ELYSIAN INNOVATIONS *School of Engineering Science · Burnaby, BC · V5A 1S6*

December 16, 2011

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

Re: ENSC 440 Post-Mortem for an Avatar 3G

Dear Dr. Rawicz:

This documentation, *Post-Mortem for Avatar 3G*, describes the current state and future developments of Elysian Innovations' current project, Avatar 3G. Our goal was to design, build, and program a remote controlled device that allows the user to navigate using a 3G network through a mobile phone.

This document shows the current state of our design, deviations from our original plans, as well as our team's future development plans. We will also discuss the budget and timeline of the design and manufacturing progress. Finally, we will talk about the team dynamics and experience gained while developing the proof-of-concept product.

Elysian Innovations is innovative, creative, and aspires to go beyond the limit. This company consists of five young engineers filled with passion and motivation. They are Leo Chan, Anthony DiNicolo, Simon Mai, Celestine Poon, and Sherman Tse. If any questions arise about our Post-Mortem, please contact our CCO, Celestine Poon, through email at ccp2@sfu.ca.

Sincerely,

Sherman Tse

Sherman Tse
President and CEO
Elysian Innovations

Enclosure: *Post-Mortem for Avatar 3G*

Post-Mortem for

Avatar 3G

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Submitted to: Dr. Andrew Rawicz
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Due Date: December 16, 2011

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Glossary

3G - 3rd generation mobile telecommunications

Android - Operating system for mobile devices developed by Google Inc.

Arduino – Open source electronic prototyping platform

DNS – Domain System Name

IP – Internet Protocol

LAN – Local Area Network

LED – Light-Emitting Diode

TCP - Transmission Control Protocol

WiFi – Brand for IEEE 802.11 family of wireless connectivity standards.

1. Introduction

Elysian Innovations is formed by five young and innovative engineers who have worked together for the past thirteen weeks and come up with the Avatar 3G. The Avatar 3G is a robotic device which allows the user to operate it remotely using an Android application from anywhere at any time.

This document is going to discuss the current state of the design of the Avatar 3G and also any future developments that the team has planned on doing if time and money are permitted. Also the five members of the team will share their personal comments on this entire development progress.

2. Current State of Project

2.1 Overall System

The Avatar 3G allows for communication and control via a 3G connection from a wireless provider using an Android smartphone. Figure 2.1.1 shows a system overview of the Avatar 3G.

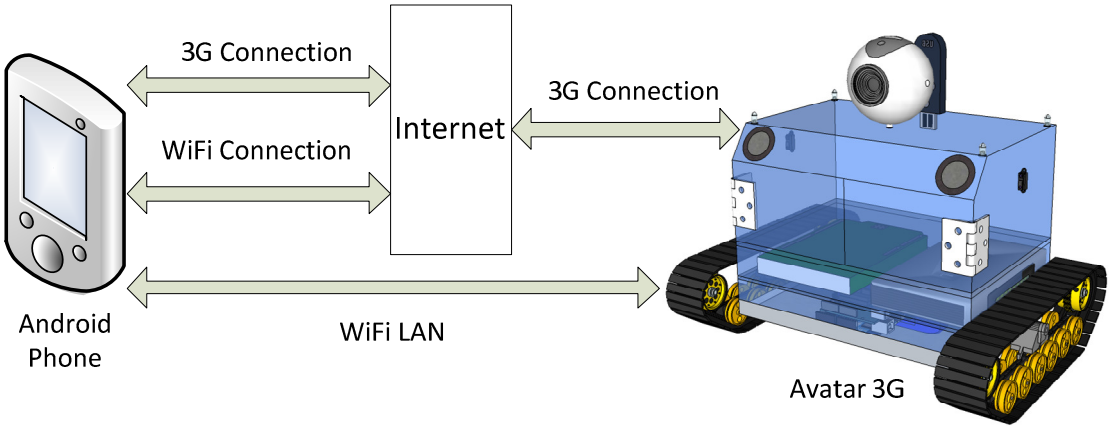

Figure 2.1.1 Avatar 3G System Overview

The Android phone runs an application for controlling the Avatar 3G. The Android phone can communicate with the Avatar 3G in several ways. A 3G or WiFi connection must first be established from the phone to the internet. Through the internet, the phone then connects to the Avatar 3G using a 3G connection. To facilitate this process, a dynamic DNS service translates the public IP address of the Avatar 3G into a static domain name.

An alternative method of connectivity is also available through WiFi LAN. Instead of connecting through the internet and using the 3G connection, an Android phone in range of the Avatar 3G's WiFi LAN can connect directly. This is very useful for areas in which there is no 3G service provided, or there is no access to the internet. Latency, data rates, and stability are also superior to 3G connections, since the

connection does not need to pass through wireless providers and the internet, but the operational range is reduced drastically when using WiFi LAN.

