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Computer Modelling of Projectile Trajectory through Fluid

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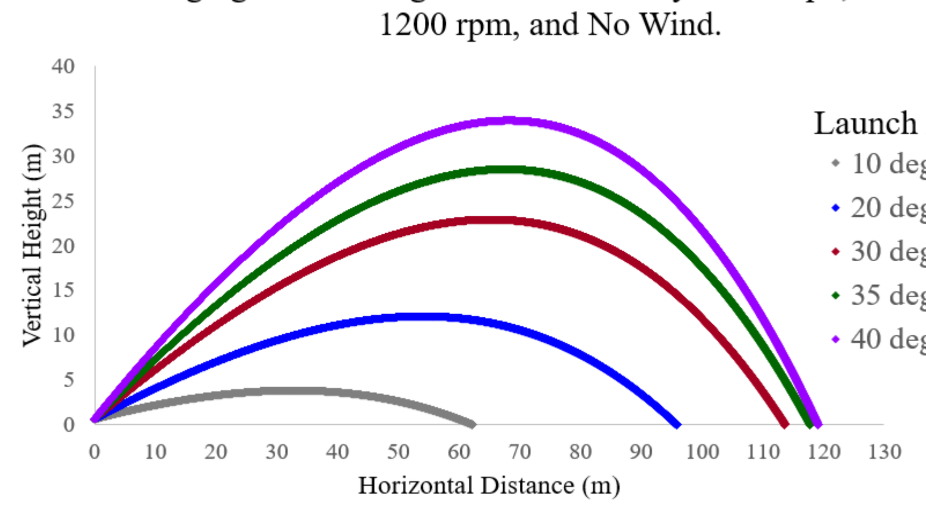
Abstract

Computer modelling provides a visual and quantitative way to study the physics of motion. When an object travels through a fluid, several forces and parameters affect its trajectory. These include gravity, the drag force, the density and motion within the fluid, and spin of the object. In this project, a simulation of a baseball traveling through air will be modelled to illustrate these forces and parameters. This model will display the effects of variables including wind, spin rate, initial velocity and initial angle, and show how the variation affects the motion, with particular interest on the range and trajectory of the baseball. The project will also explore and discuss use of computational techniques involved in producing the simulation.

Results

To show how each parameter affects the trajectory, I plotted the flight path of the baseball with variations of each variable on the same graph. In the Major Leagues, balls are launched between approximately 85-95 mph. Homerun balls usually have a launch angle of approximately 30 degrees with 1000-1400 rpm of backspin. These parameters where the default values. In the simulations varying only launch angle, the range of the baseball is not substantially increased after about 30 degrees.

Changing Launch Angles at Exit Velocity of 90 mph, Backspin 1200 rpm, and No Wind.



