



Simon Fraser University,
8888 University Dr.
Burnaby, BC Canada
Email: rmt3@sfu.ca

December 10, 2012

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Port Mortem for QuickScan Mapping Device

Dear Dr. Rawicz,

Enclosed is our *post mortem document for a Quick Scan Mapping Device*, which describes our company's product development process this term. We have designed a portable scanning device that can quickly measure the area of a given room in 3D space. This device eliminates the need of manually measuring the dimensions using measuring tape or similar tools.

The post mortem outlines our final QuickScan implementation. It includes a discussion of potential markets and product pricing. Additionally, a reflection on the past 4 months is also included.

Dimension Technologies consists of five senior engineering students, Chris Kwong, Oliver Huang, William Chiang, Rahul Thomas, Jack Zhang. We have a wide range of abilities with systems, electrical, and computing background.

If there are any questions or concerns regarding our document or device, please contact me by phone at 604-807-0486 or by e-mail at rmt3@sfu.ca.

Sincerely,

A handwritten signature in black ink, appearing to read "Rahul Thomas", written over a white rectangular background.

Rahul Thomas
CEO
Dimension Technologies

Enclosure: *Post Mortem for a QuickScan Mapping Device*



POST MORTEM:
QUICKSCAN MAPPING DEVICE

Rahul
Thomas

CEO

Chris Kwong

CTO

Yumin Oliver
Huang

CFO

Jack Zhang

COO

William
Chiang

Managing
Director

Contact Person:

Rahul Thomas
rmt3@sfu.ca

Submitted To :

Dr. Andrew Rawicz-ENSC 440
Steve Whitmore-ENSC 305

School of Engineering Science
Simon Fraser University

Issued Date:

December 10, 2012



Executive Summary

The QuickScan Mapping Device is a product that Dimension Technologies has developed to assist building professionals in the industrial & residential sectors. The present rapid growth that the world is experiencing has led to an increase in the demand for facilities and houses. Typically, one main consideration in each of these cases is the size and dimensions of different property areas. Dimension Technologies' product will solve these questions through a relatively low cost product. While other solutions have been developed in the past, QuickScan is a standalone device that measures room dimensions in a very short time.

This document will summarize our entire design process and results. Specifically, the following items will be discussed:

- Final design implementation – comparison with originally planned design
- Budget – comparison with estimated budget
- Timeline – comparison with originally planned timeline
- Market Research – comparison with competitor products
- Personal reflections from each of the design team members

Table of Contents

1.	Introduction	1
2.	System Design	2
2.1	System Overview	2
2.2	QuickScan Device (Structural)	3
2.3	Pan/Tilt Enclosure	4
2.4	QuickScan Software & Sample Results	7
2.4	Future Work & Recommendations	10
3.	Business Considerations	11
3.1	Project Budget	11
3.2	Market Analysis	12
3.3	Project Timeline.....	12
4.	Team Reflection	14
4.1	Overall Reflection.....	14
4.2	Rahul Thomas	15
4.3	Chris Kwong.....	16
4.4	Jack Zhang.....	17
4.5	Oliver Huang	18
4.6	William Chiang	19
5.	Conclusion.....	20
6.	References	21

List of Figures

Figure 2.1 QuickScan Functional Overview	2
Figure 2.2 QuickScan Mapping Device	3
Figure 2.3 Mounted Circuitry & Battery Unit	4
Figure 2.4 Initial Pan/Tilt Design.....	5
Figure 2.5 Modified Pan/Tilt Design	6
Figure 2.6 QuickScan Flow	7
Figure 2.7 QuickScan GUI.....	8
Figure 2.8 QuickScan GUI - 2D Floor Plan	8
Figure 2.9 Sample Test Room	9
Figure 2.10 3D Point Cloud Representation of Sample Room	9
Figure 3.1 Project Timeline - Expected vs. Actual	13



1. Introduction

The QuickScan mapping device is a relatively low cost device that can be used by drafters and realtors for various dimensioning applications. It provides a quick and accurate method for creating a 3D render of a given room and extracting the desired dimensions. It is compatible with industry standard CAD tools such as AutoCAD and MeshLab.

Over the past 13 weeks the Dimension Technologies' design team has been working vigorously to produce a prototype QuickScan module. This document will outline our overall accomplishments for this project. The final implemented design will be compared to originally planned concepts. In addition, a section is provided which compares our original budget and timeline to the actual budget and timeline. Finally, each individual has contributed a personal reflection on their experiences during this term.

2. System Design

2.1 High Level System Overview

The QuickScan functional block diagram overview is shown in Figure 2.1.

