Army Integrated Combat Model for Synthetic Force based on Information Cognition

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Abstract. Army integrated warfare presents a nonlinear form of system confrontation, which not only changes the decisive factors of combat victory, but also makes the complex interrelations in the system more chaotic. Based on the theory of complex adaptive system, land battle is regarded as a complex system with hierarchical inrush, nonlinear, self-organizing, decentralized control. The integrated combat model of army is established, the influence of firepower, maneuverability, communication perception and other factors on the overall combat capability of the army is studied, the factors are optimized, and the optimal scheme of combat force operation is put forward. It provides certain theoretical support for the development of military weapons and equipment, the rational allocation of troops and the organization of combat coordination in the future.

Keywords: Complex system, Land battle model, Multi-Agent, Combat forces

1 Introduction
Army integration refers to the digital army tactical module, relying on the military information system, and the highly integrated real-time integrated operation implemented in the networked multi-dimensional combat space. In addition to that characteristic of the multi-element of combat power, the multi-dimension of the combat space, the rapid combat operation, the integrated operation of the army has the advantages of the combat maneuver, the enemy, the information sharing of the operational information, the success or failure of the battlefield awareness, the self-adaptation of the operational action, the random strain of the combat control, combat system confrontation, operational support accuracy support, and so on. [1]Army integration is a new model of land-war operations, which has all the complexity of the land-war effort.[2]

2 Lanchester's Equation
The Lanchester equation describes the linear dependence of the average loss rate on the single-shot kill probability when the simple scene combat power evolution is described. Because the EINSTIP system shows the weapon kill characteristic with the single hit probability, and for a party in the simulation, every Agent has a $P_{SS}(i) = P_{SS}$, the average loss rate is defined as the average number $\langle \alpha \rangle$ of casualties of the combat unit at a certain time interval, the EINSTIP system has the advantage that the average loss rate is defined as the average number of casualties of the combat unit at a certain
time. [3]

\[
\alpha = \frac{\Delta n}{\Delta t} = \frac{n(t + \tau) - n(t)}{\Delta t} = \sum_{i=1}^{N} P_{SS}(i) = NP_{SS}
\]  

(1)

In the formula, \( N \) is the total number of Agent, \( n(t) \) is the number of Agent at the time \( t \), \( P_{SS}(i) \) is the probability of hit by the Agent for the first \( i \).

3 Information Cognition

It can use Agent class communication matrix rules to build communication links between Agents at will, use class interconnection parameters to clearly describe the information transmission direction of each communication link, and accurately construct various types of networks. By designing the relationship of information cognitive degree punishment function, an information cognition model based on network is established. [4] By using a group of the same combat formation and combat parameters, through the study of the different combat effects of different information cognition under a certain network condition, it can analyze the difference between information acquisition and information cognition, measure the benefit of information cognition, and enhance the understanding of war information cognition. [5]

There are four typical organizational network types of traditional hierarchical structure, flat hierarchical structure, annular structure and fully connected structure. After the establishment of the network between Agents, each Agent can also receive the information data collected by other Agents in addition to its own perceptual range, and can be used to increase its own effective perception range, increase the amount of information obtained, and at the same time expand the combat range. [6] Information cognition model is the degree of attention that Agent attaches to the information data collected by other Agent at present. [7] Agent converts it into individual cognition and applies it to the calculation of penalty function of moving position, that is, the degree of decision advantage. The penalty function is as follows: [8]

\[
Z_{G(x,y)} = Z_{A(x,y)} + \omega_{comm} Z_{comm}(x,y)
\]  

(2)

In the formula, The penalty function value \( Z_{A(x,y)} \) is calculated by the current Agent according to its own perceptual information in \( (x, y) \), that is, the decision-making behavior made according to its own perception, the penalty function value \( Z_{comm}(x,y) \) is calculated according to the shared information, that is, the shared information decision behavior. The weight value \( \omega_{comm} \) is the current Agent's degree of importance on the shared information, which can be valued between \( 0 \sim 1 \) the current Agent. If \( \omega_{comm} = 0 \), it means that all the shared information is ignored and does not affect the decision. If \( \omega_{comm} = 1 \), it means the sharing cognitive information as a reference for decision-making.

