

# Modeling in Battle Damage Based on Multi-agent

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**Abstract** Traditional model about battle damage is static by use of the statistics from the real battle field without considering the actual battle environment well. However, complex adaptive system theory is another new alternative for research on dynamic battle damage. In this paper, we attempt to establish a dynamic battle environment on Swarm, and present a simple dynamic battle damage model in order to illustrate the methodologies of modeling based on the fact and reasonable presumption.

## **1. the new development of research on the battle damage**

The establishment of dynamic battle damage model is based on the typical characteristics abstracted from the battle damage system through multi-agent, while the traditional modeling method is through the presumptions of abstract features.

It's rather limited to collect statistics of battle damage from real battle field. However, it's an efficient method to abstract useful data through experiments on battle.

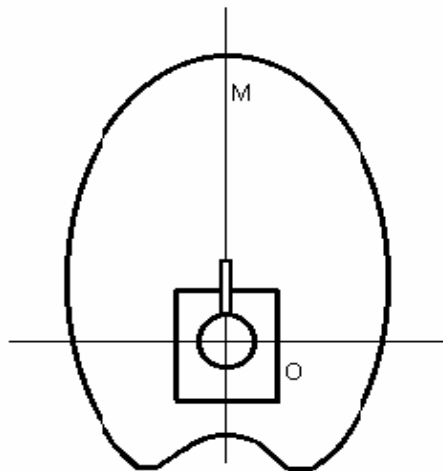


Figure 1.1 Distributing of Hit Probability

Since 80es, western countries have carried out a variety of researches through large scale denotation experiments, in which there are mainly two methods used, viz, static denotation experiment and direct shootings.

Direct shootings: analyze the statistics through directly assault weapon devices by use of canons, tanks, rocket-propelled grenades and so on.

If the tank is a rectangle in our paper according to the scale for simplicity, the crosspoint of the two diagonals is the original point "O", the direction of tank proceeds "OM" is the vertical axis, the angle between trajectory and vertical axis is theta "θ" (the counter-clock is the right direction), and the hit probabilities of the parts of tank "ρ" is the radius. And now we've established the coordinate used in our model. The hit probability "ρ" is attained through historical battle data and artificial war experiments.

$$\rho(\theta_1 - \theta_2) = 0.1[\frac{\Delta\theta}{360} + 0.596(\cos\theta_1 + \cos\theta_2) + 1.157] \quad (1.1)$$

The distribution of hit probabilities deduced from the above formula is displayed in figure 1.1. This formula is the factual basis of our model.

## 2. the model framework of the dynamic battle damage

### 2.1 the computational model of the battle environments

The battle damage model of dynamic weapon devices is closely related to the main fuction partition of battle field that is referred to the function of the relatively separate area of battle field. Because CA(Cellular Automata) can describe well this kind of geographical features of battle field, we use it as the main framework of the dynamic battle model. CA is also used to approximate the battle environments, distributions of weapon devices and strategies of the two parties ( red party and blue party) in the artificial battle.

#### 1. geographical features CA1

The battle field is approximated through a lattice with 50\*50. Every point in this lattice is assigned a value, the only value, selected from 1,2,3 and 4 which respectively represents the road, common terrain, river and obstacle.

## 2. weapon devices features CA2

There is different dynamic distribution in this lattice with 50\*50 which well describe the effects on the environments caused by agents. At the same time, tank agents' actions such as move and assault are also directly affected by the distribution of the firepower of the battle.

## 3. strategies features CA3

The input of strategies makes every tank agent in this lattice with 50\*50 have his respective aim that is the target of the party to which the tank agent belongs. Note, though strategies features CA3 appears identical to CA1 and CA2, it, in fact, is a tricky maneuver of including external strategies into the main framework of this model.

These CA s can work well in the battle map in a discreted way during simulations. So it's vision-friendly.

## 2.2 the presumptions about tank agent attributes

The tank agents of the two parties work in the battle environment made of three CA s. And every tank agent has a unique locus represented by (x,y) which is the same at every CA.

