Dokkō Designs

School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6
lannj-440@sfu.ca

April 18, 2003

Lakshman One
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

RE: ENSC 440 – Post-Mortem Report for Voice Activated Control System

Dear Mr. One,

Attached, please find Dokko Designs' Post-Mortem Report for ENSC 440. The included document gives an overview of the system in its current state, a brief description of the problems encountered during the design process. The report also summarizes the team dynamics as well as outlining changes that would be made in retrospect. Finally we discuss our personal contributions and future plans for the project.

The Dokkō Design team members include five energetic, talented, and hardworking senior engineering students: Natisha Joshi, Jessica McAlister, Loïc Markley, Nick Meisl, and Adam Stefanski. If you should have any comments or queries about the included document please feel free to contact me by email at jmcalist@sfu.ca or the team at lannj-440@sfu.ca.

Sincerely,

Jessica McAlister

Jessica McAlister
President & CEO
Dokkō Designs

Enclosure: Post-Mortem Report for a Voice Activated Control System

Dokkō Designs

Freedom Voice Control™
Post-Mortem Report

Submitted to: Lakshman One – Ensc 440
Steve Whitmore – Ensc 405
School of Engineering Science
Simon Fraser University

Released: April 18th 2003

Table of Contents

Executive Summary

Decubitus ulcers, more commonly known as bed sores, are caused by pressure or friction against the skin and can range in severity from a slight pink discoloration to a deep wound extending through internal organs to the bone. Patients who suffer from a lack of mobility and spend much time in bed are at a high risk of developing bed sores unless they are rotated at regular intervals. This work is usually performed by a care aide. The patient is dependent upon another individual.

ProBed Medical Technologies Inc., has developed the Freedom Bed, "a programmable, automatic, laterally rotating bed designed to meet the needs of those patients with, or at risk of developing bedsores and other complications of immobility". The bed may be programmed to perform a series of rotations or controlled in real time using a series of buttons. Many patients are physically unable to operate the bed controller and therefore someone must still control the bed for them. The patient is still dependent upon another individual.

Dokko
Self-reliance, autonomy, independence

Independence is a luxury often taken for granted. When reduced or limited, independence becomes a great desire. This document proposes an add-on device to Pro Bed's Freedom Bed aimed to greatly increase the independence of the user. Using speech recognition technology, all the functionality of the Freedom Bed will be put at the disposal of the user. In order to operate their bed and prevent bed sores and improve comfort, the patient will have no dependence on another individual.

Dokko Designs is composed of five senior engineering students whose chosen study concentrations and work experience cover a wide range of engineering fields: computer, biomedical, physics, electronic, and systems integration. The pooled skill sets of its members include signal processing, analog/digital circuit design, microprocessor programming, and hardware design.

The development of this project will take place over a 13-week period, culminating with a working prototype by April 1st 2003. This will be accomplished on a projected budget of just over $700 with funding coming from Pro Bed Medical Technologies Inc.

1. Introduction

Immobile patients who spend much of their time in bed are at a high risk of developing *bed sores* and accumulating unhealthy amounts of fluid in their lungs. To overcome these health risks, it is routine to physically rotate the patient regularly over a 24-hour period. Traditionally, this is done by hand, forcing the patient to be dependent on a caregiver.

ProBed Medical Technologies Inc. is a young company based in Abbotsford, British Columbia that recently released the Freedom Bed™. The Freedom Bed™ is a computer controlled, laterally rotating bed designed to meet the needs of those patients with, or at risk of developing, pressure sores and other complications of immobility. The Freedom Bed™ may be operated in either manual or automatic pre-programmed mode and is smooth and silent so as to provide the user with a good night's sleep while preventing bed sores and excessive fluid build up in the lungs.

Unfortunately, many users are physically unable to operate the button-based control wand for the bed. The Freedom Voice Controller's™ purpose is to bridge the gap between immobile users and control of the bed through voice activation.

2. Current State of the Device

The Freedom Voice Controller is at a prototype level. The project accepts voice commands, translates them to commands for the bed and the bed acts upon the commands. The controller does not currently accept feedback from the bed as to system status and has not yet been tested with the intended user group.

CAN Controller

The CAN controller board was designed as outlined in the functional specifications. The power was drawn from the existing 12V rail on the CAN network. This passed through 2 voltage regulators, a 5V and a 3.3V, to accommodate the voltage requirement specified but the different IC's we utilized. A block diagram of the final CAN controller board is shown below in Figure 1.

