Final Report:

Executive Summary

Our team is working on a program that automatically measures the necessary data for snipers and then outputs the angle they need to fire at. Such a program would be beneficial for several reasons. Snipers often have to memorize certain specifics about their gun and bullet. Snipers also use spotters to help them locate targets. Snipers either memorize methods for compensating for target movement, elevation, wind speed, and other relevant factors or they learn how to use their inbuilt scope devices. All of this requires intensive training. The methods for compensating for target movement, elevation, wind speed, and other factors are estimates and consume time on the battlefield which could put the soldier at risk. If a new gun was developed, snipers have to learn a whole new set of data. We feel a computer program would be faster, more adaptable, and more accurate.

Problem Description

In the times before firearms, special archers trained to hit high-value targets, such as enemy commanders. They were the medieval versions of snipers. Since the invention of the gun, snipers have been used in every major conflict. However, not every army trained people specifically as snipers. Most of the soldiers who learned sniping skills were sharpshooters (elite infantry). However, with the advent of automatic weapons, snipers became their own category. They used to use bolt action rifles because of their accuracy and stealth. Semi-automatic sniper rifles that were accurate proved too expensive to manufacture in the past. However, due to recent advances in technology, the sniper rifle currently used by the US Army (M107) is an accurate semi-automatic sniper rifle. There are some problems related to the M107, though. It's very loud, which can give away the sniper's position. The only compensation for this is that they are usually aiming at distant targets. Also, the scope has a zoom of 500, 1000, and 1500 meters. This unfortunately causes shots between 1000 and 1500 to be inaccurate. Lastly, shooting at an uphill angle can injure the sniper.

The targeting compensators represent a major improvement from several decades ago. For shots over 1000 yards, the targeting compensators used to be inadequate. Older scopes had magnification that could only go up to 11X, so the target's height wasn't too easy to calculate. Also, the target was blurry due to glare problems. A large (50mm) objective lens that's coated to allow more light to enter restricts glare problems, and the magnification limit has been raised to 14X on commercial models. This allows snipers to make shots at a maximum of 2000 meters, though the scope can only zoom up to 1500 meters. Mil dots are still an effective system built into the scope that measures the angle of the target. A mil dot's diameter plus the distance of the line connecting two dots is a mil(radian) which is 1/1000th of a radian. The mil dots form a coordinate plane on the scope. Once zoomed in to the appropriate zoom level, the sniper calculates the angle at which he has to aim at the target in order to hit. The scope magnification tells the sniper the distance, which in turn determines what angle above horizontal the shot must be made at to compensate for gravity. An experienced sniper can estimate this very well, or use a Bullet Drop Compensator (BDC). At the distances the M107 can shoot, gravity plays a much larger role in the bullet's trajectory. The BDC and other devices that measure elevation, wind, and other relevant factors are built into the scope. These devices have knobs that are turned to calculate the effects of the factor, when matched to the appropriate value of a known variable. In the case of gravity, the known variable is distance to the target. However, the height of the target must be guessed. Using visible laser rangefinders is not encouraged because lasers can be seen by the target, especially if the target is employing night vision goggles, which gives away the sniper's position. Some lasers are invisible, but those are weak magnifiers, so they take a lot of power in order to travel distances in excess of a mile.

There are 2 major physics expressions, depending on whether air resistance is added or not. Without air resistance, $y=t|v|\sin\theta+1/2gt^2$, while $x=t|v|\cos\theta$ where y is the height, t is time, x is the distance, |v| is the vector of the initial velocity, θ the launch angle, g the vector of gravity. This was the equation used in our first trajectory program. Of course, air resistance exists, so motion with air resistance must be used. First, drag should be determined. $D=|v|^2*1/2*A*C*\rho$. D is drag, v is velocity, A is the silhouette area or the area seen from the front, C is the drag coefficient, which is determined usually by wind tunnels, and ρ is the air's density. Since we don't have access to a wind tunnel, C must be determined through other means. The drag coefficient is related to an older method of calculation called the ballistic coefficient. If one knows the ballistic coefficient and the bullet type, one can determine the drag coefficient. However, there are several ballistic coefficient models used for bullets, each giving different measurements. The ballistic coefficient is inaccurate at high speeds and at long distances, two of the factors that are present on sniper rifles. Bullet manufacturers tend to inflate the ballistic coefficients. This is why the military uses drag coefficient which is determined by radar. The drag coefficient is around .75 if the bullet is assumed as a blunt cone. However, the bullet is more rounded than a real cone and probably has a lower drag coefficient which is more aerodynamic. Since an exact value of C cannot be found, C was set as an input variable in our trajectory program that included air resistance.

