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December 20, 2011

Andrew Rawicz
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Re: ENSC 440, Post Mortem: Display Augmentation System

Dear Dr. Rawicz

Enclosed is our Post Mortem for Display Augmentation System, which describes the processes our team undertake to successfully implement this product. Daedalus Technologies' goal is to design a product that is capable of providing the user with an ideal ergonomic view to help reduce the likelihood of strain related injuries.

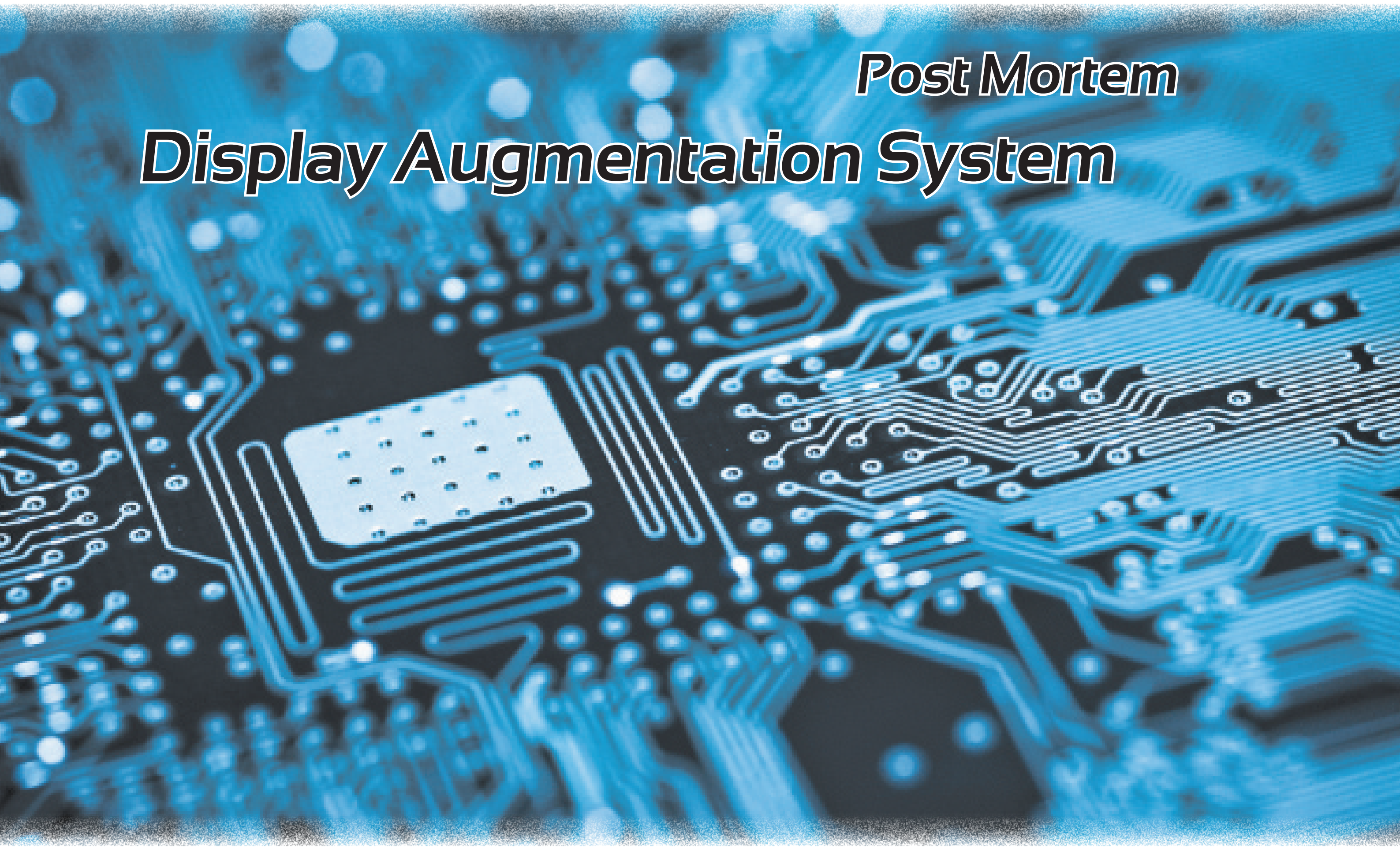
This post mortem summarizes our project, budget and timeline. It includes a list of some of the problems we have encountered, and as well as description of each individual reflections and knowledge we have gained over the semester.

Daedalus Technologies is comprised of four senior engineering students all from electrical engineering concentrations. For further inquiries about our company or this documentation please contact us at Daedalus-tech@googlegroups.com or at lfz2@sfu.ca

Sincerely,

Larry Zhao
Chief Executive Officer
Daedalus Technologies

Enclosure: Post Mortem for Display Augmentation System



Post Mortem

Display Augmentation System

DAEDALUS
Technologies

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Glossary

AIT -Artificial Intelligent Tracking
DAS - Display Augmentation System
ESSEF - Engineering Science Student Endowment Fund
FPS - Frames per Second
GUI -Graphical User Interface
GUIDE - Graphical User Interface Development Environment
LED - Light Emitting Diode
OpenCV - Open Source Computing Vision
PCB -Printed Circuit Board
RoHS - Restriction of Hazardous Substances Directive
RS232 - Recommended Standard 232
USB - Universal Serial Bus
VDU - Visual Display Unit

1.0 Introduction

In modern society, there is a growing trend of increased computer usage and dependency in office, school, hospital, and government settings. With more people requiring increased sessions of working with or around computers, problems are bound to arise. A predicament of sorts is growing where more and more citizens are being plagued with eye, back, and repetitive-strain injuries with no end in sight.