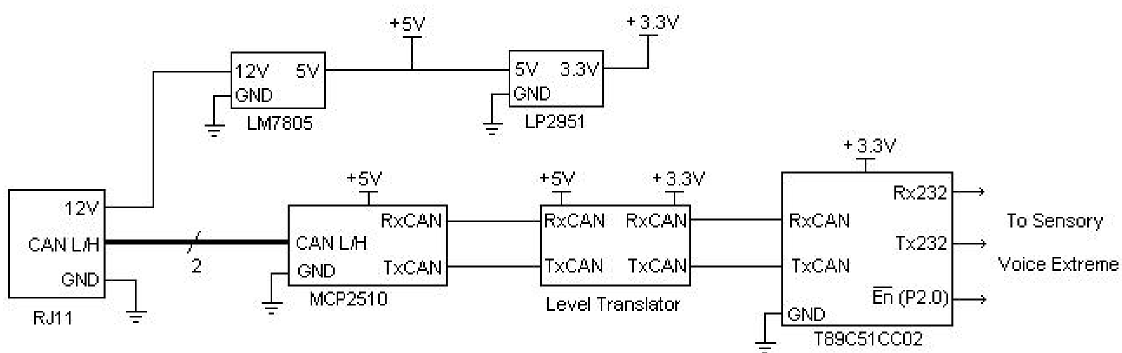

Figure 1: CAN Controller Block Diagram

Speech Recognition Software

During development, the Dokko Design team sought major changes to the intended voice recognition grammar set. Initially, commands would be single or double word phrases which would be recognized by the system as a single command. However, upon further testing, we discovered that recognition of these phrases was quite poor. Since we needed to associated different actions with a single function of the bed, like "bed up" and "bed down", there was considerable matching between the two phrases.

We decided to employ a triggered command hierarchy instead, that included a trigger level, function level, action level, and finally end trigger level. In order to say a command a user would first say a trigger word that would allow the voice recognition to become activated. If the user then wanted to raise the mattress, they would say the command "mattress", wait for acknowledgement, and then say "raise." They can choose to say the end trigger word to exit the triggered level or a timeout on trigger will occur otherwise.

As a result, the current voice recognition software developed on the Sensory Voice Extreme platform is conceptually different from the proposed software outlined functional requirements.

Currently, the software recognizes all possible commands and sends a high level command to the CAN. In the command is latching time information, which the CAN is able to decode and it uses it appropriate timers and interrupts to latch specific commands onto the CAN. While we had planned to include the latching code in the Sensory, due to the lack of real-time utilities, we instead allowed the CAN to perform this task. Through the use of bit-wise detection, the CAN chip is still unaware of commands and their associated actions. Therefore, the upgradeability of the Sensory software is possible while maintaining the CAN firmware; however, should there be fundamental changes in the ProBed CAN command specification, it is possible that the CAN firmware may need to be upgraded.

Finally, the voice recognition software is capable of tracking the user's voice over time. When the user says a command that is a "match", the system will average that sample with one of the internal command voice patterns. In actual testing, while the system will not pick up any abrupt changes in how a user says a word, it can track small changes in the user's voice to eventually match major changes in the user's voice. At the same time, the reliability of the system is maintained by keeping two original voice patterns in the system.

User Interface

The caregiver user interface is to be used by those charged with the care of the main user of the bed: the operator, a patient with severe mobility limitations. The caregiver is to use the interface for assisting the operator to train the word set into the system, and as such, the user interface will likely be seldom used. Therefore, we designed the user interface to be transparent and easy to figure out by individuals with little exposure to our system. The learning curve for the caregiver interface should be very gentle.

Through several iterations of the user interface and consultations with various professors and our contacts at ProBed, we came up with a proposed user interface. This user interface was to have 18 LEDs, one for each of the words to be trained. Additionally there would be four buttons: up, down, OK and cancel. These buttons will be used to navigate through the training procedure. There would also be a slide switch on the user interface that would allow the user to choose between training and operational mode. Two final buttons, hidden from the user, are the reset and download buttons to aid in programming and debugging. These buttons will also be used in conjunction with the d-sub connector to perform future upgrades to the Sensory voice recognition software.

A speaker and microphone make up the operator user interface.

