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April 1st, 2009

Prof. Patrick Leung
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Burnaby, British Columbia
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Re: ENSC 440/305 Process Report for the Nomad Digital Pen

Dear Prof. Leung:

The attached document, Process Report for the Nomad Digital Pen, outlines the process that TechStyles Inc. went through in the procedure of design, implementation and calibration for the Nomad Pen proof of concept in the context of the two courses ENSC 440 and ENSC 305. The Nomad project was to design a digital writing device that would allow for recording the movements to draw/write and hence restore and later retain information instantly having the intuitiveness of a normal pen.

The following document describes, in details, the current state of the Nomad Pen, the deviations from the original project specifics and plans, and also plans for future work for the device. In addition, some of the budgetary and time constraints along with technological limitation and challenges that the team experienced throughout the project time period are outlined. Also the inter-personal and technical experience gained from the work on the project is explained.

TechStyles Inc. consists of four experienced, motivated, innovative, and talented fourth-year engineering students: Zhen Gang Xiao, Simran Kumar Sarai, Unnati Sapre, and Behzad Jazizadeh. Should you have any questions or require any further information, please contact TechStyles Inc. by phone at 604 518 9152 or by e-mail at nomadpen@techstyles.ca.

Sincerely,

Behzad Jazizadeh
Chief Executive Officer
TechStyles Incorporation

Enclosure: Process Report for the Nomad Digital Pen

THE PROPOSAL FOR THE NOMAD DIGITAL PEN

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Submitted to: *Prof. Patrick Leung – ENSC 440*
Steve Whitmore – ENSC 305
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Issued date: *April 1st, 2009*

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Glossary

CSA	Canadian Standards Association
ISO	International Organization for Standards
UART	Universal Asynchronous Receiver/Transmitter
LED	Light Emitting Diode
GUI	Graphical User Interface
DC	Direct Current
USB	Universal Serial Bus
RoHS	Restriction of Hazardous Substances
IEC	International Electrotechnical Committee
LCD	Liquid Crystal Display
MCU	Micro Controller Unit
PDIP	Plastic Dual In-line Package
SOIC	Small-Outline Integrated Circuit
SD	Secure Digital
COM	COMmunication port
QA	Quality Assurance
API	Application Peripheral Interface
A2D	Analog to Digital converter
ARF	Acceleration Reference Point

Introduction

The Nomad Digital Pen is a paper less stand alone solution for capturing data while writing and/or drawing that will have the capability of working on any surface with any slope. The comfort and ease of use that this pen brings to its users would be distinct aspects of this pen which are not found in any other alternatives in the market. Data capturing is done by sensing the position of the tip of the pen as its moves, and then translating the raw data into useful information for the graphical application use. This smart pen also provides a built-in storage for data such that the user can reliably keep the captured data for later upload. The process report document re-examines the overall procedure that took the Nomad Pen from an idea in our minds to a working proof of concept and documents the knowledge and experience of each of our four members.

Current State of the Device

As described in the project proposal, the proof of concept for Nomad Pen detects hand motion in two different categories, translational movements and rotational movements. For translational movements the three axis accelerometer is used that has a maximum sensitivity of +/- 3g and determines the acceleration which is then double integrated to extract the position data. Although the assumption for this level of product development is that the pen is to be used tangent to the surface with planar movements, three single-axis gyro-meters are used to detect the small angular movements, determine the axis of rotation and hence compensate for the discrepancies generated as a result of angular motion of the wrist.

