envision today

School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC
V5A 1S6

February 11, 2013

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Functional Specification for NaviCane: Navigation-Assisting White Cane

Dear Dr. Rawicz,

Enclosed with this letter is our *Functional Specification for NaviCane: Navigation-Assisting White Cane* for our Engineering Science 440 Capstone Project class. Our design and implementation will provide additional ways for those that are visually impaired to navigate freely in almost all urban areas.

In our functional specifications, we will be outlining a series of high-level requirements necessary for the product to function in its multiple development phases, such as the proof-of-concept, prototype, and production stages. This document will allow our engineers and managers to follow the requirements and development activities when bringing the product into fruition.

Envision Today is composed of a four-member team of senior engineering students whose knowledge and expertise allows for an effective delivery in products featuring hardware and software solutions. The team, Vincent Guan, Edwin Leong, Raymond Li, and Darren Tong, has a background in systems and computing engineering. If you have any questions or concerns regarding our functional specifications, please feel free to contact Raymond Li via email at rla41@sfu.ca.

Sincerely,

Vincent Guan
CEO
Envision Today

Enclosure: *Functional Specification for NaviCane: Navigation-Assisting White Cane* envision today

Functional Specification for NaviCane: Navigation-Assisting White Cane

Project Team:
Vincent Guan
Edwin Leong
Raymond Li
Darren Tong

Contact Person:
Raymond Li
rla41@sfu.ca

Submitted to:
Dr. Andrew Rawicz - ENSC 440
Steve Whitmore - ENSC 305
School of Engineering Science

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Executive Summary

While there are many navigational-assisting products on the market for the visually impaired, there are still fundamental flaws in allowing visually impaired users to travel independently. The NaviCane, Navigation-Assisting White Cane, is a product that Envision Today is developing to enhance the quality of life for the visually impaired. NaviCane allows their users to program desired locations to their white cane. By following the haptic feedback provided by the cane, the user is able to travel to new locations without relying on further assistance. The NaviCane reduces the concerns arising from current navigational-assisting devices, such as cognitive and economical requirements.

The development cycle is modeled after the figure below.