The UI components consist of 18 green, low power LEDs connected via a load resistor to 3 8x3 decoders that in turn is controlled by a 4x2 decoder. The decoders are connected directly to the IO pins of the sensory. The buttons are connected to a 3x8 priority encoder that is wired to the IO of the Sensory. Due to the limited number of IO pins on the Sensory, decoding and encoding of signals was a very important design consideration. Circuitry was created such that when the reset button in pressed, the reset is held high. When the download button is pressed, both the download and reset buttons are held high. A MAXIM chip was used in order to convert voltages from a CMOS level to a serial communication level. The Sensory chip plugs into the caregiver user interface via a header. All connections are wired to this header.

3. Problems Encountered

CAN Controller

The development of the CAN controller went smoothly, even though it entailed a large amount of work and research. Since the design on the CAN controller involved hardware and software development, minor problems were encounter in both stages of the process. The main problems that were encountered in the hardware stage were the need for a level translator from 5V to 3.3V and also changing the oscillator frequency in the last minute. The level translator was built using 4 resistors and a hand full of pull-up resistors. The oscillator frequency had to be changed from 8 MHz to 20 MHz because an 8 MHz oscillator can not be used for timing 9600 baud serial transmissions. The major obstacle encountered while developing the software for chip was learning a new protocol, CAN 2.0A, luckily all the programming was done is C, which is much faster but offers less control than machine code.

Speech Recognition Software

The most serious problem encountered during the design of the voice recognition software is that it does not allow for any real time processing. The proprietary C subset, VE-C, does not allow the use of software interrupts. To circumvent this difficulty we had to deal with all critical timing issues through the CAN micro controller.

We needed to employ voice prompts and feedback for the operator. We followed the Sensory instructions to create sentence tables of synthesized voice files. Upon implementing the synthesized voice feedback we realized that the quality was unacceptable. Sensory's only advice was to have their linguists create our sentence tables. Because we are only at a prototype level, this was not an option. We solved the sound quality problem by writing a simple bootstrap program allowing us to program the voice feedback as wave files the first time the program is run. This solution, however, although effective for the prototype, uses a substantial amount of the 2M-FLASH and is not robust enough for a final product.

Another software difficulty was the poor documentation, and scarcity of information offered by Sensory.

User Interface

The UI design and construction went fairly smoothly, although soldering all the components together on the small vector board we had was a very long and delicate process. One difficulty we had was a result of terrible documentation by Sensory. The header on the module and its evaluation board were each labeled from pin 1 to 34 but did not line up with each other. We designed our board using the EVB and module circuit diagrams as references but did not realize until well into the testing phase that half our signals we not communicating properly with the module, an issue that resulted from their badly laid out circuits.

The biggest issue we had occurred four days before our demo was scheduled when we fried our module. This component costs $90 to replace and would take two days to ship, which made us doubt we could finish on time. Lucky, thankfully, determined the cause of failure to be a power amplifier driving the speaker output from the module, which occurred when the audio output leads were accidentally shorted together. By raising the power pin on the chip, it was disabled and the module returned to functionality. We built a replacement circuit which included a power amplifier external to the module which used the raw DAC signal direct from the Sensory chip as an input.

When we integrated the modules with the bed, we noticed that although the module was completely functional, the speaker output was extremely quiet with a high noise floor. We noticed that that the output from the DAC had an amplitude of only 60mV instead of the expected 10V. Referring to the Sensory circuit diagram, we noticed that although the burnt out amplifier was disabled, the resistor circuitry surrounding it was affecting our signals. We disabled the loading circuit and used an internally amplified circuit instead of the external power amplifier for effective audio output.

4. Summary of Budget

From the Table 1, shown below, we can see that the expenses for Dokko Designs Freedom Voice Control were less than expected. We had a total of $293.45 remaining, which means that approximately 40% of our budget is still available. The one thing that we did not purchase is a very good microphone because at our stage in design we could not justify spending the money until we knew exactly what we needed.

