LETTER Simulation-Based Tactics Generation for Warship Combat Using the Genetic Algorithm

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SUMMARY In most existing warships combat simulation system, the tactics of a warship is manipulated by human operators. For this reason, the simulation results are restricted due to the capabilities of human operators. To deal with this, we have employed the genetic algorithm for supporting the evolutionary simulation environment. In which, the tactical decision by human operators is replaced by the human model with a rule-based chromosome for representing tactics so that the population of simulations are created and hundreds of simulation runs are continued on the basis of the genetic algorithm without any human intervention until finding emergent tactics which shows the best performance throughout the simulation. Several simulation tests demonstrate the techniques.

key words: genetic algorithm, warship combat, tactics generation, evolutionary simulation

1. Introduction

Military tactics are known as the techniques for using weapons or military units in combination for engaging and defeating an enemy in battle [1]. There exist various mathematical and/or simulation-based methodologies [2]–[4] in the field of national defense for analyzing the tactical efficiency, however, the tactics in most approaches are specified and injected by human operators (by captains, commanders, etc.) [5].

The overall goal of this paper is to propose a method of generating warship combat tactics by employing the simulation technique combined with the genetic algorithm (GA). Evolutionary algorithms such as GA have become promising methods in solving various optimization problems [6], [7], especially in representing emergent phenomena [8], so they have been applied to various fields such as mobile robots and multi-agent systems [9], [10]. In national defense field, the GA has been successfully used for analyzing the optimal behavior of land combat units [2] and analyzing the effectiveness of the decision-making-factor structure in sea combat [3]. The stochastic GA has been used for analyzing the optimal tactics quantitatively in air combat [4]. Those researches showed the possibilities to adopt the evolutionary algorithm to effectively find the optimal one among given tactics in various defense fields. However, the automated

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generation of emergent tactics through the evolutionary simulation is not known yet.

To deal with this, we have employed the GA to support the evolutionary simulation environment. The proposed simulation is proceeded along with the following steps; (i) hundreds of combat simulations with tactics model (initially at random) are carried out until to satisfy the termination condition (defeating the enemy), (ii) the several tactics with good performance (pre-defined combat efficiency) are survived to have the right for breeding their descendants, (iii) several genetic operations between survived tactics are proceeded to create next generation, (iv) the evolutionary simulation process is continued until to find effective tactics or to given number of generation.

The proposed approach has the following essential characteristics: (i) the evolutionary simulation supports a convenient means to generate the emergent and/or efficient tactics, (ii) it does not need any humans (i.e., captains) intervention so that it can support the variety of simulation tests with a faster simulation speed.

This paper is organized as follows. First it discusses the overall methodology for warship combat tactics generation using GA. This is followed by a concrete example applied to the one-to-one warship combat simulation for generating emergent tactics.

2. Overall Methodology for Warship Combat Tactics Generation

The proposed methodology for generating warship combat tactics is given in Fig. 1. The methodology starts by specifying the combat scenario, objectives, requirements, and constraints to be tested as in PHASE I. Then the model structure in PHASE II is created based on the combat scenario and objectives. Then each behavioral model such as warship, captain, etc. is retrieved from the model repository and initialized based on the given scenario. It then finally transformed along with the model structure to construct the simulation model. The rule-based chromosome (i.e., tactics) for GA operation is loaded in a captain model. In PHASE III, the simulation model is finally ready to run. The evolutionary simulation is performed in PHASE IV where (i) hundreds of combat simulations are carried out until to satisfy the termination condition, (ii) the several tactics with good performance (pre-defined combat efficiency) are survived to have the right for breeding their descendants, (iii) genetic operations (i.e., crossover and mutation) between survived tactics

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Fig. 1 Overall methodology of simulation-based warship combat tactics generation using the GA.

are proceeded to create next generation, (iv) the evolutionary simulation process is continued until to find effective tactics or to given number of generation.

The description of each model in PHASE II is summarized as follows;

• Scenario Generator Model: generates warship combat simulation scenario.