As shown in figure, when there are no communication links between \( A, B \) for the two Agents, the global awareness range \( S_G \) of \( A \) is its own perceptual range, that is \( S_A \), the following:

\[
S_G = S_A
\]  

(3)

When the two Agents have a communication link between \( A, B \), the global awareness range \( S_G \) of \( A \) is the sum of the two Agent aware ranges \( (S_A, S_B) \), that is,

\[
S_G = S_A \cup S_B
\]  

(4)
When there is no communication between $A, B$ for the two Agents, if $R_s, R_f$ is the perceived range and the firepower range, $R_c$ is the combat range of $A$:

$$A_{Rc} = A_{Rs} \cap A_{Rf}$$  \hspace{1cm} (5)

When two Agents between $A, B$ establish communication connection, the operational scope $R_c$ of $A$ will be expanded as follows:

$$A_{Rc} = (A_{Rs} \cup B_{Rs}) \cap A_{Rf}$$  \hspace{1cm} (6)

If the Force Loss Exchange Ratio (FLER) is defined as the ratio of the average war-loss ratio at a certain time interval of combat units for the Red Army and Blue Army, and it is used to represent the final operational results, FLER is described as follows:

$$FLER = \frac{dx}{ydt} = \frac{dx}{dy} \frac{y}{x} = \frac{1-r_c}{1-r_y}$$  \hspace{1cm} (7)

In the formula, $r_c, r_y$ is the ratio of the average surplus strength at the time $t$ for the Red Army and the Blue Army.

It is necessary to consider the influence of terrain and combat nature on combat damage, which can refer to the terrain factor and defense combat factor correction method empirical index method. [9] The coefficient of defense combat property is 1.5 for Red and Blue army, and the terrain coefficient of flat ground, hilly and mountain defense is 1.1 and 1.2 respectively, so that the correction coefficient is constant. If the Red and Blue troops fight on their own, they will take 1, 1.1 and 1.2 respectively on flat, hilly, mountainous and other terrain; if the Red Army attacks, the Blue army defends, when the terrain is flat, hilly, mountainous and other terrain, 1.5, 1.65, 1.8 respectively. If $FLER = C$, the battle of the Red and Blue troops is a draw; if $FLER < C$, the red army wins, the smaller value means that the red army wins at a smaller price; if $FLER > C$, the blue army wins, the larger value indicates that the blue army wins at a smaller price; that is, the value of $FLER$ directly reflects the advantages of the Red and Blue troops in winning.

4 Research Scenario and Parameter Setting

4.1 Environment Setting

It can imagine a combat scene which has no maneuverability, can be seen and fired, which called Lanchester equation combat scene. in the same force condition, the random maneuvering scene without combat rules on the initial battlefield has the same force, the initial battlefield is fixed distribution, and the intelligent maneuvering scene with combat rules is fixed. [10]

In the EINSTEIn system, the initial field size of the three scenarios is $100 \times 100$, red, the forces of the Red and Blue army is 250 Agents. The first scene, the Red and Blue army are closely gathered in the matrix of c, and the coordinates of the respective formation centers for the Red and Blue armies are (38,50),(62,50), and the distance between the two formation centers is 24 units. The sensing range of the Red and the Blue armies is large enough, the fire range is 80,60, the mobile capability is 0. In the second scene, the Red and the Blue armies are randomly distributed, which the random maneuver is carried out without opening the rules such as advance, aggregation, operation and the like, the mobile capability is 2. In the third scene, the Red and the Blue armies is the same formation, the coordinates of the respective formation centers is (0.9,0.9),(91,91) for the two armed forces, the
sensing range and the fire range are 5 and 3, and the maneuvering capability is 2. The specific parameter is follows in Table 1.

