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January 23, 2006

Mr. Steve Whitmore and Dr. Andrew Rawicz
School of Engineering Science
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Re: ENSC 440 Functional Specification for an intelligent walking aid

Dear Mr. Whitmore and Dr. Rawicz,

Please find attached a copy of the Incedonex's functional specification for the Sense-Step® intelligent walking aid. Sense-Step® is a technologically advanced walker created to assist elderly users. It is comprised of an integrated mechanical and electronic sensing system which aims to address problems such as breaking, hazard detection and path planning in order to better assist and protect the user.

The purpose of our functional specification is to list the requirements that our proof-of-concept design will fulfill, as well as list the requirements that our product will comply with, should we pursue prototyping and production. We are currently in the process of designing and building our device and are targeting a completion date of mid-April 2006.

Incedonex is comprised of six highly skilled and ambitious engineering students at Simon Fraser University with backgrounds in Engineering and Computer Science. You can find more information on Mr. Daniel Agyar, Mr. Duncan Chan, Mr. Steven Dai, Mr. Yijun Jing, Mr. Victor Tai and Mr. Li Xu in the attached proposal.

If you have any questions or comments please to contact me by e-mail at lxu@sfu.ca. Alternatively, you may contact me directly by telephone at 604-505-9063.

Sincerely,

Li Xu

Li Xu,
Chief Executive Officer
Incedonex

Enclosure: Functional Specification for the Sure-Step® intelligent walking aid.



Functional Specification for an Intelligent Walking Aid

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Submitted To Dr. Andrew Rawicz
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Issued Date January 19, 2006

Executive Summary

The world's elderly population is greatly increasing. According to the World Health Organization, 390 million people are over the age of 65, and this number is expected to double by 2025 [5]. As people age, their mobility deteriorate and are prone to falling, which has become the leading cause for injury-related deaths in recent years [3]. As a result, the use of wheeled walkers has become a popular choice for elderly.

Though walkers offer support for the elderly to walk, they are often difficult to use in certain situations. For example, when walking uphill or downhill, the walker tends to roll in the respective directions, forcing the elderly to provide extra force in order to control the walker. Although a mechanical brake can be used to slow down and stop the walker, the brake usually results in an abrupt stop and may consequently cause injury to the user. Another problem is balancing the walker in uneven road conditions, such as on a sloped sidewalk. This is primarily due to the elderly not having the dexterity to balance themselves and keep the walker in control.

Moving past convention, Incedonex will address these problems and modify the current wheeled walkers by adding an advanced automatic braking system to prevent the walkers from unwanted rolling backwards or forwards on sloped surfaces, as well as combining automatic balance control on uneven grounds for better maneuvering. In addition, when users are in an unfamiliar surrounding, such as a shopping center, where they are unaware of where washrooms or elevators are located, Incedonex provides a solution by incorporating a state-of-the-art path planning navigating system embedded on the walkers to guide them to their destination. Together with these features and by providing a user-friendly interface, our product is the most advanced walker on the planet.

The Incedonix Intelligent Walking Aid Sure-Step® consists of three modules: M-brake™, Sense-Steer™, and Nav-Pro®. Each module has its own set of functionalities. The functions of each module are outlined below.

- **M-brake Module:**
Improved braking control for Sure-Step®
- **Sense-Steer Module:**
Hazard detection and avoidance for Sure-Step®
- **Nav-Pro Module:**
Navigate and plan a path to the destination for the user

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1 Introduction

The Sure-Step® walking aid is a revolutionary assistive device, which aims to improve upon current designs and provide elderly users with additional safety and control. The system is comprised of three sub-systems: the M-Brake™, the Sense-Steer™, and the Nav-Pro™. Each module has sets of functional requirements, which will be described in following subsections.