Here at Daedalus Technologies, we are confident that our Display Augmentation System (DAS) can address these health issues. Our main objective is to reduce the strain injuries occurring to these individuals, by constantly readjusting where the user is, thus keep the users in an optimal view position while providing visual feedback about the whole process.

Our main market is the various section of the service industry, such as hospitals, office buildings and schools. With that being said DAS's specification is essential the same as exist products on the market but with special face tracking feature integrated, which we called it Artificial Intelligent Tracking (AIT). We opt to adapt a very aggressive pricing strategy due to there are no comparable product exist in the market. We plan to price our product at the $150, which is $20 more expansive then the next leading competitors. This strategy will help us achieve a greater profit per unit sold comparing to our competitors as well as the edge in market competition.

2.0 System Overview

A system overview diagram is show in figure 1 below. On the software side, a Graphical User Interface (GUI) manages the image acquisition, face detection and user interaction. In addition, it contains features such as a selectable timer to signal the user that a break is needed. The GUI also provides manual position control for the user to interact with. The image acquisition feature takes in video feedback from the Microsoft Lifecam Cinema webcam which connected via Universal Serial Bus (USB) and periodically takes snapshots. These saved images will then be fed to the face detection algorithm which will draw a rectangular box around the user's face. The largest face will be returned with positional data to the main GUI program. With this positional data, the motion estimation algorithm will take over to calculate the distance the user has moved with respect to the centre position value. With the position value, the GUI then sends this data through the USB port via USB to RS232 converter into the Arduino microcontroller unit. On the hardware side, the Arduino Mega, in conjunction with the DAS shield inside the DAS stand itself, will control a linear actuator, motor function and mechanical feedback. Communication between the Arduino and GUI operate using a strict protocol in development by the engineers at Daedalus Technologies. Power supplied to our DAS unit is through a 12V, 20 watts power supply unit connected to an electrical outlet.

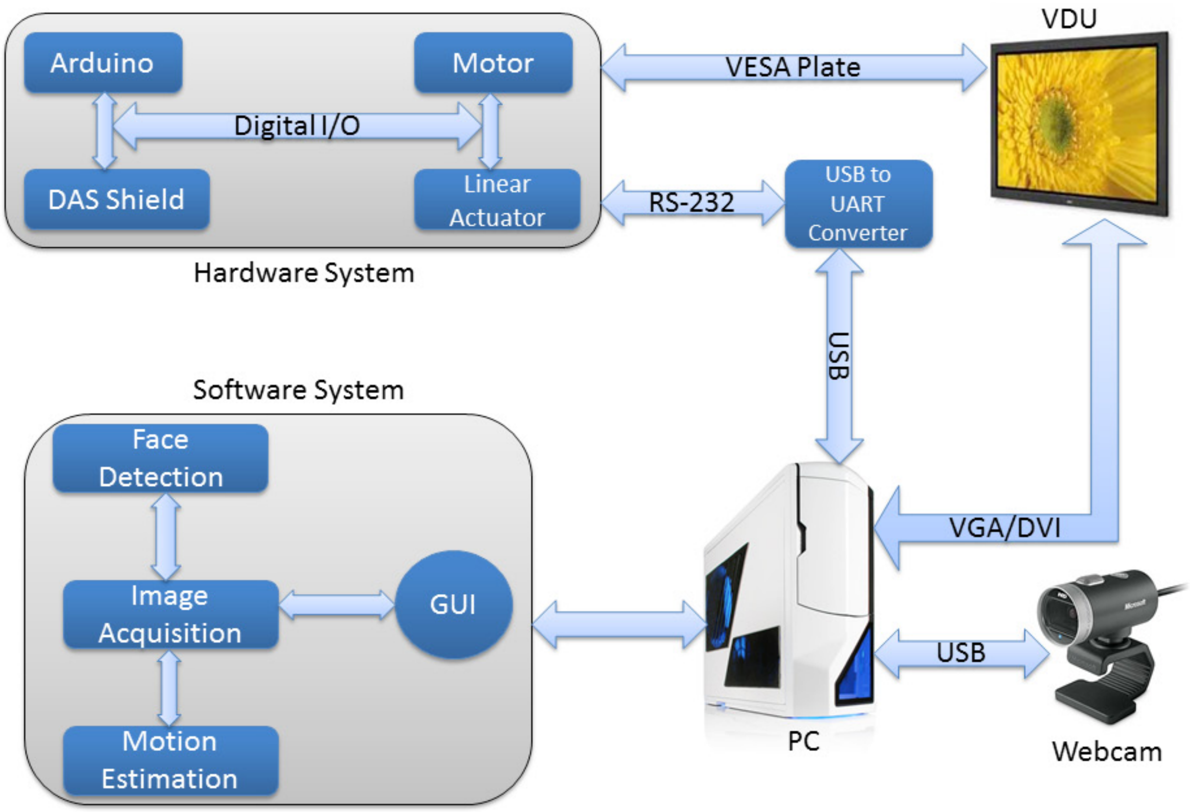

Figure 1 System Overiew

2.0 System Overview

2.1 Mechnical System

The biggest challenge in the creation of the system was the mechanical design. The design called for a moving support stand for VESA compatible monitors which must pan and tilt. This meant that the mechanical design must be strong and dependable yet attractive and cost effective. The design implemented for the proof of concept attempted to address these challenges. Our design was primarily based off earlier concept models.

