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Research on RF Environment Simulation in KD-JMASE

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Abstract. KD-JMASE is a supporting environment for modeling and simulation. It is a set of standards services and application programming interfaces. It provides the simulation of RF environment to calculate the superposition effect of electromagnetic wave signal in the process of transmitting and receiving. Reproduce the transmission process of scattering, diffraction, refraction and absorption of actual signals in real environment. This paper mainly studies the framework of RF environment simulation and the basic principles of simulation in KD-JMASE. The class structure design of RF environment effect model and the design of external communication port and the realization of actor-object cooperation in environment simulation are introduced in detail and design a simulation scenario to verify the atmospheric effect model in the RF environmental effect model.

1. Introduction

The manifestations of modern warfare have undergone significant and profound changes. Electronic warfare has become an indispensable part of modern warfare. It runs through the whole process of modern warfare and all operations. Radar electronic warfare is an important field of electronic warfare. RF (radio frequency) environment simulation is an important part of radar electronic warfare simulation. The reliability of radar electronic warfare simulation results depends on the precision of weapon system electronic equipment model and the accuracy of RF environment model. The establishment of a comprehensive and reusable RF simulation environment is of great significance to the research of radar electronic warfare.

KD-JMASE is a modeling and simulation support environment developed by the Military Simulation Laboratory of National University of Defense Technology. It is mainly used to construct engineering-level and combat-level digital system models and simulation systems for analysis and testing. This paper mainly studies its RF environment simulation module and develops a RF environment simulation example through JMASE public service and API interface.

2. KD-JMASE overview

KD-JMASE adopts object-oriented design, it defines a series of standards, services, models, and API interfaces, which greatly promote the reuse of model code and the interoperability of system models. The basic concept of JMASE [2]:

1. Component: a model for simulating real-world entity behavior logic.
2. Player: the highest level of model components composed of components, representing a class of objects that exist as separate entities.
3. Port: an object for communication between actors or components, a port can deliver many different types of messages and the same type of port can deliver messages to each other, port communication is
the only means of communication within JMASE, actors or components must have ports to communicate with each other.

4. Team: a collection of actors, components and ports, then an executable program is formed after allocation.

5. Scenario: a specific configuration of a group. The scenario generally defines the initial settings of a simulation, the information recorded during the execution of the simulation and other information.

KD-JMASE provides a range of tools and services for model and simulation development, including: Integrated development environment; Component definition files for creating actors, components and ports; Automatic code generation tool; Automatic generation system based on make; Configure scenario tools, simulation execution tools and ex post analysis tools.

JMASE also provides a series of public services to facilitate model development and ensure that all models conform to the same specification. JMASE mainly provides the following six service types, users can also develop or customize the services they need.

1. Simulation scheduling service: JMASE default scheduling mechanism is suitable for multi-CPU, multi-threading capabilities, event-based scheduling. JMASE also supports real-time scheduling function, which can be applied to hardware in loop simulation.

2. Six degree of freedom space service: Space services mainly provide users with the definition of coordinate system and coordinate transformation.

3. Message recording service: JMASE provides a message recording service based on file and graphical user interface. The messages generated by the model can be output to the screen or saved to the file during interactive operation.

4. Log service: Log service is used to record all kinds of data in the simulation running model. Logging services use JMASE's data management system to access and access various model data, thus reducing the workload of developers writing output code. JMASE provides three kinds of log data formats: binary format, ASCII format and MATLAB format.

5. Terrain and atmospheric services: Providing terrain and atmospheric information for the model.

3. Framework of RF environment simulation system in KD-JMASE

KD-JMASE RF environment simulation framework is mainly composed of environment service, RF environment effect model and weapon system model.

Environmental services mainly refer to terrain services, atmospheric services, space services and other services related to the natural environment, providing function calls for terrain, space, atmosphere and other information queries, such as terrain height and surface vegetation information, spatial information and atmospheric parameters information.