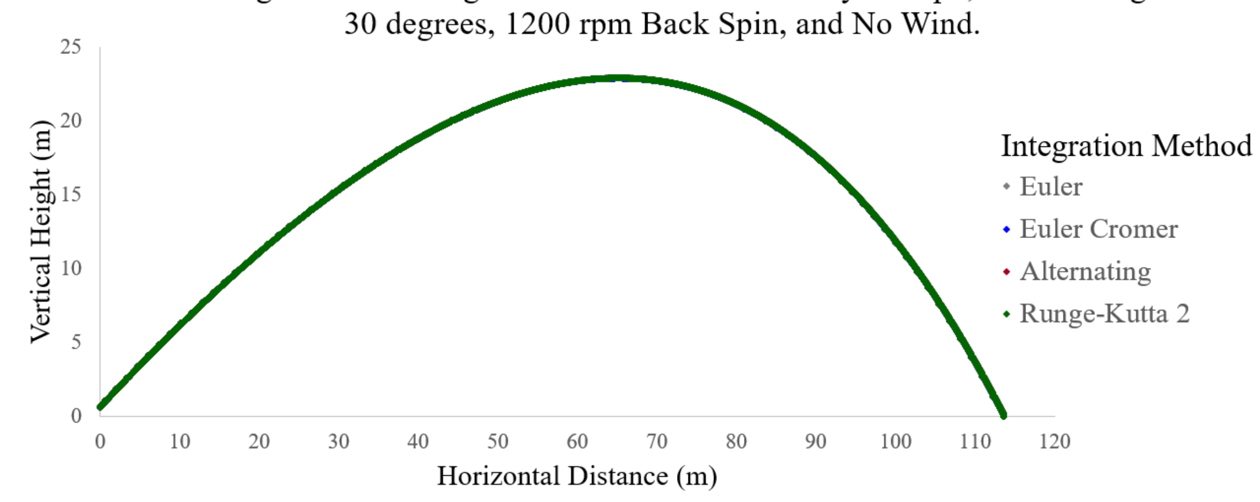
Integration Techniques

To plot the trajectory of the baseball, the path needs to be approximated. There are many different techniques to quantitatively determine the pathway. These methods vary in complexity and accuracy. The easiest is Euler's Method, which is derived from the Fundamental Theorem of Calculus. In this model I selected the Euler-Cromer Method, which is based on Euler's Method, with a correction:

$$v_{n+1} = v_n + a_n \Delta t \qquad x_{n+1} = x_n + v_{n+1} \Delta t$$

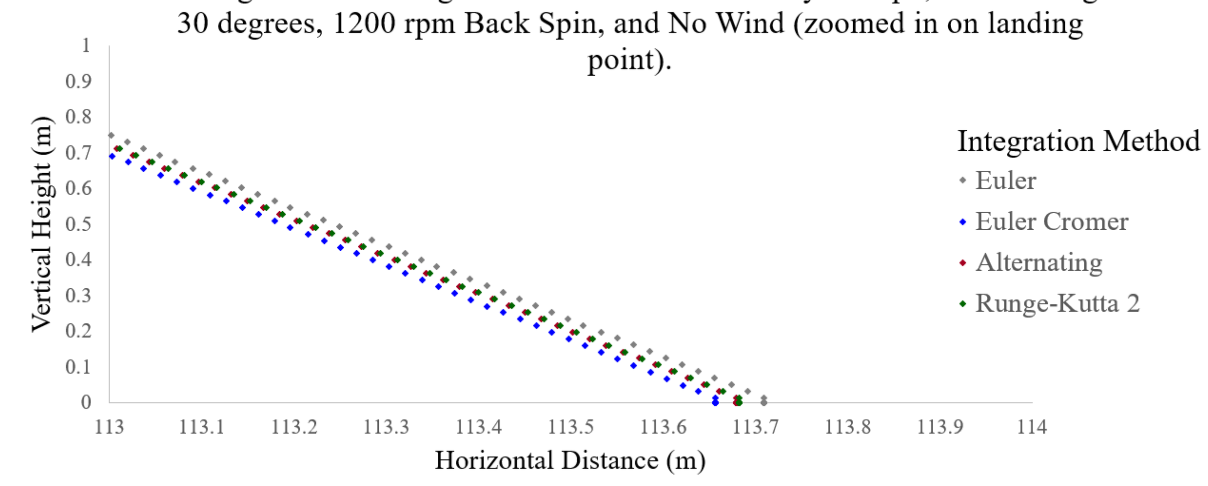
This method was tested against others, including a half-step method which alternates updating velocity and position first, and the 2nd order Runge-Kutta Method. Due to the short flight time for the baseball, the difference between all four was insignificant and, as result, the simpler Euler-Cromer Method was selected.

Utilizing Different Integration Methods at a Velocity 90 mph, Launch Angle 30 degrees, 1200 rpm Back Spin, and No Wind.



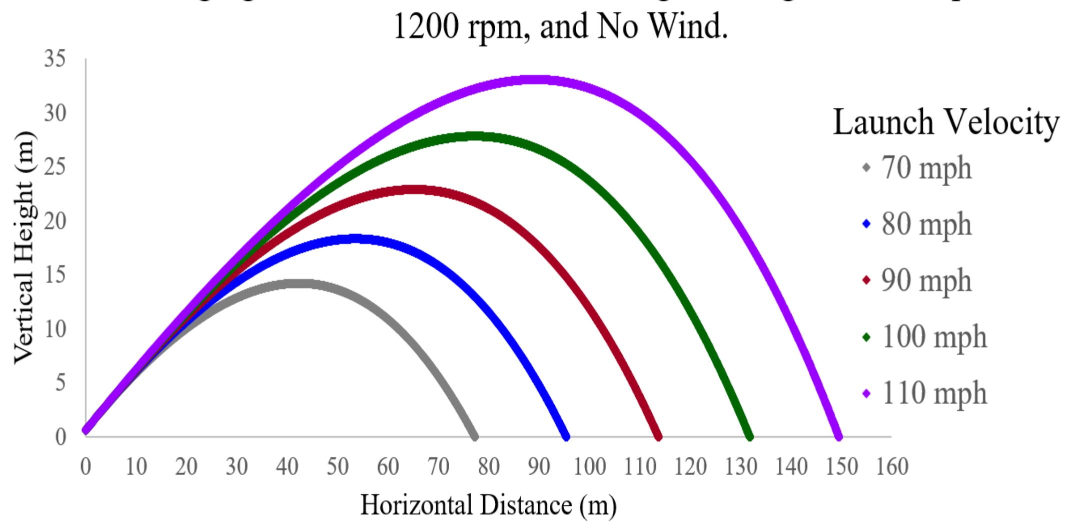
An enlargement of the landing points demonstrates the minor difference between the four methods:

