SYNTHETIC BATTLEFIELD BASED SIMULATION FRAMEWORK FOR THE AVIATION ENGAGEMENT IN DISTRIBUDTED SYSTEM

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ABSTRACT

This paper presents a framework for the synthetic battlefield based aviation engagement simulation in the distributed system. The framework represents the radar detection system based on the synthetic battlefield using HLA (High-Level Architecture) based distributed system. An engagement simulation system requires the synthetic battlefield to reflect environmental effects to the simulation result, because behaviors of weapon systems are vulnerable by environmental effects in the real engagement. However, it is difficult to apply environmental effects to the engagement simulation by a gap between the requirements of simulation engineers and the provided data by environment engineers. This paper proposes a framework to bridge the gap and applies the framework to the synthetic battlefield for the radar detection system. This paper demonstrates the proposed framework by the implementation of the aviation engagement simulation in HLA system as an example, and the simulation results are changeable by environmental effects on the detection system.

Keywords: Aviation Engagement, Distributed System, High-Level Architecture (HLA), Radar Detection System, Synthetic Battlefield

1. INTRODUCTION

Due to the future combat paradigms that have been changed along the remarkable progression of the weapon system development, military forces are facing unprecedented, various, and complex requirements for such as the tactical deployment and new weapon development. However, available military resources are limited comparing to the requirements. Defense Modeling and Simulation (DM&S) has risen as a key to solve the conflict between the resource and the requirements. DM&S helps the efficient resource consuming plans by the verification of whether a plan meets the requirements, before the resources were committed. Thus, DM&S is an inevitable trend for whom to operate military forces (Smith, 1998). Recently, many countries endeavor to apply DM&S, beyond the traditional purposes such as the training and analyzing, to the acquisition cycle of weapon systems that comprises seven steps; development concept, design verification, prototyping, evaluation and testing, production and deployment, operation, and subsequent logistics (Keane et al., 2000).

DM&S is classified by the detail level of the representation defined by the DoD (Department of Defense) into four levels: campaign, mission, engagement, and engineering. The engagement simulation model, which is the target level of this paper, describes sophisticated behaviors and functions of weapon systems for short duration from minutes to hours, but it is not concerned with tactical command relatively. The expected outcomes of the engagement simulation model are such as survivability, vulnerability, and detection-ability of weapon systems (Hawley and Blauwkamp, 2010). According to the characteristics of the engagement simulation model, the model has to represent design properties and behaviors of each weapon system that is involved in the combat. However, the operation results of weapon systems are possible to not-follow own design factors in the real engagement situations, because of environmental effects. The environmental effects can be a decisive factor to decide the success of operations by referring to the history of war, and it is still effective, although the technologies of the weapon systems have been very developed (ROKSA, 2007). Hence, the engagement simulation model requires the synthetic battlefield to reflect environmental effects to the simulation entities, and the simulation results have to be changeable by the effects from the synthetic battlefield (Park et al., 2010).

In spite of the importance of embedding the synthetic battlefield in the engagement simulation, the construction of the synthetic battlefield has been hindered by the gap that is the synthetic battlefield for engagement simulations, simulation engineers (whom that construct a simulation system) demand environmental data of which are formed to meet the simulation purpose. But environment engineers provide only sets of numerical environmental data collected from observation. The gap between the requirements and the available service causes difficulties for the construction of the synthetic battlefield. Thus, existing efforts on developments of the engagement simulation were not available to reflect environmental effects, because simulation engineers could not use the provided environmental data from environment engineers.

In order to bridge the gap, this paper proposes a framework to construct a simulation system in the distributed system using HLA (High-Level Architecture). HLA is the standard for the distributed system by IEEE 1516 (IEEE Std 1516^{TM}, 2010), and it is developed to facilitate the interoperability and reusability by M&SCO (Modeling and Simulation Coordination Office: an affiliated organization of US DoD to lead DoD M&S standardization and empowering M&S capabilities) (M&SCO, 2012). In HLA, an entire system is called as 'federation' and each client is called as 'federate', and other details of HLA will be described in the section 2. The approach is for the HLA based simulation system including an environment federate of which stores numerical environmental data and extracts the data to meet requirements of the engagement simulation. In this paper, the framework is applied to the radar detection system. Hence, the framework proposes a design of the system that reflects environmental data to the radar detection probability computation.

