Ballistics of Long Distance Rifle Shooting

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Abstract

This project develops a mathematical model of the ballistics of long distance rifle shooting by using several differential equations. Furthermore, we discuss additional real-world effects that can affect the trajectory of a projectile travelling through long distances, such as the Magnus effect and the Coriolis drift, illustrating the vast complexity of predicting the exact path of the aforementioned projectile.

Introduction

In long distance shooting, the key to success is hitting the desired target. For that to happen, nonetheless, the shooter must know all the factors that can alter the trajectory of the bullet when the bullet is on the way to the target. Drag, rotational effects, and gravity are the main factors that a long-distance shooter must consider before performing the shot. Using differential equations, we can predict and adjust the trajectory of a bullet. Despite the complexity of long rifle shooting, this project will build a realistic model of differential equations that will describe the path that a bullet will follow when shot from a long distance.

Sample Shot

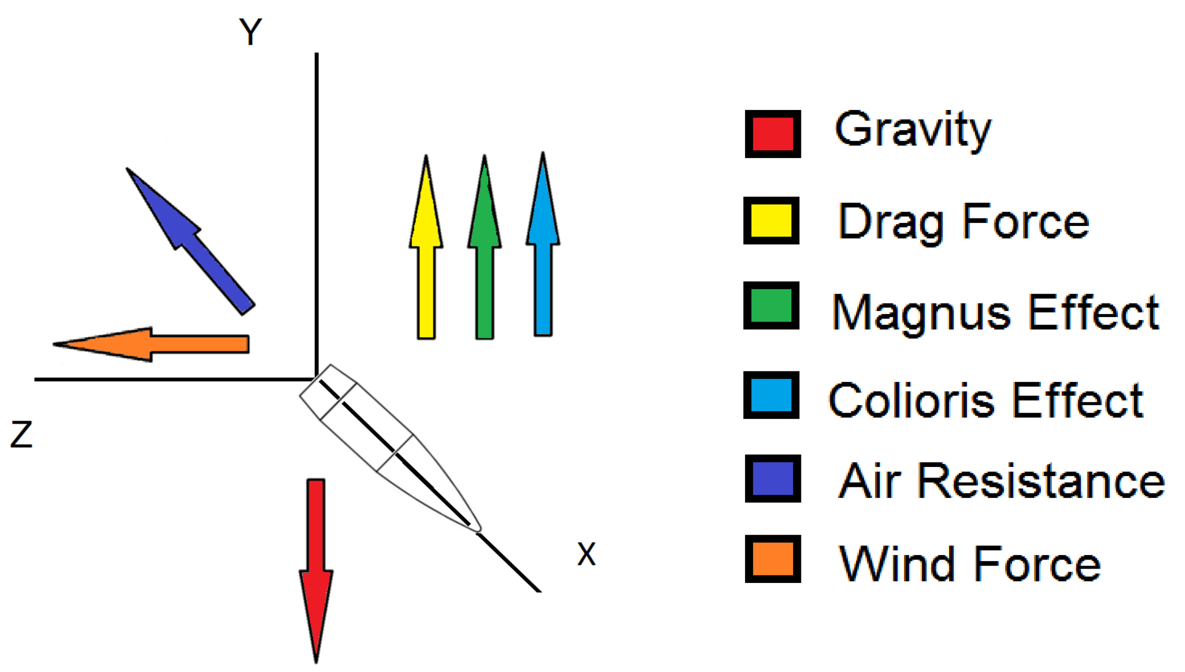
To see the results of our differential equations, we will perform a hypothetical sample shot. This sample shot will be directed eastward and the shooter will be located in the northern part of the equator. From this initial condition, we can predict that both the Magnus effect and the Coriolis effect will shift our bullet upward. The bullet to be used is a 6.16-gram G7 drag model bullet with a coefficient of drag equal to 0.28. The target of the rifle is at a distance of 1400 meters from the shooter.

Magnus Effect

This effect is the result of the interaction between the rotating bullet and the air surrounding it. When the bullet rotates, it pushes the air either up or down (depending on the location of the bullet with respect to the equator). By Newton's 3rd law of motion, the air must push the bullet with a force of the same magnitude in the opposite direction. If the bullet is shot from the northern part of the equator, the bullet will push the air down and as a consequence the air will push the bullet up. When shot from the southern part of the equator, the opposite happens.

