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Research on Wargaming Decision Support Based on Electromagnetic Spectrum Mapping

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Abstract: *To address the challenges of complex battlefield scenarios, complex electromagnetic environments, and difficulty in quickly formulating offensive operation plans based on changes in the electromagnetic spectrum, this paper first explores the method of constructing spectrum maps and their application in military simulations. Then, based on the electromagnetic spectrum map, an optimal framework for battlefield assistant decision-making in wargames is proposed. The framework targets heterogeneous electromagnetic environment information on the battlefield and provides a comprehensive, full-spectrum, and all-time visualization of the communication electromagnetic spectrum situation. It is also integrated with existing wargame systems, enabling fast evaluation of action plans before or during wargames, assisting wargame commanders in conducting wargames under complex electromagnetic environment conditions and enhancing the accuracy and effectiveness of wargames in supporting military operations.*

Keywords: *Spectrum map; War games; Electromagnetic environment; Combat simulation; Electromagnetic spectrum management*

1. Introduction

Wargaming, as an ancient and effective military strategy evaluation method, has been increasingly combined with artificial intelligence technology in recent years [1]. In modern electronic warfare, mastering and utilizing the electromagnetic spectrum has become one of the key factors to determine the outcome. As a visual tool, spectrum map can display the use of spectrum in a specific area, which is of great significance for the formulation and adjustment of electronic warfare strategies [2].

War game simulation is an important means of combat simulation and combat plan verification. It uses the chessboard and pieces representing the battlefield and its military forces, according to the rules summarized from the war experience, combined with the probability principle, through deducing a series of decision-making confrontation between personnel of all parties, to carry out logical research and scientific evaluation of the combat process, and can play a positive role in military research, war research and combat research Assisting effect [3]. As a combination of human decision making and computer simulation, war game simulation plays an important role in in-depth analysis and understanding of complex war systems. The wargame system provides a platform that enables the promoters to conduct war simulation and strategy development in a controlled environment [4].

Li C et al. [5] proposed a deep learning architecture to address the challenges brought by the incompleteness and imperfection of battlefield situation to intention recognition methods. The architecture integrates a contrastive predictive coding (CPC) model, a variable-length Long short-term memory network (LSTM) model, and an Attention weight divider (W-CPCLSTM) specifically designed for information incompleteness in war games to improve the efficiency, stability, and reliability of online intent recognition. Lu Qianru et al. [6] proposed a tactical path planning algorithm that integrates battlefield situation and map information, which numerically analyzes and calculates battlefield situation factors by using influence maps. Zheng Peng et al. [7] proposed a new method of quantitative evaluation of information communication efficiency by using entropy value method, including the construction of war game model, specific steps of program implementation and operation flow. The system design proves the validity and rationality of this method, provides a valuable reference for the quantitative evaluation of communication efficiency, and promotes the progress of related technologies.

In the face of the complexity of current war games, the discreteness of real-time data and the complexity, diversity and dynamics of future battlefield electromagnetic environment, it is difficult for

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commanders to quickly formulate urban offensive combat plans and research key technologies according to the electromagnetic spectrum situation. This paper intends to propose a research on the decision-making framework of war games based on electromagnetic spectrum map.

This method is helpful to analyze the real-time data, improve the strategy of warfare and improve the completeness of deduction. Through war games, different electromagnetic spectrum use scenarios can be simulated to help commanders understand the allocation and optimization of spectrum resources, assess the needs of electromagnetic spectrum resources for different combat missions, rationally allocate resources, determine the priority of combat operations, and ensure the efficient operation of critical communications and radar systems. The electromagnetic spectrum map is used to conduct war games to improve commanders' ability to perceive battlefield situation and make more accurate tactical decisions, electronic attack and defense strategies [8].

2. Deduction module of electromagnetic spectrum map of battlefield environment

Battlefield electromagnetic spectrum map is a kind of multi-dimensional data expression, showing the distribution and propagation characteristics of electromagnetic waves in different frequencies in a specific area (Figure 1 and 2). The electromagnetic spectrum map can clearly show the distribution of electromagnetic energy and spectrum resources, and provide a visual basis for optimizing spectrum utilization and interference management strategies.

By simulating and predicting various situations in the electromagnetic environment, the study of war game simulation tactics based on electromagnetic spectrum map provides a powerful decision support tool for commanders, which helps to improve combat efficiency and success rate.