The system development will consist of 3 phases. In the first stage, we will focus on conceptualizing our design, and use various development tools to simulate and test our design and algorithm with offline data. Through design iterations, attempts will be made to try to come up with better solution, because current design and algorithm does not completely meet our functional requirements. The second stage will involve using actual components to assemble individual modules. This stage will also include testing and solving any circuits or algorithm bugs of the modules, especially the problematic area where the M-Brake™ and Sense-Steer™ sub systems directly interact with each other. Finally, we will integrate the whole system after we have full confidence with our modules. Then prepare it for commercial deployment at the same time.

1.1 Scope

This document describes the functional specifications of the Sure-Step® walking aid. We cover the required specifications for our proof-of-concept design as well as additional specifications for the prototype and commercial final product.

1.2 Intended Audience

This document is intended for use by the designers and engineers of Incedonex, as well as potential investors. The project managers shall use this document to gauge progress through the development phase. Design Engineers shall use this document as a framework when designing and implementing the various modules of our products. Testing shall be carried out as defined in this document and potential investors shall use this document as a guide of what end consumers can expect of the production version of our product.

1.3 Classification

Throughout this document the following convention shall be used to denote a functional requirement

$R[\#]-N$

Where # is the functional requirement number and N is the precedence of the requirement as determined by the following

- I – The requirement applies to the proof-of-concept system
- II – The requirement applies to the production system
- III – The requirement applies to both, the proof-of-concept and the final production system.

2 System Overview

This section outlines the basic functions of our Sure-Step® intelligent walking aid. This is a brief overview to give the reader a better understanding of the overall system operation. The main function of the Sure-step® is to provide safety and mobility to senior's life. There are three subsystems in Sure-Step ®: the M-Brake™, the Sense-Steer™ and the Nav-Pro™.

Figure 1 shows a general block diagram of the various subsystems of the Incedonex Sure-Step® intelligent walking aid.

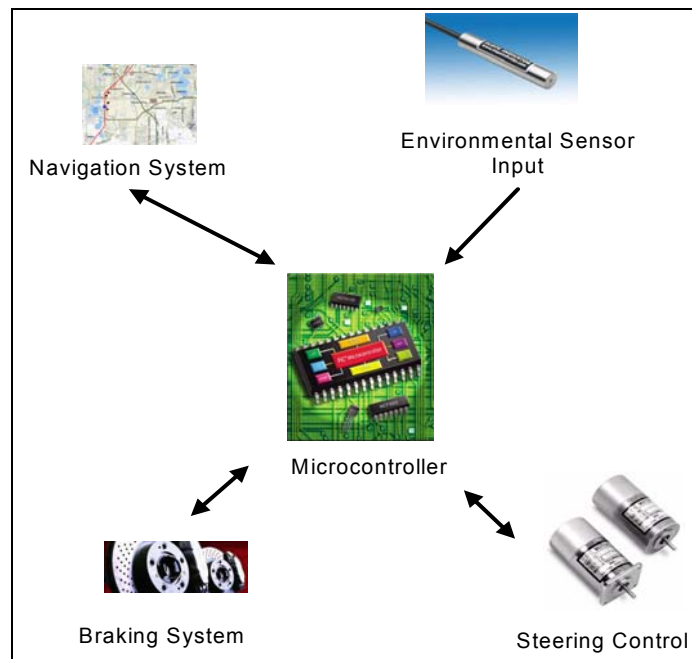


Figure 1: Block Diagram of Incedonex Walker System

For M-Brake, a touch switch is used as user interface, which is connected to a pair of electronically controlled brakes. The walker will also automatically slow down when the acceleration or speed changes too rapidly. The braking system will also prevent the walker from rolling backwards or forward when on an incline.

Sense-Steer™ is used to detect and avoid a potentially hazardous situation of the walker tipping over the curb, as well avoiding obstacles in front of the walker. When walker is close to curb, the walker will move away from the curb. When there's an obstacle in front of walker, the walker will stop before the obstacle.