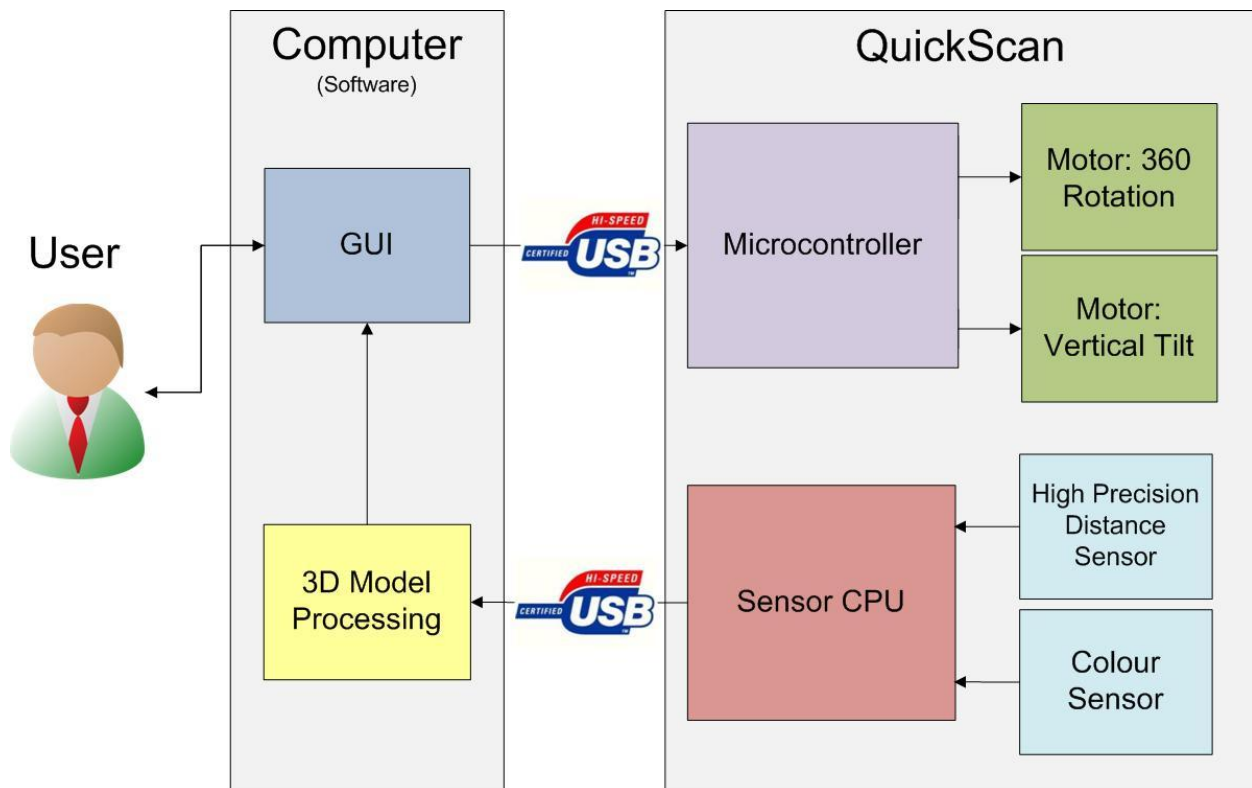


Figure 2.1 QuickScan Functional Overview

The block diagram shows the various connections between the different functions. The following sections will discuss our final implementation of various system functions.

2.2 QuickScan Device (Structural)

Figures 2.2a and 2.2b display the model QuickScan device with the final implementation.



Figure 2.2 QuickScan Mapping Device

There are three main structural features that are present in the above figure; the first being the tripod stand. The tripod is adjustable in height; to a maximum height of 57". The next feature is the pan/tilt enclosure with the mounted Kinect sensor. This feature will be explained in more detail in the following section. Lastly, the circuitry and battery module have been mounted onto one of the tripod's legs. Figure 2.3 shows a close-up of this mounted feature:

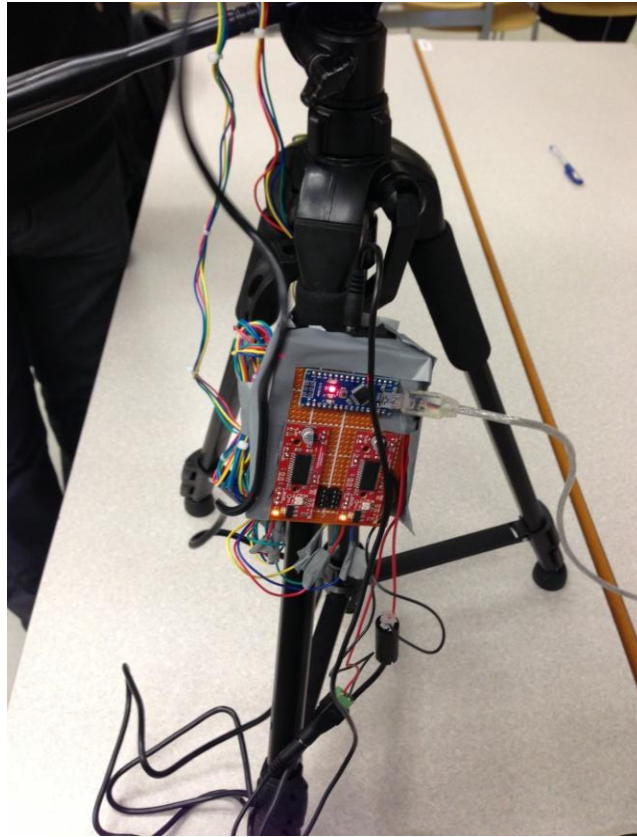


Figure 2.3 Mounted Circuitry & Battery Unit

2.3 Pan/Tilt Enclosure

The pan/tilt enclosure is an absolutely necessary feature for our product. It enables the device to reach a much larger acquisition range by providing 2 degrees of freedom in rotation. Two stepper motors have been used to tilt the Kinect vertically and horizontally. Our initial design model is shown in the figure below:

