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# Lessons from Beyond (Botball)

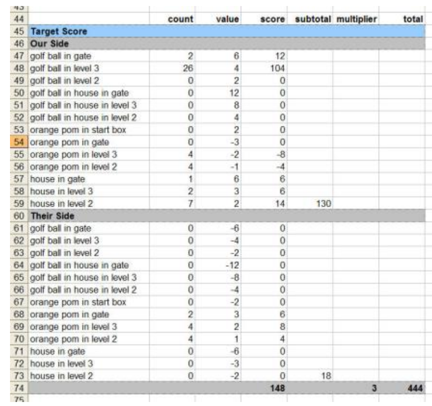
## 1 Introduction

After several years of competition in Beyond Botball, I have some observations on this class of robotics that I would like to share. I have a collection of videos and stories that others may find interesting and helpful in their future developments. Most of these videos are available on the Explorer Post 1010 web site.

## 2 Lessons (some learned and some not)

### 2.1 Solving the Problem

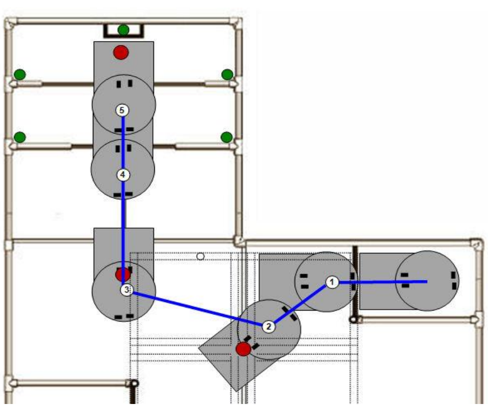
To state the obvious, there are many ways to solve a Botball game problem. You will not be able to score the maximum points possible, certainly not in the limited game time. You will be lucky to score even twenty percent of the maximum points. Your first effort should be to read the documentation on scoring points. After understanding the requirements for scoring, you should make a spread sheet of the scoring possibilities. By working with the spread sheet, you will begin to develop an optimized scoring strategy.



| 44 | | count | value | score | subtotal | multiplier | total |
|---|---|---|---|---|---|---|---|
| 45 | **Target Score** | | | | | | |
| 46 | **Our Side** | | | | | | |
| 47 | golf ball in gate | 2 | 6 | 12 | | | |
| 48 | golf ball in level 3 | 26 | 4 | 104 | | | |
| 49 | golf ball in level 2 | 0 | 2 | 0 | | | |
| 50 | golf ball in house in gate | 0 | 12 | 0 | | | |
| 51 | golf ball in house in level 3 | 0 | 8 | 0 | | | |
| 52 | golf ball in house in level 2 | 0 | 4 | 0 | | | |
| 53 | orange pom in start box | 0 | 2 | 0 | | | |
| 54 | orange pom in gate | 0 | -3 | 0 | | | |
| 55 | orange pom in level 3 | 4 | -2 | -8 | | | |
| 56 | orange pom in level 2 | 4 | -1 | -4 | | | |
| 57 | house in gate | 1 | 6 | 6 | | | |
| 58 | house in level 3 | 2 | 3 | 6 | | | |
| 59 | house in level 2 | 7 | 2 | 14 | 130 | | |
| 60 | **Their Side** | | | | | | |
| 61 | golf ball in gate | 0 | -6 | 0 | | | |
| 62 | golf ball in level 3 | 0 | -4 | 0 | | | |
| 63 | golf ball in level 2 | 0 | -2 | 0 | | | |
| 64 | golf ball in house in gate | 0 | -12 | 0 | | | |
| 65 | golf ball in house in level 3 | 0 | -8 | 0 | | | |
| 66 | golf ball in house in level 2 | 0 | -4 | 0 | | | |
| 67 | orange pom in start box | 0 | -2 | 0 | | | |
| 68 | orange pom in gate | 2 | 3 | 6 | | | |
| 69 | orange pom in level 3 | 4 | 2 | 8 | | | |
| 70 | orange pom in level 2 | 4 | 1 | 4 | | | |
| 71 | house in gate | 0 | -6 | 0 | | | |
| 72 | house in level 3 | 0 | -3 | 0 | | | |
| 73 | house in level 2 | 0 | -2 | 0 | 18 | | |
| 74 | | | | **148** | | **3** | **444** |