1. identification hongf=1: the red party , hongf=2: the blue party
2. resisting abilities variable resist : the abilities against assaults
3. field of fire variable vision: tank agent's own field of fire
4. the state of damage In order to accurately analyze the state of damage in tank agent, we assume the direction which the head of the tank agent face is the start, and the area around the tank agent is divided into 7 subarea. They are respectively begins with 0° 、 30° 、 90° 、 150° 、 210° 、 270° 、 330° 、 360° . We use a float array continuousState[7] to represent the states of the 7 subareas during the battle.
5. the weight of the 7 subarea during the battle, every subarea is assigned by a weight that is kept in a float array quanZhong[7] and is used to represent the importance of the 7 subarea.
6. the whole state of the tank agents variable wholeContinuousState: the whole state of the tank agents, which is the simple addition of the multiple of weight and the state of subarea.
7. goals in this two-dimension lattice with 50\*50, the fire area of the red party is represented by a rectangular area with width from xlmin to xlmax and length from ylmin to ylmax, while the fire area of the blue party is represented by x2min、 x2max、 y2min and y2max. The fire area is the target input and all the parameters related to this is the external ones, so that they can be changed before simulation to analyze battle damage under different conditions.
8. flexible strategies variables tactics1 and tactics2 is used to designify

whether the two parties use flexible strategies. If variable value is equal to 1, then flexible strategy is used. Otherwise, vice versa. The flexible strategies require that tank agent will take actions, assault or withdraw, given the its own analysis of the power of the opposites within the fire area.

### 2.3 interactive actions between tank agents

#### 1. move

The adaptive agent that receive the strategies from the director of its own can take its own action based its analysis of the terrain around itself and the conditions of itself.

(a). if the tank agent has the ability to move, then move, otherwise, stay wait for repair.

(b). each time when tank agent moves, it first has to know which point is vacancy, because it can possibly move toward one of the 8 positions around itself.

(c). compute the move weight  $a[i]$  of every vacancy position  $i(xlook, ylook)$ : first randomly select the hit area of the opposite party tank  $(x0, y0)$ , then

compute the distance to the target tank L:

$$L = \sqrt{(x - x0)^2 + (y - y0)^2} \quad (2.1)$$

then compute the distance to every vacancy position  $(xlook, ylook)$

$$L_i = \sqrt{(xlook - x0)^2 + (ylook - y0)^2} \quad (i=1, 2, \dots, 8) \quad (2.2)$$

$$a[i] = \begin{cases} 0.1 & \frac{L}{L_i} < 1 \\ 0.2 & \frac{L}{L_i} = 1 \\ 0.4 & \frac{L}{L_i} > 1 \end{cases} \quad (2.3)$$

(d) compute the terrain weight  $b[i]$  of every vacancy position. Extract the terrain value of the vacancy position around the tank agent from CA1, it can be 1,2,3 or4 which respectively represents road,common terrain,river and obstacle. The precedence of choice among the 4 different terrains is identical to the values. That's 1 road has the highest priority, 2 common terrain is the second highest priority, 3 river the third highest priority and 4 obstacle has the lowest priority. But given strategies and tank agents nearby, tank moves based on distribution of probabilities. So compute the weight

$b[i]$  by use of the variable value:

$$b[i] = \begin{cases} 1.0 & \text{value} = 1 \\ 0.8 & \text{value} = 2 \\ 0.2 & \text{value} = 3 \\ 0.05 & \text{value} = 4 \end{cases} \quad (2.4)$$

(e) compute the probability of every vacancy position  $p[i]$  by use of formula (2.3) and (2.4):

$$p[i] = a[i] * b[i] \quad (2.5)$$

(f) choose the vacancy position to which the tank moves: use

$p_1, p_2, \dots, p_8$  to represent the probabilities of the 8 positions around the tank agent, the probabilities of the occupied positions are assigned to zero, and the probabilities of the vacancy positions are assigned to the values calculated from the above formula, where  $i$  is the index of the position and  $0 \leq p_i \leq 1$  and  $\sum_{i=1}^8 p_i = 1$ . The

choice of  $i$  is based on roulette laws.

2. attack:

(a) judge whether the opposite tank agent has the abilities to attack, if it is, attack, otherwise, vice versa.

(b) If the current position of the tank agent is  $(x, y)$ , it will attack the opposite tank agent within its fire field. The scope of searching the opposite tank is from  $x$ -vision to  $x$ +vision in the  $x$  direction, from  $y$ -vision to  $y$ +vision in the  $y$  direction.

(c). For all the tanks within the fire field, calculate the number of the tanks of the two parties. Suppose the number of the opposite tanks is  $j$ , and the number of another side is  $i$ .