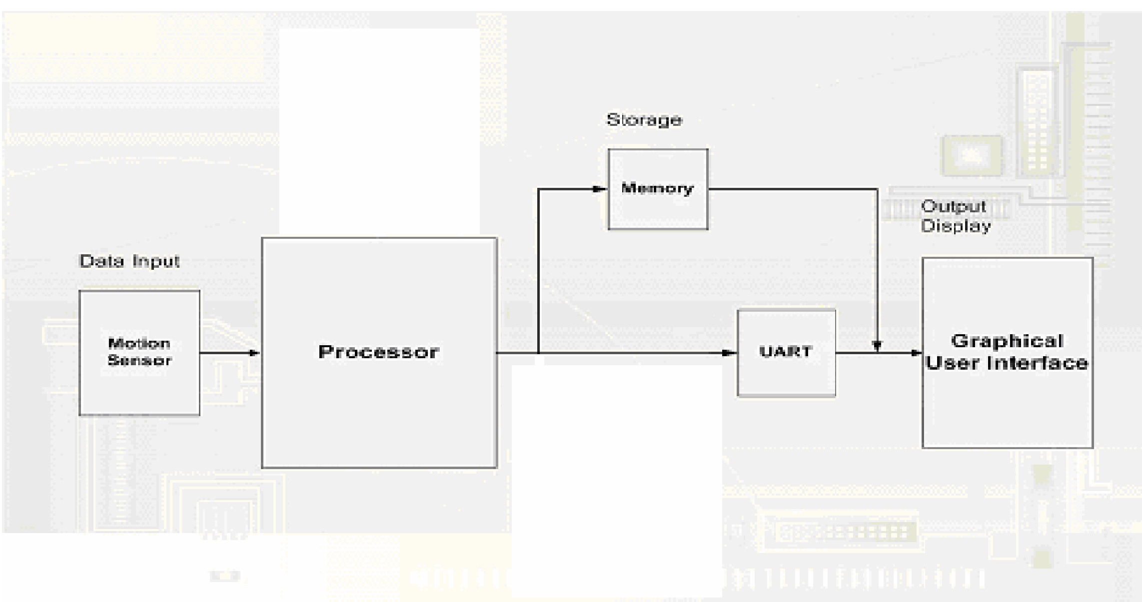

Figure 1: System Overview

Figure-1 in the previous page illustrates the logical connection among subunits and between subunits and the MCU. The current state of the Nomad will be explained by the review of each of the units and subunits according to Figure-1.

Motion Sensing Unit

In the motion sensing unit, three single axis gyro-meters and one three-axis accelerometer are used to capture the movements. The accelerometer, as mentioned above, captures the acceleration data in analog form and sends the data to the MCU. The gyro-meter captures the angular velocity data in analog form and sends the data to the MCU. The analog data is then sampled and digitized using the A2D.

Processor Unit (MCU)

The MCU, in general, takes care of all decision making procedures, buffering and A2D conversions. The raw data from the motion sensing unit is first buffered into the A2D module and then digitized for further use. The digital data is then transferred to two different modules and units. In order to display the data in real time on the GUI, the digital data is transferred to the UART module. In addition, for storage purposes, the data is transferred into the flash memory unit (that is to be built-in to the Nomad Pen prototype later). The digital data is stored in the memory in the text (.txt) file format.

UART Module

UART in the proof of concept is the serial data transfer module operating at a baud rate of 9600 bps. It is connected to the PC COM port (either COM1 or COM2). The UART module in the Nomad proof of concept works compatible with EIA RS-232 standard for serial communications in half-duplex mode. In the Nomad project, the use of the PIC18F4685 (Micro-Controller Unit) brings the advantage of using the USART module that is a built-in on-chip feature of the MCU [5].

Flash Memory Unit

The memory unit was used to store the data for later use. In the proof of concept current state of the memory is a SD memory with 512 Mbytes storage capacity. The SPI buffer for the data to transfer to the memory is 15 bytes. The preferred mode of communication between the memory and the MCU was chosen to be the SPI mode over the SD mode, due to its lower complexity and ease of use (SD mode uses 8-wire communication compared to SPI mode which uses 4-wire communication) [11, 12].

Graphical User Interface (GUI)

The graphical user interface is designed to give the sense of a real-time display of motion data being received from the UART module. The application consists of a window with a “main” menu. There are different tabs considered for the display of the graphs for “XY Position”, “X Data”, “Y Data” and “Z Data” that are all related to accelerometer data. There are also tabs considered for gyro-meter data: “Gyro 1 Data”, “Gyro 2 Data” and “Gyro 3 Data”.