Our final working prototype(see figure 2 below) has met all of the initial requirements as stated in our functional specification. Despite our progress there are a few imperfections in the mechanical design, one is the way the pan bracket attaches to the nacelle, when a heavy load is mounted (such as a 20 pound LCD monitor) the whole nacelle tips forward a little. We also made our own linear actuator which we can control pretty precisely, we initially made one which did not perform according to our standards (it was not properly centered and hence it created lots of friction therefore reducing performance and increasing power consumption). Our second attempt at making a linear actuator was successful in the sense that it works as it should. The current one still draws a fair bit of power however it is more efficient and far less complicated.

Figure 2 Actualy DAS Structure

2.2 Electrical System

The Electronics System consists of an Arduino microcontroller mounted to the custom Daedalus Technologies' DAS shield (see the integrated system in figure 3 below). A custom, two layer RoHS Printed Circuit Board (PCB) that attaches on to the arduino. The DAS shield houses necessary components like motor drivers, RS-232 level shifter and operational amplifiers for gain control.

The electronic subsystem interfaces with the software subsystem via RS-232 serial port connection, it also interfaces with the mechanical subsystem by controlling the pan and tilt actuators. The electronic subsystem as a whole was implemented according to the functional specification requirements and there was little difficulty in implementing the desired features. The big challenge with the electronic subsystem was the integration with the software subsystem and not just the serial communication but also the overall algorithm to control the actuators.

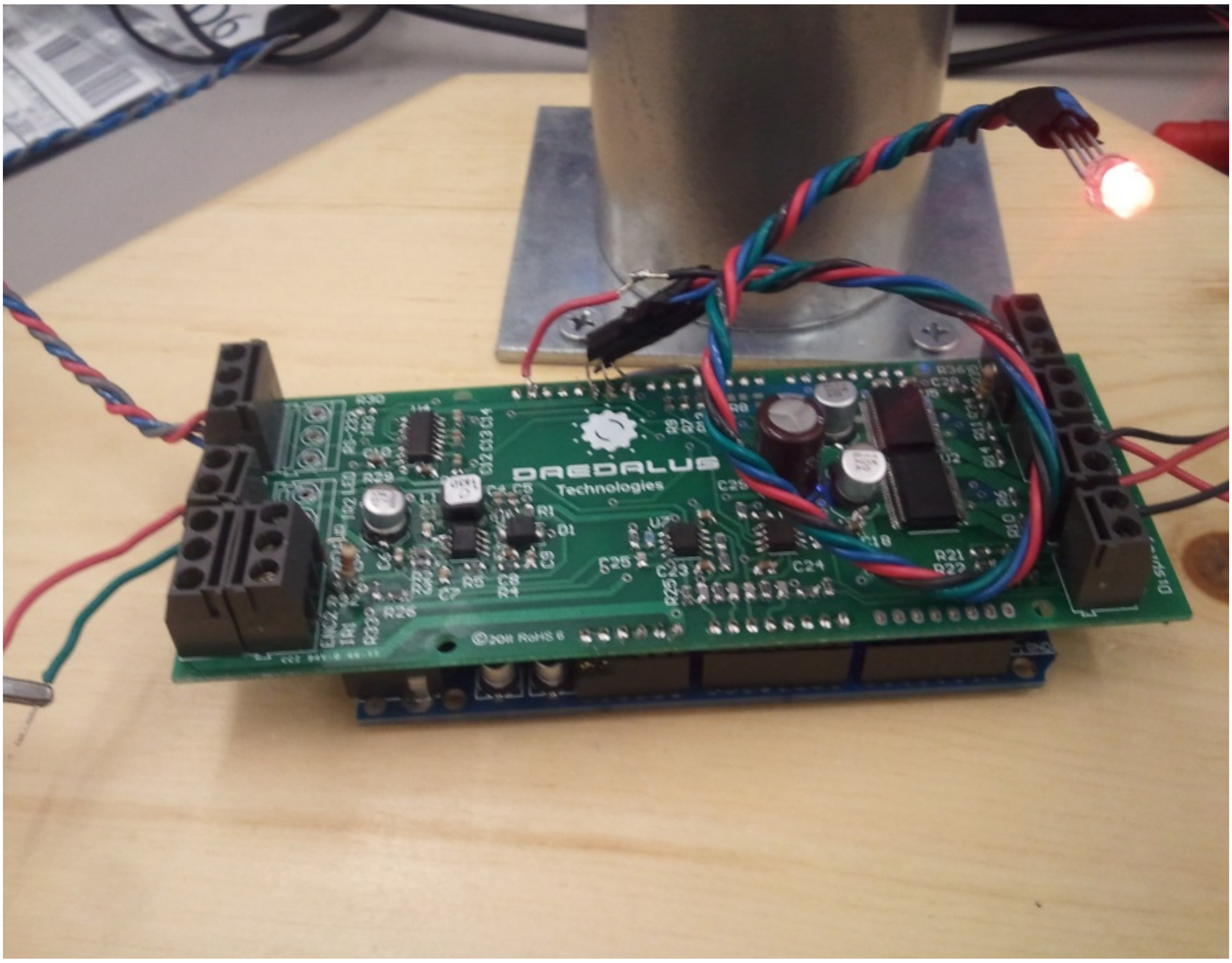

Figure 3 Final PCB Assembled

2.3 Software System

The GUI, or DAS Control Center, is designed to act as a communication portal to transmit information between our peripheral devices and Arduino as well as provide the user with different flexibilities such as the option to manual move our mechanical system to an optional timer that notifies the user when a break is needed.