The Avatar 3G prototype is shown below in Figure 2.1.2. Figure 2.1.2 (a) shows the left view, during power charging with the power level indicators on. Figure 2.1.2(b) shows the front view of the prototype. Figure 2.1.2 (c) shows a nighttime view with the LED headlights turned on.

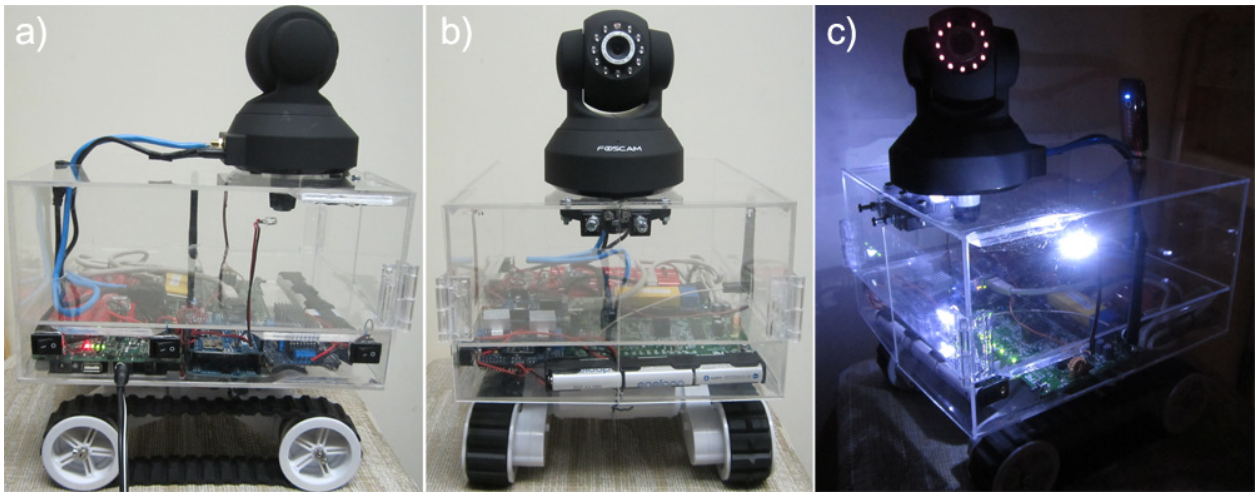

Figure 2.1.2 – Avatar 3G Prototype (a) Left View (b) Front View (c) Nighttime View

2.2 Electrical System/ Power Supply

The electrical system of the Avatar 3G is centered on the use of a high capacity lithium ion battery as well as six AA NiMH batteries. We make use of one 5V voltage regulator to provide power to the camera from the Li-ion battery. We found that the Li-ion battery lasted approximately 4-5 hours while the AA NiMH's last closer to 2 hours. The addition of the AA batteries gives the user great convenience in the fact that they can swap the batteries out at any time, without having to wait for them to charge.

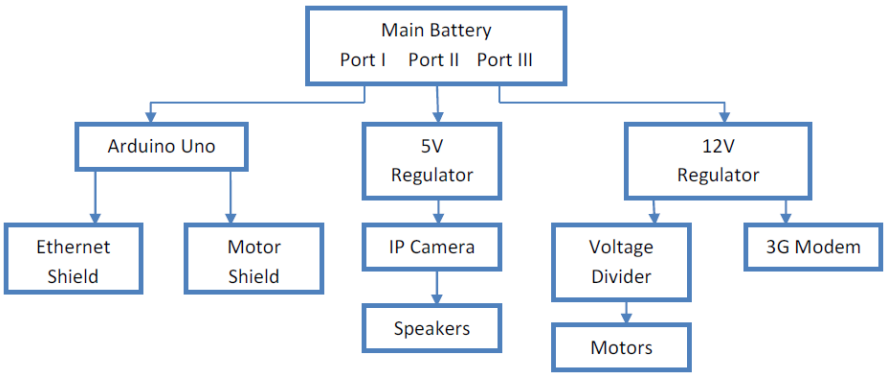

Figure 2.2.1 – Early Design of the Avatar 3G Electrical System

The electrical system of the Avatar 3G is something that went through many redesigns from the time it was originally designed until the final demo. Figure 2.2.1 shows one of our early designs compared with the final design of the system shown in Figure 2.2.2. We had originally proposed to run the Avatar 3G from one high capacity battery that would power the entire system. We believe this would have worked, but would require plenty of complex circuitry to regulate the voltages to many different values and provide the appropriate currents. Since time is a big issue in ENSC 440, we decided to avoid all that circuit design by adding an extra power supply in six AA batteries. This improvement added great simplicity while adding significantly to battery life at very little extra cost.

