Research on Police Weapon Virtual Simulation Training System

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Abstract: In Order to Improve Police officers' Capability to Using Gun in Actual Combat, and Meanwhile Solving the Several Accidental Discharge Problems That Occur When the Police Use Weapons Such as Pistols, This Study Develops and Establishes a Distributed Virtual Simulation System Based on Hla and Composed of Multiple Federal Members. the System, with Makvr-Link as the Development Environment, Constructed the Simulation Implementation Model of Each Subsystem That Constitutes the System According to the Federal Development Execution Process, Including the Bullet Trajectory Model and Delaunay Triangulation, and Finally Simulated the Omnidirectional Pistol Training Environment through the Visual Simulation System. after a Series of Tests, It Shows That the Constrained Delaunay Algorithm is More Efficient, and the Error in Using the System for Training is Stabilized within a Certain Range. the Network Communication Time Can Meet the Real-Time Requirements of the System. It Follows That That the System Established in This Study Can Meet the Requirements of Virtual Simulation Design and the Training Need of the Police Force or Police Colleges.

1. Introduction

Police lethal weapons mainly include pistols, submachine guns, assault rifles, sniper rifles and light machine guns. Police pistols are an important part of the police lethal weapons and also the domain of this study.

Virtual simulation technology is a technology that simulates real systems and virtual systems. Via the powerful ability of the computer to process data, it can conduct visual simulation of the research object, accomplish dynamic simulation of function, structure and behavior, to create a visual operating environment [1]. Pistol is one of the important equipment for the police to protect citizens and themselves, and to stop criminal acts, so pistol shooting skill is one of the professional skills that police must possess [2]. In order to improve the police's actual capability to using gun, this study helps strengthen the police shooting training by establishing a virtual simulation system to better ensure the safety of the police in the police activities and reduce the casualties of police.

2. Methodology

In terms of research methods, this study develops and establishes a distributed virtual simulation system composed of multiple federal members based on HLA and simulate an omnidirectional pistol training environments through the visual simulation system.

2.1 Distributed Simulation Based on High-Level Architecture Hla

HLA is an open, universal, object-oriented simulation architecture that defines the relationships between the various components of the simulation, enhancing the reusability of resource and interoperability of simulation applications [3]. It specifies a series of standards for the simulation process, including HLA rules, object model templates, and interface specifications for federal members accessing RTI.

HLA rules ensure the compatibility of federation and federal members. The object model template OMT provides a standard template for describing the classes, attributes, and interrelationships between different simulation objects, specifying the structure used by the federal

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object model FOM and the simulation object model SOM [4]. The simulation run support structure RTI defines management of common services for federal members. The interface specification defines the standard services used by federal members to exchange information with other members when participating in federal execution. The HLA simulation system adopts a hierarchical structure and is divided into three levels: a federal member level, an RTI level, and a network level.

MAK Technologies' VR-Link is adopted as the HLA simulation engine. It provides a standard C++ class library and runtime library API to support rapid simulation development of HLA. The interactive structure of the federated members based on VR-Link is shown in Figure 1.

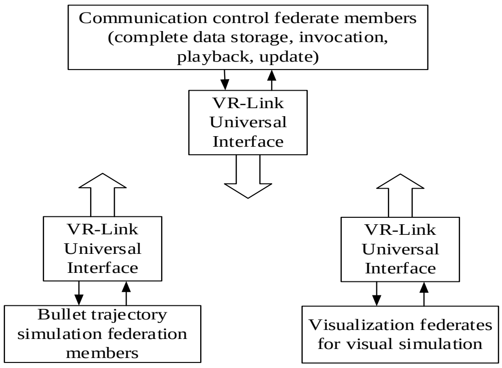

Fig.1 The Interactive Structure of the Federated Members Based on Vr-Link

2.2 Bullet Trajectory Model

The forces and moments of the bullet in motion are mainly: gravity G, aerodynamic R and so on. The aerodynamic force and aerodynamic moments are otherwise the same, depending on the aerodynamic shape of the bullet. The bullet is axisymmetric. The instantaneous centroid of the bullet is the origin of the ballistic coordinate system, and Xc - Zc=0. The projection of aerodynamic force, gravity G, and thrust P on the ballistic coordinate system are obtained as shown in equations below:

$$\begin{bmatrix} R_{x2} \\ R_{y2} \\ R_{z2} \end{bmatrix} = L^T(\gamma_v) \begin{bmatrix} R_{x3} \\ R_{y3} \\ R_{z3} \end{bmatrix} = \begin{bmatrix} -X \\ Y\cos\gamma_v - Z\sin\gamma_v \\ Y\sin\gamma_v + Z\cos\gamma_v \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} G_{x2} \\ G_{y2} \\ G_{z2} \end{bmatrix} = L(\theta, \psi_r) \begin{bmatrix} G_x \\ G_y \\ G_z \end{bmatrix} = \begin{bmatrix} -mg\sin\theta \\ -mg\cos\theta \\ 0 \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} P_{x2} \\ P_{y2} \\ P_{z2} \end{bmatrix} = L^T(\gamma_v) L^T(\alpha, \beta) \begin{bmatrix} P_{x1} \\ P_{y1} \\ P_{z1} \end{bmatrix} = \begin{bmatrix} P\cos\alpha\cos\beta \\ P(\sin\alpha\cos\gamma_v + \cos\alpha\sin\beta\sin\gamma_v) \\ P(\sin\alpha\sin\gamma_v - \cos\alpha\sin\beta\cos\gamma_v) \end{bmatrix} \tag{3}$$

The bullet simulation is built to simplify the mathematical model, and the centroid motion and the round-centroid motion of the bullet are modeled as a whole.

2.3 Delaunay Triangulation

To construct Delaunay in the simplified domain, the Delaunay triangulation needs to be constructed in three-dimensional space due to the different Z values of the feature points. The simplification algorithm continuously adds and deletes feature points during the process of viewpoint change. Such an operation requires reconstruction of the entire triangulation network for the segmentation merging algorithm and the triangulation growth algorithm, as a result it reduces the modeling efficiency. On the other hand, for the point-by-point insertion algorithm, adding or deleting a feature point will only cause the reconstruction of the local grid, which has an advantage in the efficiency of modeling. So we use a point-by-point insertion method to construct a Delaunay triangle.

In large-scale terrain modeling, in order to avoid the z-buffer contention, no solid model is built on the terrain surface, but in practical environment applications, it is sometimes necessary to identify the terrain through these terrain surface features. With this in mind, the DEM discrete data point set is used to generate constrained Delaunay triangle [6]. The algorithm is implemented as follows: Firstly, with the contour vector line as the constraint condition, while constructing the grid model, the elevation control points of the contour line are directly involved in the TIN triangulation modeling. Secondly, the rule data is further processed by the point-by-point interpolation method, and the contour line elevation control point is used as the feature point to update the Delaunay triangulation result in the local area of the contour line.

There are two ways to insert the contours. One is to construct the unconstrained Delaunay triangulation without considering the constraints, then add the constraint lines one by one and change the triangulation around the vector lines. This method needs to reconstruct the triangulation, so the efficiency is relatively low. The other way is to insert the constraint line and construct the Delaunay triangle after inserting the two endpoints of the constraint line. This method only needs to adjust the local area, and the algorithm is relatively efficient. The direct insertion contour is mainly used in the construction of the Delaunay triangulation.

2.4 Implementation of Visual Simulation System

Terrain generation. Graphical modeling generally includes terrain generation and target modeling. The terrain can be generated according to different conditions. The typical method is directly generated according to electronic terrain (DEM or DED format), whose advantage is simple and convenient, and the detailed level can be controlled in situation, but the access is limited.

Target modeling. CreatorPro is very powerful for building simulation models, which is shown in real-time generation of 3D models, dynamic meter generators, dynamic 3D sound settings, LOD and Morphing level detailing techniques, DOF degrees of freedom technology, Switch state switching technology, texture mapping technology and various third-party plug-ins.

In visual simulation, scene management and rendering directly reflect the effects of a system. The management of the scene mainly includes setting the state of each model in the display scene, the relationship and effect between the models, the display and change of the weather environment, and the setting of the viewpoint angle. MuItiGen-Paradigm's Vega is the leader in scene management and drive. It provides a good visual programming environment Lynx; users can complete a certain system design without writing any code. Surely, a specific application system still needs to be completed with programming. After Lynx sets up a scene, it forms a database file with the extension adf, by default Vega.exe is used to display the scene. Vega provides a complete C language application interface in order to enable programmers to call the adf files set up in nx and manage the scene through the program. Users can call these interface functions to simply display and manage the scene.

