LAB 3: Motion Control

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Abstract
The motion control experiment introduces and delves into the problem of having to deal with different values of gravity at a hypothetical asteroid. This experiment employs the use of the tracking camera, the CNC arm, and the values recorded and outputted by the tracking camera. With this data, the velocity, acceleration, and ultimately the gravity will be calculated.

Keywords *velocity, gravity, acceleration, tracking camera, thrust*

Introduction:

This experiment begins with a summary of the overview. The experiment revolves around a space rocket attempting to land on a hypothetical asteroid. The rocket begins its descent at 80 km above the surface of the asteroid with a free-fall acceleration. Once the rocket has fallen for 32 km, an upward thrust is applied to the rocket to prevent it from crashing on the asteroid surface below. For the rocket to "softly" land, the rocket must have a velocity of -10 km/s or less by the time the rocket reaches the surface. The values to be determined are the gravitational acceleration due to the asteroid and the velocity of the upward thrust to prevent a crash.

Several of the concepts to be applied are those related to kinematics. Equations such as $v_f^2 - v_i^2 = 2a(x_f - x_f)$ and the position function $x(t) = \frac{1}{2}gt^2 + v_0 t + x_0$ will be used throughout the experiment to make calculations. Furthermore, the conversion ratio found in the previous experiment for converting pixels to centimeters will be employed. For this experiment, kilometers will be scaled down to a ratio of 1km:1cm. In addition, the provided *python3* simulator program will be used to record experimental data. During the simulation, the tracking camera will track and record the position of the rocket ship. This data will be used to determine the velocity of the rocket after it has fallen for 32 km. Finally, this data will be analyzed to find the required thrust to prevent the rocket from crashing.

Experimental Procedure:

To commence the experiment, our team first ran the provided *python3* simulation. Following the simulation, a value for the gravitational force was outputted by the program. For the first part of the problem, our team evaluated the equation by hand to calculate the V_f value after free-falling for 32 km.

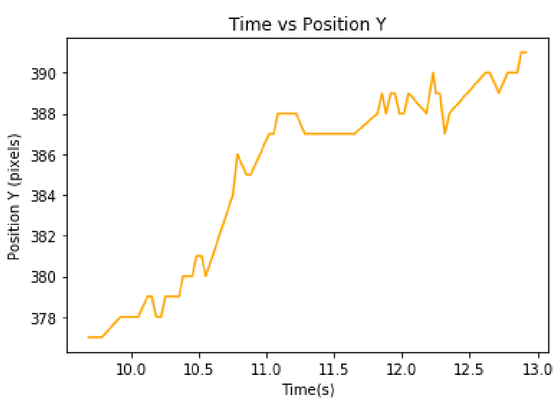
After obtaining this value for V_f, the equation for acceleration could be integrated to find the velocity function plus the unknown thrust velocity and the initial velocity of V_f. The equation for velocity was also integrated to find the equation for a position with an initial height of 80 km – 32 km. Once this equation was derived, the time at which the rocket was at a height of 0 km could be evaluated. This time could then be substituted into the velocity function to find what value of velocity was necessary to prevent the rocket from crashing. Thus, the approximate hand-calculated value for the upward thrust velocity was found.

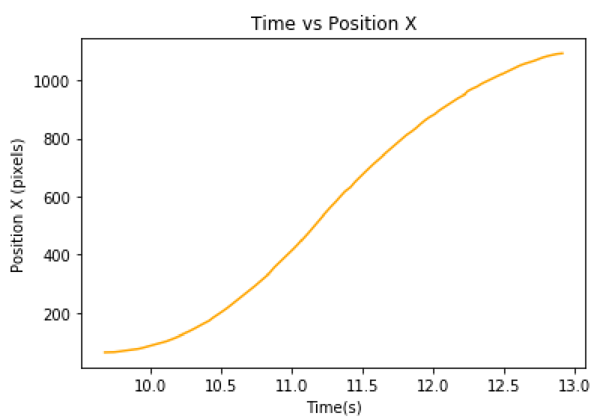
Next, to prove that the calculation for upward thrust was within the desired constraints, the value found for thrust was inputted into the simulator. With a slight error due to rounding, the estimated value of thrust proved successful. The appropriate data could then be accrued from the tracking camera to create presentable graphs and results.