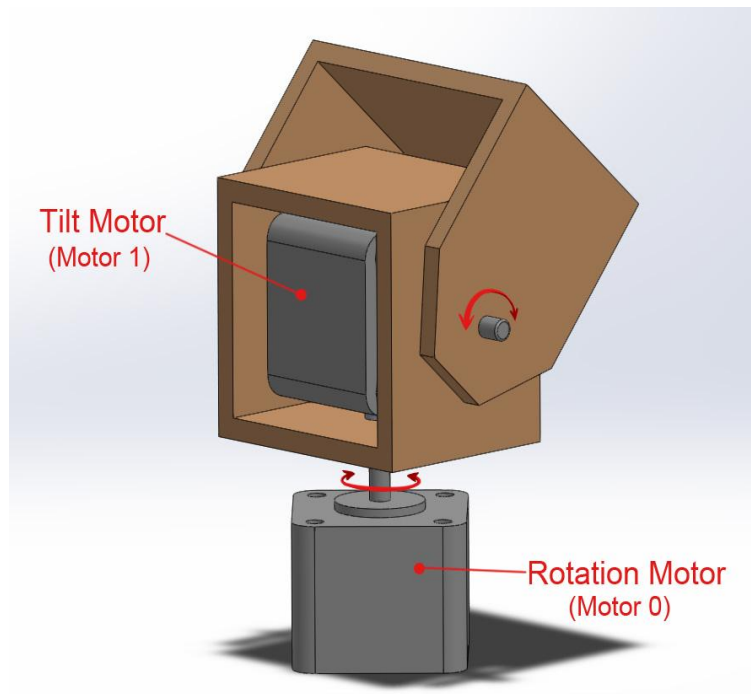
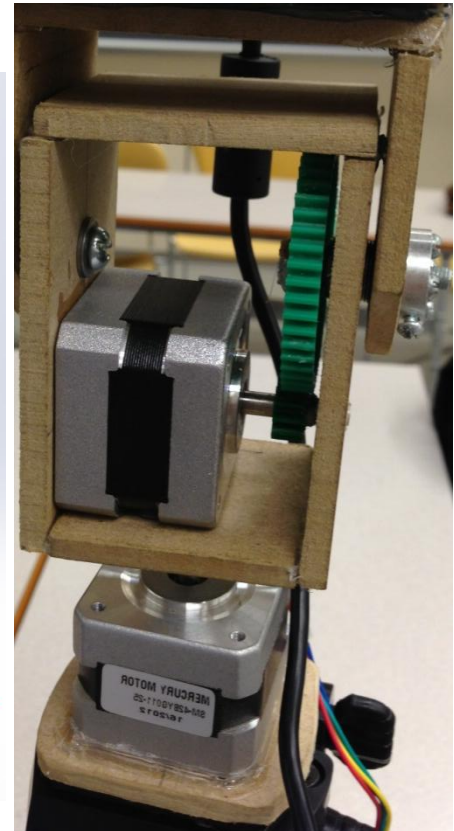
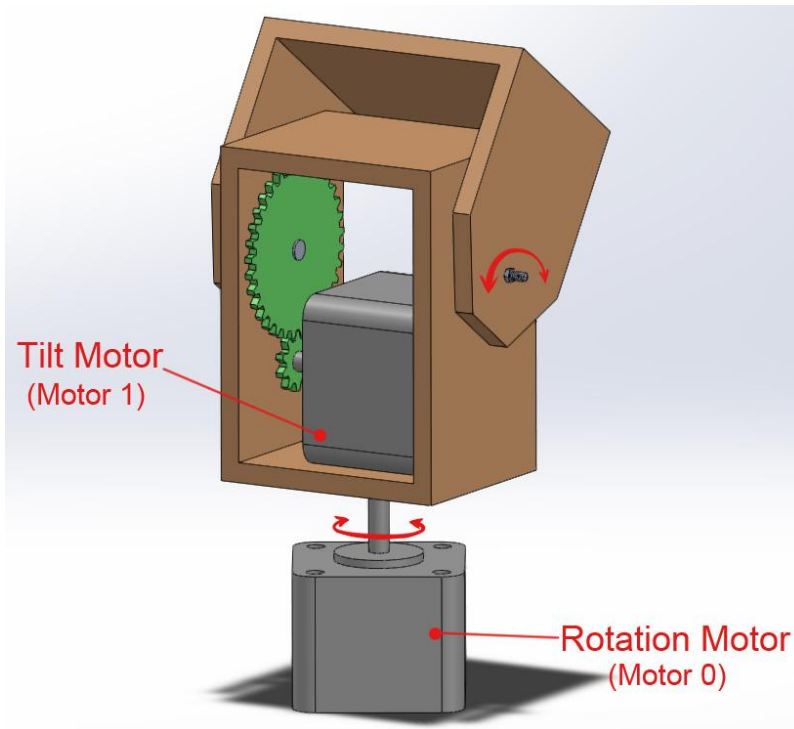


Figure 2.4 Initial Pan/Tilt Design

However, our initial design had a problem which made it unusable in our application. This design would only support a maximum vertical tilt of 10° . We needed to attain a tilt of 45° . At angles greater than 10° the vertical motor could not handle the weight of the Kinect and thus it would fail. This is because stepper motors do not have an internal gearing system that is found in other motors. The solution to this problem was to create our own gearing system to enable a larger vertical tilt. With this modified design we are able to reach large angles of vertical tilt. In our standard scan procedure we use 45° and -45° . The modified model and implementation is shown in the Figure 2.5a and 2.5b.



a)

b)

Figure 2.5 Modified Pan/Tilt Design

2.4 QuickScan Software & Sample Results

The software subsystem can be divided into parts:

1. Data Processing System
2. QuickScan GUI

The data processing system is a combination of algorithms and process that create a final 3D point cloud representation of the scanned room. It uses the method of forward kinematics to stitch different scans together. The overall QuickScan flow is shown in the diagram below:

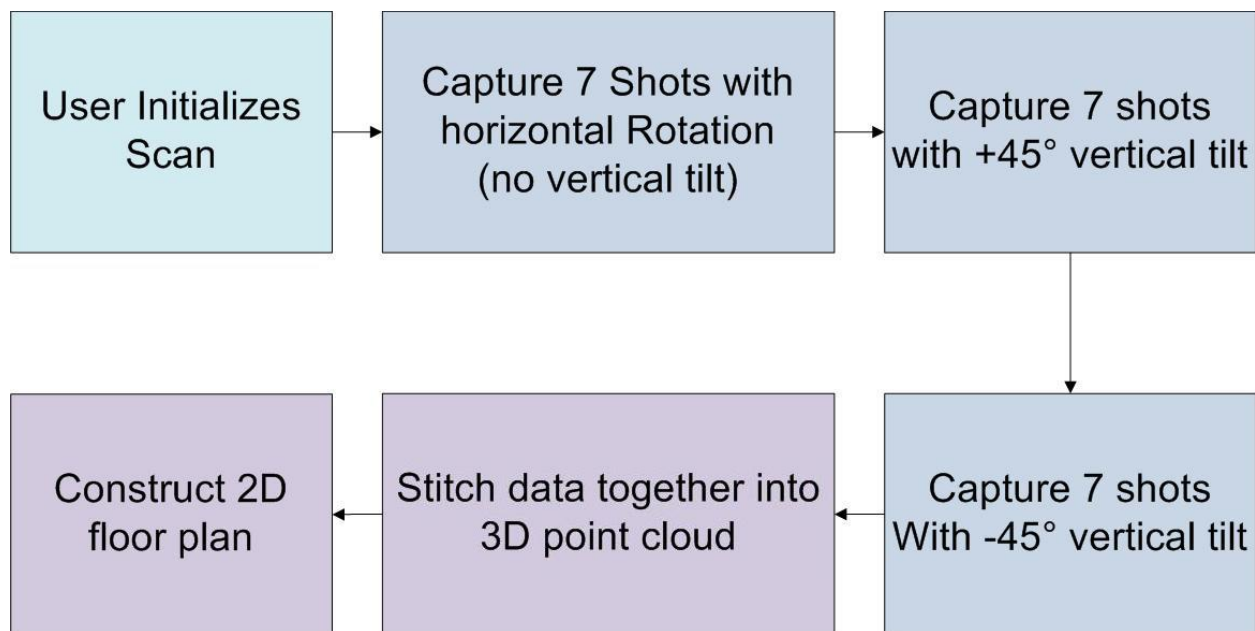


Figure 2.6 QuickScan Flow

The GUI is the sole method of interaction between user and the QuickScan module. The GUI has the following functions:

- Execute a full room scan – approximately 1 minute in duration
- Open and save point cloud files
- View 2d floor plans – top and side perspectives
- Dialogue messages to inform user of current status
- Ability to view 2d live image

A snapshot of the GUI is shown in Figure 2.8. The 2D floor plan view is shown in Figure 2.9.