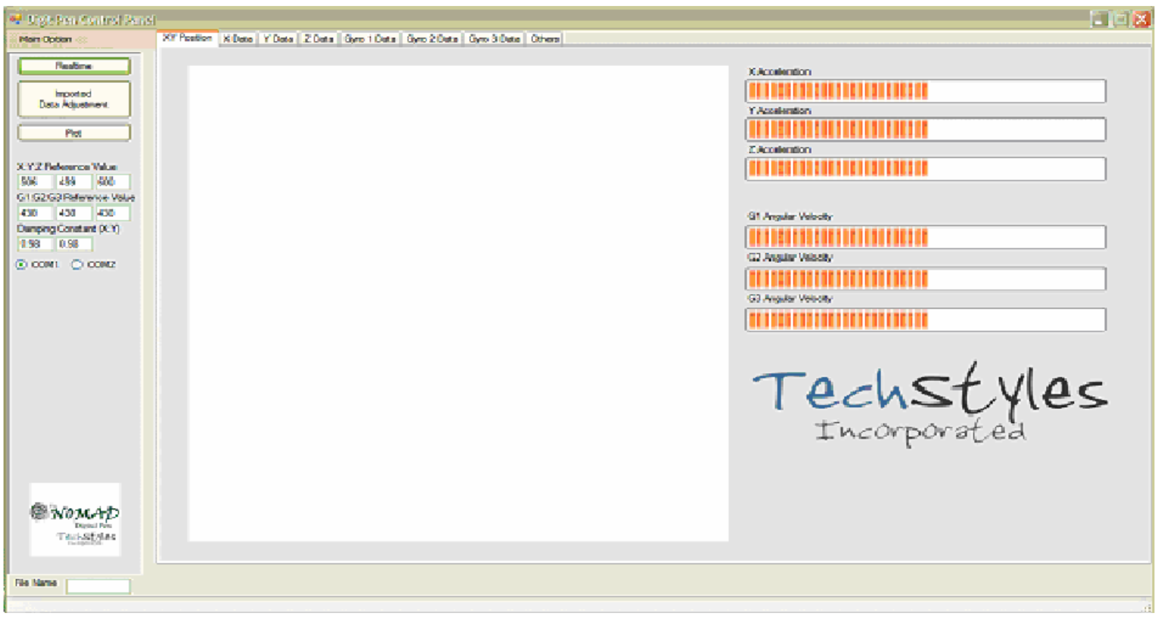

Figure-2, A screen capture from the GUI

As it can be seen from the screen shot of the GUI above, under the “main” menu there are three other buttons:

- “**Real time**”: is used for real-time display of motion data
- “**Imported Data Adjustment**”: is used for the raw data received from memory. This data is to be adjusted later to show a proper graph of what has been written.
- “**Plot**”: is used to plot the graph once it is properly adjusted.

Underneath the following buttons, there are windows into which the user can input reference values for X, Y and Z accelerations and also for Gyros Number 1, 2 and 3. Further, two more windows are implemented for the user to input the damping coefficients. The reference values are to adjust the zero value for every single set of data and the damping coefficients are for further adjustments to compensate for error that is accumulated during numerical integration.
Below the mentioned windows, the user is given the option to choose the preferred COM port to connect to.

On the right hand side of the GUI window, there are three windows indicating the change in X, Y and Z acceleration data in real time. There are also three windows indicating the change in G1, G2 and G3 gyro-meters angular velocity data in real time.

At the bottom of the screen and to the left, there is a window that indicated the file name that is input to the user interface application.

Deviations of PoC from proposed idea

Overall System

In terms of functionality, considering certain deviations and minor changes, what was planned was achieved. Specifically the goal for this project, to be able to write with the pen, is fulfilled. However, certain limitations to the design were also brought up to the team's attention as will be discussed in what follows in the next coupe of sections. Although the time was a considerable restriction, TechStyles Inc. were able to manage a certain level of integrity with respect to both hardware and software.

Currently, the proof of concept consists of a circuit board. The board interfaces the serial connection to the PC COM port, the connection to the pen and the connection to the MCU programmer. The circuit board also provides for on/off switch, internal connections and mounted parts for signal conditioning (such as diodes, capacitors, resistors, etc.).

The device is not portable due to restrictions in size of the board. Another reason is the modularity of device, in the sense that, the board was accessible for any changes and modifications in the parts and connections and also the adding/removing of components. Due to changes in the amount of voltage supplied to each component and the fact that several different components and units are used for the pen, the device is not powered by batteries, and just with the regular power supplied by the programmer instead.

