Robot Soccer

Functional Specification Document

Team Slash-Dash-Bang-Hash (/-!#)

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# Introduction

This document contains an analysis of the goals and requirements of the robot soccer senior project. We start with a discussion of who our customers are and their needs. We then move into a discussion of specifications and metrics that we will use in order to measure how well we are fulfilling those needs. Our goal in this document is to provide benchmarks by which we will be able to guide our efforts throughout this project.

# Project Description

1. **Background/Product Description**

This is the fourth consecutive year that robot soccer has been done as a senior project at BYU. As a centerpiece of the ECEn on Display event, its primary purpose is to drum up excitement for and interest in the Electrical and Computer Engineering department. However, recent entries have often fallen short of this goal because they do not perform at a high level. Thus, the primary objective of our project is to create a product that will be entertaining to watch.

That product will consist of a team of two robots who will cooperate in order to autonomously play a modified version of soccer. In order for them to complete this objective, we will need to implement a complex system with major components responsible for:

Computer Vision - We will need to take images from a camera placed over the playing field and determine the locations of the ball, friendly robots, and opposing robots.

Artificial Intelligence - The robots will need to be able to analyze the data from the camera and determine an optimal play to execute.

Motor Control - The robots will need to be able to move where the AI tells them to quickly and effectively.

1. **Market Analysis**

|  |  |
| --- | --- |
| Product Description | Two robots that autonomously play a modified version of soccer against another team of two autonomous robots. |
| Primary Market or Use | -Fulfill ABET requirement for an engineering design project.  -Advertise the Electrical Engineering Department in order to attract more students |
| Key technology or features | -Autonomous, self-powered robots driven by Raspberry Pi 3’s.  -Overhead camera and computer for vision processing. |
| Describe the intended user | -Students advertising to the public |
| Critical Assumptions | -Outputs to robots are PWM commands to motors and similar commands to any additional hardware that we add.  -Collisions are illegal  -The field is designed so that the ball cannot get stuck along the walls  -Vision processing will be the most computationally intensive bottleneck  -Motion control will be comparatively difficult to implement  -This simulation has good fidelity relative to the actual operation of the robots |
| Stakeholders | -Team members  -Advisors  -Electrical and Computer Engineering Department |

# Project Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| **Need #** | **Customer Statement** | **Interpretation** | Priority level  (1=high to 3=low) |
| **1** | **Be entertaining** | Play soccer at a level that is entertaining, score points, avoid down time and deadlocks | 1 |
| **2** | **Follow Rules** | Rules as defined <http://rwbclasses.groups.et.byu.net/doku.php?id=robot_soccer:2016:rules> must be followed | 1 |
| **3** | **Robot is fully functional** | The robot operates without human intervention for the course of a game | 1 |
| **4** | Batteries last full match | The batteries powering the robot last the entirety of a match | 3 |
| **5** | Parts are not dropped on the field | During normal play the robot does not drop any parts on the field | 2 |
| **6** | Robot can withstand collisions | The robots can remain fully functioning when hit head on with another robot both going at top speed | 3 |
| **7** | Easily maintained | The robots are designed and built such that each part is easily disconnected and reconnected without disconnecting any other pieces | 2 |
| **8** | Simple design | The robots have a simple hardware design that can be easily taught to the full team | 2 |
| **9** | Robot moves smoothly | The constructions of the robot allows smooth movement in any direction | 3 |
| **10** | **Outperform other teams** | Score more points than opposing teams | 1 |
| **11** | Teamwork | Ally robots take mutually beneficial actions | 2 |
| **12** | Can pass ball | Ally robot in possession of ball can accurately pass possession of ball to the other ally robot | 3 |
| **13** | Can dribble ball | Ally robot in possession of ball can reliably traverse the field in any given direction and maintain control\ over the ball | 3 |
| **14** | Can defend | Gain possession of ball and/or remove ball from opponent control | 2 |
| **15** | Can block shots | Block ball from entering our goal | 3 |
| **16** | Can shoot ball | Ally robot can accurately shoot ball at opponent goal | 3 |
| **17** | Obstacle avoidance | Robots avoid obstacles in their path to any given point | 3 |
| **18** | Screening play | Ally robot blocks opponent robot by moving into its path | 3 |
| **19** | Avoid walls | Robot avoids running into walls | 3 |
| **20** | Movements reflect AI decisions | Robots move and kick in order to take possession of ball or to better position the robot to score | 3 |

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# Product Specifications

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Metric** | **Need** | **Metric** | **Ideal Value** | **Margin Value** |
| 1 | 1 | Number of audible positive reactions from the crowd | > 5 times | > 1 time |
| 2 | 2 | Number of rule infringements in a match | 0 | < 2 |
| 3 | 3, 4 | Average battery life in minutes | > 90 min | > 30 min |
| 4 | 3, 5, 6 | Number of fallen/broken parts throughout semester | 0 | < 3 |
| 5 | 7, 8 | Average time spent on a single replacement/repair | < 10 min | < 30 min |
| 6 | 9 | Translational movement in a 360 degree rotation | 0 cm | < 5 cm |
| 7 | 9 | Rotation that can be made in 1 m straight line translation | > 360 deg | > 180 deg |
| 8 | 10 | Average number of goals made in excess of the other team. | > 3 | > 1 |
| 9 | 11, 20 | Number of consistently successful team strategies | > 3 | > 1 |
| 10 | 12, 13 | Success rate for attempted passes | > 80% | > 50% |
| 11 | 13 | Turning radius while maintaining control of the ball | < 5 cm | < 50 cm |
| 12 | 14, 18 | Success rate for intercepting opposing robot | > 90% | > 70% |
| 13 | 15 | Success rate for intercepting ball shot at our goal | > 90% | > 60% |
| 14 | 16, 20 | Success rate for shots on opponent goal | > 75% | > 30% |
| 15 | 17, 20 | Number of collisions with other robots per game | < 2 | < 5 |
| 16 | 19 | Number of collisions with walls per game | < 2 | < 4 |

# Analysis of Metrics

**Metric 1:** This is a measure of how entertaining our robot soccer matches are. We use audience reactions to gauge how entertained they are. These numbers will mostly be collected during the final public competition. We can get some preliminary data at practice competitions, but since the audience there will probably mostly consist of project participants, the numbers may be skewed.