Figure 1: 2009 Target Score Spread Sheet

Once you have a potential scoring strategy, you need to develop a navigation strategy for your robot. You need a navigation path that will permit your robot to score the points in your scoring strategy. You should develop a two dimensional diagram of the navigation path against a diagram of the game board. The diagram will help you identify “way points” for sensing the navigation path, and will lead to an outline of your initial program. These diagrams are from our Beyond Botball 2009 effort.




**Phase 1**
**Step 1**
Pre Action: close arms fully
Drive: straight
Drive Condition: none
Time: 3sec
Stop Condition: either rear line sensors black
Post Action: turn left 40 degrees

**Step 2**
Pre Action: Botguy arm up
Drive: straight
Drive Condition: none
Time: 2sec
Stop Condition: none (timer only)
Post Action: knock down Botguy; wait for golf balls

Figure 2: Beyond 2009 Navigation Design

***Lesson:*** **You must solve the navigation problem, or nothing else matters.**

### 2.2 Overall Strategy

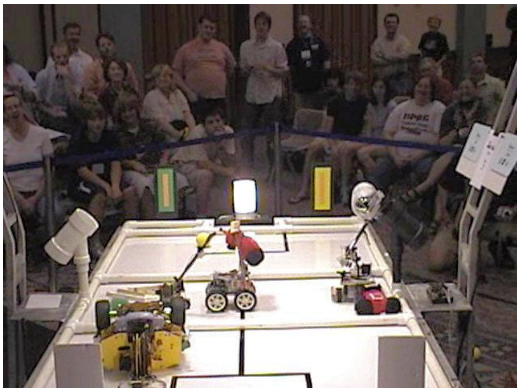


Figure 3: Beyond 2006 Multiple Robots

The more robots you have scoring points, the better chance you have to get a good score. You need to spread out your risk, and reduce the complexity of any one robot. If you can have four objects on the table, you should put four objects on the table.

In Beyond Botball 2006, we had three operating robots. They started in a rather small starting box. Each one could score points independently. They used different spaces on the board, but provided a front across the board for the opponents to deal with.


Figure 4: Beyond 2008 Multiple Robots

For Beyond Botball 2008, we had two robots which could score points independently. We also had a simple static blocker robot. This collection of robots proved to be very important in winning the seeding rounds and competition rounds. When one robot would fail or get stopped by the competition, the other one would score enough points to win the round.

***Lesson:*** **Multiple robots score multiple points.**

### 2.3 Mechanical Design

Simple, tight structures are always more consistent and reliable. Good structures give you confidence in their operations. They provide a versatile base and will lead to an observable style.


Figure 5: Beyond 2005 Lego Robots

Our robots in Beyond Botball 2005 were made out of Legos, compression fittings, and paper. While they had some great runs, they also wobbled and had some inconsistency. So in Beyond Botball 2006, we decided to use bolts, nuts, and lock washers to attach motors, servos, and arms. The bodies were made out of plastic boxes. We increased stability and reliability.

In Beyond Botball 2007, we realized that 8 of the 12 scoring objects were within two feet of the corner of the starting box. We decided on a static robot to grab four Botguys and four foam balls. By eliminating the navigation, we could concentrate on the arms, grabbers, and the servos. And since all the objects were in fixed locations, be didn't need any object sensors. We used wood for arms and structures because it is rigid, but very light weight. We were trying to stretch over a long distance.

And then in Beyond Botball 2008, we used metal parts from an extra IFI kit to make rigid base structures. We focused on building trusses and attaching arms sensors, and controllers to the trusses. A great example of a truss structure is the International Space Station.

***Lesson:*** **Tight structures are more operationally consistent.**

## 2.4 Programming

Figure 6: Beyond 2007 Static Robots

Code style is important. Code comments are important. Tight code is important. You are writing code to be read by humans. The computers don't need comments.

