REQUIREMENT SPECIFICATION METHOD BASED ON SES AND DEVS FORMALISM IN DEFENSE SYSTEM SIMULATION

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ABSTRACT

A precise analysis of the requirements in the development of the software and verification of the software is essential. Moreover, for classified solutions, the importance of requirements analysis is even greater. Defense simulation is a representative example of a classified solution. It is essential to set up appropriate requirements, analyze them, and perform verification in simulation configurations such as simulation resolution, simulation target setting, damage evaluation model, and engagement scenarios. However, the requirements of the existing defense system simulation are not specified in the requirement specification method based on the theoretical background, so it is hard to analyze through the formal approach. Therefore, this study establishes the basic structure of the simulation model used in the defense simulation configuration through the SES formalism, and introduces the specification method based on the DEVS formalism about the interaction between the models.

Keywords: requirement specification, system entity structure, discrete event system specification, base model for combat system

1. INTRODUCTION

The requirements analysis phase during the software development is a major step in establishing the overall design and the functions to be implemented. Therefore, it is necessary to accurately analyze and specify the requirements in the process to verify that the later developed products meet the requirements. Specification techniques are needed to perform a precise analysis and verification of the requirements. To make a formal specification of the requirements, the structure of the system should be represented by the formalism, and a mathematical model that can express the interaction of the components constituting the system is needed. The defense system is a complex system of sub-systems with various types of functions and structures depending on the experience of personnel, organization, equipment, materials, doctrine, military and commander. Therefore, in the case of defense system simulation, a methodology is required as a combination of elements that perform independent functions rather than a general simulation methodology. The defense system can be classified as a complex system.

To construct a defense system simulation, a particular role model is created as a combination of independent functional sub-models, and simulations such as engagement, detection, and reconnaissance are performed through a combination of models. Therefore, a complex system constructs a simulation based on a combination of previously defined models. Complex system simulation of models consisting of a mix of independent sub-models forms a hierarchical structure. In the case of such a complex system simulation, reusability becomes important because it is made up of a combination of sub-models, and a structural expression of the system for ensuring reusability is needed.

In this study, simulation of combat system participating directly in the engagement of the defense system is targeted. The basic model structure that is the basis of engagement is established through SES. SES is a formalism that defines a hierarchical structure based on a formalism and organizes the model based on reuse. The Pruned Entity Structure is derived through pruning, which is a process of obtaining one behavioral model through System Entity Structure which collectively represents the alternatives of one system. The basic model consists of a combination of a physical layer, a logical layer, and an information layer, which correspond to the Pruned Entity Structure, which is a behavioral model derived from the basic structure of System Entity Structure. In this study, the rules about the structural characteristics are formulated regarding inheritance and combination. The simulation is constructed based on the basic model and protocol thus established.

Therefore, this study establishes the basic model structure of simulation for the battle system which is directly applied to engage in the defense system through

System Entity Structure, and introduces Discrete Event System Specification formalism based on the part of the interaction between models. This paper introduces the protocols required for the simulation configuration, the specification of the XML-based model structure and the model generation based on the specifications. Finally, This paper introduces the case study of the simulation which is composed through the basic model and simulation configuration method finally introduced.

2. RELATED WORKS & BACKGROUNDS

This chapter introduces related research and background knowledge related to this study. The related work deals with DEVS-based combat modeling for engagement-level simulation and introduces SES formalism and DEVS formalism which are basic knowledge of this study.

2.1. Related Works

A study related to this study is called "DEVS-based combat modeling for engagement-level simulation" by Dr. Seo, Kyung-min. This research is based on the DEVS formalism for the basic model of the combat model participating in the engaging class simulation. The basic model of the combat is classified according to the platform and the weapon system, and the discrete event model and the object model. It is meaningful that DEVS is used to form a composite of a single model with a combination of sub-models by expressing the structure of the engagement model according to the level. The overall structure of the engagement system model is shown in Figure 1.