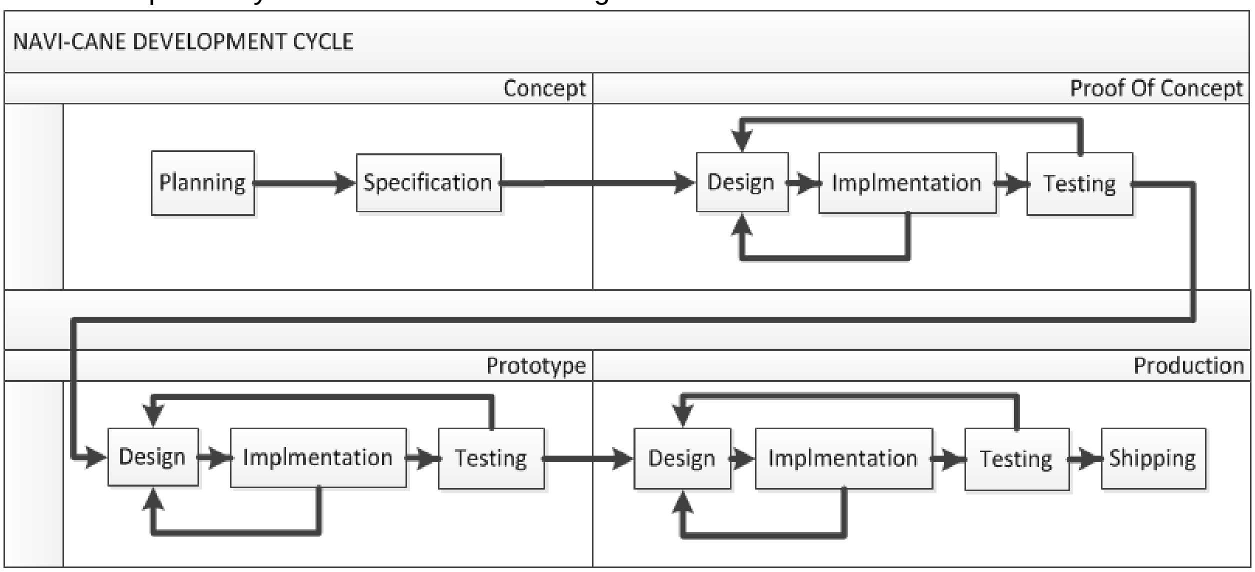

Figure 0-1: NaviCane's Development Cycle

There are four different phases for the NaviCane's development cycle. In the concept phase, brainstorming, research, and planning of functions take place. Ideas are trimmed down and specified to as we approach the proof-of-concept design. During the proof-of-concept phase, we incorporate the simplest and most basic functionalities in order to physically demonstrate our concept. Designing, implementation, and testing are all core components of each phase. The prototype phase allows for more functions to be added. Afterwards, the production phase includes the certification of medical device regulations and final improvements upon the functionalities. As each phase builds on top of the previous phase, functions implemented in the previous phases will be available in the future phases.

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Glossary

API	Acronym; Application Programming Interface
CFR	Acronym; Code of Federal Regulations for the United States
Crosstalk	Definition; Interference in an electronic circuit caused by a signal
CSA	Acronym; Canadian Standards Association
EEC	Acronym; European Economic Community
GPS	Acronym; General Position System
Haptic Feedback	Definition; Tactile/Vibration Feedback
I^2C	Definition; Multi-master serial single-ended computer bus
IEEE	Acronym; Institute of Electrical and Electronics Engineers
ISO	Acronym; International Organization for Standardization
OS	Acronym; Operating System
PC	Acronym; Personal Computer
PWM	Acronym; Pulse-Width Modulation
QI	Definition; Inductive Power Standard
SOR	Acronym; Statutory Orders and Regulations for Canada
USB	Acronym; Universal Serial Bus
Wi-Fi	Acronym; Wireless Fidelity

1. Introduction

The NaviCane, Navigation-Assisting White Cane, is a mobility device being developed for the visually impaired. Navicane allows users to freely program their desired destinations to the cane and it will provide feedback to safely guide them to their target location through an optimized path that consumes the least amount of travel time.

1.1 Scope

This document provides the necessary requirements for a functional NaviCane device. The requirements will be categorized according to its functional priority. The priority requirements pertain to the proof-of-concept, prototype, and production design from highest to lowest, respectively.

1.2 Intended Audience

The functional specification will be used by all members at Envision Today. It will allow us to measure the progression of our design during the development phase. Furthermore, this document becomes our guideline for function implementation, which ensures compliance between both design and implementation phases. The testing of the product will also follow the procedures listed below as a final evaluation.

1.3 Classification

This entire document follows the functional requirement priority-listing convention listed below.

[Rn-p] *Functional requirement*,

where *n* represents the functional requirement number and *p* denotes the priority level of the functional requirement. The notation *p* is classified as follows:

A. High priority; important requirements that are critical and essential to all our designs, especially the proof-of-concept design.
B. Medium priority; requirements that enhance the functionalities of our design in the prototype design.
C. Low priority; additional requirements will be implemented for the production design if there is sufficient time.

2. System Requirements

2.1 System Overview

The NaviCane's system block diagrams are modeled below.

