Design of the Autonomous Intelligent Simulation Model (AISM) using Computer Generated Force

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Abstract: This paper is concerned to the next generation technology in virtual training simulation. Most virtual training simulations have been executed in human-in-the-loop type in which one side is computer and the other side is human. Many computers and participants are needed for players. This is big problem in increasing simulation usage and its effectiveness. This paper proposes an approach to solve such problem by allowing the simulated entities to act like human. The techniques enabling intelligence are devised. Based on the techniques, we implement a prototype in which some weapons and units autonomously engage with each other in common battlefield.

Key-Words: Knowledge Acquisition & Knowledge Engineering (KA/KE), Fuzzy-Rule inference, Agent based simulation model, Computer Generated Force (CGF)

1 Introduction

Most virtual training simulations have been executed in human-in-the-loop type in which one side is computer and the other side is human. So, many computers and participants are needed for players. This is big problem in increasing simulation usage and its effectiveness. One of the methods to solve this problem is to endow intelligent capability to entity so that the entity can act like human. If intelligent entity can delegate human, then number of human will be decreased. The DoD (Department of Defense) of USA already counts on this technique called by CGF (Computer Generated Force) as one of the essential military simulation technologies. The DoD defines CGF in DoD M&S Master Plan (1995), DoD 5000.59-M (1998) as follows.

A generic term used to refer to computer representation of entities in simulations which attempts to model human behavior sufficiently, so that the forces will take some actions automatically without man-in-the-loop interaction.

The distinguishing features of CGF are automatic decision making and thinking automated opposing. That is, CGF automatically behave like human using its intelligent capability and can play a role as friendly forces as well as opposing forces.

We propose one approach to implement CGF. For our approach, the following issues must be answered.

- How to obtain knowledge
- How to recognize situation
- How to make a decision and act
- How to follow goal
- How to verify intelligence

This paper devises technical solution for each issue. Integrating with the devised methods, we design an Autonomous Intelligent Simulation Model, called as AISM in this paper, which is to simulate small unit training.

In Section 2, we describe the technical solution for the issues identified above. Section 3 discusses integration of solutions. Section 4 explains the prototype. Finally, future works are addressed in Section 5.

2 Intelligence enabling Technique

This section describes the technical solution for the issues described above. They will be techniques enabling intelligence.

2.1 Knowledge Acquisition and Engineering
In order for entity to have intelligence, the entity must have the knowledge required to execute intelligence. Knowledge must be appropriate for entity to execute the assigned mission. Knowledge must be acquired through sources such as procedure, doctrine and descriptions in domain. Also the acquired knowledge must be engineered so that it can be used in process of inference. These works are called as knowledge acquisition and knowledge engineering (KA/KE). Knowledge acquisition collects information from domain sources and specifies it into situations such as decision table. Knowledge engineering formalizes the obtained situations into knowledge format so that it can be used for inference. Since our AISM uses the rule based inference technology, knowledge must be engineered in the format of rule. Fig.1 shows the KA/KE process in conceptual. Because knowledge context influence to simulation result, KA/KE work is very carious and difficult. Knowledge acquisition should be executed by domain expert, and knowledge engineering is executed by knowledge engineer.

Through KA/KE process of small unit combat, we extract about 170 tasks for 8 military operation domains. After identifying the behaviors for each task and the conditions invoking each behavior, we produce knowledge of rule format.

2.2 Inference

The autonomous entity must recognize the facing situation, interpret it and should make proper decisions by itself. For example, when an entity seeks 15 infantry of enemy by LOS within the area of interest, entity has to interpret whether number of enemy is big size or not. According to interpretation, entity decides behavior. If it is interpreted that 15 infantry of enemy is small size, then friendly force can attack the enemy by doctrine that friendly force can attack enemy force in case that friendly force is bigger than enemy force. If not, friendly force will not attack. Among many techniques for interpretation, fuzzy technique is particularly useful to classify ambiguous situation such as battlefield. Fuzzy technique represents the recognition result quantitatively as fuzzy value.

It is required to react to the situation. This is executed by inference. Inference must choose proper behavior so that entity can react to facing situation. The rule based inference technique is one of the most useful techniques. The rule is represented in format: if (fact) then (action). In inference, when a situation is matched with fact-part of rule, action-part of rule is fired. Again action part can be used to find the fact part in other rule. This process is repeated until other rules are no longer referenced. The action of final rule is executed.