Processor Unit (MCU)

Due to restrictions on the number of pins that support the SPI/I^2C modes of communication, and also the fact that each single SPI path is dedicated to one subunit (such as a memory unit), the technical lead decided to use analog output of the sensors instead of digital outputs (that used SPI bus). Even by implementing an interrupt, the same path could not be used for communication with another unit. As a result, the memory now uses the dedicated SPI bus to talk to the MCU and the sensors transfer the analog data to the A2D. This itself resulted in lower speeds in transmission of data, but made it feasible to make use of the MCU in its (almost) full capacity.

UART Module

The design and implementation of the UART module does not have any deviations from the original proposed design. As a result, there has been no modifications related to the module, since the functionality of the module from the perspective of the MCU and that of the PC are unchanged.

Flash Memory Unit

Although in the proposed design, the idea was to make use of a micro-SD memory, in the actual proof of concept available now, the deviation from the proposed idea is that we used the SD memory shown below in Figure-3, for storage of data, instead of micro-SD memory.

Figure-3, *512 MB* SD-Memory

The main reason for this change is the fact that in the Micro-SD, the data was to be transferred in chunks of 512 Bytes, which drastically reduced the speed of operation. However, the use of SD memory forced the data to transfer in chunks of 15 Bytes which resulted in higher operation and storage speed.

Graphical User Interface (GUI)

The GUI is rebuilt using the Micro Soft Visual C++ and is compatible with all WIN32 systems. The main deviation from the proposed design for the GUI is the rebuilt from Windows API to the Visual C ++. Other changes and deviations in the GUI include:

- Elimination of the Menu bar that was previously consisting of: File, Open, Save As…
- Addition of tabs for different sets of data from accelerometer and gyro
- Addition of a window for X-Y-Z acceleration graph over time, in real-time
- Addition of "Live Motion Status" bar for acceleration and angular velocity data
- Implementation of the windows for input values for X-Y-Z acceleration reference points and damping coefficients.

Challenges and Solutions

From the time that the idea was developed to the time that the team made a working proof of concept, a considerable number of issues came up that challenged the team for the solutions. While, some of the issues are already solved, there are still a handful of unresolved problems.

Dependence of ARF on each trial

By fixing the pen at a certain position and recording the acceleration data, we can find out what the ARF (zero acceleration point) is. This data is then normalized by self subtraction to give us the zero acceleration. From this point onwards we perform the integration once to get to the velocity and once to get to the position. But this initial set of numbers change every time the pen is on.

Solution: this issue was resolved by filtering the initial set of data (essentially treating it as noise data to be thrown away), hence cancelling all the deviations from the initial zero movement acceleration. This ensures that the final result is once again consistent with zero point acceleration.

Existence of invalid data due to vibrations

Due to vibrations of the sensors from their relatively fixed positions (within the PoC packaging) and caused by the human finger/wrist/arm movements while writing, external noise was determined and recognized from the data that was captured. This dispersion in acceleration data although, by itself does not seem to be harmful, after integration becomes a very large number, resulting in either negative or positive divergence.

Solution: mechanical filtering solved this issue. That is the sensors were tightly packaged to further reduce any possible mechanical vibrations which would contribute to the noise.

Existence of invalid data at initialization

From the time that the pen was turned on to the time that the initialization occurs and the sensors start capturing the position, there is a set of data that was found to be absolutely meaningless. This set of data was not noise, nor was it due to vibrations. However, it used to create error particularly after double integration.

Solution: to resolve this issue, we tried a couple of different approaches, one of which was to treat this data as the initial position of the pen and filter out any oscillations from a certain reference point. But the dispersion in the data was too much that it was difficult to even recognize a pattern of reference and filter out deviations. Ultimately we decided to consider the data as the result of sensors warming up, hence discarded this initial set of data and then performing double integration.

Limitations and proposed solutions

In addition to the challenges and problems, there are some limitations to the design that are considered as restrictive assumption for instructional use. These are essentially challenges to be fulfilled in the near future. For some of them, the team has proposed some possible solutions.

Hard to trace movement when pen lifted up from surface

When the pen is lifted up, from the surface in the air, it is difficult to detect the planar movement and to keep track of the previous position. This is due to the effect of gravitational force.

