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Visual Simulation of Missile Attacking Battleplane Based on Vega

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Abstract

A visual simulation system of fragment warhead missile attacking F-16C "Falcon" battle plane based on simulation and virtual reality technology is put forward. Firstly, the overall design of visual simulation of missile attacking F16 battleplane is implemented, and all functions of each module are demonstrated in detailed. Then 3D models in virtual battle field are optimized by level of detail, texture mapping, billboard and instance technology. Finally, Vega scene driving program is developed, and the implementation of special effect, view transform, preview and collision detect are emphasized. The result of simulation provides reference for damage assessment of missile attacking F16 battle plane.

***Keywords**: fragment warhead missile, missile-target encounter, visual simulation, 3D modeling, collision detection*

1. Introduction

The research of warhead missile [1] attacking typical target, especially the simulation of battleplane, has existed at home and abroad. Early approach is to use firing practice in order to get the real data of the missile's power field and the target's damage. However, this approach is not only a waste of manpower, material and financial resources, but also is very dangerous, and the attacking process can not be represented. Using the approach of numerical simulation to simulate the entire process of the missile-target encounter can solve these problems. However, the output of numerical simulation results is limited to text and chart, and is not enable to make user to visually observe the process of the missile-target encounter [2]. In recent years, with the development of computer graphics technology, the research of simulation of missile-target encounter develops toward visualization and is widely used. Especially, using the approach of visual simulation [3-4] to simulate the process of missile-target encounter and present the results of simulation to user with image has become the main technical method of experimental research.

Domestic and foreign scholars have begun the relevant research. Using OpenGL, visual simulation of missile attack process is researched and implemented, and the attacking process can be observed from any angle in Literature 5. The simulation of missile's flight and attack is researched and developed from the angle of virtual reality [5] in reference 6. The main problems that the simulation of implementing missile attacking target are that only the immersion of scene is emphasized, but the process of missile-target encounter does not reflect really in reference [6- 7].

Aim at the current problems that simulation's process of missile attacking target, according to 3D modeling [8-9] and scene driving, the process of missile-target encounter of missile attacking F16 battleplane, which is based on researching numerical simulation of damage analysis of missile attacking F16 battleplane, is implemented in the paper.

2. Research Method

Visual simulation system of Missile attacking F16 battleplane is required to complete the work including two areas: on the one hand, completing missile's power field model, guidance model, fuze-start model, equivalent model of F16 target and numerical simulation of probability calculation of F16 damaged by missile, and calculating the missile's relative position to fuze and

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the position of explosion point, as well as missile's damage probability for overall F16 and its vital cabin; On the other hand, vividly displaying with animating the process of the missile attacking F16, and the missile's power field, and damage effect after the missile hits the target.

Based on above system requirement, a general flow chart of the system is described in Figure 1.