2.3.1 Webcam

We used the "Microsoft Lifecam Cinema" (see figure 4 below) for the image capture because of its fast response time and wide range of capabilities. With a wide 73 diagonal degree field of view, 2 mega pixel HD sensor, auto focus, high speed USB 2.0 and 1280x720 pixels video [1] with up to thirty frames per second (FPS), this webcam has provided excellent images for our proof of concept model. It also comes with a unique mounting feature which fits almost all Visual Display Units (VDU). Currently the proof of concept prototype is only compatible with this webcam.

Figure 4 Lifecam Cinema

2.3.1 GUI

The Matlab-based GUI was designed to link between the Arduino located in the DAS hardware unit and DAS control software while providing user feedback. In the end, the GUI achieved all of these goals. Utilizing Matlab's Graphical User Interface Development Environment (GUIDE), serial port objects, timers, and Image handling toolboxes could be managed from the resulting GUI and automate several features. As we were using serial port communication to link the software and hardware, connecting and sending data was automated with the GUI, allowing us to rapidly troubleshoot any problems we encountered while extracting data from the Arduino. Timers proved to be the key when automating repeated calls of the face detection function. Problems did arise when variables were not passed properly in the timer function but this was solved due to the introduction of global variables. This problem was not witnessed in our optional break timer as no data needed to be passed but simply a window being generated reminding the user to take a break. The final aspect of the GUI was its ability to automate Matlab's image processing and image acquisition toolboxes. This was crucial when interfacing with webcams and displaying a snapshot of the webcam's video on the GUI. With a push of a button, serial communication could be toggled, timers could be started, and manual control initialed. Using two sliders, manual control of the system was possible by simply telling the motors to go one way or another. We also included a manual homing button to centre the system whenever the user deemed necessary. All of this was incorporated into the final GUI as shown in figure 4 below.

