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A Topographic-Awareness and Situational-Perception Based Mobility Model with Artificial Bee Colony Algorithm for Tactical MANET

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Abstract. A topographic-awareness and situational-perception based mobility model with path optimization for tactical MANET is proposed in this paper. Firstly, a formalized process is constructed to generate a random acceleration on nodes as the disturbance caused by small-scale topographic factors in the battlefield. Secondly, a path optimization method with the artificial bee colony algorithm is introduced to mimic the trace planning when the nodes possess the terrain information of battlefield. Thirdly, a topographic-awareness based bypass strategy is proposed to simulate the action of nodes facing large-scale terrain factors in the case when the terrain information is lacking. Finally, a situational-perception based avoidance strategy is built to simulate the process of cognition and decision when there is an encounter with the enemies on the march. The mobility model consists of the four parts above and imitates the dynamic characteristics of tactical nodes in military environment.

Keywords: mobility model, tactical MANET, the ABC algorithm, bypass strategy

1. Introduction

A Mobile Ad-hoc Network (MANET) [1] is a collection of mobile facilities and nodes which can build a communication network in the absence of infrastructure. Due to this characteristic, the MANET is widely utilized in military environment and is considered as the foundation of Network-Centric Warfare (NCW) [2]. Mobility models play an essential role in MANET simulation since the trajectories of nodes have an influence on the routing protocol performance[3, 4, 5] and topology algorithm design. The mobility features of nodes separate from each other in various scenarios. Thus, it is necessary to build a model facing military demands which can reproduce the dynamic characteristics in the battlefield environment.

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Most of the existing models are constructed for social network[6,7] or urban cellular mobile network[8], but military application has its own features. The terrain factors such as torturous roads in small-scale and mountains in large-scale will force the nodes to adjust the path in the battlefield. The perception of enemies will also influence the trajectories of tactical nodes.

In the last paper [9], we had considered the impacts of terrain factors on the dynamic characteristics of mobile nodes in tactical MANET. We established a formalized process to imitate the disturbance of small-scale terrain factors and proposed a terrain-awareness based bypass strategy to imitate the nodes perceiving and bypassing the large-scale terrain factors. However, we did not notice the troops might often acquire the terrain information of the battlefield before the military mission. Meanwhile, the influence that enemy situation might have on the mobility feature was not considered. These omissions had required an improvement in our work.

With the consideration above, a topographic-awareness and situational-perception based mobility model is designed with path optimization for tactical MANET in this work. As is shown in Fig.1, we separate the elements that influence the mobility of nodes into two parts: the static element of terrain factors and the dynamic element of enemy situations. As to the static element, there are small-scale and large-scale topographic factors. Furthermore, when the nodes bypass the large-scale topographic factors, they may have acquired the terrain knowledge or not. Thus, we firstly generate a colored noise with first-order Markov property as the random disturbance on nodes caused by small-scale topographic factors. Secondly, we utilize the artificial bee colony (ABC) algorithm[10] to simulate the path optimization when bypassing large-scale topographic factors if the nodes possess terrain information of the battlefield. Thirdly, if the information is lacking, we propose a topographic-awareness based bypass strategy to mimic the judgment process of nodes about the path selection. Fourthly, we build a situational-perception based avoidance strategy to simulate the process of cognition and decision when facing the dynamic element of enemy situations.

The rest of this paper is organized as follows. A survey of related works in mobility modeling is reviewed in Section 2. The description of the Markov random disturbance on the acceleration is given in Section 3. The procedure of path optimization based on terrain information is proposed in Section 4. The topographic-awareness based bypassing strategy is described in Section 5. The principle of situational-perception based avoidance strategy is given in Section 6. The simulation is shown in Section 7. The conclusion and future works are given in Section 8.

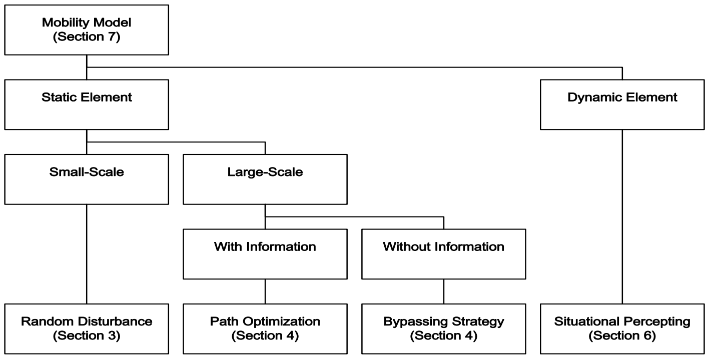

Fig. 1. The structure of mobility model in this work

2. Related Works

Many mobility models have been proposed to simulate the movement of nodes in MANET. Most classical mobility models are based on randomly walking of nodes while some are based on the collection and abstraction of entity movement trajectories in real world. There are also some models aimed at describing mobility feature in specific scenarios. According to the different principles above when designing the mobility models, we can classify them into three categories: synthetic mobility models, realistic trace mobility models and specific scenario mobility models, as is shown in Fig. 2.