Utilizing Different Integration Methods at a Velocity 90 mph, Launch Angle 30 degrees, 1200 rpm Back Spin, and No Wind (zoomed in on landing point).



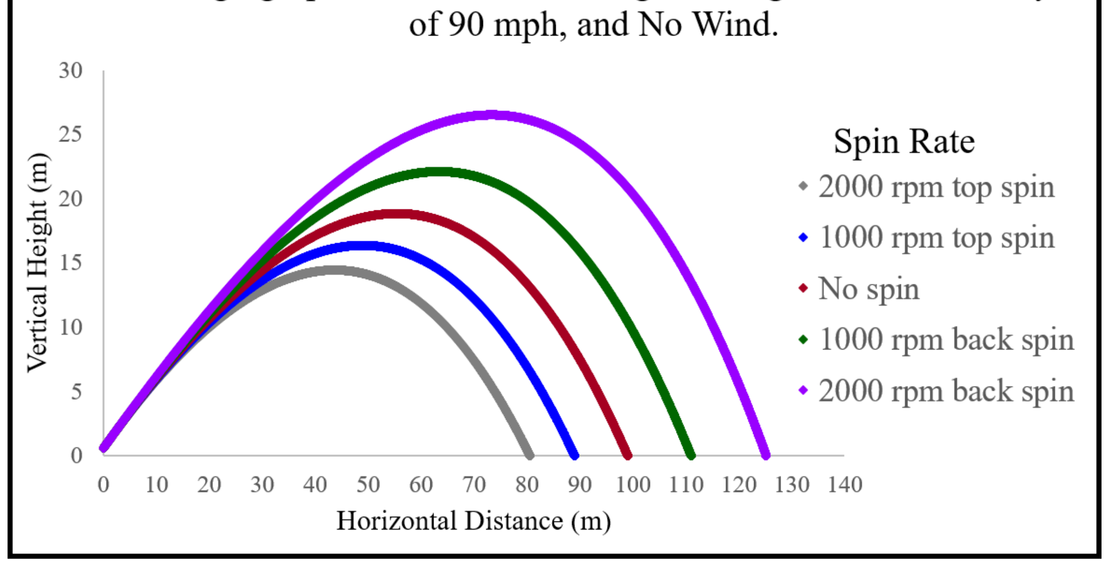
Initially the simulation was altered to explore how the Launch Velocity changes the maximum range and height of the path of the baseball. This demonstrates how range is proportional to Launch Velocity.

Changing Exit Velocities at Launch Angle 30 degrees, Backspin 1200 rpm, and No Wind.