Data

Data Without Air Resistance

	15°	30°	45°	60°
Peak	132331.732 feet	229183.499 feet	264634.204 feet	229183.499 feet
Time	47.08 sec.	90.94 sec.	128.61 sec.	157.51 sec.

Obviously, this lack of realism shows that air resistance is a major factor in bullet trajectory. Bullets do not fly 2 minutes in the air; they fly in about 2 seconds.

Our Approach

We used JAVA as our computer program with Netbeans IDE. We first created a program that did basic conversions. It could convert between centimeters and inches, grains to grams, MOA (minutes of an angle) to radians, feet per second to miles per hour, and millibars to inches of mercury (air pressure). This would help us later when we had disorganized units because of different sources. Then, we created a program that calculated a bullet's trajectory without air resistance. This used the equations mentioned above. |v| was determined to be 2910 feet/sec. Since we used feet, 32 ft/sec^2=gravity. The launch angle θ was the input. The program would then output the time it takes for the bullet to reach the ground, its maximum height and a graph of its trajectory. Of course, this is opposite our program's goal, but it's easily modified so that distance is an input and the angle was the output. The graph was especially challenging because of the difficulties scaling the graph correctly as well as getting the computer to draw the graph. Also, since a computer can only connect lines and not actually draw a curve, we had to make the computer draw so many tiny lines that the human eye could barely tell the difference between a curve and that many microscopic lines. This was done by incrementing t (time) by .1 seconds. Then, we set up a program that does the same thing as the trajectory program, but it included air resistance. In the drag equation, C and ρ are the variables (inputs). |v| is 2910 feet/sec=886.968m/s and A=4.080637cm^2. Since drag is a force, and F=ma, we find acceleration by dividing F by m. m= 45.88961g. However, it's more useful to find the acceleration in both the x and y directions. $A_x=(-D/m)vv_x$. v_x is the vector in the x direction which equals cosθv where θ is the launch angle. $A_y= -(g+D/mvv_y)$. v_y is the vector in the x direction which equals sinθv. g is gravity which is 9.8m/s^2. Once acceleration is determined, the concept of the time increment comes in. The acceleration is constantly changing, but for a small period of time, it can be safely assumed to be constant. Our time increment is .01 seconds. In the equation without air resistance, gravity was the negative acceleration. Now, the acceleration is drag force so that's substituted into the equation instead. However, because these are increments, a change from a non-zero time increment to another non-zero time increment can happen. Therefore, the equations for x and y must be adjusted. Also, acceleration due to drag isn't constant. However, over a short amount of time, it's constant enough. $V_x+\Delta V_x= V_x+A_x\Delta t$ and $V_y+\Delta V_y= V_y+A_y\Delta t$ where Δt is our time increment .01. ΔV_y or ΔV_x is to be determined by $A_x=-Dv^2\cos\theta/m$ where $v^2=V^2_y+V^2_x$ and $A_y= -(Dv^2\sin\theta/m+g)$. Then, the a_x and a_y is put into the equation without air resistance where the gravity is substituted by acceleration. In parameter form (in terms of t), $x+\Delta x=x+v\cos\theta t+1/2A_xt^2$ and

$y+\Delta y=y+1.524+\sin\theta vt+1/2A_yt^2$. The 1.524 is added because snipers don't shoot on the ground. They're standing up so the gun's about 5 feet=1.524 meters off the ground on their hands. The computer outputs the graph and distance the bullet travels when it touches the ground.

Our Most Significant Achievement

Our most significant achievement was gathering the information because compiling all the information from all the different sources was challenging. The information was split into so many sources that it took the researcher many months to piece together the information. Often times, the information was misleading, outdated, incorrect, or irrelevant. This is why the team had to scrutinize the research to ensure validity. This is also why the researcher had to constantly search for more information because every new program required new research and information that seemed correct needed fixing.

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Thanks to Daniel Parrott for the idea.

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