Proposed solution: To solve this problem, we tried to use the gyro to detect the module's orientation in the 3D space, but due to the limitation in the sensitivity of the gyro, it could not accurately calculate the small rotation which is required to retrieve the precise movement. An alternative solution is to use the magnetic sensor to detect the module's orientation with respect to the earth's magnetic field.

Poor sensitivity of accelerometer at low acceleration

This problem arises at low accelerations (which happen sometimes at low speed too). Due to the relatively low change in the velocity, noise is introduced into the data captured from the movements. Tests for different normal speeds of human writings are to be performed, but still the same problem exists.

Proposed solution: one solution could to be replaced the current accelerometer in-use with another sensor (accelerometer) that has relatively higher sensitivity.

SPI speed limitation for the use with memory

Proposed solution: to use the full-speed SD mode instead. This has the advantage over the SPI mode, because it uses 8 wire connections, and all the data are processed in parallel.

Future plans

The Nomad Pen has great potential for further research and improvement. As mentioned in the proposed idea and also regarding the prototyping, the review and reexamination of the device brought up the following, as suggested by our members in TechStyles Inc. for future development.

Implementation of the USB module

The USB module shall be implemented in the pen. Hence the shift from RS232 to USB would be inevitable. This provides the Nomad the advantage of having the market standard wired communication.

Implementation of the Bluetooth module

TechStyles requires the Nomad pen to also have a wireless mode of data transfer. The Bluetooth module is well suited for this purpose, since a great portion of the electronic market is using this standard for their wireless (short range) connectivity.

Mechanical design for the compact NOMAD PEN

A complete mechanical design is to be done for the Nomad to have a compact look just as a normal pen should have. This however requires certain assumptions and considerations since there is a fairly complicated PCB design going to be implemented inside the case. As a result, a detailed internal design should be considered and a careful assembly will have it finished.

Optimization of the positioning algorithm

The current algorithm for the positioning process of the pen is definitely not the best that it could be. The algorithm needs to be changed. Additional function codes and sub routines are required for an optimal and effective interaction between different segments of the algorithm code. Routines for integration as well as for filtration and noise reduction would need modifications. We might even need a better and more accurate numerical method for integration from the numerical computations point of view.

Optimization of the firmware

The firmware needs optimization with respect to the run time and also regarding the amount of memory its code takes each time from initialization. Also, after more in dept studies the team might decide to implement parts of the integration and data interpretation code in the hardware instead of the software. This might involve a trade-off between the memory usage and the run time.

Implementation of the first prototype for field trial

With all the modifications and changes, minor and major, the team would be ready to launch the Nomad's first prototype. This stage will definitely be having its own issues, most of which will be determined in field trial.

Budgetary and Time Constraints

Budget

Table-1 below contains the estimated cost and the actual cost of the project up to the date May 15th, 2009.

Required Material	Estimated Cost (in Canadian)	Actual Cost (in Canadian)
Tri-Axis Accelerometer	$50	$132
Tri-Axis Gyro-meter	$100	$88
MCU	$50	$0
MCU Programmer	$50	$100
Cables/Connectors	$100	$30
Serial Interface chip	$50	$5
PCB/Signal Processing components	$200	$35
Miscellaneous	$500	$22
Total	$1100	$412

Table-1, Estimated Cost vs. Actual Cost for the Nomad project

Due to the fact that the project will be continued to prepare for the first working prototype for field trial, the costs listed above are not an indication of the total cost of the project as a whole, but *only* reflect the costs up to and including the working proof of concept design. One major reason for the large difference in expected and actual costs is the lack of knowledge from the market for advanced electronic components. Another reason for the significant reduction is the fact that the team could apply for free samples of MCUs based on the fact that the research was a student project and not for commercial use. This of course had to bear the long shipment periods of two to three weeks as a trade off for the free samples. Samples that were bought were shipped considerably faster than the free samples (within two to three days delivery).

Time

The following is a Gantt chart attached, to support this document. In the chart the blue line shows the expected timeline and the red line illustrates the actual time/task division.

