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Multi-Agent Unmanned Swarm Combat Architecture Based on Ooda Loop

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Abstract: The demand for the modern war against unmanned swarm is imminent, aiming at the new combat method of unmanned swarm, analyzing the operational structure of OODA loop is proposed. The design of unmanned swarm operation architecture will fully consider the operational requirements. Based on the classic operational mode OODA loop, the architecture design scheme is proposed from two parts: unmanned swarm combat planning based on OODA loop and unmanned swarm combat application. The functions of the architecture are divided and described in detail, and finally a multi-agent unmanned swarm operation architecture based on OODA loop is constructed. The design and planning of the operation architecture will contribute to the development of unmanned swarm operation.

1. Introduction

OODA Loop theory is a strategic decision-making theory in military operations proposed by Boyd[1]. It has become a scientific method to describe the conflict problems in operations. Once put forward, this theory was immediately recognized by the military circles of the whole western world, and is still widely used in the research of military combat experiments[2]. Based on the original theory, many scholars have extended it and derived new theories such as modular OODA Loop, intelligent OODA Loop and cognitive OODA Loop[3-5]. In the era of information warfare, the increasing demand for multinational joint military exercises, coordinated military strikes and joint operations with other services and arms makes it difficult for ordinary combat forces to deal with them[6,7].

With the continuous progress of artificial intelligence technology, weapons and equipment have been continuously developed. The proportion of intelligent weapons led by unmanned swarm equipment in conventional weapons is gradually increasing, and unmanned swarm equipment will become one of the main combat equipment in the future battlefield. As a new combat weapon, the conventional combat architecture will not be able to adapt to the flexible future battlefield. Therefore, it is particularly important to build a new combat architecture, which determines the overall performance of unmanned swarm combat experiment, and has been continuously studied and improved by researchers in this field[8,9].

Based on the classic military operation decision-making theory of OODA Loop, this paper constructs a multi-agent unmanned swarm operation architecture based on OODA Loop, which provides a research basis for the actual combat of unmanned swarm operation.

2. Unmanned Swarm Operation Planning Architecture Based on Ooda Loop

Boyd's OODA Loop theory points out that military action is basically composed of a series of decision-making processes or cycles. The basic OODA Loop mainly includes four parts: Observation, Orientation, Decision and Action[10], as shown in Figure 1. OODA Loop decomposes combat operations into multiple discrete events, which meets the requirements of discrete event simulation.

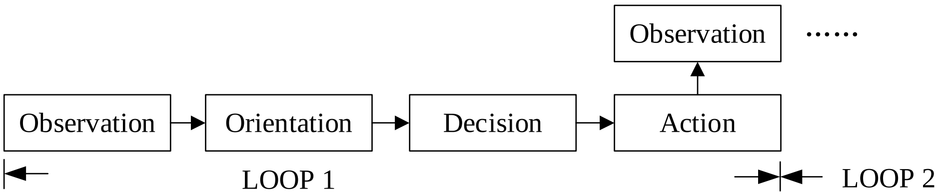


Fig.1 Ooda Loop

The military operation OODA Loop with command and control characteristics carries out cyclic combat according to the above four parts, and starts a new Loop after the end of a Loop. The length of the Loop is related to the specific combat situation. The force scale, battlefield situation and scope of unmanned swarm will have an impact on it. Among them, the Observation part is a stage of observation and collection of the battle unit to the battlefield environment, the enemy's strength, and the weapons and equipment deployment; The Orientation part is the stage of sorting and analyzing the collected original battlefield information, obtaining the current battlefield situation and predicting the future battlefield situation; The Decision part is the part in which the decision-maker makes decisions and deploys the next operation intention according to the processed information; The Action part will realize the decision-making made by the decision-maker according to the information integration planning of the previous three links.

OODA Loop can cover and describe most combat modes, but unmanned swarm operations require high autonomy because of its unmanned nature. The most important thing is the embodiment of swarm intelligence. The cooperation, decision-making and action of unmanned swarm equipment are inseparable from the characteristics of swarm intelligence, which is implemented in all links of OODA Loop. The Observation link is the first link of unmanned swarm operation, which is mainly responsible for collecting battlefield environment and combat situation information. The interaction architecture between unmanned swarm and environment is shown in Figure 2.