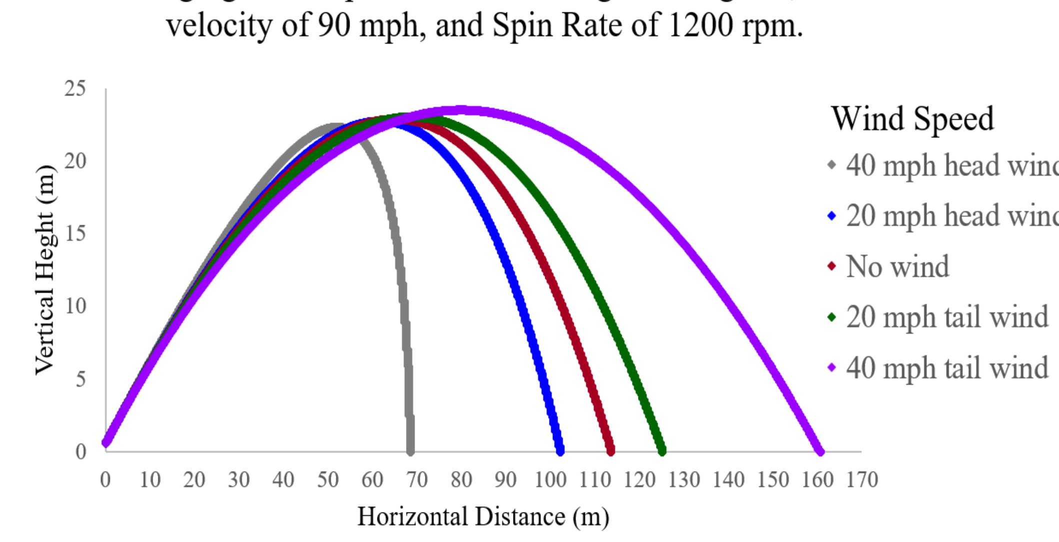
The next image exhibits how Spin Rate of the batted ball changes the trajectory of the baseball we studied. Range is shown to be reduced due to top spin on the baseball and increased for back spin.

Changing Spin Rate at Launch Angle 30 degrees, Exit Velocity of 90 mph, and No Wind.

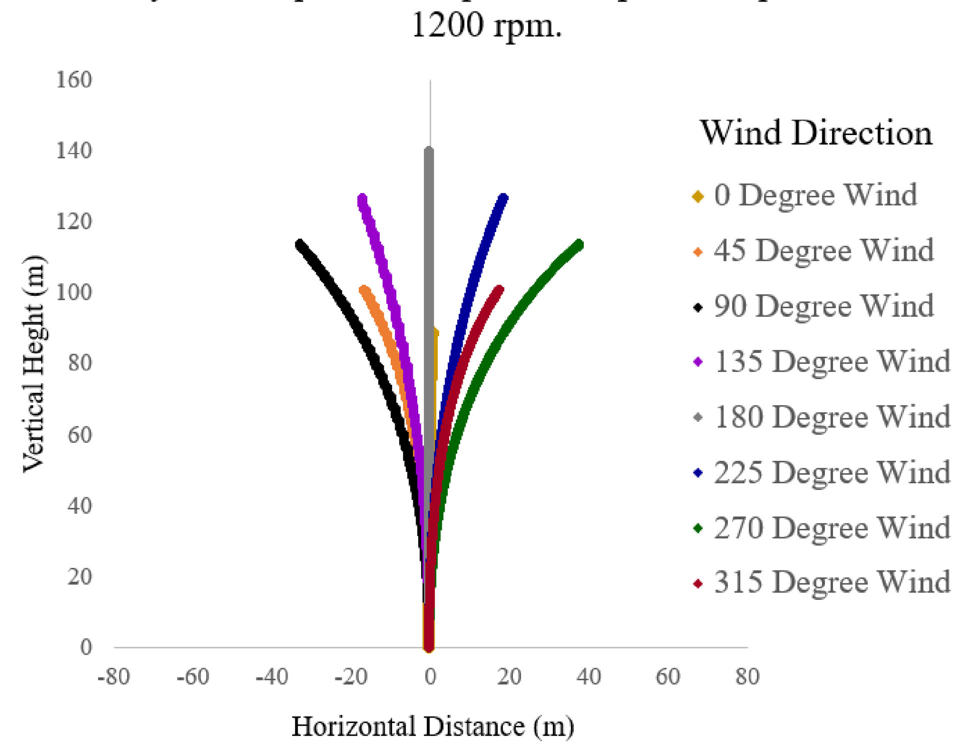


Adding head and tail winds can substantially affect both overall range as well as the distance at which the peak height is achieved, as seen in the image below.

Changing Wind Speed at Launch Angle 30 degrees, Exit velocity of 90 mph, and Spin Rate of 1200 rpm.



Changing Wind Direction at Launch Angle 30 degrees, Exit velocity of 90 mph, Wind Speed 30 mph, and Spin Rate of 1200 rpm.



The final image (left) displays a Top-Down view showing how wind direction affects both the deflection and range of the baseball. Here, 0 degrees is from the top of the graph, 90 degrees is from the right, 180 degrees is from the bottom, and 270 degrees is from the left.

Acknowledgements

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