2.1. Synthetic Mobility Model

The synthetic mobility models attempt to present the movement of entities based on random walking. In these models, nodes can move freely in the simulation area at a randomly chosen speed. The trajectories of movements are straight lines towards each destination ignoring the influence of the environment. These mobility models are the most commonly utilized and can be classified into entity mobility models and group mobility models based on whether clusters of nodes moving together[11]. The authors of [12] have given a detailed description and comparison of five classical synthetic mobility models: Random Walk Mobility Model, Random Waypoint Mobility Model, Random Direction Mobility Model, City Section Mobility Model, and Reference Point Group Mobility Model. In recent years, researchers also proposed some improvements on these models. For instance, the authors of [13] focus on the boundary of a group. They prefer an elliptic scope with the reference point at the center to imitate the group mobility in a battlefield. The authors of [14] centralized in the direction of node movements and specified them with given angles instead of random directions. The authors of [15] proposed a trust-based framework to support evaluation of information in a VANET.

The synthetic mobility models are simple and ubiquitous, but the random movement brings the problems that the nodes fail to capture the normal human mobility characteristics[16]. Furthermore, the nodes can move anywhere in the area along a straight line instead of being restricted by the environments.

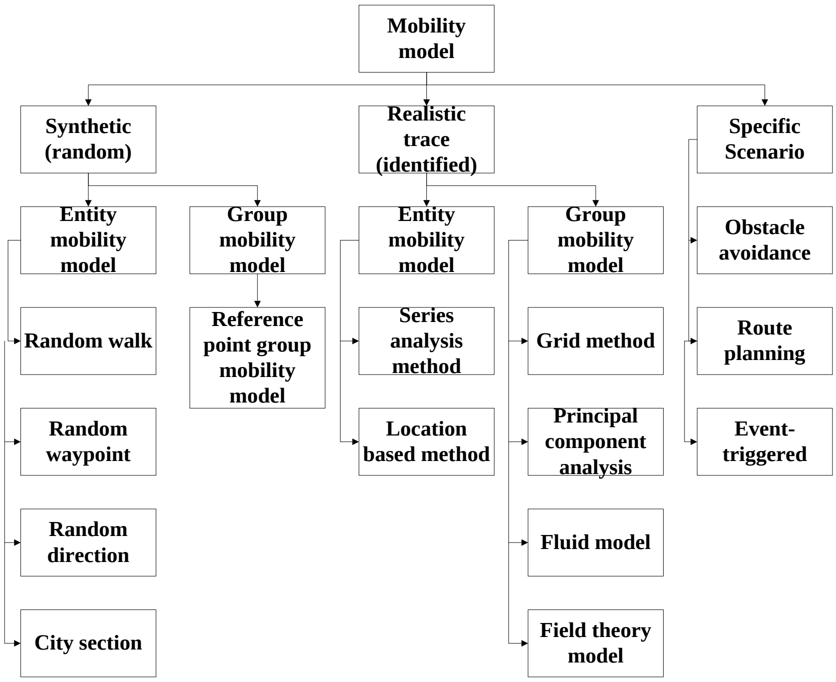

Fig. 2.The classification of mobility model

2.2. Realistic Trace Mobility Model

In the consideration of movement in real world, some researchers attempt to build a mobility model based on realistic trajectories of nodes. They collect the accurate mobility traces of UAVs, vehicles, and humans to abstract the information such as velocity and angle. With the data they build mobility models that reproduce the scene of experiment. The mobility models in [17] and [18] are good examples. The authors in [17] use the trace data collected from a military experiment carried out in Lakehurst, N.J., U.S.A. The distribution of absolute relative direction angle during the experiment is depicted to build the trace model. In [18], more characteristics are collected such as distribution of distance between the leader and followers, distribution of speed for movement duration and probability on pause and move.

These mobility models are extraction of realistic traces, thus truly describe the feature of movement in real world. However, these scene reconstruction based models are strictly restricted in single scenarios. The dependence on experiment data has confined the application since the experiments in the battlefield are difficult to achieve [19].

2.3. Specific Scenario Mobility Model

Specific Scenario mobility models are presented for special applications with temporal and spatial dependency. The movement of nodes is correlated in time and commonly has correlations with topographic factors[20] or clear destinations[21]. The action of nodes may be triggered by some events and the route is probably planned to avoid some obstacles[22]. For example, entities in Obstacle Avoidance Mobility Model (OAM) [23] need to avoid some obstacles on their way to the target. The Smooth-turn Mobility Model[24] for Airborne Networks captures the correlation of acceleration for airborne vehicles as they cannot make sharp turns as easily as ground vehicles do.

It is a good attempt to take the geographic restrictions into account. However, current route planning algorithms are based on the awareness of limited path selections which are not suitable for real world with intricate terrain factors.

Currently, barely any models could achieve path optimization based on the cognition of topographic factors. Furthermore, hardly any mobility models have considered the dynamic feature when the entities encounter enemies. Therefore, a topographic-awareness and situational-perception based mobility model with path optimization is required.