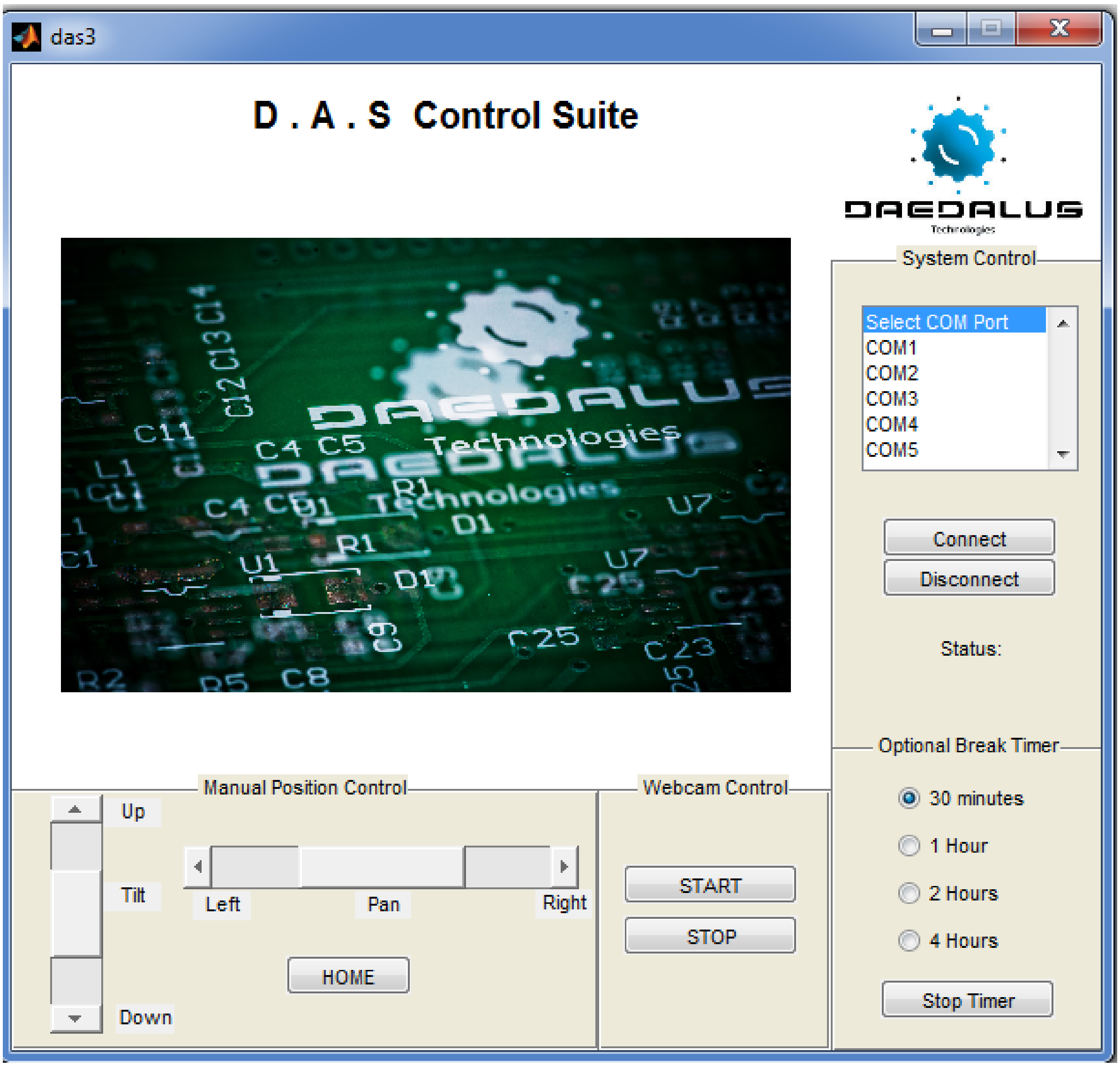

Figure 5 Final version of DAS Control Suite

As you can see, connecting to the correct serial port, setting the break timer, controlling the face detection system, and using manual control was simplified heavily using Matlab. It is more than possible to do this using something other than Matlab but due to time restrictions, we felt that Matlab was the best option. There was one drawback to Matlab which was its execution time. Matlab is meant for post processing which implied that running loops, activating timers, and optimizing for speed proved to be time consuming. Part of the problem was a memory leak in the OpenCV code in the MEX file but that was solved early December.

2.3.2 Face Detection

The face detection system created for the DAS software was a combination of Matlab features, Open Source Computing Vision (OpenCV) code, and our own specialized analysis on the available data. The face detection occurred in three parts: acquisition, detection, and interpolation.

The acquisition phase occurred first after the face detection timer was triggered. Using Matlab's Image Acquisition Toolbox, interfacing with the webcam was easy. By pre-setting features of the video capture object, all that was required was utilizing Matlab to take one frame from the resulting video stream. After the picture was acquired, it was displayed on the GUI and immediately turned to gray scale for the detection phase.

Detection occurred using the OpenCV Libraries compiled to work with Matlab. This was a simple matter using the MEX compiler. As for the algorithm itself, we discovered that basic face detection already existed on the Matlab forums. This Viola-Jones algorithm used basic OpenCV operations in conjunction an analysis of haar-like features. These haar-like classifiers are actually a set of parameters that allow OpenCV to recognize face or face-like features. While this proved to be rather accurate for our purposes, we did encounter numerous false positives. To avoid this, trained image sets would be required and identifying individual faces would be a next step. Training image sets takes an enormous amount of time and adding new faces to the file requires the same level of complexity which was beyond the scope of this class. We also discovered that this code had a memory leak which was not detected until the end of November. This was solved by looking over the source code and observing comments made about the code found of the Matlab forums.

The final step in the face detection system was interpolation. This step consisted of preparing the resulting information for transmission over the serial lines. The information obtained from the detection phase left us with either a "-1" or an Nx4 array where 'N" is the number of detected faces and 4 represents the positional data of the face. In the end, we managed to have the largest face tracked at all times. The offset of the face was then converted into data the Arduino could use once sent via serial.

Once the timer for the face detection system was started, we found that a period of .5 seconds sufficed. Anything higher began to cause delays in Matlab though that might have been caused by the memory leak mentioned later. Higher rates should be explored in the future but DAS performed well under the circumstances and we were pleased with the results.

3.0 Finance

During the funding presentation to the ESSEF in September, we provided the following financial breakdown for our $800 budget in figure 6 below:

Electrical

Equipment	Unit Price	Qty	Price
Printed Circuit Board	$ 200	1	$ 200
Infrared Proximity Sensors	$ 20	2	$ 40
Microcontroller & Development Tools	$ 160	1	$ 160
Miscellaneous electrical componets	$ 40	1	$ 40
			Total $ 440

Mechnical

Equipment	Unit Price	Qty	Price
Servo Motors	$ 20	2	$ 40
Webcam	$ 30	1	$ 30
Designing and building the base	$ 90	1	$ 90
Buttons and controls	$ 100	1	$ 100
Other controls peripherals	$ 100	1	$ 100
			Total $ 360

Total Cost

$ 800

Figure 6 Initial Proposed Cost

3.0 Finance

We had divided our expenses up into two sensible categories - microcontroller with peripherals and stand construction as shown in the figure 7 below

Electrical

Equipment	Unit Price	Qty	Price
Printed Circuit Board	$ 170	1	$ 170
Microcontroller Arduino Mega 2560	$ 55	2	$ 110
Miscellaneous electrical componets	$ 40	1	$ 40
			Total $ 320

Mechnical

Equipment	Unit Price	Qty	Price
Motors	$ 20	2	$ 50
Structure	$ 30	1	$ 30
			Total $ 80

Total Cost
$ 450

Figure 7 Actual Cost

We came in under budget for numerous reasons. The main contributing factors were design and fabrication of our own actuators and the entire mechanical system instead of buying the whole structure according to our proposed budget. Possessing numerous pieces of equipment also helped keep costs down. The Arduino Mega2 560 and low volume PCBs did add to our overall costs compared to the cost of a single microcontroller and higher volume PCB. Keeping orders to a minimum did help reduce our overall costs as well. We were pleased that our cost projections were correct and the overall cost of materials was low.

