The Perfect Free-Throw

New Mexico
Supercomputing Challenge
Final Report
April 1, 2009

Team 24
Bloomfield High School

Team Members:
Matthew Crockett
Lane Pablo
Riki Edwards
Cameron Corley
Sunni Baird

Teachers:
Hank Starr
Jeff Raichel

Project Mentor:
Elvira Crockett

Table of Contents

Summary:

Observing the physics used in shooting a free throw and sinking the shot can reveal to us the technique you can use to master free throw shooting. This model shows that with some precise factors, you can examine how thrust and trajectory affect an athlete's free throw shot. A lower trajectory and higher thrust made the ball travel way too low and straight at the hoop with no arch to make the shot, where on the other hand a high trajectory with low thrust created a simulation wherein the ball never made it to the hoop.

Problem:

During this time of intense March Madness basketball, wouldn't it be ideal if you could make every free throw that you shot? This was the problem that our Super Computers group attempted to solve with a simulation using Star Logo TNG programming. This is a huge problem because in the world of basketball, free throw shots can win or lose a game for teams extremely often. Two of our members actually witnessed this problem during their season of basketball this year; free throws would make or break the game for their team. These shooting percentages then create a perfect problem that could be solved to create a legendary universal answer. Obviously our problem is not like a virus that has an extensive range of effects, we have narrowed our characteristics to a field of basic basketball players.

By using the simple question of, “Is there a specific trajectory, thrust, and positioning that can sink a free throw every time it is used?” it tapered our search to basic physics equations, and prior experiments that were also used for this problem. Many prior experiments have been conducted to solve this problem due to the relevance and importance of the solution, but the challenge with our problem was to perform an accurate simulation. One similar experiment was created by Mindy Gutman who used a basketball to find the coefficient of restitution for different balls and floors. Though her purpose and basic information was useful, she did not use the same variables so this factor made it difficult to compare our two experiments. We found another that was created by Daniel Engber a Slate scientist who actually created an experiment to perform the opposite effect of our simulation. He created an idea that if all of the fans behind the basket would move their “distractions” and themselves in one fluid movement in one direction, the player’s mind would actually think the player was moving and attempt to compensate for this movement in the shot. This experiment was tried with the Mavericks NBA basketball team and in their game against the Celtics, the Celtics actually only shot 18 for 30 at the line showing that the movement really does affect the shot of the players. With cohesion of these experiments, we were able to work together to create a simulation to actually show our experiment that could be used to make the shot.

Method:

In the world of basketball, it is necessary to practice a specific technique when you shoot, we favored the BEEF method to distinguish the technique we figured we could use in our simulation. Though in TNG we could not make a shooter agent that could be edited so we could change their procedures, we still needed a basis to work from. The BEEF method has four easy steps that can easily be remembered. First, keep your **B**alance. Every shooter has a different routine when they step up to the free throw line, whether it is two dribbles or no dribbles at all. However, every good shooter begins with balance, there is always a nail or dot at the middle of the free throw line, find the nail or dot and line your shooting foot up with it and be on balance. This is the B in BEEF, BALANCE. Keep your **E**lbow straight. After you have your balance, have your elbow on your shooting hand line up to make an L right under the ball. This is the first E in BEEF, ELBOW STRAIGHT. Focus your **E**yes on the rim. Keep your eyes on the back of the rim, so you are basically looking through the net. Aim for the back of the rim. This is the second E in BEEF, EYES ON THE RIM. **F**ollow through. After you release the ball, keep your hand up in the air as you were reaching into a cookie jar. This is the F in BEEF, FOLLOW THROUGH. Remember to keep your eyes on the basket the whole time and hold your follow through. The most important thing in a free throw is where you put your shooting hand leg. That means, if you are right-handed, line up your right foot exactly even with the basket right on the line, vice-versa for left handed players. This will improve your free throw percentage dramatically. Another important factor is bending your knees! If you don't bend your knees you have a hard time getting the basketball all the way to the basket.