In the Nav-Pro™ system, the user selects one of the three programmed locations: washroom, exit, and elevator. Using preloaded map and wireless way-point beacons, the Nav-Pro™ system will guide the user to the nearest desired location by providing visual and audio aid.

3 General Requirements

The next two subsections outline the general and regulatory requirements of Sure-Step®. General requirements refer to overall requirements of physical components needed in our system. Regulatory requirements refer to that our system, as a safety device, complies with various industry standards.

3.1 General Requirements

- R[1]-II** The commercial version of the Sure-Step walker shall not exceed a retail price of \$500.
- R[2]-II** The total weight of the walker shall not exceed 45 lbs.
- R[3]-II** Battery life will be longer than 1 week.
- R[4]-II** The battery unit will be rechargeable.
- R[5]-II** Battery recharge time will be less than 4 hours.
- R[6]-I** The dimensions of the walker unit are specified as follows
- Width shall not exceed 25 inches
 - Height shall not exceed 36 inches
 - Length shall not exceed 25 inches
- R[7]-III** The walker shall be able to support a user who weighs a maximum of 250 lbs.
- R[8]-II** Operating Conditions
- i. The walker will be suitable for use in any indoor environment with room temperature and limited dampness.
 - ii. Outdoor use in heavy rainfall, snowfall and temperatures below -2° C are not encouraged.
- R[9]-III** The maximum dimension of the battery unit will be limited to 5 × 5 × 5 inches.
- R[10]-II** There will be battery level indicator that warns the user when the remaining battery life is less than 4 hours.
- R[11]-II** Battery unit recharge interface should include battery full indicator.
- R[12]-II** The maximum weight of the battery unit will be limited to less than 5 lbs.

3.2 Regulatory Requirements

R[13]-II The product shall comply with CSA standards CAN/CSA-Z323.3.1-1982 (R2003) Electrical Aids for Physically Disabled Persons [1].

R[14]-II The product shall comply with IEEE standards.

R[15]-II The wireless components shall comply with FCC emission guidelines.

R[16]-II The walker shall comply with the following ISO Standards [2]:

- i. ISO 11199-1:1999 Walking aids manipulated by both arms -- Requirements and test methods -- Part 1: Walking frames
- ii. ISO 11199-2:2005 Walking aids manipulated by both arms -- Requirements and test methods -- Part 2: Rollators
- iii. ISO 11199-3:2005 Walking aids manipulated by both arms -- Requirements and test methods -- Part 3: Walking tables
- iv. ISO 9999:2002 Technical aids for persons with disabilities -- Classification and terminology

4 M-Brake Requirements

The following sub-sections outline the physical requirement, the operational requirement and the performance requirement, as well as the test plan for verification of the listed requirements. Physical requirement specifies the physical qualities of the component. Operational requirement specifies the operation of the component under different conditions. Performance requirement specifies how well the component achieves the functionalities stated previously.

4.1 *Physical requirement*

- R[17]-II** The maximum total weight of the brake mechanism will be limited to less than 10 lbs.
- R[18]-II** The maximum size of the brake mechanism will be limited to less than 3 inches in radius and less than 10 inches in depth.

4.2 *Operational requirement*

- R[19]-III** Without any user input, on an incline or decline of up to 20°, the brake applies a force proportional reaction force to hold the walker along with the possible payload on the walker (excluding the user) stationary.
- R[20]-III** The user will be able to move the walker when the user applies force on the walker by either pushing or pulling.
- R[21]-III** The user will be able to stop the walker by activating the braking system at will through some form of input (switch, button, touch pad etc).
- R[22]-III** When user input is received, the brake mechanism will be able to hold the walker stationary without the weight of the user.
- R[23]-III** When user input is received, the brake will be activated and work in such a way as to bring the walker to a smooth stop.
- R[24]-III** The brake will be automatically activated to maintain the threshold speed on up to 20° of incline or decline, when the walk exceeds the threshold speed of 1.3 meters/second.

