Architecture of HLA Based Distributed Virtual Geographic Environment

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ABSTRACT Integrating the theory of distributed virtual geographic environment (DVGE) and high level architecture (HLA), the architecture of DVGE based on HLA is designed. The data flow and the object models of the architecture are also discussed. The architecture basically meets the need of DVGE in real-time communication, distribution, collaboration, reusing and interoperability, expansion, and standard.

KEY WORDS distributed virtual geographic environment; high level architecture; runtime infrastructure; architecture

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Introduction

DVGE was first proposed by Lin Hui and Gong Jianhua in 1999. DVGE is not only an advanced development of geographic information science, but also a distributed three dimensions virtual environment. It is based on avatar and has many characters, such as distribution, multi-users and agent process. It digitally combines the special geographic phenomenon and rules with multi-channel recognitions, representation, calculation and simulation. It can be used in multi-dimension geographic information management, multimedia integration and publication, some scientific innovation of interaction between human and computer, design of distributed geographic cooperation, design and decision, tour, education, training, entertainment and so on. It can support digital information project (digital zone, digital city, and digital drainage area) in methods and technology. VGE visualizes the abstract geographic data and information, creates a nearly real virtual world to study some examinations that are hard or even impossible to do in reality[1-4].

HLA was developed under the leadership of the Defense Modeling and Simulation Office (DMSO), is a general purpose architecture for simulation reuse and interoperability covering the large numbers of different types of simulations developed and maintained by the Department of Defense (DoD). The HLA was approved as an open standard through the Institute of Electrical and Electronic Engineers (IEEE) — IEEE Standard 1516—in September 2000. In November 2000 the Services and Joint Staff signed the HLA memorandum of agreement identifying the HLA as the preferred architecture for simulation interoperability within the DoD. While the HLA is an architecture, not software, use of runtime infrastructure (RTI) software is required to support operations of a federation execution. The RTI software provides a set of services used by federates to coordinate their operations and data exchange during a runtime execution. Access to these services is defined by the HLA interface specification[5].

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Nowadays, many universities, companies and institutes, have done hard work into HLA and RTI, and made many achievements. And also, some scientific research units focus on VGE and DVGE. DVGE is a new research field, and does not have a common architecture to organize its components. What we discuss in this paper is to construct DVGE based on HLA.

In this paper, we first discuss the main contents of DVGE, the requirement of DVGE architecture, then narrate the HLA and RTI, and finally design the HLA based architecture of DVGE and demonstrate some key technologies.

1 Distributed virtual geographic environment

To construct the architecture of distributed virtual geographic environment, we must know its primary contents, and be familiar with its requirements. The contents of DVGE are the same as VGE's. DVGE should implement VGE contents and distribute its components or nodes in different places.

1.1 Basic contents of virtual geographic environment

The basic contents of virtual geographic environment include principles, technologies and applications, which is showed in Fig. 1 [1-4].

1.2 Requirements of distributed virtual geographic environment architecture

To construct the architecture of virtual geographic environment, some basic attributes are required. These attributes include real-time communication, extension, distribution, collaboration, reusing, interoperation and standard.

Real time includes fast network transmission and image display. Extension requires the system to be added some new functions in need. At the same time, the new functions can be added without disturbing origin system, as distribution means the functions and the nodes can be distributed. Collaboration is a very important part of VGE. VGE collaboration includes data collaboration, model collaboration, operation collaboration, visualization collaboration and decision making collaboration from down level to upper level. Reusing makes it easy to transplant and
extent module codes or functions. When interacting with other avatars or environment, an avatar should use interoperation which means all the members should right understand each other. In VGE, we call the member as avatar. Interoperation is of two directions. An avatar can not only send out message and need be understood, but also receive message from others and understand it. Last but not least, standard should be kept in mind when designing VGE system architecture.

