Research on HLA-based Forest Fire Fighting Simulation System

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SUMMARY
This paper describes the design of a distributed architecture to support an interactive, interoperable, and collaborative forest fire fighting simulation using IEEE standard 1516 - High Level Architecture (HLA). Based on the Run-time Infrastructure (RTI) services which are specified in HLA and C++ application programming interface (API) of the RTI, The distributed virtual fire fighting environment provides a practical foundation to enhance interactivity, interoperability for distributed simulation.. Users can build new federation application by the way of the goal system reorganization. The key techniques, such as FOM/SOM design, system structure, running mechanism of simulation system are discussed. From the system implementation and experimental results, the proposed HLA distributed architecture is a practical and scalable, and applicable for a large-scale of fire fighting simulation.

KEYWORDS: *virtual forest environment, fire fighting simulation, High Level Architecture, FOM/SOM Federation member*

INTRODUCTION

The spatial spreading is one of main behaviours of forest fire. The traditional approach to forest fire fighting training was usually based on the real-life practice, which is intrinsic of many drawbacks. It costs too much, pollutes the environment, and sometimes hurts the firemen (Wang et al., 2001). In addition, the process of the forest fire fighting could be irreversible, and the experimentalist or trainee could not hold the whole details of the real-life simulation process in control (Chen et al., 2003). Hereby, the real-life simulation method usually could not achieve the purpose of the experiment or training.

In order to overcome these drawbacks, the scientists and forest resource manager have explored the other approaches instead of the real-life simulation from the 1980s (Chen et al., 2005). These substitutes have many advantages, such as little costs, no pollution, and no restriction by the experimental location and area because of virtual geographical environment (i.e. forest landscape) being established during fighting simulation (Li et al., 2004). When a distributed or collaborative environment is applied for forest fire fighting simulation, Interoperability and reusability of goal system become the key issues for the developer and the users. To date, the High Level Architecture (HLA) has become a research hotspot on of the distributed simulation field. And it has been proved successfully to facilitate the development of the distributed system.

The simulation system of forest fire fighting is originated from development of the forest fire spreading model and distributed simulation system. The scientists have studied and analyzed the factors to induce and affect the forest fire and its spreading in order to simulate and control the forest fire fighting. The fire fighting simulation applications, along with the modern simulation, virtual reality, visualization technologies have had the considerable progresses. The concept of the fire fighting simulation refers to as a comprehensive 3D forest fighting behaviour modelling on the digital terrain, in which some natural environment elements, such as temperature, humidity, wind condition, slope, as well as the types of combustible substances are involved. Based on this simulation

environment, the occurrence, development and spread of the forest fire, and fighting behaviours are simulated virtually and interactively, and enable the users to experience the process of the fire scene from any visual view. The users also review the fire fighting simulation history (Yang et al, 2003).

In the view of system integration, there exist many fire fighting systems, which are based on forest fire spreading models, spatial information technologies (such as remote sensing, GPS, GIS), and some distributed simulation tools (Andrew et al., 2001; Goldberg et al., 2001).Some of them have been used for on-spot emergency command platforms (Morgan et al, 2001), others for Parallel & Distributed PVM platform of high performance. Wherein, FARSITE, a forest management system which developed by USDA is the most widely used in the world (Chi et al, 2003).Wybo (1998) introduced a decision support system for forest fire prevention and fighting, FMIS). Kramisoglou et al. (2004) developed multi-disciplinary forest fire crisis management system to meet the dynamic information needs of large scale fire fighting. Similar to the fire preventing system built in Guangzhou city, South of China, the National Forest Fire Protection Management System has been set up in 2000.

HLA was approved as an open standard by IEEE in September 2000, and it consists of three primary components, namely federation rules, the HLA interface specification, and the object model template (OMT). Though it was originally designed for the large-scale military simulation, but HLA also has been widely used in non-military fields, such as product design, distance learning, medical service, shopping and so on, along with the rapid development of the simulation system and the related technologies in past decade. Recently, with the emergence of the notion “Digital Forestry” and demand for the management of information on the forestry, traditional approach could not satisfy the large-scale forest fire simulation which is formed based on 2D environment. In order to meet the increasing needs, this paper we apply HLA/RTI paradigm to construct the distributed system of forest fire fighting simulation.