3. The Formalized Process of Markov Random Disturbance

The random disturbance on the mobile entity is caused by the present small-scale terrain factors like muddy paths and tortuous roads instead of the former ones. This can be modeled as a Markov process. Thus in the work [9], we established a formalized process as shown in Fig.3 to generate the random disturbance on the acceleration of nodes. And the noise is superimposed on the entity as a disturbance of movement.

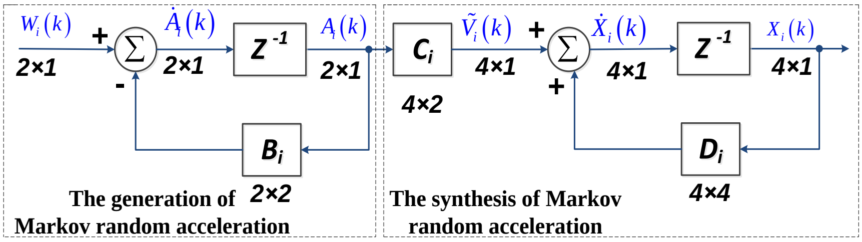

Fig. 3. The state space model of Markov random mobility

3.1. The Generation of Colored Noise

As is shown in Fig.4, the node N_i departs from (x_{i0}, y_{i0}) and marches along the direction α_{Ci} at the constant velocity $\bar{v}_{Ci}$. The node is disturbed by the uncertainty of terrain factors $\vec{a}_R$ on direction θ_i. $x_i(t)$, $y_i(t)$ are the coordinate of N_i. $\dot{x}_i(t)$, $\dot{y}_i(t)$ are the constant velocity of N_i whist $v_{x_i}(t)$ and $v_{y_i}(t)$ are the speed caused by random disturbance $a_{x_i}(t)$ and $a_{y_i}(t)$. ΔT_i is the very short acceleration time on N_i.

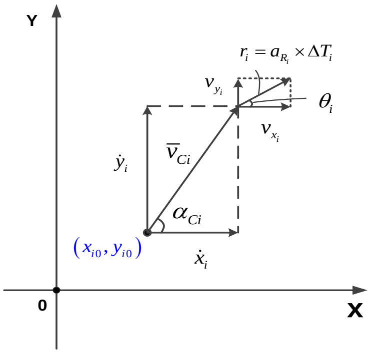

Fig. 4. The speed decomposition of nodes

The Markov random acceleration is generated by the first part of the discrete time system in Fig.3. The state equation is:

$$A_i(k+1) = -B_i A_i(k) + W_i(k) \tag{1}$$

Where $A_i = \begin{bmatrix} a_{x_i} & a_{y_i} \end{bmatrix}'$ is the random acceleration vector, and

$B_i = \begin{bmatrix} b_{i1} & 0 \\ 0 & b_{i2} \end{bmatrix}$, $\|B_i\| < 1$ effects the correlation of output A_i.

$W_i(k) = \begin{bmatrix} a_{R_i}(k)\cos\theta_i(k) \\ a_{R_i}(k)\sin\theta_i(k) \end{bmatrix}$ is a Gaussian white noise signal whose margin submits the Rayleigh distribution and the phase submits the uniform distribution. A colored noise with first-order Markov property is the output.

3.2. The Synthesis of Random Acceleration

In the process, the constant velocity of N_i remains the same whist the random disturbance on velocity changes over time. The trace of nodes is determined by the combination of the two velocities shown in the second part of Fig. 3. The state equation of the recursive process is:

$$\begin{cases} X_i(k+1) = D_i X_i(k) + \tilde{V}_i(k) \\ \tilde{V}_i(k) = C_i A_i(k) \end{cases} \quad (2)$$

$X_i = [x_i \quad \dot{x}_i \quad y_i \quad \dot{y}_i]'$ is the vector of position coordinates and velocities.

$D_i = \begin{bmatrix} 1 & 0 & 0 & 0 \\ T_R & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & T_R & 1 \end{bmatrix}$, $C_i = \begin{bmatrix} T_R \Delta T_i & 0 \\ 0 & 0 \\ 0 & T_R \Delta T \\ 0 & 0 \end{bmatrix}$ T_R is the interval of generating random acceleration and ΔT_i is the interval between different disturbance.

Then the expressions of the coordinates and the velocities are as follows:

$$\begin{cases} x_i(k+1) = x_i(k) + T_R \dot{x}_i(k) + T_R \Delta T_i a_{x_i}(k) \\ y_i(k+1) = y_i(k) + T_R \dot{y}_i(k) + T_R \Delta T_i a_{y_i}(k) \end{cases} \quad (3)$$

$$\begin{cases} \dot{x}_i(k+1) = \dot{x}_i(k) \\ \dot{y}_i(k+1) = \dot{y}_i(k) \end{cases} \quad (4)$$

Eq.3 gives the recurrence relation between the coordinates and the random accelerations of N_i. And Eq.4 shows that the constant velocity remains unchanged during the moving process.