Coriolis Effect

This effect is the result of the interaction between the bullet and the rotation of the Earth. All bodies with mass (except Earth itself) are subject to a circular trajectory due to Earth's rotation. This implies that all bodies with mass on Earth experience tangential velocity due to a circular motion. When a body breaks the sound barrier, it is said that Earth, for a short period of time, has no gravitational effect on the bullet, implying that this body is temporarily not traveling a circular trajectory and thus experiencing only the tangential velocity from the circular motion it used to experience. In the case of a bullet, there is a deviation due to this tangential velocity, which depends on direction. Thus, if the bullet is shot eastward, then the bullet will deviate upwards. If shot westward the bullet deviates downward. If shot northward it deviates to the right and deviates to the left if shot southward.



Trajectory of a bullet when shoot eastward

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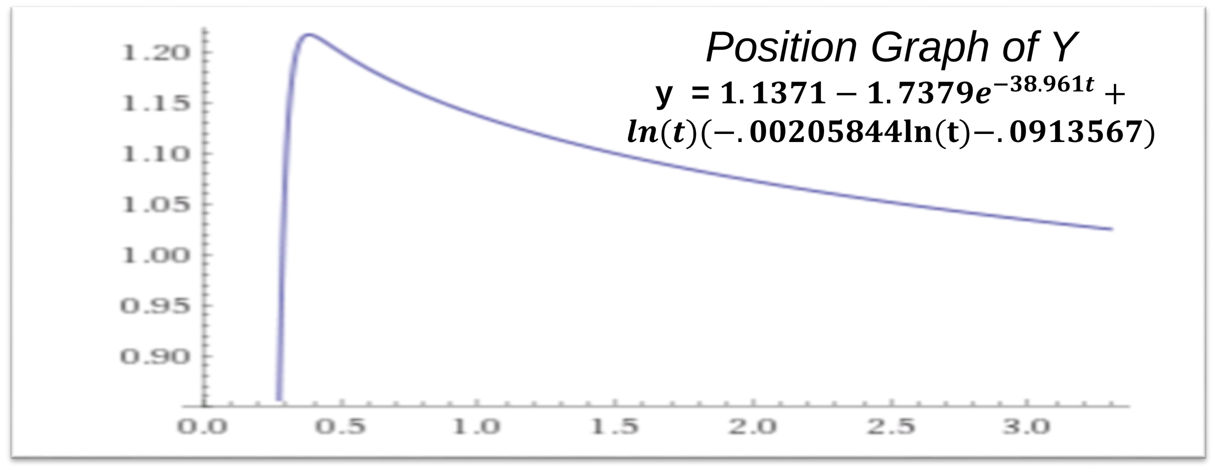

