ECSE 211 - Design Principles and Methods

Final Report

GROUP 11
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Abstract

This document will review the process Group 11 took to design LeBot James (our robot); it will address any issues encountered during the design process, as well as how organization, budget, and team management affected the outcome of the project.

NOTE: We consider the allotted 6 pages to begin on page 4 and conclude on page 9, since the previous pages are for organizational purposes.

The undersigned members of Team 11 agree that the contents of 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.

Alex Lam:

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1 EDIT HISTORY

- Saturday April 8, 2017:
  - **Durham Abric:** Initial set-up of document and entry of team management information/overview.
- Sunday April 9, 2017:
  - **Durham Abric:** Completion of report, edits made based on team feedback.

2 Introduction

2.1 Project Goal:

"Construct an autonomous robot to play a one-on-one game that is a cross between soccer and basketball. The robot must be able to play either forward or defense and be capable of navigating the field without hitting obstacles. Instructions are received via WiFi prior to the game."
- ***Project Description - March 12 2017***

2.2 Specific Requirements:

In order to compete in the competition, any robot had to receive parameters over WiFi, localize within 30 seconds (and beep once localization was completed), and remain in its designated offensive or defensive zone once it had been reached. During the competition, the robot had to perform without being touched or moved by the team, otherwise it would have been eliminated.

2.3 Necessary Functionality:

In order to accomplish the task described in section *2.1*, a robot had to be able to localize, navigate the field accurately (this requires odometry in itself), and avoid obstacles. Additionally, the robot had to have methods and mechanisms to retrieve and accurately launch a ball. The robot also had to have a methodology for preventing its opponent from scoring, although this didn't necessarily require any additional hardware design.

2.4 Purpose:

The purpose of this project, aside from competing in and winning the competition, was to provide hands-on experience working on a design team. Students gained insight into project management, design principles, team dynamics, communication skills, documentation, and software/hardware construction. All of these skills will be relevant in any engineering discipline or career, and also apply to most non-engineering disciplines.

3 Team Organization:

3.1 Task Allocation:

Due to the short time frame of this project, our team utilized an agile design process in order to grant us the flexibility to change our design continuously throughout the six weeks. As such, all team members were allotted tasks in parallel for each of our four sprints (summarized as *mobility*, *avoidance*, *ball manipulation*, *competition methods*). At any given time, the software and hardware teams would be working in conjunction to create an initial design, the testing team would test this design for proof of concept and calibration, and the entire process would be documented. This parallel approach was preferred since it allowed us to rule out ineffective designs and perfect our final design quickly, before the entire system had been created. Tasks were allocated based on the current sprint our team was undertaking, in a logical and straightforward manner. Due to the parallel and symmetrical manner of each of our sprints, our team's efficiency in accomplishing its tasks increased in each subsequent sprint as our team members became accustomed to the flow of work, design process, and the team dynamic.

Other, unique tasks (e.g. initial documentation, first 3 hardware designs, final integration testing) were assigned to the logical sectors of our team on an as-needed basis. As team manager, Durham was in charge of delegating these tasks and ensuring they were accomplished in a timely manner. The hardware/software/testing/documentation managers understood the parallel and iterative manner of the agile design process and were responsible for keeping their sectors on track with minimal oversight.

3.2 Gantt Chart Design:

The initial gantt chart was designed according to the typical agile design process, that is with each sector's tasks running in parallel. We initially planned on having a completed design (i.e. having full functionality) before the beta demo. Given that goal, we estimated each sprint's time frame using understanding of our team's prior knowledge, the perceived complexity of the task and whether or not we had the ability to recycle hardware/software. We then established delivery dates for each of our four sprints, and allocated time for the outlying tasks such as poster design and time for final integrative testing and final design revisions. We also took into account the *Preliminary Gantt Chart for Winter 2017*, as well as examples of a prototypical, agile gantt charts as guides for our own design; although, our initial chart didn't necessarily resemble either.

4 Project Flow:

4.1 Dependencies:

The great majority of dependencies identified in version 1 of our gantt chart were correct and necessary. Due to our agile design methodology, each sprint was dependent on the completion of the previous sprint. The initial sprint (mobility: navigation, odometry, localization), was dependent on the creation of initial documentation (including the first 4 documents and testing procedures) as well as certain project management tasks including the creating the initial gantt chart. While some dependencies were technologically mandatory (i.e. completing odometry before navigation), others were logically necessary. For example, we could have designed our ball launching and retrieval mechanism before completing navigation, however an immobile robot would not be feasibly able to use the ball manipulation mechanisms due to its inability to navigate to the ball retriever and a shooting position.