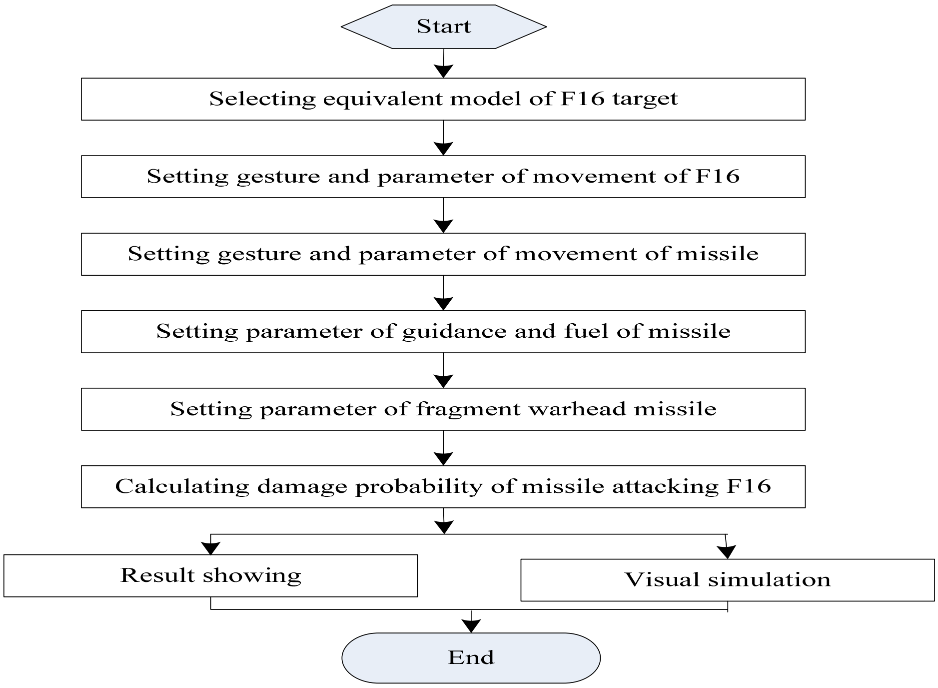

Figure 1. System flow chart

2.1. Numerical Simulation of Damage Analysis

Numerical simulation of damage analysis is the basis of visual simulation of missile attacking F16, and mainly includes the following modules:

- Choosing different target equivalent model according to the type of missile warhead. The aim of establishing target equivalent model is to make the target's vulnerability digitalization in order to concretely analyze performance of missile. Straight killing model and key cabin model are mainly considered. Relying on a dense fragments flow to cut target component, straight killing model simulates focused fragment warhead missiles. For precast and natural fragment warhead missiles, key cabin model is used to calculate the number of hits for the key target component.
- Setting the information of missile-target encounter by human-computer interactive interface, which includes missile and F16's air gesture and the height of encountered spot. Real flying process of missiles and F16 is very complex, so, in the paper, visual simulation assumes that the missile and the target fly toward encountered spot according to the user-specified encountered attitude.
- Setting the work mode of missile guidance and fuze. The parameters of missile guidance and fuze determine the instant relative air position of the missile and target when they encounter. According to guidance mode and parameter of missile, missile flies towards target along ideal trajectory that is determined by guidance principle. Fuel is exploded at the final stage of attacking and in the appropriate position.
- Setting the parameters of the missile warhead. The parameters of missile warhead mainly include: type, quality, charge weight of warhead, and size, shape, amount, muzzle velocity, Attenuation coefficient, and spatial distribution of fragment. The parameters of warhead determine the size of shock wave and maximum range of overpressure, and the parameters of fragment determine the operation process of fragment's power field.

- Calculating damage probability of missile attacking F16. By analyzing the power field of missiles and the vulnerability of F16, the model of endpoint effectology on warhead, mainly including: fuel-start model of missile, operating model of fragment and shock wave, vulnerability model of F16, is used to calculate damage probability that a particular warhead attacks F16 battleplane.
- After implementing numerical simulation of damage analysis of missile attacking F16, user can output result of simulation as a local file, and also can use visual simulation to express with 3D animation the process of missile-target encounter.

2.2. Visual Simulation of Missile-Target Encounter

If we want to implement the process of visual simulation of missile attacking F16, firstly, we must implement the simulation of the missile's field power, and fragment and shock wave are the most important damage factors of the missile. According to research of characteristics and analysis of mathematical and physics model about fragment and shock wave, the idea of particle system is used to implement visual simulation of fragment and shock wave in the paper.

The definition of a particle structure is used to describe a fragment particle.

```
struct {
bool status;  //current state of fragment: stillness or motion
int type;   //0-5, respectively denote: sphere, cuboids, cube, rhombus, irregular shape
bool crashed;  //whether fragment hits target
double attenuate;//attenuation coefficient of fragment
double time;     //scattering time of fragment
double dir_h, dir_p, dir_r; //scattering direction of fragment
double x, y, z;    //spatial location of fragment
double h, p, r;    //current gesture of fragment
double dx, dy, dz; //next moving distance of fragment
double dh, dp, dr; //change of fragment's gesture
} FragmentParticle;   //definition of data structure of fragment particle
```

Due to the randomness of scattering and distribution of fragment, the generation of random number is also very important in visual simulation. Currently, the most wide linear congruential generator is an iterative process, and its algorithm is simple and easy to implement, and the statistical properties of uniformly distributed random number generated by linear congruential generator are better. In the paper, the iterative formulas of line congruential are shown as follows:

$$yn + 1 = a\ yn + b\ (\bmod M) \tag{1}$$

$$rn = yn / M \tag{2}$$

In formula, a, b, M and initial value of yn – y0 are positive integers, and rn is a random number of uniform distribution in [0, 1].