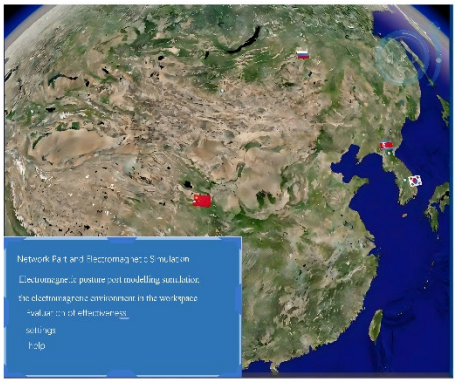

Figure 1: Battlefield electromagnetic spectrum map war game dynamic deduction flow chart

In this paper, a strategy based on spectrum map is proposed to enhance the efficiency and accuracy of military operations through in-depth analysis and simulation of electromagnetic environment. By integrating spectrum maps into military simulations, combat missions can be better planned and executed, the use of spectrum resources optimized, the ability to combat electromagnetic interference enhanced, and battlefield situational awareness improved. This paper first reviews the theoretical basis and development of war game calculation, then discusses the construction method of spectrum map and its application in military simulation, and finally verifies the practical application effect of this scheme through case analysis. Based on electromagnetic spectrum map, an optimal combat decision framework is proposed, which is based on the heterogeneous perception information of the battlefield, and can be formed into an all-round, full-spectrum and all-time multi-dimensional combat system. By visualizing the electromagnetic spectrum situation of battlefield communication, the iterative optimization of the maneuver strategy based on fast simulation can provide a quick evaluation of the action plan before or during the maneuver, which can effectively assist the commanders of the war game maneuver in complex situations.

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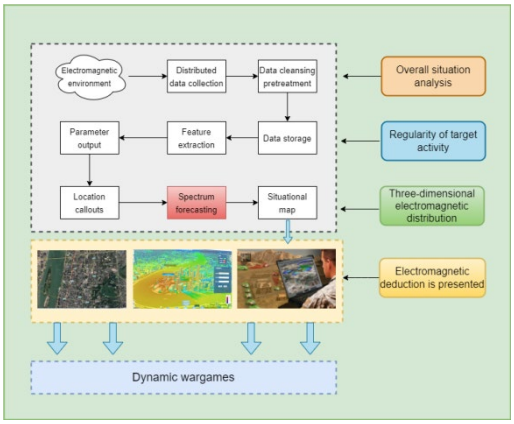

Figure 2: Battlefield electromagnetic spectrum map war game dynamic deduction flow chart

3. The system work flow of war game deduction

By integrating the spectrum map into the war game, commanders can visually see the spectrum usage, optimize the allocation of spectrum resources, and develop interference countermeasures. Spectrum maps can also be used to evaluate the effectiveness of electronic warfare strategies and are an indispensable tool for conducting electronic warfare simulations.

Through the collected battlefield situation information, we can learn tactical rules, acquire combat experience and optimize strategies in simulated confrontation, and then conduct pre-war situation analysis, scientifically formulate combat plans, and improve real-time decision-making ability and emergency response ability in the course of combat.

The computer model plays a central role in the war game system. These models are built on a deep understanding of historical warfare and military theory, and they incorporate not only a wealth of war knowledge but also basic military common sense. Under this model framework, the promoters can give full play to their initiative and creativity, and carry out strategic confrontation and simulated combat exercises. In this way, war games not only simulate various aspects of war, but also provide a platform for the promoters to experiment and learn, allowing them to explore different tactical and strategic options without being exposed to the risks of actual war (Figure 3). This process of simulation and pre-practice helps to improve commanders' decision-making ability, enhance their understanding of the complexities of war and their ability to respond.

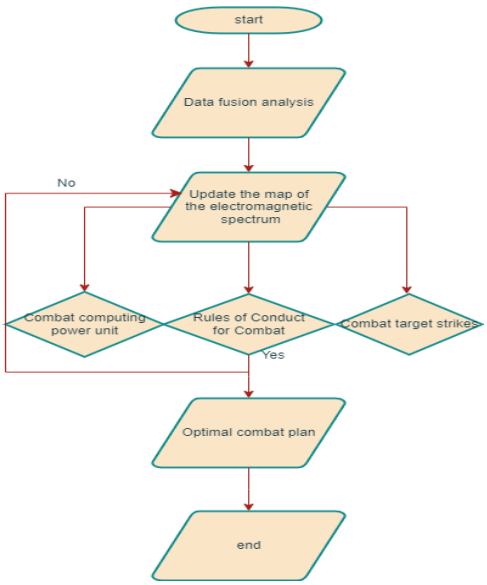

Figure 3: Flow chart of war game deduction based on electromagnetic spectrum map

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3.1 Principle and application of war game deduction

War game play is a method of simulating military conflict by setting up imaginary enemies and analyzing the possible outcomes of various combat strategies. Its main purpose is to validate tactics and strategies without actually having to fight, and to improve commanders' understanding and judgment of the battlefield environment. Combat command is a multi-disciplinary and multi-task comprehensive strategic activity that integrates equipment system, combat environment, command art, intelligent research and judgment, etc. War game simulation is to simulate, simulate and deduce the whole process of the war, which is a miniature version of the combat command process.

The process of war game simulation is a systematic simulation activity, which aims to improve the understanding and response ability of decision makers to potential situations by simulating military conflicts or strategic decisions. The following is the detailed process of the war game, including the preparation stage, the conduct stage and the analysis stage: The war game process is a systematic simulation activity, which aims to improve the understanding and response ability of decision makers to potential situations by simulating military conflicts or strategic decisions. The following is the detailed process of war games, including the setting of the preparation stage, the conduct stage and the analysis stage: The preparation stage is mainly the goal setting, scene development, rule making, chess pieces and board preparation, role allocation and so on. The implementation stage mainly includes initial deployment, turn-based or real-time simulation, decision making, action execution, rule ruling, information feedback, etc. The analysis stage mainly includes result recording, post-action evaluation, overall analysis, learning point extraction, report writing, feedback loop, etc.