(d). If the coordinate of the opposite tanks is  $(xlook, ylook)$ , compute the distance to the opposite:

$$L = \sqrt{(xlook - x)^2 + (ylook - y)^2} \quad (2.7)$$

then the coordinate of the tank of the opposite side with the shortest distance is  $(theX, theY)$ .

(e). if the current tank enters the fire field of the tanks of its opposite side, it fire towards the tank at the position  $(theX, theY)$ .

(f). if the current tank is out of the fire field of the tanks

of its opposite side, it chooses whether to attack or not based on a probability  $p = \frac{i}{i+j}$ . Once it decides to attack, it will

attack the tank at the position(theX,theY).

(g). otherwise, it checks its own flexible strategies variable, if this variable is equal to 1, then carry out the flexible strategies. It will come close to the area where the tanks of its own side aggregate. Otherwise withdraw.

3. damage

(a). every tank is divided into seven sub area described above, and the probabilities of hit in each subarea is calculated by use of the emperical formulus (1.1).

(b). based on the probabilities of hit of each subarea, random number generator generates a number between 0 and 1 to choose the subarea to attack.

(c). the state of damage. During the initializtion of the simulation, the value of every state (continuousState[i ]) is assigned to 1. after attacked , the state will change according to the following formulus:

```
continuousState[i]*=1-[uniformDblRand
                                getDoubleWithMin:0.0000001
                                withMax: 1.0/resist]
```

where resist is the coefficient of the abilities against attack. The probability is subject to the uniform distribution between 0.0000001 and 1.0/resist.

(d). if there is a subarea destroyed completely, the tank will lose the abilities to attack. Because we only care about the damage regularities without repairing it, the tank which loses the abilities to fight will just stay like a dead tank.

**3 the implementation of the dynamic battle damage model**

figure 3.1 displays the movement of the two parties during the battle.

Through changing the parameters in the model, we can change the movement.

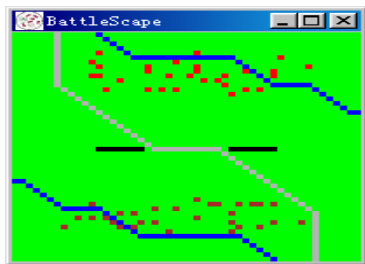


figure3.1 movement of tanks

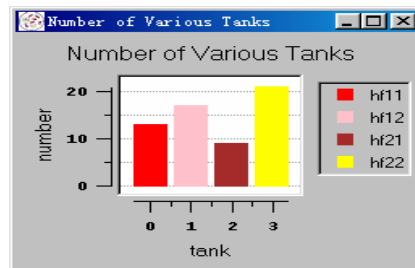


figure 3.2 the fire power of the two parties

According to this figure, we can without doubts discern the different terrain, where the blue areas are rivers, the grey is road, the black is obstacle and the rest green area is the common terrain. The tanks of the two parties are scattered in the whole terrain, where the red rectangles represent the tanks of the red party, while the blue ones are those of the blue party. This figure is the initial distribution of the tanks of the two parties under given parameters.

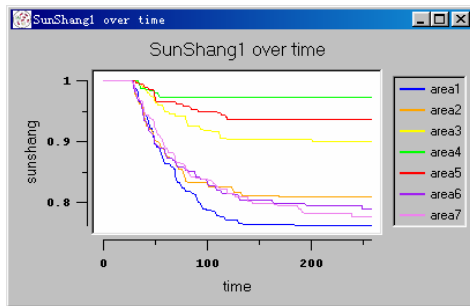


figure3.3 the damage of the red

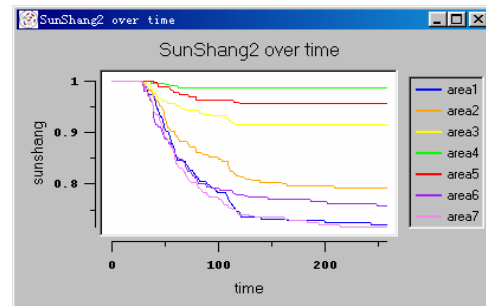


figure3.4the damage of the blue

Figure 3.2 displays the whole attack abilities of the two parties, where hf11, the red rectangle is the number of tanks of the red party with the attack abilities, hf12, the pink rectangle is the number of destroyed tanks of the red party, hf21, the brown rectangle represents the tanks of the blue party with the attack abilities, and hf22, the yellow one stands for the destroyed tanks of the blue party. It's predicted that the red and brown rectangles will definitely diminish while the pink and yellow rectangles increase gradually.