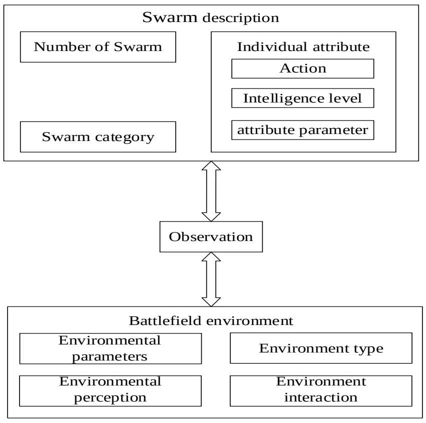


Fig.2 Interaction Architecture between Unmanned Swarm and Environment

Firstly, the unmanned swarm combat agent is constructed to standardize the number and category of swarm, the behavior, intelligence level and attribute parameters of agent individuals. The construction of battlefield environment mainly includes environmental parameters, categories, perception and interaction. In the reconnaissance stage, the constructed agent mainly obtains the relevant parameter information of the battlefield environment and the relevant information of the enemy and ourselves through the interaction with the environment. The information is used in the next stage of OODA Loop operation. The Orientation, Decision and Action of unmanned swarm combat agent belong to a part of intelligent behavior planning. Behavior planning can be realized through rule-based methods and intelligent algorithm based methods.

(1) Rule based intelligent behavior planning method

In the process of actual combat, the deployment and dispatch of troops, the planning and issuance of combat tasks, operational decision-making and command are supported by corresponding operational rules, and the combat personnel at all levels of the force complete the operation based on the combat rules. Combat rules are the agreed behavioral requirements for the accumulation and summary of weapons and equipment, personnel composition, battlefield behavior and other elements in perennial operations. Unmanned swarm operations can also refer to some combat rules for combat planning. Combat rules can promote the behavior and state changes of all unmanned swarm equipment in the battlefield environment, and endow unmanned swarm with intelligent characteristics.

(2) Intelligent behavior planning method based on Intelligent Algorithm

Due to the rapid development of artificial intelligence, combat simulation in computer and command and control of unmanned equipment can be carried out through various intelligent algorithms. The algorithm can enable the combat entity agent to have the ability of autonomous “learning”, conduct behavior planning through “learning”, and produce autonomous and cooperative behavior. It is also a method to endow unmanned clusters with intelligent characteristics.

The intelligent behavior planning architecture of unmanned swarm is shown in Figure 3.

