BRIGHAM YOUNG UNIVERSITY

Robot Soccer

Functional Specification Document

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This document provides the functional specifications that will be used throughout the development of the robot soccer project.

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Introduction

This document defines the features and specifications of a pair of soccer-playing robots. It also analyzes customer needs and how well the product meets these needs. This document serves as an outline for our product, and will be updated as new information becomes available. Our customers are interdisciplinary researchers who will use this robot to study control systems, system architecture, robotics, and artificial intelligence.

Background

Robot Soccer is an international phenomenon, with elite teams from all over the world gather to pit technique, strategy, and brawn against each other to earn victory on the soccer field. There are currently two international organizations that regulate robot soccer competitions: The Federation of International Robot-soccer Association (FIRA) and RoboCup. Both of these organizations were founded in 1997 and have continued to gain international popularity.

Brigham Young University also hosts a robot soccer competition. Our robot soccer project is designed to be a dominant and competitive team in our BYU competition. This project is the second iteration of the senior project since it was put on hiatus and will involve completely new hardware components.

Product Description

Robot soccer requires true system-level design. Our team must integrate a wireless communication system, computer vision, feedback control, real-time programming, artificial intelligence, and mechanical design. Second, the overall project is much too ambitious for a single student, so teamwork is essential.

The overall layout of the project is shown in the figure below.

The robots will be competing 2 vs. 2 on small, walled soccer field. The field will be approximately 5 feet wide by 10 feed long. Goals will be 2 feet wide. An overhead camera will provide images to each team's base computer to allow algorithms to compute the location and orientation of the four robots and the ball. This information will then be streamed via wireless communication to the individual robots, who posses the artificial intelligence to analyze the data and make a competitive play.

Our project is to design the robot system, as well as the image processing software. These robots will be completely autonomous and will require no human interaction after being activated and placed on the playing field. The scope of our project will involve mechanical design, computer vision, motion control systems, artificial intelligence, and system architecture. Most importantly, all of these systems will work seamlessly together while following the pre-programmed game rules.

Our robots will consist of several subsystems. Processing will be done on an ODROID-U3running Linux off of a microSD card. We will use Robot Operating System (ROS) to allow inter-process communication. All our robots will be equipped with a USB WiFi adapter to allow communication. Our robots will be powered by two 7.2 V NiMH batteries connected in series. Mobility will be provided by 3 omnidirectional wheels driven by motors. TheRoboclaw 2x5A board will be used to control the motors. Finally, the robot will include a solenoid-powered kicker and dribbling bar to allow it to control and shoot the ball.

Project Requirements

Our project will need to meet requirements specified by both the BYU robot soccer competition and our customers. To design the best product possible, we gathered input from our customers and studied the competition rules. Our customers have provided several different constraints. Some are more important to the success of the project than others. Furthermore, some would require more resources than we have available for this project in our current time frame.

Our product cannot compromise in meeting game rules. Consequently, meeting all of the rule constraints are top priority. We then analyzed the customer requirements and prioritized them based on their importance to the success of the project.

Mission Statement

Our mission is to create a fully autonomous robot that through superior hardware and software design is capable of playing within specified game rules and outperforming the competition.

Game Rules

One set of requirements come directly from the rules of the BYU robot soccer competition:

- Robots must fit within a cylinder of 8-inch diameter and 10-inch height
- The ball is a standard golf ball, the color will be determined by majority vote.
- The playing field is 5 feet wide by 10 feet long. The sides of the field are angled so that a ball cannot get stuck against the sides or corners.
- Goals will be 2 feet wide.
- Robots must be designed in a way that will not damage other robots, the playing field, or human spectators.
    - Kickers are not allowed to shoot the ball hard enough to damage other players.
    - Robots must avoid collisions.
    - Any contact with a defender while in the defense area will be a violation
    - Outside the defense area, contact that noticeably changes a player's orientation, position, or motion will be a violation.
- We will not observe the traditional off-sides rule.
- Robots cannot drop parts on the field
- Robots are not allowed to fix the ball to their frame or encompass the ball in any way that prevents access by other players.

Point Evaluation of Customer Needs

The table below specifies our customers requirements. We have ranked them by priority.

Priority: 1 = Very High, 2 = High, 3 = Moderate, 4 = Low

Req. #	Customer Statement	Interpreted Need	Priority
1	Follow the rules of the game	Robot's AI must abide the BYU competition rules.	1
2	Win the game	Robot must be competitive and be able to score on the opposing team.	1
3	Be able to kick into the goal from any field position	Robot must be able to find goal and kick with enough strength to reach the goal.	3
4	Batteries last the whole match	Robot should be power efficient to maximize battery life.	1
5	Robots work together as a team	Robots should be aware of each other and use coordinated 2-robot tactics.	2
6	Robots can block shots from going in goal	Robots can maneuver between ball and goal from any arbitrary position.	1
7	Robots are agile and move quickly	Robots can move in any direction, change direction quickly, and have high speed.	3
8	Robots are robust	Robots can survive being hit by ball or other robots without issues.	3
9	Robots look cool	Robots appearance well designed	4

Req. #	Customer Statement	Interpreted Need	Priority
		and constructed with precision.	
10	Robots are not expensive	Robots use commercially available, low-cost components.	3
11	Robots have an easy to use API	Software is well organized and clear documentation is available.	2
12	Easy to add and modify tactics	Software is extensible so tactics can be added/modified without breaking it.	2
13	High cross compatibility with common protocols	Common communication standards and software are used (e.g., WiFi, Linux, C++)	4
14	The system is simple	Software has a minimal amount of code and the robot has minimal components.	2
15	Vision algorithms are accurate and fast	Computer vision software can precisely and accurate location robots and ball.	1
16	Robots can dribble the ball	Robot must maintain control of the ball when maneuvering.	1

Product Specifications

Measurable engineering characteristics and target values are critical for our design. This section outlines both the metrics we will use along with ideal and actual results.