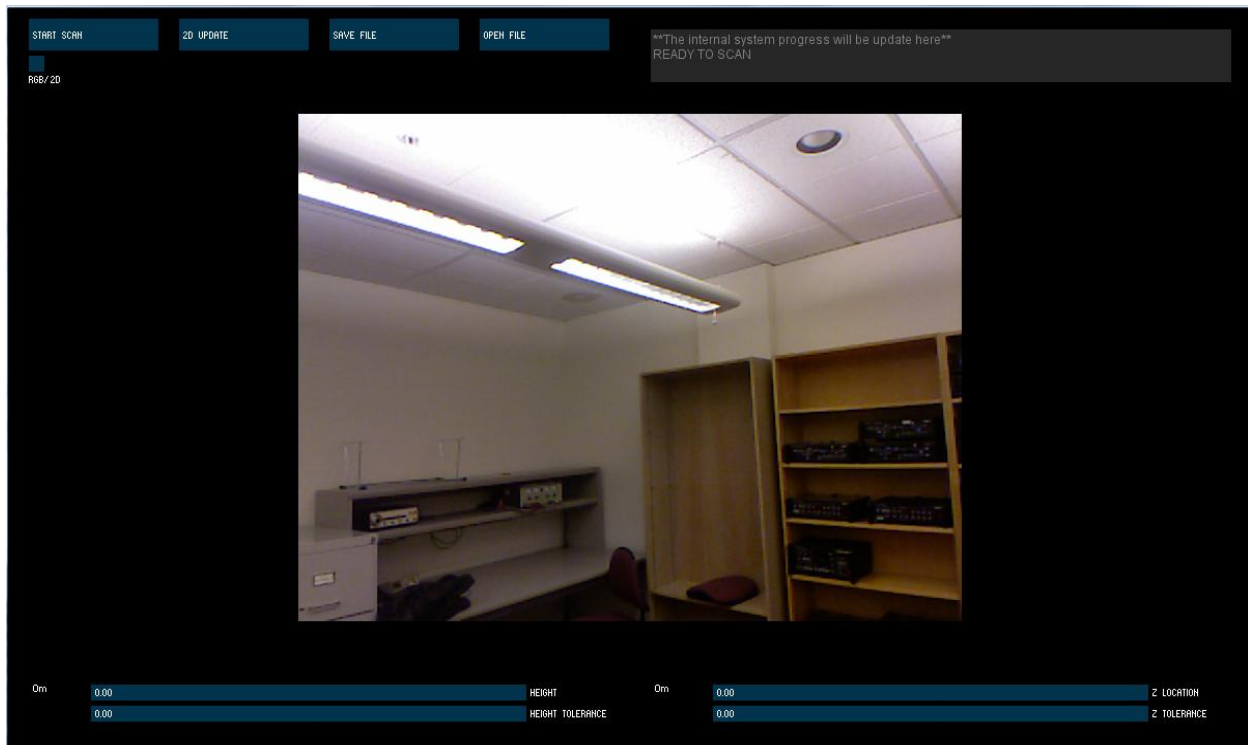


Figure 2.7 QuickScan GUI

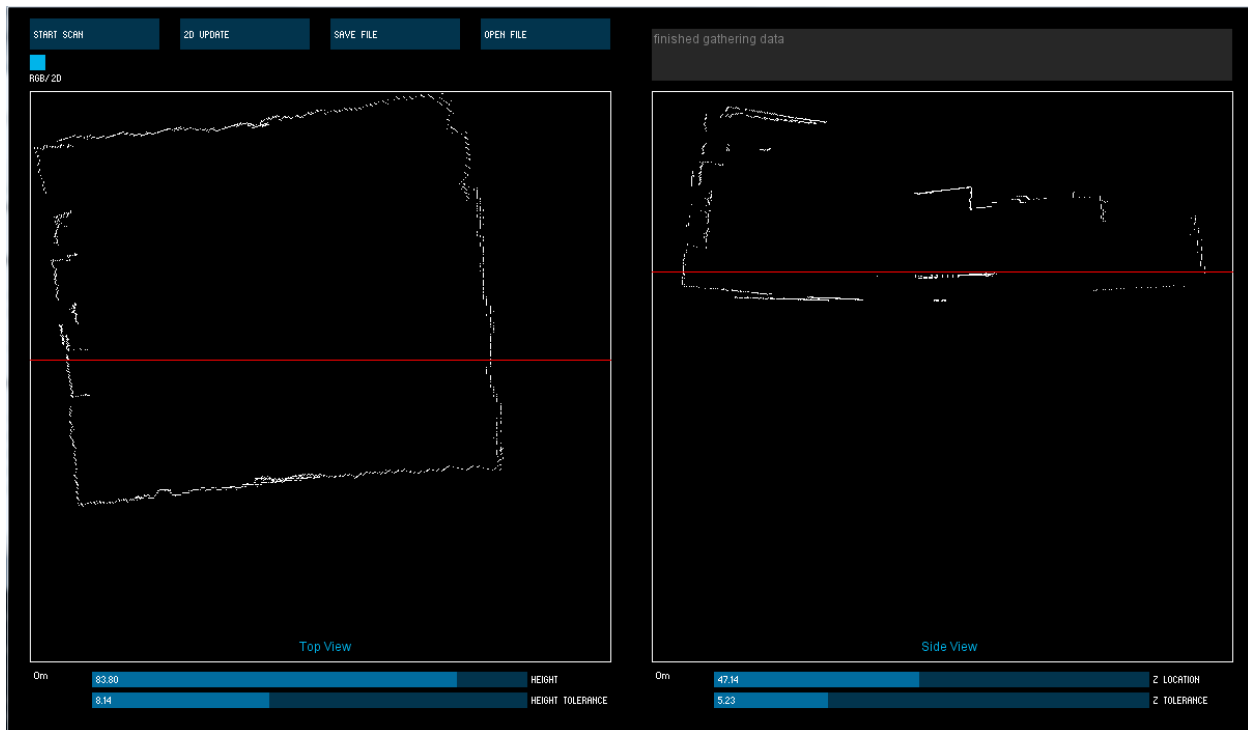


Figure 2.8 QuickScan GUI - 2D Floor Plan

Figure 2.9 displays a photo of a room that we used to test the QuickScan device. Using the above GUI, we were able to create a 3D point cloud representation of the room. A snapshot of this is shown in Figure 2.10.



Figure 2.9 Sample Test Room

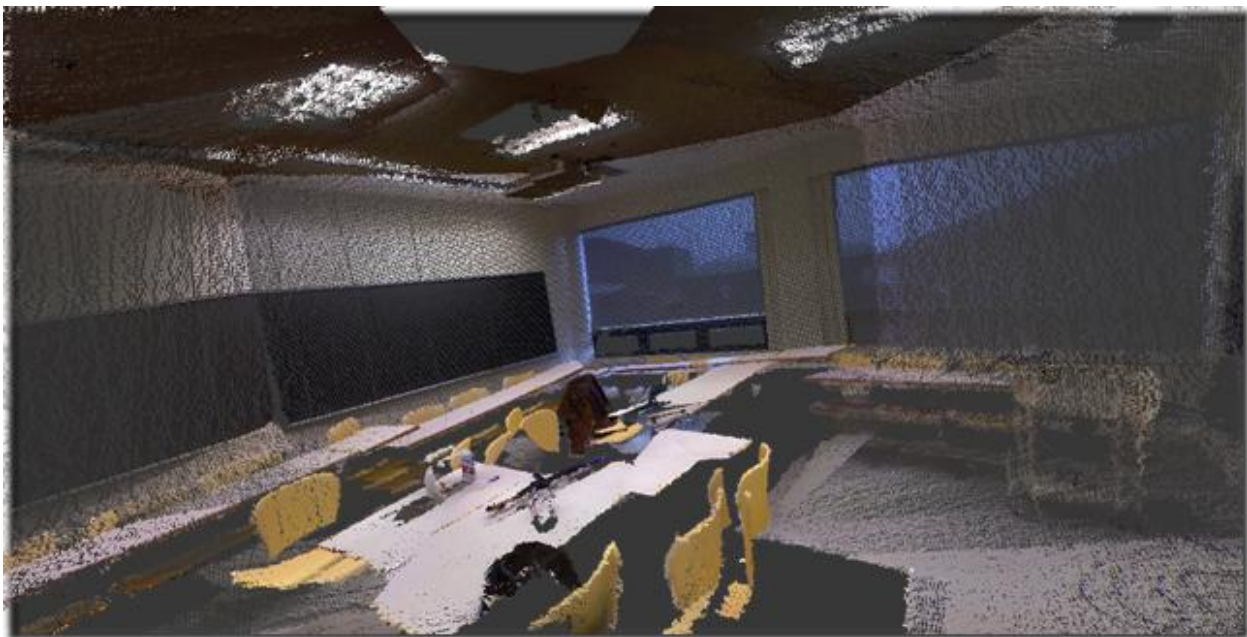


Figure 2.10 3D Point Cloud Representation of Sample Room

2.4 Future Work & Recommendations

Due to time restrictions there are some features that Dimension Technologies' was not able to implement. The following is a list of recommendations for future work on the QuickScan device.