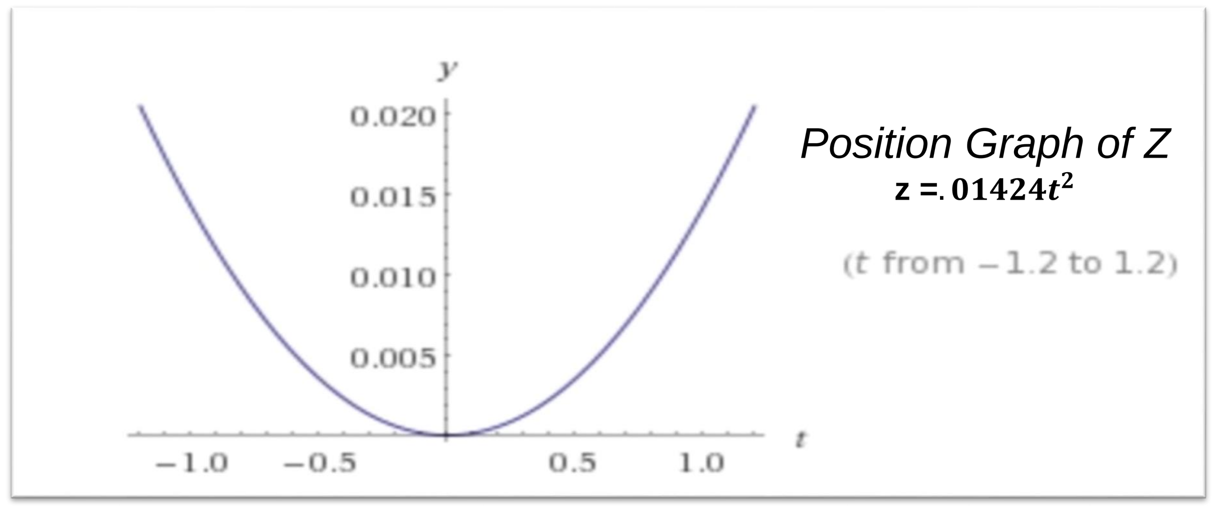

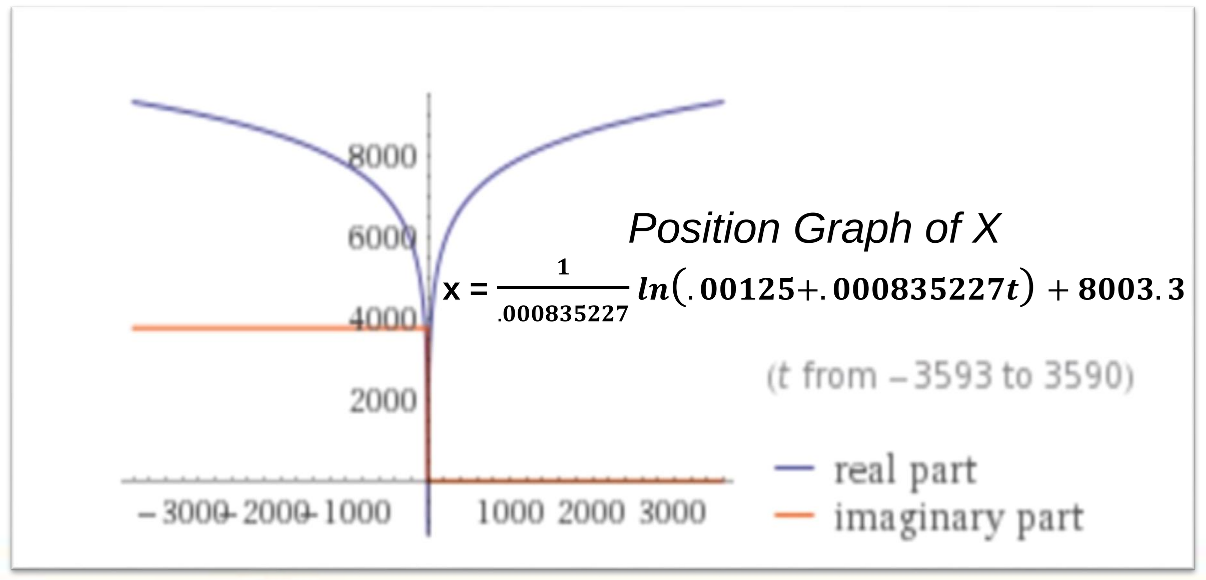

Results

The graphs of our differential equations indicate a 0.157-meter deviation to the right and a 1.02-meter deviation upward by the time the bullet travels 1400 meters. Using trigonometry, it was found the shooter must initially adjust his initial shooting sight by an angle of 0.042° downward and 0.0064° to the left. By making this adjustment, the shooter is more likely to hit the initial target directly. Moreover, this results also shows how much a small angle adjustment can alter the path of a bullet

Conclusion

By using the concept of dynamics, it is possible to model the trajectory of fast-moving objects. Considering variables such as acceleration and time, we could derive differential equations that describe the trajectory of a bullet. In long distance shooting, models of such nature are crucial. However, it must be taken into account the amount of complexity of the many minor factors that dictate the direction of bullets, some of which were not included in the model. For this reason, our model must not be taken as a perfect model but rather as a limited yet fairly accurate model for long distance shooting.

Differential Equations (Spring 2017) MAC2302-0H1
Faculty Mentor: Aharon Dagan

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