Simulation Evolution Method for system of systems confrontation

Yang Chu\textsuperscript{a}, Jun Li\textsuperscript{b} and Yufang Zhou\textsuperscript{c}
Jiangsu Automation Research Institute, Jiangsu 222006, China
\textsuperscript{a}chuyang_716@163.com, \textsuperscript{b}287508634@qq.com, \textsuperscript{c}773768050@qq.com

Abstract. System of systems confrontation is the main form of modern warfare. In order to meet different modeling and simulation needs, a large number of evolution ideas of system of systems simulation have emerged. This paper gives two different definitions of evolution ways of system of systems simulation through induction and summary, and makes a comparative analysis from the perspective of evolution mechanism and application scope. Taking a typical parallel simulation system as an example, it gives different evolution ideas Design of simulation application framework under mechanism.

1. Introduction
Future war is across domain and multi domain joint operation between systems. Commanders need to analyze battlefield data efficiently and accurately, and make overall, predictable and accurately, and make overall, predictable and reasonable operational decisions. System of systems simulation should not only have the simulation ability of battlefield combat forces, but also have the simulation ability of battlefield command relationship, communication networking, information process, cooperative warfare, etc. According to the above understanding, system of systems simulation can be divided into two types: entity-based simulation and organization-based simulation\textsuperscript{1}.

2. Entity-based Simulation Advancement
During the simulation advancement process, all battlefield behavior and state evolution are centered on the battlefield simulation force entity. The simulation engine dispatches the force entity from top to bottom and the simulation component models of sensors, weapons, tasks and target characteristics carried by the force entity, so as to realize the dispatch of the whole model system. In this way, battlefield communication relations, command relations, formation movements and other battlefield behaviors with organizational and group characteristics are mainly realized through information transmission between entities, as shown in Figure 1.
Many simulation systems adopt this method. Typical OODA loop scheduling mechanism is usually adopted inside the military entities [2]. It is promoted and transmitted in order of perception, confirmation, decision-making and action. It can realize the simulation of battlefield behavior processes such as detection, threat judgment, decision-making and action of a single combat entity. The disorder of inter-body information transfer makes it difficult for the simulation model to reflect the emergence characteristics brought about by the participation of a large number of autonomous agents, as shown in Figure 2.

The advantage of entity-based simulation advancement is that the simulation scheduling layer is progressive and the logic is clear. It can be applied to two types of simulation engines, time-stepping and discrete events. The disadvantage is that it produces a lot of redundant scheduling, which can’t well reflect the characteristics of multi-layer command and complex communication network in system-
based confrontation. It is difficult to realize battlefield simulation with complex group and organizational relationship behavior.

3. Organization-based simulation advancement
Organizational-centered group simulation evolution is a common simulation advancement method in large and complex simulation systems. The evolution content is not limited to traditional battlefield behaviors such as entity motion, detection and attack, but also includes complex organizational behaviors such as command and dispatch, communication networking, aspect battle decision-making, group maneuvering and so on. The simulation engine realizes the automatic evolution of battlefield command relationship, communication network, aspect task and so on by scheduling the organizational structure model of each alliance, and indirectly dispatches the simulation entity model on demand, requesting information from the entity on demand, as shown in Figure 3.

![Figure 3. Organization-based simulation advancement](image)

In this mode, the simulation entity does not need to be scheduled every cycle. It only needs to be scheduled when there are "unexpected" changes in force status and behavior or external instructions. The operational process is not only a single-layer OODA loop, but also a multi-layer complex OODA process nested with each other. It can simulate the information sharing and command collaboration ability among command entities in the whole operational process, as shown in Figure 4.
Figure 4. Organization internal dispatching mode

The advantage of organizational-based simulation is that simulation scheduling is implemented on demand, which greatly improves engine efficiency and can reflect complex behaviors such as multi-layer command and complex communication networking under system-based confrontation. The disadvantage is that most of them can only be used in discrete event simulation engine.

Comparison of two evolution modes shown in table 1.

Table 1. Comparison of two evolution modes.

| Evolution mode      | Evolution mode | Simulation engine          | Control process   | Efficiency | Scale  |
|---------------------|----------------|----------------------------|-------------------|------------|--------|
| Entity-based        | Tactic Level   | Time-engine                | Single-Layer OODA | Low        | Many   |
| Organization-based  | Campaign Level | Time-engine Event-engine   | Multi-layer OODA  | High       | Less   |

4. Parallel Simulation System

Parallel simulation refers to the construction of a simulation image system running in parallel with the command information system [3] [4]. Through the interconnection and information interaction with the command information system, the latest battlefield situation information is continuously obtained from the actual command information system, and the battlefield entity simulation model is established. The image system can keep the identity and status of the target consistent with the actual situation. It can be used as the operation and calculation environment of super real-time simulation operation and artificial intelligence. It can help the commander to make decisions or form the operation plan by constantly judging the possible operation intention and behavior of the enemy target. Parallel simulation based on entity simulation has been proposed in literature [5]. This paper focuses on the implementation of parallel simulation technology under Organizational simulation.