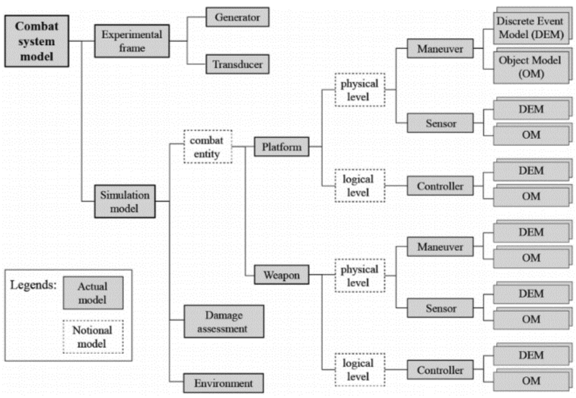

Figure 1: Overall model structure of combat system model

Figure 1 represents the decomposition tree for the overall model structure which systematically organizes a family of models.

2.2. Backgrounds

This section introduces DEVS formalism and SES formalism, which is related to this study.

2.2.1. DEVS

As it is well-known, the classical DEVS formalism can specify a system in two aspects: one for the behavior of a basic component, and the other for the overall structure of a system. An atomic DEVS formalism describes the behavior of a unit component not further decomposable, which consists of three sets and four functions.

$$AM = \langle X, Y, S, \delta ext, \delta int, \lambda, ta \rangle$$

, where
X : input event set,
Y : output event set,
S : sequential state set, and total state set
$Q = \{(s,e) \mid s \in S, 0 \le e \le ta(s)\}$,
$\delta ext : Q \rightarrow Q$:external transition function, for $\delta ext(s,e,x) = (s', e'), e < ta(s), e' = 0$
$\delta int : Q \times X \rightarrow Q$: internal transition function, for $\delta int(s, e) = (s', e'), e = ta(s), e' = 0$
$\lambda : Q \rightarrow Y$: output function, for$(s, e) \in Q, e = ta(s)$
$ta : S \rightarrow$: time advance function, is the non-negative real number set.

There are two types of transitions of a model: 1) external transitions entailed by external events; and 2) internal transitions in the case of no event occurrence until current state sojourn time has elapsed. In the latter case, just before the internal transition, an output event is produced at the state. In analogy to the continuous systems, external transitions would correspond to the input is driven state
transition and internal ones the input-free state transition.

The coupled DEVS formalism specifies the structure of discrete event systems composed of components communicating with each other through event couplings,

$$CM = \langle X, Y, M, EIC, EOC, IC, SELECT \rangle$$

, where
X : input event set,
Y : output event set,
M : component model set, either atomic models or coupled models,
$EIC \subseteq CM.X \times Ui\ Mi.Yi$: external input coupling relation,
$EOC \subseteq Uj\ Mj.Yj \times CM.Y$: external output coupling relation,
$IC \subseteq Uj\ Mj.\ Yj \times Ui\ Mi.Xi$: internal coupling relation
SELECT : $2M — ø \rightarrow M$: select function

Notice that the coupled DEVS formalism above has the closure property, i.e., a coupled model may

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contain another coupled models as well as atomic models as its components. It captures the structure of a system, the components hierarchy and the interfaces between components. The SELECT function relates to the simultaneous scheduling problem of simulation that arranges the priorities of components when more than one component is to be scheduled at the same time.

2.2.2. SES

System Entity Structure is a representation scheme which contains the decomposition, coupling, and taxonomy information for a system(Zeigler, 1984). Formally, SES is a labeled tree with attached variable types that satisfy five axioms – alternating mode, uniformity, strict hierarchy, valid brothers, and attached variables. Detail description of the axiom is available in (Zeigler, 1984).

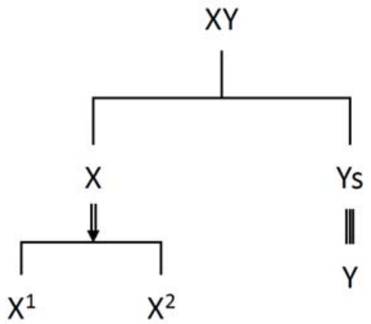

Figure 2: System Entity Structure example

There are three types of nodes in SES – entity, aspect, and specialization – which represent three types of knowledge about systems. The entity node, having several aspects and/or specializations, corresponds to a model component that represents a real world object. The aspect node (a single vertical line in the labeled tree of Figure 2) represents one decomposition, out of many possible, of an entity.

