Challenges of Teaching Modeling and Simulation Theory to the Domain Experts in a Blended Learning Environment

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Abstract

Modeling and Simulation (M&S) engineering is one of the challenging area to cooperate between different fields. Usually, experts in many fields such as domain and M&S experts cooperate with each other to build a complete simulator. However, the cooperation is often difficult due to the security policies in some domains, such as military areas. Therefore, in such domain, the domain experts are required to know about the M&S knowledge to design the simulation models so that they can build the simulation model without violating the security policies. In order to keep the security policy, we described our experience of supporting the domain experts to learn the DEVS formalism using the blended learning concept. From our experiences, we found that the DEVS formalism is intuitive for the modeler to model the real system, and the blended learning is effective to learn the knowledge of new field.

1. Introduction

Computer simulation has become a useful method of representing various systems, such as physics, biology, economics, psychology and social science. It helps to gain insights about the operation of those systems or to observe their behavior [1]. With the insights, we can evaluate and estimate the systems with a specific aspect [2]. Especially, computer simulation is usually used in high cost and dangerous domain, such as military, nuclear and commercial industry.

When developing a domain-specific simulator, domain knowledge and M&S technology are required. For example, in military domain, domain knowledge is not opened to the publics and handled by security policies. Therefore, domain experts, who knows behaviors of the simulated system, and M&S experts, who have knowledge about modeling and simulating a system, are required to cooperate for making a complete simulator [5].

The general procedures of developing domain-specific simulator are as follows. The domain experts specify the requirements of simulation and the M&S experts design simulation models based on the requirements from domain experts. With the simulation models and simulation technology, the domain-specific simulator is implemented using programming languages, such as C++ and JAVA. After all works are done, all experts test the implemented software to check whether the implemented simulator meets the requirements or not.

In developing domain-specific simulators, most important issue is how domain and M&S experts are cooperated. To give a detailed account of it, the domain experts are required to give unambiguous requirements of the simulation model, and the M&S experts build an architecture of the simulator and design simulation models based on the given requirement specification. However, in some cases, providing unambiguous requirements may be impossible. Such as military field and commercial product, detail information of the system is not exposed to others because of their security policies. Therefore, it may cause that M&S experts design defective simulation models and these simulation models also may lead to inaccurate simulation results. One of solutions, not violating security policies, is that the domain experts obtain the M&S theory and design simulation models by themselves and M&S experts helps the domain experts to design the architecture of the simulator. We adopted this solution to the development of a war game simulator. The M&S experts of the System Modeling and Simulation Laboratory (SMSLAB) in Korea Advanced Institute of Science and Technology (KAIST) supported the domain experts in national defense research institute to learn the DEVS formalism and design simulation models by themselves.

There are some challenges during adopting our methodology to the development. The first challenge is the domain

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knowledge of the domain experts. It can be an obstacle for the domain experts to obtain M&S theory. Therefore, it is essential to find relationship between the domain knowledge and the M&S theory. With this relationship, the domain experts can accept the M&S theory easily based on their knowledge. To tackle this challenge, we have experienced that the building simulation model and its simulator might bridge the M&S theory and the domain knowledge. Therefore, we have educated the simulation software development methodology to domain experts and assisted the domain experts to develop the simulator.

The other challenge is the geographical distance between the domain experts and the M&S experts. Since the distance of the laboratory and the research institute is far away, it is impossible to give lectures periodically. To tackle this challenge, we adopted a blended learning environment. Blended learning means combining online and face to face instruction [12].

In order to build a blended learning environment, we have introduced the course website which contains lots of M&S theory materials to the domain experts to acquire background information using online self-paced learning [3]. Then, we have given lectures to the domain experts face to face.

The rest of this paper is organized as follows. Section two presents the brief background knowledge which related to M&S theory and the simulation software development methodology. In section three, we explain the conceptual framework of blended learning to the domain experts. Section four introduces the case study using our conceptual framework and section five presents the lessons which we learned during the education phase. Finally, we conclude this paper.

2. Background Knowledge

Once objectives of simulation are decided, the domain experts and the M&S experts work together to build a domain-specific simulator with doing their own work. Modeling and implementation requires cooperative teamwork and unambiguous communication methods between the experts in a whole development process [5].