After random number of uniform distribution in [0, 1] is generated, a random number of standard normal distribution is generated by direct sampling to construct a function of standard normal distribution. The formulas of generating random number are shown as follows:

$$y_1 = \sqrt{-2\ln r_1} \cdot \sin(2\pi r_2) \tag{3}$$

$$y_2 = \sqrt{-2\ln r_1} \cdot \cos(2\pi r_2) \tag{4}$$

On the basis of implementing the simulation of missile's field power, the information of fuel- start must be acquired when missile encounters target, accordingly, the missile's spot of fuel-start and the missile's position of fuel exploding, relative to F16, can be acquired. In the paper, according to the information of missile-target encounter and the use of endpoint effectology model, the average spot of fuel-start and exploded position that missile relative to the center point of target is acquired after 2500 statistical test. Therefore, we can use simulation model of missile's power field to simulate the process of missile-target encounter.

After simulating the process of missile-target encounter, endpoint effectology model is used to implement damage analysis of overall F16 and each key cabin. According to judge whether F16 is damaged and how level F16 is damaged, simulation's module of damage corresponding to the level is started to simulate damage effect of F16.

The flow chart of visual simulation that missile encounters target is shown in Figure 2.

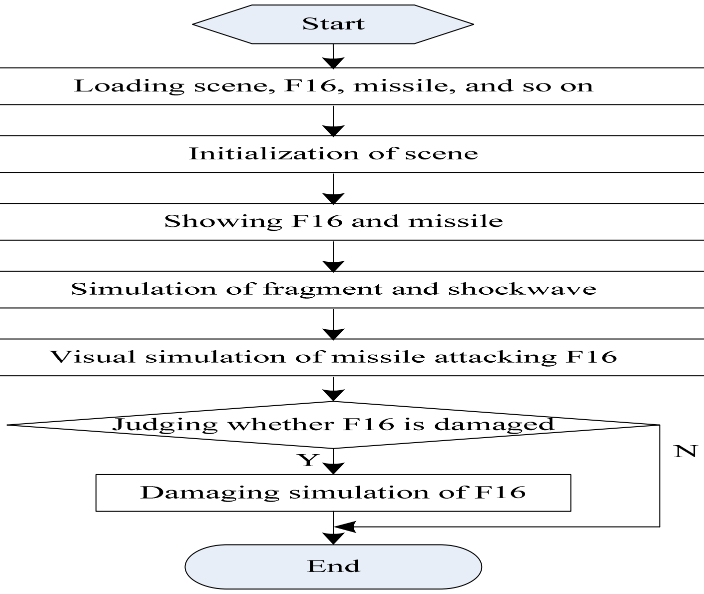

Figure 2. flow chart of visual simulation

2.3. Scene Modeling

3D modeling is the basis of the entire visual simulation. So only by establishing vivid and realistic three-dimensional models, the advantage of visual simulation can be reflected unlike other simulation approach - enabling users to feel immersive. Graph-based rendering and image-base rendering are used in the paper. Firstly, graph-based rendering is used to render scene model structure, and then scene model structure is pasted texture in order to buildup realism. In the paper, Multigen Creator is used to accurately model for all kinds of targets.

When modeling for scene, expecting the entity model of virtual battlefield, missile, battleplane, wreckage and fragment when battleplane bombs, are included. General speaking, three-dimensional model is created according to logic structure, geometry structure, and motion characteristics, actual size of entity objects. But, modeling for entity objects waste time and labor. So, in the paper, on the basis of not lowing authenticity of scene, the texture mapping technology, Level of detail, billboard and instantiation technology are used to improve the complexity of modeling.