In this paper, we propose an interactive, reusable forest fire fighting system architecture based on HLA. The functions of system and FOM/SOM modelling process also were discussed. The left parts of this paper are organized as follows. Section 2 gives a overview of the fire fighting system with the background information on the system. Section 3 describes the design of the FOM and SOM table, and the design of the concrete federation members also be discussed in this parts. In section 4 and section 5, some illustrative interfaces to this experimental simulation are listed, which followed by a brief conclusion and our plans for future research.

ARCHITECTURE AND FUNCTIONS

System architecture

The prototype system of forest fire fighting simulation is developed based on HLA/RTI1.3. Purpose of the system is to construct the distributed simulation environment on the local area network in order to meet the basic requirement for the simulation of fire fighting, including various resources of the fire model, terrain, forest, fire fighting tools, and its visualization. So the users can establish many kinds of distributed forest fire fighting systems, respectively suitable for different application backgrounds and objectives. Figure 1 is HLA-based distributed architecture we proposed. Each simulation node is defined as a federate member or a federate on the Local Area Network environment. The collection of federates interconnecting through the Run-time Infrastructure (RTI) as an HLA federation.

There are four federate members till now, namely the terrain federate, fire federate, fire fighting tool federate and the forest federate, were aggregated in an HLA federation. Each federate member is responsible for its initialization and the related running management. For example, the initialization of fire federate member defines initial parameters, such as the position of the fire starting, the size of

initialized fire, spread direction, wind direction, wind power, etc. At the same time, The RTI provides the means for each federate agent to coordinate the execution and exchange of shared information.

Based on these federate members defined above, the users of simulation can do concrete simulation behaviours according to the various demands and the concrete simulation task by choosing the related federate member. The paradigm we proposed could overcome the drawbacks of the tradition approaches to fire fighting simulation.

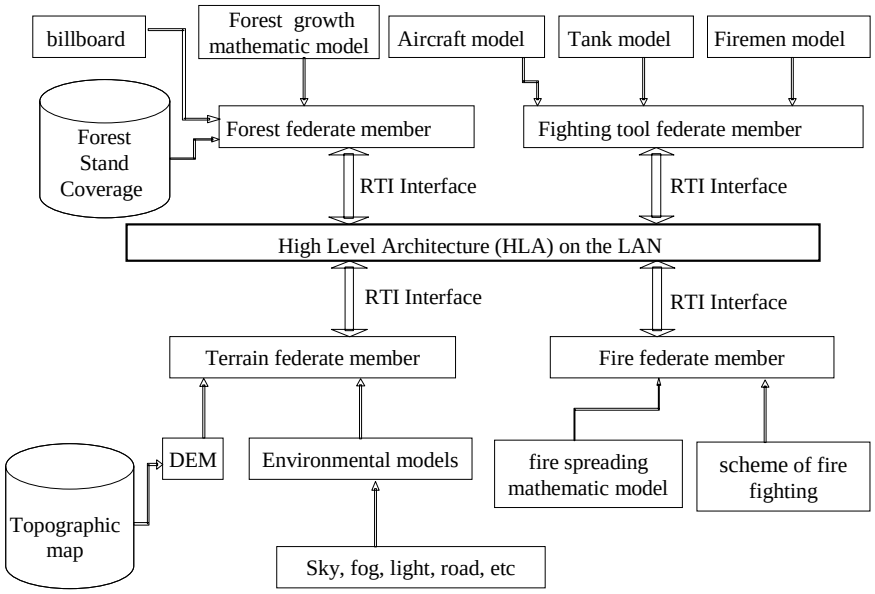

Figure 1: An HLA-based architecture of forest fire fighting system

System Function description

The basic task of the fire fighting simulation system is to implement the virtual forest environment constructing, forest fire constructing, fight fire tool constructing and the fire fighting process constructing. All of the federate members interconnect through the local area network. The federation execution managed all of federate members. We apply the Run-time Infrastructure (RTI1.3 v5) as basic system environment. The RTI Lib also were loaded into each federate member in order to realize the function that one federate member communicate with other by HLA/RTI. During simulation, these federate members have capabilities of controlling and communicating parameters and states in real time. This whole process could be shown in 3D view in order to go on further analysis and application.

