**ECSE 211 Final Report**

1. Introduction

*i) What were the main reasons for the project?*

Despite seeming like a robotics challenge, the aim of the final project was to teach students the core objective of this class, the design process. The robotics project was just an interesting challenge to get some hands on experience about the underlying principles and the methods of design. As it was repeatedly stated during lectures, design is a process that cannot be grasped through mere theorizing as it also requires experience acquired through a hands on approach. Therefore, the goal of the project was to provide a stimulating academic environment where students could acquire some valuable experience and insight by simulating how the engineering process works in the real world.

*ii) What was the project intended to achieve?*

As stated in the specifications, this semester’s project entailed each team building an autonomous vehicle that plays a one versus one game of ‘Capture the Flag’. The robot was required to get to the flag zone by crossing a zip-line or traversing the virtual river through a specified path, search for the flag, and then return to its initial location. To simulate a realistic work environment throughout the project there was a top down structure in terms of organization. The professors, who played the roles of the client, presented the engineering team with a list of requirements and deadlines and reviewed our progress in weekly meetings. The teams were randomly formed resulting in members not knowing each other at the start of the semester. Part of the intended goals of the project was to teach students the communication skills needed to perform well in an intense project while co-operating with people they have never met before. To achieve a solution to the design problem, that includes inelastic deadline and budget constraints, the teams had to come up with an efficient process that consists of good planning and specialization of labor by sub-groups dedicated to parts of the design. All in all, the project intended to teach students the necessary steps of the process of designing a solution to an engineering problem given the usual constraints that apply in the industry.

2. Team organization- the startup of the project

*i) How were the tasks allocated?*

The two main factors that lead to the allocation of roles in the team were the capabilities as well as the availability of each member. At the start of the semester the members were asked to rate their own skills in various fields that pertain to the subject at hand and to fill in their weekly availability as well as any days that they would be unavailable. The tasks were then allocated such that the best individual in each department would get the lead position, as well as other secondary aid positions. The availability chart of each member was used as an aid for planning the project.

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| *Team member:* | *Assigned primary role:* |
| Antonios Valkanas | Team Manager |
| Ezz Aboulezz | Documentation Manager |
| Oscar Deceus | Testing Manager |
| Borui Tao | Lead Software Engineer |
| Hailey Kang | Lead Hardware Engineer |
| Raphael Di Piazza | Software Engineer |

*ii) How was the initial Gantt chart designed?*

Initially, the first version of the Gantt chart had several problems. Various dates were wrong and our resources where overused. There was little to no parallelism in tasks that were independent. Furthermore, there were issues with the team not working enough during certain weeks and overloading during others, while there were very few big tasks had subtasks. Thankfully, with the guidance of the supervising professor we quickly resolved these issues in the following weeks.

*iii) What information was used to estimate the initial task breakdown?*

The initial task breakdown was planned and budgeted according to our experience from labs 1-5. While these labs provided us with useful insight about the nature of the project, they lead us to severely underestimate the role of documentation in the budget. We quickly changed our initial approach since we realized that good documentation was vital for the purposes of communicating our work to members who were not in the lab to see it and to be able to go back to previous version of our design and fix mistakes when needed.

*iv) Were any guidelines followed in developing the first version of the chart?*

The initial Gantt chart was based on the template provided to us by the professors to help us get started with the project. Subsequent work was need to modify and improve it.

3. Issues encountered in the progress of the project

*i) Were all the dependencies correctly identified at the start of the project?*

At the start of the project the dependencies were mostly correctly identified with a few exceptions. The mistakes were fixed in later versions following the professor’s advice.

*ii) What dependencies contributed to the critical path of the project?*

The task dependencies in the critical path signify the interdependence of our software and hardware components as well as our testing. More concretely, only after choosing the initial design and developing the software can the robot be tested. Similarly, it is only possible to determine the constraints and reliability of our hardware only after having tested and fully characterized all of the sensors so that their behavior is known.

*iii) What initial ideas turned out either not to work or be based on wrong assumptions?*

The first two hardware design ideas were proven to be unreliable as they were unbalanced. It turned out that our assumption that the location of the center of mass of the robot wouldn’t matter was wrong as it affected both our navigation and the zip-line traversal.

*iv) What other issues/factors had an impact on the project?*

A very important factor that positively impacted our progress in the project was the collaborative mentality of the team. Team members were willing to go out of their way and help others to prevent overloading any individual with too much work in single week.

*v) How did these affect the project progress?*

The fact that all of our team members were eager to help each other in times of need created a sense of trust. Instead of keeping close track of everyone’s work and attempting to micro-manage every team member the team manager was able to allow team members to make more design choices on their own, as long as they were well documented so the rest of the team could keep up. This created a bottom-up approach to problem solving that sped up our progress.