2.4. Visual Simulation Driver-Vega

Vega is an application software produced by Multigen Paradigm Company, and Vega is applied in virtual reality, real-time visual simulation and other visualization field.

The application based on Vega mainly includes two stages. The first stage is system configuration which is necessary to ensure the normal running of the Vega system. Firstly, the vgInitSys function is called in order to initialize Vega system; secondly, vgDefineSys function is called to load "adf" file and a variety of instance object of class Vega is created; finally, vgConfigSys function is called to complete system configuration. The second stage is to make Vega system into system's dynamic loop. The main simulation process based on Vega is completed in the main loop. The main processes of visual simulation of the missile attacking F16 are shown as following:

```
vgSyncFrame();          // frame synchronization
vgFrame();              // internal processing of current frame
GetInputKey();          //keyboard capturing and processing
F16Update();            //updating F16's status
MissileUpdate();        //updating missile's status
ShowFragment();    // fragment simulation when missile-target encounter
ShowShockWave ();  // shockwave simulation when missile-target encounter
F16DemageAnalyz(); //damage analysis and damage simulation on F16 after missile-target encounter
```

2.5. Implementation of Special Effect

To implement the special effect, such as exhaust of missile and F16, exploding, burning and smoking of F16 after being hit, exploded fragment, burning and smoking of F16 after falling to the ground, wave effect after F16 falls in the sea, and so on. Those effects do not only be rendered by simple geometric model, but also be implemented by particle system.

In the special effect of Vega, a class of particle system is included and user can define the property in this class at a very wide range. Once a necessary particle system is created, some properties of the particles can be changed dynamically at runtime, and so the particles can show a variety of behavior. In the paper, the missile with exhaust is shown in Figure 3.

2.6. Viewpoint Transforms and Object Preview

Transforming flexibly the position of viewpoint and the mode of track is also a characteristic. According to the selection of key 0 to 9 on the keyboard, user can change the position of viewpoint and the mode of track in the process of missile-target encounter. The launching position of missile can be of side-glance according to inputting key 1. Missile can be observed from back and side according to inputting respectively key 2 and 3. F16 can be observed from back and side according to inputting respectively key 4 and 5. Missile-target encounter can be observed from top and side according to inputting respectively key 6 and 7. Key 8 is viewpoint track of missile. Key 9 is viewpoint track of F16. Key 0 is used to cancel the state of tracking. Figure 4 shows an instant of encounter that missile attacks F16 at different angles.

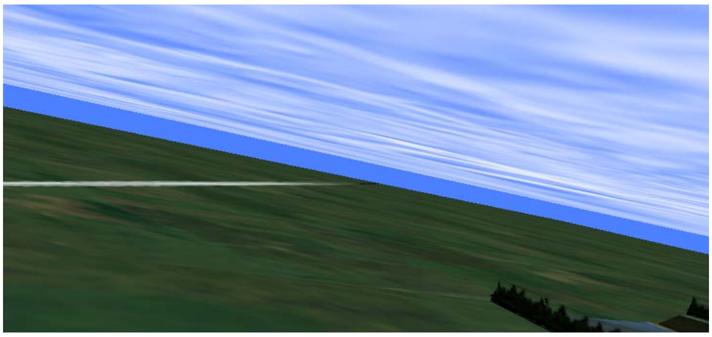

Figure 3. Missile in flying

Figure 4. Instant of missile-target encounter

Standing, flying and encountering F16 and missile can be previewed, and overall F16 and each key cabin of F16 can also be previewed when damaging or after damaging in the paper. In the mode of preview, user can change the direction of viewpoint by dragging the mouse in order to observe the process of missile-target encounter at different angle.

2.7. Implementation of Collision Detection

Collision detection [10] that the missile attacks F16 is an important role in the visual simulation. After F16 is attacked by missile, damaged F16 is possible to lose control and fall. In order to avoid F16 falling down endlessly, collision needs be detected between models to determine when and how F16 falls to ground.

