

# Trajectory Simulation of Electromagnetic Gun Bullet

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**Keywords:** trajectory simulation; electromagnetic gun bullet; C language; OpenGL

**Abstract.** This article provides a reference for the structural design of electromagnetic bullet. Electromagnetic gun bullet is slow and non-lethal, this study creates a bullet model based on the rigid body mechanics and the simplified aerodynamics, the motion simulation is realized by calculating the force and moment of the bullet in the aerodynamic model, and using C language with OpenGL graphics library prepared simulation program, the flight process of the bullet can be observed by 3D animation. To improve the simulation accuracy, the simulation program can be corrected by using the test data, eventually may replace the ballistic test to a certain extent.

## 1 Introduction

Based on the rigid body mechanics, the model of the rigid body motion is realized by using the C language design algorithm. First define the projectile's structure, this project, projectile consists of  $n$  points on the quality, according to the parametric equation of the circle get  $y$  and  $Z$  coordinates, the surface of the projectile by 50 round by on the circumference of the sequentially connected to form, as shown in the figure below. Need to explain is that the points of a triangle in order not to disrupt, the order of the three points of the triangle will affect the following function of each triangle of the surface normal direction calculation, and surface normal direction and projectile by the direction of air power and graphics rendering time according to the direction of the reflection about<sup>[1]</sup>.

## 2 Create rigid body motion simulation model

Create constitutes a good quality of projectile contour points define a plurality of array giving physical attributes to the point mass, respectively for the position, velocity, acceleration, angular velocity, angular acceleration, 3 axis moment of inertia, quality, at the same time, the definition of the projectile as the attribute of a rigid body.

After the definition of the physical quantity, in every time the program cycle, first of all centroid position based on the total mass of the mass and position of the particles and the product divided by the projectile, according to each particle and centroid distance and mass calculated respectively in  $xoy$ ,  $DT$  values can be at any time within the program through the keyboard (concrete operation in the back of the user manual of the changes will be described in detail). Every operation cycle, acceleration and angular acceleration multiplied by  $DT$  and accumulate to velocity,

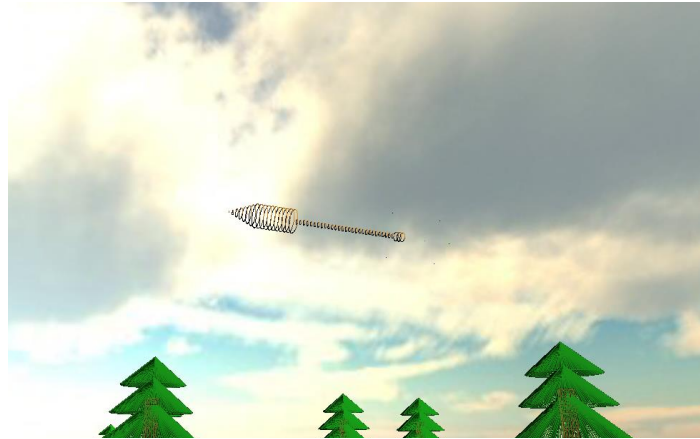


Fig. 1 Create bullet rigid model

angular velocity, then the calculated before every particle of income and distance to the centroid distance in the three planes of multiplied by the projection of angular velocity, linear velocity of each particle relative to the centroid of the angular velocity and the line speed and the speed of the projectile mass to obtain particle of actual speed. The actual velocity of the projectile is multiplied by the DT to be added to the position of the projectile, and each time the position is refreshed, the potential target is output to the graphic function.

$$\mathbf{p} = \mathbf{v} \bullet dt + \mathbf{p} \quad (1)$$

$$\mathbf{v} = \mathbf{a} \bullet dt + \mathbf{v} \quad (2)$$

$$\mathbf{a} = \mathbf{F} / m \quad (3)$$

$\mathbf{p}$  --- position;

$\mathbf{v}$  --- Speed;

$\mathbf{a}$  --- is – acceleration;

$\mathbf{F}$  --- bullet combined force;

$m$  --- projectile mass.

The triangle f for each mass point where the air power divided by three is because the entire surface of the force assigned to three points, due to a point may also in different triangles, the superposition of all the force, the force. Where R is the distance between the centroid point quality, I is the moment of inertia. K is the aerodynamic coefficient, which needs to be adjusted according to the contrast experiment<sup>[2]</sup>.

### 3 Create aerodynamic model

Before the introduction of aerodynamic function. Firstly, the thesis introduces the composition of projectile surface, all of the computations involved in aerodynamic surface, which is based on the triangle, the sequence in which the three points of the triangle in the rigid body model has been described. Is defined as three M3DVector3f vector array (M3D is a matrix operation, vector operations and other functions of the Mathematical Library), the array contains 3 floating point variables, respectively, the vector in the X, y, Z axis component. The first one is a vector of second points for the first point of the triangle, and the second is a vector of second points to third points.

The two unit vectors of executive function M3Dcrossproduct function (two vector cross), the third vector is obtained, the vectors are perpendicular to the rest of the two vectors, the direction to meet the right-hand rule, the vector is triangle lies on a plane normal to the surface. Create an array to store the surface normal of each triangle. And then define the two units of vector array, respectively, pointing to the direction of the missile axis and speed. Due to the low velocity of the projectile, the shock and eddy current resistance are neglected, only the head-on resistance of the frontal plane is considered, which is proportional to the square of the velocity and the velocity of the projectile.