Table 1. Setting table of some parameters of Red and Blue army in different combat scenarios

| Parameter | Lanchester scenarios | Random maneuver scenarios | Intelligent maneuvering scenarios |
|-----------|----------------------|---------------------------|----------------------------------|
|           | Red army             | Blue army                 | Red army                         | Blue army | Red army | Blue army |
| Number of Agent | 250 | 250 | 250 | 250 | 250 | 250 |
| Perceptual range \( r_S \) | 80 | 80 | 15 | 15 | 5 | 5 |
| Firepower range \( r_F \) | 60 | 60 | 9 | 9 | 3 | 2 |
| moving range \( r_M \) | 0 | 0 | 2 | 2 | 2 | 2 |
| Tend to one's own perfect individual \( \omega_1 \) | 10 | 10 | 10 | 10 | 10 | 10 |
| Tend to the enemy intact individual \( \omega_2 \) | 40 | 40 | 40 | 40 | 40 | 40 |
| Parameter | Lanchester scenarios | Random maneuver scenarios | Intelligent maneuvering scenarios |
|-----------|----------------------|---------------------------|----------------------------------|
|           | Red army             | Blue army                 | Red army                         | Blue army | Red army | Blue army |
| Tend to one's own injured individual \( \omega_3 \) | 10 | 10 | 10 | 10 | 10 | 10 |
| Tend to enemy injured individuals \( \omega_4 \) | 40 | 40 | 40 | 40 | 40 | 40 |
| Tend to one's own military flag \( \omega_5 \) | 0 | 0 | 0 | 0 | 0 | 0 |
| trend enemy's military flag \( \omega_6 \) | 25 | 25 | 25 | 25 | 25 | 25 |
| Forward weight \( t_{\text{Advance}} \) | / | / | / | / | 3 | 3 |
| Aggregation weight \( t_{\text{Cluster}} \) | / | / | / | / | 8 | 8 |
| The right to fight \( \Delta \text{Combat} \) | / | / | / | / | -99 | -3 |

4.2 Operation Results and Analysis

It carried out five groups experiments for the three scenarios. The killing probability of the Red and Blue armies is the same in each group, that is \( P_{ss \text{ red}} = P_{ss \text{ blue}} = P_{ss} \). The killing probability is set to 0.005, 0.01, 0.02, 0.03, 0.04. If there are half of the casualties in one side of Agent every time, the simulation is stopped. When 400 steps per test running, the average loss rate of 40 experiments was taken as the experimental result. By running three scenarios, the average loss rate is shown in Table 2.
Table 2. Average loss rate of the Blue army Agent when different single hit probability in different scenarios

| Kill probability | 0.005 | 0.01 | 0.02 | 0.03 | 0.04 |
|------------------|-------|------|------|------|------|
| Average rate of loss |       |      |      |      |      |
| Lanchester scenarios | 0.3607 | 0.7210 | 1.443 | 2.1640 | 2.881 |
| Random maneuvering scenarios | 0.6442 | 0.9908 | 1.5237 | 1.960 | 2.3434 |
| Intelligent maneuvering scenarios | 0.3203 | 0.4971 | 0.7714 | 0.9975 | 1.197 |

If one complete operation of EINSTein system is taken as a meaningful event, the military casualties of the whole system for Red and Blue army reach 50% as a meaningful event, then three different combat scenarios run 40 times at a time, each running 400 step, and the average time distribution condition of military casualties between the Red and Blue armys to reach 50% can be obtained by using EINSTein system. In the Lanchester scene, the relationship between force damage and firepower is as follows:

\[ \langle \alpha \rangle = 72.142 P_{ss} \]  

(8)

In the case of random maneuvering scenario, the relationship between force damage and firepower is as follows:

\[ \langle \alpha \rangle = 17.297 P_{ss}^{0.62} \]  

(9)

Under the condition of intelligent maneuver, the relationship between the force damage and the firepower is as follows:

\[ \langle \alpha \rangle = 9.213 P_{ss}^{0.634} \]  

(10)

Therefor, Statistics of the average residual Force ratio and Information cognitive model shown in Table 3 and Table 4.