- R[25]-III** The brake will be automatically activated to maintain the threshold acceleration on up to 20° of incline or decline, when the walker exceeds the threshold acceleration of normal walking.
- R[26]-II** There will be a M-brake bypass switch; when switched on, M-brake will be offline, the walker will be working without a brake.
- R[27]-II** When M-brake is bypassed, manual brake control will be engaged.

4.3 Performance requirement

- R[28]-II** The braking mechanism will bring the walker to full stop from maximum speed (specified in section 4.2) in less than 1.2 seconds.
- R[29]-II** Maximum braking distance approximately 1.5 meters.
- R[30]-II** Maximum braking force strength approximately 120 lbs.
- R[31]-II** The brake system will work under ambient temperature condition between 0 degrees Celsius to 40° Celsius.
- R[32]-II** The exposed brake system operational temperature will be less than 50° Celsius.
- R[33]-I** Maximum deceleration of output by the brake system will be less than an uncomfortable level determined through clinical test on elderly users.

4.4 Module Test Plan

To verify the operation and performance of the M-Brake™ system, this test plan shall be carried out.

1. Maximum speed test: With M-Brake™ engaged, the walker is pushed at a speed of 1.3 meters/second. Further attempt to increase the speed of the walker will be met with resistance from the M-Brake. The walker is thus maintained at speed of 1.3 meters/second despite the additional push force. This verifies the activation of the M-Brake™ system and its ability to maintain the threshold speed.
2. Maximum acceleration test: The walker is pushed from resting state with acceleration greater than the threshold acceleration. A simulated fall while holding the walker can be executed by the test to bring the acceleration above the

- threshold value. The M-Brake should be automatically activated to provide a resistance force that keeps the acceleration at the threshold level.
3. Anti-roll test: The walker is placed on an incline of 20° with no additional weight imposed on it. The walker should be able to stay stationary due to the M-Brake™ assistance. The test will then be carried out on 10°, 5° and 2° inclines.
 4. Normal braking test: The tester will push the walker around on a flat and inclined road. The tester will attempt to activate the braking by pressing down the input device for the brake. The smooth braking force should be felt. The walker should be brought to a stop.
 5. Braking on slopes: The tester will manually activate the braking system by pressing down the input device. The walker should be brought to a smooth stop and remain stationary for as long as the user input is received.
 6. Walking without brake: The tester will push the walker on flat and inclined road under conditions as to not active the braking system. The tester should not feel the effect of the braking system.
 7. Battery and durability test: Activate the braking system by pressing down the input device or by running the walker under any of the conditions which will automatically activate the brake. Keep the brake engaged until the battery runs out.
 8. Maximum weight test: Engage the brake on an incline of 20 degrees with maximum weight of 180 lbs payload (including the user's body weight) resting on it. The walker should be able to stay stationary.
 9. Bypass mechanism test: (optional) Engage the M-Brake™ bypass option. The walker should operate without any effect of the braking system.

5 Sense-Steer Requirements

The following section discusses the various requirements for the module which will detect and avoid curbs and obstacles.

5.1 Operation & performance requirement

- R[34]-III** The walker will be able to detect that it is within $8\pm 3\text{cm}$ of the curb.
- R[35]-III** Within 1 second of detection, the walker will maneuver itself away from the curb until it is no longer within $8\pm 3\text{cm}$ of the curb.
- R[36]-II** The walker will detect obstacles within $20\pm 5\text{cm}$ in front of the walker.
- R[37]-II** For the obstacle to be detected, the obstacles' height must be $17\pm 5\text{cm}$ above the ground that the walker is on. Within 0.1 seconds of detection, the walker will apply brake, and stop the walker before hitting the walker.

5.2 System limitation

1. The above specification is limited to the walker's speed less than or equal to 1.3 meters/second. The maximum speed of walker is chosen according to the average human walking speed, with consideration that most of the users have below average speed [4].