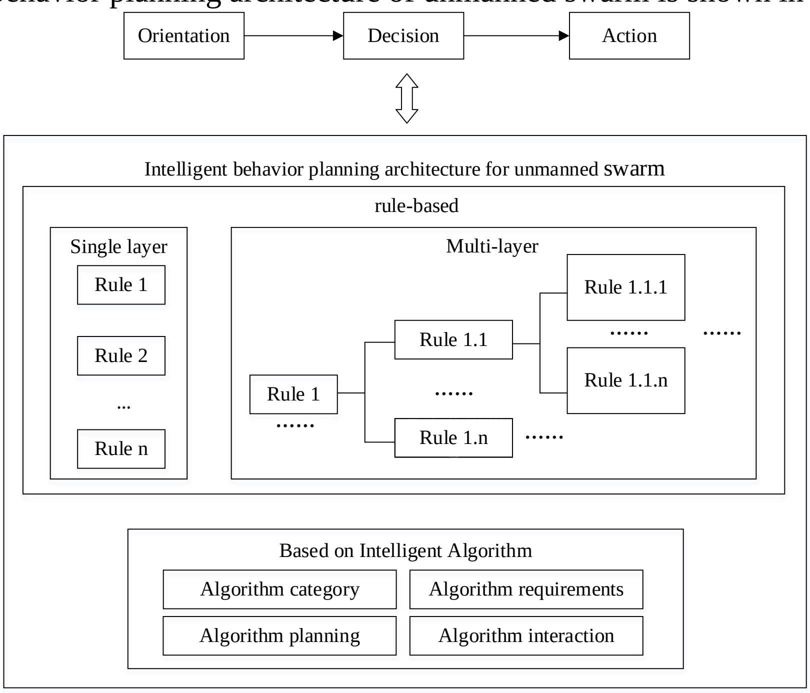
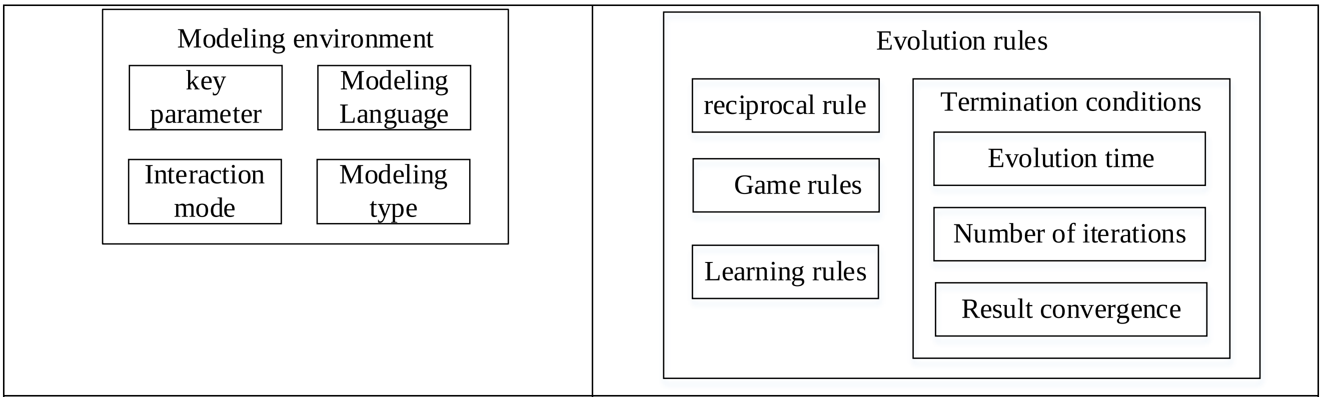


Fig.3 Intelligent Behavior Planning Architecture for Unmanned Swarm

The rule-based method can be single-layer simple rules or multi-layer nested rules. With the increase of the complexity of rules, the intelligent behavior planning ability of unmanned clusters is swarm. The method based on intelligent algorithm mainly sets the category, requirements, planning and interaction of the algorithm. The algorithm category includes classical swarm intelligence algorithms such as ant colony and particle swarm optimization, game theory, reinforcement learning and other intelligent algorithms.

The architecture design of the four parts of the OODA Loop is also affected by the modeling environment and evolution rules. The architecture of these two parts is shown in Figure 4. The embodiment of the intelligence of unmanned swarm is mainly controlled by the evolution rules, including its interaction, game and learning rules. Finally, the evolution process is managed by the termination conditions.



(1) Modeling environment architecture | (2) Evolution rules architecture

Fig.4 Unmanned Swarm Combat Modeling Environment and Evolution Rule Architecture

In the course of combat, our side and the enemy will continue to observe the battlefield to obtain combat information, make decisions and take corresponding actions after judging and analyzing the information. Its confrontation and conflict is mainly reflected in the length of the OODA Loop. The party that gives priority to action will gain the initiative and advantage, Both parties will shorten their Loop as much as possible and extend the Loop of the other party at the same time. The cause and effect relationship between the two sides of OODA Loop combat is shown in Figure 5.

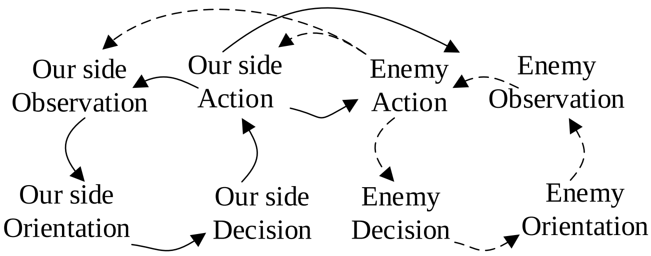


Fig.5 Cause and Effect Relationship between Two Sides in Ooda Loop Combat

If our OODA loop has a short cycle and takes priority over the enemy to take action, the enemy's OODA loop will be restrained and can not make subsequent decisions, and new observations and orientation will be made on the current situation. Rapid decision and action is the decisive factor in war, which can cause the pressure of the enemy. During this period, the enemy may be constantly restrained, resulting in operational failure.