Our first recommendation is to incorporate the open source Point Cloud Library (PCL) in the data processing algorithms. The PCL library is an open source library which assists in 3D point cloud processing. However, given its complexity, implementation of such a library requires an immense amount of resources. PCL enables one to efficiently stitch point cloud shots together and ultimately reconstruct surfaces from the point cloud data.

A more robust depth sensor could be used to increase efficiency. A laser sensor could be used to increase acquisition range and precision. The Kinect has limited range and is quite heavy decreasing the system's accuracy. A more efficient sensor would enable scans of larger areas (perhaps industrial real-estate).

Another recommendation is to create a more accurately pan/tilt cage. Our current cage is made using wood which we manually cut using typical machine shop tools. This method creates uncertainty and inaccuracies in our measurements as the enclosure has some non-idealities. In our prototype we compensated for these non-idealities using processing algorithms. However, going forward this enclosure should be professionally manufactured. Laser cutting the enclosure from a 3D model would provide a much more accurate design.

Our circuitry was made using a generic PCB design with the interconnections being made using standard wires and soldering techniques. However, a professional custom PCB design will ensure compactness and introduce less electrical noise in the system.

One key feature in standard floor plans is the identification of cardinal coordinates (i.e. north). Due to limited time resources, we were not able to integrate the compass module. In future designs, this module should be integrated into the overall device so that the north direction can be shown in the extracted floor plans.

Also, the GUI should extract a PDF floor plan that indicated the major dimensions of the scanned room. This helps in the automation process and enables the user to quickly view necessary dimensions.

Lastly, our design was implemented on a Windows operating system. To increase portability, iPhone and Android apps can be written to interact and control the QuickScan device. The user could view the 3D data and floor plans on mobile devices. This eliminates the need for a laptop computer.



3. Business Considerations

3.1 Project Budget

Table 1 compares our original estimated budget, with our actual final project budget. We were granted \$550.00 from the ESSEF funding source. From the table it is clear that we are about \$132.00 lower than our initial estimated budget. We have been fairly prudent in our parts purchasing and have found relatively cheap prices from different sources.

Table 1 QuickScan Budget Comparison

Component	Estimated	Actual
Development Board – Arduino Mega 2560	\$55.00	\$10.99 ¹
XBOX Kinect	\$125.00	\$80.00
Scanner Chassis Kit	\$80.00	\$40.63
Servo Motor	\$20.00	\$29.90 ²
Arduino Bluetooth Module	\$30.00	\$0.00 ³
Batteries/Charging Kit	\$100.00	\$30.00
Custom PCB Board Design	\$150.00	\$1.98 ⁴
HMC5883L Compass	\$30.00	\$15.00
Miscellaneous – Wires, cables, etc...	\$50.00	\$300.00 ⁵
Total	\$640.00 CAD	\$508.50 CAD

¹ Dimension Technologies has determined that an Arduino Nano will be sufficient for the scope of our product – this has greatly reduced the costs on our development board

² In early October we had decided to use stepper motors instead of servo motors due to the stepper’s higher step accuracy; thus this component has increased costs

³ Bluetooth connectivity is a feature that Dimension Technologies had originally planned to implement. However, due to increased costs and complexity, we have decided not to pursue this functionality

⁴ Initially, we had decided to create a custom PCB design. This would involve creating a PCB schematic layout using a CAD program. This could then be given to a PCB manufacturer to design a custom PCB for our project. However, we have opted to create a ‘home-made’ PCB design for this prototype – hence the reduction in costs.

⁵ This amount includes miscellaneous items such as:

- Pan/tilt enclosure design and construction – includes plywood, screws, nuts, bolts, and gears
- Research materials – We initially felt it was better to design our rotation and tilt enclosure using servo motors. After testing the servos we felt they were not as accurate as we desired. Thus we moved onto stepper motors. However, the amount spent on the servos could not be recovered.
- Shipping costs – Many of the amounts in the above table do not include shipping charges. In many cases, items were being shipped from an international source which needed to be expedited in order to ensure timely delivery of parts.
- Various cables and other costs.

3.2 Market Analysis

Services and devices that are similar to QuickScan exist in the current market. Some competitors include XMeasures [1] and 3Deling [2]. Both these firms offer similar services. If a client wants a 3D laser scanning job performed, it would simply contract the job out to one of these firms. XMeasures or 3Deling would simply bring in their proprietary and perform the necessary scans. Once the data has been acquired they will submit the point cloud data to the client. In essence, these companies only provide a 3D laser scanning service. They do not sell a standalone device. This is where the QuickScan module differs from its competitors. Dimension Technologies has created a device that can be reused by the customer. The customer only needs to pay a onetime fee for purchasing the device. From this point, the customer can reuse the device in future projects. Dimension Technologies' competitors require the customer to pay recurring costs for each project they contract out. This makes the QuickScan device a more feasible and affordable 3D mapping solution.

3.3 Project Timeline

The figure below compares our predicted and actual timeline for our development process. For each task the estimated duration is shown with solid bars while the actual task duration is shown using dashed bars.



