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A novel accurate and expandable infrared radiation transmission effect computing service

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ABSTRACT

In infrared imaging simulation system, the infrared radiation transmission is significantly affected by natural environment. Attenuation and blurring are introduced by atmospheric environment impacts on the transmission process from zero sight infrared radiation to the detector. The classic IR transmission calculation methods have been intensively studied and many applicable approaches are proposed. The novel IR transmission effect computing service introduced in this paper could render accurate and expandable IR simulation result based on synthetic natural environment, especially concerning the atmosphere effects imposed on the IR transmission process. A simulation architecture is constructed and supports an infrared imaging simulation system for the IR transmission process calculation. The environment representation approach and the transmission effect calculation method were elaborated. Simulation experiment was carried out and the result was shown to be more accurate than that of conventional MODTRAN based atmosphere transmission simulation results. The two results are both compared with the physically captured image. The comprehensive simulation experiment results are implied to be competent and offered an applicable solution for the infrared imaging simulation system. Furthermore, this interdisciplinary simulation method can be extended to other synthetic natural environment supported military simulation and further serve the large-scale distributed collaborative combat simulation.

1. Introduction

The SNE (synthetic natural environment) imposes an important impact on the effectiveness of the weapon entities in military systems [1,2]. The AE (atmospheric environment) is a part of the SNE and the infrared imaging system equipped on some weapon entities is significantly affected by the AE. The motive of this paper is to contribute to an accurate, expandable and real-time IR (infrared radiation) transmission effect computing service platform with effective environment representation and application service and reasonable transmission effect calculation approaches, which is significant for the design and performance evaluation of the infrared system.

Two important concerns are emphasized: (1) the SNE (contains AE) representation; (2) the IR transmission effect calculation. On the aspect of the SNE representation, it is accomplished by the INE (Integrated Natural Environment) plan sponsored by the Modeling and Simulation Office of the U.S. Department of Defense [3]. Dynamic atmosphere and terrain models were built in the EnviroFed of the INE to simulate the impact of the environment and the dynamic variations of the internal environmental factors [4]. However, the EnvirFed project lacks the IR imaging simulation application. A novel SNE representation method and the corresponding SNE based computing service for IR transmission effect calculation are proposed in this paper. On the aspect of the IR transmission effect calculation, two methods were commonly used: one method is based on the commercial software (MODTRAN, FASCODE, HITRAN, etc.) [5,6], which have complicated atmospheric transmission models but difficult to achieve real-time calculation because of the source closed and time-consuming features. As for the co-simulation with various entities in military system, the software based environmental factors are difficult to be unified with the environment factors of the military system. The other method is based on empirical or semi-empirical formulae [7–9]. For most engineering calculations, this method can obtain acceptable results and can be used for real-time calculations. However, it fails to adopt a unified method with versatile considered environmental factors. In this paper, the requirements of the real-time atmospheric transmission simulation and the unified environment co-simulation in military system are satisfied with the novel IR atmospheric transmission computing service and method.

The SNE based IR transmission effect computing service is capable to provide the infrared imaging simulation system with an accurate, comprehensive and easily integrated environment. This paper focuses on the interdisciplinary problem between the SNE and the IR transmission effect calculation. A novel integrated SNE

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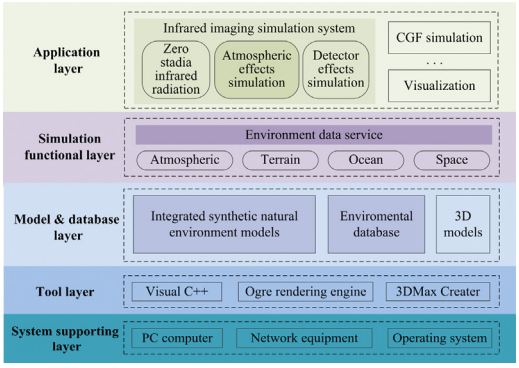

Fig. 1. The simulation system architecture diagram.