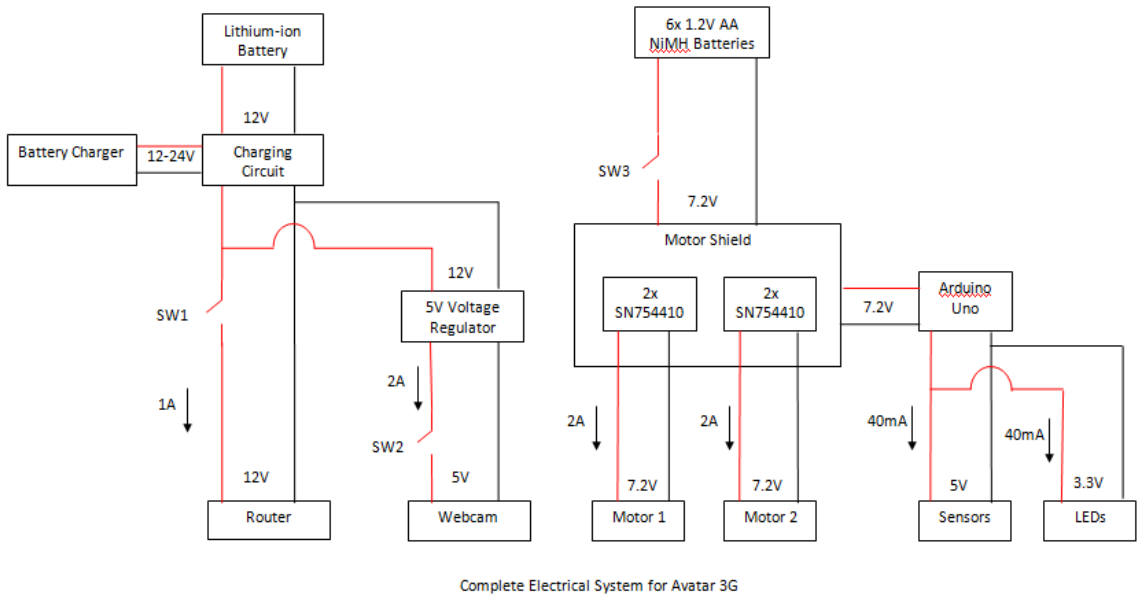

Figure 2.2.2 – Final Design of the Avatar 3G Electrical System

2.3 Motors and Treads

We had difficulties with the original schematics of the motors and treads design, but after taking the feedback from our professors into consideration, we decided to go in a different direction. We purchased the Rover 5 to use as the base, treads and motors of the Avatar 3G. The motors use six AA batteries for power and are controlled by the Arduino Uno board for forward, backward, and turning movements.

2.4 Camera and Speakers

We have chosen the FOSCAM WI8918W IP camera for the project. This IP camera serves as the video feedback to the android application and also provides two way audio communication by making use of its internal microphone and speaker. The user can press a button in the android application and he/she will be able to talk into the microphone in their smartphone and broadcast it through the speaker of the IP camera. On the other hand, people around the robot will be able to speak into the IP camera's

microphone and it will be broadcasted via the speaker of the smartphone, thus providing a two way audio communication system.

2.5 Sensors

The sensors were simple to configure. We had chosen to use the Sharp GP2Y0A21YK0F IR sensors for the Avatar 3G. There are two of these sensors currently placed under the casing and above the treads of the device. They are powered by the Arduino Uno board and they collect data of distances between 10cm to 80cm. As the distance between the Avatar 3G and an object decreases, the speed of the Avatar also decreases until it reaches roughly 12cm, when it is programmed to come to a full stop. However, there is a manual override to overcome the preset parameters.

2.6 Android Application

Because of time constraints, the Android application is an amalgamation of two separate applications running at the same time, with one overlaying the other. The first application is our custom control app. This application connects to the Avatar 3G and sends command signals via TCP, utilizing socket 5000 to bypass provider restrictions. To establish a connection, the user must first be connected to either the internet or the Avatar 3G's WiFi LAN. The user then selects either 3G or WiFi mode. 3G should be utilized when the user is out of range of the Avatar 3G's WiFi LAN, and user has access to internet through their phone, either through WiFi or 3G. Pressing 3G will attempt a connection to the dynamic DNS address of the Avatar 3G through the internet. WiFi LAN should be used when user is connected to the WiFi network generated by the Avatar 3G, and will attempt a connection using LAN IP addresses.

