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Research Paper 체계공학 부문

HLA/RTI 기반의 시뮬레이션 조합 기술

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HLA/RTI based on the Simulation Composition Technology

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ABSTRACT

In defense domain, mission level and engagement level simulation tools exist. In order to experiment a simulation scenario for obtaining results of both mission level and engagement level simulations, we should write a same simulation scenario in a mission level simulation tool as well as an engagement level simulation tool, and we have to operate these tools for analysis of each purpose. Moreover, we could not guarantee that these scenarios are completely same since each scenario is composed of different fidelities of simulation models, although the scenarios are written by a same experimenter and with same simulation purpose. To deal with the difficulties, I propose an approach to analysis of both mission level and engagement level simulations from one simulation result. For this, I have built Composite Combat Mission Planning Simulation Environment (CCMPSE). In this paper, the HLA/RTI based simulation composition technology and my experiences for the designed Composite Combat Mission Planning Simulation Control System (CCMPSCS) are explained. Moreover, This paper also conducts a case study with EADSIM, SADM, and the CCMPSCS. Finally, this paper provides lesson learned from the case study.

Key Words : Composite Combat Mission Planning Simulation Environment, EADSIM, SADM, Simulation Composition, System Interoperability, Guided Missile Simulation

1. Introduction

As a standard of structure technology, High-Level Architecture (HLA) indicates composing distributed computer systems into one large system[1,7,8].

Run-Time Infrastructure (RTI) is standard software for distributed simulation, and it implements HLA interface specifications for the distributed simulation software to form one HLA[5,9,10]. In other words, HLA/RTI provides

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a technology to create one huge simulation system with individual simulators that are developed for different purposes. Simulation is a trial run of an examination in PC environment that is difficult for real world experiments due to financial or confidential reasons. In defense domain, experiments through simulations are significant. The simulation is used in determining performance specifications of weapon systems or in planning Live Fire Testing (LFT) for them before actual LFT. A lot of simulation tools have been developed individually, and in defense domain, the most of simulation tools were developed only for analyses of a specific weapon system.

Extended Air Defense SIMulation (EADSIM) and Ship Air Defense Model (SADM) are clear examples of simulation tools for common weapon systems in defense domain. EADSIM was developed to analyze air defense systems against air/surface threats[12], and SADM was developed to analyze ship defense ability for air/surface threats in seaside or ocean environments[3].

EADSIM is a mission level simulation tool, and SADM is an engagement level simulation tool. I found that each simulation tool has different advantages in simulation model and simulation engine[14]. I had a lot of attempts to merge EADSIM and SADM whose simulation characteristics are different. Through the fusion, more realistic and complicated scenarios could be produced in order to obtain comprehensive simulation results in both mission and engagement levels. As one of my approaches, I attempt to build network systems for Composite Combat Mission Planning Simulation Environment (CCMPSE) that allows all simulation models from each simulation tool to participate one simulation scenario.

For the CCMPSE, this paper provides HLA/RTI based simulation composition technology and the design of Composite Combat Mission Planning Simulation Control System (CCMPSCS). This paper also offers a case study of simulation composition using EADSIM, SADM, and the CCMPSCS, and it finally provides lesson learned from the case study.

2. Research Motivation and Related Works

In simulations, experimenters define time and space. Observers record what happened in the simulation and analyze the results to draw a conclusion. Simulations consist of time, space, actors, and events. The time indicates an absolute period defined by experimenters. The space is a set of really (or virtually) existing locations, and the set sometimes includes environmental elements. The actors indicate simulation objects in predefined time and space. The events are behaviors and responses to the behaviors in a temporal order. Simulation records changes of status of simulation objects in response to the events. Actors are defined through simulation models; therefore, the more complex and various attributes simulation model has, the more sophisticated and closer to real world actors are. In simulations, events between actors are conducted through a simulation engine that is composed of engineered computation formulas, and status of actors is also determined by the simulation engine.