5.3 Safety issue

1. Because the walker takes over control when it is close to the curb and obstacles, the user must follow the walker. Otherwise, the user may head in a different direction than the walker, and may experience discomfort or even injure themselves. Thus, it's recommended that the user familiarizes themselves with the walker and always follow the walker.

5.4 Module test plan

1. Curb detection and avoidance test: Tester will walk with the walker at 1.3 m/s, 0.6 m/s and 0.3 m/s, and will walk towards the curb at 15° , 30° and 45° with respect

- to the curb's normal. The walker must be able to maneuver itself so that the walker doesn't tip over the curb.
2. Obstacle detection and avoidance test: Tester will walk with the walker at 1.3 m/s, 0.6 m/s and 0.3 m/s, and will walk towards an obstacle of height 17cm above the ground that the walker is on. The walker must be able to stop before hitting the obstacle.

6 Nav-Pro Requirements

6.1 Operational Requirement

- R[38]-III** The wireless positioning system should have a range of detection greater than 30cm.
- R[39]-III** The path-planning system is capable of detecting eight distinct directions: N, W, S, E, SE, SW, NE, and SE.
- R[40]-III** The path-planning system allows user to select from three buttons on the keypad to determine the path to the destination.
- R[41]-II** The path-planning system should alert the user when there is a change of direction via audio signal.
- R[42]-II** The alert signal in requirement R[41] can be optionally turned off by the user via selecting a button from the keypad.
- R[43]-III** The path-planning system should be able to detect four destinations, two of which are considered as the same destinations.

6.2 Performance Requirement

- R[44]-III** The path-planning algorithm computes the optimal path in less four second.
- R[45]-III** The wireless positioning system should perform seamlessly through obstacles in between signal paths.

6.3 Module Test Plan

To test the Nav-Pro™ system, the following testing procedures will be conducted:

1. Wireless positioning interference test: Obstacles such as people or objects are situated in between the signal path to determine whether the performance of the wireless link is maintained. The test plan will demonstrate the functioning of the wireless positioning system when interference exists in the signal path.
2. Maximum range test: The walker will be positioned in the maximum specified distance apart (30cm) from the wireless receiver to verify the maximum range of detection.
3. Walker direction test: The walker is placed at a direction which is to be compared to the direction computed by the Nav-Pro™ system. This verifies the accuracy of the location of the walker.
4. Shortest-Path Destination Test: The walker will be put in a random location and assigned to one of two locations. The outcome of the path can then be verified as whether or not it is the shortest path.
5. Destination Accuracy Test: The walker will be assigned a destination, and the outcome of the path-planning system will be compared to the actual destination to determine the accuracy of the overall system.

7 Conclusion

The functional requirements for Sense-Step® defined in this document details how our proof-of-concept design will perform, as well as lists requirements for a potential prototype or production unit. The specifications of our system and its components will ensure our product meets the expectations of our target market comprised of all senior population who use rolling walkers. These specifications also provide a framework for us to develop a cheap, powerful and easy-to-use new generation walker. The functional requirement implementation for the prototype will be completed by April 2006. Optimization of the prototype will be pushed further thereafter.

8 References

- [1] Canadian Standards Association Catalogue. *Health and Safety* <www.csa.ca>
- [2] International Standards Organization Catalogue. *Health Care Technology, Aids for disabled or handicapped persons* <www.iso.org>
- [3] National Center for Injury Prevention and Control. Sep. 9, 2005. *Falls and Hip Fractures Among Older Adults*. Jan. 19, 2006 <<http://www.cdc.gov/ncipc/factsheets/falls.htm>>
- [4] TranSafety Inc. 1997. *Road Management & Engineering Journal*. <<http://www.usroads.com/journals/rej/9704/re970404.htm>>
- [5] World Health Organization. 2006. *Elderly People: Improving oral health amongst the elderly*. Jan. 18, 2006 <http://www.who.int/oral_health/action/groups/en/index1.html>