Simulation of a Free Kick

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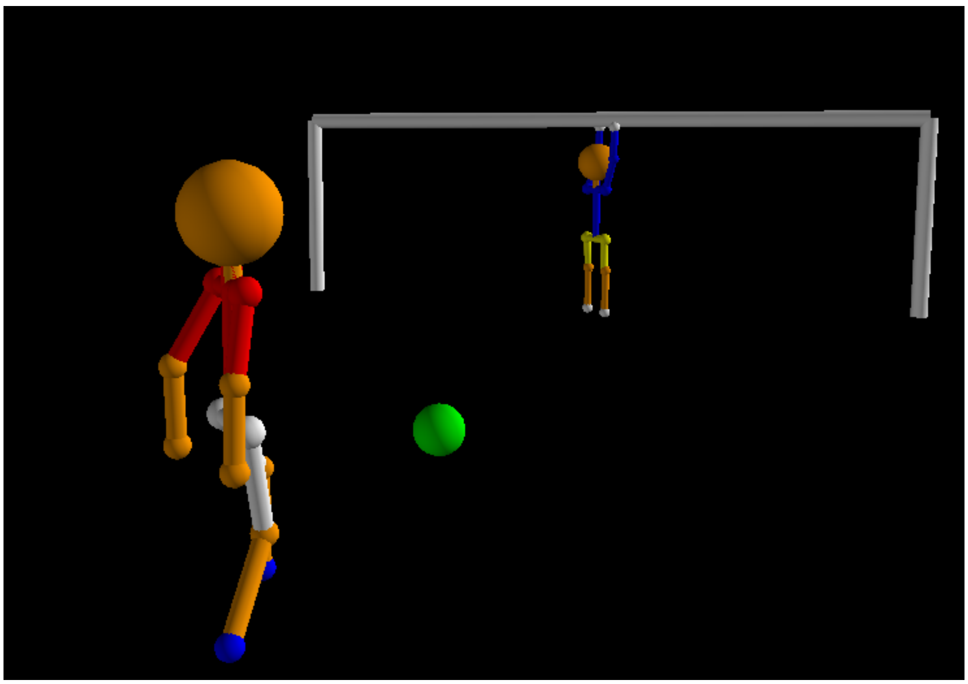


Contents

1 Abstract

Over the course of a semester I embarked on a project with the goals of: learning how to program using Python and Vpython, and creating an animated model of a soccer player taking a free kick. The end result includes not only the free kick simulation, but also an animation of a player performing some basic ball juggling. I chose this topic in particular because I am an avid soccer fan and player.

2 Background

I have always enjoyed playing and watching soccer, for as long as I can remember. My father coached my first soccer team, 15 years ago when I was 3 years old. Ever since then I have always played and enjoyed the sport. I played in the local Park District league and on the local club, and most recently, I played for my high school soccer team.

To fully appreciate my project one must first understand the fundamentals of a free kick. This begs the question: what is a free kick? A free kick, in soccer, is a stoppage of play that occurs when a player is challenged harshly and is awarded a foul. Once play is stopped the attacking team is able to play the ball from a standing start i.e. the ball is not in motion and starts in place on the ground. Defenders are not allowed to come within 10m of the kicker in any direction. This gives the attackers the advantage of planning there move and being able to take the kick without the usual stress of defenders or fast paced play. Free kicks can be given anywhere on the field but they are most dangerous when they are in a teams attacking third of the field, near to the opponents goal.