As shown in Figure 1, Terrain federate (including sky, fog, light, fog etc) and forest federate (including forest stand growth modeling) are acted as virtual nature environment, while the fire federate (including process visualization of dynamic fire spot, fire spreading) and Fire fighting tool federate (including creation and management of tools, data order and distribution) are acted as behaviors characterization of forest fire fighting. The terrain federate member acts as the basic view of the HLA federation, with responsibility for the management of the federation execution and the whole visualization of the federation. The forest federate member mainly answers for the tree object simulation. This federate member is not imperative of the HLA federation. It joins in the HLA federation or not depending on the simulation task. Also, the fire fighting tool federate member joins

in the HLA federation only when needed. When the fire fighting tool joined in, this federate member could execute the function of fire fighting.

FEDERATION AND FEDERATE MEMBER DESIGN

FOM/SOM design

The Federation Object Model (FOM) describes the information shared between the federate members during federate execution. It is a collection of the object classes and interactive classes with related attributes and parameters. The Simulation Object Model (SOM) describes what information could be published and subscribed. The tables of FOM and SOM usually are designed before the detailed system design. It is the foundation for interaction between the federation executions. The quality of the FOM development have direct effect on the capacity of the network flux and the system burden, thus the quality of the FOM development often become "the software bottleneck" of the simulation application(Su et al,2004).

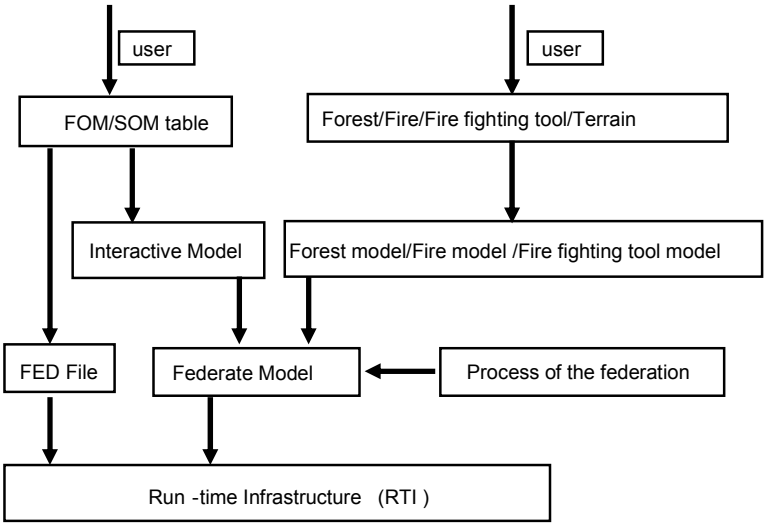

Figure 2: Design flowchart of the HLA federation

Figure 2 shows the process of the HLA federation modeling and designing. The method of the object-oriented analysis and design provides way to design the federate members and the HLA federation. The process of the SOM design includes several key steps. 1) To determine the ability of each federate member to publish and subscribe the object class and the interactive class; 2) To determine the system to the object attribute announcement and the subscription demand; 3) To construct SOM table by the OMDTv1.3, and then the Federate Execution Data (FED) files which the federation execution needs.

Figure 3 and Figure 4 show the object classes and the interaction classes which designed for the fire fighting simulation. The object classes mainly include forest object class, forest fire object class, fire fighting tools object class and the terrain object class. And the fire fighting tools consist of the fire-fighting aircraft model, the fire-fighting tank model and the fireman model. The interaction classes contain the fire starting, fighting start and end.

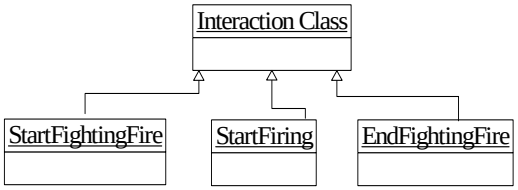

Figure 3: ***Object*** class hierarchy of the System

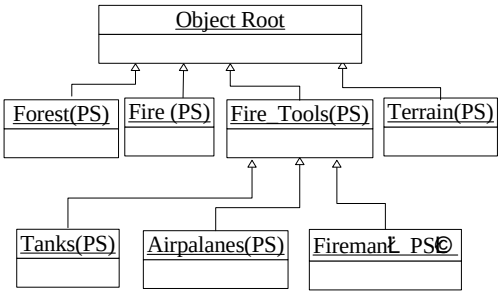

Figure 4: Interaction class hierarchy of the system

Federate member design

(1) The forest federate member. The design of the forest federate member contributes to a real-life three-dimensional forest scene. Constructing a real-life 3D forest scene need several essential factors, such as 3D terrain, hypothesized forest as well as some essential special effect like water, smoke, fog, etc. All of these are combined to create a basic, simple forest model (Li et al, 2005).