Once a connection is established, the user can send commands to the Avatar 3G by pressing the buttons in the display. The directional pad will send commands to the Avatar 3G to have it move in the direction of the arrows for as long as the arrows are held down. This is accomplished by sending 50 ms pulses for as long as the arrow is held down.

To control the headlights and proximity sensors, the user can tap the respective icon in the HUD for their function of choice. Tapping the headlight icon will send a single command to the Avatar 3G which will toggle the LED status. Tapping the sensor icon will send a single command that toggles function of the proximity sensors. The directional pad and HUD are overlaid on top of the video feed. In order to accomplish this, open source code from SoftKeys by Steve Slaven was used [1].

The second application we used was the commercially developed tinyCam Monitor by Alexey Vasilyev [2]. This application handles the video streaming, camera control, and two-way audio communication with our IP webcam.

While we would have preferred to use a single, entirely custom Android application, time constraints and the proprietary and closed nature of the IP webcam forced us to make this compromise. Even though two applications are used, the end result is still attractive, usable, and fulfills our requirements.

Figure 2.6.1 shows the final result of our application overlaying the video feed and camera controls. Please note that the display resolution of this particular phone is low. Visibility of the environment is greatly improved on higher end phones with higher resolution displays.

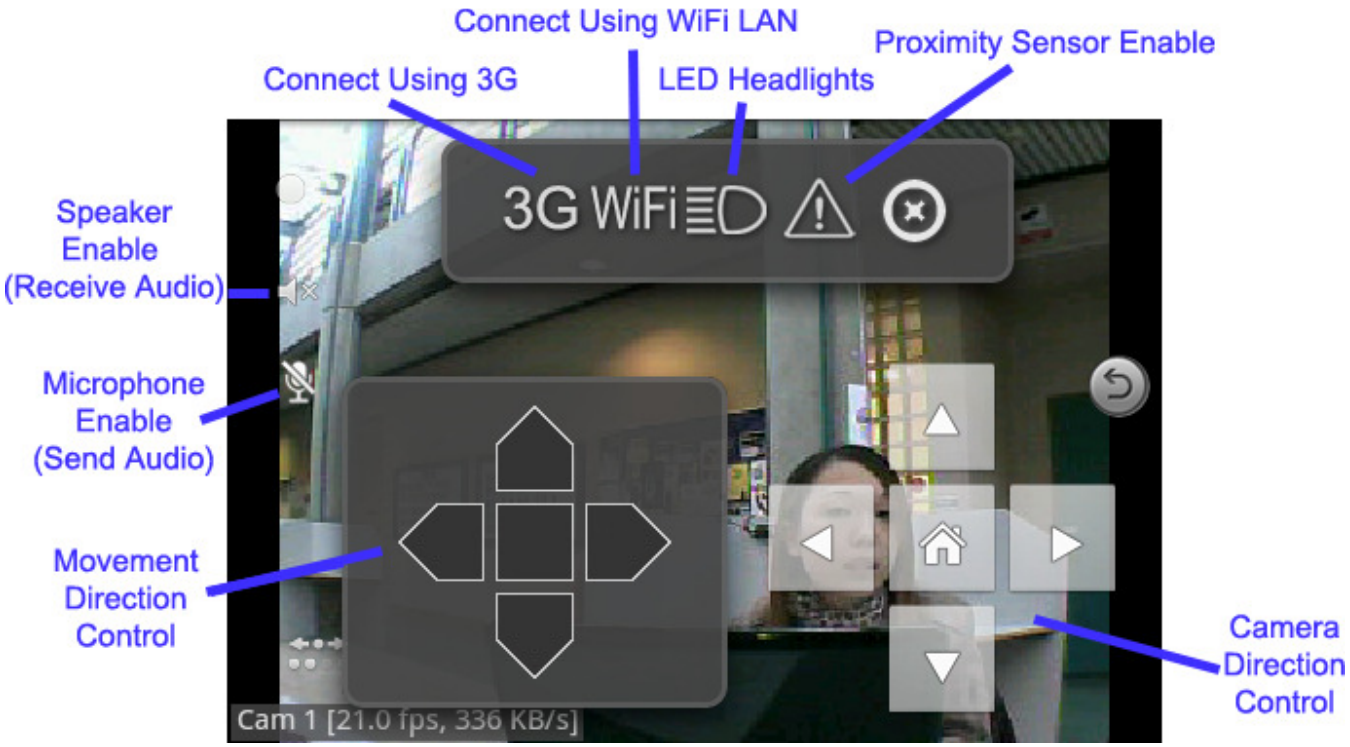

Figure 2.6.1 – Android Application Final Results

2.7 Control Communications

To control the Avatar 3G, a TCP server is run on the Arduino board. This server awaits the connection of clients and carries out the commands it receives. In order to effectively and safely send commands to the Avatar 3G, timing of the commands must be a serious consideration. A safety requirement of the Avatar 3G is that it must stop movement as soon as connection to the client is lost. This is accomplished by having a client send a command every 50 ms. The TCP server will receive these commands, but will not execute them immediately. Instead, it will only execute the latest command received every 250 ms. This allows for consistent movement performance in various network conditions using various clients.

