supply, which is a light-weight battery.

Analog information from the sensors is input to an analog to digital converter before being sent to the microcontroller (Figure 6). The microcontroller processes the converted signals from the sensors to determine information about the surrounding environment. The microcontroller specifically interprets to determine distances and directions to potential obstacles within the sensor ranges. The microcontroller then sends the processed information to a digital to analog converter before supplying the information to the dual purpose, bi-directional haptic force feedback devices and the vibrator to provide information about the surrounding environment to the user through tactile feedback. The handle positioner allows a user to ensure consistent hand positioning with respect to the tactile pad.

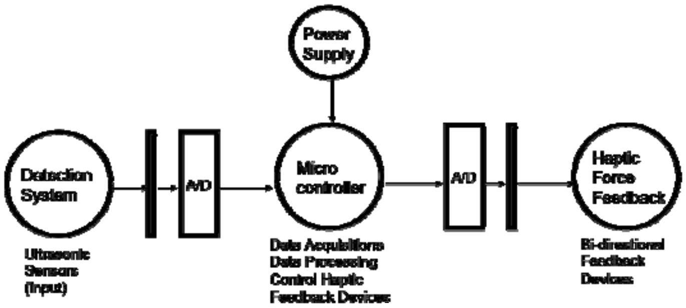


Figure 6. System architecture.

Evaluation

The Association of Blind and Visual Impaired has a user group, which consist of 10 to 15 blind and blind-deaf individuals from the blind community. The group evaluated the usability of the smart cane, particularly, the cane handle with haptic feedback. To perform the evaluation, a series of questions were developed to obtain feedback about usability and effectiveness of the cane. In most cases, the user group liked the roller system feedback and the speed of the rotation, indicating information about the sharpness of the turn needed to avoid the object. The group also agreed that the design was unique and the left and right indications were very clear. Some of the group’s concerns were about the battery life of the cane since the moving roller system needs good amount of energy to rotate the roller. However, our design uses a rechargeable battery and when it is fully recharged, the cane can be used for several hours continually without any battery drainage issue. Another concern was that the sensitivity is reduced when the cane is used with gloves. The team has reviewed the solution and identified missing integration requirements and changes that need to be made. During this phase of the design process is common jump back and forth between steps. With this **iteration design process**, we ensure the right changes and refinements of the prototypes.

Future work: Internet of Things (IoT)

The IoT is the currently driving technological force of global markets over the next several years. One of major benefits of the IoT is to improve productivity and save costs. Consumer demand is also driving IoT adoption as the embrace new technology to improve health, energy savings and safety that will make new things we haven’t even thought of yet. For example, due to the advent and heavy use of smartphones, they are now becoming the personal gateway to the IoT as shown as Figure 7.

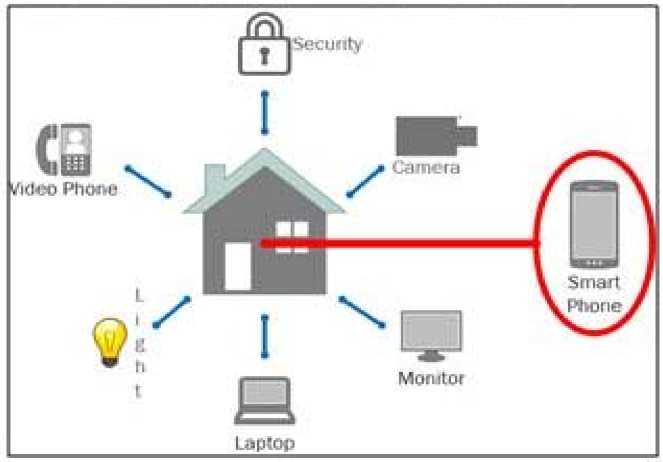


Figure 7. High-level design overview.

Figure 7 illustrates the connectivity between different control devices with computer based devices (smartphone and laptop). The IoT is the network of physical objects or "things" embedded with electronics, software, sensors and connectivity to enable it to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices. For the Intelligent Mobility Cane application, the IoT would be embedded with the microcontroller, and connectivity devices (via Bluetooth and WiFi) to allow the user to be connected with internet for navigation purpose.

CONCLUSIONS

This paper describes and discusses a multidisciplinary project which is to design and build a low cost, light weight “Intelligent Mobility Cane” prototype. The cane aids deaf-blind and blind persons in navigating surroundings via real-time tactile and directional force feedback and guidance.

Completing the design of the Intelligent Mobile cane provided great learning experience for undergraduate students, blind-deaf students, and faculty involved in the project.

Research and evaluation will continue to improve the current prototype and additional technology will be considered.

ACKNOWLEDGMENTS

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