![Figure 1. Framework of RF environment simulation system in KD-JMASE.](image-url)
The model of RF environmental effects mainly includes clutter model, multipath and diffraction model and atmospheric effect model. Clutter is a kind of useless signal existing in radar echo, which is caused by the echo of numerous small scatterers in the background of the target. It mainly includes single-base pulse radar clutter, double-base pulse radar clutter, single-base continuous wave radar clutter and double-base continuous wave radar clutter. Multipath means that there is more than one path for radar transmitting electromagnetic wave to reach the target, including one direct path and one or more reflecting paths from the ground or sea. Diffraction is the phenomenon that electromagnetic wave propagates to the sheltered area. It is caused by obstacles in the beam propagation path. It mainly includes standard multipath and diffraction model and SEKE model. The atmospheric effect model mainly refers to the atmospheric refraction effect model and the atmospheric absorption model. The atmospheric refraction effect model determines the propagation path of electromagnetic wave in the atmosphere. The electromagnetic wave is regarded as a ray. Each ray passes through the atmosphere, the refraction angle is calculated, and the propagation path can be described in turn. Atmospheric absorption effect model mainly calculates the energy loss of radio frequency signal caused by oxygen O₂ and water vapor H₂O absorption. The complete effect model consists of absorption loss data and absorption loss path integral.

Radar, electronic jamming and target model in weapon system model are all solid objects in simulation. Electronic jamming model mainly provides a credible electronic environment for the test and evaluation of radar system model. They all interact with natural environment model through radio frequency environment effect model.

4. RF environment simulation principle in KD-JMASE

The radio frequency environment effect model is an independent object in KD-JMASE. It interacts with radar object, electronic jamming object, target model object and environment service object through a specific interface. As shown in Figure 2, the radar model object transmits the radio frequency signal to the radio frequency environment effect object through the interface. The radio frequency environment effect object obtains the environment information through the KD-JMASE environment service object (terrain service, atmospheric service, etc.) and calculates the various effects imposed on the radio frequency signal, finally the RF signal with environmental effect is transmitted to the target model object. Target model objects receive or reflect RF signals. If it is received, the target model object processes the radio frequency signal. If it is reflected, the target model object can send the radio frequency signal directly to the radio frequency effect model object for next propagation, thus reaching the radar model object. The target model object may have an electronic jamming model module to reflect the target echo and jamming signal.

![Figure 2. RF environment simulation signal processing in KD-JMASE.](image-url)
5. Design and implementation of RF environment effect model

Radio frequency environment simulation developed on KD-JMASE is used to support the performers of radio frequency simulation. Its function is to calculate the superposition effect of electromagnetic wave signal in the process of transmission from emission to reception and to reproduce the propagation process of scattering, diffraction, refraction and absorption, etc of the actual signal in the actual environment. The technical specifications of radio frequency simulation environment are: supporting the simulation of radio frequency range from 100MHz to 100GHz; providing a more complete radio frequency effect model, including ground clutter, multi-path diffraction, atmospheric absorption and atmospheric refraction; It supports both functional level simulation and signal simulation.

5.1. Class structure design
KD-JMASE radio frequency environment simulation is mainly implemented by radio frequency environment actors. Radio frequency environment actors adopt modular object-oriented design, including five sub-components, as shown in Figure 3.

The MemMgrType class is responsible for memory management; The ExternalCommType class is responsible for external port communication; the PropController Type class is responsible for managing various types of propagation effect model controllers, which include: scattering type effect model controller, transmission effect type controller, and propagation effect matrix, the propagation effect matrix recording propagation path. Each model controller is responsible for scheduling the same type of effect model; The ModelInfoType class is responsible for managing various propagation effect models, it mainly includes: clutter model base class, multipath model base class and transmission model base class, clutter model base class and multipath model base class all inherit the scattering model base class; The SystemControlObject class provides user options for the use of PropControllerType and ModelInfoType instances.

![Figure 3. Inheritance relation of actors in RF environment simulation in KD-JMASE.](image)

5.2. Design of external communication port
The JMASE modeling and simulation environment provides port communication mechanism for communication between actors. RF environment access interface mainly designs the receiver message port class, transmitter message port class, platform control port class and synchronization port class, each port class contains the external actor associated with the communication port and its message
processing function. External actors can send registration, control and exit messages to the RF environment. The environment actor receives the message, calls the internal function through the synchronous port to process the signal and then sends the processed signal packet to the corresponding receiver port. The external communication ports in RF environment are all managed by ExternalCommType components.

Figure 4. Design of external communication port for RF environment simulation actor in KD-JMASE.

5.3. Implementation of actor object collaboration in RF environment simulation

As shown in Figure 3 [3]: The JMASE Scheduler (JMASE_Executive) starts the processing of the RF environment by calling EnvPlayer's Update function; EnvPlayer reads the signal (RFSignalClass) transmitted by all RF transmitter objects in the simulation through the ExternalCommType component; If the signal list is not empty, ExternalCommType calls PropControllerType's ProcessPacket function to start processing the signal, PropControllerType is the core component of EnvPlayer, which is responsible for calculating all the propagation paths of RF signals from transmission to reception and call the ProcessModel function of ModelInfoType to calculate the effect of signal superimposed on each propagation path. ModelInfoType is responsible for managing all the effect models (EffectsModel). It calls the Model function of the effect model in turn to calculate the RF environmental effect. After all the effects are computed, PropControllerType is responsible for packing the paths and finally sends all the signals to the external corresponding receiver by calling the ExternalCommType's SendSignal function.