The Android application is programmed to send a control command every 50 ms, but network conditions or timing conditions on the phone may prevent the signals from arriving in a consistent and timely manner. Having a delay of 250 ms between execution of commands allow for a wide margin of error in the timing of control signals. Likewise, for a client that sends commands too quickly, such as

when using a TCP client on the computer for debugging purposes, the delay will ensure that the command buffer is not overrun.

When a movement command is executed, the motors will move in the direction specified for 250 ms. It will then check again to see the next command and move in the direction specified. If no command was issued, then movement will cease. In our tests, this 250 ms delay between commands is difficult to notice, appears to be nearly instantaneous, and is a good compromise between responsiveness of the system and smoothness of movement.

3. Deviation from the Original Plan

The final design of the Avatar 3G adhered closely to our original concept design. Only a few minor deviations occurred and are addressed below.

3.1 Speakers

We had planned to use high quality external speakers for broadcasting audio from the Avatar 3G. We found that the built-in speakers for the IP webcam were sufficient in terms of quality and loudness. Therefore the external speakers were not included in our final design.

3.2 Sensor Placement

Placing the sensors on the sides of the Avatar 3G as originally intended was not a good choice because the hinges at the front would interfere with the operation of the sensors. The sensors were moved to underneath the Avatar 3G where there would be no interference or obstructions.

3.3 Number of Batteries

We had originally intended to use only the Lithium-Ion battery to supply power to the router, IP webcam, Arduino, and motors. We changed this configuration so that the Arduino and motors are powered by six rechargeable AA NiMH batteries. This was done in order to avoid the use of another voltage regulator, as well for testing purposes. Using AA batteries allowed us to test for extended periods of time, as we could simply change the batteries once they were depleted and resume testing. Since the majority of power consumption came from motors, and the Lithium-Ion batteries lasted for long periods of time in powering the other components, we were able to complete entire days of testing without having to wait for recharges.

4. Budgetary and Time Constraints

4.1 Budget

Equipment/ Service	Actual Cost
3G Modem	$47.61
Arduino Ethernet + Uno	$89.02
TP-Link Router	$51.61
Motor Shield, Motors, Gear Box	$83.56
IP Webcam	$97.22
LED, Gearbox, Sensors	$65.63
Rogers PAYG Data Plan	$28.00
Rogers Rocket Stick (Used)	$25.00
Li-Ion Battery	$123.94
Rover 5 Platform	$86.46
Backup drives, switches, jacks, 10w regulators	$64.92
Backup regulator, piezo, speaker, resistors	$46.93
Perspex Casing	$36.50
Public IP from Rogers	$6.72
Motor Drive Chips	$24.15
Total	**$877.27**

Table 4.1.1 – Final Development Cost

The actual development cost of the Avatar3G prototype was $877.27, as seen in Table 4.1.1. The most expensive items were the IP webcam and the Li-Ion battery. Comparing with the estimated budget from our Project Proposal, our final product cost over $200 more. The increased budget was a result of shipping costs, taxes, as well as replacement and backup parts. If we put the Avatar3G in production in future it will cost $505.13 per unit in terms of parts, as seen in Table 4.1.2.

Equipment	Actual Cost
Foscam FI8918W	$97.22
2x Super Bright 5mm LED	$1.90
2x Sharp IR Sensor	$23.90
BP 75 Lithium Ion Battery	$123.94
Rover 5 Platform	$62.95
3x Rocker Switch	$2.04
10W Voltage Regulator	$16.08
Perspex Casing	$36.5
TP-Link Router	$51.61
Total	**$505.13**

Table 4.1.2 – Actual Part Costs of Avatar 3G

The prices in Table 4.1.2 do not include the cost of shipping or taxes, and the 3G modem has not been included because we will be expecting customers to purchase or sign contracts for their own 3G modem from the wireless provider of their choice.