3. Combat Application Architecture

In the process of combat application of unmanned swarm, the hierarchical structure of combat tasks is shown in Figure 6.

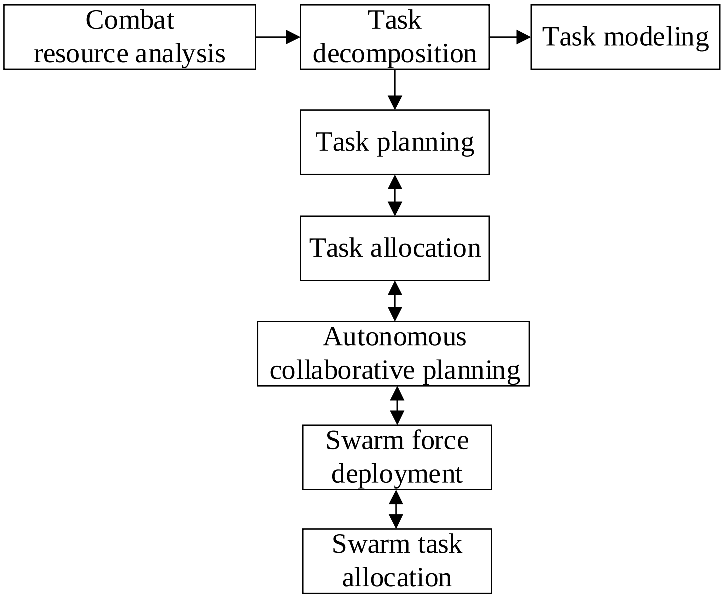


Fig.6 Hierarchy of Unmanned Swarm Combat Mission

The development of combat tasks requires hierarchical planning of tasks, and subsequent task design based on task decomposition, including task planning, allocation, autonomous collaborative planning and planning of unmanned swarm. They can confirm the task allocation, cooperation and command relationship of unmanned swarm.

The realization of unmanned swarm warfare computer experiment is inseparable from the planning and analysis of experimental modeling. Computer experiment can be carried out in serial or parallel. The implementation steps of unmanned swarm combat modeling and experiment are shown in Figure 7.

According to different unmanned swarm combat tasks and targets, the model and target system are abstractly divided. This division is an important step of the experiment. The scheme obtained after the division of the specific combat process will be expressed by simulation experiment. According to the division results, the message flow protocol is established, the agents are classified, and the agent model is established. The agent model includes the mechanism, internal state, message flow and rules of the agent model. Refine the behavior representation of the agent, build a distributed operation mode based on the agent, and judge the requirements of the overall behavior. If it does not meet the requirements, improve the hierarchical division of the model again. If it meets the requirements, conduct model experiment or simulation, and update the parameters at any time to obtain different experimental results.

4. Multi-Agent Unmanned Swarm Combat Architecture Based on Ooda Loop

To sum up, the architecture of each part is integrated to obtain the multi-agent unmanned swarm combat architecture based on OODA Loop, as shown in Figure 8. The combat application part is the bottom framework of the unmanned swarm combat experiment, which is responsible for the construction and operation of the model. Through the interaction between the OODA Loop part and the combat application part, the Multi-Agent unmanned swarm combat architecture based on the OODA ring is realized.