The tasks that made up the critical path of our project were: initial documentation, each of the four sprints (and each including design, testing, and documentation), integrative testing, poster design, and final documentation.

4.2 Failed Ideas:

Some of our failed design ideas include:

- Not using odometry correction: Decreased accuracy of navigation
- A launch arm oriented perpendicularly to the robots motion: Difficulty with ball retrieval
- Single motor launching mechanism: Did not generate enough power
- Multiple ultrasonic sensors: EV3 brick had trouble handling the increased workload

4.3 Ideal vs. Real Project Timeline:

Our project was delayed by multiple factors; some within our control, some ineluctable. We were delayed in our implementation of ball retrieval by approximately 10 days due to the late delivery of the dispenser model. Additionally, we fell behind our initial gantt chart delivery dates for obstacle avoidance and ball manipulation since the sprint to create the navigation/mapping capabilities ran overtime. We had initially planned to have a final design before the beta demo; however, we did not achieve this goal. Even so, we maintained the necessary pace of design to have a functional robot for the beta demonstration and a successful performance on competition day. We were able to succeed in completing the project on time due to an efficient design of our ball retrieval/launching mechanism. By keeping the ball retrieval/launching mechanism simple, we minimized the time we spent designing extra hardware and writing software to control it.

5 Budget:

5.1 Planning:

We felt it unnecessary to denote hours (i.e. budget) to certain tasks at the start of the project due to the uncertain nature of design (unknown complication, changes in requirements) and specifically the agile design process. This being the case, we focused on delivery dates instead of specific hour allocations for each of our tasks and sprints, as seen on the gantt chart. That being said, we devoted a longer period of time to certain tasks and sprints than others, given their expected complexity (addressed in section 3: Team Organization). We always fully expected to use all of our budget, and possibly go over budget; though this didn't end up being the case. Additionally, we strategically accomplished some major tasks (odometry, localization, basic navigation) over reading week, meaning the hours spent on these tasks didn't restrict our budget later on in the design process.

5.2 Constraints:

As a team of 5, we constantly felt constrained by the 270 (as opposed to 324) hours we were allotted to complete the robot. As a result, we tailored our design process to be as efficient as possible. Tasks were undertaken by the group as a whole, not by individuals; as a result of this collaboration we believe we were more efficient in the creation of the more basic elements of our design than if we had worked independently on multiple tasks concurrently. We felt it would be an inefficient use of budget to devote time exclusively to testing. Using a tenet of the agile design process, we conducted testing while we were still working on specific elements of the design. We also saved time on menial tasks by automating processes, including: debugging, the creation of tables containing test results, and task allotment (reminders, time tracking, etc.).

Our team constantly focused on quality of design, meaning we worked towards a robot that would work in *all* situations, not just one that would mediate error when possible. We used this principle both when designing hardware and software. As such, we would have most likely spent 350-400 hours of total budget if given the opportunity. The additional 80-130 hours would have been devoted to solving issues we felt unsure about on competition day. Namely, we'd have worked towards increasing the speed at which our robot performed (we managed 2 shots on target in the 7 minute competition), as well as increasing the efficiency of our code. The 4,000+ lines of code we wrote often overpowered the EV3 brick and caused threading errors, a constant source of frustration. We'd also have devoted approximately 15 of the additional hours to exhaustive competition-style testing on the 12x12 field if we'd have had access to it.

6 Design Process:

6.1 Our Process:

As previously stated, we followed the agile design process, which was integral to the success of our robot. The flexibility it offered allowed us to make design changes as we felt necessary, without throwing off our expected timeline. In retrospect, we'd have devoted more time to design revisions after integrative testing: we were able to successfully complete the offensive/defensive procedures in our final testing (on the 12x12 field), but we often suffered threading errors, throwing off the robot's performance. If we had had conducted this testing earlier in the design process, we could have eliminated these errors entirely before competition day. Instead, while we were confident in the robot's performance and worked to limit and manage our threads (after realizing threading was the cause of these errors during the Beta Demo), we were worried about experiencing one of these errors during the competition.

During the entire design process we devoted 61 hours to testing. Tests were conducted throughout the process, with each sprint also being tested as a whole. Finally, we conducted integrative testing before the competition, ultimately amounting to approximately 12 hours, with additional time devoted to fixing bugs we found in our software during this process (but we classified this as software). We had initially hoped to devote up to 20 hours to integrative testing, but due to the time and budget restrictions we faced approaching competition day ultimately cut back on this allotment. Our tests were absolutely sufficient; we knew our design's performance capabilities and limitations. And, although we still had a few bugs in our software on competition day (threading issues, calibrating obstacle avoidance/ultrasonic sensors), we were aware of them and would have fixed them if we had extra budget.