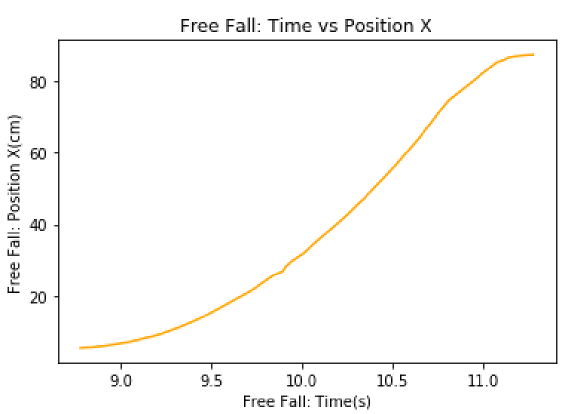
Results:

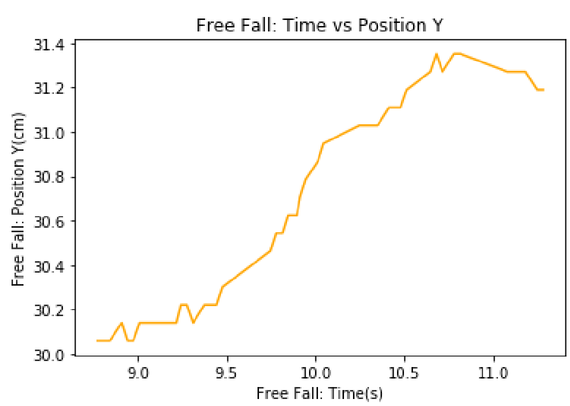
The graphs below include time vs position, time vs velocity, and time vs acceleration, for both the x and y components. It also includes the free fall graphs of time vs position, time vs velocity, and time vs acceleration, for both the x and y components. These graphs utilize the raw data of the trials in order to calculate the gravitational acceleration and find the thrust to safely land the asteroid. For both x and y components of the position, it is measured in pixels. The x and y component of velocity is measured in meters per second. Acceleration's x and y components are measured in meters per second squared.