There have been some efforts for communicating and cooperation between domain experts and M&S experts using Unified Modeling Language (UML)[4]. In this approach, domain experts first specify the requirements of the target system using UML diagrams, and then M&S experts design simulation models based on these diagrams using the Discrete Event Systems Specification (DEVS) formalism. The DEVS formalism, developed by Zeigler, supports specification of discrete-event models in a hierarchical modular manner. In this paper, we assume that the domain experts are already accustomed to use the UML Diagrams, since the UML diagrams are widely used in the industry. In the following section, we take an overlook about UML, DEVS and modeling process using them.

2.1. UML Modeling

The Unified Modeling Language (UML) is a standard language for specifying, visualizing, and documenting the artifacts of an object-oriented system under development[7][8][9]. It simplifies the complex process of software design, making a blueprint for construction. This sub-section describes only three diagrams in UML, which are widely used in the software development. They are use case diagram, class diagram, and sequence diagram.

2.2. DEVS Formalism

The DEVS formalism is a set-theoretic formalism which specifies discrete event models in a hierarchical and modular form[**?**]. With this formalism, one can perform modeling more easily by decomposing a large system into smaller component models with coupling specification between them. There are two kinds of models: atomic model and coupled model.

An atomic model is the basic model and has specifications for the dynamics of the model. A coupled model provides the method of assembly of several atomic and/or coupled models to build complex systems hierarchically. An overall system consists of a set of component models, either atomic or coupled, thus being in hierarchical structure. Detailed descriptions for the definitions of the atomic and coupled DEVS can be found in [2].

2.3. Modeling Process using UML and DEVS

Co-operating between domain experts and M&S experts is especially required in domain simulators. In such cases, The co-modeling methodology explains an efficient methodology by separating roles of each expert in the developing domain specific simulators [5][6]. The objective of the co-modeling methodology is providing concurrent process in simulation models development. In co-modeling approach, models are separated DEVS model and object model, which represents abstract operations and detail behaviors of models, respectively. They are developed concurrently by M&S experts and domain experts as DEVS diagram and UML diagram forms. Figure 1 describes these procedures. In Figure 1, by co-modeling methodology, domain experts make DEVS model as DEVS model forms and M&S experts make Object model as UML DEVS model.

By synthesizing theses DEVS and UML models, domain-specific simulators can be implemented. With co-modeling methodology, time cost of developing simulators can be reduced and models are more reusable.

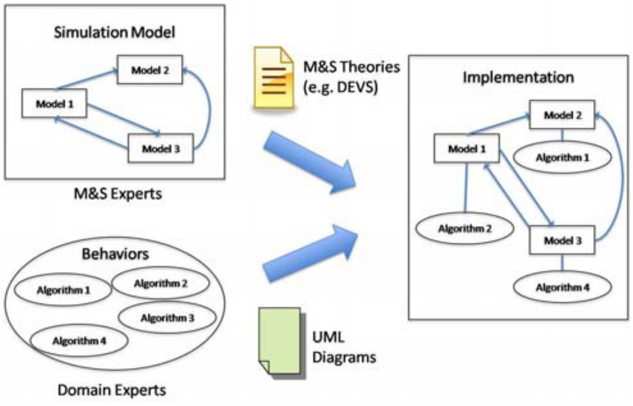


Figure 1. Developing Simulator using Co-modeling Methodology

The co-modeling methodology assumes that the each expert is professional in their part and they do not have any knowledge about other's part. However, because of the security policy of some domains, the domain experts want to know M&S theory to build simulation model by them. Therefore, the domain experts request for the lectures about M&S theory to the M&S experts.

3. Educational Framework using Blended Learning

The blended learning is one of top ten emerging trends in the knowledge delivery industry [11]. The blended learning is the combination of instruction from two historically separate models of teaching and learning: Traditional Face to Face (F2F) learning systems and distributed learning system, which is computer based technology[12]. In our educational model, the blended learning takes important roles. Since domain experts are far from M&S experts, we frequently used e-mails, bulletin board, and websites to enhance the educational effects and sometimes provided lectures face to face. For the following sections, we present the assumptions and out educational frameworks.

3.1. Assumptions

The assumptions of the educational framework are:

3.1.1. Previous Knowledge

Each expert might have different level of domain knowledge and M&S knowledge. However, we assume that the domain experts are accustomed to use the UML diagrams, which are the industrial standard, and have elementary programming language skill.