2 High level architecture

2.1 Concepts

Federate: an application that may be or is currently coupled with other software applications under a federation object model document data/federation execution data (FDD/FED) and an RTI. This may include federation managers, data collectors, real world ("live") systems (e.g., C4I systems, instrumented ranges, sensors), simulations, passive viewers, and other utilities.

Federation: a named set of federate applications and a common federation object model that are used as a whole to achieve some specific objective.

Federation object model (FOM): a specification defining the information exchanged at runtime to achieve a given set of federation objectives. This includes object classes, object class attributes, interaction classes, interaction parameters, and other relevant information.

2.2 Basic principle of HLA

2.2.1 Components

HLA has three components; HLA rules, interface specification and object model template (OMT).

HLA has ten rules, five for federate and other five for federation. The ten rules give the basic principles to guide design, using and obeying of HLA. HLA interface specification prescribes six managements, i.e. federation management, declaration management, object management, ownership management, time management and data distribution management. OMT specification defines the format and syntax (but not content) of HLA object models. HLA object models may be used to describe an individual federation member (federate), creating an HLA simulation object model (SOM), or to describe a named set of multiple interacting federates (federation), creating an FOM. In either case, the primary objective of the HLA OMT is to facilitate interoperability among simulations and reuse of simulation components. The OMT consists of the following components; object model identification table; object class structure table; interaction class structure table; attribute table; parameter table; dimension table; time representation table; user-supplied tag table; synchronization table; transportation type table; switches table; data type tables; notes table; FOM/SOM lexicon.

2.2.2 Run time infrastructure

While the HLA is architecture, not software, use of RTI software is required to support operations of a federation execution. The RTI software provides a set of services used by federates to coordinate their operations and data exchange during a runtime execution.

2.2.3 Basic principles of HLA

The HLA provides a general framework within which simulation developers can make and describe their simulation applications. Flexibility is the aim of the HLA. In particular, the HLA stresses two key issues; promoting interoperability between simulations and aiding the reuse of models in different contexts. Two main components are described within the set of products forming the HLA. The first is the OMT, which forms a documentation standard describing the data used by a particular model, a necessary basis for reuse. The second component, the federate interface specification, describes a generic communications interface that allows simulation models to be connected and coordinated, thus, addressing interoperability. Although the HLA is an architecture, not software such as RTI software, which provides six kinds of manage-
ment services as defined by the federate interface specification, supports operations of a federation execution. The RTI software is used by federates to coordinate operations and data exchange during a runtime execution.

RTI, which likes a soft bus, can be plugged into standard simulation and management software. These characters make it possible to implement inter-connection and inter-operation of simulation system, and to reuse federates. The logic structure of RTI is shown in Fig. 2.

![Fig. 2 Logic structure of HLA/RTI running.](image)

3 Using HLA principles to construct the DVGE architecture

VGE is complex. There are mass computation, communication, representation, analysis, visualization and decision making to be done in real time or near real time. Although computer technology has developed fast and has arrived at an advanced state, it is also impossible to integrate all functions into one computer, even super-computer. That is the reason that we develop distributed virtual geographic environment.

In this paper, we do not discuss the rules and interface of HLA, because they are already widely studied. Here we focus on how to use HLA principles to build the architecture of distributed virtual geographic environment. We will also discuss object model in this designed architecture.

3.1 HLA based DVGE system architecture

The architecture of DVGE based on HLA can be shown in Fig. 3. DVGE is composed by several local area network virtual geographic environments (LANVGE). Every LANVGE can be a self-governed system. LANVGE is not only a part of a DVGE, but also a DVGE of low level LANVGE. LANVGE is also a local distributed virtual geographic environment whose functions or computations are allocated at several computers. Of course, LANVGE can be congested into one computer, which we call the terminal VGE.

HLA based DVGE adopts the structure of HLA/RTI to build DVGE federates. The federates of DVGE include 3D visualization federate, data management federate and system management federate. The main tasks of 3D visualization federate are to display 3D scene and interact messages transmitting between avatars. Data management federate implements data organization, management and database collaboration. System management is the whole system manager to initialize system, allocate tasks, monitor system state, deal with reported error and so on.