· Combat Space Model: manages battlefield variables such



as changes of warship location and condition.

• **GA Operator Model**: manages the GA operations based on the following operations;

<u>Selection</u>: is carried out by selecting several chromosomes (tactics) with superior performance to be survived so that they have right to breed their off-springs by applying the genetic operations.

<u>Crossover:</u> is a genetic operator used to vary the programming of a chromosome from one generation to the next. In our rule-based chromosome, a single crossover point is randomly selected and crossed to create next off-springs as depicted in Fig. 2-(a).

<u>Mutation</u>: is a genetic operator used to support the genetic diversity just like the biological mutation. In our rule-base chromosome, the action part of randomly selected rule in a chromosome is modified as shown in Fig. 2-(b).

• Warship Model: represents the platform model of warship. It is consisted with the Sensor model, Gunny Model, Movement model, CFCS model, etc. to inform various sensory data to Captain model as well as to execute the movement and/or attack commands from Captain model.

• Fitness Evaluator Model: evaluates the fitness (i.e., the combat efficiency) when a simulation is terminated. We have defined that the combat efficiency is the difference between the accumulated amount of damage of our ship and enemy ship. Note that the value of the combat efficiency is defined as ranging from -1 to 1, in which 1 means that our ship is not attacked (no damage) but the enemy ship is completely damaged (sunken).

• **Captain Model**: is a human model with tactics to make decision to control the warship model. The tactics (i.e., rulebased chromosomes) of each captain model consist of conditions and actions, and evolve through the GA. Figure 2-(b) illustrates the rule structure. A captain has 96 rules, the condition part of each rule includes the range of naval gun (WITHIN, OUTSIDE), the speed of the opposite warship (HIGH, MIDDLE, LOW), the exposed part of the opposite warship toward our warship (FRONT, LEFT, RIGHT, BACK), the exposed part of our warship toward the opposite warship (FRONT, LEFT, RIGHT, BACK). The action part of each rule consists of attack, next direction, and next speed of warship.

3. Case Study: One-to-One Warship Combat Simulation

3.1 Simulation Scenario

As a concrete example of the simulation-based tactics generation, we have employed the warship combat scenario based on the actual combat accidents happened recently on the West Sea in Korean peninsula as shown in Fig. 3. To simplify the simulation test, we have defined the simulation conditions as follows; the defensive and/or offensive tactics is consisted with 96 rules, the number of population and generation are 20 and 10, respectively. The probability of mutation and crossover are 4% and 50%, respectively. The evolutionary modeling and simulation system is developed by using DeSim++ S/W which is an implementation of DEVS modeling and simulation framework [11].

3.2 Simulation Results Analysis

The evolutionary simulation on the basis of the model structure as depicted in PHASE IV of Fig. 1 has been successfully tested. The result shows the feasibility to generate emergent and/or effective tactics with high performance in warship combats. Among the variety of tactics generated through the evolutionary simulation, let us consider the following tactics;

CASE-I: Tactics *"using Obstacles"* As represented in Fig. 3-(a), the Blue_Warship with this tactics first lures the enemy and then surprise the enemy by making use of islands. Table 1 illustrates the executed tactical rules at some time point explained in Fig. 3-(a). In this case, the combat efficiency of the Blue_Warship was 0.2, since the accumulated amount of damage of the Blue_ Warship and the Red_Warship was 0.17 and 0.37, respectively.

CASE-II: Tactics "Zigzag" the Blue_Warship with this tactics (see Fig. 3-(b)) repeats zigzag movement to avoid enemy's attacks. In this case, the combat efficiency of the Blue_Warship showed 0.19, since the accumulated amount of damage of the Blue_Warship and the Red_Warship is 0.23 and 0.42, respectively.



 $^{\circ}$: The Blue_Warship had lured the enemy by using the obstacle(island). (Simulation time = 4300~7200).

- ②~③ : After some intensive combats each other, the enemy's warship was immobilized and the Blue_Warship also got some damage. (Simulation time = 7200~8800).
- ③~④ : The Blue_Warship moves behind the island and continue to attack. (Simulation time = 8800~10000).

