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http://www.drivomatic.com
Drivomatic Technology Corporation

April 11, 2008

Dr. Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 440 Project Post-Mortem for a Self-Driving Wheelchair System

Dear Dr. Leung:

Enclosed is the Post Mortem document for a Self-Driving Wheelchair System from Drivomatic Technology Corporation. We are focused on developing a self-driving wheelchair system that allows the mobility impaired to navigate within buildings such as airports or nursing homes with maximum independence.

The Post Mortem document summarizes the process for the project. Challenges and milestones achieved will be discussed, along with the project future development and possible future projects for the company. Additional topics mentioned in this document would also include the project time-line and the project financial summaries. To conclude, members of the DTC will share our interpersonal and technical experiences.

Drivomatic Technology Corporation consists of five spirited engineering students: Jonathan Hung, Andy Chen, Jian Guo, Benjamin Chang, and Ammar Zaidi. If you have any questions or concerns about the Post Mortem, please do not hesitate to contact me by phone at (604) 721-0585 or via e-mail at ensc440-spring08-dtc-ensc@sfu.ca.

Sincerely,

Jonathan Hung
President and CEO
Drivomatic Technology Corporation

Enclosure: *Post-Mortem for a Self-Driving Wheelchair System*

Drivomatic Technology Corp.

Post-Mortem for a

Self-Driving Wheelchair

Project Team: Jonathan Hung
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Jian Guo
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

During the past 4 months, the 5 talented engineers of DTC have worked tirelessly on a self-driving wheelchair module that will allow individuals with severe physical disabilities to maneuver independently in an indoor environment. The SDW module is designed to allow wheelchair users to move from one location to another inside a private or a nursing home with a press of a button. This document examines the overall development of the SDW module as well as the deviation of the design, project management and future development. Also, the 5 DTC engineers discuss their individual achievements and personal experiences gained from this exciting venture.

2 CURRENT STATE OF THE SYSTEM

As described in the proposal, the SDW system is designed to help elderly and disabled individuals regain their independence. Currently the system is capable of maneuvering on a track in an indoor environment with the capability of turning around at the end of a track as well as follows corners and smooth turns. The SDW is also able to identify marked locations, calculate the desired path as well as allowing the user to switch between automatic to manual mode. Currently the only user input of system is a button allowing users to input their desired location based on the number of times the button is pressed. The button also provides the ability of stopping the wheelchair to select a new destination anytime during the self-driving process. Following is the flowchart of the current system state.

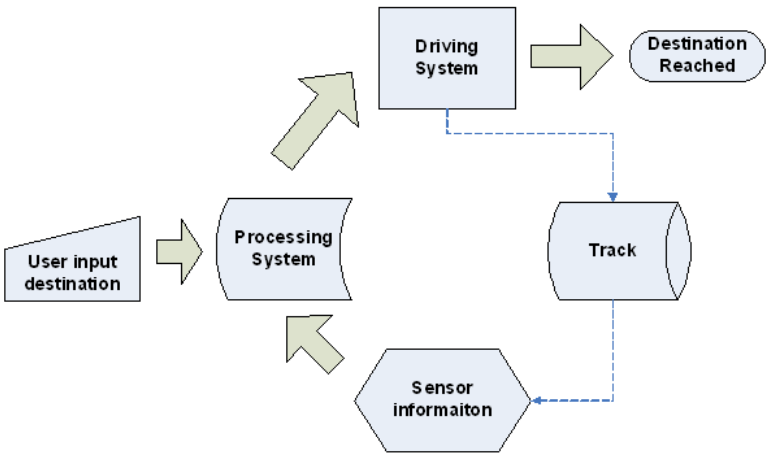

Figure 1 System Design Flowchart

3 DEVIATION OF THE SYSTEM

3.1 Button

In our design specification, we mentioned that a big button would be used to enter a destination. However, because the technique used to enter destination is pressing the button multiple times, we found it laborious to press a big button. Also, due to the limited area on the interface, a big button that requires a lot of room is very difficult to place. Hence, a small button is used on the side of the interface.

3.2 Track

In our design specification, we proposed two kinds of track designs, one is with curved intersection and the other is the 90° intersection. The curved intersection was originally designed to switch between left edge and right edge depending on the turn decision. After implementing the edge following algorithm, we realized that in order to perform control algorithm, a constant edge is required. Thus, a simple edge following with 90° intersection is chosen over the other.

3.3 Lighting and Cover for Camera

The lights and the cover were added onto the system for better image procession results. The shadow created by surrounding lightings will cause the camera to see undesired edges, thus the cover we employed. However, with no light source, the camera was unable to see. Extra lights were added to illuminate the track.