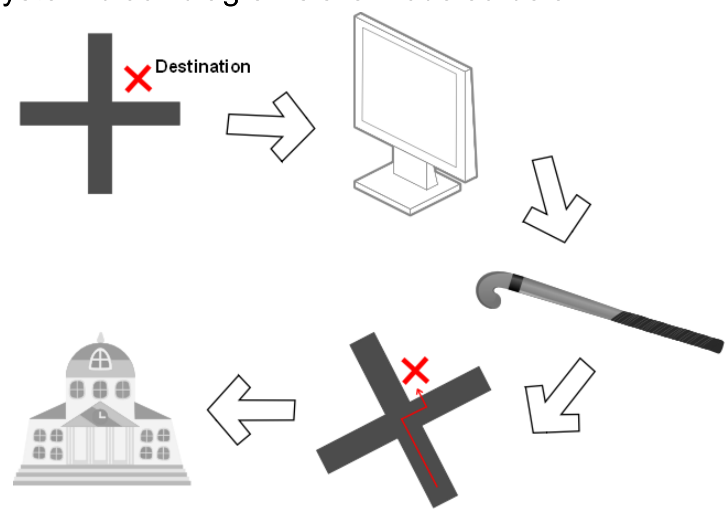

Figure 2-1: Top-level Block Diagram

The NaviCane can be divided into two subsystems: software application and hardware. The software application is where the user will indicate their starting location and destination via computer interface either by way of address or name. The program will return details of the location in speech readable text allowing the user to determine whether the information is correct. The application will then retrieve the longitudinal and latitudinal coordinates of the user-specified destinations as well as routes and nodes demarcating the route from the user's current location to their destination. All required data will then be transmitted to the microprocessor through a USB port located at the top of the handle of the cane. The interface will also detail the current battery charged status of the device in speech readable text. The software application process flow diagram is shown in figure 2-2.

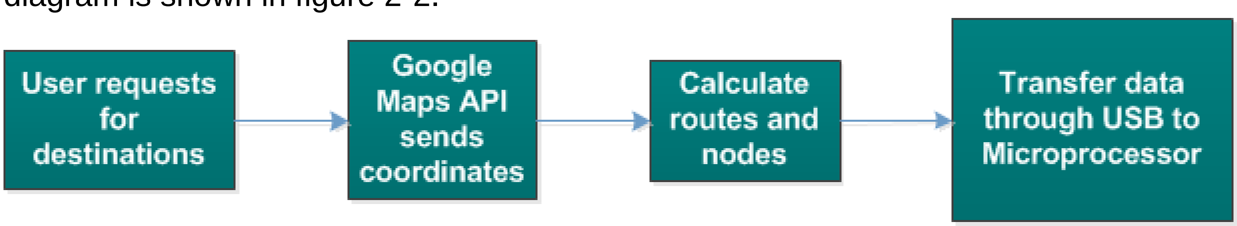

Figure 2-2: NaviCane's Software Application Process Flow Diagram

Once the user is ready to go to their destination, the cane will be detached from its USB connection. Once removed and held, the user can toggle a switch on the cane located near the handle that will activate the haptic feedback that will direct the user in the direction of the next waypoint. The haptic feedback will be produced by two vibration motors located in the handle of the cane; these vibration motors are located opposite one another and as the device has a forward facing portion, are located on the left and right side with respect to this forward facing. As the cane is rotated in the direction of the next waypoint with respect to the forward facing, the haptic feedback will increase in strength with a specific frequency and intensity indicating to the user the direction of the next waypoint. This direction is determined by a compass which is located inside the handle facing in the forwards position. Once the current waypoint has been reached within a reasonable distance, the next waypoint in the route will become active. Once the final waypoint and thus destination has been reached, a very specific pattern of haptic feedback will be given to indicate to the user that they are in the immediate vicinity of their destination. The top level process flow diagram is shown in figure 2-3 while a detailed diagram of the location of various features is shown in figure 2-4.