4.2 Timeline

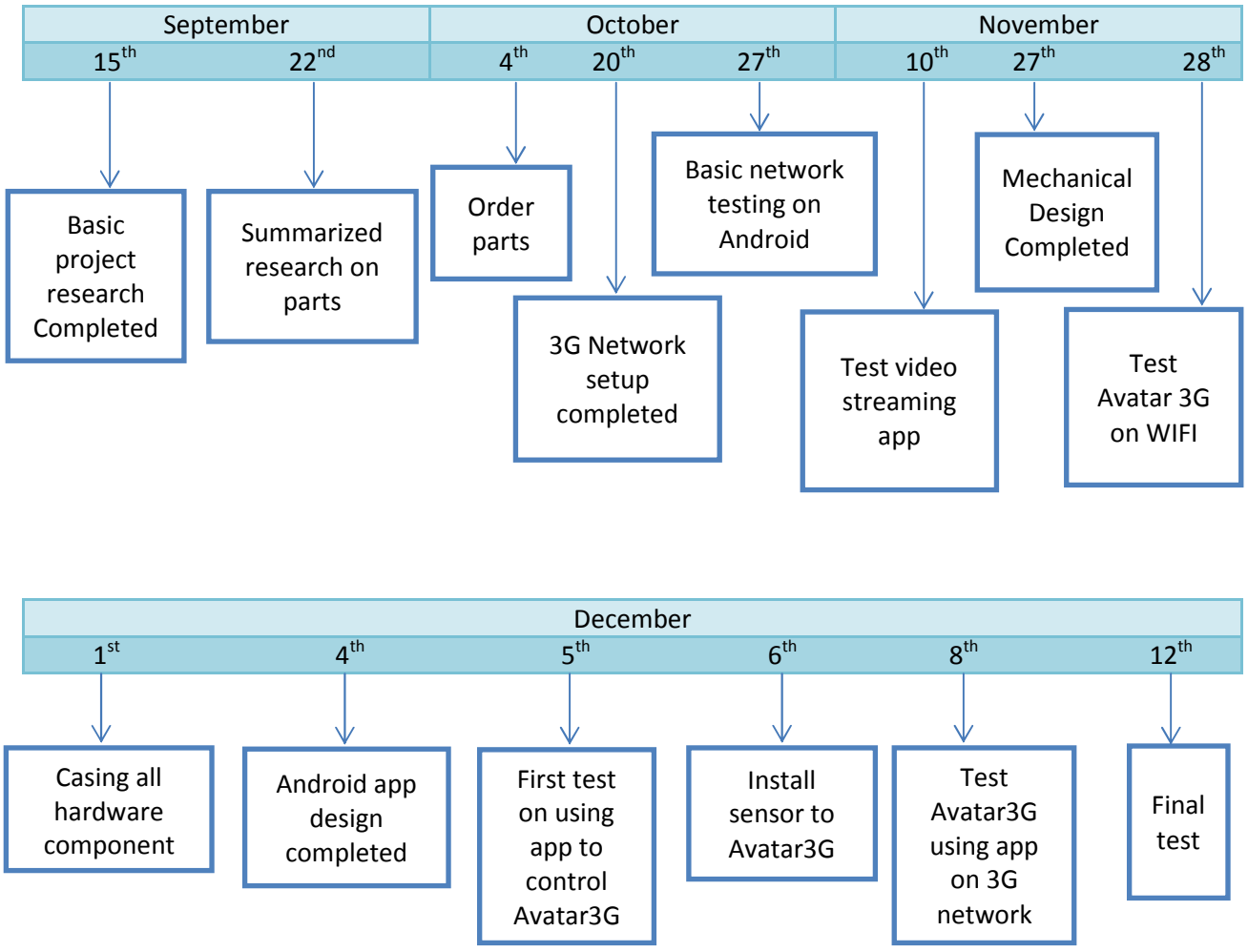

Figure 4.1.1 – Project Timeline

This is the actual timeline we have used to complete the project is seen in Figure 4.1.1. We pushed our schedule back compare to the initial timeline. This was due to the 3G network taking longer to setup than anticipated. Therefore, we had to rush in November to catch up the mechanical designs and start integrating the software and hardware.

5. Future Development

Elysian Innovations has built a successful proof-of-concept product of the Avatar 3G. However, there are several improvements that our team will make in the future. The following sections detail the future advances of the Avatar 3G.

5.1 Mechanical Improvements

We found that using treaded tracks for locomotion provided us with substantial grip on terrain, but were inefficient because of the excessive friction between the tracks and the ground. This friction made movement and mobility slow. At the suggestion of Dr. Rawicz, the treads will be replaced by wheels in the next iteration of the design. Wheels should allow for increased speed, movement, and efficiency, allowing for a much faster and responsive Avatar 3G that has a longer battery life.