The main objective of this paper is to propose a framework for the aviation engagement simulation with the radar detection system based on the synthetic battlefield, in order to bridge the gap in the reflection of environmental data provided by environment engineers to the simulation. The results of the simulation are diverse by the radar detection probabilities which reflect environmental effects. This paper demonstrates the proposed framework by the implementation of an example system based on the proposed framework.

This paper is organized as follows. Section 2 explains the approach of this paper. Section 3 details the proposed framework for the aviation engagement simulation system, and section 4 includes a description of the implementation of an example system for the demonstration of the proposed framework. Finally, section 5 summarizes the main conclusion of this paper.

2. APPROACH

2.1. HLA based Distributed System

The HLA based distributed system is one of the indirect communication systems that follows P-S (Publish-Subscribe) paradigm and this is designated by a server and clients, for distributed event-based systems. In the system, clients are assumed as publishers and/or subscribers, publishers publish structured events to an event service and subscribers express interests on particular events through subscriptions (Coulouris et al., 2012).

In the simulation system that is based on HLA, a client is called as a federate, and federates publish/subscribe information to/from the RTI (Runtime Infra Structure) server. RTI is software that is an implementation of HLA. The whole simulation system is termed as federation. This specifies, in advance the start of a simulation, a set of federate applications and a common Federation Object Model (FOM). FOM is a specification that defines the information which is exchanged at runtime to achieve the given objectives of federation. It includes communication detail of federates, such as object/interaction classes which are ways of communication among federates.

In order to communicate with the RTI server, a federate is indispensable to have an interface. This is referred to as Simulation Object Model (SOM), and SOM contains information on what its federate is going to publish and/or subscribe data of the classes that are defined in FOM.

In HLA based distributed system, the application connects RTI server as a federate that environment federate subscribes synthetic battlefield information and publishes the pertinent environmental data. The battle simulator federate publishes the synthetic battlefield information and it subscribes environmental data of the requested battlefield which is published by the environment federate. It uses the subscribed data to increase or decrease the characteristics of battle objects that are affected by the environmental effects. According to the variation, the results of an engagement simulation are changeable (ADSO, 2004).

2.2. Synthetic Battlefield for Aviation Engagement

In the aviation engagement, radar (an abbreviation for RAdio Detecting And Ranging) is the most efficient detection system to search objects, such as aircraft, ships, and missiles, in a specific area. The radar detection system uses radio waves, and it is composed of two parts; a transmitter and a receiver. The transmitter emits pulses of radio waves, and the emitted radio waves propagate along the straight line of the emitted direction of the transmitter as light speed. The emitted radio waves are bounced from the objects that are in the way of the propagation direction, and the bounced radio waves are returned to the receiver. The radar detection system analyzes differences between the returned radio waves and the emitted radio waves to determine the object that the radio waves were bounced from.

During the travel of the radio waves from the transmitter to an object and from an object to the receiver, the radio waves are propagated in the atmosphere, such as the troposphere and the stratosphere. Although the propagation of radio waves is predictable by the mathematical equation in the free space, the atmosphere of the real battlefield for the engagement is not the free space. The atmosphere includes various elements that are not equal by times, days, regions, heights, and so on, such as water vapor in the troposphere, and those elements cause the phenomena of reflection, refraction, diffraction, absorption, polarization and scattering, which affect the propagation of the radio waves. By the effects of the phenomena to the radio waves, the attenuation of the radio waves is occurred. The radar detection system is able to confuse the determination of the returned radio waves, because the radio waves can be weaker than the detection threshold of the radar system or can be modulated to be difficult to identify.