(2) The forest fire federate member. The forest fire federate member, which mainly composes of the fire spread model, the fire fighting model, as well as the two- dimensional map. When the forest federate member sends the command of “catch fire”, the forest fire federate member will join in the federation execution as a sub-member. When the forest catches fire, there are two types of the fire model according to the situation of the wind. One is that there is wind, the fire spread model would spread with the parameter of the wind, and other is that there is no wind. At the same time, the state of the fire could be displayed as a two-dimensional image.

(3) The fire fighting tool federate members. The fire fighting tool federate member could provide the fire fighting tool model which is needed to join in the forest scene of fire fighting. This federate member is composed of the fire-fighting aircraft model, fire-fighting tank model, the artificial fireman model and the two-dimensional image. When an object sends out a command of “starting fire fighting”, this federate member begins to register the instance of the class object, and join in the process of federation execution. The instance not only needs to judge the scope of the current fire, but also need to start the fire fighting according to the certain principle of putting fire out. When this instance receives the “end” order or the energy of this is used up, this federate member should destroy the instance, and register the new one to join in the federation execution.

(4) The terrain federate member. The terrain federate member designed as the visualization member in all process of simulation. It will display current state in 3D way to the viewers. In order to improve the effect and the speed of the system, we use the multi-texture fusion technology. We also

use the particle system for the forest fire fighting simulation to enhance the fidelity of the simulation of the real-life system.

EXPERIMENTAL RESULTS AND ANALYSIS

The major characteristic of the forest fire fighting training system is presented above. It aims at setting up a simulation environment for fire fighting training purposes. To reach the objective, Simulations are performed using the software agents and HLA/RTI. The HLA is the middleware that handles the exchange process of needs and interests that occurs between the different simulated federate members. This federation consists of four different independent federates. Each federate can run under stand-alone condition. We designed and performed it based on Visual C++ and the industry standard OpenGL.

From Fig. 5 to Fig 7 listed below are typical interfaces of the integrated simulation system. The system is run by taking Zhangpu County forest in Fujian Province as a pilot study. Forest inventory data, forest stand maps and DEMs were stored and managed in a relational database management system Oracle 9i by ESRI ArcSDE, a spatial database engine.

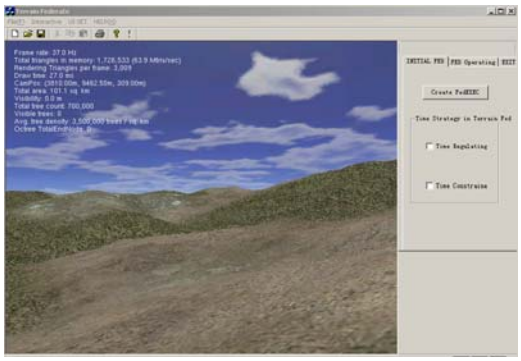

Figure 5: The interface of terrain federate member

Figure 6: The interface of forest federate with fighting tool

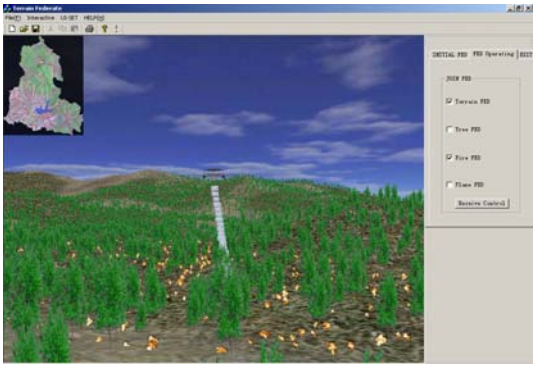

Figure 7: The interface of integrated system

CONCLUSION AND FURTHER WORK

Practical implementation of the fire fighting simulation involves much more issues than those discussed above. This paper addressed some of the fundamental design issues related to the manner in which independent applications can be made to interact with each other. The system architecture and functions of the fire fighting simulation based on the HLA, as well as the detailed process of the development of each federate member were proposed. Then the design of the FOM and the SOM table discussed. Finally, we developed the prototype system of the fire fighting simulation on the local area network.

