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April 17, 2010

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

Re: ENSC 440 Post Mortem for a Musical Carpet

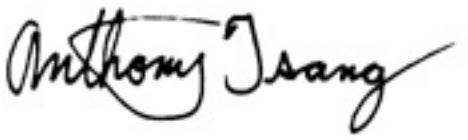
Dear Dr. Rawicz:

The enclose document, *Post Mortem for a Musical Carpet*, describes the past, present and future of our device. The musical carpet will replicate one octave of a piano embedded into a carpet and will contain additional features that will act as educational aids. This device allows the user to grasp the fundamentals of music in an entertaining fashion.

This post mortem is used as a chance to reflect on a busy project term that is finally winding down. We now look back at our mistakes and our successes in all facets of our project. We have also provided individual reflections on what we have gained from this experience.

MusEd Technologies is a team of four driven and skilled individuals: Anthony Tsang, Anton Ayzikovsky, Danny Jiang and Payam Norouzi. If you would like to contact us with questions or comments, please contact Anton Ayzikovsky via e-mail at aaa75@sfu.ca.

Sincerely,



Anthony Tsang
MusEd Technologies Inc.

Enclosure: Post Mortem for a Musical Carpet

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POST MORTEM FOR A MUSICAL CARPET

Project Team: Anthony Tsang
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Submitted to: Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science
Simon Fraser University

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Glossary

ADC	Analog-to-Digital Converter
APU	Audio Processing Unit
DAC	Digital-to-Analog Converter
DSP	Digital Signal Processing
GUI	Graphical User Interface
LCD	Liquid Crystal Display
LED	Light Emitting Diode
RAM	Random Access Memory
UI	User Interface

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1. INTRODUCTION

The musical carpet is an educational device aimed at younger children. The goal is to create a product that can both teach and entertain. The device consists of one octave of piano keys that can be played intuitively primarily with your feet, though the device will also be able to synthesize other instruments. This post mortem examines the current state of the device, deviations from our original plans as well as our future plans for the device. We also assess the success of our budgeting and time managements as well our individual growth through this experience.

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2. CURRENT STATE OF THE DEVICE

2.1 The system consists of three main modules. Main unit includes all the circuitry and resides behind the control module, an on-wall art installation with control buttons and status/feedback LEDs. Microphone and speakers are attached separately, but in later revisions will be mounted onto the control board. Sensor module is embedded into the carpet, which is connected by a wire bus to the control module.

Figure 2-1 describes the high-level block diagram for the musical carpet.