4. The Terrain Information Based Path Optimization

In this section, we propose a terrain information based path optimization method with artificial bee colony (ABC) algorithm to imitate the behavior when the nodes avoiding large-scale terrain factors. In the battlefield environment, the path is often the optimization considering a variety of factors. We abstract the tactical node path planning as a constrained optimization of a multi-dimensional function[25]. The path selection is abstracted as a solution while the terrain factors construct the parameters of the utility function.

4.1. The Theory of Artificial Bee Colony (ABC) Algorithm

The Artificial Bee Colony (ABC) algorithm proposed by Karaboga in 2005 is a branch among the attempts such as ant colony optimization, particle swarm optimization[26] and bird flocking which employ insect behavior to solve optimization problems[27,28,29]. The ABC algorithm is designed based on two fundamental concepts: self-organization and division of labor. The main feature of the ABC algorithm is the collective global optimization can be achieved through individual partial optimization[30], so the convergence rate is faster.

The honey observation process of the ABC algorithm consists of three components[31]: food sources, employed foragers and unemployed foragers. The algorithm defines two leading modes of behavior: the recruitment to a nectar source and the abandonment of a source.

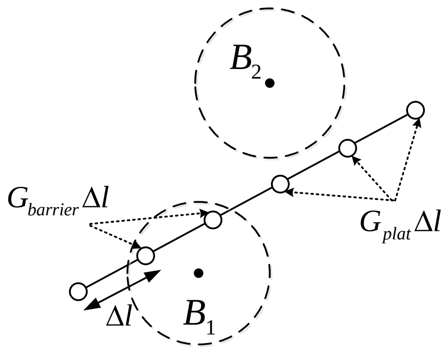

Fig. 5. The process of path optimization

1) Food sources: every food source has a value depends on the parameters of the function.

2) Employed forgers: the bees associated with a particular food source are regarded as “being employed”. They carry the information about this particular source and share them with unemployed foragers.

3) Unemployed foragers: They continually look for a food source to exploit and search the environment surrounding the food source shared by employed foragers to optimize the solution.

4.2. The Process of Path Optimization

As is shown in Fig.5, the path selecting problem is turned into a constrained optimization[32]. Set the line from departure to destination as x-axis and the former coordinate is converted by the equation below:

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix} + \begin{pmatrix} x_0 \\ y_0 \end{pmatrix}, \theta = \arg\tan\frac{y_t - y_0}{x_t - x_0} \quad (5)$$

$S(x_0, y_0)$ is the departure point. We divided the path into N_t pieces and calculate the synthesis of every piece. Define

$$J = \sum_{j=1}^{Nt}\sum_{k=1}^{M} \omega_k(x_j, y_j)\cdot\sqrt{(y_j - y_{j-1})^2 + (x_j - x_{j-1})^2} \quad (6)$$

J is the utility function with the concept "Road Loss". $\omega_k(x_j, y_j)$ represents the parameter that influence node mobility and M is the number of parameters taken into account. In this paper, the only ω represents the obstacle. And the value of ω represents the impact level on node mobility. In this paper, we assign $\omega = 1000$ in obstacle area and $\omega = 10$ in plain area. The integration of $\sum_{j=1}^{Nt}\sqrt{(y_{k-1,j} - y_{k-1,j-1})^2 + (x_{k-1,j} - x_{k-1,j-1})^2}$ represents the length of path. Thus the entity can minimize the Road Loss by avoiding the barriers with high value of ω while reducing the length of the path.

The procedure is shown in flow chart Fig.6:

1) Initialize the parameters. Divided the x-axis into N_t pieces and every probable solution is a trial of ordinates.

2) Generate some initial path randomly as the food source and calculate the function J of them.

3) Unemployed foragers search for a better path near the food source shared by the employed foragers. If any, replace the former path and record.

4) If there is no better path near the food source, the employed foragers will leave for a new food source.

5) If the number of iterations reaches the limit, then convert the coordinate back and terminate the calculation. Otherwise go to step 2).

6) End.