Fuzzy technique is applied to determine the fact part value of rule. In Fig.3(a), when number of enemy infantry is recognized about 26, fuzzy value in small side is about 0.8 and in medium side is about 0.4. The threat value by multiplying two values is 0.32. If we define that over 0.5 is high threat level by doctrine, then we can decide that 26 enemy infantry is not threat for friendly force. This inference method is called by the FuzzyRule inference technique in which fuzzy method and rule inference method are combined. Fig. 3(b) shows the inference process and the methods applied in the process. Rule inference may be enforced by adding other techniques such as neural network method, etc.
2.3 Behavior
The action chosen by inference influences on environment and changes its state. The action can be a composite behavior or primitive behavior. Composite behavior is combined with several primitive behaviors. Composite behaviors are executed for task. Primitive behaviors must be executed for composite behavior. For example, for ‘tactical move’ task in small unit doctrine, two composite behaviors such as ‘move along planned route’ and ‘make a detour at obstacle’ must be executed in repeat. Here, ‘move along planned route’ is executed by primitive behavior ‘move on foot’ with speed and deployment attributes. In Fig.3(b), the action A3 of final visited rule is primitive behavior. In our research for small unit battle, about 59 composite behaviors and 66 primitive behaviors are identified.

2.4 Goal oriented Planning and Collaboration
Although individual entity has intelligence and acts autonomously, it doesn’t mean that the assigned mission must be achieved. Also even if each entity achieves its goal, it doesn’t mean that the overall goal is achieved. It is necessary for entities to go forward to the overall goal(mission). That is, entities must go to achieve their goals and collaborate with each other to achieve overall goal. The goal oriented action and the collaboration are very important issues. In our work, GOAL(Goal Oriented Action Planning) method for goal oriented action is considered. This is the method that reversely plans the actions from goal to starting position. Fig.4 shows the GOAP method concept. The routes to goal in Fig.4 is attack(start)-2quad-indirect fire-mine pass-grenade-encampment occupation(goal).

It is necessary for entities to interact with each other to achieve overall goal. We devise the blackboard architecture to support interaction. There are two type blackboards: internal and external blackboard. Internal blackboard supports interaction within entity. External blackboard supports interaction among entities. Each entity informs its state and event information to internal blackboard. If the internal event occurs, then the event is executed in internal. If not, the event is transmitted into external blackboard with destination entity. The destination entity takes the transmitted message and executes the assigned action. Fig.5 briefly shows the collaboration by the blackboards. In short, internal blackboard supports collaboration among agents in entity and external blackboard supports collaboration among entities.
2.5 Verification
It is necessary to verify whether entities have autonomous intelligence. Also we must know the level of intelligence and its usefulness. In general, the level of autonomy can be classified into semi-automated level that human intervention is needed during simulation or fully-automated level without intervention. However, fully-automated level is ideal level. We are focused on semi-automated level.

In order to verify autonomous intelligence of entity, in situation that both autonomous entity and human join with common environment, we check that both sides can interact with each other as if both sides are human trainees. If human feels that counterpart (autonomous entity) is also human, then it can say that the entity is semi-automated level at least.

For the approach described above, we try to construct the interoperable simulation environment that both autonomous entity in AISM and human trainee in human-in-the-loop simulation model join on common battlefield and engage with each other. For human-in-the-loop side, we use DSBS (Distributed Synthetic Battlefield Simulation), a human-in-the-loop simulation model developed by us at 2007 year, is a small-scale virtual training simulation model in which human directly participate as trainee. Fig.6 shows interoperation concept between AISM and DSBS. In Fig.6, the entities e1, e3 and human trainee h2, h3 engage with each other on common battlefield environment.

If actions of entities e1 and e3 look like actions of human, then we can say that entity has autonomy and intelligence. Here, e1, e3 can be weapons, individuals or units. They are called by SAF, semi-automated force CGF.

Fig.6 shows interoperation concept between AISM and DSBS. In Fig.6, the entities e1, e3 and human trainee h2, h3 engage with each other on common battlefield environment.

3 Integration of Techniques
In Sec.2, we invoke some issues to implement intelligence and devise the techniques or methods to solve the invoked issues. Using the devised techniques, we design an autonomous intelligence simulation model, AISM in which entities autonomously act to achieve goal. This section describes the architecture and features of AISM. Sec. 4 explains our prototype for AISM.