With such a detailed setting, war games not only provide an in-depth understanding of military operations, but also enhance the strategic thinking ability of decision makers and the ability to respond to complex situations.

This kind of simulation and learning mechanism is an indispensable part of modern military training and strategic research. It provides a safe environment in which commanders and military analysts can conduct in-depth analysis and preparation for a wide range of possible scenarios before war occurs.

4. Case studies or applications in military simulations

The electromagnetic spectrum is the basis of various military functions such as radar reconnaissance, communication and electronic warfare. The correct management and utilization of spectrum resources is of vital significance to ensure the normal operation of these functions and avoid spectrum congestion and interference.

Suppose that the typical combat scenario is a military conflict between the red side and the blue side, and the red side fights with electronic warfare aircraft, jamming drones, ground jamming equipment, and special operations forces. Blue computing power mainly includes air defense radar, communication base stations, electronic warfare units, and white is the auxiliary force (Table 1). The Red side plans to gain the battlefield initiative through electronic warfare superiority. The objective was to suppress the Blue side's communications and radar systems and ensure freedom of movement for the Red side's air and ground forces. The electromagnetic spectrum map setting includes a detailed map showing the electromagnetic environment of the combat area, including communication frequencies, radar frequencies, interference sources, etc. The rules of operation are that the movements of all combat units are limited by a map of the electromagnetic spectrum.

Table 1: Elements of war game simulation

Equipment parameter	**satellite**	**vehicle**	**drone**	**Base station**	**radar**
red	5	121	7	3	9
blue	6	150	5	3	8
white	2	20	2	1	5

In the process of deduction: it is necessary to consider the influence of actual geographical and meteorological conditions on electromagnetic propagation. Simulate possible countermeasures of the enemy, such as rapid switching of communication frequencies, the use of alternate means of communication, etc., as well as the actual capabilities and limitations of the combat unit, such as the endurance time of electronic warfare aircraft, and the combat radius of interference drones.

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Intelligence gathering: Use reconnaissance drones and satellites to monitor the electromagnetic activity of the blue side and collect communications and radar frequency information. Operation planning: Based on the collected intelligence, develop a detailed electronic warfare plan, including jamming targets, jamming time, jamming methods. Electronic warfare preparation: Deploy electronic warfare aircraft and jamming drones to predetermined locations, and debug ground jamming equipment. Initial jamming: At a predetermined time, electronic warfare aircraft and jamming drones jam the Blue Side's primary communications and radar systems. Effect evaluation: Using reconnaissance equipment to evaluate the jamming effect and adjust the jamming strategy. Deep jamming: Special Operations forces infiltrate enemy territory to physically damage critical communications base stations and radar facilities. Battle for air superiority: Under the cover of electronic jamming, the red fighter group strikes the important military targets of the Blue side. Ground offensive: Ground forces, supported by electronic warfare superiority, launch an offensive against the core area. Continuous monitoring and adjustment: Continuously monitor the electromagnetic spectrum map and adjust jamming strategies based on enemy responses.

Through a specific military simulation case, this section shows the specific operation and effect of the spectrum map-based military chess deduction in practical application. How spectrum maps can help commanders make tactical decisions during maneuvers and predict the outcome of confrontations is analyzed in detail.

In order to verify the feasibility and accuracy of the combat framework proposed in this paper, the combat plan is simulated by reducing the electromagnetic spectrum map visualization in the battlefield electromagnetic spectrum map environment (Figure 4).

In the inference scenario used by the validation framework, the entities of both sides are heterogeneous and can be visually demonstrated by the inference entities, mainly including radio, radar, base station, aircraft, satellite, etc. The simulation environment is set in the field environment, and the simulation task is to master the electromagnetic spectrum situation simulation according to the communication equipment in the target area, and the warfighter can make decisions quickly based on the electromagnetic distribution.

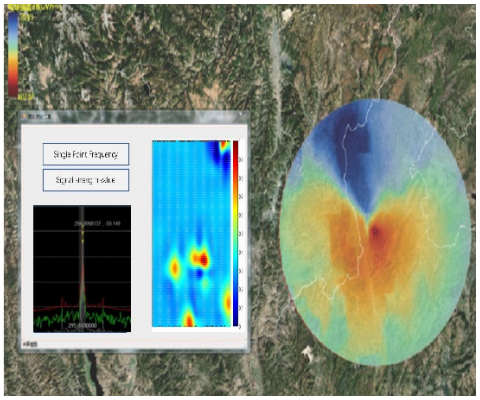

Figure 4: Battlefield electromagnetic spectrum map dynamic calculation flow chart of war game

5. Conclusion

The spectrum map-based war game calculation provides a new perspective and tool for modern electronic warfare. By analyzing the spectrum environment in detail, this method can improve the decision quality of military command and enhance the ability to adapt and control the complex electromagnetic environment. Future research can further explore more efficient spectrum data processing algorithms to achieve more refined spectrum management and applications.

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