#### **4 Calculation process**

The user through the size of the input of the projectile warhead, cylindrical part and tail rod of, the program will call the function automatically generated given bullet shaped projectile contour node, and the calculation results are given. The calculation process as shown below.

#### **5 The image output**

OpenGL is a used to create a programming interface to the real time 3D images, have very high rendering speed and high portability, which does not affect the simulation program operation efficiency, and can generate high quality of the projectile and the scene model. Below is a brief introduction of OpenGL graphics library in this program and function<sup>[4]</sup>.

First, define a glBatch class, a glBatch class is a number of points of the render batch, including the need to render the graphics type, the coordinates of each point, the surface normal and texture coordinates. These three properties are the three elements of the array, respectively, record x, y, Z axis of the coordinates, the vector in the three axis of the component and texture image of the two-dimensional coordinates and texture parameters.

GlBatch then in renderscene function calls a previously defined, the definition of some transformation matrix, complete the model of translation, rotation and scaling position transformation, at the same time by the perspective transformation matrix with moving camera lens complete perspective transformation, thus the model in the coordinate transformation for the content of the user coordinate system display on the screen. In order to achieve a good visual effect, the projectile model seems to be a three-dimensional object, the need for light and reflection, or the projectile will appear to be a no depth of the two-dimensional plane. At this time need to OpenGL calls internal point light source diffuse texture shader. After the definition of a number of attributes, join the sky box and simple scene rendering, to achieve the effect as shown below<sup>[5]-[6]</sup>.

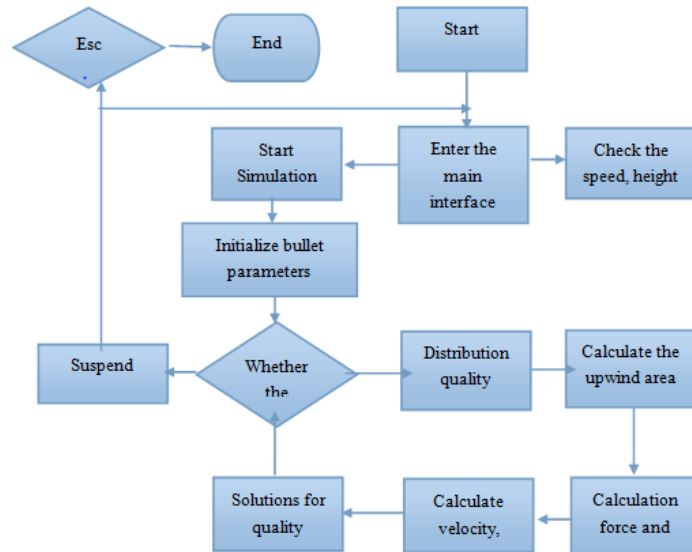
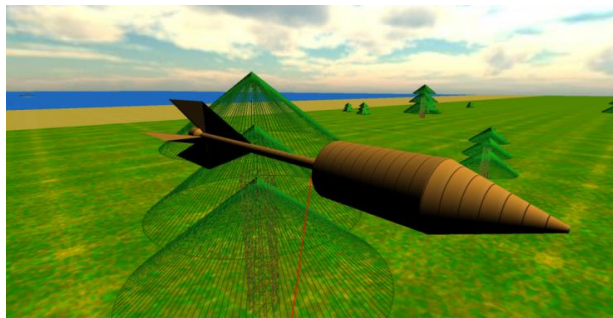


Fig. 2 Calculation flowchart



(a)

Fig. 3 Three dimensional animation output of bullet flight process

## 6 Bullet flight simulation test

After setting up the projectile model and aerodynamic model, it is necessary to carry out the repeated testing of the projectile flying attitude and the target in the air, so as to repair the program error, improve the program algorithm and adjust the accuracy. From the following a few pictures, we can see that the displacement of the projectile in the projectile motion play a right role, can produce and the stability moment of projectile overturning moment reverse, so that the elastic axis and the angle between the velocity vector gradually decay, achieve the effect of stabilizing fins.

At the same time, for the simulation in the actual firing initial angle of fire and angular velocity random effect on the spread of the projectile target, when the projectile is launched at a time can choose to join the 0.1 degrees the firing angle deviation and 1 degree per second initial angular velocity deviation, in order to facilitate the observation and comparison, this procedure can save 100 of the projectile target position.

## References

- [1] Wang Y, Richard A M, Chen S K. The Physics of Electric Launch[M].Beijing: Science Publishers, 2004.
- [2] G. William Slade. A Simple Unified Physical Model for a Reluctance Accelerator[J]. IEEE Trans. Magn,2005.
- [3] Mahdi Mahmoodi Vaneghi. Design and Switching Position Optimization of Multi-Stage Coilgun[C]. International Conference on Business, Engineering and Industrial Applications,2011.
- [4] XIE Yangliu ,Research on Models and Simulation of Electromagnetic Railgun Exterior Trajectory[T], Harbin Technical University, 2008.
- [5] QU Boting, Research of C Programming Exercises Recommendation Based on Hierarchical Lables, Northwestern University,2014.
- [6] QU Xiao, Research on Visualization Techonlogy for Space Simulation Based on OpenGL, Xi'an Electronic Technology Universit,2013.