Figure 5. Object collaboration diagram for RF environment simulation in KD-JMASE.
6. Simulation example

6.1. Simulation plot
A red plane carries a missiles flying from the coordinates (0,100000,80000) to the blue side tank (0,0,0). At a distance of 40 kilometers from the tank, the tank was found and missiles were fired at the same time, the missile autonomously flew to the tank until it hit the target. The missile is added to radio frequency seeker and active guidance.

6.2. Model design
Simulation modeling using KD-JMASE, the model mainly includes: actors, ports and components. Actors include: aircraft actors, missile actors, tank actors; the components are: a seeker assembly, a seeker antenna assembly and a TankPlatform platform; Ports include: fire control port, explosion message port, seeker antenna component and radio frequency environment transmitter port, seeker antenna component and RF environment receiver output port, seeker antenna component and RF environment receiver input port. The structure of the simulation model is shown in Figure 6.

At the beginning of the simulation, the aircraft carries the missile at the initial speed (10, -120, -0.1) and uniform linear flight. The attitude of the missile is updated automatically according to the attitude of the aircraft. When the simulation program calls Update function every time, the aircraft acquires the coordinates of the tank and calculates its distance through the space service. When their distance is less than 40 kilometers, the aircraft sends fire messages to the missile through the fire control port.

The missile flies at a speed of 300 m/s after it leaves the aircraft. Each time the simulation program calls Update function to update, the missile transmits RF signals to the target through the seeker antenna module transmitter and receives the returned RF signals from the receiver, calculates the missile's axis deflection angle and target distance, provides guidance information for the missile. When their distance is less than 30 meters, the missile hits the target, sends a message to the tank through the explosion message port and then destroys itself. When the missile is less than 0, the missile falls into the sea.

The tank has a platform reflector component, at the beginning of the simulation, the tank starts from the coordinates (0,0,0) at a speed of (20,20,20,0) uniform rectilinear motion. After receiving the explosion news of the missile actor, he judged whether he was hit according to the position of the missile.

Figure 6. Simulation model system structure.
Establish a RF signal propagation matrix PMF file, as shown in Table 1. The RF environmental effect calculation signal is transmitted from MsI/Seeker/Antenna to the propagation process of MsI/Seeker/Antenna reception. In this process, the reflection of the signal on the Tank/Platform is considered and the atmospheric absorption effect and atmospheric refraction effect are considered.

Table 1. RF signal transmission file.

| recordstart | MsI/Seeker/Antenna Tank/Platform MsI/Seeker/Antenna |
|-------------|-----------------------------------------------------|
| AtmosModelsStrat | JMOOSEStandardAtmosModel |
| .AtmosModelsEnd | |
| RefractModelsStart | JMOOSEStandardRefractionModel |
| .RefractModelsEnd | |

6.3. Result analysis

Through KD-JMASE simulation modeling, after the simulation program runs, the result is analyzed by JPlot tool. Figure 7 is the trajectory of a tank and a missile on the ground. The missile guides itself to the target and hits it after launching. Figure 8 is the distance curve between the missile and the ground tank. m_dRealRange is the real distance between the two. m_dRange is the distance monitored by the RF seeker. As can be seen from the graph, there is little difference between the two.

![Figure 7. Tank and missile movement trajectory graph.](image)

![Figure 8. RF test distance and actual distance.](image)
Through the above simulation, it can be known that the RF simulation environment provided by KD-JMASE can completely realize an RF environment simulation level system. The RF seeker can accurately calculate the propagation of electromagnetic wave signals in the atmosphere and monitor the position of the target. The missile can effectively attack its target.

7. Conclusion
Based on the research of KD-JMASE RF environment simulation model, this paper designs an object-oriented RF environment simulation example and uses KD-JMASE modeling and simulation. The results show that KD-JMASE provides a good modeling and simulation support environment for weapon system development, testing and evaluation, provides a good series of standards, protocols, toolsets and operational environment and models. The whole development process is convenient and the work between RF modules is well coordinated and a complete RF environment simulation level system is realized.

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