EADSIM was developed by Teledyne Brown Engineering[12]. USA, Japan, United Kingdom, and Israel currently use EADSIM for analyses of weapon systems. Time duration and specific area are should be defined for creation of an EADSIM simulation scenario. Under the conditions, topographic information and combats can be modeled. EADSIM simulation engine operates the created scenarios in order to draw experiment results. EADSIM is composed of laydowns, platforms, systems, and elements (include weapons, sensors, communication devices, and jammers). A laydown is a set of platforms which can harmoniously response against threads; for example, a laydown could be a platform set of commander, radar, and launchers. A platform is defined by a system type, and a system consists of elements that are actually working components in a platform. In EADSIM, users are allowed to generate new elements by predefined element templates in regard to each type and to register them into EADSIM local element library. Therefore, we can create a variety of weapon systems through compositions of them like ‘LEGO bricks’.

SADM was developed by BAE systems[3]. Canada, USA, UK, Norway, Sweden, Denmark, Netherlands, Greece, Portugal, Spain, Germany, Turkey, South Korea, Japan, South Africa, Australia, and New Zealand currently use SADM for analyses of ship defense models. SADM models maritime self-defense and air/surface threats, and SADM simulates interactions between them. SADM consists of models of platforms, sensors, weapons (include hard-kill and soft-kill), weapons control systems (include C2), and environmental elements (such as terrain, propagation, and atmosphere). Each model provides detailed attributes and high fidelity that are useful for practical analysis in engineering or engagement level simulations. Moreover, SADM has an interface to be integrated with SIMulation DISplay (SIMDIS)[13]; therefore, SADM can provide 3D-visualizations of simulation results through SIMDIS.

This paper newly defines simulation composition. The simulation composition is to implement simulation to be operated with more than two simulation tools that define exactly same time and space. In other words, these simulation tools create a common scenario, and all actors of these tools can be participated the common scenario; therefore, complicated and sophisticated scenarios can be created.

In regard to the simulation composition, the previous studies considered that simulation is one software component, and they focused on how to integrate these independently developed components. According to Schutte[11], he presented a domain-specific modeling language for specific distributed system, and he also proposed an approach to formally describe and evaluate simulation components with the language. Benail et al. proposed a Component-Based Framework (CBF) for component interoperability[4], and it allows simulation components that are developed based on conceptual interoperability model in CBF to seamlessly integrate other components from CBF without additional efforts. Aronson et al.[2] proposed a common simulation model and argued that simulation components should be developed based on the model; therefore these simulation components are interoperated each other via commonly defined interfaces in the model. So far, analysis via commercial simulation tools that were independently developed to work together, such a new paradigm to analysis approach did not reported to academic fields. Petty et al. proposed an approach to combine entity and unit level combat models in a same simulation scenario, which links these models using interface modules, i.e. Multi-Resolution Combat Modeling[20]. An entity level combat model is an individual object that cannot be separated as simulation actors and be operated by parameter- or table-driven functionalities. A unit level combat model is a set of entity level combat models as a complete military platform that can be applied to the Lanchester equations. However, this paper focuses on heterogeneity of unit level combat models which have different levels of accuracies/fidelities and making them interoperable in a same simulation scenario.

In defense domain, there are mission level and engagement level simulation tools. In order to experiment a simulation situation for obtaining results of both mission level and engagement level simulations, we should write a same simulation scenario in a mission level simulation tool and an engagement level simulation tool, and we should operate each simulation tool for analysis of its purpose. Moreover, we could not guarantee that these scenarios are completely same since each scenario is composed of different fidelities of simulation models, even though the scenario are written by a same experimenter and with a same simulation purpose.

In studies with HLA/RTI, most of researches are focused on distributed data processing[16, 17], monitoring simulations[18] or remote time management[19]. In regard to the applied researches of the HLA/RTI, no study has been conducted for combining or interoperating simulations of mission and engagement levels. In order to deal with this challenge, this paper attempts to integrate independently developed simulation tools via HLA/RTI networks. In other words, this paper proposes an approach to composite two different simulation scenarios on a third network system and controls the composited scenario. each simulation engine observes situation/affairs in order to analyze results of simulations in each viewpoint.