Thus, the children of an aspect node are entities, distinct components of the decomposition. The specialization node(a double vertical arrows in the labeled tree of Figure 2) represents a way in which a general entity can be specialized into special entities.

A multiple entity is an entity that represents a collection of homogeneous. We call such components a multiple decomposition of the multiple entity. The aspect of such a multiple entity is called multiple aspect(triple vertical lines in the labeled tree of Figure 2). Note that instead of presenting all Ys's components, only one B is placed in the labeled tree.

Pruning extracts a sub-structure of the SES by selecting one aspect and /or one specialization for each entity in the SES. The pruning operation also expands multiple entities as well as assigning values of attributes attached to entities in the SES.

3. REQURIREMENT SPECIFICATION METHOD IN DEFENSE SIMULATION

To specify the requirements, it is necessary to understand the domain. In the case of defense simulation, the simulation is made up of a combat system and a non-combat system. Different models are used depending on the resolution of the target simulation. The model of simulation differs in the way of expressing even the same object according to abstraction. Therefore, the process of constructing the simulation environment every time is a process of creating new models and combining them. Therefore, in this chapter, a basic model is set up for the engagement models participating directly in combat in the defense simulation system, and simulation configuration and requirement specification technique based on this model are introduced.

3.1. Base Combat Model for Requirement Specification in Defense Simulation

The basic model of the combat system, which is operated directly in the engagement of the defense system, can be composed of the information layer, the physical layer, and the logical layer. The information layer deals with the information related to the weapon system and manages information such as the characteristics of the weapon system, acquisition information, spatial information (position and attitude), movement path, attribute value, and scenario list. When generating the initial model, the values are initialized to a predetermined value and then act as a condition or restriction on the selection decision of the behavior of the model in the logical layer as necessary.

The physical layer is a part that manages the physical behavior or characteristics of the weapon system and consists of sub-models such as sensor detection, communication, movement, shooting, detection, and survival response. When creating a single engagement model, a physical layer is constructed using only the necessary sub-models. For example, in the case of a ground weapon system, there is no part of a flight, so there is no need to add a sub-model related to flight when constructing a real model.

The Logical Layer is a part that determines what action to take according to the characteristics of the weapon system based on the data from the information layer and is compatible with the sub-models constituting the Physical Layer. In other words, if the physical layer is composed of sensor sensing, communication, and movement models, the Logical Layer is composed of sensor sensing control, communication control, and movement control models.

The base model, consisting of three basic layers, is expressed on an SES basis. SES was introduced as a formalism that defined hierarchical models and organized them for reuse on a model basis. SES, which represents the alternatives that a system can have, is a tree structure expressed by three nodes: entity, aspect, and specialization. The basic model expressed by SES is shown in Figure 3.