5.2 Chip Consolidation

The Avatar 3G uses three main chips: the ATmega328 in the Arduino, the Atheros AR7241 in the router, and the ARM processor in the IP webcam. If mass production is to be achieved, functionality of all three chips should be combined into a single chip. The functionality of routing, image processing, and control command execution should be possible to implement on a single chip. As noted by Dr. Rawicz, this single chip design improvement would reduce production costs and power consumption

5.3 Security System

Since the Avatar 3G is a robot that is designed to be used outdoors, the Elysian Innovations team notices that the security of the robot will be a huge concern. Therefore we are prepared to implement a security system into the robot which will work in a similar way as a car alarm. If someone is trying to steal the Avatar 3G, the user will be able to remotely arm the alarm system and the Avatar 3G will make an alarming sound which will seek attention from surrounding people. Also the user can take pictures or record video of the appearance of the thief.

5.4 Enclosure Improvement

The proof-of-concept product of the Avatar 3G has a clear plastic casing which was picked because it can show the inside of the robot, making the demonstration more convenient. However it is not very strong and exposes the storage space. Therefore, we are going to switch to a much stronger material to serve as the case of the robot and also we will paint the case so that the contents of the storage compartment will not be visible on the outside. Also, most of the exposed components (for example: the IP camera and the “rocket stick”) will be hidden under the new improved case, making the robot more weatherproof and extending the life expectancy of the robot.

5.5 Control Application via PC

In the future, Elysian Innovations will develop a control application that is similar to the current Android phone based application, however this new control application will work on a PC instead. The user will be asked to pick the method of connection on the front page and then it will send the user to the corresponding page with the chosen connection. The web page will consist of two main components: video feedback and control buttons. The video feedback will be a live video stream from the IP camera and the controls buttons will be a directional pad which can control the Avatar 3G in the same way as the android application. This will serve as a backup plan in case the android application does not work or the battery of the Smartphone runs out while controlling the robot. This will also make the product marketable to those who do not have an Android smartphone, but would still enjoy the Avatar 3G.

5.6 Sensors System Improvement

We have included two forward facing sensors in the proof-of-concept product which will be able to stop the Avatar 3G if it senses any obstacle within 12cm in front of the robot. However it is not able to detect anything behind or around the robot. This will be fixed by adding a rotating dock on the two currently available sensors on the Avatar 3G. There are market available docks for such purposes, and they rotate 180°. Furthermore, after rotating sensors, we will add a sensor facing downward near the front of the Avatar 3G to detect the possibility of stairs that could be otherwise hazardous.

6. Individual Reflection

Sherman Tse – Chief Executive Officer (CEO)

As CEO, it has been a very rewarding experience managing and working on this project. I have had experience managing project groups in the past, but this project has definitely been the most complicated and unique. In order to manage this project effectively, I had to acquire a deep understanding of both the project and the people working on it. I tried to utilize the strengths and interests of members, and plan out and assign tasks that they would be most interested in and likely to complete with the highest quality.

Being an effective manager also means knowing the project inside and out at both a high and low level. I was in charge of providing the high level design, as well as looking over all the details of the low level designs in order to make sure everything would actually work together. I analyzed every component and part, and went through mountains of information before deciding which parts to order.

Being able to apply all the things that I've learnt in school in a practical way is a great way to finish my undergraduate study. It was my first time programming for the Arduino board, but I was able to use many of the skills I had acquired in my Embedded Systems course. It was also my first time programming for the Android application, but I was able to apply my Software Engineering experience as well.

Knowledge of circuits was also very important, and all those long hours spent in the lab with a breadboard finally paid off when working on the power system.

I was also responsible for final integration and was able to put my soldering skills to the test. Soldering 22-pins of an Arduino shield to its board via ribbon cable in order to reduce clearance was the easy, albeit tedious part. Soldering power connections to a hot high capacity Lithium-ion charging board circuit while working within the confines of an enclosure was the difficult and scary part.

Overall, I am very pleased with my group and the final result of our prototype. Driving a 3G robot that is out of line of sight and a few hundred meters away, is probably the most fun I've had in engineering so far.

Leo Chan – Chief Information Officer (CIO)

For the past thirteen weeks I have been working closely with my fellow team members towards the completion of the Avatar 3G. We have been having productive weekly meetings under a harmonic and positive atmosphere among the team members. We assigned different aspects of the project to different members of the team to increase the efficiency of the development process. Thus we were able to finalize the ordering list and order the parts within a month into the semester. The positive attitude among the team was the motivation that guided the team towards our goal and allowed us to finish the proof-of-concept product before the deadline.

During the process of the development of the Avatar 3G, I have learnt many skills in a lot of aspects. First of all, I have gained a lot of knowledge in IP camera networking between the IP camera and the Android application which I have never encountered before the project. Secondly by working with Simon on the android application, I gained some knowledge and experience in writing java script and debugging for programs. Also I have become more familiar with searching for solutions from the internet for any programming questions. Thirdly I learned how to work with a group of engineers for a proof-of-concept product development. Before taking this course, I have had some experience in developing a concept, however I have never had any experience in doing any hands on work and actually producing a prototype before. Therefore this course is a very good experience to me as I work my way to become an engineer. It provides me with a lot of experience in team dynamics, project development, research and problem solving.