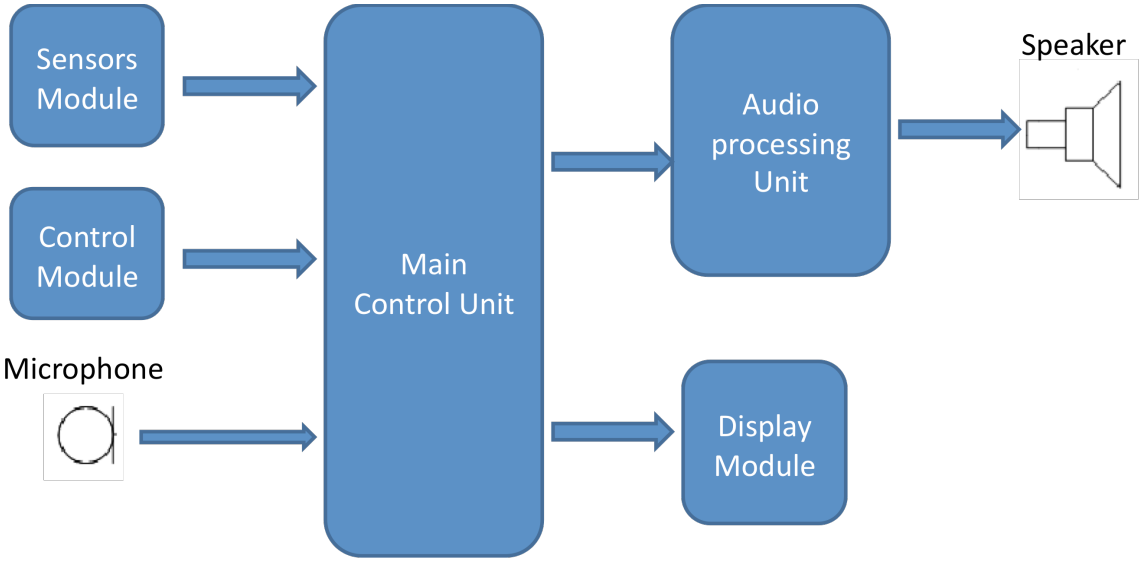

Figure 2-1 High Level Design Block Diagram

2.1 MAIN UNIT

Main unit of the device consists of two boards (ATmega32 and ATmega64) with connections implemented in regular breadboards via wire buses. The circuitry resides in a box behind the control board. The device is capable of all the designed functions, i.e. real-time playback with a selection of three instruments (piano, saxophone and organ), recording mode and playback of the recorded section and pitch detection mode, in which the control board light indicates if the singing is in tune, below or above the played note frequency.

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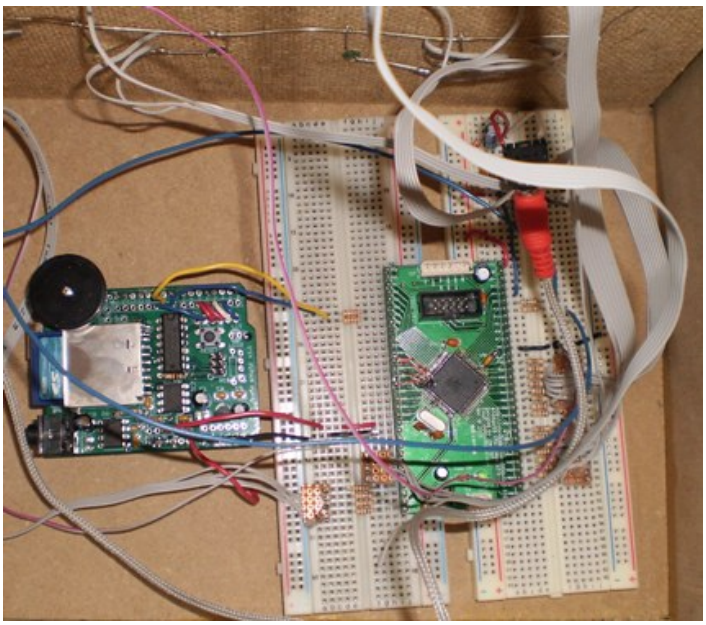

Figure 2-2 Main Unit

2.2 SENSORS MODULE

The sensing module is implemented in form of the carpet:

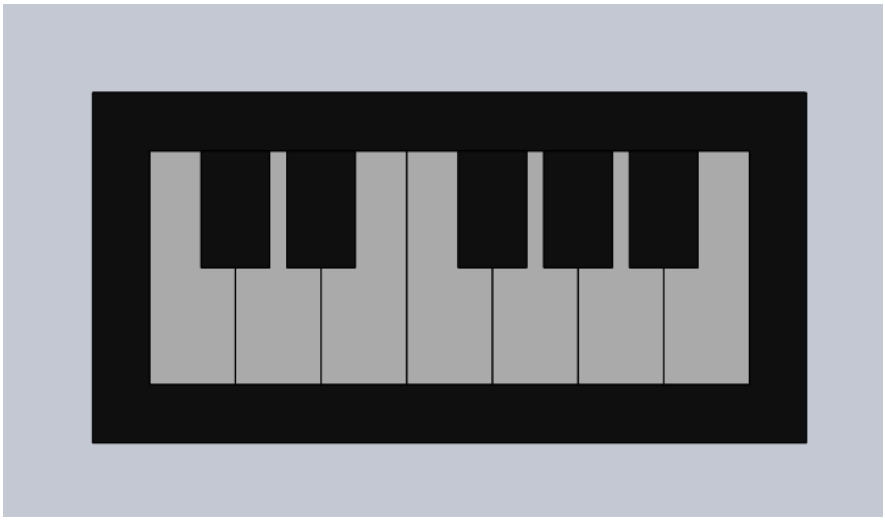

Figure 2-3 Top View of the Carpet

The finished prototype is completely within the specified dimensions, with 5 contact switches per note for best step detection. Thin foam layer separates the contacts, acting as a spring. Figure below shows the actual carpet in the regular home setting.