Figure 3.3 and figure 3.4 represent respectively the average damage state of the 7 subarea of the red and blue parties. These 7 subareas described as above have the following characteristics. Area1 and area7, area2 and area6, area3 and area4 are respectively symmetrical so that the corresponding damage states should be similar too. With the simulations going on, the tendencies of the damage states of respective subareas are clearly descent. This phenomono is closely related to a variety of parameters set in this model.

#### 4. artificial experiment and result analysis

In order to analyze the battle damage regularities under different batle environments, we set some designified simulation conditions. It is as following:

1. tanks with identification hongf=1 belong to the red party, while ones with identification hongf=2 are the blue party. When the simulatuion just begins, they aggregate in their respective area of the battle field.
2. the total number of the tanks in the battle , numTanks=60, each

party has 30 tanks.

3. the coefficient of the ability against the attack of the red party is resist1, while the one of the blue party is resist2.
4. the fire field of the red party is vision1, while the blue's is vision2.
5. the terrain of the tank battle
6. the strategies adopted by the two parties: we use different identifications, tactics1 and tactics2, to represent the strategies of the red party and the blue party respectively. The value of the identification is the concrete tactic in order to realize the given strategies. When the value of the identification is assigned to 1, it will adopt flexible strategies. When it's zero, flexible strategies won't be carried out.

In the following part, we just change the parameters of this model to analyze the regularities of the battle damage and further prove the effects on the battle damage caused by those factors. We here only present the result of strategies targets and flexible strategies.

(1) strategies target experiment

In this experiment, the two parties have their strategies target in common and the distances of proceeds are the same, viz, both parties move towards the center of the battle field, during the simulation. When we only change their strategies targets:

$$x_{1min}=x_{2min}=22, x_{1max}=x_{2max}=27, y_{1min}=y_{2min}=5, y_{2max}=y_{2max}=12$$

the red party doesn't move out of its own defend area, while the blue party intrude into the area of the red party. As a result, they have different proceeds distances. The simulation results are shown in figure4.1 and figure4.4.



Figure4.1 the movement of the tanks

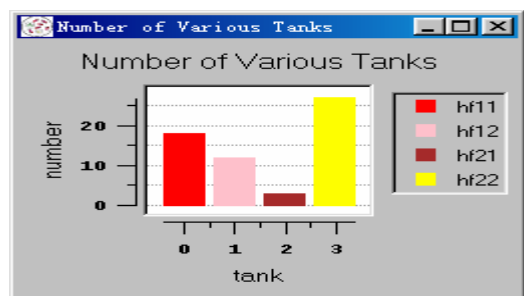


figure4.2 the total attack abilities of the two parties

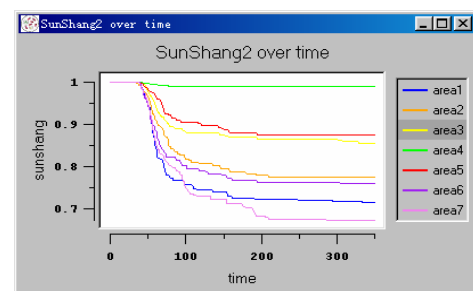
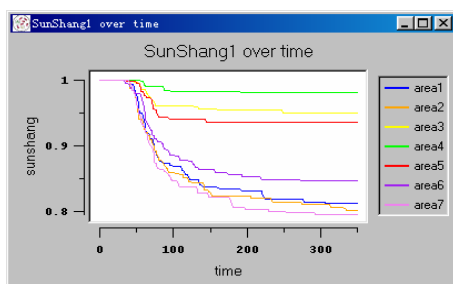


Figure4.3 damage state of the red

figure4.4 the damage state of the blue

From the figure4.1 and figure4.2, when the simulation goes on until 400 simulation steps, the fire power of the red is obviously stronger than that of the blue. Figure4.3 and figure4.4 display the damage states of the two parties, the damage of the blue is severer than that of the red party.

(2) strategies experiment

Tanks can adopt flexible strategies in the battle field. When variable  $tactics1=0$ , the red party won't take the flexible strategies. When variable  $tactics1=1$ , the red party will adopt the flexible strategies. When  $tactics2=0$ , the blue won't carry out the flexible strategies. When it's equal to 1, the flexible strategies will be adopted by the blue party.