Due to the relationship between the radio waves and the atmosphere, the probability that the radar

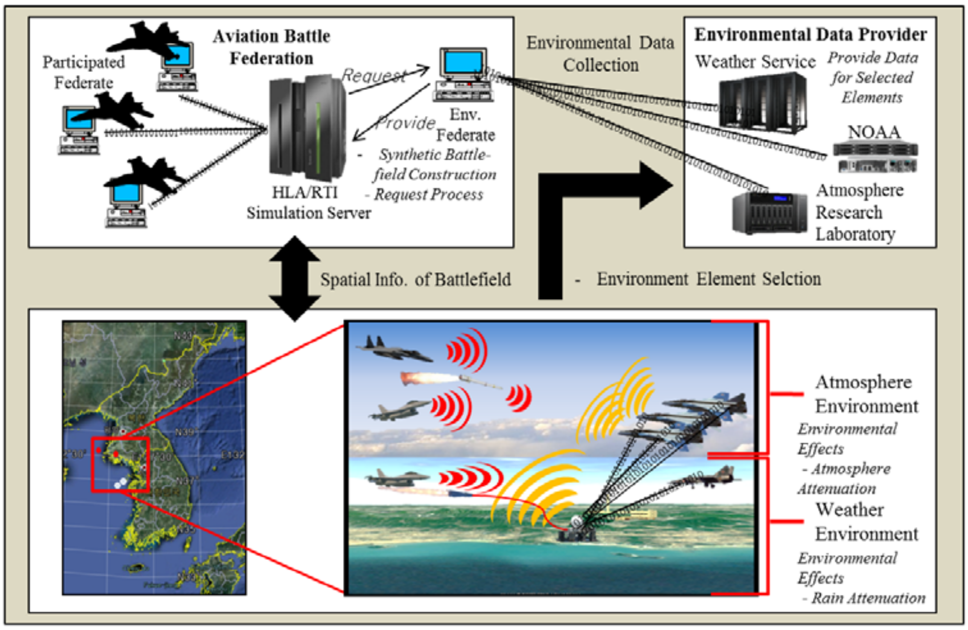

Figure 1: Synthetic Battlefield Construction for Aviation Engagement

detection system detects objects in the searching area is not constant as in the free space, but rather a value which is changeable by environmental effects. Therefore, the detection system in the aviation engagement simulation has to be based on the synthetic battlefield to reflect environmental effects to the computation of the detection probability.

By the former research, propagation of radio waves is attenuated by the rain and atmosphere elements. There are environmental elements that are decisive for the strength of two types of attenuation, such as precipitation for the rain attenuation and oxygen and vapor density in atmosphere for the atmosphere attenuation. Accordingly, the synthetic battlefield for the aviation engagement simulation is required to contain environmental data for the two types of attenuation and provide of the HLA based simulation system. For this process of the synthetic battlefield construction based on the environmental data, environment federate is laid in the engagement system to take the role shown as Figure 1.

3. SIMULATION FRAMEWORK

In the federation for the aviation engagement simulation, each federate connects to the federation as a function of the entire system, although a federate operation seems an independent application in a terminal that runs the federate. In this paper, the federation is structured as three federate; simulation federate, environment federate and radar detection federate (see Figure 2). The simulation federate has simulation entities, such as radar bases, aircraft, and missiles, and it executes the anti-air