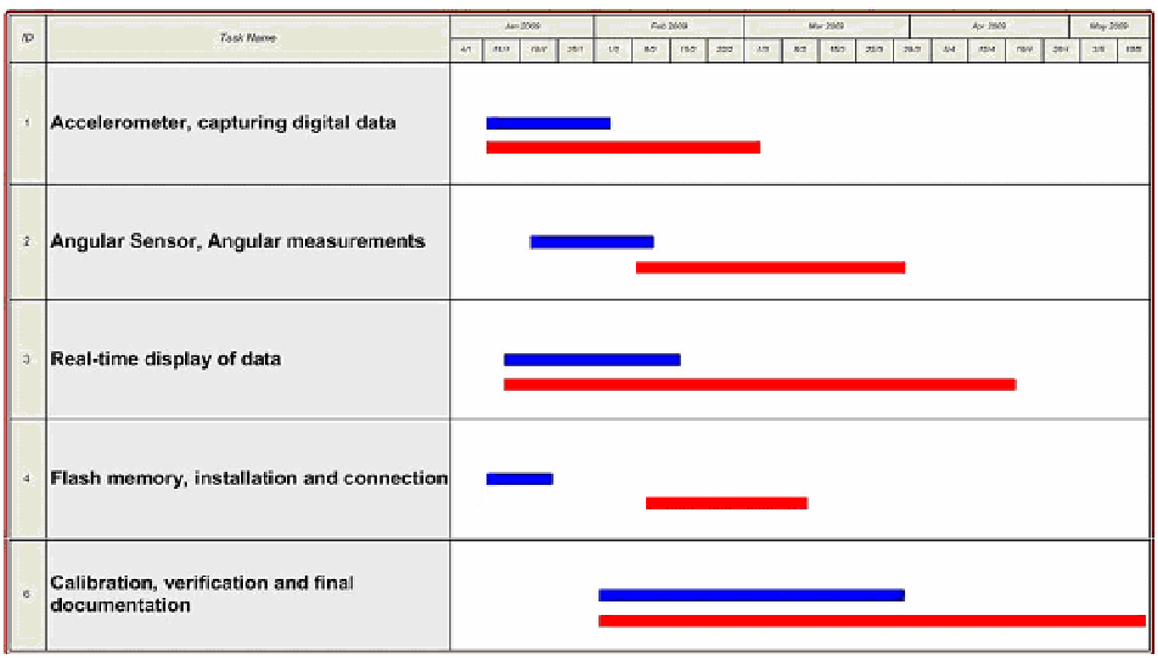

Figure-4, Gantt chart for the project time table

It is noticeable from the time chart above that the actual implementation of the different stages required at least twice as much time as it was first expected. One important and also obvious reason is that the team underestimated the levels of complexity of different stages, and hence assumed considerably shorter time lines for different stages. Another very important reason for this delay is the fact that this project was a "design from scratch", almost no other similar products (with the same technology) existed out there in the high-tech market. It was not an addition or some modifications to an already existing design, but a completely new and neat idea that was to be proved to work.

Also, due to exam conflicts, and other unexpected incidents we could not demo our proof of concept on time. For a fact we all knew the importance of sticking with the project timeline and hence tried to keep up with it to finish on-time. Although that did not happen as it was expected, despite all our efforts, by adhering to the project schedule as much as possible, the team was able to undermine and weaken the frustration, stress and pressure of the project throughout the entire semester, by frequent meetings and giving self feedback on their work. Last but not the least reason for the delay in demo and the shift in project time line was the wait time for the shipment of different components.

Inter-Personal and Technical Experiences

Zhen Gang Xiao

Many people say the ENSC 440/305 is one of the most challenging courses throughout the engineering program, and I truly agree. But at the same time, because it is a challenge, I have learned much more than I expected. Before the semester starts, I had little background in windows software programming and embedded system design, and this project gave me an opportunity to learn both of them. There are so many windows applications have been made, and I always wondered how I could do it myself. I started from searching the right book in the library, then going through the tutorials one by one, and finally creating my own application. Throughout the process, I discovered so many interesting features in Visual C++, and it gave me some insight about this area of engineering (software engineering). Just like the windows programming, I knew very little about embedded design before. From lighting up a single LED to constructing the current proof of concept, I have spent hundreds of hours to research and experiment. Frustration and excitement alter like a sine wave, constantly exciting my curious mind. And when I finally was able to draw a little happy face on the screen with the proof of concept pen, it was all worth it.

