Concept Generation and Selection Document

Robot Soccer:

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Introduction

The purpose of this project is to design and build two autonomous robots that can play soccer. The robots on our team, Cristiauto Robaldo, will be competing against other teams in a tournament at the end of this semester.

In order to win the final tournament, our robots will need to outperform the other teams' robots. The best robots will need to have superior mechanical design, smarter artificial intelligence algorithms, faster computer vision, and more efficient control systems.

This documents outlines how our team decided on various components of our robots. The body-of-facts will be presented, followed by our key assumptions about this project. We will then demonstrate how we arrived at a few critical decisions pertaining to the design and construction of our robots, showing the design matrix and our justification for how we rated each alternative before settling on a final decision.

As a team, we determined the body-of-facts, assumptions, and critical design decisions during our regularly scheduled weekly team meetings, when all members were present. All members were invited to suggest ideas, and if any idea had the support or agreement of any other members then it was added to this document.

The numbers associated with the decision matrices in the Critical Design Decisions section were similarly determined in a group setting. Because the numbers were subjective, and because many of the numbers were selected through hypothesizing and estimating, we took some liberty in adjusting the numbers, where appropriate. The final numbers were agreed upon by all the members of the team.

Body of Facts

Below is a list of some of the key facts that our project will build upon:

- There are two robots per team.
- The robots will be autonomous, with all processing done on board.
- There is a set list of the same hardware for each team.
- The ECEn shop will supply us with motors, a Raspberry Pi, and batteries.
- We have five members on our team.
- We will use ROS, and can code the nodes in C++ or Python.
- We will receive a view of the playing field from an overhead camera.
- We will be given a uniform to cover our robot for competitions.
- The final competition will be April 18th, 2017, or right around then.
- Our standard for success will be our outcome in the final competition.

Assumptions

Below is a list of some of the key assumptions that we are making as our project progresses from the core body-of-facts to the actual product:

- We will receive hardware with ample time to assemble the robots before the deadline.
- We will implement the ROS nodes, AI, and PID control in Python.
- Each team member will put in at least 5 hours each week, outside of classes.
- Each team member will complete multiple assignments, jobs, and responsibilities.
- We will all learn the hardware and software necessary for the project.
- The rules for the competition will be predetermined, with ample time to incorporate any changes into our robots and algorithms.
- The simplified McThuggets code, which the TA's have placed online for our reference, works properly.
- Each member will document their code.
- Our entire team will meet on a regular basis, at 11am on Fridays.

Critical Design Areas

Robot Construction Material

Criteria

The material from which we will construct our robots will have a large effect on the appearance, performance, reliability, and longevity of our robot. To meet our objectives and ultimately perform well in the final tournament, we determined five criteria to rank each possible construction material.

Cost - We want the material to be inexpensive. As with any project, we want to keep our budget as possible while still meeting all other specifications. We gave this criterion a

Construction Material for Robot Frame

	WEIGHT	Plastic	Plexiglass	Aluminum
Cost	0.10	5	1	4
Ease of Manufacturing	0.15	3	3	4
Effect on Hardware	0.15	5	5	1
Weight	0.30	3	3	2
Strength	0.30	2	4	3
FINAL SCORE		3.2	3.4	2.65

relatively small weight of 10%, because we are not planning on making this product commercially. The weight is also small because the cost of the frame materials is not likely to be very significant when compared to the cost of the motors, chips, and other mechanical components of the robots.

Ease of Manufacturing - We want the material to be easily shaped, cut, and attached. We are electrical and computer engineerings, not manufacturing engineers. We are capable of learning the basic manufacturing techniques, but the material cannot require any major expertise. Ease of manufacturing is also important because we will likely be making multiple prototypes before we arrive at our final system; simple manufacturing will make iteration between stages faster and more efficient. We assigned a weight of 15% to this criterion.

Effect on Hardware - The frame will be supporting many chips, motors, batteries, kicking devices, and wires. A metal frame will require taking additional precautions that there are no exposed connections, such as wires that could touch a metal frame and cause a short in our system. A conductive construction material will require all wires and connections to be insulated and padded, resulting in higher costs and additional work. We also gave this criterion a weight of 15%.

Weight - The weight of the robot affects the speed, response time, and power consumption of the robot. In order to optimize each of these categories, the robot should be lightweight. We assigned a weight of 30% to this criterion, because the weight of the construction material will be a significant amount of the total weight.

Strength - Our robot should be made of sturdy material. This will make our robot more durable, long-lasting, and more resilient to potential drops or accidents. According to the rulebook, robots should practice collision-avoidance. That being said, it is likely that our robots will make substantial contact with other robots, due to faulty collision-avoidance algorithms and to the nature of the game. Our robots should therefore be able to withstand crashes. We gave this criterion a weight of 30%.

Alternatives

We identified three alternative materials that we considered to have decent rankings on all of the above criteria. They were: plastic, plexiglass, and aluminum. Below is the ranking matrix we used to determine our final decision. We gave each alternative a score between 0 and 5 for each criteria.

Score Justification

Cost - We determined these scores by looking up the cost of each material, per square foot. Plastic was the cheapest, followed by aluminum. Plexiglass was quite a bit more expensive than either of those.

Ease of Manufacturing - Plastic and Plexiglass are both easily cut with a laser cutter. Aluminum received a high score because it can be both cut with a laser pointer and also molded into any desired shape.