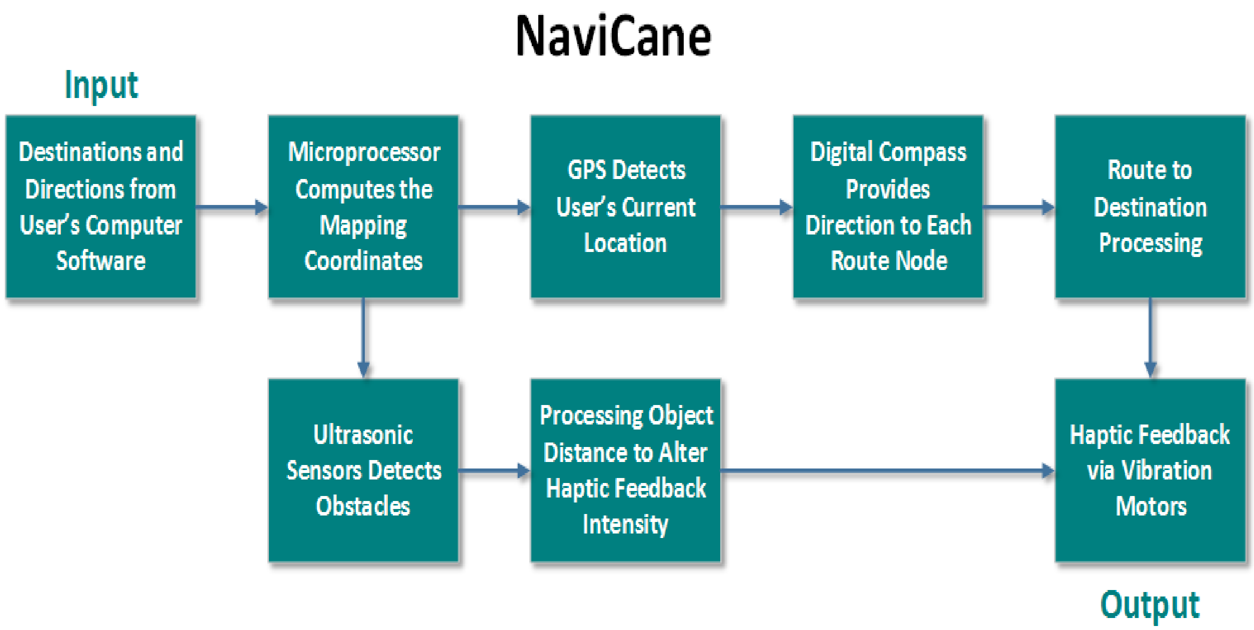

Figure 2-3: NaviCane's Top-Level Block Diagram

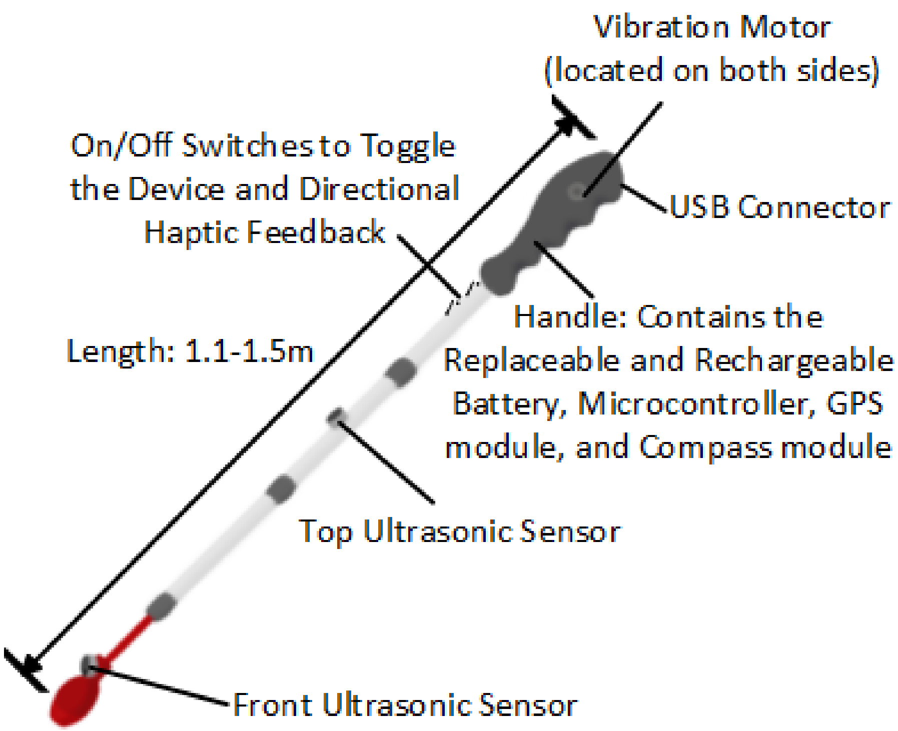

Figure 2-4: NaviCane's Mechanical Enclosure

2.2 Safety Analysis

Care must be taken when considering possibilities of causing harm to the user through usage of the device. To this end, all applicable safety standards have been applied to the various components of our device and these standards are listed in the requirements for the various components. Furthermore, we must ensure that the sum of the parts are also both within safety standards and incapable of causing harm to the user.

2.3 Sustainability Analysis

A major production concern involves the cradle-to-cradle life-cycle of the product. A large portion of the device is electronic and as such we must ensure that such a portion can be salvaged for use elsewhere. To this end, the housing in the cane for the microcontroller and its components (GPS module, Compass Module, Battery, etc) will be easily separable and salvageable. For both the production stage and the prototype stage of the device, the motor, USB Connector, and Ultrasonic Sensors will similarly be easily separable from the cane. Later considerations and future work will be made to simplify the design of the microcontroller to cut down on the amount of material used in the process of creating it for the production stage. The cane itself, when separated from the electronic parts, is easily re-used as a simple white cane. To be easily reused for its plastic component, the cane will be also made of a homogenous plastic material as possible.

2.4 General Requirements

[R1-A] The retail price of the NaviCane will remain between CDN$50 to $400.
[R2-A] The device shall not be used in strong magnetic fields.
[R3-B] The GPS module can be toggled on or off via a switch.
[R4-B] The device will be held in a specific way.
[R5-C] The tip of the device must be detachable and changeable [1].
[R6-C] The device shall contain fully preloaded maps.

2.5 Physical Requirements

[R7-C] The device shall resemble a basic white cane.
[R8-C] The device shall be coloured white.
[R9-C] The device shall have red bands if user is deafblind.