Intersect vector is used to detect whether model collides in the process of movement. In Vega, intersect vector provides eight methods to detect collision, and each method has its own characteristic. In the paper, Z method and LOS method are mainly used to detect collision when and how the F16 falls to the ground. Z method is used to calculate the height of the intersection point, and LOS method is used to calculate the range of view. First, Z method is used to calculate the altitude just below F16 after missile-target encounters. Then, LOS method is used to judge whether F16 falls and the position of fall is land or ocean. The visual simulation of F16 which is wrecked and falls to the ground is shown in Figure. 5.

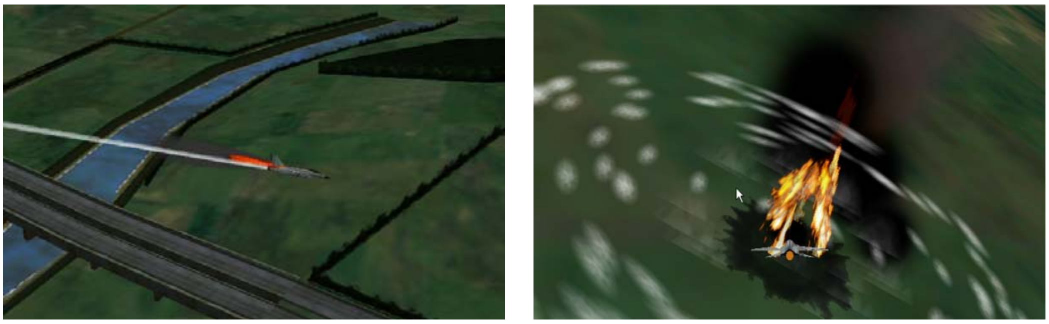

Figure 5. Crash of F16

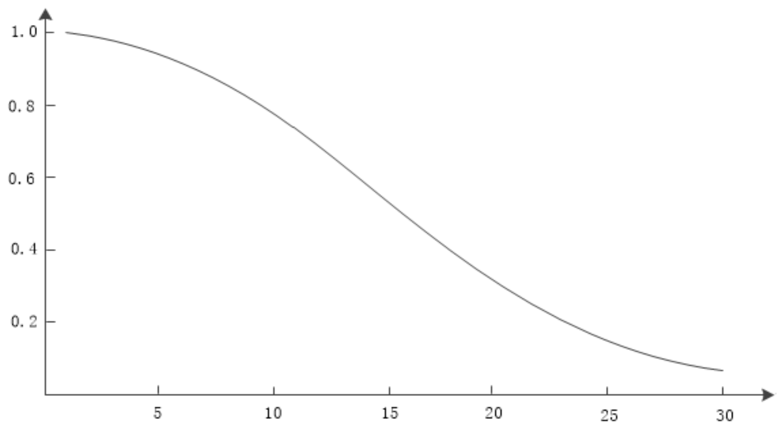

Figure 6. Probability curve of damaging F16 along with the distance’s change

3. Result and Analysis

For example: a fragmentation warhead missile attacks F16, during the simulated calculation, specific parameters of encountering spot are above: the flight speed of missile is 2500 m/s, flight speed of F16 battle plane is 1600m/s, height of encountering point is 22000m, thickness of equivalent target of F16 is 20mm, error of guidance system both are 5m, standard deviation of random error both are 8m. The specific parameters of fragment warhead missile are above: total fragment of warhead is 4000, average mass of fragment is 510g, muzzle velocity of fragment is 2500m/s, scattering angle of fragment is 20, the angle of scattering center of fragment is 90.