Effect on Hardware - Plastic and plexiglass both received top marks for being insulators, and therefore having no interfering effect on electrical components. Have a frame of aluminum would require insulating and padding all wires and connections.

Weight - Aluminum is slightly more heavy than plastic and plexiglass, so it received a slightly lower score.

Strength - Plexiglass is a thermally treated plastic, and is therefore stronger than plastic. Aluminum is less prone to breaking or cracking than plastic, but it also could potential be dented and bent out of shape.

Final Result

After scoring each alternative in light of all the criteria, and multiplying the score for each criterion with its respective weight, plexiglass received the highest total score. As seen from the numbers, this is likely due to the favorable properties it shares with plastic, but also being stronger than normal practice. It only received a low score on cost, but we had assigned a low importance to that criterion. Therefore, we came to a consensus that the construction material we will use for our robot's frame is plexiglass.

Type of Kicker

Criteria

Several of the customer needs that we outlined in the Functional Specification

Alternatives for Kicker Implementation

	WEIGHT	No Kicker	Solenoid	Pneumatic
Cost	0.10	5	2	1
Accuracy	0.30	0	3	3
Power	0.30	0	4	3
Simplicity	0.20	5	3	1
Weight	0.10	5	1	2
FINAL SCORE		2	3	2.3

Document require that our robot be able to score goals from a distance. Additionally, some of the defensive plays that we want our robots to perform require the ability to move the ball faster than the robots themselves can move. With this in mind, we need to determine if we should install a kicking device and, if so, which kicking device to install. Below are five criteria that we considered when answering these questions.

Cost - As with all our other critical design decisions, we want to take the cost of all materials into account. We assigned a weight of 10% to the cost, because the cost of the kicker should not be a very large portion of the overall cost of the robot.

Accuracy - The kicker needs to be accurate. Some of our plays and algorithms require shooting at a particular side of the goal, or passing to a particular point on the field. In order for these plays to be executed correctly, the kicker needs to place the ball where the algorithm expects the ball to go. We gave a weight of 30% to this criterion.

Power - The kicker needs to be powerful. This is important to both offense and defense. On offense, a more powerful kicker will mean a faster shot, which in turn will be more difficult for our opponents to block. On defense, a more powerful kicker will enable our defender to clear the ball to the other side of the field more quickly. We assigned to this criterion a weight of 30%.

Simplicity - We want the technology behind our kicker to be as simple as possible. This includes simplicity in implementation, integration with other hardware, and amount of power consumed. Greater simplicity will allow us to make adjustments to both the kicker and to the whole design as we iterate from design to design. We assigned a weight of 20% to simplicity.

Weight - As we mentioned in earlier design decision, we want our robot to be lightweight. This will make the robot faster, more agile, more responsible, and less power-consuming. We don't anticipate the kicker to be a significant amount of the total weight of the robot, so we gave this criterion a weight of 10%.

Alternatives

We considered three distinct alternatives: we could use a solenoid or a pneumatic device to implement the kicker, or we could decide to use no kicker at all. We evaluated each of these alternatives in light of the above criteria, giving each alternative a score between 0 and 5. Below is the resulting decision matrix.

Score Justification

Cost - We determined these scores by researching and comparing the typical costs for a solenoid actuator and a pneumatic actuator. A solenoid is slightly less expensive than a pneumatic device, while no kicker obviously receives top marks for incurring no cost.

Accuracy - We judged the solenoid and the pneumatic actuators to have similar potential to be accurate. This metric is inapplicable to the alternative of no kicker, and thus that option received a score of zero.

Power - From initial research we conducted, the solenoid appeared to be slightly more powerful than a pneumatic device. The alternative of no kicker received zero points, for obvious reasons.

Simplicity - Having no kicker would be the simplest design. Of the other two alternatives, the solenoid is simpler due to it only requiring a single electric pulse, with little overhead or response time.

Weight - Using no kicker would be most helpful for keeping our system lightweight. Pneumatic actuators are generally heavy devices, but solenoid actuators can be even heavier still.

Final Result

After giving each alternative scores for each criterion, and multiplying by that criterion's predetermined rate, we summed up the final score for each alternative. As seen from the above chart, the solenoid actuator received the highest total score. Even though it is heavier than the pneumatic device, that disadvantage is outweighed by its advantages in cost and power. After reviewing these results, our whole team agreed on the decision to use a solenoid to implement the kicker on our robot.

Non-Critical Design Areas

Shape of the Robot

While we did not enumerate the potential shapes, we agreed to use a circular frame with a straight line cut out of one end, where the kicker will be. This is the design we will use for our prototype, and we may experiment with other shapes in future iterations.

Path Planning Algorithm

To implement path planning, which enable the robot to move around obstacles between it and its desired position, we had to select a certain algorithm. While there were several good options such as Dijkstra's algorithm or RRT (rapidly-exploring random trees), we decided to use a much simpler approach that just evaluates four potential options. Once we have a working robot that performs path planning, we will consider the complex algorithms that may be more efficient.

Summary

In this document we have presented some of the facts and assumptions that our project depends on. We then identified some of the critical design elements of our robots, and we demonstrated our decision making process. We used decision matrices, and justified all of the weights and scorings that we assigned to each alternative we considered. We finished by outlining some of our non-critical design decisions.