This technique plays a huge role in the literal shooting of the ball, but in the simulation, we mainly focused on the basic factors that would affect our free throw shot. We knew that gravity would play a roll on the trajectory and thrust of the ball so we knew that this variable had to be included in our programming. Another factor we knew needed to be included was the velocity that the ball exited the shooters hands, which we hoped could be executed by using the thrust slider that we created. One other major factor was the time variable. The time it took the ball to reunite at the end at the hoop was necessary to complete our equations, and to create a comprehensive program.

Coding:

The coding language we chose was StarLogo TNG, primarily because we do not have anyone on our team who has any experience in programming, and it is a simple program to use. Our model is based off of a pre-set model in the system called “Bouncing Balls”. The StarLogo TNG program can model problems with physics. StarLogo TNG was a good choice for our project because we are modeling the perfect free-throw, which requires the use of physics equations.

When we first started the programs, we looked at the flat plane as being the x-axis and the air as being the y-axis. But once we got our project moving, we couldn’t figure out why our agent kept curving to the side instead of making an arch motion. We realized that there was a z-axis coordinate that must be involved.

We also could not figure out how to put a stop on our agent once it got moving toward the hoop. At first it was bouncing back and forth from one end of the spectrum to the other, and then the agent kept rolling past the hoop and stopping after and returning back to the beginning position. Once we mastered the stopping of the agent, we then noticed that our ball was traveling in a parabolic motion horizontally rather than vertically as initially intended.

Janet Penevolpe helped us out tremendously; she came one day to work with our team. Since none of us had any programming experience, we did not even know that there was a model library. We had started completely from scratch; we were trying to build a model by putting equations and variables in and deciding if they worked or not. If they didn't work, we would just throw them out and try a different equation. Janet showed us how to use a model and helped us begin altering it to make it do what we wanted it to do.

Once we began doing this, we decided it would also be a good idea to look up some statistics on NBA players' free throw shooting percentages. We took three big guys, Kareem Abdul-Jabbar, Yao Ming and Shaquille O'Neal, and compared their free throw shooting percentages. Yao Ming was number one on Interbaskets list of players over 7'2" with the best free throw shooting percentage, shooting at .786%. Surprisingly the NBA's all-time leading scorer Kareem Abdul-Jabbar came in ninth with a percentage of .721% from the line. And Shaquille O'Neal came in dead last on their list of twenty seven shooting .525% from the free-throw line.

What we had to figure out what made Ming so much better than O’Neal and even better than the leagues all-time highest scorer. We figured out that it was the angle of trajectory: the taller the higher the angle of trajectory would need to be to make a free throw. We looked up a formula online that showed how to calculate the perfect angle of trajectory for a particular player’s height, in our case any player over 7’2”. We found an equation that would help players calculate what their angle of trajectory should be in order to shoot a perfect free-throw. The equation said to take your height, figure the angle from the top of your head, divide the angle in half, and add forty-five degrees. This would create the perfect angle you should shoot at. Unfortunately we could not get the equation to work in our simulation.

Analysis:

In our initial programming we attempted to use equations that we figured would work that we could never get to generate the program. Now that we are using the pre-made program, our Setup already included a “clear all” section to the ball would reset every time, a “show clock” that would help us with the time variable. It was necessary that we use the “create a ball” section that included the “xy” coordinates, and the “altitude” for the ball to travel. In the Setup where we used the “create the hoop” section, we also set an “xy”, and an altitude for the hoop as well. Our “Global” section is the portion that we are attempting to change to make the program run correctly. We used a “Run” section where we set the z velocity, set the altitude, set the y coordinate, and set the x coordinate all for the ball. We did not use anything for the “Run” section for the hoop because we wanted the hoop to remain stationary. The only initial agents that we used for the ball were gravity, friction, z velocity, x velocity, y velocity, and altitude; we included all of these agents in the “Ball” section in the program.

We have realized from all of the work on the programming that our ball needs to arch to complete the shot, but our ball is only traveling halfway through the arch. Somehow we need to create an equation in the program that will finish the latter portion of the arch motion.

