Designing Winning Robots
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1 Introduction

Robots tend to be rather complex by nature, and with so many possible components, tinkering with parts is unlikely to produce a winning robot. Successful robots show design, and often make the best out of what little time and resources with which teams are presented. The design phase is crucial to a team's success, but it requires proper organization of thought. This paper discusses the use of a modified form of the Engineering and Design Process that has worked for some teams in the past (3).

2 Design Objectives

Objectives are what aspects a team wants and needs their design to have (1). Some objectives change with strategy, but many are generic to robots. Examples of generic objectives include robustness, ease of build, simplicity, and multifunctional. Task specific objectives often relate to variables such as how fast something needs to be done. The objectives can be put in an indented list to organize them and get a general idea of what things are trying to be accomplished. Here is an example of an indented objectives list for a robot that can place pyrite in the caldera.

1. Can obtain both cubes

  1.1. Can obtain consistently and quickly

2. Can place cubes in the caldera

  2.1. Can knock the third cube into the caldera

  2.2. Can place cubes consistently and quickly

3. Programming does not rely on time

3.1. Can use sensors to navigate

3.2. Does not rely on precise set up

4. Can be built within the timeline

4.1. Can be built with available materials

4.1.1. Uses few resources

4.1.2. Uses passive components

4.2. Robust

4.2.1. Simple

4.2.2. Multi-functional

3 Morphological Chart

Morph charts are used as a way of considering as many possible designs in the brainstorming process (4). On the left side of the table are sub functions and functions of the device, and in the columns are potential ways of performing that function. This chart produces a large number of potential solutions, but not all are feasible. The following is an example of a morphological chart for the robot that places the cubes in the caldera.

Example of Morphological Chart

Function	*Means*		
Drivetrain	iCreate	Demo bot	None
Obtain cubes	Gripper	Rubber band	Scoop
Lift cubes	4 bar linkage arm	2 Dof arm	Elevator
Operate lift	Gears	Linkages	Pulleys

Place cubes in caldera	Release grip	Set arm down	Dump
Positioning	Timed	Touch sensors	Distance sensors

4 Brainstorming

At this point in the design process the objectives of the design have been defined, as well as some of the means of achieving them. Now, a team must try to develop several different complete solutions so that they can diversify their options. To do this the team could be divided into sub groups, or individual members. When coming up with designs, it is important to keep the designs different in some manner. There are hundreds of possibilities, and there is no such thing as a wrong idea. A design that may sound absurd might be entirely possible; creativity is key.

4.1 Models and Proof of Concept

Since Botball is a team competition, it is necessary to be able to explain a design to the team so that a decision can be made on the final design. While words are useful, it is sometimes difficult to explain complicated designs to everyone. For this reason it is helpful to physically demonstrate the design in some matter. A model of the design could be a sketch on paper, a CAD (Computer Aided Design) model, or any kind of prototype that conveys the concept of the design.

5 Developing a Design Matrix

The next step in the process is to construct a design matrix from the objectives. The purpose of a design matrix is to create a systematic approach to evaluating how well a design satisfies the objectives of the build (2). In the matrix, the objectives are written on the top, and the designs are listed on the left. Each design is ranked according to how the team perceives the design would satisfy each objective. Rankings can be on any kind of numerical scale, and the better the design fits the objective, the higher the rank. Objectives can also be weighted when it comes to the total sum. It might be more important for the robot to be robust than it is for the robot to be easily built. In this instance, the rank for the designs under the robust objective would have a multiplier of some number based on how important the team perceives the objective to be. The following is an example of a design matrix for the robot that places cubes in the caldera.

Example of Design Matrix

_	**Ease of Build-X1**	**Parts Required-X3**	**Robustness-X2**	**Total**
Elevator bot	3	2	4	17
Catapult bot	1	4	2	15
2 DoF Arm bot	4	3	3	19

In this example, the 2 degrees of freedom arm design has won as its total score is highest. If the scores in the design matrix tie or are very close, more objectives can be compared. If one score is marginally larger than the others, it might be necessary to reconsider the rankings on it to ensure that there is no bias.

6 Implementing the Design and Summary

After the robot design has been chosen, it is time to begin building and prototyping. Since the components of the robot are known, it is beneficial to develop a tentative timeline for the completion of the robot. The final step of the design process is analyzing weaknesses and adjusting the design. In summary, the design process is crucial to the success of a team's robot, and this method can provide structure to the process. Through proper utilization, it can save a team time, resources, and lead to a better robot over all.

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8 References

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