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Figure 2-4 Carpet in its Natural Environment

2.3 CONTROL UNIT

Control unit is built on a grand piano lid-shaped board with pushbuttons operated control functions – record, playback, instrument selections and LED indicators showing the current mode, selected instrument, notes being played and in the pitch-detection mode the correctness of the sung note.

Figure 2-5 Display/Control Board

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3. DEVICE DEVIATION FROM SPECIFICATIONS

Overall, we have achieved what we planned from our initial design. However, there were few minor differences from our initial designs.

3.1 POWER SOURCE

As outline in our functional specification document, either an AC adapter or batteries can power the device. Due to time constraints, we were unable to make the device power by batteries. Currently, the speaker and the main circuitry are using different power sources.

3.2 PACKAGING

In our prototype, we package all the circuitry into a single box as we proposed. Because of limited budget and resource, the main circuitry is built on the breadboard instead a neat PCB.

3.3 SENSOR/CARPET

Our original plan was to implement 24 keys (sensors) on the carpet instead of 12. As proposed in our functional specification, the carpet should be able to easily roll without damaging the sensors. However, we were unable to accomplish that. In addition, contact switch was used instead of capacitive sensor. The main reason is that the contact switch is a cheaper and less complex solution.

3.4 MICROCONTROLLER

Initially, we were using Atmega32 for the Main Controller. However, Atmega32 has very limited RAM memory. So when we integrating the pitch detection algorithm into the Main Control Unit, there might not be enough RAM. So we upgraded the MCU from Atmega32 to Atmega64, which has two times more RAM as Atmega32. In addition, there are much more I/Os than Atmega32. So we can connect as many LEDs as we want for displaying. Table 3.1 outlines the differences between Atmega32 and Atmega64. Also, these are the main reasons why we chose Atmega64 over Atmega32.

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	Atmega32	Atmega64
Number of I/Os	32	53
RAM memory	2KB	4KB
Number of external interrupts	4	8

Table 2-1. Atmega32 vs Atmega64

3.5 AUDIO PROCESSING UNIT

Currently, the audio unit is able to play two sounds at the same time. However, when we improve it to three channels, the Audio Processing Unit occasionally crashes due to the following reason:

- Small capacity of internal SRAM
- Access speed to SD Card
- When many channels are playing at the same time, adding all samples together will lead to saturation.

3.6 CONTROL/DISPLAY BOARD

LCD was initially considered to use in the display board. Currently, couple LEDs and simple tactile buttons were used instead of LCD. There are two reasons for this change:

- LED is much cheaper than LCD
- The display board is mounted on the wall and most of the LCDs we can found are very small. So using LCD is more visible to the users.

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4. FUTURE PLANS FOR THE DEVICE

For future development, we recommend packaging to be more compact while adding an LCD screen to make the product easier to use.

4.1 AUDIO UNIT

An external RAM unit will be added for greater sound quality. This external RAM permits us to play more channels simultaneously.

4.2 PITCH DETECTION

A more complex pitch detection algorithm such as cepstrum will be implemented, which will allow for greater detection precision.

4.3 SENSOR

Capacitive sensors will be used rather than contact switches. These sensors would enable us to capture the sound intensity and provide a more immersive experience.

4.4 DISPLAY UNIT

A GUI will be implemented on a touch screen LCD to toggle between different modes. These modes will be displayed on the screen to inform the user. Usability testing with members from the intended market will be performed to increase usability.

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5. BUDGET AND TIME CONSTRAINTS

5.1 BUDGET

Our proposed budget is compared with our actual purchases in Table 5-1. Actual purchased items have been combined to conform to the initial budget item listings. One exception is the control board, which did not fall under any of the proposed categories.