(a) Case I: Generated Tactics so-called "Using Obstacles"



②~③: The Blue_Warship had moved in zigzag fashion to avoid enemy's attack (Simulation time = 8200~8850).

③~④: The enemy's ship had been sunken down after intensive attack from the Blue_Warship. (Simulation time = 8850~10000).

(b) Case II : Generated Tactics so-called "Zigzag"

Fig. 3 Simulation result: Emergent tactics.

4. Conclusion

Evolutionary simulation methodology applied to the tactical analysis of warship combat has been proposed. Simulation test performed on one-to-one warship combat example has been successfully demonstrated the possibilities to generate emergent and/or efficient tactics without any human interventions. Our approach is differentiated from others in that; (i) the evolutionary simulation is developed to provide a convenient means to generate the emergent and/or efficient

Table 1	Executed	tactical	rules in	CASE-I	(partiall	y shown).
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E Rule Name : R4 IF Red_Warship is WITHIN our naval gun range, AND speed of Red_Warship is HIGH,					
Rule Name : R4 IF Red_Warship is WITHIN our naval gun range, AND speed of Red_Warship is HIGH,					
IF Red_Warship is WITHIN our naval gun range, AND speed of Red_Warship is HIGH,					
AND speed of Red_Warship is HIGH,	IF Red_Warship is WITHIN our naval gun range,				
	AND speed of Red_Warship is HIGH,				
4300 AND exposed part of Red_Warship is BACK,	AND exposed part of Red_Warship is BACK,				
AND exposed part of Blue_Warship is FRONT,	AND exposed part of Blue_Warship is FRONT,				
THEN Blue_Warship fires to Red_Warship,					
next direction of Blue_Warship is the north-east (turn	next direction of Blue_Warship is the north-east (turning left),				
speed of Blue_Warship is middle.	speed of Blue_Warship is middle.				
	:				
Rule Name : R2					
IF Red_Warship is WITHIN our naval gun range,	IF Red_Warship is WITHIN our naval gun range,				
AND speed of Red_Warship is HIGH,					
AND exposed part of Red_Warship is FRONT,					
AND exposed part of Blue_Warship is LEFT,					
THEN Blue_Warship strongly fires to Red_Warship,	THEN Blue_Warship strongly fires to Red_Warship,				
next direction of Blue_Warship is not changed, the n	orth-east,				
speed of Blue_Warship is slow.					
Rule Name : R37	Rule Name : R37				
IF Red_Warship is WITHIN our naval gun range,	IF Red_Warship is WITHIN our naval gun range,				
AND speed of Red_Warship is SLOW,					
AND exposed part of Red_Warship is LEFT,					
AND exposed part of Blue_Warship is FRONT,	AND exposed part of Blue_Warship is FRONT,				
THEN Blue_Warship fires to Red_Warship,	THEN Blue_Warship fires to Red_Warship,				
next direction of Blue_Warship is the east (turning ri	next direction of Blue_Warship is the east (turning right),				
speed of Blue_Warship is fast.					
: : : : : : : : : : : : : : : : : : :					
Rule Name : R39					
IF Red_Warship is WITHIN our naval gun range,	IF Ked_warship is WITHIN our naval gun range,				
AND speed of Red_Warship is SLOW,	AND speed of Red_Warship is SLOW,				
AND exposed part of Red_Warship is LEFT,					
AND exposed part of Blue_Warship is RIGHT,	AND exposed part of Blue_Warship is RIGHT,				
THEN Blue_Warship fires to Red_Warship,	THEN Blue_Warship fires to Red_Warship,				
next direction of Blue_Warship is the south (turning	right),				
speed of Blue_Warship is fast.					

tactics, (ii) it does not need any humans (i.e., captains) intervention so that it can support the variety of simulation tests with fasten simulation speed. National defense representatives including warship captains will be able to utilize the generated tactics through the evolutionary simulation developed in this paper. In near future, the research should be continued to study how to create the cooperative tactics on many-on-many warship combat environment.

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