*vi) In particular, did the project run to the plan you had initially created?*

While the initial plan was very close to tracking how our progress evolved in terms of what parts of the design had to come before others and the due dates of each component, it was ultimately not perfect. Small changes in the design decisions and unpredictable problems such team members falling sick forced us to make small modifications to the plan.

4. The budget

* *i) What constraints did the budget place on your team?*

A major constraint was the fact the each team member was not supposed to work for more than 9 hours every week. Naturally, since not every week required the same amount of work in software or hardware we had to modify our division of labor plan. Instead of having the software engineers work solely on coding, when there was not enough coding work to do in the early weeks they were tasked to help with the hardware design. Similarly, when in the final weeks, most of the hardware components were finished; the hardware team was asked to help with the testing of the robot. Another major constraint was the fact that we could not exceed 350 hours. Ideally, if we had more time we would have been able to devise a good search algorithm for the flag.

* *ii) How did initial planning for available resources and budget spending affect the development of the timeline?*

Knowing that during the first half of the project our work would coincide with the midterm season we decided to reduce our workload and to do the minimum required to progress at a reasonable rate. This had the advantage of being realistic about our time management problems and ensuring that the project would at minimum still advance at an acceptable rate even during the most intense academic periods. Additionally, this allowed the team to save up on its budget and to be able to work full time for the rest of the project until its due date.

* *iii) Did you allocate resources to all the project tasks, i.e. all the way to December 1, at the start of the project and use this to estimate the budget. If not, explain why not.*

At the start of the project, a lot of what we initially assessed in terms of the budget was wrong. Even though we did fill in the chart all the way to December 1 we underestimated a lot of important tasks and had a lot of overloading. After the initial two weeks we finally were able to get a good grasp of how much time each component of the project would take and our Gantt charts became much better. We were then able to use the Gantt chart to break down tasks and plan time-efficient and highly parallelized solutions to problems with individual components.

* *iv) What would you have spent if there had been no limits on the budget and when in the process would extra budget have been useful?*

Our maximum allowed budget hours were 351 hours and we ended up using 325 total hours. Despite having used most of our available time we needed more time as all of the slack time was used in weeks prior to week 4 when we had midterms and could not work full time. Ideally we would have used our entire budget since we believe that 351 hours are enough to complete the entire project with all its specs. During our project we found that it was never possible to have enough testing as new tests always revealed problems and potential improvements to our design. Realistically, if we had one more week to just test our design with a full 54 hours of work we think that we would have been able to fix our flag detection algorithm and would have been able to find the flag instead of just going to the flag zone and returning to our base.

* *v) Where were you weak in resources and what would you have done to resolve this issue if you had fewer budgetary constraints? At what point in the project could these extra resources have been brought in?*

We strongly think that the total amount of budget was enough to complete the project. However, if our budget’s rate of consumption was not limited to 9 hours per member per week we would have used the time saved during the earlier weeks and worked overtime in the last 2-3 weeks to test our design more.

5. How the process contributed to the success of the project

* *i) Was the process useful in achieving the goals?*

The process we followed broke down the design problems into small sections, which made the design modular consisting of relatively easy sub-problems. Each week the team had to solve a number of these sub-problems. Through good planning and work ethic we made sure to never be late on any goal by the end of the week. Eventually we combined our work in each module to a working prototype design and increasingly made it more successful until the day of the competition. The main tool that helped us achieve this was the Gantt chart.

* *ii) How would you modify the process to increase your probability of success?*

If we were to start the design over we would have arranged to finish everything a week earlier before the final demo to allow for more testing time. During the last two weeks when we started our final integration process, we were surprised to find out that even two whole weeks were not enough to perfect our design.

* *iii) Which parts of the process were the most difficult to implement and why?*

The toughest part of the process was planning the project. Even though this did not seem hard to us at first, we quickly found out that when we planned things poorly on the initial Gantt it was hard to stay on top of our weekly work. We then went back to the specification, improved our understanding of the problem and made a better estimate of what the process would look like. Once everything was planned out meticulously every problem was broken down into simpler tasks and nothing proved too difficult for our team to handle.

* *iv) How much time was devoted to testing?*

All of our team members contributed to testing as it took about a third of our total work time; 100 hours.

* *v) Was this at the subcomponent level or did you leave it all to the end?*

Even before having built a hardware design we started testing the sensor characterization tests. Our testing philosophy was to immediately test any new software contributions from our engineers and to attempt to integrate them on the design. As a result, testing was a continuous process for us throughout the project.

*vi) Were the tests you designed sufficient?*

All the tests that were carried out for a sufficient amount of time were good enough to create a final product that could meet all project specifications except for the flag search. The flag search algorithm is an exception since it was not tested nearly as much as it should have been. However, the fault here lies with our lack of time to carry out the test instead of the testing procedure itself.