4. Team Reflection

4.1 Overall Reflection

Overall, ENSC 440 was a very enjoyable experience for our group. We learned many valuable skills and lessons from our development process. Some of these lessons are:

- Conduct thorough research before pursuing a certain feature.
- Narrow down device functionalities and features at the beginning of the development stage.
- Don't be too hasty in parts purchasing.
- Don't underestimate the magnitude & complexity of the ENSC305 document.

Below is a snapshot of each of our team members including each member's overall responsibility:

Rahul Thomas (CEO)

- Overall management of team dynamics, project progress & document creation
- Determined overall system functional specifications

Chris Kwong (CTO)

- Major contributor in QuickScan R&D
- Headed electromechanical subsystem

Yumin Oliver Huang (CFO)

- In charge of managing team finance & purchasing
- Design & Development of QuickScan GUI

Jack Zhang (COO)

- Development of Data Processing Software Algorithms
- Overall QuickScan tests & calibration with GUI

William Chiang (Managing Director)

- Mechanical Design
- Meeting scheduling – Agenda & Minutes

Our team dynamics were excellent throughout our project. All team members interacted well with each other. Weekly meetings were held to discuss project progress and debug design related issues. Overall, team dynamics were excellent throughout the semester.

Individual reflections from each team member are in the following sections.

4.2 Rahul Thomas

As CEO of Dimension Technologies' my main responsibility was managing the team, scheduling and ensuring timely delivery of various design tasks. Additionally, I was involved in determining the functional requirements and specifications for the QuickScan device.

The management responsibility entailed assigning target dates to various actions items. This was typically done by sorting each task based on subsystem classifications. I assigned different team members to various tasks and monitored the status of each task throughout the project. One key scheduling method that we found quite effective was the notion of over-scheduling a task. For each task I added some 'leeway' at the end to account of any unforeseen complications of issues that may occur. In essence I purposely over estimated the time a particular task would take. Additionally, I made frequent email correspondence with the group members informing them of the status of the project, meetings, upcoming deliverables, etc. I was also in charge of scheduling meetings and informing each member of such events. Overall, from a management point of view it was a pleasure to work with such a great group.

From a technical point of view, I helped in the high-level system design. This required defining functional requirements for our device. I would generally decide what we were trying to accomplish with the device. From there we would decide how we would implement such a feature. During the design stage if any problems we encountered, I would assist the team in debugging and testing the device and various features.

Additionally, I was responsible for creating the different ENSC 305W documents. I took responsibility for document planning and creation. I would also delegate work out to the other team members to write their respective sections of the document.

Overall, this course was a great experience. I thoroughly enjoyed working with each of my partners. They were very cooperative and helpful. It would be my pleasure to work with this

group in future projects. ENSC 440 taught many valuable lessons including planning and organizational skills. I was able to experience how hard it is to establish a successful start-up company.

4.3 Chris Kwong

The ENSC 440 project is the biggest project I have undertaken at SFU. I was mainly responsible for the design and development of external hardware. This comprised of finding an effective and accurate solution for moving the Kinect sensor in order to capture the fullest view of the room possible. I designed the firmware on the Arduino microcontroller with an efficient communication protocol such that the software (on the laptop) is able to asynchronously request and send commands to the respective hardware components.

The most important thing I learned from this experience is that communication is key when working in a group. This cannot be stressed enough. I feel that effective communication takes precedence over any technical ability or innovative idea. As a result, I feel much of the success from this project came from Rahul's role as a project manager. Without Rahul's role for organization project meetings, scheduling deadlines and keeping everyone on task, and taking care of bureaucratic business with financing, this project would be much more painful and most likely result in more conflict within the group.

Though there were many new technical details that required research and learning for hardware integration, I feel that technical skill is not as important as the ability to learn to learn. I realized that intrinsic motivation serves as a very strong force for this project, especially when trying to learn a new technical skill required for the project. This course is unique in the sense that there is no specific curriculum to study as a result much of the work is self-directed. I feel that it is important to find an area of the project which I am passionate in; finding my source of motivation within the project made this course much easier and enjoyable.

The dynamic within the groups was impressive, most likely due to a strong PM role. Ideas were often suggest by group members and were discussed within the group for a viable solution alternative. There were almost little to no conflict within our group as any disagreement is resolved quickly with logical rationale. I feel lucky that our group consisted with members with such compatible personality types. With the final prototype complete, I would like to thank Rahul, Jack, Oliver and William for a wonderful experience in my final undergrad project.

4.4 Jack Zhang

Overall I really enjoyed the course. It is really good to be able to put everything I have learned in the past 4 years into a neat project as such. Furthermore, it has been a great privilege to work my team; this is certainly not a one man project. We brought our different skills and abilities together and collaborated well.

My contribution to the project has been primarily software. I was responsible from the start to design the software that will control the stepper motors and the Kinect. I started off at the beginning researching on just how to use the Kinect through processing. This worked all very well, as at the beginning we were able to capture just one picture. Then we moved forward and combined the image with its depth and project a 3D image onto Meshlab. This was exciting but wasn't enough. Once one stepper motor arrived and functioning, I advanced to the next step to capture a full horizontal scan of the room. Then with the second motor arriving and the platform built, I was able to capture both vertical and horizontal shots.

The most difficult part in the project from a technical perspective was to stitch the images together. Due to various factors, when the images are put together, they are put together nicely. We originally attempted to go about this problem by using PCL (Point Cloud Library), but this turned out to be quite complicated. So we decided to go with forward kinematics to manually calibrate it such that everything is perfect. This took a while, but eventually, I figured out all the variables that cause the problem and was able to produce a fine picture.

Another difficulty that came up was how to make a 2D floor plan and to be able to measure it. Thanks to Chris' idea, we are able to just put all the 2D floor plan onto the GUI and measure it from there. I was responsible for implementing that part as well.