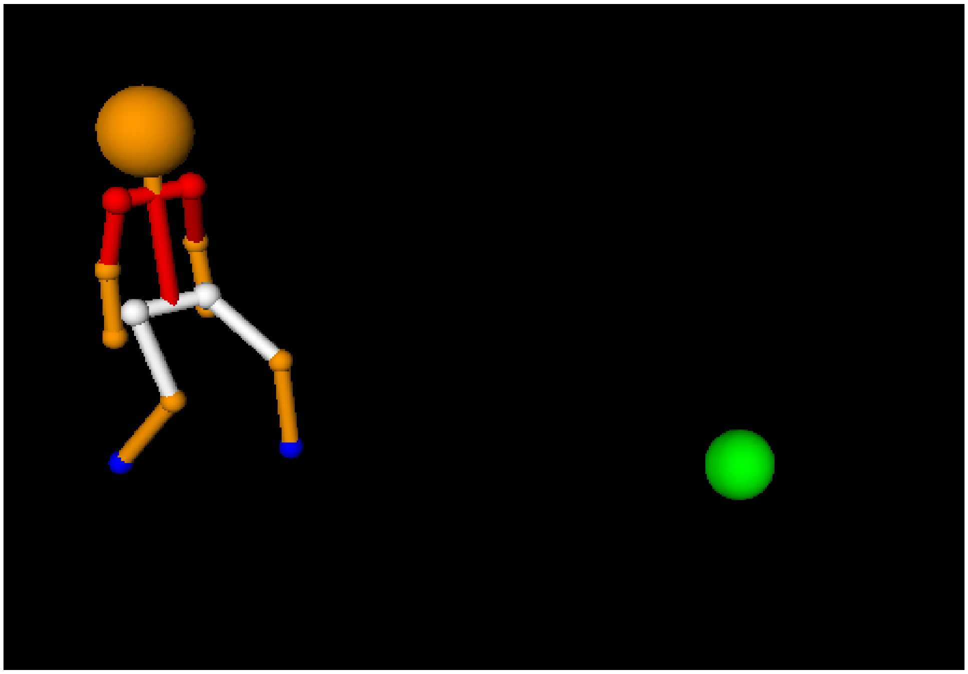
The type of free kick that I modeled in my project is this exact type, a free kick near to the opponents goal. Often in this situation the defending goalkeeper will have his defenders form a wall in front of the kicker in an attempt to block off a section of the goal, thus giving the keeper less area to cover. Many players will kick the ball to the side of the goal where there isn't a wall and take their chances with the keeper, hoping to beat him with a powerful or well placed shot. But the most skilled players possess the ability to curl the ball around the wall, catching the keeper off-guard and increasing their chances of scoring.

3 Final Program Details

The final program, Freekick1.py, uses Python 2.7 along with Vpython to display and animate the different simulations and objects in the scene. To define the displayed parametric function, users have access to the library of functions from the python math module as well as the built-in python functions.

The program uses preset starting positions for each of the figures in the animation. These positions vary depending on which model the user selects, and automatically determine the resulting final positions of the respective objects.

Figure 1: A blobby figure representing the kicker



The scene for each model contains a group of objects. For the free kick, the display shows a free kick taker, depicted as an orange stick figure wearing a red jersey, a green soccer ball and, slightly in the distance, a white goal and a goalkeeper defending the goal. For the juggling scene, the goal and keeper are gone and only the soccer player and ball remain. The simulation is user controlled and will only begin when the user presses a key to initialize it. Additionally the user can use the mouse controls embedded in Vpython to rotate around the scene and view it from different angles and perspectives.

The players in the simulation are Vpython *blobby* figures. Blobby figures are stick-like figures made up of a system of joints and limbs. Each joint (shown as a sphere in Vpython) has its own $frame$ attached and each limb is attached and controlled with respect to its joints. This makes animating motions much more efficient and streamlined. Each joint frame is constructed with respect to the main frame, in this case the figure's heart. If the heart frame is moved, entire figure moves, as everything refers back to the heart. This tree of references is most useful when animating the figure's arms and legs, by moving the shoulder/hip frame or the knee/elbow frame, you can create more broad or in specific motions that the figure performs.

4 The Science of Free Kicks

4.1 Mechanics of Kicking a Soccer Ball

The science behind a soccer free kick, or really kicking a soccer ball in general, is based mostly on physics. The ball's motion relies mostly on the transfer of energy from a player's foot to the ball. Generally in physics, the transfer of Kinetic Energy is governed by the formula:

$$KE = \frac{1}{2}mv^2$$

However, when a player kicks a soccer ball, the ball deforms for a fraction of a second at the point of impact. The ball leave the player's foot with the Kinetic Energy that they imparted but also with the stored energy from the deformation. As a result, the ball achieves a higher velocity than the player's leg. This velocity is modeled by:

$$v_{\text{ball}} = v_{\text{leg}} \frac{M_{\text{leg}}}{M_{\text{leg}} + M_{\text{ball}}}(1 + e)$$

In this formula, e is described as the $coefficient\ of\ restitution$, which measures the speed that the ball bounces after it hits the ground. The value of e ranges from 0 to 1, where 0 indicates that the ball doesn't bounce at all after hitting the ground, and 1 indicates that it bounces back up to the height it fell from.