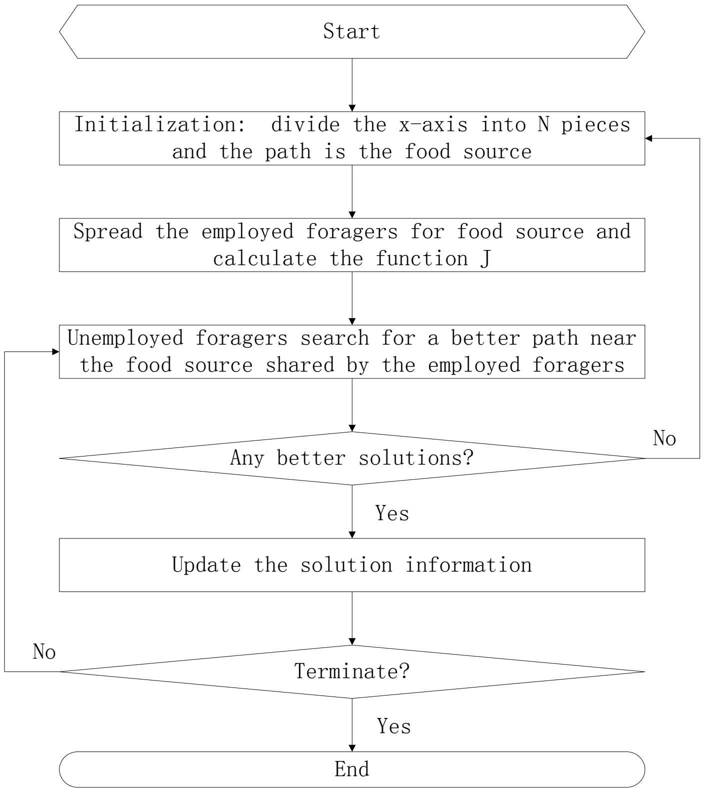

Fig. 6. The flow chart of path optimization with artificial bee colony algorithm

5. The Topographic-Awareness Based Bypass Strategy

Sometimes the entities cannot acquire the terrain information when planning the path. In this situation, we propose a topographic-awareness based bypass strategy to imitate the behavior when the node faces obstacles. The entity can detect the terrain factors within a certain range of distance. Once a barrier is observed on the way to the destination, the entity takes the strategy to bypass the obstacle. The whole procedure can be divided into two parts: the judgment of obstacles and the strategy of avoidance.

5.1. The Judgment of Obstacles

There may be several barriers observed by the entity in the same time. Thus the entity has to judge which barrier will constitute the obstruction along the path.

Take Fig.7 for example. There are three barriers in Fig.7: B_1, B_2, B_3 and the entity CH_i is marching to the target T. In the triangle constructed by CH_i, T, and B_n, define $d_{(CH_iB_n)}$ as the distance between CH_i and B_n, if

$$d^2_{(CH_iB_n)} + d^2_{(CH_iT)} \geq d^2_{(B_nT)}, r_n \leq R_n \tag{7}$$

Then the nearest B_n is the obstacle that will be bypassed in the next step.

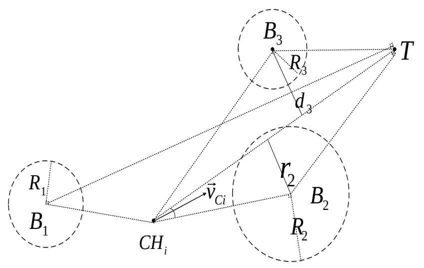

Fig. 7. The judgment of obstacles

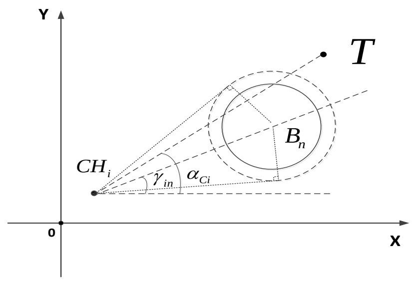

Fig. 8. The selection of bypass direction

5.2. The Bypass Strategy

There are two parameters in the strategy: the bypass direction and the bypass acceleration. As is shown in Fig.8, the bypass direction is judged by the relative location of the entity, the destination and the barrier. If $\alpha_{Ci} \geq \gamma_{in}$, the node will take the clockwise route. Otherwise, the counterclockwise route will be chosen.

In order to minimize the path, the synthesis velocity $\vec{v}_{Ri}$ should be along the boundary of the barrier B_n. If the acceleration on the entity is large enough, the situation is shown in the first figure in Fig.9. $\vec{v}_{Ci}$ is the constant velocity of entity CH_i before observing the barrier. The direction of acceleration $\vec{a}_{Ti}$ is chosen randomly from the possible range Φ_{Ci} .And ΔT is the interval between detections.

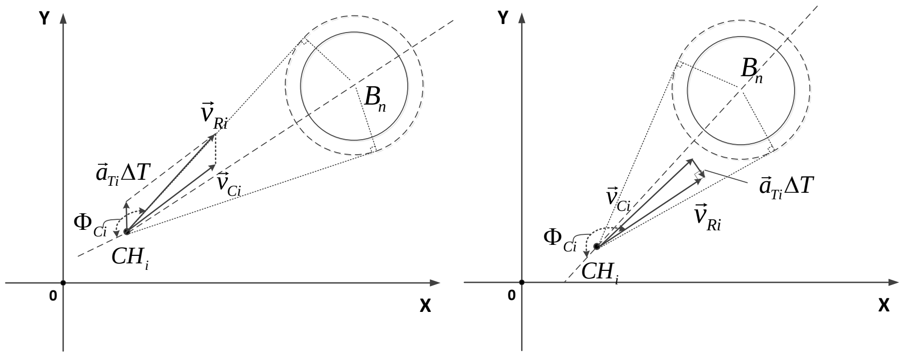

Fig. 9. The selection of bypass acceleration

As is shown in the second figure in Fig.9, once the mobility cannot turn in the necessary direction, the direction of acceleration is perpendicular to the $\vec{v}_{Ci}$ with the maximum value to avoid running into the barrier area.

6. The Situational-Perception Based Avoidance Strategy

The tactical entities may encounter enemies in the battlefield. The process of enemy avoidance brings uncertainty to the dynamic feature of entity mobility. This uncertainty will influence the performance of evaluating MANET. Therefore, it is necessary to take the situational-perception based avoidance strategy into account when designing the mobility model.