3. Implementation of The CCMPSCS

The simulation composition technology in this paper is that a specific control system and connections among individual simulation tools via HLA/RTI networks. The control system transfers information of simulation objects from each simulation tool to all the connected simulation tools in a timely manner of broadcasting approaches. In other words, all simulation objects connected by HLA/RTI are shared and form a common scenario, and the specific control system manages time of the common scenario and a period of broadcastings. Each simulation tool creates its own local scenario that is projected from the common scenario. The simulation tools obtain simulation object information from the network (such as behaviors and states) and virtualize them in the local scenario except for their own simulation objects. Finally, the simulation tools keep the local scenario in same status with the common scenario through time synchronizations of the objects. (refer to Fig. 4 in the following case study)

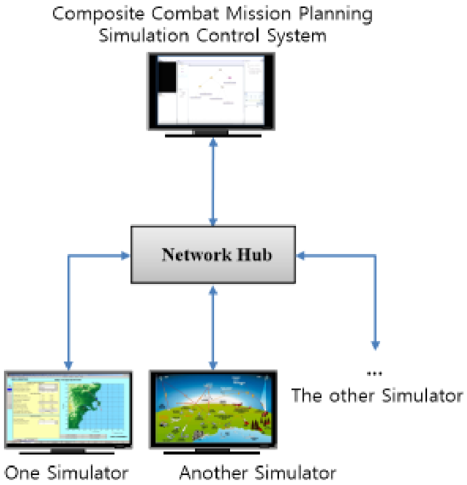

Fig. 1. Network architecture for simple composite combat mission planning simulation environment

I have designed CCMPSCS, the specific control system in CCMPSE. This section describes the implementation of the CCMPSCS. Fig. 1 illustrates the network architecture for a simple CCMPSE. The network architecture consists of more than two simulation tools, CCMPSCS, and a network hub that physically and locally connects them. The CCMPSCS individually interacts each simulation tool; therefore, they only communicate via HLA/RTI interfaces in the CCMPSCS. I have designed the HLA/RTI interface in accordance with SISO-STD-004-2004 DLC API for HLA 1.3[9] and SISO-STD-004.1-2004 DLC API for HLA 1516.1[10]. Fig. 2 shows the structure of the CCMPSCS.

The CCMPSCS is composed of two layers; 2D visualization layer and simulation control layer.

The 2D visualization layer supports transforming simulation objects into assigned icons and locates them the coordinate system of WGS-84[6]. I do not discuss detailed components and structure of the components in this layer because these are not in scopes of this paper.

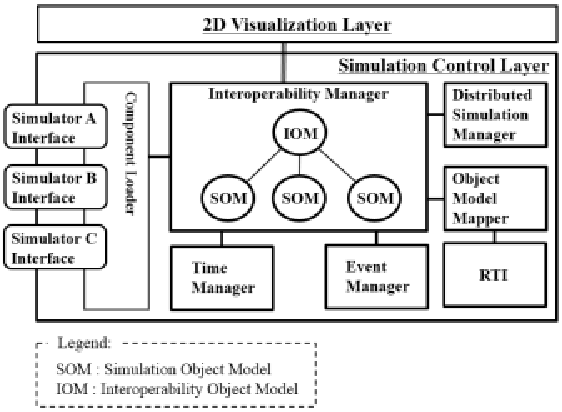

Fig. 2. Structure of composite combat mission planning simulation control system

The simulation control layer provides connections and interfaces of individual simulation tools, Time and Event managements in common scenarios, and managements of heterogeneous simulation models that come from each simulation tool. The simulation control layer consists of seven components: component loader, time manager, event manager, interoperability manager, distributed simulation manager, object model mapper, and RTI components.