Table 1: Dokko Designs Budget

			Expenses	Budget
Voice Recognition module				$200.00
1	Sensory Voice Extreme Toolkit		$231.01	
		SUB-TOTAL	*$231.01*	***-$31.01***
Logic Module				$150.00
1	Digikey Order - 11215374		$43.44	
2	Active Order - AV271758		$3.60	
3	RP Electronics - 534368		$15.09	
4	USB-Serial Download Cable		$57.24	
		SUB-TOTAL	*$119.37*	***$30.63***
CAN Connection Module				$75
1	Digikey Order - 11477902		$21.83	
		SUB-TOTAL	*$21.83*	***$53.17***
Microphone Module				$75.00
1	Test Microphone		$0.00	
		SUB-TOTAL	*$0.00*	***$75.00***
User Interface Module				$100.00
1	Active Order - AV274345		$23.09	
2	Active Order - AV275103		$6.25	
		SUB-TOTAL	*$29.34*	***$70.66***
Contingency Fund				$120.00
1	Phone Card		$5.00	
2	Misc		$20.00	
		SUB-TOTAL	*$25.00*	***$95.00***
		TOTAL	*$426.55*	**$293.45**

For future designs of the Freedom Voice Control, the expenses will be decreased by approximately $200 since all parts can be bought at once, which will save multiple shipping charges, and there were two one time cost incurred for buying an EVB and also for purchasing a USB-Serial cable, both of which total to $180.

5. Future Plans

Future recommendations would be to integrate the CAN module with the UI module onto a single PCB. This would avoid the long wires used to connect both boards together and allow for a more compact board layout and a more robust design.

In light of the difficulties encountered during development of the Sensory software, Dokko Designs will seriously re-evaluate the joint roles of the CAN microcontroller and the Sensory. The lack of real-time utilities, limited on-board timers, and scarce I/O pins may be enough argument to allow the CAN microcontroller more of master role as opposed to its current slave role. Since the CAN microcontroller is based on the Intel 8051 chipset, it has an abundance of I/O pins, timers, and other real-time utilities available for development. A worthwhile consideration would be moving everything to the CAN microcontroller, except for the voice recognition algorithms.

We also plan on exploiting averaging and weighting to accommodate users who experience changes in their voice over time. Also, we would like to make the system more robust and user-safe by using pattern detection during training. Since the user is free to train any word as a command, we would use the pattern detection to ensure that each word they input is seen as being unique by the system. Since it is important that a stop voice command be detected and acted upon quickly, the software will be revised to match for a stop command before any other commands. Finally, the voice recognition software needs to undergo extensive user testing to gauge the usefulness, accuracy, and reliability of the command matching.

As for UI implementation, a more efficient way to encode and decode the button and LED signals would have been to use a Programmable Logic Device. This will reduced the 4 decoders and 1 encoder to a single PLD chip and save a lot of soldering time.

6. Personal Contributions and Experience

Natisha Joshi

As VP Software, I initially took an onlooker's role during initial software development. Instead, I performed other duties such as speaking to professors about possible UI designs, developing a corporate website, designing the Dokko Design logo, and finally helping polish our design documents. Towards the end of the semester, Jessica McAlister and I jointly took over software development and designed and built a flexible yet intricate software framework to ensure updateability and reliability in future product iterations.

The most challenging aspect of this project took place in the 24 hours leading up to our presentation and demo. Having developed the entire Voice controller according to black box specification, it was frustrating and exhausting to debug our system when we finally integrated it with the actual bed. Furthermore, since hardware problems plagued us for most of the night, the Sensory software did not actually undergo testing till the early hours of the morning. Jessica and I then needed to focus and solve our software problems while tired and already spent having helped debug hardware. Fortunately, our software problems were fairly trivial and actual debugging of the Sensory software took much less time than anticipated.

During this project, I discovered that the tasks that are most conceptually central to a problem are usually not the ones that require the most time and energy. Instead, it is often tasks that are viewed as trivial or insignificant that seem to take up monstrous amounts of time in the end. I found it was very important to allow extra time to account for these "emergencies" and to be flexible enough to understand that these types of events happen. In a project like this, it was easy to focus on all the little things that we weren't able to do or the things that we couldn't get working just as well as we'd hoped. During this project, I discovered that while attention to detail is important during development, in order to achieve a task at hand, I need to focus on the "big picture."

Jessica McAlister

My initial role in this project was supposed to be developing or modifying an appropriate speech recognition algorithm. Unfortunately, the Sensory Voice Extreme software only allows access to its recognition software at a high-level through function calls, so this role became superfluous. Another role included researching and finding an appropriate microphone. This involved doing some research into operator needs and constraints. Because I did not have access to the user group for testing, I was not able to test the efficacy of the microphone I chose. I helped conduct research into an effective User Interface by consulting various experts in this area.

Finally, along with Natisha, I took on the role of designing and creating the software to be used in the Freedom Voice Controller™ Prototype. This involved coming up with and effectively implementing the layered grammar used in the final design as well as iteratively designing an appropriate audio user interface for the bed operator.