During the academic years, most of the course projects require working in a group, but none of them could compare to this one in terms of the importance of team dynamics. Learning to collaborate with my group members was both challenging and fun as we all come from different cultural backgrounds. The formation of the group truly reflects the diversity of Canada's multiculturalism. Besides the culture difference, we also have different academic focus and course schedule. Because of that, it was sometimes almost impossible for all of us to get together to work at the same time. As a result, we divided the team into two groups, one focusing on the hardware, and one on the software. At different stages of the project, we managed to hold weekly meeting in a dynamic schedule to exchange information. With the help of internet technology, we also managed to establish close communication by email, online chat, etc. During the semester, we did have several conflicts, but we were able to resolve it in an efficient and rational manner. It was a pleasure to work with my team members, and it not only has improved my interpersonal skills, but also established new friendships.

Simran Sarai

Since I started my engineering at SFU, I never missed the demos of ENSC 440/305 in Lab 1and labelled all the dreaded stories about these courses as a myth. Today, when I am in the shoes of those students who took ENSC 440/305, I understood that those warnings were meant to be heeded. Time just flew away from the day we enrolled in these courses to the big day when we demonstrate our project. It was definitely a great opportunity to apply all the theoretical knowledge that we supposedly gained in the past 4 years of academic curriculum, to a real world problem.

In the project, my contribution was mainly software part that included developing graphical user interface and hardware-software interface. During the development of software, I realized that windows programming is "hard" and required a lot of book reading. The level of programming involved in this project was extensive and my learning from CMPT 128 was barely sufficient to set the base of this project. Even though we had to request for extension for the project, our mutual understanding and flexibility helped keep our stress levels minimal.

Many valuable skills were acquired including managerial, interpersonal and people's skills. I felt lucky to have a well-rounded group that had strong engineering skills as well as well developed interpersonal skills. In case of conflicts, which were mostly minor, there was always one or the other person who helped diffuse such arguments. Overall, as a team, we worked together efficiently and the communication was excellent. The project went very smoothly and a huge credit goes to the extensive research we conducted before the semester started.

The strongest asset of our group was motivation. From the beginning of the semester, our focus was to actually prove that our concept is feasible and we worked towards it undauntingly. The best part is that we are still a team and look forward to make TechStyles Inc. a successful company with Nomad Pen a high-demand commercial product.

Unnati Sapre

ENSC 305/440 has not only been one of the most challenging but also the most interesting and exciting course that I took in SFU. The past 4 months have familiarized me with a variety of different concepts in both, hardware and software fields. Exposure to the different principles of hardware and software design and testing has enabled me to view Electronics Engineering from a whole new perspective.

At the start of the semester, the very aspect of our Nomad Digital Pen project seemed highly unachievable. But our whole team has made immense progress from understanding how to work with the PIC chip to designing, assembling and testing the entire working model of the pen along with its user interface. This project gave me an opportunity to study in detail the pros and cons of some different types of Graphical User Interfaces (GUI's) ranging from CXL and Cygwin to Windows API and Windows Form Design. Since we were both the programmers and the users of our program, this project gave us a golden chance to figure out exactly what an outsider would expect from our GUI and exactly how we need to program. The current prototype can display the movements of the pen on the GUI window screen along with the acceleration graphs. For future work we aim to control the start and stop of the pen from the software instead of from the hardware.

Although, no prototype can be presented without proper testing, analysis and documentation, the 305/440 project has definitely improved and honed my technical writing skills. It has also taught me how to think about the possible problems that might arise for the user and how to come up with appropriate testing methods to solve those problems. The more the number of tests and analysis performed, the more accurate the prototype will be.

In terms of interpersonal skills, some important things that I have learned from this course are time management, working in a group and friendship. 305/440 no doubt requires a major chunk of your time and I had to make sure I also find time for all my 7 courses (20 credits) throughout the semester. Huge number of different assignments, quizzes, midterms and finals had made my spring semester no less than a real-time juggling act. But I have managed to fair well in all my courses. Also, 2 out of my other 3 group members were complete strangers to me at the beginning of this course. But now, of course after a couple of ups and downs, I think I have made some great friends who always help and support me. I think this project will go a long way in shaping our future careers.