LANVGE has three kinds of federates, which are visualization federate, local system management federate and local data management federate. Visualization federate integrates RTI interface, node database, node computation, node analysis, 3D visualization and interface, and human-computer interface device. In visualization federate, RTI implements HLA six managements like node’s gateway to some extent. The RTI interface frees users to put their energies into realizing the geographic issues. The node database which includes data and models serves as the basement to create node view scene, to do geo-compute and to analyze geo-parameters. With the data and models, visualization federate can calculate model parameters, analyze model results. The computing process and the results will be visualized. 3D display provides an interface, which interacts with users through human-computer interface device. There are tens or even hundreds of graphic federates in one local area network according to the system demanding and complexity. Local data management federate stores local environment data such as object data, video data, audio data, remote sensing data and environment models such as water pollution model, wind model, ocean currency model, atmosphere model. Data management federate su-
apply environment data and models to graphic federates when receiving graphic federates' queries. Local system management federate likes transport police to make the network and system in order. Unlike local data management federate, local system management federate deals with dynamic data (exchanging data), it is the supervisor of the local system, it can monitor all the data transmitted through net and can also sent out alarm to some trespasses or even cut them out of the net to keep system security.

Visualization federate, data management federate and local system management federate communicates with each other with the supporting of RTI interface. At the same time, local system management federate exchanges local area network data with wide area network. Several LANVGEs, under the supervision by system management federate, form the whole distributed virtual geographic environment.

In this architecture, database takes a very important position. The database is divided into four level, system database (SDB), local system database (LSDB), local database (LDB) and node database (NDB). SDB and LSDB have the same tasks, but in different level. SDB deals with all the exchanging data running on wide area network, while LSDB takes order with local
area network data. For some simple VGE system with only one LANVGE, LSDB takes place of SDB to manage the whole system. LDB stores static data for LANVGE initiation. NDB has the data only for its own node. The objective of dividing these four level databases is to increase clearness of the system data logic and to decrease the data transmitting time on network.

### 3.2 Data flow

That a federate asks data from other federate is called data subscribing. On contrary, we call it data publishing that a federate replying some data. It is not users' duty, but the RTI's responsibility to fulfill data subscribing and publishing. What the users do is to prepare data and tell RTI to publish or subscribe. With the mechanism of data dealing in HLA and the architecture designed above, the data flow of HLA based DVGE is shown in Fig. 4.

### 3.3 Object model

The interoperation among federates is precondition to realize HLA platform designation. OMT guarantees interoperation among objects. Some times, an object is a federate. According to OMT, system developers should define several important attributes of an object. These attributes include object data, data operation, data update driver, data transmission mechanism, and some other information related with interoperation.

In HLA based DVGE, there are many kinds of objects. Terrain object, surface features object, entity object, geography circle object, wind object, sound object and the like are the objects for visualization federate. Data logging object, data analysis object, data statistic object, data query object form data management federate objects. System management federate objects include system self-checking object, error dealing object, network monitoring object, management order generation object and so forth.

To implement object model designation is the definition of federation object structure and federate object structure. Federation object structure prescribes DVGE federation object class and interaction class. Federate object structure stipulates for that parameters will be published and attributes will be subscribed.