4.0 Timeline

The following timeline in figure 8 illustrates the progress of our project over the previous term

ID	Task Name	Start	Finish	Duration
1	Proposal	12/09/2011	22/09/2011	1w 4d
2	Research	12/09/2011	10/10/2011	4w 1d
3	Functional Spec	23/09/2011	13/10/2011	3w
4	Design Spec	13/10/2011	18/11/2011	5w 2d
5	Original Implementation	26/10/2011	21/11/2011	3w 4d
6	Actual Implementation	21/10/2011	30/11/2011	5w 4d
7	Original Final Integration	21/11/2011	02/12/2011	2w
8	Actual final Integration	29/11/2011	05/12/2011	1w
9	Original Debugging/Testing	26/10/2011	05/12/2011	5w 4d
10	Actual Debugging/Testing	01/11/2011	09/12/2011	5w 4d
11	Original Software Research	30/09/2011	20/10/2011	3w
12	Actual Software Research	03/10/2011	21/11/2011	7w 1d
13	Original Hardware Research	15/09/2011	12/10/2011	4w
14	Actual Hardware Research	16/09/2011	03/11/2011	7w
15	Original GUI Development	03/10/2011	24/10/2011	3w 1d
16	Actual GUI Development	03/10/2011	02/12/2011	9w
17	Original Face Tracking Development	03/10/2011	03/11/2011	4w 4d
18	Actual Face Tracking Development	03/10/2011	29/11/2011	8w 2d
19	Original Stand Development	28/09/2011	24/10/2011	3w 4d
20	Actual Stand Development	27/09/2011	10/11/2011	6w 3d
21	Original Electrical Development	10/10/2011	15/11/2011	5w 2d
22	Actual Electrical Development	10/10/2011	18/11/2011	6w
23	Original Software Testing	21/10/2011	06/12/2011	6w 3d
24	Actual Software Testing	28/10/2011	08/12/2011	6w
25	Original Hardware Testing	10/10/2011	08/11/2011	4w 2d
26	Actual Hardware Testing	17/10/2011	02/12/2011	7w

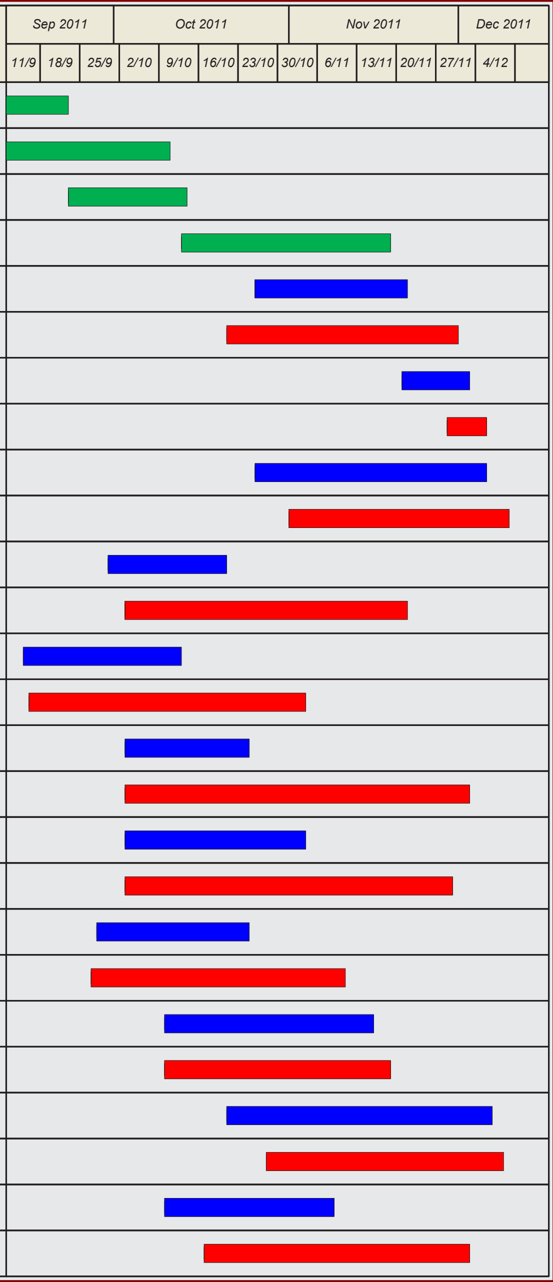

Figure 8 DAS Development Timeline

As clearly illustrated by the colour coding, the only tasks that were on track were our documentation. The actual length of the task (shown in red) of all instances took longer or were started later as a result of various shortcomings, delays, or issues. In the end, we finished in time just before exams after a few weeks of rapid integration testing and long days in the lab.

5.0 Business

In this section, the four Ps of marketing will be covered to analyze and articulate a concise vision for the business section of DAS going forward.