Overall I gained a fair amount of experience from this course. Experiences such as working with others, conflict resolution, documentation, more experience on design and debugging. It was not as bad as I thought it would be. Thankfully we started quite early (late September) in our work, so that we did not have to cram a lot in the end. In my opinion, this has been a very successful project!

4.5 Oliver Huang

During the past four months, I have worked as a CFO and a Software Programmer in the “QuickScan Mapping Device” project team, for Dimension Technologies.

As a CFO on the team, my primary role was to keep the project within the budget and I had to ensure all the purchased parts would arrive on time, in order for the team to meet our deadlines. Our team was very successful in finding economical prices for all the parts. As a result, I was able to manage the project budget within the ESSEF grant of \$550.00 and about \$130.00 lower than our original estimated amount. As a CFO, keeping track of all the shipments for individual purchase was probably the most difficult part, since I have placed the orders through different websites and providers in various countries. However, Rahul (the CEO of the team) and I were able to successfully manage the shipments of our parts before the dates when the team needed them.

My role as a CFO in the team was very successful with additional help from Rahul for keeping the project on-going from the financial side during these four months. Indeed, the most important things I have learned as CFO was that in order for the team (project) to function smoothly within the time and financial limits, the CFO has to be the main driving force behind work because he has to ensure the payments are made and the shipments came in time, which could affect the overall progress of the team (project).

As for my technical role for the project, I mainly designed the GUI and developed the functions for each aspect in the GUI. Throughout the first month, our team was debating between two different main source programs for controlling the Kinect and the Arduino (Windows SDK or Processing). Due to the limited schedule we had, I had to research potential solutions for both sides in term of controlling the Kinect and the Arduino, as well as the possible libraries for designing the GUI. The amount of time I have spent for researching both sources allowed me to understand more about the functions for the Kinect and its limitations. As a result, our team decided to use “Processing” as the primary program and I had chose the “ControlP5” library for designing the GUI for the project. I believed in the ControlP5 library's potential in freedom of customizing the GUI, which allowed me to code in various ways to fit other member's styles. The most difficult part of developing the GUI was to ensure that the program can be integrated with the codes from team members and that the GUI will not affect their code's functionality. Moreover, the GUI had to meet its individual functional specifications. In order to link all the codes together in my designed GUI, I had to have moderate knowledge about each component and a good understanding of each individual team member's coding style.

During my time spent in Dimension Technologies, I have learned much about various aspects involved in the engineering design process. As a team, we had to overcome many difficult challenges, but I am extremely delighted to see us work well with one another to overcome those challenges. Each team member was motivated right from the start and accomplished the high level of expectations they set for themselves. Overall, I had a wonderful time bonding with my team and solving the problems we had as a group.

4.6 William Chiang

During my last four months I had a great time working with the Dimension Technologies team. I have learned a great deal about team dynamics in a project environment. While the experience overall was positive, working within a team is never without its complications. For example I noticed that it was very easy to convince ourselves that our project was on track. Towards the end of the semester that seemed to be less and less like the case. However, with Rahul's leadership and overtime work on everyone's part, our team was able to pull through and make the project a success. In the future, I will make sure that time management is made a higher priority.

My main role dealt with the graphics side of the project. I worked with all members of Dimension Technologies carefully in order to create many graphical assets that would be used to explain our project in our documentation. I drew from my previous experience of Photoshop in order to create these assets.

Around midway through the project we were ready to mount the QuickScan cameras onto a chassis enclosure so that the device could rotate and tilt freely. Originally we had purchased a small pan-tilt enclosure that was based off of two servo motors, but we deemed that they wouldn't be powerful enough. This was when we decided to create the chassis ourselves. I worked with Chris in order to come up with the design and rough dimensions of the pan-tilt enclosure. After that I was responsible for creating a model of enclosure using Solidworks. Throughout the project we ran into various problems with the pan-tilt enclosure, for example, the vertical motor didn't have enough torque to tilt the enclosure while holding the camera up. Working with Chris again to find solutions, I had to revise the design and model of the chassis to include ratio gearing. Since the models were all created to scale, we were able to use these schematics to aid the construction of our final device. Learning Solidworks for the first time was a difficult and time consuming process, but this project gave me a lot of experience which should be beneficial to my future career.

In general, everyone on the team worked very hard; however I think my work load was the lightest. My take away from this project is to be more involved and not be afraid to shoulder responsibilities for the team. Overall, I am certain I will be able to apply all the technical and teamwork skills I've acquired into my future projects.



5. Conclusion

Over the past 13 weeks Dimension Technologies has developed a product that has definite market potential. The QuickScan device will enable drafters and architects in the dimensioning process. Overall, our device has met most of the major design features we initially planned to implement. This document has also shown that we have been quite prudent in our spending which has resulted in the total project costs being significantly lower than our initial estimate. Overall, this entire course was enjoyable for each of the group members. As for the state of the QuickScan device, the design team has still to decide if we will proceed in commercializing such a product. This decision will most likely be made in a few months after taking some time away from the QuickScan design realm.



6. References

- [1] "XMeasures 3D Laser Scanning ," XMeasures Inc. [Online]
Available: <http://www.xmeasures.com/> [Accessed: Nov. 26th, 2012]
- [2] "3Deling Scanning Services," 3Deling Inc. [Online]
Available: <http://www.3deling.com/> [Accessed: Nov. 26th, 2012]

Cover Photo Reference:

- [3] "Lobby Room Photo," StockFresh [Online]
Available: <http://stockfresh.com/image/402224/lobby-room> [Accessed: Sept. 12th, 2012]

Simon Fraser University,
8888 University Dr.
Burnaby, BC Canada
Email: rmt3@sfu.ca