We regard the enemies on patrol as a trail of barriers. The difference from Section 5 is that the entities can acquire the velocity of enemies as well as the location. This brings two changes in the avoidance strategy: the judgment of enemy situation and the direction of avoidance.

6.1. The Judgment of Enemy Situation

As is shown in Fig.10, we can estimate the future position of enemies by assuming the velocity of enemies remain the same between detection interval

ΔT . The zone between current position and future position is also a dangerous area that could not be passed through.

In the case $\angle B_{11}CH_iT$ and $\angle B_{12}CH_iT$ locate at both sides of the line CH_iT , if

$$d^2_{(B_{11}CH_i)} + d^2_{(TCH_i)} \geq d^2_{(B_{11}T)} \text{ or } d^2_{(B_{12}CH_i)} + d^2_{(TCH_i)} \geq d^2_{(B_{12}T)} \quad (8)$$

Then the avoidance strategy should be started.

In the case $\angle B_{11}CH_iT$ and $\angle B_{12}CH_iT$ locate at same side of the line CH_iT , if

$$d^2_{(B_{11}CH_i)} + d^2_{(TCH_i)} \geq d^2_{(B_{11}T)}, r_{11} \leq R_1 \text{ or } d^2_{(B_{12}CH_i)} + d^2_{(TCH_i)} \geq d^2_{(B_{12}T)}, r_{12} \leq R_1 \quad (9)$$

Then the avoidance strategy should be started.

6.2. The Direction of Avoidance

To avoid the enemies, the entity should move to the opposite direction of the enemy. Thus the direction should be selected based on the current position instead of the future one. As is shown in Fig.10, $\angle\theta_v = \angle\vec{v}_{Ci}CH_i\vec{v}_{Ei}$, if $0 \leq \angle\theta_v \leq \pi$,then the counterclockwise direction should be taken. Otherwise if $-\pi \leq \angle\theta_v \leq 0$ then the clockwise direction should be taken.

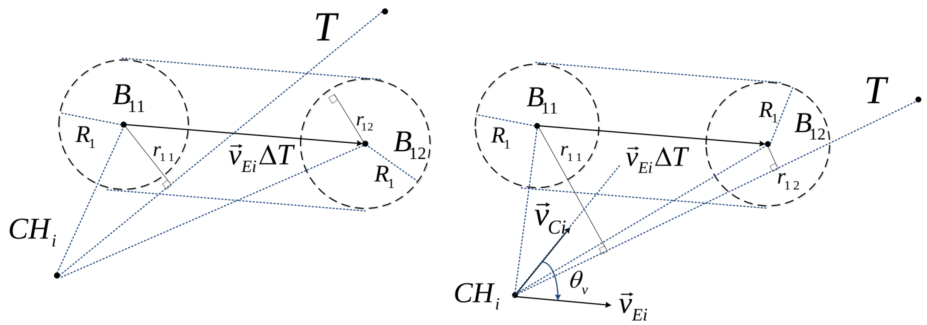

Fig. 10. The judgment of enemy situation

7. Simulation

In order to evaluate our proposal, we performed some scenes to simulate the four parts of the mobility model.

7.1. The Simulation of Random Disturbance

The simulation of the formalized process of Markov random disturbance on the acceleration is given in Fig.11. In a 3500m$\times$3500m simulation area, there are 6 nodes marching towards the destination in 500s while suffering the disturbance which changes every second. b_i =0.9, and $\sigma = 0,1,2,3,4,5$ in the Rayleigh distribution contributing to the Markov disturbance.

It can be seen that the movement of entities are disturbed and the tiny random acceleration changes like the effect of uncertain small-scale terrain factors have on the node. Different values of parameter bring different intensities of disturbance. The higher σ is, the severer disturbance is. This process mimics the influence of small-scale terrain factors on the movement. The uncertainty of topographic feature can be adjusted by the parameter σ.

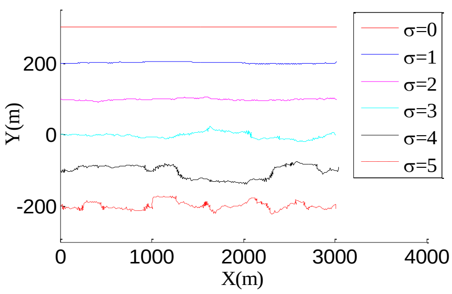

Fig. 11. The mobility trace of nodes with Markov random disturbance

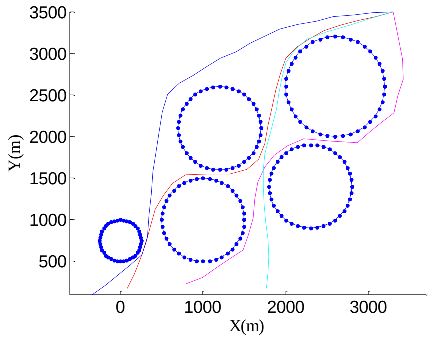

Fig. 12. The terrain information based path optimization with the ABC algorithm

7.2. The Simulation of Path Optimization

The simulation of the terrain information based path optimization is given in Fig.12. In a 4000m$\times$4000m simulation area, there are 4 nodes marching towards the destination. With the terrain information of the battlefield, the nodes can plan and optimize the path before moving. The simulation parameters are given in Tab. 1 as below:

Table 1. The parameters of the ABC algorithm for path optimization

Parameter	Value	Parameter	Value
ω (barrier/plain)	1000/ 10	Interval of optimization (m)	200(x-axis)
Employed foragers	30	Number of iteration	2000
Unemployed foragers	30	Number of search	30

It can be seen that the ABC algorithm realize the path optimization with the terrain information. The entities bypass the obstacles and select a path that takes the length as well as the terrain into account. This process mimics the path planning of nodes with the topographic information in the battlefield.

7.3. The Simulation of Bypass Strategy

The simulation of the topographic-awareness based bypass strategy is given in Fig.13. In order to contrasting the bypass strategy with path optimization, the simulation scene remains the same with Section 7.2. The detection range of entities is 200m.

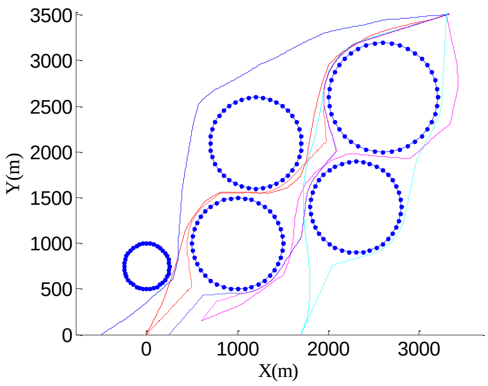

Fig. 13. The mobility route of bypass strategy comparing with path optimization

The solid line is the path optimized by the ABC algorithm in Section 6 while the dotted line is the mobility route of bypass strategy. However, the nodes will not take the bypass strategy until an obstacle is observed in a near distance. This leads to a result that the path is not the optimal selection. The phenomenon mimics the realistic situation when the troops marching in a strange environment. The entities without terrain information can only rely on the observation and awareness of topography to make the decision.

7.4. The Simulation of Avoidance Strategy

The simulation of the situational-perception based avoidance strategy is given in Fig.14 and Fig.15. In the same simulation area with Section 7.2, there are 3 nodes marching towards the destination and 5 enemies patrolling in the simulation area. The simulation parameters are given in Tab. 2 as below.

Table 2. The parameters of the entities and enemies for avoidance strategy

Parameters of entities	Value of entities	Value of enemies
Detection range (m)	200	40
Velocity (m/s)	8-16	5-7
Acceleration limit (m/s^2)	5	0 (constant patrol)

The situation of the entities and enemies in the battlefield is given in Fig.14. There are three enemies patrolling in line and two in circle at a constant velocity. Since the enemies and entities are both moving, we record the distance between one entity and five enemies by time to evaluate if the strategy could allow the entities to avoid their enemies. The five lines in Fig.15 represent the distance between one entity and the five enemies. X-axis represents the time while y-axis represent the distance. It can be seen that the entities will approach the enemy during the movement. But the avoidance strategy will be triggered to guarantee the entity does not run into the enemy.

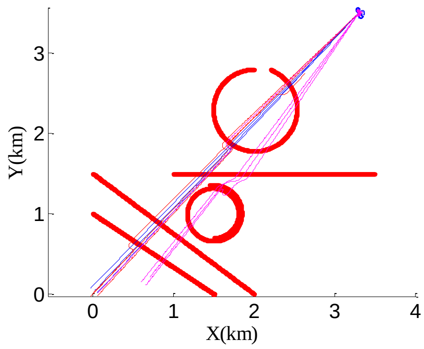

Fig. 14. The situation between the entities and enemies

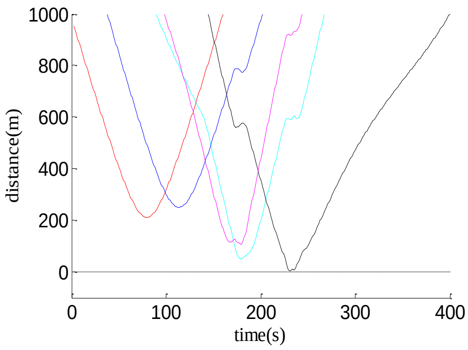

Fig. 15. The distance between one entity and the enemies

7.5. The Simulation of the Synthetic of the Mobility Model

The synthetic of random disturbance, path optimization, bypass strategy and avoidance strategy forms the integral mobility model. Firstly, the node is constantly disturbed by the random terrain factors in small-scale during the whole mobility process. Secondly, if there is a priori knowledge of terrain information, the node will optimize the path with the ABC algorithm before moving. Thirdly, if the information is lacking, the node will utilize the topographic-awareness based bypass strategy to adjust the path during the movement. Fourthly, the node will observe the enemy situation and make a decision on movement to avoid running into the enemies. The simulation of the synthetic mobility model is given in Fig.16 as follow.