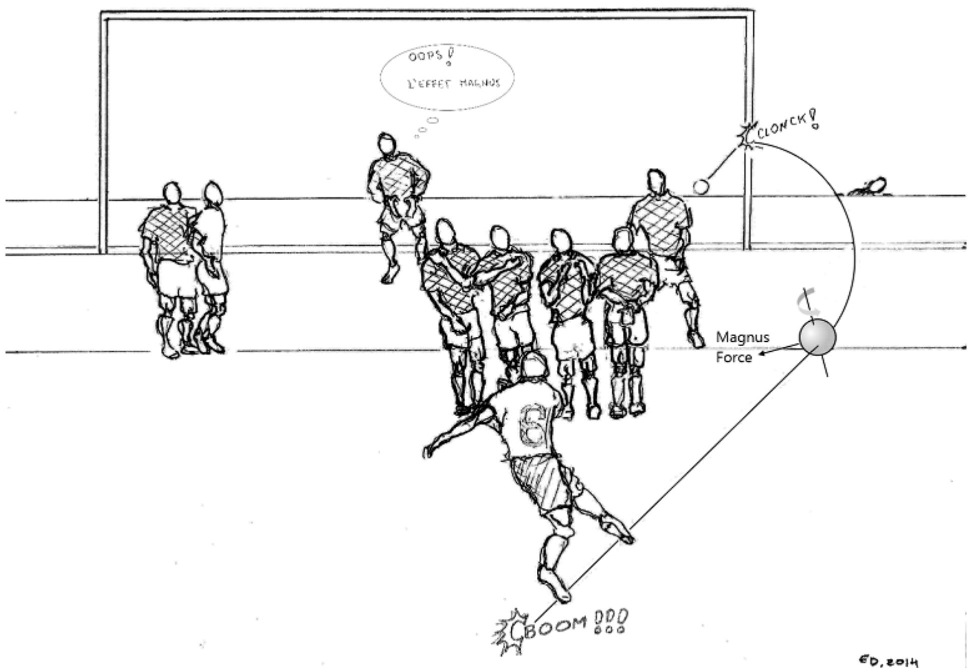
4.2 The Magnus Effect

Many soccer players around the world take free kicks quite often and possess the basic amount of skill to score one every once in a while. But the most skilled players can go beyond the basic free kick tactics of kicking the ball really hard and trying to beat the goalkeeper with the speed of the shot. These few players can bend the ball around defenders and make the ball appear to be flying way wide, only for the ball to hook back towards the goal in the last second, catching the defense and the opposing goalkeeper completely off guard.

This ability is due largely to the Magnus Effect which acts on flying objects that have a lot of spin. The basic idea is that if a player has enough distance between themselves and the goal, they can kick the ball with enough spin that, at a certain point, the primary factor in the trajectory of the ball becomes the spin of the ball itself rather than the velocity which carries the ball most of the way to the goal.

One of the most famous examples of someone implementing this in a game is Roberto Carlos' "Impossible Goal" in the 1997 Tournoi de France against the French national team. Carlos was given a free kick about 40m outside from the goal. He lined up to take the shot and then backed up all the way to the half line. Then he sprinted forward to the ball and kicked it with the outside of his foot putting maximum side-spin on the ball. The ball flew in a wide arc that seemed to be heading well wide of the goal, off to the right side. Suddenly

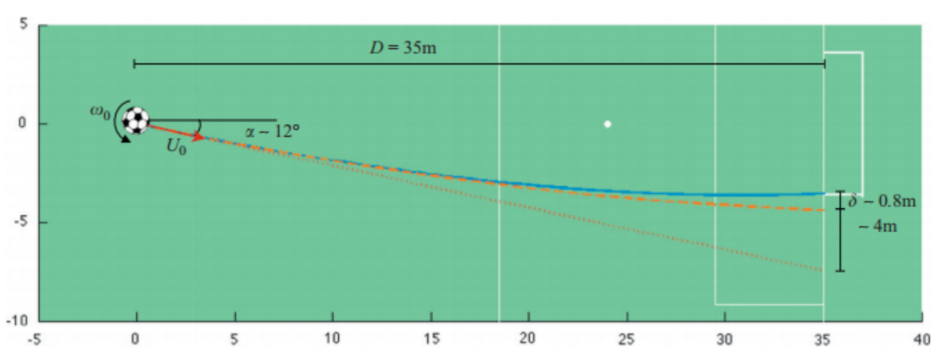
Figure 2: An illustration of Carlos' free kick



in the last second the ball hooked sharply to the left and flew off the post and into the goal, leaving the goalkeeper frozen in his spot.

Figure 2 shows an illustration of the trajectory of Carlos' free kick. As mentioned previously, the keeper was unprepared to defend the side of the goal that his wall was on and it seemed as the ball was going out of bounds. Figure 3 shows the trajectories of Carlos' free kick if it had been a straight shot (red dotted line), a regular slightly curved kick (orange dashed line) and finally the actual trajectory due to the Magnus effect (blue line).

Figure 3: A diagram of the percieved trajectory of Carlos' free kick



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