Table 3. Statistics of the average residual force ratio for different information cognitive weights experiments in information cognitive model

| Cognitive weight project | \( \omega_{comm} = 0 \) | \( \omega_{comm} = 0.4 \) | \( \omega_{comm} = 0.8 \) | \( \omega_{comm} = 1.0 \) |
|--------------------------|-----------------|-----------------|-----------------|-----------------|
| Average remaining force ratio of the Red Army | 0.1 | 0.09 | 0.50 | 0.64 |
| Average remaining force ratio of the Blue Army | 0.6 | 0.47 | 0.10 | 0.097 |

Table 4. Information cognitive model with different confidence and cognitive weight experimental force damage comparison results

| Information recognition weight | Proportion of damage at different stages of combat | Winning party |
|-------------------------------|---------------------------------|----------------|
|                               | Impact breakthrough | Depth attack | Split encirclement and annihilation | Red | Blue | Red | Blue | Red | Blue | Red | Blue |
|                               | Red | Blue | Red | Blue | Red | Blue | Red | Blue | Red | Blue | Red | Blue |
| 0                            | 0-42% | 0-19% | 42-73% | 19-32% | 73-90% | 32-57% | Blue |
| 0.4                          | 0-40% | 0-12% | 40-70% | 12-40% | 67-90% | 40-73% | Blue |
| 0.4                          | 0-12% | 0-37% | 12-38% | 37-68% | 37-60% | 68-90% | Blue |
| 0                            | 0-17% | 0-42% | 17-31% | 52-82% | 34-43% | 75-90% | Blue |
When the number of Agents is approaching the loss number, the original Agent solid block should be more and more sparse. The fractal dimension of the Lanchester scene remains smooth and the fluctuation is small. The fractal initial value of the random maneuvering scene is larger, which is larger than that of the Lanchester scene, and as the Agent is gradually eliminated, it maintains a state that is larger than that of the Lanchester scene but still is highly smooth. It can be seen that the mobile is allowed, the width of the time distribution required for the casualties of the armed forces for the Red and Blue Armies reaches the required time distribution is obviously widened. For a party in the simulation, each Agent has an Lanchester and a random maneuver scenario that can reach 50% of the casualties in a time, which is far less than or greater than the other two scenarios. And the probability that the intelligent mobile scene is achieved for a long time is not zero. In a smart mobility scenario, the Agent is constantly adapted to the surrounding environment, and the fighting is not a simple “open fire” until one of the troops is destroyed. The Agent is only able to move into the battle if they have the opportunity to move in a position. When the situation becomes negative, the Agent will be withdrawn again instead of continuing to fight. In some cases, the individual Agents may find it necessary to maneuver for a period of time to seek for locally advantageous operational conditions.

5 Conclusion

By the above analysis, it can be found not only the relationship between firepower damage and maneuvering, but also the loss rate depends on the killing probability, the initial quantity, and on the fractal dimension of distribution. It is embodied in the assembly mode, deployment effect and spatial distribution of troops. That is to say, under the condition of certain killing probability and the number of troops, the tactical means such as effective battlefield mobility, changing the assembly mode of troops, adjusting the distribution position of troops, etc., It can make their own side emerge more fighting effectiveness on the existing basis, and cause greater force loss and casualties to the other side. Therefore, the maneuver can control the rhythm of war, seize asymmetrical advantages, and carry out limited contact operations against the enemy, so as to maximize the initiative of the battlefield and ensure the overall victory of the war.

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