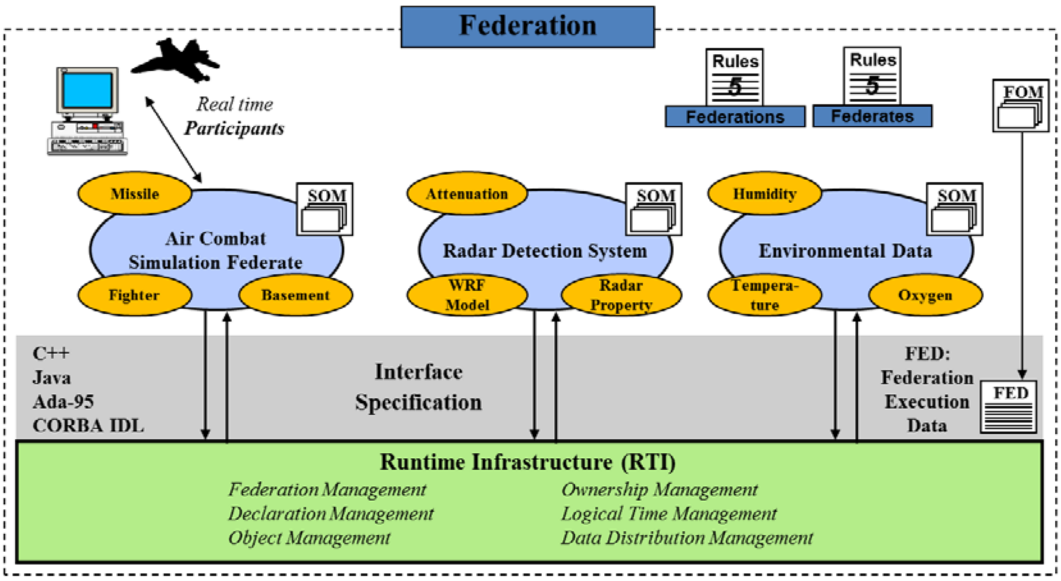

Figure 2: Federation Structure

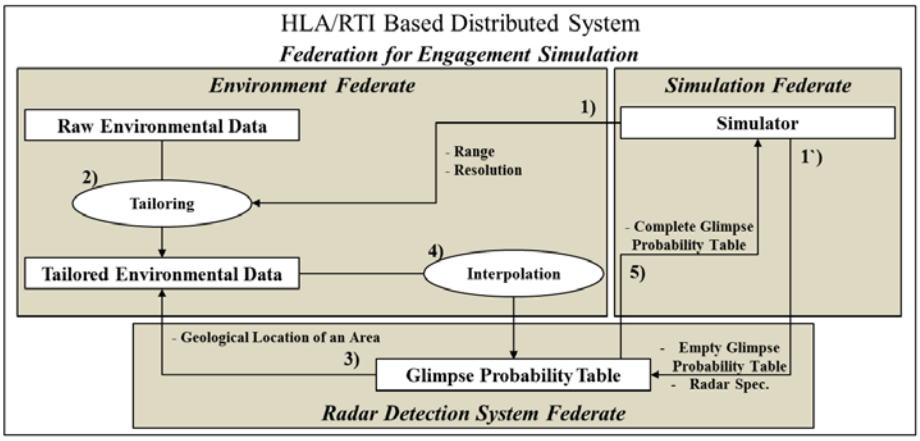

Figure 3: Data Interchange Procedure

engagement simulations using the simulation entities. The radar detection federate calculates radar detection probabilities using radar specification factors and environmental factors, and the environment federate searches environmental data of the synthetic battlefield. The operation results of each federate are exchanged via RTI server, and the data interchange procedure of the federation is described in Figure 3.

Before an explanation of the data interchange procedure, it needs to be represented that the concept of a table for interchange of detection probabilities. In this paper, we adopt 'GP (Glimpse Probability) table' to help reflection of radar detection probabilities among simulation entities. The GP means a detection probability at the indicated distance range, and a GP is computed using the radar performance and environmental data. The GP table defines detection probabilities by distances between a radar system and objects, so it is able to be applied to the detection states of simulation entities in the engagement. Using the GP table, detection probability P is calculated by formula (1), and accumulated probability F is calculated by formula (2). Thus, the detection probability of an enemy entity is increase along F (Driels, 2004).

$$P_n = (1\text{-}GP_1) \cdot \ldots \cdot (1\text{-}GP_{n\text{-}1}) \cdot GP_n \qquad (1)$$

$$F_n = \sum_{k=1}^{n} P_k \qquad (2)$$

In the proposed framework, all data interchanges are executed via RTI server by protocols of HLA based distributed system. A process of a publisher federate publishes a data and a subscriber federate subscribe the data is written as a term of 'Sending' in the explanation of the procedure. The data interchange procedure is explained as follow.

1) The simulation federate sends time and spatial information to the environment federate.
1`) The simulation federate sends radar location information, specification and empty GP table to the radar detection federate.

