Angry Ball Physics Explained

Constantine Bolschikov
HSSE, MIPT, Russia
2024

Introduction

The Angry Ball project is a Flutter app developed by a second-year student of the HSSE (Software Engineering) faculty at the Moscow Institute of Physics and Technology. It demonstrates the principles of physics through an interactive game where players throw a ball in the environment with linear friction function from velocity. The project is designed to be both entertaining and educational, providing an opportunity to learn about gravity, differential equations, mobile development and game engines. The author hopes that this game can potentially spark one's motivation to learn more.

Content

This paper explains physics that stands behind the Angry Ball project.

Related Work

What are the forces that have the effect on the ball? There are 2 of them:

- The force of gravity $F_g = mg$, where m is the mass of the ball and g is the gravity constant, around $9.81\frac{m}{s^2}$
- The linear friction: $F_{\text{fr}} = -\beta * \overline{v}(t)$, where β is the coefficient of the viscous environment friction and $\overline{v}(t)$ is the velocity vector in the given moment t.

To not deal with the velocity vector and leave numbers only, let's assume:

$$\begin{cases} \varphi(\overline{v}(t)) & \text{is the angle between } \overline{v} \text{ and } O_x \text{ in the moment t} \\ \varphi(\overline{v}(0)) = \alpha & \text{is the launching angle} \end{cases}$$

With the help of the Newton's 2nd law of motion: $F = ma$, the differential equation for the ball in the air will be:

$$\begin{cases} a_x(t) = \frac{\partial^2 x}{\partial t^2}(t) = -\frac{\beta v(t) \cos(\varphi(\overline{v}(t)))}{m} \\ a_y(t) = \frac{\partial^2 y}{\partial t^2}(t) = -\frac{\beta v(t) \sin(\varphi(\overline{v}(t))) + mg}{m} \\ v_x(0) = \frac{\partial x}{\partial t}(0) = v_0 \cos\alpha = v_{0x} \\ v_y(0) = \frac{\partial y}{\partial t}(0) = v_0 \sin\alpha = v_{0y} \\ x(0) = 0 \\ y(0) = 0 \end{cases}$$

Figure 1:
the base system for Angry ball

Length and height of the ball from time:

$$\begin{cases} x(t) = \frac{m v_{0x}\left(1 - e^{-\frac{\beta t}{m}}\right)}{\beta} \\ y(t) = m\left(g\left(m\left(-e^{-\frac{\beta t}{m}}\right) + m - \beta t\right) + (\beta v_{0y})\left(1 - e^{-\frac{\beta t}{m}}\right)\right)\beta^2 \end{cases}$$

Figure 2:
the solution for the base system in the Figure 1

We need the moment t_0, when:

$$y(t_0) = 0$$

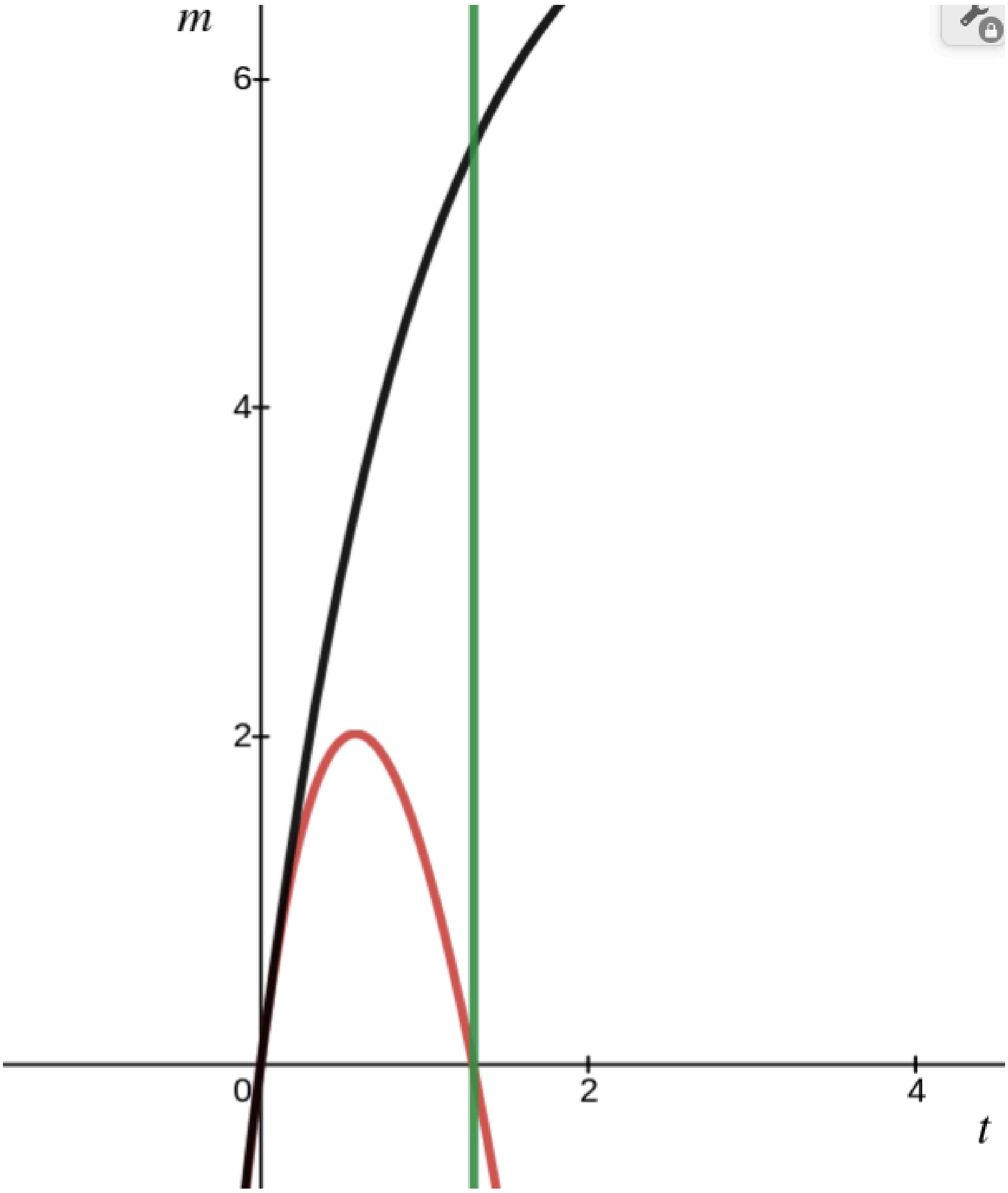

Figure 3: red line is height, black is distance, green is t_0

By plotting these 2 graphics in Desmos we notice that $y(t)$ has only 2 solutions (Figure 3). The first one is $t = 0$ and indeed $y(0) = 0$ due to the initial conditions of the differential equation. The second root can be found using a ternary search algorithm. Now, knowing t_0, the program pastes the value of it into the length function $x(t_0)$ to get x_0 coordinate, the estimate distance of a current throw.