3.1 Architecture
From the techniques or methods described in previous section, we establish directions to design the AISM as follows.
- Knowledge is basically extracted along knowledge hierarchy by KA/KE process. The format of knowledge is rule.
- Inference is fuzzy rule method using fuzzy value with rule.
- Behavior is classified into composite behavior and primitive behavior.
- Goal oriented action planning technique is used for entity to reach goal.
- Collaboration among entities is supported by external blackboard.
- Collaboration among agents within entity is executed via internal blackboard.
- Entity has agents for its functions and models for its behaviors.
- Intelligence is verified by interoperation between intelligent entities and human trainees.

Fig.7 shows the architecture of entity and
interaction among entities. Each entity has agents and models. Agents execute the functions using models.

The operation flow of Fig.7 is as follows. Entity A sends “Entity C, go to position X” (message1) to the external blackboard. Entity C checks messages and finds the message. Communication-agent receives the message1 and writes it on internal blackboard of Entity C. The internal blackboard passes the message1 to fuzzyrule inference engine. The inference engine decides the behavior to process message1. The move-agent related to the behavior takes message1 and make Entity C move to the position X using move-model. When enemy is found by sensor-agent during move, inference can decide to engage with enemy, the engagement-agent takes the message from internal blackboard and engages with enemy. This process is continued until the entity reaches the position X.

3.2 Features
The primary characteristics of AISM are as followings.
- Agent based simulation. One of the key points in AISM design is the agent concept. Agents execute the actions of entities such as movement, communication, sensing etc. Agents play a role as like delegator for entity.
- Broker communication. The interaction among agents is executed via internal blackboard. Internal blackboard plays a role of broker among agents. Interaction among entities is executed via external blackboard. External blackboard plays a role of broker among entities.
- Doctrine based knowledge. The knowledge of AISM is obtained from doctrines. Knowledge is formalized into rule form so that inference engine can directly use it in inference.
- Semi-automated intelligence. Since inference is based on knowledge within certain doctrine, it can’t say that entities have complete knowledge and act in fully automated. Hence, entities in AISM are a kind of SAFs.

Based on architecture and its features, AISM supports small scale battle training simulation. Entities in AISM can play as opposing forces or friendly forces(unit, weapon, individual etc).

4 Prototype Implementation
AISM prototype is to confirm the usefulness of the techniques enabling intelligence and the architecture design described in previous sections. The scope of prototype is squad battle including one blue squad CGF, one blue tank
human and one red squad CGF. Scenario for prototype is as follows:

In the situation that one red squad deploys behind obstacle, one blue squad is approaching to the obstacle along road by walk. When the blue squad comes within attack possible distance, the red squad first finds the blue squad and attacks blue squad. The blue squad quickly conceals behind rock and attacks the red squad. The engagement between blue squad and red squad is happened. After a while, one blue tank operated by human arrives at the area and attacks the red squad. The red squad finds tank and attacks for a while. When the red squad recognizes that its fire capability is lower than blue fire capability, the red squad retreats to the opposite direction.

In this scenario, red and blue squad is autonomous entities, and tank is the entity that human operates. If engagement between red squad and blue tank is executed as if both of them are human, then it can say that the red squad acts autonomously. Fig.9 shows the initial deployment and the expected combat situation.

![Fig.9 Prototype-Scenario](image)

The prototype uses rules and behaviors extracted from military small infantry unit combat doctrine. The prototype shows that squad autonomously moves, conceals and fires based on its military doctrine. On being inferior in battle situation, red squad autonomously retreats to the opposing direction of blue squad. The blue tank operated by human(trainee) engages with the autonomous red squad naturally, so human feels as if he directly engages with the red squad. In actual, the red squad is being operated by rule. From the result of prototype, we make sure that the techniques and architecture devised in our research are useful and they make it possible to develop the real AISM.

### 5 Conclusion

This paper proposes the techniques and architecture for autonomous intelligent simulation. KA/KE method is newly devised. Interoperation for verification is also unique approach. Inference, GOAP and collaboration techniques improve the existing techniques. The most important point is integration with the techniques so that they can develop autonomous intelligent simulation model.

We implement small scale military simulation prototype. Although it is experimental, it shows the technical possibility for AISM. Currently we are developing real simulation model using the techniques and architecture devised in this paper.

To improve our research, more efficient technique for rule management, goal oriented planning and collaboration is required. As further research, the advanced researches such as inference enforcement, learning, human behavior representation(HBR) techniques to leverage fully automated level are required.

The techniques for autonomous intelligent simulation must be an essential technique in future simulation.

**References:**