<u>Position</u>

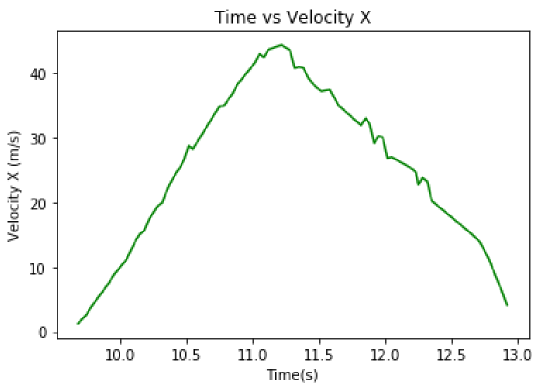


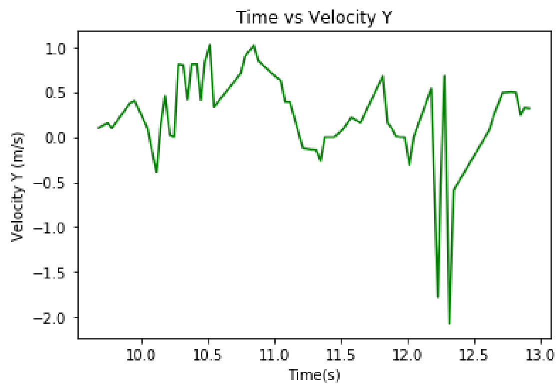


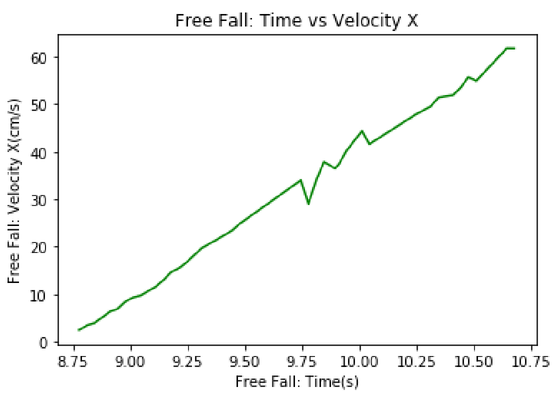


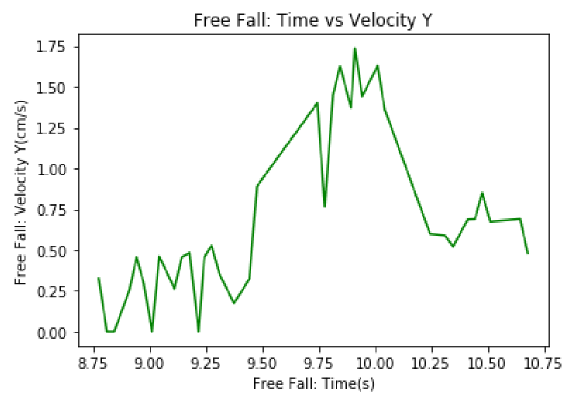


<u>Velocity</u>

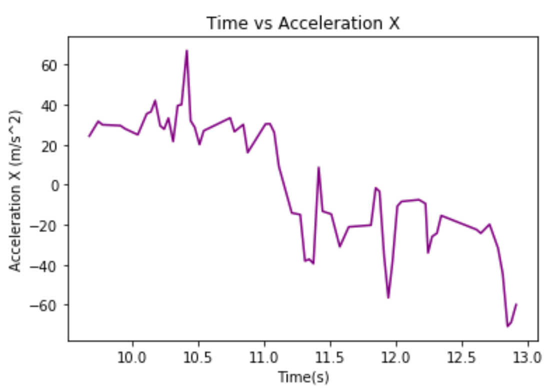


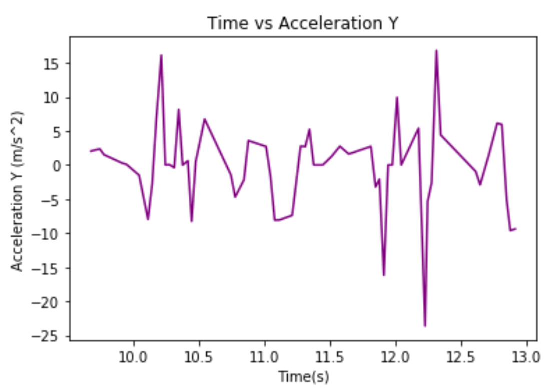


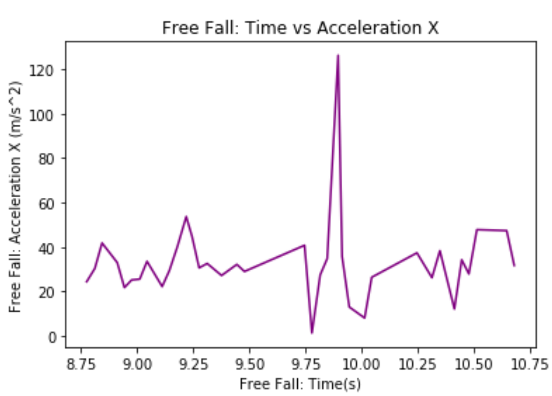


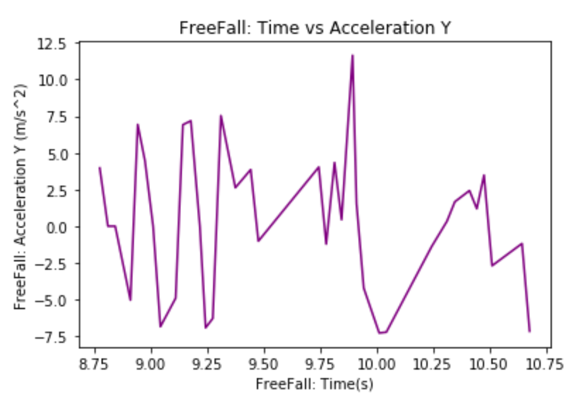


Acceleration

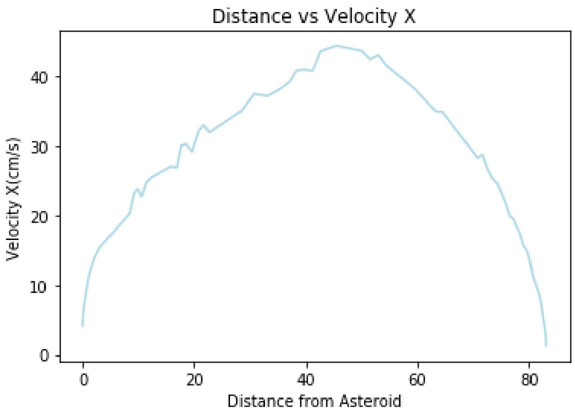








Distance vs Velocity X



Calculations:

After letting the spaceship run and crash with no thrust applied and finding the crash velocity, the equation $v_f^2 - v_i^2 = 2a(x_f - x_f)$was solved for acceleration and used to find a gravity constant of 30.538 cm/s. Once the gravity was known, we could then use the same equation to solve for a net acceleration that would land the ship at both 10 cm/s and 0 cm/s, giving us the desired range of thrust values. The velocity after the 32 cm of free fall was used as the initial, and the desired velocity was used as the final, with the initial position being 32 cm and the final position being 80 cm, or on the asteroid. The needed net accelerations were found, and using the mass of the spaceship, the thrust required in newtons could be found. The range of thrust values landing the ship at an acceptable velocity was found to be (239.304, 246.342) N. Finally, visual data was used to calculate the uncertainty of g, taking the standard deviation of the acceleration values measured of the ship in free fall, providing an uncertainty of 30.538 +- 9.121 cm/s.

Conclusions:

Based on the results of our analysis, it was concluded that an opposite force, in this case, thrust, can overcome the force of gravity. In addition, the distance to be traveled, with a given velocity and acceleration can all be related through the kinematic equations to solve real-life applications such as this.