Component loader keeps connections between different simulation tools during operating a common scenario. Time and event managers deal with differences time among simulation tools and event processing such as engagements. Interoperability manager connects more than two Simulation Object Models (SOM) with one Interoperability Object Model (IOM) for conversions in a HLA/RTI federation. Fig. 3 illustrates the abstracted structure of data/event exchanges in CCMPSCS. Simulation objects in each scenario are registered in IOM as common objects (ghost objects in a common scenario in CCMPSCS), and the IOM identifies types of the registered objects. According to the types, IOM maps each common object to a pair of SOMs. Each SOM has a direction to a certain Simulator Interface, and it handles processing of data/event transformations for the Simulator Interface by referring converting mechanisms in Converting Library. Distributed simulation manager decides influences of objects from a certain event, and it distributes results of the event and status of influenced objects in order to update objects in different simulation tools. Object model mapper links simulation models that do not need to convert each other. RTI component provides regulations related to HLA/RTI standard in order to operate each simulation model in HLA/RTI 1.3 or 1516.1.

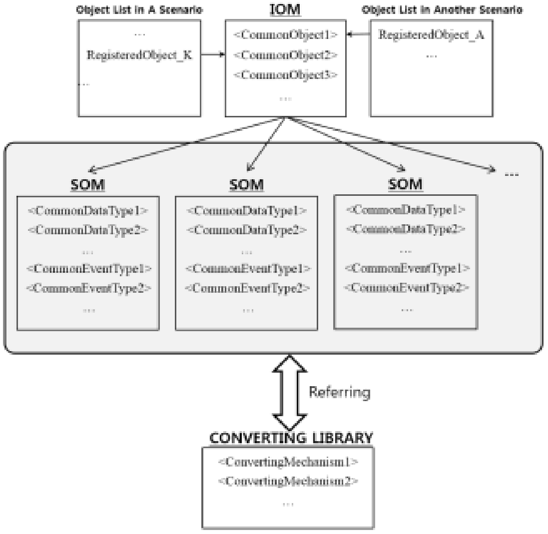

Fig. 3. Abstracted structure of data/event exchanges in CCMPSCS

4. A Case Study

In this section, I present a case study that creates a common scenario for mission planning simulations in the CCMPSCS, and the common scenario is interoperated with SADM and EADSIM. As multiple-case study[15] with example analyses, this case study is to prove that the created mission planning scenario can produce simulation analysis results of both mission and engagement levels in the CCMPSE. In other words, with the common scenario, the case study conducts simulation analyses of mission planning that are representative and necessary on guided missiles.

In order to interconnect EADSIM and SADM with the CCMPSCS, we have additional sets in EADSIM and SADM scenarios. In SADM scenarios, we should activate external interface for HLA, and DIS enumerations for each platform should be set such as platform kind, platform domain, platform country, platform category/subcategory, platform specific, and extra data[3]. In EADSIM scenarios, we should set platform properties of Element Cross-Reference File[12], such as transmit DIS, transmit HLA, DIS enumerations, and force IDs. Table 1 shows a classification of simulation objects from EADSIM and SADM scenarios in the case study.

Table 1. Simulation objects in the case study

	EADSIM	SADM
Red Team	BM(1), MIG-21(4)	SAM(7), Bunker(1)
Blue Team	F-15K(1), ATGM(2), Satellite(2)	Aegis(2), Destroyer(1), Convey(2), SAM(1)

* ATGM: Air-To-Ground Missile, BM: Ballistic Missile, SAM: Surface-to-Air Missile

In this case study, I set the Korean peninsula as the simulation space and composite battlefields. In the Yellow Sea areas, a blue team aircraft, F-15K, launches two ATGMs for a ground target of a red team, a bunker that are sheltered by seven SAM systems. Four red team aircraft, MIG-21s, attack a blue team destroyer that are escorted by two convoys. In the East Sea areas, a blue team SAM system intercepts a red team ballistic missile with radars of two satellites and aegises.

Fig. 4 illustrates the concepts of simulation composition between SADM and EADSIM in the CCMPSE. In the simulation composition, three scenarios simultaneously exist via a HLA/RTI network. The EADSIM scenario consists of EADSIM objects and ghost objects that come from the SADM scenario. The SADM scenario consists of SADM objects and ghost objects that come from the EADSIM scenario. The common scenario located in the CCMPSCS consists of all ghost objects that come from both SADM and EADSIM scenarios.