5.1 Product

DAS's offers Daedalus Technologies' exclusive AIT feature, supports up to 15 kilograms of weight, screen size up to 24 inches, Tilt movement from 0 to 60 degrees, pan movement from 0 to 180 degrees, and lastly VESA mounting support. DAS has the necessary features that would permit a reasonable market acceptance due to its compatibility with VESA mounting standards; our innovative design which there are no other comparable product; DAS's reliability has been tested and verified extensively by our engineering team; and lastly there is definitely a consumer's need as shown by Ergontron's net profit of $190 million made in 2010 [2].

5.2 Place

DAS's target market includes home and various section of the service industry ranging from offices, government, health care and schools. Our product can potentially be available to local retailers such as Memory Express and NCIX; regional distributors such as Future Shop, Staples and London Drugs; we can also implement online direct sales. After our product as become successful we can even distribute bulk quantities to government agencies such as hospitals and libraries.

5.3 Promotion

DAS has many ways where Daedalus Technologies can market and promote. As a small starting company, the 1st stage of marketing would start with Metro Vancouver region, due to very low cost benefit analysis and very fast market feedback. Our projected sales for first year of operation would be very close to our breakeven point at around 1000 units. With increase market acceptance and slowly expanding to all of British Colombia region, we projected to sell 2500 units by the second year. And From that point we will slowly expand towards Alberta and Manitoba with a third year project of 5000 units sold. The second stage would have us move slowly towards the eastern Canada, and eventually able to distribute all over Canada.

5.4 Price

As mentioned in our introduction of our post mortem, we discussed about our pricing strategy. But with our aggressive pricing strategy, there are some associated risks involved. For one, the market acceptable risks could involve our product being too expansive, which could potentially price out some consumers. Or DAS could be too advanced, perhaps the market cannot adapt to daily automatons.

6.0 Contributions

Daedalus Technologies consists of four highly skilled members which specialised in different areas. During the whole project, we assigned tasks according to each specialty. A brief team breakdown is shown in the following:

Team

Larry Zhao
CEO

•Managed overall team dynamics and keep track in project progress

•Supported in both the soft and hardware side of the project

Ian Brown
VP Finance

•In charge of project budget

•Supported software development and integration

Jordan Anguelov
VP Hardware

•In charge of the hardware side of the project

•Built the entire mechanical model and programed the Arduino for controlling the system

Calvin Ho
VP Software

•In charge of the software side of the project

•Developed image capturing and motion estimation for the systemn.

Our team, at first, held weekly meeting for progress update and discussion, and argent questions were either discuss through emails or phone. Later on, we changed to daily meeting during the integration phase for a more efficient progress.

7.0 Lesson Learned

We have faced numerous problems over the entire project. At first we tried to come up with our own algorithm for the face detection part of the project. However, we found out that it is very difficult to design it from scratch. Therefore, we decided to implement the Viola-Jones algorithm with OpenCV. We also had a rough time designing the mechanical part due to our lack of knowledge about mechanical design. However, after all the hard work and time our team had provided, these problems became a stepping stone to our success of building our system.

7.1 Larry Zhao

As the CEO of this company, my primary duties included scheduling meetings, sending out status reports, coordinating work flow, as well as involved in all facet of project development from hardware design to overall system testing. Our group is unique among ENSC 440 groups, in the sense that every member is taking a full course load. Time management is repeatedly stressed and addressed in every meeting to ensure our team not only work hard but also work smart.

I would say the most valuable experience I gained from this project would be summed up with a single quote from Liane Cordes: "Continuous effort - not strength or intelligence - is the key to unlocking our potential." Did our team give a continuous effort throughout this semester? I would honestly be lying if I said yes, but speaking from my perspective, I fully believe I gave everything I got.

The most challenging aspect of this project I found was to motivate and address to each and every member that the completion of this project lies in hard work, determination and proper time management. Major issues such as a member missing committed due dates to a member disappearing for weeks. These issues seem like tiny road blocks to me now, but I still remember them as being flagged as catastrophic incidents that could tip this project to total failure. Despite of these road blocks, our commitment and determination forced us to act swiftly and devise alternative plans to ensure this project finish on time.

Through the completions of my duties as the CEO, I have learned so much, not just extensive software and hardware skills, but most importantly leadership and team management skills. The most important management skill was how to efficiently assign tasks according to each individual's abilities. Even though they assure you the experiences from their co-op or previous classes qualifies them to accomplish a certain task. I find that you have to re-evaluate their talent and abilities based on observations of their work ethic and deliverable results. What they can contribute to the project might significantly improve if it is diverged to a different area.

ENSC 440 is one of the most valuable classes of my engineering degree at SFU. Working for Daedalus Technologies over the past 4 months has been a great experience. I have worked extremely hard, and dealt with frustration and anger, as well as countless sleepless nights. I have learned from my mistakes and failures and as a result I have emerged as a more successful person.

7.2 Calvin Ho

Throughout the project I have had a great opportunity to work with my highly skilled teammate, and learnt a great deal of technical skills in mainly software, and some hardware. With all the hard work and effort, we successfully completed our Display Augmentation System as our ENSC 440 capstone project.

As a team member of Daedalus Technologies, my main responsibility is to focus on the software side for our Display Augmentation System. With the help from Larry, we completed the main core of the software side which included image capturing, face detection, GUI and motion estimation which is, later on, integrated with the hardware side from Jordan. Aside from the technical part, I also learned about time management and team cooperation. Due to there are no physical harsh deadline, time management and project planning are very important. The fact that there are not immediate penalty for not meeting some deadline causes a lot of problems later on. Therefore, we have to ensure that every deadline is met and keep track on our schedule.