[R10-C] The length of the device shall be between 1.1m to 1.5m [5].

2.6 Electrical Requirements

[R11-A] The device will operate with a 2000 mAh polymer lithium battery.
[R12-A] The battery will operate at a maximum voltage of 4.2V.
[R13-A] The device shall communicate and recharge through the USB interface.
[R14-A] The device will operate at a typical voltage of 3.3V.
[R15-B] No electronic components will be exposed to the user.
[R16-C] The battery must be easily accessible for replacement.
[R17-C] The battery will be able to last at most 12 hours of continuous operation.

2.7 Mechanical Requirements

[R18-B] The power button will be mounted on the outside.
[R19-B] A simple switch to toggle on/off for vibration motors.
[R20-C] The mechanical components shall not be physically intrusive.
[R21-C] The device shall be retractable and adjustable.
[R22-C] The microprocessor, GPS module, compass module, and battery shall be stored within the handle of the device.

2.8 Environmental Requirements

[R23-C] The vibration feedback noise level shall be subtle.

[R24-C] The device shall operate in temperature -10 to 50 degrees Celsius.
[R25-C] The device can operate in both indoor and outdoor.

2.9 Standards

[R26-C] The device shall conform to SOR/98-282 regulations [3].
[R27-C] The device shall conform to ISO 9999 [7].
[R28-C] The tip of the device shall conform to ISO 24415-1 [4].
[R29-C] The device shall conform to 93/42/EEC [2].

2.10 Reliability and Durability

[R30-A] The GPS signal requires 35 seconds to operate on a cold start.
[R31-A] The GPS signal requires 2 seconds to operate on a hot start.
[R32-C] The device shall withstand day-to-day usage of a basic white cane.
[R33-C] The tip of the device shall be changed periodically.

2.11 Safety Requirements

[R34-C] The device shall conform to CFR Title 21 Part 860.7 (21CFR860.7) [6].
[R35-C] The device shall not have any sharp edges.
[R36-C] The internal components shall not be exposed or obtrusive.
[R37-C] The device shall not resemble a toy.
[R38-C] The device shall conform to CSA standards.
[R39-A] The device shall not overcharge or over-discharge the battery.