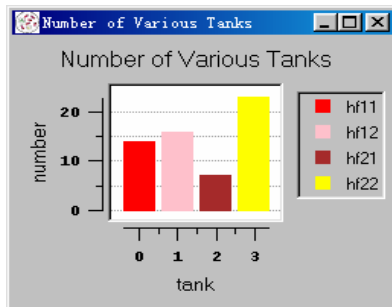
( $tactics1=1, tactics2=0$ )



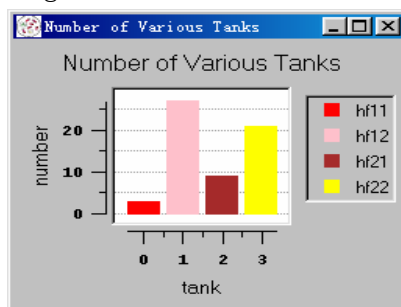
( $tactics1=0, tactics2=1$ )

figure4.5 the movement of tanks

figure4.6 the movement of tanks



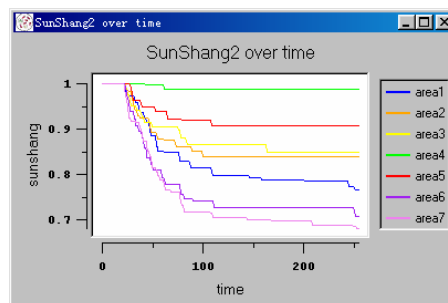
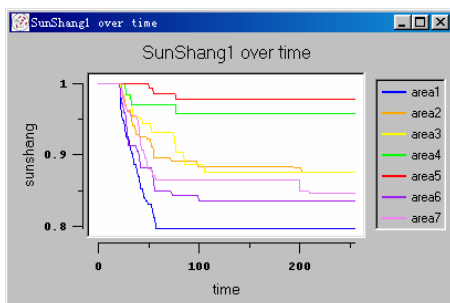
( $tactics1=1, tactics2=0$ )



( $tactics1=0, tactics2=1$ )

figure4.7 the total abilities of the two parties

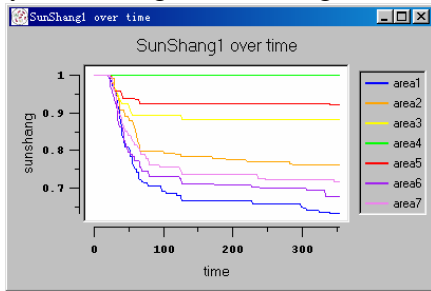
图 4.8 the total abilities of the two parties



(tactics1=1, tactics2=0)

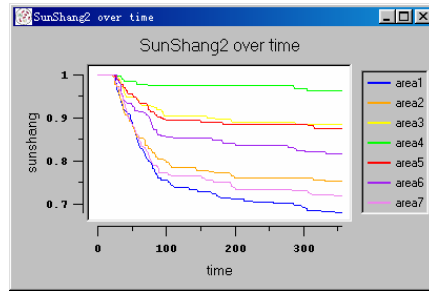
figure4.9 the damage of the 7 subarea of the red party

Whenever any party takes the flexible strategies, the simulation results are displayed from figure 4.5 to figure 4.12.



(tactics1=1, tactics2=0)

figure4.10 the damage of the 7 subarea of the blue party



(tactics1=0, tactics2=1)

figure4.11 the damage of the 7 subarea of the red party

(tactics1=0, tactics2=1)

figure4.12 the damage of the 7 subarea of the blue party

From figure4.5 to figure4.12, we draw the conclusion that the party which takes the flexible strategies will suffer from less damage than the party which doesn't adopt them, so they have stronger attack abilities.

analysis of the experiment results

From the simulation results, we can see:

1. In the performance of the tanks, when variable abilities against attack and variable the effective fire field are increased, the abilities of tanks against damage will become stronger and fight powers tend to be stronger too.
2. In the battle environments, when one party meets bad terrain, that party will definitely suffer from larger damage .
3. In the strategies, when one party adopts flexible strategies, that party will suffer from less damage.

In this paper, we present a novel method to research dynamic battle damage under complex battle environments, based on the fact and reasonable presumptions.

There is still a lot of important issues yet to be handled, such as the multi-rank weapon devices problem, the cooperation of the multi-strategies, the telecommunication devices and so on. We leave these sophisticated things to get done in the future research. We need further point out that the main factor dominating the battle is the human beings. The research of recognition of human beings is already relatively mature in the complex economy system. So we present the future research on battle damage should be inclusion of the functions of human into model.

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