Behzad Jazizadeh

ENSC 440/305 is, with no doubt the most challenging and comprehensive course in the curriculum of the engineering science. This is not new quote and has always been said about this course. However, what many might not say or notice about this course is the amount of knowledge and experience, expertise and excellence they gained though out the course.

For the past 5 months, I have strongly felt that I have learned to analyze seemingly meaningless data from hand motions and to extract from it what I need to accomplish with my positioning tasks.

Getting used to work on Micro Controllers on a daily basis was one of the most profound experiences and learning curves I have had through the course of the Capstone project. Gaining hands-on expertise with the I/O ports, initialization, communication protocols, data structures and buffering, and hardware coding practices was just one side of this long aisle.

Working on micro electro mechanical sensors, specifically accelerometers and gyro-meters has given me the ability to further get familiar with their working concepts, the protocols over which they communicate with the controller. In addition, the way these sensors should interact with one another, the methodology and theory behind the fact that where and when which set of data should be recorded and further interpreted.

Although I have a fairly strong mathematical background, the fact that I had to use my knowledge and apply it to this project to interpret the data and particularly perform numerical integration to extract position information from the accelerometer and gyro-meters, was worth reviewing what I have previously learned in applied mathematics. Studying the theory behind the positioning via the accelerometer, performing research to find the best and most feasible formula for integration and then performing error correction procedures and filtering routines were also of the most important aspects of this course in my learning timeline.

Studying the concept of the project in dept, I started to do a comprehensive and extensive research to find out about similar products that perform similar end results in one hand and to find applications that use similar technology in the market. As if it was a real-world project and me being a consultant, I managed to do a vast feasibility study not only with respect to the technical aspects but also regarding the marketing and business aspects of the end-user product. In this process, I was lucky enough to get together with experts from SFU School of Business, Marketing and Finance, Professor Ean Jackson, Mr. Khosrow Mossannen, Brook Ewert and Wassell Abdelloui. Also I am thankful to Professor John Jones who helped me with financing aspects that I later on applied to this project.

Validation and verification in an engineering project play an important role. In every stage of the project I learned and practiced validation to make sure we are still on the right track. During the project, I learned how to arrange test outlines, perform analytical problem solving, look at a problem from several different views and try to catch them and resolve them. In this aspect, I got great help from Professor Patrick Leung, Mr. Fred Heep, Mr. Jason Lee, Mr. Jaime Westell and Professor Albert Leung. Specifically Patrick taught me, with his great experience in micro sensors and embedded systems, how to check for problems in different areas of a design and what tests to do first and how to quickly find out if the problem is fixable or the component in faulty and needs to be replaced.

One of the most profound skills I learned during the course of 440/305 project, was documentation. I learned how to perform technical writing, how to maintain note-taking and how to keep track of different steps in the project. I also realized how to write, talk and act like a professional engineer, prepare for a lab journal, divide the project documentation into separate stages from the proposal to post mortem. I also learned and practiced the engineering codes of ethics and how to apply them throughout the course of this project. I have also practiced my team working skills and challenged my presentation and communication capabilities. I owe all this to Professor Steve Whitmore, Mr. Mike **S**joerdsma, and also great feedbacks from Jason Lee and Jaime Westell.

In 440/305 I also practiced my interpersonal skills. I practiced to be understanding and to be a critical thinker. I practiced leadership and management. I learned to be an initiator individual while working in a group. This means to compromise from time to time, since any one of the team members including myself is entitled to have their ideas to be listened to while maintaining a certain level of discipline and prevent from chaos to dominate the team project atmosphere. This will account for every single individual attempt to make a better product and to proceed to the next level in the project. I also practiced to be patient in a matter of crisis and to be thoughtful of what talents different people in a group have to make the best use of them all. And above all this, I found that after all this stressful and intensive time, nothing will remain but friendship that was and still is among us. I am proud of every single one of my team members and consider myself so lucky to have them on my side in the good and bad days of capstone project. I happened to be friends with my group members before this semester starts, but never felt closer to them than in this semester. I am thankful to all of them and I hope I can work with them again real soon.

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