Conclusion:

From our gathering of data we have concluded that though there is a precise way to simulate the shooting of a free throw that can be made every time, it is humanly impossible to create a flawless free throw record. In our simulation it was possible to control all of the factors necessary, especially because we did not have to deal with the reactions or movements of the shooter themselves, because we were mainly focusing on the ball alone. However with research, we have found that an athlete cannot control one’s muscles enough to create the intricate factors necessary to perform the simulation.

In our research we found that though a higher trajectory helps with the shooting of the ball, it would result in the use of a higher thrust as well. However, using a lower trajectory can be beneficial if you can master the small amount of thrust that would be essential.

Accomplishments:

Our team had many things to overcome. Our team started out with a programmer, whom we lost almost immediately due to other commitments he had made. Our original project idea started out as, “How many licks does it take to get to the tootsie roll center of a tootsie pop?” Unfortunately we were told that was going to be very difficult to model on StarLogo TNG. We then decided we would try modeling population growth. That idea was shot down because none of us were truly interested in the subject. Finally, we found a subject that we could all relate to: basketball. We had three basketball players on our team and two of us kept statistics for the team. We noticed that free-throws could make or break a game, and they were a growing problem on all levels of play.

Our team still struggled greatly due to the loss of our programmer; none of us truly had any real programming experience. We finally were able to get some help from Janet Penevolpe, Talaya White, and John Paul Gonzales, who are members of the Supercomputers mentors and advisors. With their help, we were able to figure out where to begin programming, instead of just playing around with the program and trying to start from scratch.

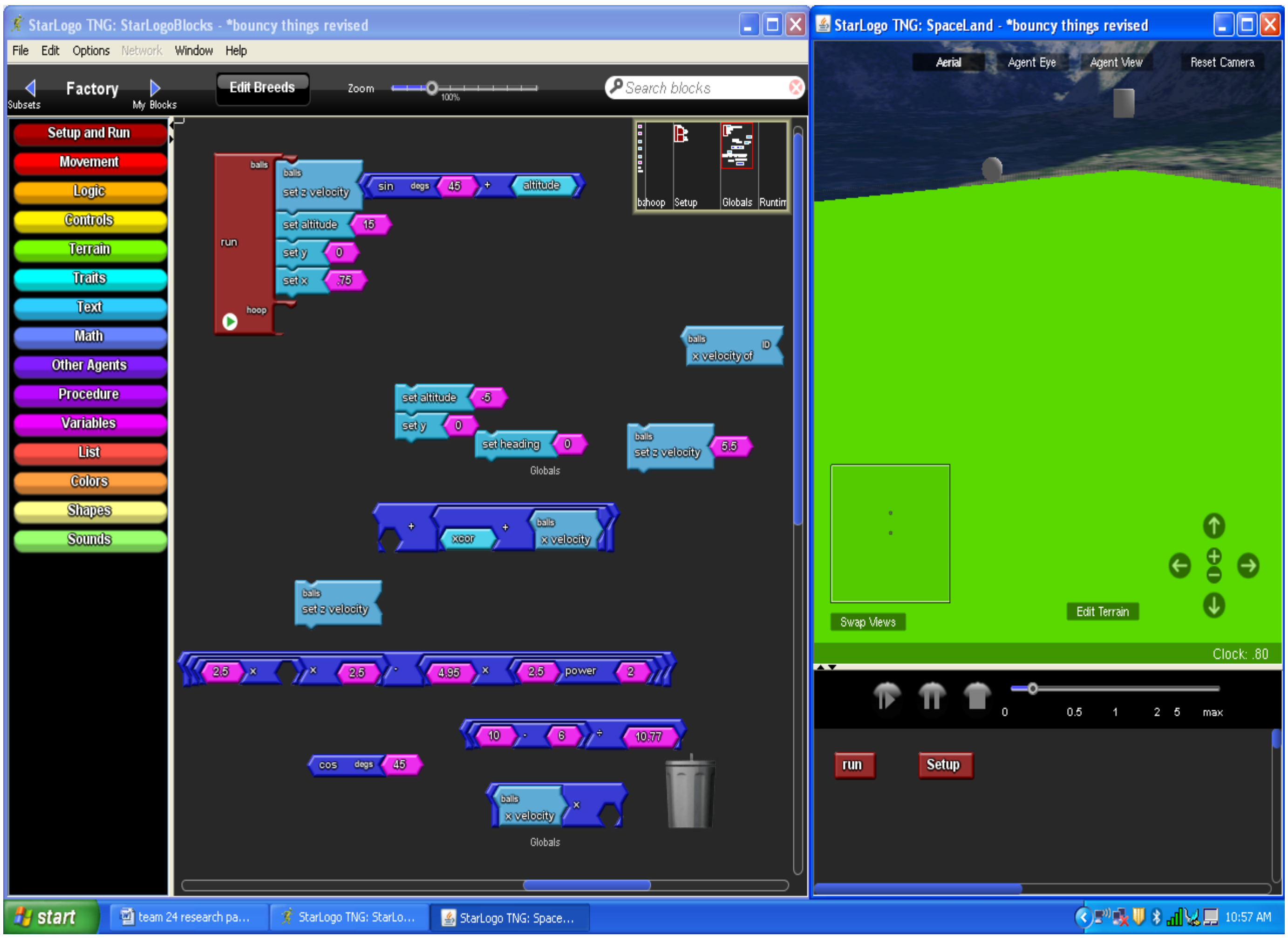
Our team was made up of a bunch of us who had never worked together before, so we learned a lot about each other. One thing that became a conflict was that not all of us had the same goals. As seniors we initially were more geared towards doing this to get scholarship money, but as time went on, we have learned that it is not all about the money; we must put the project, as well as our other team members first in order to accomplish the assignment. And as juniors they really had no motivation to work for our goal, because they still have one more year. They now understand what it means to us, and have come together and put forth effort on our behalf. We also learned that each of us have different skills and talents that we were able to put to use in creating our project. We have learned to lean on each other, and also that some of us are more willing to step up to certain tasks then others.