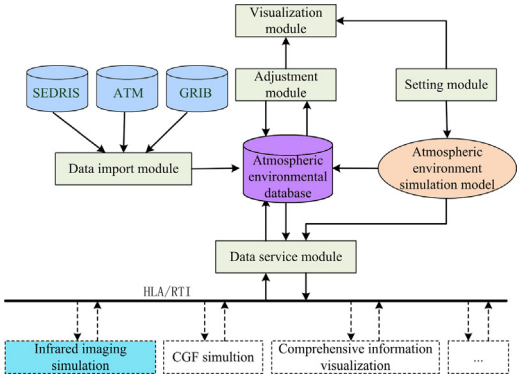

Fig. 2. The atmospheric environment data formation process.

representation method was proposed, according to which the AE representation, data organization and exchange are elaborated. A new effectiveness IR transmission effect calculation computing service platform is constructed by the integrated SNE representation and application methods, majorly concerning the AE impacts on the IR transmission process. The attenuation and blurring effect on the transmission process from the zero sight infrared radiation to the detector is calculated with the environment data acquired from the platform and modified empirical formulae. This IR transmission effect computing service is capable to serve advanced military simulation systems and higher level SNE integration systems.

The remainder of the paper is organized as follows: Section 2 describes the new simulation platform; this platform supports infrared imaging simulation system for the IR transmission process calculation. Section 3 proposes a novel integrated SNE representation method, based on which the AE modeling method is elaborated. Section 4 introduces the transmission effect calculation method. Simulation results and analysis are given in Section 5. Section 6 draws the conclusion.

2. Simulation system architecture

The architecture of the SNE based IR transmission effect computing service is illustrated in Fig. 1. It consists of system supporting layer, tool layer, model and database layer, simulation functional layer and the application layer. The model and database layer and the functional layer are the kernel of the whole system.

The system supporting layer consists of the basic hardware and operating system. The tool layer contains the software and APIs for simulation. In the current study the environmental affected simulation system makes use of the OGRE 3D graphics engine to complete the scene organization and image rendering. The model and database layer and the functional layer provide environment models, data and the data interaction services to the simulation application systems in the application layer. The infrared imaging simulation contains the complete simulation procedure (zero stadia infrared radiation, atmospheric impacts and detector effects). The zero stadia infrared radiation and detector effects are calculated by the conventional simulation method and are not elaborated in the current study. The AE impacts (attenuation and blurring) are calculated by the atmospheric models and data in Section 3 and the computational formulae are detailed in Section 4. The simulation needed AE data formation process is detailed in Fig. 2.

The atmospheric environment data formation process is centralized in the atmospheric environmental database and is divided into data import module, adjustment module, atmospheric environment simulation model, setting module, visualization module and data service module. The data import module receives complexity and variety of atmospheric environmental data format (SEDRIS, GRIB and ATM). The ATM format is atmospheric environment database in this paper. It organizes in quad-tree structure. The data import module converts the input SEDRIS and GRIB format into ATM. The adjust module is used to regulate the atmospheric environment database (both at the runtime and before the runtime) when the imported database does not satisfy the simulation requirements. The atmospheric environment simulation model provides a means to manually generate the atmospheric environment database. The setting module is devised to setup the atmospheric environment simulation model. The visualization module offers the user interface for the adjustment module and setting module. The data service module is responsible for the data interaction with the simulation systems. It receives the data request from the simulation system and obtains the required atmospheric environment data by database query and calculation. It is also responsible for receiving interactive data from the other simulation systems impacting the atmospheric environment.

3. A new integrated environment representation method

In this paper, the SNE representation method is the cornerstone of the new computing service, based on which the AE representation, data organization and exchanging method are established and applied for the IR transmission effect simulation.

3.1. SNE representation

The SNE conceptual reference model is the theoretical basis of the SNE study [10,11]. The SNE modeling in this study aims to meet the different needs of environment data access for the simulation subsystems (IR imaging simulation system, visualization, CGF, etc.) and ensures the consistency between different representations of the environment data.

While constructing the SNE data models, the SNE is divided into different kinds of environment objects. The environment objects possesses a variety of forms, which are expressed in different attribute sets, different behavior models and different object relations. Each environment object is expressed with a triple-layer five-tuple set by Eq. (1):

$$\begin{cases} EO = (ID, C, A_b, N, \sum_{i=1}^{N} \text{Behave}_i) \\ \text{Behave}_i = (IDB_i, CB_i, A_i, R_i, BM_i = f(CB_i, R_i)), \quad i = 1, \ldots, N \\ R_i = \sum_{j=1}^{M} Relation(RIDC_j, C_j, CB_j, EO_j, IDB_{EO_j}) \end{cases} \quad (1)$$

Eq. (1) is modified from the relatively simple SNE representation formula in [12], by adding environment object behaviors and