* *vii) How much time did you estimate full prototype (i.e. integration) testing would take?*

The initial prototype for the beta demo was estimated to require 21 hours of testing. This was indeed the actual amount it took. On the other hand, the final integration testing for the November 24 presentation took us 32 hours. This was also predicted by our estimation; however we would have worked more if we had not reached our work-hours limit for the week. This shows that the total cost for the final integration was underestimated.

* *viii) How much time did it actually take? If there was a difference, why?*

As discussed above, since we were capped in terms of the number of hours for these two weeks we used all of our time left for testing. Ideally, if we had more budget for that particular week we would have spent it in testing since more was needed.

* *ix) How would you change your test design process to make it more effective?*

If we had more time to test we could have significantly improved our results. Having acknowledged that we can see that if we had worked harder in the initial stages of the project and finished the beta version of the robot earlier we would have had more time to test both before the beta and the final demo. Another factor that affected our lack of time during the final stages of the project is the fact that we didn’t plan our project very well from the start. If we had a good Gantt chart form the first day we would have saved both time and resources through better planning. Unfortunately, our initial mistakes in terms of planning cost us too much time.

* *x) What was the impact of the beta demo on your design process?*

The beta demo provided evidence that the design process was relatively effective but prone to failure, which reduced its reliability. After having localized and navigated to the zip-line. From what we assumed was sheer luck the robot’s circular guide managed to tilt just enough so as to hit the rail of the zip-line at a right angle which caused it to get stuck at the bottom of the zip-line. We were never able to replicate a run like this in our tests before or after the demo.

6. The success of the Design (Robot) in meeting the original specifications and the performance requirements

* *i) What is your impression of how the robot performed?*

We are quite satisfied with our robot’s performance. We were able to localize, navigate to the zip-line, traverse it and get to the enemy flag location. Due to accumulations of error our robot usually had problems returning to its original position. Our two main issues that we would have like to improve before the competition were the overall reliability of the system so it fails less often, and the addition of a good search algorithm for the enemy flag.

* *ii) Did the robot perform as you expected – i.e. if you wrote down what you thought it would do before the demonstration, did it meet or exceed these expectations?*

The robot performed as we had expected only in one run; when it localized, navigated to the zip-line, traversed it, went the flag location but failed to return to its original zone. Unfortunately, during one of the runs it crashed at its initial position for reasons that are still unknown to us and the other two runs we were not successful due to error accumulation on the odometer, which caused us to miss the zip-line.

* *iii) If the robot failed (i.e. did not meet all the performance requirements), why did it fail? Can you point to the sections of the documents that describe the decisions that led to the failure (provide the references to those decisions)?*

As evidenced by the demo our robot was able on at least one occasion to do what we expected it to do. The main reason for its failures can be seen in our software section, were we decided not to include odometry correction as we thought we could just re-localize often and avoid significant error accumulation. This decision was fine for the 8x8 grid but proved to be very bad for the 12x12 competition floor.

[\*Please refer to the Software Document, System model section p.5](Design%20Documents/Software/Software%20Document.docx)

7. Conclusions

*i) What did you learn from this course?*

The most important thing we learned in this course is the approach taken to solving engineering problems under budgetary, temporal and material constraints. Unlike, all the other courses where time for work is usually ample, we learned the value of planning long term and breaking big problems in parts, which can be solved systematically. Another important lesson we learned was that good team communication and organization matter much more than individual capabilities of any one team member in the overall success of a design process.

*ii) Explain why a clear, effective and controlled process is necessary when working in a team and what it helped you achieve.*

When working as a team it is a clear advantage to have a clear, controlled and effective process for the project. Firstly, a clear division of tasks ensures that no team member is unsure of what to do, which decreases the probability that multiple team members independently work on the same task while potentially leaving other tasks unfinished. Secondly, an effective process makes sure to maximize the breaking down of big tasks to subtasks and organizes the parallelization of said subtasks so as to minimize the time spent on any particular problem. Finally, a controlled process has a rigorous system of testing that allows it to self-correct based on what specifications it is failing to meet. Finally, having a clear, effective and controlled process ensures a high level of communication is present between the team members, hence allowing the team to have increased flexibility and encourages a good work ethic amongst the members.

*iii) Is any of it applicable to other courses you might take? (Name the courses)*

We expect the experience we acquired in the design process to be useful for our final year design courses as they will be similar in essence and maybe longer in comparison with the length of this project.

*iv) What would you change in what you did if you were doing it over?*

If we had the chance to redo the project from the start we would have spent more time understanding the specification and planning our workload out. A good Gantt chart from day one could have saved enough time to allow us test our robot for a few days more which would have allowed us to increase the reliability of our design and to have made a better flag search algorithm.

“The undersigned members of team 8 agree that the contents of both this report and the information handed in on cd, dvd or memory key, provide an accurate representation of the work done on this course and the contributions of each team member.”

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| **Name:** | **Signature:** |

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