2.12 Performance Requirements

[R40-A] The device shall start up and guide the user within 45 seconds.
[R41-A] The device shall provide sensory vibration feedback at most every second.
[R42-A] The device is dependent on third party API for maps.
[R43-B] The device shall detect obstacles in front and above.
[R44-B] The front sensor shall detect up to distances of 3.6 m long and 1.8 m wide.
[R45-B] The top sensor shall detect up to distances of 2.4 m long and 0.6 m wide.

2.13 Usability Requirements

[R46-A] The device shall not exceed 3 lbs.
[R47-B] The device shall operate similarly to a basic white cane.
[R48-C] The device shall have a touch screen interface.

[R49-C] The device shall support QI wireless inductive charging.
[R50-C] The device shall provide audio feedback.
[R51-C] The device shall have speakers and a microphone.
[R52-C] The device shall have a cellular network modem.
[R53-C] The device shall update and calculate user positions on-the-go.
[R54-C] The device shall be compatible with Wi-Fi and Bluetooth.

3. Software Interface

3.1 General Requirements

[R55-A] Software will be built on Microsoft .NET framework 4.5
[R56-A] The application requires online capabilities.
[R57-C] The application shall update periodically.

3.2 Performance Requirements

[R58-A] The application shall finish data processing within 5 minutes.
[R59-C] The application shall be bug-free.

3.3 Usability Requirements

[R60-A] The application shall be compatible with Windows OS.
[R61-C] The application shall be compatible with text-to-speech software and speech-to-text software.
[R62-C] The application shall be compatible with MAC OS X and Linux-based OS.
[R63-C] The application shall be compatible with mobile OS.

4. User Documentation

[R64-C] There will be an online user manual in languages of English, French, Spanish, German, Portuguese, Simplified Chinese, Traditional Chinese, Russian, Japanese, and Korean.
[R65-C] The online user manuals shall be compatible with text-to-speech software.
[R66-C] The user manual shall include a troubleshooting guide with common diagnosis and solutions.
[R67-C] The user manual shall include a detailed setup guide for technicians and experienced users.
[R68-C] The user manual shall include a quick start guide for users with minimal knowledge.

[R69-C] The user manual shall include braille versions of the troubleshooting, detailed setup, and quick start guide.

5. System Test Plan

In order to provide products of the utmost quality, each component and subsystem will be rigorously tested to ensure that they meet functional specifications. We will be analyzing the hardware signals of each subsystem to ensure that they are up to specifications. Each element of the subsystems will be tested for its integrity, functionality, and power consumption. During the development of the prototype, we will test the implementation between the software and hardware systems. In addition, we will also validate the physical properties of the device such as its ability to handle different kinds of stress, temperature, and environmental conditions. The tests listed must be passed multiple times during different phases of the development cycle.

5.1 Ultrasonic Sensor Test

The ultrasonic sensor will be tested against its specifications for its accuracy at distance and range detection. Its interface to the microcontroller via analog signal lines will be analyzed to ensure proper range calculation and processing. Testing of the the ultrasonic sensor includes, but is not limited to:

- Analyzing the accuracy of the analog signal to distance algorithm
- Testing sensor for detections of false positives
- Measuring the maximum distance the sensor can reliably detect an obstacle
- Ensuring signal detection is maintained while the cane is in motion
- Ensuring the casing of the sensor is able to handle external shocks and environmental conditions

5.2 GPS Module Test

The GPS module will be tested to ensure that it is able to precisely and timely obtain the longitude and latitude coordinates of the user's current location. The serial communication lines used to interface with the microcontroller will also be analyzed to ensure signal integrity. Testing of the GPS module includes, but is not limited to:

- Measuring the accuracy of the user's coordinate
- Measuring the time it takes the GPS to acquire the satellite signals (during a cold start-up and a hot start-up)