3.1.2. Distance

Since the domain experts build a domain-specific simulator by themselves, Because of security policies, they are willing to learn about the M&S theories. However, since the distance between the experts is too far away, we assume that the online communication is preferable rather than face to face meeting regularly.

3.1.3. Simulation Environment

We assume that domain experts have the simulation environments to build a simulator. Therefore, the domain experts can build their simulation models and test it by themselves with their elementary programming language skill.

3.2. Educational Framework

To teach the domain experts effectively, we designed the educational framework with two phases. Following Figure 2 is the proposed educational framework. In this framework, there are two phases: Rapid Prototyping phase and Blended Learning phase.

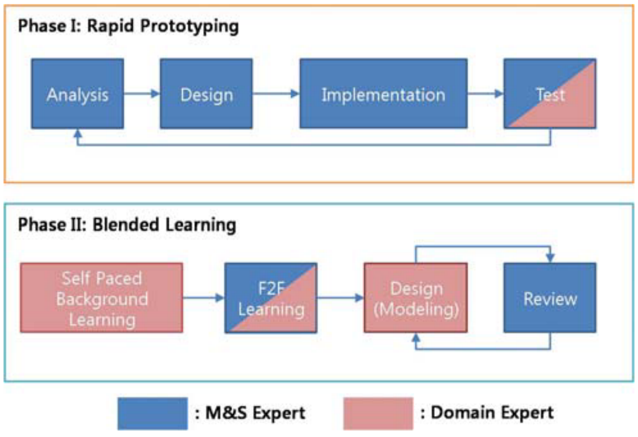


Figure 2. Educational Framework

3.2.1. Phase I: Rapid Prototyping

We adopt the rapid prototyping to the Phase I in our framework. Traditionally, Rapid Prototyping is making prototypes of products with virtual designs in the manufacturing field. With Rapid Prototyping, error-handling cost can be reduced. In the Phase I, the domain experts and the M&S experts build a prototype together. We assume that the domain experts cannot give the detail information of simulation models. In such situation, the simulation models might not well reflect requirements of domain experts in this phase. However, the domain experts can learn about implementation issues in a simulator development. In this stage, the communication method is based on the UML diagrams and the DEVS diagrams [4].

The Phase I enables the M&S experts to give design and implementation knowhow to the domain experts. Moreover, using rapid prototyping method helps the domain experts to find the ambiguous requirements and revise it during the iterative procedure. The Phase I ends when the domain experts and the M&S experts have consent to simulation models.

3.2.2. Phase II: Blended Learning

In the Phase II, the domain experts design the simulation model by themselves. In order to do that, the M&S experts setup the blended learning environment which is mixing distributed learning environments using internet and F2F lectures. The domain experts study the background information using online self-paced learning and have F2F lectures using this environment. During the F2F learning, the M&S experts teaches the M&S theories, such as DEVS formalism, and its implementation such as scheduling algorithms, network management, simulation model managements, and etc. During this phase, the domain experts can design the simulation model. The M&S experts help the domain experts by reviewing the simulation models using e-mails or bulletin boards in the website and the testing their models by providing environments.

3.3. Evaluation

The evaluation has been undertaken with the help of following methods:

- Asking for direct feedback of the experts via face-to-face or e-mail
- Reviewing the design results

The domain experts, who already take M&S lectures, can design simulation models reflecting their domain knowledge. However, the designed models may not work correctly, because they are not professionals but just-learned novices in M&S technology. In order to make the models accurate, the M&S experts are required to support the domain experts by blended learning environments. In detail, the M&S experts can reply the question of the domain experts via on-line and review their models in person. According to the level of security policies in domain, one of the two methods are determined. In the Phase II of educational framework, these two methods can be used in the website and lectures.

4. Case Study: Military Domain Experts

To develop the military simulator, a kind of domain-specific simulator, we helped the domain experts of the national defense research institute applying our educational framework[1]. During the Education Phase I, the M&S experts of SMSLAB developed DEVS models based on the Simulation Logic Documents (SLD) which contains the requirements written by the domain experts. Then, both experts verified the DEVS models together with their own knowledge. In Education Phase II, domain experts developed the DEVS models using their M&S knowledge learned in the blended environments. After DEVS models are developed, the M&S experts help the models more accurate in the view of M&S with verifying the models based on the DEVS formalism.