3. Results and Discussion

3.1 Delaunay Triangulation Velocity Analysis

Delaunay triangulation velocity is one of the keys to determine the efficiency of the algorithm. Using the feature-based Delaunay triangulation algorithm, Delaunay connection time test is performed via the discrete data point connection, as shown in Figure 2.

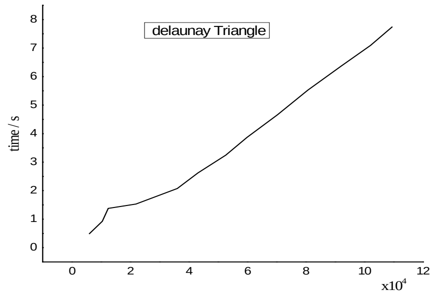

Fig.2 Constrained Delaunary Algorithm Execution Time

It shows that the constrained Delaunay algorithm is more efficient. When the number of discrete data vertices is within a certain range, the time complexity is basically linear, and the construction time does not increase sharply with the increase of the number of data points.

3.2 System Error

Several police officers were randomly selected to experience the operating system, and the changes of the bullet velocity and the side slip angle β in the virtual system were counted. The results are shown in Figure 3, Figure 4.

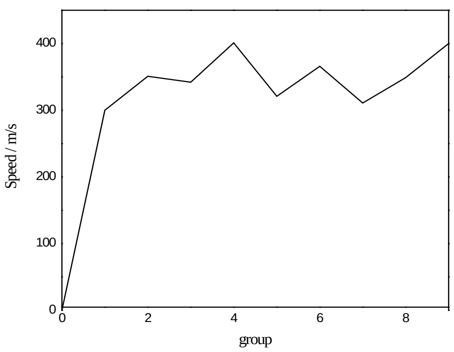

Fig.3 Group Bullet Speed

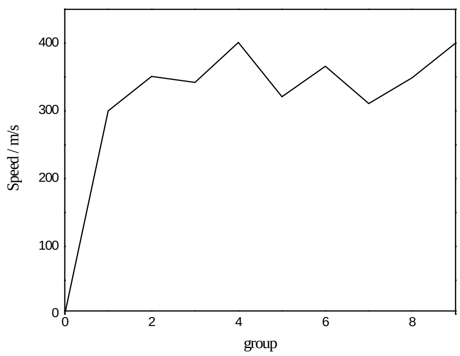

Figure 4. Pitch Angle Time Curve

It can be seen from figures that system error is stabilized within a certain range, and the system can simulate a relatively realistic training environment in practice.

3.3 Communication Establishment Time

For simulation systems, data transmission delay is unavoidable by the system. Delay includes the time it takes to pass change information to a computer program for processing accordingly. For the distributed simulation system, the network communication time is tested. The specific method is: the control member sends a data packet to one of the simulation members, the first packet's departure time is recorded as *tstart*, and a response packet is sent to a bullet control member after receiving, and then another data packet is sent by the bullet control member. When it receives the response packet again, it sends out the next packet. The two members continuously run *n* times without interruption, and finally the bullet control member records the local time *tend* of the last response packet, then (*tend*-*tstart*)/(2×*n*) is the time that network communication need to send a data packet. The measured results are shown in Table 1.

Table 1 Test Results Of Network Communication Time

Number	Times of Communication	Average Time (ms)
1	100	7.47
2	1000	8.12
3	10000	8.33

The bullet simulation system has a step size of 50ms. From the above results, the network communication time can meet the real-time requirements of the system.

4. Conclusion

This paper develops and builds a HLA-based distributed virtual simulation system composed of multiple federal members, with MAKVR-Link as the development environment, and in accordance with the federal development and execution process, the simulation implementation model of each subsystem that constitutes the system is built, including bullets trajectory model and Delaunay triangulation, and finally simulate a. omnidirectional pistol training environment through the visual simulation system. After testing, the system can meet the requirements of virtual simulation design and meet the training requirements of the police force or police colleges.

Due to the limitations of the conditions, the system still has inadequacy; for example, the simulation is short of the real training environment, and the system error may affect the user experience. It is expected that these problems can be improved in future studies.

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