3.4 Mounting Position

We have separated the camera and RFID as opposed from the design specification. The camera module with the microcontroller is now mounted in front of the wheelchair between the feet of the passenger, whereas the RFID reader module is mounted behind at the center of the actuating axle. This change in design is due to the track implementation and wheelchair's turning characteristics. Because a camera is used to follow a line, mounting the camera and RFID together may produces problems to our line following algorithm.

3.5 Histogram Matching

Because mounting of the camera is high, the track is too thin for histogram matching. Also, edge following provides enough functionality hence eliminates the need for histogram matching.

3.6 Off-track Searching

Initially, we have designed the off-track searching routine to maneuver in a spiral fashion until the track is found. Since our system lacks obstacle detection, we have reduced the spiral action into a simple spinning action due to safety concern.

3.7 Change of Destination

We have implemented an extra change-of-destination feature to our system. The function allows the user to stop the wheelchair and change their destination anytime during the self-driving process.

3.8 RFID Reader Control

Initially, The RFID reader is enabled all the time by means of hardwiring. However, long period of operation will make the RFID reader component heat up, which will decrease its reading range. For this reason, the RFID enable pin is now connected to a GPIO pin of the microcontroller. The enabling function is performed by setting the GPIO pin low. With this approach, the RFID reader's operation time can be greatly extended.

3.9 RFID Interrupt

In the course of design, it was decided that the RFID reader will trigger an interrupt when an RFID is read. The benefit of this design is that it frees CPU usage as well as ensuring the RFID tags will not be missed. However, in the course of combining the code together and debugging, it was discovered that the RFID interrupt conflicts with another already running timer interrupt. Due to the lack of assembly decompiling utility and time constraint, we were unable to identify the source of the problem and decided to use polling instead of interrupt. Fortunately, our microcontroller is powerful enough to perform all the actions required in this project without delay.

3.10 PID Control

To be able to follow a track that is seen by the camera, we have employed a PID control algorithm to ensure that the wheelchair adjust its position to keep the camera module always on top of the track. This feature was intended at the time of composing the design specification, but was missed out while writing the document.

3.11 Power Supply

To ensure the stability and lengthen the continuous operation time of our system, we have decided use the 12V lead-acid battery onboard of the wheelchair. To use this design, an 8V voltage regulator that sits between our modules and the battery was required.

4 BUDGETARY AND TIME CONSTRAINTS

Because of the time constraint, we could not build our own modules. Instead, we purchased most of our components off the shelf and integrate them together. Due to the hardware requirement of the project, the research and development cost is higher. The following table shows our original estimated budget, modified budget and actual costs.

Item	Estimated	Modified	Actual
Power Wheelchair	$450	$950	$950.00
Microcontroller	$300	$574	$624.29
3 Color CCD Cameras	$100		
RFID Reader/Tags	$75	$75	$72.66
Obstacle sensors	$100	$0	$0.00
LCD/LED	$40	$10	$79.65
Cables/Wires	$20	$36	
Keypad	$20	$0	$0.00
Miscellaneous	$225	$150	$4.48
Total	**$1,330**	**$1,795**	**$1,731.08**

Table 1 Budgets and Costs

As you can see, the estimated budget prepared in the proposal was based on the research, at which point, most components had not been finalized. However, around half way through the project, the budget was modified to meet our financial needs. Special thanks to the ESSEF and Wighton's fund who made this project possible.

5 GROUP DYNAMICS

Overall our team members cooperated and coordinated well with each other. We supported each other in difficult times, particularly when failures of integration occurs. Relationships between members are kept strong by the CEO's management skills. The group is well motivated at most of the times. A supportive atmosphere was kept at all the time during the development process and all the members willingly accepts and take on extra work whenever available.