Item	Proposed	Actual	Difference
Microprocessor Development kit	$200.00	$232.60	($32.60)
Electronic Components + LED x 10	$120.00	$26.32	$93.68
Carpet material + Pressure Sensor x10	$200.00	$71.42	$128.58
Control board	$0.00	$31.19	($31.19)
Balance	$520.00	$361.53	$158.47
Funding	$520.00	$375.00	$145.00

Table 5-1 Budget Comparison

Our actual funding was lower than what we initially expected to need. Fortunately, due to cost cutting measures, we managed to stay under budget. The carpet and sensor costs were significantly decreased. Creating both items from non-expensive materials rather than buying ready-made parts achieved this goal. The only part that went over budget was the microprocessor and related materials. This occurred due to insufficient planning which resulted in the need to purchase a second board as well as slow international shipping that forced us to buy overpriced local parts due to time constraints. We would like to give special thanks to the ESSEF who funded our project.

5.2 TIME

Figure 5-1 compares our proposed time line with our actual time line. For the design and implementation of our device, we were overly optimistic on the amount of time it would take to complete. On the other hand, we budgeted far more time than was necessary to complete the various documents that accompanied the project. GUI software development only has a proposed bar since we later decided against a software UI.

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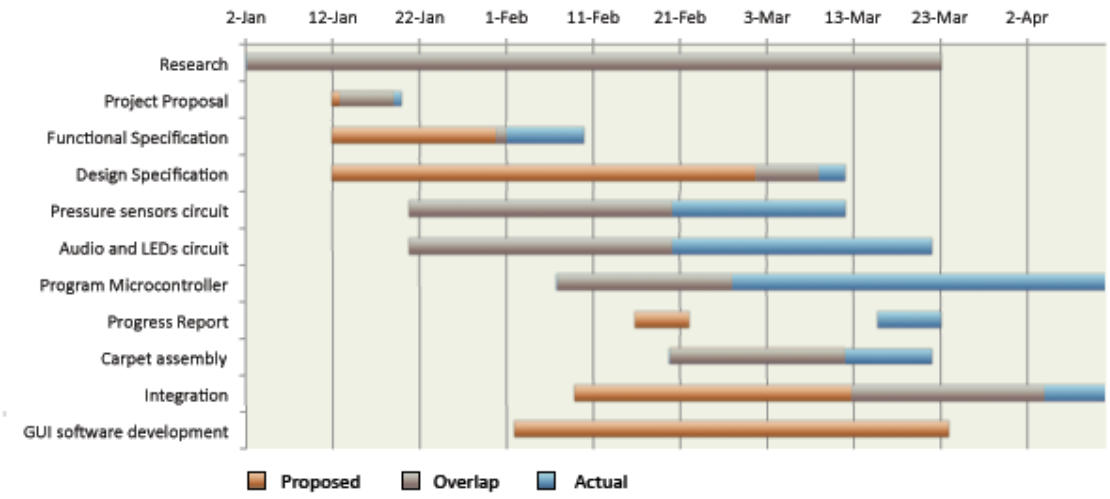

Figure 5-1 Before and After Gantt Chart

6. INDIVIDUAL EXPERIENCES

6.1 ANTHONY TSANG – CHIEF EXECUTIVE OFFICER

Throughout this term I've seen many courses I've taken finally put to use. Even some of the more obscure courses that I never expected to revisit popped back up. While working on pitch detection, I dealt with DSP and was able to apply my knowledge from ENSC 327, communication systems. Due to the limitations of the microcontroller, we considered fixed-point options and briefly touched on knowledge I'm currently acquiring on numerical analysis in MACM 316. Programming the microcontroller in C tapped into the many programming courses I've taken over the course of my studies. I also had a chance to do some experimentation and modeling in Matlab, another area I was previously introduced to in various courses I've taken. This project opened my eyes to just how much I've learnt (and surprisingly retained) over the last five years.

As part of our brilliant scheme to improve efficiency, we split our group into two groups for hardware and software. Little did we know, this would also create a divide in the relationships between the two groups. One difficulty I've yet to overcome is the issue of enforcing deadlines. This is especially difficult since we are all peers and there are no tangible repercussions for last minute work. Given the high probability that I will end up in a leadership role during my career, this chance to observe and participate in our unique group dynamic was invaluable. Overall, I'm very glad to have been able to collaborate with my group and I feel that I was able to gain some insight on group dynamics, which was definitely more than I expected to gain from a technical project course.