In conclusion, this is a new way to simulate the forest fire fighting using the technology of HLA/RTI, OpenGL and visualization. Based on what we proposed, it is possible to construct the large-scale distributed fire fighting simulation system. In our future work, adaptive visibility culling for 3D locales is the on-going research issues to reduce the computation costs and accelerate the rendering time. Moreover, the HLA time management is intended to be integrated with our current HLA distributed architecture to deal with both soft and hard real-time simulations.

ACKNOWLEDGEMENTS

The authors wish to thank Prof. Lang Yichi for his constant support during our research, especially during field investigation for sampling. This project is sponsored by Preliminary Project of 973 Program (No.2004CCA02100) in China.

BIBLIOGRAPHY

Andrews P.L., QueenB L.P., 2001 Fire modeling and information system technology. International Journal of Wildland Fire, Vol.10:343–352.

Chen C., Li J., Yu Q., Qi M., 2003 A Collaborative Forest Firefighting Training System Based on VGE. In: Proceedings of International Advanced Workshop on Virtual Geographic Environments and Geocollaboration. December 15-16, 2003, CUHK, Hong Kong.

Chen C., Li J., Tang L., Feng X., 2005 Research advance in simulation and visualization of forest fire spreading via computer. Scientia Silvae Sinicae, 2005, 41(5):155-162. (in Chinese)

Chi S.D., Lim Y.H., Lee J.K., et al. , 2003 A simulation-based decision support system for forest fire fighting. In: Proceedings of AI*IA: Advances in Artificial Intelligence, Lecture Notes in Computer Science, Vol.28/29, pp487-498.

Gollberg G.E., Neuenschwander L.F., Ryan K.C., 2001 Introduction: Integrating spatial technologies and ecological principles for a new age in fire management. International Journal of Wildland Fire, Vol.10, pp263-265.

Hanson H.P., Bradley M.M., Bossert J.E. et al., 2000 The potential and promise of physics-based wildfire simulation. Environmental Science & Policy, Vol.3, pp161-172.

Jorba J., Margalef T., Luque E., 2001 Simulation of Forest Fire Propagation on Parallel & Distributed PVM Platforms. In: Y. Cotronis and J. Dongarra (Eds): Euro PVM/MPI 2001, LNCS 2131. Santorini Island, Greece, April 17-20, pp386–392.

Keramitsoglou I., KiranoudisC.T., Sarimvels H. et al., 2004.A multidisciplinary decision support system for forest fire crisis management. Environmental Management, Vol.33, No.2, pp212–225.

Li J., Chen C., Tang L., 2004 Realization of collaborative forest fire fighting training system and its key technology. Journal of computer simulation. Vol.22, pp170-174.(in Chinese)

Li J., Chen C., Yu Q., Pan Z., 2005 Forest fire spread modeling and 3D visualization in virtual forest landscape. Journal of applied ecology. Vol.16,838-842. (in Chinese)

Morgan P., Hardy C.C., Swetnam T.W., et al., 2001. Mapping fire regimes across time and space: Understanding coarse and fine scale fire patterns. International Journal of Wildland Fire, Vol.10, pp329-342.

Su Y., Kang F., 2004 Research on HLA-Compliant Underwater Warfare Simulation system. Journal of System Simulation. Vol.16, pp2732-2736 . (in Chinese)

Wang X., Qi H., Zhang Y., 2001 Study on DIS System Framework of Fire Drill Simulation. Journal of Chinese Safety Science, Vol.11, pp58-61. (in Chinese)

Wybo J.L., 1998 FMIS: A decision support system for forest fire prevention and fighting. IEEE Transactions on Engineering Management, Vol.45,No.2, pp127-131.

Yang Z., Zhang G., Qian S., 2003.The computer simulation research of forest conflagration. Journal of the Human Forest Science & Technology. Vol.30, pp58-61. (in Chinese)