I feel that one of the most important things I have learned from this project is that when creating a device, particularly in the bio-medical field, designing with the user's needs in mind is paramount. It was easy to make decisions based on what we felt would be best. Quite often we neglected to consider that we are five healthy, young adults who don't have the first clue what it would be like to lie immobile in a bed; when you try to imagine yourself in that position, design decisions tend to be more user friendly.

I also learned that in a prototype stage it is important to design with expansion in mind. At several stages during the software development, we came up with new ideas that were easily implemented due to the hard work that when into the creation of an elegant program. I also learned the importance of writing easily readable, well-commented code, especially when someone else will be expanding on your work in the future.

Loic Markley

In brief, my contribution entailed initial software coding followed by UI implementation, working together with Nick for the majority of the project. We conducted the initial research for different voice recognition development packages, choosing the Sensory Voice Extreme out of the few available options. When it arrived we started figuring out how the module worked and how to program and run it. This led to the initial voice recognition testing and the coding of a working first draft of the software. It was developed for the EVB and could record two words including a trigger word when in training mode and recognize among the three when in operating mode. From this version of the code we handed the software over the Jessica and Natisha to complete and moved on to implementing the user interface. The UI required 18 LED's and 5 buttons to be decoded/encoded into 8 Sensory I/O lines. As well an RS232 level converter was added to interface the UI with a PC. This serial line was used for debugging as well as downloading code to the Sensory so the RESET and DOWNLOAD pins had to be connected to two extra buttons using circuitry that tied both lines to the download button and only one to the reset button. We also dealt with repairing the module after it was destroyed.

I learnt a lot from this project about actually developing a hardware circuit from scratch. From designing the circuit on paper to acquiring hardware components from various sources to soldering them all together cleanly, most of these steps I hadn't covered in any of my classes so far. I also was reminded of several lessons I had learnt in Ensc151 about the difficulties in integrated modules together for a final product and not leaving things until the last minute. Our group pulled together, however, and with everybody working hard over the last 17 hours we managed to complete everything we wanted to and still remain friends.

Nick Meisl

During the past semester, I have contributed the following to the design and implementation of Dokko Designs Freedom Voice Control. I was involved in the investigation and choosing of components for the device, in particular the choice of the Sensory Voice Extreme Module. In addition, I designed and implemented the initial code for the Sensory chip. Working together with Loïc, we created the caregiver user interface with 18 leds and several buttons all of which needed to be decoded and encoded, respectively, in order to interface to the Sensory chip.

I have learned a lot from completing this capstone project. The entire process of designing a device from start was a very interesting and challenging one. Researching ICs that would be the most appropriate for our application was a time consuming task and one that I had little previous experience with. Although the initial design for the caregiver interface started off relatively basic, it soon became quite complicated due to all the encoding and decoding required as a result of the limited IO pins on the Sensory. This led to much soldering and headache. Helping design and putting together all this hardware was quite interesting as I was creating something very tangible. Finally, I very much enjoyed working my group. I think that we functioned very well together, particularly when coming up with initial project design and user interface iterations.

Adam Stefanski

The development of this project has been a long and painstaking process but once the modules were integrated and functional, it allowed me at appreciate and reflect on the amazing potential of the product Dokko Designs developed. Throughout the project, I have learned many skills that will lay the foundation for future projects.

First and foremost, the development of a chip, without the use of an evaluation board was very gratifying. Since for all my previous projects I had the luxury of an evaluation board and the main concern was software development, it was a great educational experience to be required to first choose every single piece of hardware, from the oscillator to coupling capacitors, and correctly solder it onto a vector board, before any software development began. I found out the importance of data specifications and what things to specifically pay special attention to. Once the hardware was complete, it was onto software development for the CAN controller. This required learning a complete new protocol, CAN 2.0A, in order to implement reliable communication with the existing CAN network on the Freedom Bed. Having limited C experience, it was a challenge to make sure all the drivers function correctly. Nonetheless, with the reference from Natisha, I managed to write a function program which can be updated easily.

7. Conclusion

Even though Dokko Designs encountered many frustrations over the past months designing the Freedom Voice Control, it was very gratifying to witness the potential of this project. We believe our project allows the Freedom Bed user control and added independence in life, something which most people take for granted. Dokko Designs plans on working with ProBed Medical Technologies in the future to help them make this project a standard feature on the Freedom Bed.