**Metric 2:** This is a measure of how well our robots follow the rules. We will watch for rule violations during our practice matches in order to measure this.

**Metric 3:** This measures how long our robots will run effectively without having to charge or replace their batteries. It will be crucial to be able to run for long periods of time during tournaments. We will test this throughout the course of our robot development by running tests for other metrics for extended periods of time. The batteries are considered dead when the robot stops moving or when its movements become sluggish enough to adversely affect performance.

**Metric 4:** This measures sturdy robot construction by measuring how often the robot catastrophically breaks (losing parts on the field iis both against the rules and likely to make the robot non-functional). We will keep track of this throughout our testing during robot development as well as in official matches.

**Metric 5:** Robots often must be repaired quickly during competitions as there might not be much time between rounds. This measures both how maintainable our robot is and how prepared our team is to repair the robot in a short amount of time. We will measure this throughout the course of the semester as the robot breaks during testing or competitions.

**Metric 6:** We want our robot to be able to rotate in place without having to translate. To measure this, we will place our robot on the field and measure the x and y coordinates of the center of the robot. We will then instruct the robot to spin 360 degrees without translating and measure the x and y coordinates of the robot again in order to find the translational displacement.

**Metric 7:** We would like for our robot to be able to rotate and translate at the same time. To measure this, we will place our robot on the field and measure its x and y coordinates. We will then make instruct the robot to move one meter in a specified direction at a constant speed while rotating a specific number of degrees. To be considered successful, the robot’s final position must be one meter away from its starting position in the specified direction. It’s angle of rotation is also measured. We theorize that this translational rotation will be more difficult to do as the number of degrees it must rotate increases.

**Metric 8:** We would like our robots to consistently outperform other teams. We will measure this by the number of points that we scored in excess of other teams at the end of a match.

**Metric 9:** We would like our robots to have multiple strategies or plays to use against other teams, and we would like for at least some of these plays to achieve their desired effect consistently. To be considered consistent, a play must achieve its intended purpose (score a goal, block an incoming robot, take possession of the ball, etc.) at least 80% of the time. We will measure this both in simulation and in actual games by having the robots create a log file of the plays they are attempting so that we can determine when each play was successful through analysis.

**Metric 10:** We want our robots to successfully and consistently pass the ball from one robot to another since this will allow for more varied plays. We will measure this by having our robots attempt passes and measuring their success rates. In full-game environments, we will have our robots log when they are attempting a pass so that we can analyze if the pass was successful or not.

**Metric 11:** We want our robots to be able to maneuver while maintaining control of the ball including making tight turns. We will measure this by having the robot turn 90 degrees at different turn radii while attempting to control the ball. If the robot still has control of the ball at the end of the turn, then it is successful. Control is defined as begin able to move the ball as the robot moves as well as keeping the ball in range of our robot’s kicker.

**Metric 12:** This is a measure of how well we can intercept other robots either to defend our goal or perform a screening play. In simulations, we will test this by having our AI run a defensive or screening play while the enemy AI runs an attack play. In physical testing, we will configure one of our robots as a defender/screener and one as an attacker. In games, we will use our log file to analyze when our robots attempted a defensive/screening play. A success occurs when the defending/screening robot successfully intercepts the attacking robot and prevents them from reaching their intended destination. In simulation and testing, we will know the attacker’s intended destination and will thus be able to determine this metric with 100% accuracy. In games, we will not know that attacker’s intended destination and will have analyze whether the defender/screener was successful based on where it appears the attacker was headed.

**Metric 13:** We want our robots to effectively block shots headed for our goal. To measure this, we will keep track of how many times a ball is headed into our goal, based on its position and velocity. If the ball makes it into our goal, it is a failure; if one of our robots blocks the ball from going into our goal, it is a success. If our robot blocks the ball, but it still goes into our goal, it is also a failure.

**Metric 14:** This is a measure of how well our robots score goals on our opponents through shots. We will keep track of every time that our robots attempt to shoot a ball into the goal using log files and we will compare that with the actual number of goals scored in order to measure this metric.

**Metric 15:** We want our robots to avoid colliding with other robots since it is both against the rules and has the potential to cause damage to either robot. This metric also measures our obstacle avoidance. To measure this, we will simply count the number of times a robot collision occurs each game.

**Metric 16:** We want our robots to avoid colliding with the walls in order to avoid damage. We will measure this by counting the number of wall collisions during each game. This should be easier than Metric 15 since walls are stationary.

# Conclusion

In order to fulfill the objectives that we have identified, we have also identified benchmarks and specifications to measure our progress. As we work on this project throughout the semester, we will use those benchmarks in order to tell how well we are meeting the customer needs. By creating a product that meets the specifications listed above, we will have a successful senior project

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