6.2 Possible Modifications:

We felt confident in our design process throughout the project; and still, as the process has been completed, are comfortable with the steps we took towards solving the problem at hand. That isn't to say our process was perfect by any means; we should have transferred hours between sectors and conducted more testing instead of devoting more time to exploring different hardware designs we explored in order to make ball retrieval easier, but ultimately abandoned. Ideally, we'd have tested more thoroughly on the 12x12 field as our mapping capabilities, shooting/retrieval algorithms, and navigation algorithms were specifically designed to perform on the competition-sized surface. These process were difficult to test in unison on the 8x8 field: this was the most significant challenge we encountered during the project.

7 Design Evaluation:

7.1 Performance Evaluation:

We believe our robot performed extremely well during the competition. Our design ethos (discussed in paragraph two of section 5.2: Constraints) meant that we would rather have created a robot that, although slow and methodical, would score perfectly once instead of firing three uncertain shots at the target. This design choice affected our performance during the competition positively. By re-localizing before ball retrieval and shooting, we expended extra time but performed consistently. Of the 5 shots we took during the competition, all 5 passed through the target. Moreover, 6 out of our 8 attempts at ball retrieval were successful, with the two failures occurring because we drifted off our path and attempted to odometry correct at an incompatible line. We also demonstrated our ability to avoid obstacles (scanning the destination square before making any moves), and block shots.

By any standard, we believe our robot's performance should be classified as a success; especially so when compared to the average performance of our competition.

7.2 Revisions:

Our robot performed according to our expectations, as established during integrative testing. During this testing phase, we determined that our robot could accomplish all the tasks laid out in the project description, so we were confident entering the competition. Our only real concern was whether we would experience a threading error, which although would not have immediately caused a failure, could have limited the robot's accuracy of movement and therefore its ability to play defense, retrieve and shoot balls effectively. This did not happen and our robot performed according to our expectations.

8 Conclusions:

During this course, we learned the value of design process (discussed below), as well as more specific information, which was taught during the lectures and labs, but intended to be utilized during the project (odometry, localization, etc.). We also gained invaluable experience working on a design team; specifically, we improved our communication skills, documentation abilities, and were introduced to testing and refining a design in order to accomplish a specific task. For most of us, this course was also an introduction to robotics and it pushed at least two members of our group (Alex and Durham) to explore this field further by joining the ECSESS Robo-electronics club. Aside from teaching new skills, *Design Principles and Methods* also allowed our team to practice and improve upon skills in fields we'd already begun exploring. For example, while all of our team members have had experience developing Java programs, we all learned new techniques in Java development, including: multi-threading, use of the volatile keyword, polling analog sensors, using Git, and maintaining/organizing a large-scale, collaborative project. We even learned basics about structural integrity and statics while building the stable base and tower of our robot, and applied principles of energy conservation and rotational motion when constructing the ball launching mechanism.

Given our experience in this project, the value of an established and controlled process has become evident to our team. We believe our commitment to an agile design process, as opposed to the more traditional waterfall process, was integral to our success as a team. Aside from giving us design flexibility, it also minimized the budget that we would have had to devote to the exploration of possible designs before we began building the robot. In addition, a clear process is necessary when working in a team because it helps keep team members coordinated and on task at all times. Regardless of the hours we could have expended on this project, without the organization of a clear design process, it's dubious that we would have been able to accomplish the tasks laid out in the project description. The major challenges of working with a team are communication and organization; by agreeing on a design process early in the project timeline, we curbed both of these issues. Additionally, it became unnecessary for us to debate the "next steps" after completing a task, because we already had an established process to follow. We even featured a description of our design process prominently on our poster, after realizing its massive contribution to our success as a team.

The values of employing an controlled process can be applied to any problem solving situation, as well as to any collaborative effort. Even more so, the communication and team management skills learned while building the robot are applicable far beyond the classroom, into industry and even personal ventures and projects. These skills are also applicable to some McGill courses, including but not limited to: ***CCOM** 206, **COMP** 250/251/360, **ECSE** 222/223/456/457.* All of these classes contain some sort of creative design, software development, or team project aspect.

We discuss the changes we would've made to our design process in sections: *4.1, 5.2, 6.1, 6.2,* and *7.2*. In summary, we would have allotted additional time to our final testing and increased the efficiency of our code to suit the limitations of the EV3 brick. Overall, we are content with our design process and the entire path we took to accomplishing the task outlined in section *2.1*; as a team we've learned a great deal during this project, feel that we worked well together, and were, as a whole, successful.