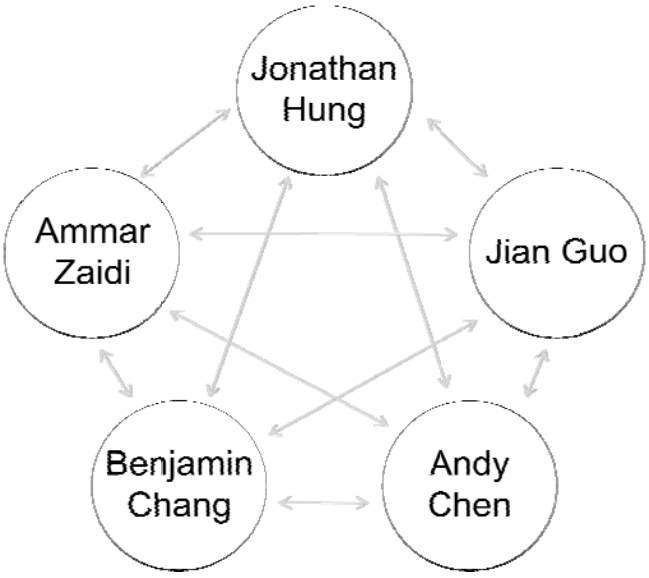

Figure 2 Group Dynamics

6 INTER-PERSONAL AND TECHNICAL EXPERIENCE

6.1 Jonathan Hung – Chief Executive Officer (CEO)

In the past months during the process of the project, I have developed numerous skills and obtained much valuable experiences. The project gave me an idea of how the process of developing a new product in the real world is approached and developed; from the process of brainstorming to the process of prototyping and documentation.

I have discovered that launching a new product to society is not a straight forward task. Many factors must be considered such as need for the product, marketability of the application, profitability of the business, and the ethics involved in the design and engineering of the new product.

During the process of prototyping our SDW system, I have also gained technical experiences from working together with the team. Specifically I've touched base on circuit prototyping, microcontroller programming using C, and Systems design.

Taking on the responsibility of the CEO enabled me to explore my abilities to manage the team through the project and finally lead the team to success. This role allowed me to associate myself with all aspects the project development, such as Finance, Marketing, Operation, and R&D aspects.

One of the difficulties of taking on the position of the CEO is to satisfy the team's individual objectives. Often times, it is required to compromise the needs between members and delegate work accordingly. It was also difficult trying to facilitate the team to keep the project on schedule. I learned that to be a successful leader, maintaining constant communication with the team is essential. To be able to earn the respect from the other team members was constantly my goal throughout the project.

If I were to redo this project again, I would encourage the team to source more help from the professors and facilitate additional market research in the early stages of the Product Functional Specifications.

6.2 Andy Chen – Chief Financial Officer (CFO)

As the chief financial officer, I have gained experience on how to convey ideas across to the potential investors. With the support from the team, I was able to address the need for our product and how it can provide convenience to the users. This special opportunity allows me to improve interpersonal skills when dealing with administrative tasks.

As a systems engineer, I found myself able to integrate devices together to perform the desired functions in a high level point of view. However, sometimes I can come up with ideas, but unable to implement myself. But being in a group, working together, ideas can turn into a design, then into a module. The most valuable lesson I learned throughout this project is that as a group, one can always find strength in other members.

As a visual system engineer, I was in charge of the visual processing of the SDW system. This resulted from the technical skill I obtained from the ENSC 460 – Digital Imaging Processing course, which makes edge following possible.

To conclude my inter-personal and technical experience, I would like to say this is the best group ever. We have shared the down times when modules fried, and we have shared the joy when the SDW system is up and running. Most of all, by putting together our skills obtained over the years in engineering, we are able to accomplish our goal in a short four-month period.

6.3 Ammar Zaidi – Chief Marketing Officer (CMO)

My past 4 months have been a great learning experience. During this time I gained valuable insights into project development as well as developed various skills that will be an asset in my future career as an engineer.

From the beginning of the project development process I was heavily involved in research and development. My responsibilities, as a chief marketing officer allowed me to earn valuable research and business analysis skills. As the public relations representative of our team, I had to contact and interact with various potential customers as well as care/nursing homes and hospitals. During the marketing process I gained valuable communication and interpersonal skills.

My other role as an electronics/hardware engineer involved providing electronic components and circuit designs to the DTC team. At various stages in our project I was able to provide electronic components and hardware parts for our physical design of the module. My circuit debugging and designing skills were also tested when I helped implement the voltage subtraction circuit to control the Pulse Width Modulation of the microcontroller. I also re-designed the layout of the PCB and re-implemented the circuit within one day with lower EM noise and interference. These circuit design and debugging exercises allowed me to further improve my electronic design skills and increased my confidence as an electronics engineer.

Overall our team cooperated and managed the time quite effectively. Even though there were times when our project looked to be heading into a dead end due to circuit failure, fried user interface module or burnt microcontroller, in the end we managed to reach our goal within the allotted time.

If I was to redo this project, I would do extra research into product demand and market outlook before choosing a product. I would also like to do more C/C++ programming as I was unable to do too much of it due to other responsibilities.

6.4 Benjamin Chang – Chief Operations Officer (COO)

The past few months, throughout the span of SDW development, I have acquired the most valuable project experience in my university life. The project has allowed me to experience the process of developing a system that requires the integrations of many smaller subsystems.

As the chief operations officer, my job was to oversee the operation of the project and to ensure that the project goes on schedule. I kept in touch with the progress of all the subsystem of the project and obtained various circuit components required by each group member to minimize the delay of the project development.