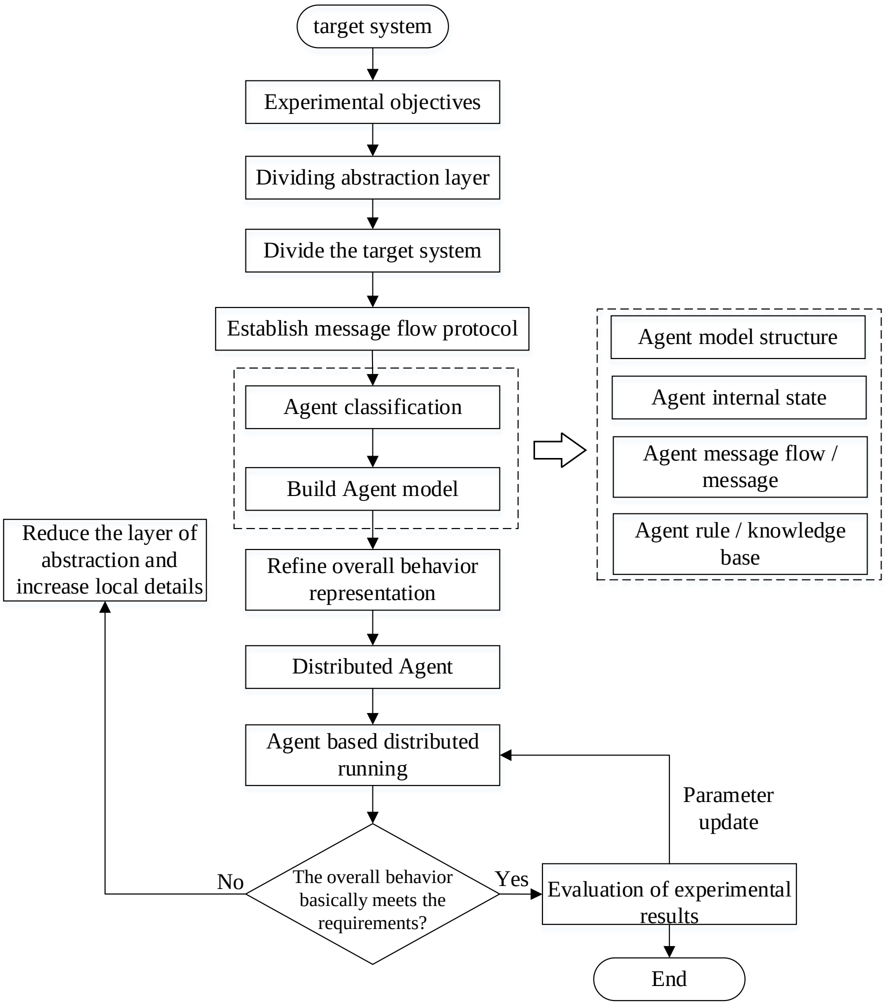


Fig.7 Unmanned Swarm Combat Modeling and Experimental Implementation Steps

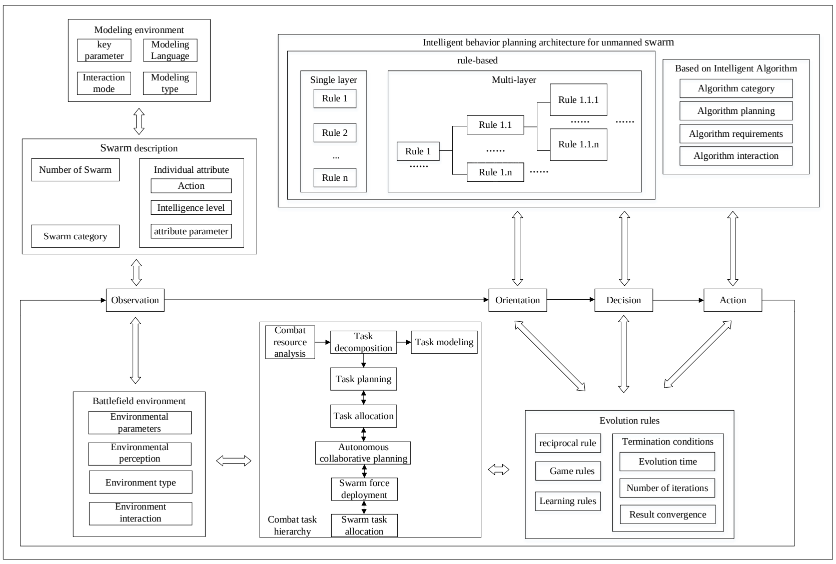


Fig.8 Multi-Agent Unmanned Swarm Combat Architecture Based on Ooda Loop

5. Conclusion

Based on the analysis of the characteristics of OODA Loop, a Multi-Agent unmanned swarm combat architecture based on OODA Loop is carefully analyzed and proposed from the two aspects of unmanned swarm combat planning and Combat application based on OODA Loop. At the same time, the computer experiment of unmanned swarm combat is analyzed, and the modeling and experimental implementation steps of unmanned swarm combat are given.

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