6.2 DANNY JIANG – CHIEF TECHNOLOGY OFFICER

Through this semester, I can finally apply the knowledge I gained from the past five years into this project. Unlike any other courses where instructions are usually given to students, this course requires us come up a creative and useful idea and start it from scratch.

From the technical perspective, I primarily work on the main control unit and the audio processing unit. While working on the audio processing unit, my goal was to make it to generate multiple sounds at the same time. As soon as I started, I realized the major problem I was facing was the lack of memory. Then I started reading many online sources and journals about DSP. I have learned that writing a structural piece of code is extremely important when we adding additional features in the future. Throughout this

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project, the pitch detection algorithm was changed from time to time. We have investigated different methods and done many testing in Matlab.

Most importantly, I learned about the value of teamwork because no matter how smart you are you cannot do everything by yourself. I learned about how to respect others. While working towards this project, we will regularly have meetings every week to monitor progress of the project and discuss technical issues encountered during the project. I think the roles were properly assigned to each member based on his strengths, weaknesses and past experiences.

Planning ahead is a key to success. We have done sufficient research before ordering parts. So we are managed to complete our project under budget. However, I think better planning could be done to avoid some unexpected problems. During week 10, I fried the MCU on the main unit. Then I stuck for one week waiting for the replacement to come.

Overall, it is my pleasure working with my teammates and I am impressed with their contributions.

6.3 ANTON AYZIKOVSKY – CHIEF FINANCIAL OFFICER

Even though I was not able to fully exercise the knowledge in all the areas of my studies, I have had invaluable experience handling the financial side of the project. Also I was responsible for design and construction of the sensors module, which was a pleasure for me – widely known hardware enthusiast. I got to research various ways to implement step-sensing switches, to communicate with many professionals in the area, to bargain with the manufacturers, to move around the city searching for the best deals. Upon finishing the preparation I was lucky to enjoy working with my hands building the planned system.

While communicating with my team I discovered a lot about team dynamics, confirmed my knowledge of the vast differences between people and their approach to work and realized how important staying calm and focused and finishing tasks ON_TIME might be for one's peace of mind as well as the project's success and on-time execution.

I find it the best course in the program, partly thanks to the professors teaching it and partly – to the independence they grant us to complete the project. It was a delight working with my teammates and I would definitely take on another project with them.

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6.4 PAYAM NOROUZI – CHIEF OPERATING OFFICER

The project I participated in has been very insightful. I am proud of the group results we achieved this semester, as we not only created a fully functional device, but the audio quality was also comparable to that of a commercial product on the market. While completing my assigned task, I communicated with several individuals who have an industrial design background, in order to obtain insight into the design process.
I also turned to lessons taught through the course, ENSC 304, and applied the principle of "natural mapping". Since the product was designed for children, this task had to be performed with extreme care.

The structure of this project provided our group with much more liberty and freedom than is normally allowed in similar courses I have previously taken. This has caused me to be able to overcome the fear of designing something from scratch and allowed me to involve my creativity in the process. Furthermore, working with my group was also a very positive experience. I was impressed by the work ethic of my fellow group members, which enabled our group to complete the project before the assigned due date. This allowed us to avoid the state of panic that tends to accompany leaving tasks to the last minute and ensured that we had sufficient time to produce a solid product.

This project has allowed us to become directly engaged in project development and has exposed us to the type of environment which this process occurs within. Additionally, these tasks have provided us with certain technical knowledge that may not have otherwise been obtained through regular academia and course work. A hands-on approach provided experiences that a textbook, however well it is worded, could not teach as sufficiently. Overall, this course has proven to be a very valuable learning experience.

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7. CONCLUSION

The goal of the post mortem is to assess and reflect on the work that we have completed. It examines our initial goals and plans and determines how closely we adhered to them. We also take a look at ways in which the device can be improved in future development. Finally, we consider the opportunities provided by this project and the experiences we've gained both from creating a technical device and from interacting with our group members.

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