2) The environment federate extracts environmental data for the received information from the database.

3) The radar detection federate sends the received radar location information to the environment federate.

4) The environment federate sends environmental data for the received radar location information.

5) The radar detection federate completes the GP table using the internal propagation model and the environmental data from the environment federate and radar specification. The complete GP table is sent to the simulation federate.

Finally, the simulation federate applies the received complete GP table to detection states of simulation entities in the aviation engagement simulation. By the proposed framework, environment engineers are for the environment federate, radar engineers are for the radar detection federate and simulation engineers are for the simulation federate.

4. IMPLEMENTED RESULT

The proposed framework is implemented as an example system. The federates of the framework are developed using C++ programming language and MFC (Microsoft Foundation Class) library, and the federation is constructed on pRTI 1516® developed by Pitch. Atmosphere environmental data of the environment federate are collected by Korea meteorological administration. The simulation federate executes simulations using OGRE3D (Object- oriented Graphics Rendering Engine 3D) that is a C++ based open visualization engine library.

The example system executes simulations for the example scenario the following scenario. Enemy aircraft are generated in the aircraft generation zone 'A' and moving across the area, which is under surveillance by the ally surface ship, to reach the aircraft destination zone 'B' that is laid on the opposite side of the generation zone. If the surface ship detected enemies, it launches missiles to enemies, and the missiles trace enemies to shoot them down. The aircraft can be

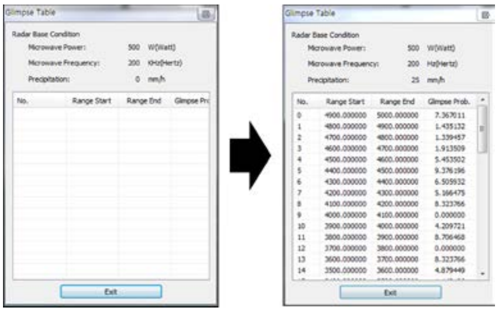

Figure 4: GP Table Generation

destroyed by missiles or can be survived and arrive at the destination. For the simulation of the example scenario, the surface ship calculates the distances between itself and every aircraft and derives the glimpse probabilities at each distance from the GP table. The surface ship launches missiles to enemies that are detected based on the GP. After launching a missile from the surface ship, the missile flies to the targeted enemy aircraft. A missile has maximum tracing distance and flight speed, and an aircraft also has the movement speed. If a missile navigated as much as the maximum tracing distance, the missile stops tracing the target and the targeted aircraft is able to arrive at the zone 'B'.

The implemented results of the example system are shown in next. Figure 4 is the representation of GP table generation. Figure 5 is the 3D visualized results of the example scenario simulation.

5. SUMMARY AND FUTURE STUDY

The proposed framework of this paper was developed to bridge the gap that is mentioned in the introduction, and the framework was applied to the anti-air engagement simulation for reflecting environmental effects of the atmosphere to the radar detection system in this study. In order to apply environmental effects of the atmosphere to the radar detection system, this paper defined the essential environmental factors which causes the attenuation to the propagation of radio waves. During the execution of the anti-air engagement simulation, the complete GP table is utilized to decide detection states of enemy aircraft by the simulation federate. Finally, the anti-air engagement simulation system based on the proposed framework of this paper performs simulations with the synthetic battlefield based radar detection states.

This paper is the radar base location is constant during the simulation. Thus, the creation of the GP table is occurred once at the beginning of the simulation. In the future study, the location of the radar base is changeable, and the GP table is re-created by the movement of the radar base.

ACKNOWLEDGMENTS

This work was supported by the Defense Acquisition Program Administration (DAPA), the Agency for Defense Development (ADD), and Korea Association of Industry Academy and Research Institute (C00035790100384919) under the Contract No. UD110006MD (DAPA), UD100009DD &

(a) Surface Ship

(b) Engagement

(c) Detected and Destroyed Aircraft

(d) Undetected and Survived Aircraft

Figure 5: Simulation Results

UD120035JD (ADD). The authors wish to express sincere gratitude for the financial support.

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