### 3.4 Database collaboration

Because DVGE database is distributed, we must solve the database collaboration. There are two key tasks in DVGE database collaboration. One is data consistent, and the other is collaboratively to support the system execution with the distributed database. Data consistent is that when an entity changes its attributes, the same entity attributes in other computers or places are
also altered accordingly. Another database collaboration task, collaboratively supporting system execution, is that nearly all the data from distributed databases can be united together to form a likely unitary database. When initiating the DVGE system, of all the nodes one should analyze their data requirements, collect the occurring in high-frequency using data and store them in node databases. When requiring data to construct it or execute its proceeding, a node will enquire the data from its local database. If the data can not be found in local database, the node will transmit the inquiring statement to the local system database or system database and get the results from there. But unfortunately, large number of such simple query processes may occur at the same time. So, if not taking any measure, some nodes will not submit their orders and of course could not get the results. To solve this problem, we design a method, namely "pre-data-preparing". The goal of pre-data-preparing is to decrease, or even to eliminate, the waiting time of the processing when there is needs of query results. Pre-data-preparing principle can be explained from Fig. 5. When a node is being constructed or executing, it will start a data dealing agent (DDA) at the same time. DDA can check what data will be needed, the next step, search data from local area or wide area database, prepare the data before DVGE system proceeding comes to the right step, and pass the results to the proceeding. To reach the goal of pre-data-preparing, DDA should decide when to forecast the needed data and how long from now it should be prepared. Because of the net congesting, within the period of preparation, it is a difficult to guarantee the results to be got in time.

On the assumption that the net band is enough for data transmitting, the pre-data-preparing process is like Fig. 5. Fig. 5 only shows one time data preparing. Multi-time preparing is the simple repetition of Fig. 5.

In fact, there are a lot of DDAs in DVGE. So, we design the collaboration of DDAs for the DV-
GE database as shown in Fig. 6, which realizes the DVGE database collaboration. In Fig. 6, local DDA can upload or download data. When local DDA download data from system database, wide area DDA will collect the needed data from system database and local system databases, interchange the result data into the local compatible format, and transmit it to the local DDA. When local DDA upload its data to global database, the wide area DDA will inspect the data consistency. Only if the uploaded data do not conflict with other data in system database, can the data from local DDA be accepted, interchanged and stored.

4 Conclusions

This paper focuses on how to use HLA/RTI idea and structure to build distributed virtual geographic environment. DVGE requires real-time communication, distribution, collaboration, reusing, interoperation and standard. The basic idea of HLA is to realize the interoperation among different types of simulation and to reuse simulation software. HLA adopts multi-cast mechanism of net communication to decrease unnecessary data running through network, which makes the real time communication reliable. Collaboration is upon RTI. HLA is already IEEE standard. From above, we know that HLA based DVGE architecture meets the requirements successfully.

Virtual geographic environment is a new research area, and what we did in this paper is a foundation study. In the future, we will try to test this architecture and will also research the architectures of some other type.

REFERENCES

[1] Gong Jianhua, Lin Hui (1999) Virtual geographical environments, concept, design, and applications[C]. The International Symposium on Digital Earth (ISDE), Beijing, China

[2] Gong Jianhua, Lin Hui (2000) Virtual geographical environments and virtual geography[C]. The 9th International Symposium on Spatial Data Handling, Beijing, China

[3] Lin Hui, Gong Jianhua (2000) Distributed virtual environments for managing country parks in Hong Kong; a case study of the Shing Mun country park [C]. The 9th International Symposium on Spatial Data Handling, Beijing, China

[4] Lin Hui, Gong Jianhua (2002) On virtual geographic environments[J]. Acta Geodaetica et Cartographica Sinica, 31(1):1-6 (in Chinese)

[5] Defense Modeling and Simulation Office of United State Department of Defense (2005) High level architecture[OL]. http://www.dmso.mil

[6] IEEE-SA Standards Board (2000) IEEE standard for modeling and simulation (M&S) high level architecture (HLA); framework and rules[S]. New York: IEEE

[7] IEEE-SA Standards Board (2000) IEEE standard for modeling and simulation (M&S) high level architecture (HLA); federate interface specification[S]. New York: IEEE

[8] IEEE-SA Standards Board (2000) IEEE standard for modeling and simulation (M&S) high level architecture (HLA); object model template (OMT) specification[S]. New York: IEEE

[9] Xu Bingli, Gong Jianhua, Lin Hui, et al. (2005) Virtual geographic environment database design and collaboration[C]. International Geoscience and Remote Sensing Symposium, Seoul, Korea