Metrics

Metric #	Req. #	Metric	Ideal	Margin	Units
1	2,6	Goals scored minus conceded goals	>2	>0	goals
2	6	Percentage of shots blocked given random speed and location of robot	>99	>80	percent
3	15,6	Maximum difference between calculated ball position and actual position	<1	<3	cm
4	5,3,15	Maximum difference between calculated robot position and actual position	<1	<3	cm
5	10	Maximum total cost of all components of both robots	<25	<50	USD
6	14	Maximum number of physical components in	<10	<15	components

Metric #	Req. #	Metric	Ideal	Margin	Units
		each robot			
7	7,6	Maximum speed of robot in one direction	>200	>100	cm/s
8	14,11,12	Number of lines of code (total)	2000	<3500	lines
9	7,4	Maximum weight of a single robot	<5	<8	kg
10	4	Minimum battery life while robot spins in place	>60	>30	minutes
11	16,7	Maximum distance from ball to dribbler while moving at top speed	<2	<5	cm
12	8	Minimum force that sides and top surface of robot can withstand uninjured	>8	>5	newtons
13	3	Percentage of goals when shot from random location by stationary robot	100	>80	percent
14	1	Compliance to the rules	100	100	percent

Metric #	Req. #	Metric	Ideal	Margin	Units
15	9	Beta customer ratings on product aesthetics	>8	>6	scale from 1 to 10
16	13	Compliance with 802.11b/g/n standards; Compatible with Linux 3.12	100	100	percent

Analysis

Here, we list a description of each metric and how it will be tested.

Metric 1: This metric is simply a judge of how effective our robot soccer players are. We would like to win each match by a margin of 2 pts. We can gather data after each match.
Metric 2: This tests the effectiveness of both our computer vision algorithms and the ability of our onboard AI to react to the ball. The robot will be placed at a random location on the home-side of the field. A ball can then be shot towards the goal from the away side of the field with random starting location and varied speeds (with a maximum speed of 7m/s) and we can calculate the percentage of shots block out of 30 shots taken.
Metric 3: This tests the accuracy of our computer vision algorithms. The actual location of a stationary ball (measured using tape measures) will be compared to the location that is output from the computer vision algorithm.
Metric 4: This tests the accuracy of our computer vision algorithm be comparing the actual location of randomly placed, stationary robots with their actual positions.
Metric 5: We want our robot to be affordable on a student budget. We will track how much we spend on components and record the total.
Metric 6: For simplicity, we want our robot to be made of a few subsystem components as possible. This is simply the total count of these subsystems (e.g., 3 motors, 2

batteries, 1 power board, etc).
Metric 7: We want to measure the maximum speed of our robot moving forward in a straight line. To measure this, we can time how long to takes for the robot to travel a pre-measured distance.
Metric 8: This metric will count the total lines of code we produces for the software and artificial intelligence of the robot (including comments). This just provides a rough measure how our code's simplicity.
Metric 9: To improve battery life and speed, we want our robot to be lightweight. This is just the measure of the mass of the fully assembled robot as a whole (including batteries).
Metric 10: To get a sense of how long our battery will last during a game, we measure how long it takes to drain a fully-charged battery by simply spinning the robot in place.
Metric 11: To measure how well the robot controls the ball while dribbling, we measure the maximum distance of the ball from the dribbler while moving forward at top speed.
Metric 12: This metric will not be tested until the failure point. Rather, we will simply place weight on the robot's top as well as placing weight on the robots side (by laying it down sideways) and confirm that the body can handle the specified amount of weight.
Metric 13: To test the accuracy of our robot's kicks, we randomly place the robot on the field and place the ball in it's possession. Then, we allow the robot to turn to face the goal and shoot. We measure the percentage of shots that went in our of 30 shots taken.
Metric 14: To participate, our robot must obey all competition rules. We need to go through all the rules and verify that all are met.
Metric 15: We will ask a sample of people to rate the aesthetics of our robot on a scale from 1 to 10 and take the arithmetic average.
Metric 16: In order to operate, our robot will need to run Linux and be able to receive data over WiFi.

Note that several of these metrics are related to each other. As we design our robot, we will need to be aware that changed made to meet one metric may affect another. For example, change in the weight of the robot may affect the maximum speed of the robot and how long the battery lasts.

Robot Soccer's Hardware and Software Organization

A block diagram of this information will be added shortly.

Summary

In order to meet the expectations of our customer's need, we will create prototypes to test based on this Functional Specification Document. This document outlines our requirements and priorities. It also summarizes the hardware we will have to use along with a brief description of how our software should behave. The document also provides high level diagrams and descriptions of the robot soccer competition as well as the robots themselves. Most of the individual subsystems and components that will be used are well documented. Our principle challenge will be integrating these separate parts into a competitive soccer-playing robot. There will be two general stages of development. First, we will create a mechanical prototype and software architecture that allows us to communicate with and move the robot in simple patterns. Second, we will fine tune our artificial intelligence to utilize more effective and fine-tuned strategies. To accomplish this goal, we will create a schedule to meet different benchmarks. During development, we will work on meeting as many metrics as possible until the deadline.