- Ensuring the GPS transmits the serial data accurately during processing
- Testing the interference caused by dense areas (beside tall buildings, inside of buildings, and inside of forests)
- Ensuring that the antenna does not cause outside interference with other devices
- Ensuring that external signals and forces do not interfere with the device's antenna

5.3 Compass Module Test

The compass module (composing of the magnetometer and the accelerometer sensors) will be thoroughly tested for its accuracy at pointing to magnetic north. The module's tilt compensation must also be tested for proper implementation such that tilting the device will not interfere with the compass module pointing to magnetic north. Testing of the compass module includes, but is not limited to:

- Measuring the accuracy of the compass (with and without tilting the device)
- Ensuring that the directional data is transmitted quickly to the microprocessor (via i^2c signal lines) even when the device is in constant motion
- Testing for the potential disruptions caused by external magnetic forces

5.4 Battery and Charger Test

The charging circuit will be tested to ensure it meets safety standards while providing a quick recharging cycle. The charger will be implemented into the device and supports charging through the USB interface at 500 mA. The battery will be tested to ensure that it provides 12 hours of continuous usage as outlined in the requirements. Testing of the battery and charger includes, but is not limited to:

- Measuring the device's power consumption to analyze how many hours of usage the battery will yield.
- Real world testing with the device to monitor power usage.
- Ensuring the charger circuit does not overcharge the battery pass 4.2V.
- Ensuring the charger circuit terminates the discharge of the battery at 2.75V.
- Ensuring the charger terminates discharging when outside of the range -20 to 60°C.
- Ensuring the charger terminates charging when outside of the range 0 to 40°C.
- Measuring the time required to fully recharge the battery under USB charging.
- Measuring the device's standby current consumption.
- Measuring the device's current consumption when turned off.

5.5 Microcontroller Test

The microcontroller will be tested to ensure the signal integrity of all the data and power lines. It is also necessary to ensure that the microcontroller is able to handle the simultaneous usage of all of the sensors and subsystems of the device. Testing of the microcontroller includes, but is not limited to:

- Ensuring the microcontroller is able to process and power the subsystems connecting to it.
- Measuring the power consumption of the microcontroller when the different subsystems are connected.
- Ensuring the signal lines are isolated from external interferences and crosstalk
- Ensuring the device is running at 3.3V.

5.6 Vibration Motor Test

The vibration motor will be tested to ensure it provides adequate haptic feedback that varies in intensity. Testing of the vibration motor includes, but is not limited to:

- Measuring the power draw from the motors.
- Ensuring the power draw from the motor is sourced from a regulated source from the battery and not from the microprocessor's PWM line.
- Testing of the ability to vary the intensity of the vibrations.
- Ensuring the mechanical housing of the vibration motor adequately protects the motor from vibration shocks and from external environmental conditions.

5.7 Software (PC Interface/Microcontroller implementation) Test

All modules of the software (PC GUI interface) will include tests to ensure proper functionality, responsiveness, ease of use and response to various mapping inputs (null, overflow, etc).Testing of the software includes, but is not limited to:

- Usability tests and analysis of the GUI
- Compatibility tests with regards to text-to-speech and speech-to-text software
- Regression testing
- Platform testing
- Path planning accuracy tests
- Weekly smoke tests

5.8 Physical Test

The physical test ensures that each individual element of the device is able to durable enough to handle normal stress and environmental conditions during normal, everyday usage. Testing of the physical device includes, but is not limited to:

- Drop testing the device to monitor how the device drops and what areas must be mechanically strengthened.
- Stress testing the device to monitor any locations that are mechanically weak.
- Checking for areas on the device that can be exposed to electrostatic discharge or environmental elements such as water, dust, ice, and magnetic interferences.

6. Conclusion

The functional specifications illustrate the capabilities and requirements that will be held for this device and accompanied software. Envision Today is fully committed to implementing the core features of the device that we have elaborated upon in this document. If time permits, lower priority features will be implemented as well. Development is well underway and we expect to see a complete and functional working prototype by early April.

7. References

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