All simulation objects are mapped to ghost objects individually, and no event is generated from ghost objects themselves. In other words, all ghost objects are just projected from their original simulation objects. For example, if a SADM object generates a certain event to an EADSIM object, a ghost object of the mapped EADSIM object transforms the event and transfers to the EADSIM object. If there is a response-event, the ghost object transforms it and transfer to the SADM object.

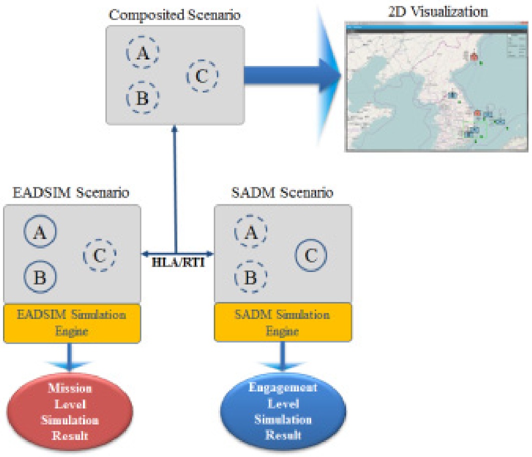

Fig. 4. The Concept of simulation composition in the CCMPSE

Each object is completely synchronized each other; therefore, we can concurrently operate three different scenarios in remote locations. In the common scenario, the CCMPSCS collects results of events at each time via networks and conduct real-time reflections on each object. Finally, results of three scenarios that come from each simulation engine can be simultaneously shared. I do not need to develop an independent simulation engine for composited scenarios; however, I should have newly designed a 2D visualization module in order to support visual verifications of each weapon platform on a composited scenario. The 2D visualization module allows us to selectively display each platform for individual visual verifications.

As the three simulations completely are same, we can obtain both simulation results of mission level and engagement level using EADSIM and SADM.

In the case study, I could have analysed cruise missiles for TOT (Time on Target), attack tactic, seeker algorithms with SADM simulation engine (engagement level simulation). With EADSIM simulation engine (mission level simulation), results of multiple sensor coverage analysis, footprint analysis, lethal (launch/intercept) envelops analysis, analysis of engagement rule for air defenses, and C2 network analysis could be obtained. For confidentiality reasons, the detailed results of the simulations could not be discussed in this paper.

5. Conclusion and Lesson Learned

In this paper, I have proposed the CCMPSCS, a network control system that interconnects heterogeneous simulation tools. From my previous studies[14], I had attempted to build the CCMPSE in order to conduct more comprehensive analysis rather than individual analysis from each simulation result. Through the case study of the CCMPSCS in this paper, I could have taken the following advantages:

- ✓ As the simulation compositions are operated based on networks, I could have expendability to plug-in a variety of different simulation engines and models.
- ✓ There is no limitation of physical spaces and computation resources because I can organize remote simulation systems into one simulation by networks.

- ✓ We can create a composited simulation by simply overlaying individual scenarios but without any additional modifications of each scenario that comes from different simulation tools.

- ✓ Results from a composited simulation can be analyzed from different aspects of each simulation engine, such as engineering, engagement, mission, and campaign levels of simulations.

However, I have also identified the following limitations:

- ✓ There is further simulation time since participated simulation engines have different time schedules on networks, and I have to mediate simulation time by waiting or accelerating simulations between participated simulation engines.

- ✓ As another simulation time problem, it potentially has communication delays because simulation compositions virtually exist on networks.

- ✓ Precise simulation model in a certain simulation engine should be down-graded to levels of imprecise models that come from the other simulation engines because more accurate attributions and events from precise simulation models are not acceptable in the other imprecise simulation models. Therefore, I should develop new technologies to mediate precision problems between different simulation models on the simulation compositions.

For the future work, I would like to focus on mediation technologies that are concerned with differences of simulation time and simulation model precisions between heterogeneous simulation engines on the CCMPSE.

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