Being the chief systems engineer, it was important for me to understand the behavior of each individual parts of the project to ensure that the integration of the system is possible. After Jonathan Hung, our CEO and systems engineer, laid out the structure of the software, I have taken over the job of managing the overall software integration. In the late development stage of the project, I made sure that the firmware would function as expected. Being a major software developer of the team, I have also developed most of the software functions that do not fall under the category of image processing nor RFID reading.

A major difficulty that I have encountered was the implementation of the PID control algorithm. Calibrating the PID constants and fine-tuning the PID algorithm was a very lengthy process, thankfully everyone in the team has contributed much valuable time in this process. Toward the end of the integration process many unexpected hardware behavior has also caused us many problem which I eventually patched up with software fix.

If I were to redo the project, I would look into the video processing and interrupt service routine in more detail at the early development stage of the project to ensure that I would be able to integrate the system more easily. Also, I would not have implemented the whole set of PID control, since including the integral control doesn't seem to increase the control response of the system.

6.5 Jian Guo – Chief Technology Officer (CTO)

In the duration of this project, I have developed numerous skills and obtained valuable experiences. This project allowed me to familiarize with development process of a new product in the industry. Formerly appointed as CMO, I switched position with the former CTO Ammar Zaidi after discussion, due to his heavy work load at VTech co-op. Taking on the role of CTO gave me the opportunity to experience the problems professional engineers face each day.

I have discovered that to design a new product, many factors must be considered. Some of these factors include cost, benefit, power consumption, loading, safety and ethics involved in the design and engineering.

In addition, I have gain a lot of technical knowledge and experience from the development process. A lot of knowledge was gained on circuit designing. By obtaining technical feedback from Dr. Leung and other faculty members who are experienced in circuit design, I was able to realize my lack of consideration to circuit loading in time, and changed the design to prevent potential breakdown. Furthermore, I have gained valuable knowledge and developed new skills on hardware programming from implementing interrupts and linking hardware communication in C. These experiences will become valuable assets in the future.

Taking on the role of CTO enabled me to get in touch with all aspects of technical design. The responsibility of this role allowed me to discuss every aspects of the technical design with other members and make sure everyone is in phase. Also, being the CTO helped me tune my interpersonal and communication skills. In a team project, communication is essential to the success of the project and proportional to the progress made. Fortunately, our DTC team has kept constant communication on daily basis, which speed up the design and decision making process.

If I were to redo this project, I would try to take the advantage of our environment and consult more with professionals. Also, I would try to spend more time and effort on utilizing the microprocessor so that I can use the potential of the microprocessor to a greater extent. Furthermore, I would try to pick a better development environment to improve the debugging capability.

7 FUTURE PLANS

7.1 Safety Features

In order to provide users complete safety and security, the SDW system will be further improved with the following features.

7.1.1 Obstacle Detection

To avoid running into physical obstructions, an obstacle detection system will be added onto the SDW system. This will allow the users to avoid other people in their location and will give them comfort and peace of mind when using the SDW system.

7.1.2 Staircase Detection

It is important for the system to identify staircases and to break from its current operation to avoid falling accidents. To ensure the safety of the passengers, this feature will be essential in the production model of the product.

7.2 Advanced Features

7.2.1 Multiple Wheelchairs Operation

For the SDW system to be ready for commercialization, multiple wheelchair operation is essential. A simple solution to this issue is to place multiple parallel tracks with a higher concentration of RFID tags.

7.2.2 Elevator interaction

Elevator is a common feature for it provides a convenient solution for wheelchair users to travel vertically. It is anticipated that the SDW system will be able to interact with an elevator via some radio frequency protocol. To achieve such goal, the elevators that are of interest will need to undergo some minor modifications.

7.2.3 Joystick Mode Switch

Currently we are switching between joystick mode and autopilot mode with a hardware switch. Ideally, the system should not need an extra switch, but to allow the joystick to always overwrite autopilot command. This can be implemented with a simple switching comparator circuit that selects the joystick signal (bypassing the autopilot command) whenever the joystick is being operated.

7.2.4 Advanced Track System

In the prototype, a visible track with high colour contrast with the background floor is required. In the future, we expect that no visible track is needed. For example, an ultraviolet track invisible to human eye could be used. Ideally, no track should be needed; the wheelchair should be able to determine its location simply by image processing its surroundings.

8 CONCLUSION

This Post Mortem document summarizes the result of the 4 month long product research and development cycle. Discussions on possible future improvement of the product and various development issues have been included in the document. Applying knowledge and abilities acquired throughout the university experience, we have accomplished what we set out to do 4 month ago. Throughout the development cycle, all the members of the DTC have developed skills that are valuable in their future career.