Speaking of the team dynamics, I think we have worked pretty well as a team. If given the chance of carrying on the development of the Avatar 3G, I would like to work with the same team without any hesitation.

Anthony DiNicolo – Chief Operating Officer (COO)

Undertaking this project was a great opportunity for me to apply what I've learnt throughout my engineering degree while also learning many new skills. I also learned plenty about team dynamics and the importance of organization and planning to meet deadlines in a group setting.

My main responsibilities were to design the electrical system of the Avatar 3G and construct its main body. I was also able to contribute to programming the motor control aspect of the Avatar 3G. Designing the electrical system proved to be quite tricky since our main concern was having a suitable battery life for the Avatar 3G to allow it to travel significant distances while still having the power to make it back home. I enjoyed being able to apply my knowledge from circuits courses, especially ENSC 425, to regulate the voltages and connect everything in a suitable way for the system to operate efficiently. I also enjoyed learning about the mechanics of how motors operate and also the kind of structure required for the body. I was able to get my Grandpa's help with some of the construction and design which was excellent since we were pretty new to the field.

Being a soccer player, I especially enjoy tackling problems in a team atmosphere, so I appreciated that aspect of this project a great deal. One of my favourite parts of the project was brainstorming ideas with the group. Discussing new problems and solutions to the problem was always fun at meetings. Then seeing how successful we were when combing those ideas made it that much more rewarding. I found the team got along very well which made it a much easier environment to work in and people weren't afraid to share any suggestions.

I had plenty of fun with the Avatar 3G project and was able to learn plenty. If given the option to complete another project in the similar fashion with the same team I would be very excited for the opportunity.

Simon Mai – Chief Marketing Officer (CMO)

I was about to switch my Android phone by the time that iPhone 4S is released; however, I changed my mind while I was working on the project. My role in this project was to write up codes for the Android application. Initially I thought it was an impossible mission for me to handle this task, but after conducting some research and self-study on Android programming, I started getting comfortable with programing in Java and trying to break down each project task smoothly. Throughout this project, I have gained a lot of programming experiences, which a biomedical engineering student may never have; moreover, I also decided to keep my Android in my pocket.

For this course, the most valuable thing I have learned is time management. ENSC 440/305 is the most challenging and time-consuming course I have ever taken. However, I did learn a lot this semester. In our first ENSC 305 lecture, we were told that we were already been behind the schedule, and our instructor provided us a daily timetable to illustrate the importance of time management. I was frightened, so once I went home, printed out 13 copies of the timetable and used it to remind me of the schedule for the course and project.

I really enjoyed being a part of our team because I learned a lot in terms of communication skills and teamwork skills. During the last four months, our group put a lot of effort to make sure that good communication has been reached between each group member. I am pretty confident that these skills are transferable and will benefit all of us in our future career.

Overall, this has been a great experience for me while I was working with others in a group setting and working with actual circuits in the end. The knowledge which I have acquired will help me with future projects, classes and jobs.

Celestine Poon – Chief Communications Officer (CCO)

The experience of creating the Avatar 3G was indescribable. During which I worked especially close with Anthony DiNicolo regarding the movements and power consumption of the motors. Furthermore, I also worked on the sensors of the Avatar 3G as a failsafe in case there are delays in control so the Avatar 3G will not hit anyone or anything when it comes too close. Both the motors and the sensors are controlled by the Arduino Uno board. During this time, I realized that the Arduino is a very simple to code for. It comes pre-packaged with header files for the motors and sensors. You can easily include those header files and design a code to retrieve and send information between the Arduino and the motors or sensors.

If there are opportunities to continue working on the 3G, I would love to further develop the device.

7. Conclusion

The Elysian Innovations team has completed the development of the proof-of-concept product of the Avatar 3G. There are some minor changes in the final proof-of-concept product compared to the original plan, but the differences are not significant. The team is happy about the current state of the Avatar 3G, however it will need a few more improvements before we can put it on the market. We have not yet decided if we are going to carry on the development of the project. If we do, we will follow the guidelines listed earlier in this documentation under the “Future Developments” section. Our team will put in some time in discussing if we will continue the development of the Avatar 3G in the near future.

8. Reference

[1] SoftKeys Open Source Project Files by Steve Slaven (2011). Retrieved Dec, 15 2011. http://git.hoopajoo.net/

[2] tinyCam Monitor for Android by Alexey Vasilyev (2011). Retrieved Dec, 15 2011. http://tinycammonitor.com