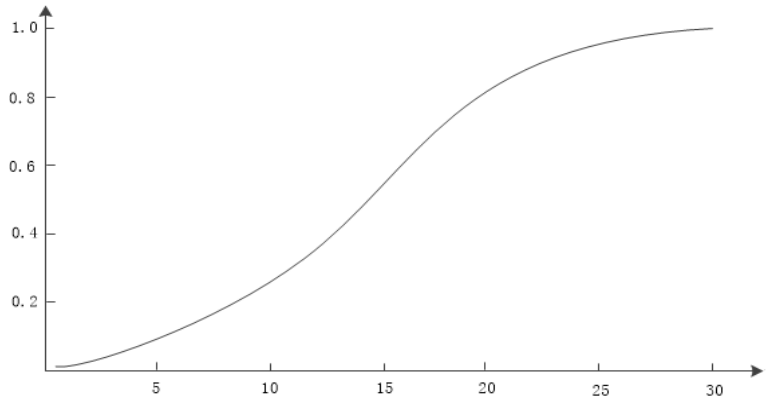

Figure 7. Probability curve of damaging F16 along with change of damaging radius

Along with the distance's change between fragment warhead missile and F16, the probability curve of damaging F16 with single fragment warhead missile is shown in figure 6. Along with the change of damaging radius of fragment warhead missile, the probability curve of attacking F16 with single fragment warhead missile is shown in Figure 7. From Figure 6, we can see that the damaging probability of fragment warhead missile will diminish rapidly along with the increase of distance between fragmentation warhead missile and F16. So, improving guidance accuracy and reduce the amount of off-target can greatly improve damaging probability. From Figure 7, we can see that damaging radius of warhead is larger and the damaging probability of missile is larger. But, improving the power of warhead will increase the total weight of missile at the same time. It is a problem that must be considered compositely.

4. Conclusion

In the paper, on the basis of fragment warhead missile attacking F16 battleplane, according to analysis and numerical simulation of damage principle and damage model of F16 in different missile power field and missile's attack, and according to combination of Multigen Creator and Vega, and according to real model and special effect of entity object, and simulation such as power field of fragment and shockwave, damaged effect of F16, and so on, the visual simulation of missile attacking F16 is implemented. The result of simulation vividly reproduces the process of missile attacking F16, and solves the problem that the authenticity is of shortage in the simulation's field of the missile attacking target.

References

[1] Jau-yeu Menq, Pan-chio Tuan, Ta-sheng Liu. Discrete Markov ballistic missile defense system modeling. *European Journal of Operational Research*. 2007; 178(2): 560-578.
[2] Orhan Karasakal. Air defense missile-target allocation models for a naval task group. *Computers & Operations Research*. 2008; 35(6): 1759-1770.
[3] Yingbo Ji. Analysis and Optimization Schedule for Tunnel Engineering Based on Information Management and Visual Simulation. *JCIT*. 2011; 6(5): 175-182.
[4] FENG Zhigao. Research on the Real-Time Simulation System Design for Missile Based on RT-LAB. *JCIT*. 2012; 7(11): 89-98.
[5] Huang Wusha, Chen Qiang, Wang Minzhuo, Ye Haonan. Virtual training system for hydraulic pump cart based on virtual reality. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(8): 4282-4290.

[6] Li Hai-Jun, Li Ke-Jie, Liu Xiao, Yu Yong-Qing, Zhang Zhong-Guo, Zhang Ji-Fu. Visual simulation of missile's attack course based on OpenGL. Xitong Fangzhen Xuebao. *Journal of System Simulation*. 2004; 16(3): 530-533.
[7] Dong Guang-Bo, Ma Li-Yuan, Zhang Xi-En, Liu Peng-Yuan. Research and implementation on simulation of missile flight-attack. Xitong Fangzhen Xuebao. *Journal of System Simulation*. 2003; 15(3): 408-411.
[8] Pablo G. Del Valle, David Atienza. Emulation-based transient thermal modeling of 2D/3D systems-on-chip with active cooling. *Microelectronics Journal*. 2011; 42(4): 564-571.
[9] Nicola Brusco, Marco Andreetto, Luca Lucchese, Simone Carmignato, Guido M. Cortelazzo. Metrological validation for 3D modeling of dental plaster casts. *Medical Engineering & Physics*. 2007; 29(9): 954-966.
[10] Yanhong Zhou, Dong Wen, Shukai Cao, Mengya Lv. The Algorithm of Cloth Fast Collision Detection Based on the Characteristics Triangle. *IJACT*. 2012; 4(7): 231-238.