4.1. Education Phase I

Since the M&S experts of SMSLAB have insufficient domain knowledge, the domain experts are required to specify their requirements unambiguously. In our case, the domain experts made documents, called SLD. In the SLD, use case diagrams, sequence diagrams, and some functions are representing behaviors of simulation models. With the SLD, the M&S experts made the DEVS models based on the sequence diagrams and the functions of the simulation models. Figure 3 and Figure 4 are the sequence diagram and the DEVS model of the sensor model.

After DEVS models have been made, the domain experts and the M&S experts had a meeting to understand the SLD and DEVS graph. This meeting assists both experts to understand the relation between the UML diagrams and the DEVS diagrams. More specifically, the domain experts represent their knowledge using Use Case diagrams, Sequence diagrams, and so on. Then, we translate the UML diagrams into the DEVS diagrams. Moreover, in order to help the domain experts to understand the DEVS graphs, we have made a prototype of the many-to-many engagement simulation software using DEVSim++ which is implementation of DEVS formalism in C++ [10]. We have handed the source code of the prototype to the domain experts. By showing the source code and the results of the prototype in the debugging mode, the domain experts have understood how

[1] This case study related to the national defense, the modeling and implementation results are classified at the CONFIDENTIAL level. Therefore, we give the prototype and information of initial model in this case study.

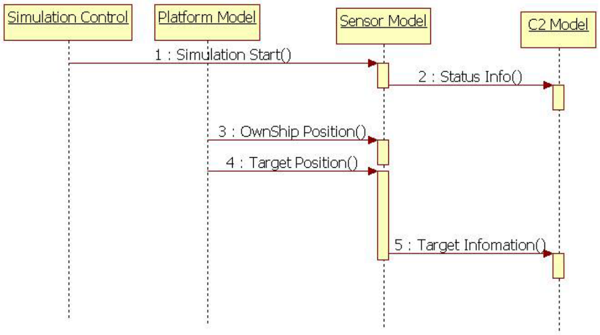


Figure 3. Sequence Diagram of Sensor Model

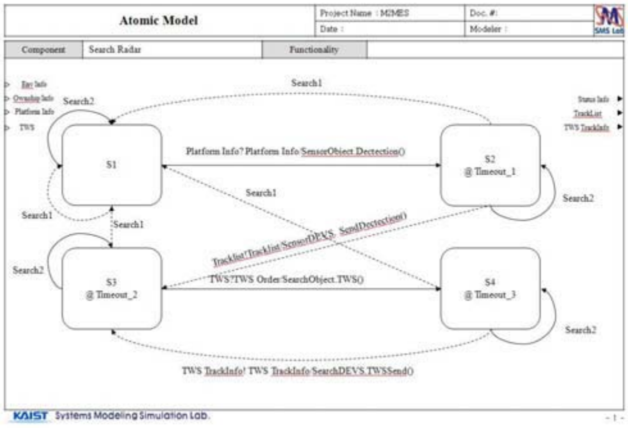
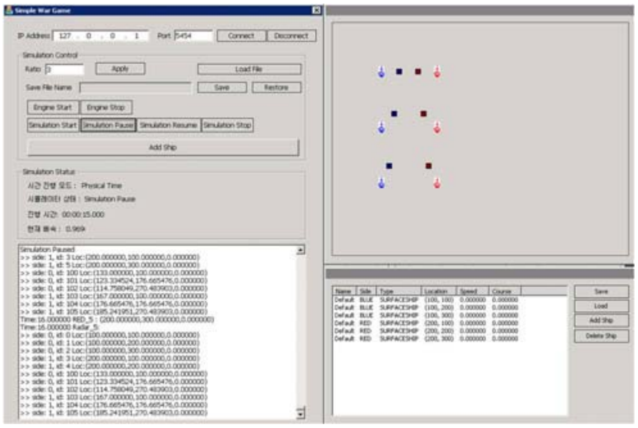


Figure 4. DEVS Graph of Sensor Model

simulation models work. Figure 5 shows the prototype of the many-to-many engagement simulator.



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Default	BLUE	SURFACESHIP	(100, 300)	0.000000	0.000000
Default	RED	SURFACESHIP	(200, 100)	0.000000	0.000000
Default	RED	SURFACESHIP	(200, 200)	0.000000	0.000000
Default	RED	SURFACESHIP	(200, 300)	0.000000	0.000000

Figure 5. Prototype of Many-to-Many Engagement Simulator

After the meeting with the domain experts, we have found several misunderstanding of the simulation models. For example, in the case of some simulation models, the M&S experts have made the DEVS graph completely wrong due to the lack of domain knowledge and the domain experts have found some insufficient models based on the result of the prototype. Therefore, we have revised the SLD and the DEVS graphs based on the results of the meeting and the domain experts have implemented the detail object models and the M&S experts have implemented the DEVS models by co-modeling method [5].