Our static robot in Beyond Botball 2007 used an array of positions and actions to drive the arm It was easy to arrange object order and refine positions by making changes to a single array. The array also helped in reveling alternate strategies.

Optional behavior should be programmed in and made available to the operators. In Beyond Botball 2008 there were two starting boxes and a left or right side to the assigned starting boxes. We used several variables to drive the behavior of the robots based on where they started and our opinion of the competition.

***Lesson:*** **Write clean code with optional behaviors.**

## 2.5 Refinement

Once you have a basic solution, you should be prepared to add subtle behaviors that increase consistent scoring and reduce risk. Usually this refinement takes place after you have a complete design and implementation. So it is important to complete your implementation early enough so you have time to add the refinements. If you can get your maximum score about 90% of the time, you are ready to compete.

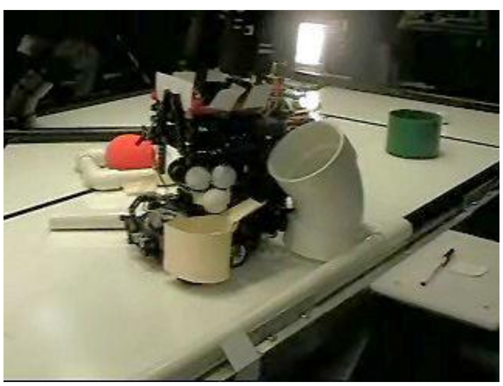


Figure 7: Beyond 2005 Ball Shake

In Beyond Botball 2005, we had a robot that grabbed twelve ping pong balls and sorted them into different containers. Sometimes they would get stuck, so we introduced a slight wiggle to the sorter.

In Beyond Botball 2007, we had a robot that picked up four different Botguys and dropped them in a specific place. Sometimes their eyes would catch on the grabber, so we introduced a little shaking right after we dropped them to make sure they were out of the grabber.

***Lessons:*** **Subtle actions can make big differences.**

## 2.6 Participation

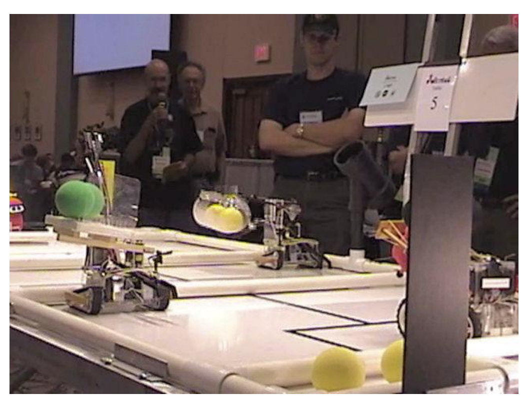


Figure 8: Paul Newell Watching Beyond 2006

Get other people to run your robots. As a developer, you may not be the best operator. You may out-think yourself and you can learn a lot about your robot when you watch someone else operate it.

Try to video your runs. The videos make great learning tools. And watching the audience and other participants can be as interesting as watching the robots.

***Lesson:*** **Have other people run your robot.**

## 3 References

The primary references for this report are the videos of our robots for Beyond Botball 2005, 2006, 2007, and 2008. They can be found in the archives of the Explorer Post 1010 web site at http://exploring.external.lmco.com/archive.html.

The following are some references for other robotic efforts that detailed their lessons. While the robots are very intriguing, it is important to look at the way they conducted their effort. You can learn from the tools and techniques that the developers used to create and operate their robots.

Balch, T., Santamaría, J., Boone, G., Collins, T., Forbes, H., and Mackenzie D. 1994. Lessons Learned in the Implementation of a Multi-robot Trash-collecting Team. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.56.7697.

Bares, J. and Wettergreen, D. 1999. Dante II: Technical Description, Results and Lessons Learned. *International Journal of Robotics Research*, Vol. 18, No. 7, July, 1999, pp. 621-649. http://www.ri.cmu.edu/publication_view.html?pub_id=3050

Luis Montesano, L., Minguez, J., and Montano, J. 2006. Lessons Learned in Integration for Sensor-Based Robot Navigation Systems. http://intechweb.org/downloadpdf.php?id=4168