Acknowledgements:

We would like to thank Mrs. Crockett for organizing our Supercomputing group, and assisting us in all of our time management, and resources. We would also like to thank Mr. Raichel and Mr. Starr for helping us create equations to use, and how to form the variables to fit our particular problem. More thanks goes to Janet Penevolpe, Talaya White, and John Paul Gonzales for coming to our school and helping us learn the programming and narrow our project to a definite possibility. We would like to also extend thanks to MESA for the transportation of these individuals to come and assist us during our Supercomputing Challenge.

Appendix I

Perfect Free Throw Model



Citation:

1. Engber, Daniel. Slate Scientists. January 12, 2005. http://www.slate.com/id/2111939//.
2. "From 15 Feet, Yao Towers over Shaq, NBA Giants." Interbasket. March 31, 2009. http://www.interbasket.net/news/518/2008/11/16/tallest-basketball-nba-players-free-throw-shooting/
3. Gutman, Mindy. "The Physics of Sports." June 6, 1997. http://www.glenbrook.k12.il.us/gbssci/phys/projects/frig/yepbymgu/sport1.html
4. <u>NBA Encyclopedia: Playoff Edition</u>. NBA Media Ventures. March 31, 2009 http://www.nba.com/history/players/abduljabbar_bio.html
5. Rubenstein, Ben. "How to Shoot a Free Throw." http://www.wikihow.com/Shoot-a- Free-Throw
6. Serway, Raymond A., Faugh, Jerry S. <u>Holt Physics</u>. Harcourt Brace & Company, New York. 1999.
7. "The Physics of a Free Throw." March 30, 2009. http://lc3.littlechute.k12.wi.us/High%20School/Academics/Science%20Department/Janssen/Physics%20Of%20Project/projects/danross/The%20Physics%20of%20a%20Free%20Throw.htm