4.2. Education Phase II

Based on the experience of Phase I, SLD has some limitations to let the M&S experts understand domain knowledge. Therefore, the domain experts want to build simulators by themselves. The domain experts studied the materials form the website and F2F lectures in the blended learning environment. The domain experts have designed several DEVS models using learned M&S theory and they send the DEVS graphs to the M&S experts using e-mail. The M&S experts have analyzed the DEVS graph and informed the domain experts that the simulation models may be wrong in the aspect of DEVS formalism. With this information, the domain experts are modifying their simulation models based on their domain knowledge. While the domain experts build the DEVS model based on their DEVS model, the M&S experts made the simulation framework using DEVSim++. Therefore, by supporting the simulation environments, the domain experts enables to build their own models in DEVSim++ and analyze the result without violating their security polices.

5. Lessons Learned

In this section, we share the lessons learned from the case study.

5.1. Necessity of formalism in development of a simulator

With our experience, we are convinced that DEVS formalism is one of the M&S theories which is useful for the development of a simulator. We have applied the DEVS Formalism to develop a simulation models and there are several advantages which the domain experts agreed with.

First, DEVS formalism can support the modelers to make an accurate simulation models. By developing the DEVS graph, the domain experts, who learned M&S theory, can understand how simulation models work. Moreover, by implementing the DEVS models using DEVSim++, the modelers can verify their models quickly using DEVSim++ environment.

Second, DEVS formalism is efficient to design the discrete event simulation model. In discrete event simulations, UML diagrams are not sufficient to express the domain knowledge, due to the properties of events. The events may be periodic and it may cause complex transitions base on the state of the models. Therefore, it is impossible to represent behaviors of models using the sequence diagram sometimes. However, the DEVS formalism specifies discrete event models in a hierarchical and modular form so that the DEVS formalism can express the complex models by decomposing a high-level model into several low-level models.

Third, the DEVS formalism is easy to learn and can be applied in the development of simulator easily. During the Phase I, there were one lecture and two meetings for the domain experts. After that, the domain experts who attained the lectures were able to teach and help other the domain experts to understand the DEVS formalism.

5.2. Rapid Prototyping & Education

We have found that the rapid prototyping can assist the domain experts to understand the operations of the simulation models. Usually, the domain experts have a little knowledge to understand easy source code so that the source code of simulator helped the domain experts to understand the operation of simulation model in the aspect of programming language. We have handed the source code of the prototype to the domain experts. The domain experts, who take educations about M&S theory, have compared the source code and the design documents, i.e. DEVS graph, to understand the simulation models. Moreover, the domain experts have built their own models in C++ and test their models. it enabled them to build accurate models without violating the security policies.

5.3. Blended learning environment & Rapid Prototyping in Simulation Software Development

Since the domain experts are not like students in the universities, they cannot attend the face to face lecture regularly. They have their own works to do. They cannot invest their time and efforts, especially, when the location of the research institute is far from the lecturing places. However, because of their security policy, they have to design simulation models by themselves. They need to learn about the M&S theories. The blended learning environment and the rapid prototyping take an important role here. Since the domain experts are limited to take a class, they can learn M&S theories by our educational framework, which consisted of blended learning environment and rapid. With the effectiveness of our educational framework, the domain experts can complete building a domain-specific simulator.

6. Conclusions

In this paper, we described our experience of assisting the domain experts to obtain the M&S knowledge, in order to build a domain-specific simulator. Through the case study of the high-security domain experts, we have found the formalism is necessary for the developing the simulators in some domain fields and DEVS formalism is suitable for developing a simulator. Moreover, our educational framework, which consists of the rapid prototyping and blended learning environment, can be useful methods to teach the M&S theories to the domain experts who does not know about the M&S theories. We believe that this case study can serve the domain experts how to obtain simulation knowledge and design the simulation models of their domains. As a future work, we will revise the evaluation method to measure the effectiveness of the educational framework formally.

7. ACKNOWLEDGMENTS

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