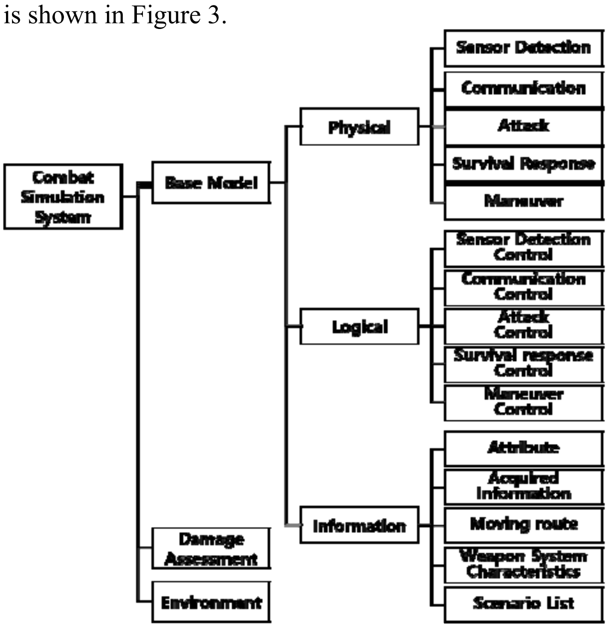

Figure 3: Representative structure based on the SES formalism

The base models that make up the engagement simulation have a multiple aspect relationships. And we can confirm that there are a Physical layer, a Logical layer, and an Information layer as sub-models that constitute Base Model. The pruned entity structure is derived from pruning process through basic SES, and the simulation is constructed through the combination of these.

In the process of constructing an engagement simulation, there are parts that cannot be expressed because they simulate the reality, and these parts are omitted as abstract values or considered as constant values. In other words, it is necessary to specify a rule for parts such as constraints because it is not enough to express the basic model using only SES. This part is considered in the information layer.

In the case of constructing the simulation through the modeling process based on the Base Model, it is advantageous that the reuse, requirement verification, and testing are easy in the multi-layer simulation environment because the role of the Base Model is sure to be performed even in the different environment.

3.2. Simulation Composition

The configuration of the simulation automatically generates and assembles the model according to a predefined protocol. This process allows specification of the requirements. Except for the performance part of the software in the process of specifying the requirements of the simulation, the process of modeling takes up most of the requirements specification process. That is, if the initial modeling process is described according to a predefined protocol, then the simulation is configured to satisfy the requirements.

In this study, model structure is established through XML. In case of atomic model based on DEVS formalism, model name, port information, state information, and attribute value are read through XML file. Coupled model reads coupling information of EIC(External Input Coupling), EOC(External Output Coupling), IC(Internal Coupling), etc., and reads information about sub-component.

Each PES from SES consists of hierarchically combined atomic models and coupled models. Since PES basically consists of physical, logical, and information layers, it has a tree structure with two depths. Thus, it forms a combined structure of complex coupled models.

The specification of the requirements is specified as a tag that enters the attribute in describing the DEVS model in XML. Because modeling is done within predefined protocols, modeling-related requirements are automatically satisfied if the initial modeling process describes XML with the protocol. For other additional requirements, we will proceed to validate the XML in the test scenario tag and verify that it is satisfied, which we will study later.

4. CASE STUDY

We developed a prototype program that automatically generates the model based on SES structure information in XML format. Information about the model was assigned to the attribute in the model tag in XML. The models are divided into an atomic model and coupled model based on DEVS. The program is based on C ++ and is implemented based on the DEVSim ++ module. An example of a basic model XML structure is shown in Figure 4.

```
<ModelStructure>
  <Model name="Outmost" type="Coupled" lib_path="./lib/outmost.so">
    <Ports>
      <Port type="input" name="in1"/>
      <Port type="output" name="out"/>
    </Ports>
    <Componets>
      <Compnent name="ABC" file_path="./model/abc.xml"/>
    </Componets>
    <Coupling>
      <Coupling from="Outmost" o_port="out1" to="ABC" i_port="in1" />
      <Coupling from="ABC" o_port="out1" to="Outmost" i_port="in1" />
    </Coupling>
  </Model>
</ModelStructure>
```

Figure 4: XML Base Model Structure example

Because it is based on DEVS, the type of model is composed of coupled and atomic, and consists of basic

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information such as <Ports> tag, <Components> tag, and <Coupling> tag which is necessary for a model. Coupled model consists of <Coupling> tag simply for EIC, EOC, IC. The state information of the atomic model, the attribute value, etc. are specified in the <Info> tag.

5. CONCLUSION

In this paper, we introduce the basic model used in the defense simulation environment based on the SES formalism and the DEVS formalism. Models created according to predefined protocols can satisfy the requirements in the modeling process if the XML file is described well in structure. Future work will be based on this study, unit testing according to the actual scenarios of the test scenarios, and testing to perform interactions between the models automatically.

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