The most challenging part of the project I found was to complete all the tasks given on time and make sure they work perfectly along with the other components. Due to most of the team member is taking full course load, which means time management and interact between team member are one of the key to success. Throughout the course, I have learnt a lot on the technical side, however, the most important thing I learnt was working as a team and fulfill my commitments. Even a small delay will led to a total failure and lost trust from teammate.

ENSC 440 is definitely one of the most important courses in my SFU career. Working with my teammate to form Daedalus Technologies has been a great experience. I have provided all I have and faced a lot of stressful and harsh time. However, these became my stepping stones to be success.

7.3 Jordan Anguelov

These four months have been a big enjoyable challenge. As VP Hardware I was responsible for developing the complete system, developing the mechanical and electrical sub systems and integrating them with the software system to form the finished product.

When I first began working on the project back in September I had a wealth of experience in working with micro controllers and interfacing them with hardware. I also had plenty of experience from my Co-ops in PCB design, Power electronics and electrical system debugging. This allowed me to deal with the electronics sub system relatively quickly. When we first agreed on the project I made a schematic diagram with a number of our ideas which over time evolved until we were ready to begin development, after which I made a PCB and began debugging the electrical subsystem.

One of my biggest challenges during the project was designing the mechanical system. Given that I knew next to nothing about mechanical design and that the mechanical system was needed as soon as possible in order to begin writing firmware for the microcontroller, I had to spend many hours (up to 40 hours a week) working on that particular section with the help from Larry. Even though it was a big challenge I managed to learn a wealth of mechanical design skills.

I can say without doubt that the project and the work we have done in these past four months has been a challenge for us all. We have had our ups and downs and despite the sometimes unforeseen problems we have overcome our challenges and solved all our problems as a group. We have met all of our initial requirements for the project and to some extent exceeded our expectations, I am happy with mine and the group's achievements and our project's evolution from an idea into reality.

7.4 Ian Brown

Over the past 4 months, I divided my time between various tasks. I spent a lot of time learning about Matlab's Image Acquisition Toolbox and and GUI Development Environments. This proved to be invaluable when I was assisting Jordan with the system integration. We spent the better part of two weeks in the lab testing and sorting out errors. What we had wasn't necessarily wrong, it was just that values were off or something was incomplete. In addition to a testing blitz at the end, I also enhancing our face handling code and troubleshooted a memory leak in the OpenCV face detection code we were using. I discovered this while testing the GUI software independently and while trying to manage multiple face detections.

7.0 Lesson Learned

Learning more about Matlab through GUI development proved to be useful in many ways. Not only did I learn about GUIs and how matlab interfaces with webcams, but it also helped me analyze the data we got. Planning and organizing a higher level software system was something I had never done before as well so that was a good experience for me. I had experience working with communication systems from my previous Co-op so that provided a good basis for reasoning. After spending weeks playing with examples and running basic tests on the command line, the others figured out the missing pieces of information and began to build a GUI while I was told to work on other aspects of the project.

In the end, a lot of sleep, emotion, and hours went into producing a product that we can be proud of creating. Many of our friends and engineers we didn't even know were excited and interested in our project. This proved quite useful while testing as they got to play with something interesting and we got to see how others interacted with our project. It's a shame 440 was not 8 months because I am sure we could have done a lot more and avoided a lot of problems if we had some more time to work through problems. It would have also helped us in our other classes as well but all we can do now is look at what we've learned and move on.

8.0 Conclusion

Over the past three months Daedalus Technologies has developed a fully functioning proof-of-concept model of DAS. The only major discrepancy between our final product and our original proposed product is that we left out the IR sensor that we specified in our functional specifications. This is one of those instances where once you reach the end of a product development cycle; both the business team and engineering team at Daedalus Technologies feel that it is unnecessary for such of implementation. But for the commercialized version this implementation will instead be an optional add-on to our product. The original goal for the IR sensor was to push user back when they become too near to their monitor screen. Our team soon realize not many people will have this tendency, unless they have a vision problem or disease, so we opt to have this as on optional add on feature that our end user can purchase.

In order for our product to be commercialized, there are couple of adjustments we would have to make. The first one is that our motor noise is a bit high; it is within our functional requirement, but our business team would like the noise to be barely audible, in order for our product to not be a distraction to our end users. The second feature we would like to implement would be refining our software aspect our DAS. For example add help section to our GUI, make sure our GUI can handle all possible errors and finally package our software into an executable file for easier distribution via MATLAB compiler. Finally, DAS should undergo a refining and redesigning of its appearance. The business team would like to see a smaller, sleeker, more universal appealing design.

In the end, DAS has been completed under budget, and on time, and Daedalus Technologies is extremely pleased with the final product they have developed. As for the future of DAS, Daedalus Technologies has yet to decide if they wish to continue with the development of DAS. After taking some time away from the project, it will be decided if DAS will continue development or not.

9.0 References

[1] Microsofe Hardware (2011) LifeCam Cinema [Online]. Available: http://www.microsoft.com/hardware/en-ca/p/lifecam-cinema

[2] Ergontron (Dec 2010) Nortek to Acquire Ergotron, Inc. [Online]. Available: http://www.ergotron.com/tabid/95/ItemID/184/default.aspx