4.1. Parallel Simulation System Framework

Parallel simulation system consists of battlefield real-time situation receiving and processing, simulation model dynamic construction and modification, real-time/ultra-real-time simulation deduction, assistant decision analysis, efficient simulation engine and so on, as shown in Figure 5.
Real-time situation receiving and processing in battlefield mainly receives real-time situation continuously from the situation subsystem of command information system, and filters and preprocesses real-time situation. This module is the premise and foundation of realizing the function of building and revising battlefield entity model. Dynamic construction and revision of simulation model can establish realistic battlefield entity simulation model, which can be revised in real time with battlefield situation, and used in battlefield. Real-time/ultra-real-time simulation deduction is used to carry out real-time deduction parallel to real-time situation, assist in real-time situation analysis, and carry out ultra-real-time simulation deduction and evaluation of combat plan, support the intervention of manual instructions, support artificial intelligence participation in operation; assistant decision-making analysis can realize special situation prediction and situation analysis products; efficient operation simulation The engine provides distributed simulation model scheduling, load balancing, multi-branch deduction support, simulation management, operation control and other capabilities for system operation and interaction.

4.2. Parallel Simulation Model Revision Rule
Revision rule is an important module to judge when and how to modify parallel simulation model. Referring to the typical ECA rule modeling method of "if-then rule", a modified rule model based on feature analysis is constructed. The model structure is shown in Figure 6.
The modified rule based on feature analysis consists of trigger condition, criterion and response. 

(a) Trigger conditions include three aspects: creating, updating and deleting situation data;

(b) Criteria are divided into six categories according to the model of feature analysis, namely, identity characteristics, physical characteristics, relationship with other objectives, action characteristics, state characteristics and historical trajectory characteristics, each of which can be used as a criterion or condition for situation filtering and screening.

(c) Response includes two aspects: first, to describe whether to modify or not, the main content is the model correction threshold; second, to describe how to modify, the main content includes four aspects: model category modification, model parameter item modification, sub-model combination modification, entity model relationship modification. Model categories are usually used to describe the changes in the nature of the model itself, such as the change of ship entity into aircraft entity model, which usually needs to be deleted and reconstructed; the change of model parameters usually needs to modify the corresponding model values; and the combination of sub-models usually describes the changes of some components in the model, such as the mounting of helicopters. Torpedo weapon is...
changed to hoisting sonar; entity model relationship used to describe the external relationship of entity has changed, such as out of formation.

4.3. Verification of simulation experiment
Take a typical combat scenario as the application background, build a parallel simulation system, design the number of targets and task types of different scales to carry out simulation experiments, and count the completion rate of simulation model creation, generation time of simulation entity relationship, modification time and other indicators under different scenarios, as shown in table 2.

| Entity Numbers Index | 50   | 100  | 150  | 200  | 250  | 300  | 350  | 400  | 450  | 500  |
|----------------------|------|------|------|------|------|------|------|------|------|------|
| Integrity rate (%)   | 95.4 | 90.2 | 87.8 | 85.0 | 84.3 | 83.2 | 82.6 | 82.0 | 81.8 | 80.8 |
| Generation time(ms)  | 100  | 305  | 320  | 360  | 388  | 412  | 426  | 460  | 484  | 490  |
| Correction time(ms)  | 105  | 480  | 525  | 556  | 584  | 594  | 618  | 620  | 652  | 688  |

It can be seen that the creation and revision time of entity relationship model increases with the increase of the number of targets. The number of targets changes obviously between 50 and 100. The creation time of entity relationship of 500 batches of targets is about 700 ms and the revision time is about 500 ms.

5. Conclusion
Based on the analysis and summary of typical simulation system, this paper summarizes two evolution methods of system simulation model: simulation evolution based on entity and simulation evolution based on organization. From the aspects of evolution mechanism, trial scope, advantages and disadvantages, this paper makes a comparative analysis from multiple perspectives. Combined with parallel simulation system architecture, this paper gives a parallel simulation framework based on organization and constructs parallel simulation. Model modification rules are of great significance to the research of military system simulation.

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