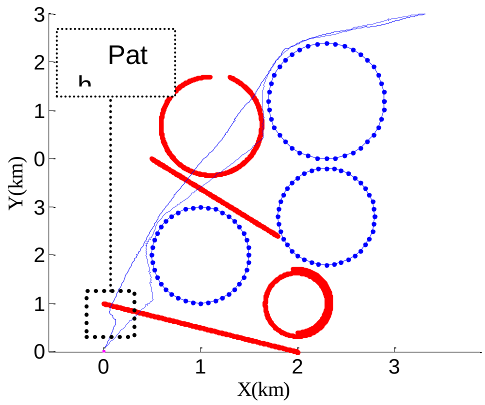

Fig. 16. The trace of the node in the synthetic of the mobility model

The solid line is the path optimized by the ABC algorithm in Section 6 while the dotted line is the mobility trace of bypass strategy. It can be seen that the node will follow the path planned by the optimization or adjusted by the bypass strategy. When an enemy is observed, the node will utilize the avoidance strategy. This phenomenon entirely mimics the realistic situation when the node marching in the battlefield.

7.6. The Parametric analysis

There are five parameters that may have significant influence on the simulation. They are the σ, the entity detection internals, the entity detection range, the entity acceleration and the enemy detection range. In order to evaluate the selection of these parameters, we introduce a concept as "successful bypass rate" which represents the probability that the entity avoids all the barriers and enemies during the movement. The higher the successful bypass rate is, the more appropriate the parameter is within a reasonable range. The simulation results are given in Fig.17 as follow.

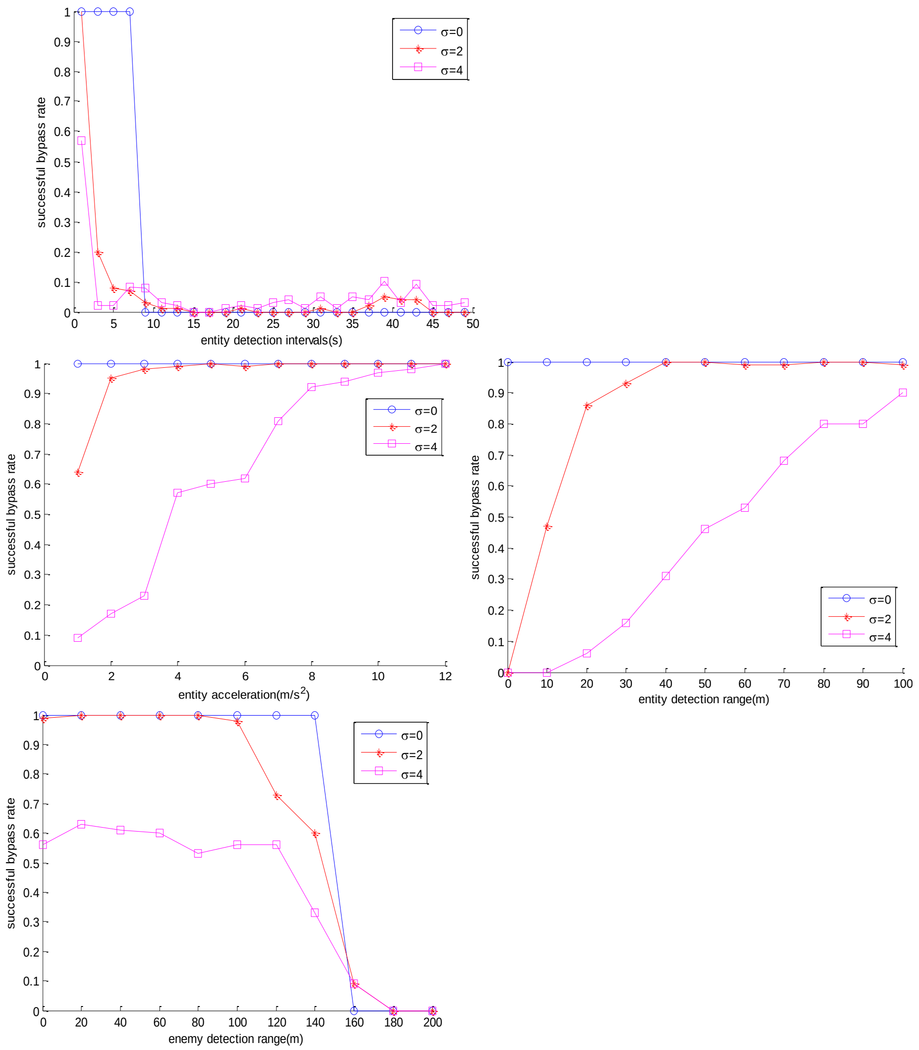

Fig. 17. The analysis of parameters

Firstly, the higher the σ is, the lower the successful bypass rate is acquired. The phenomenon implies that severe disturbance caused by small-scale terrain factors may lower the successful bypass rate of nodes. Secondly, a longer detection internal of entities may lower the successful bypass rate. It suggests that the node will encounter the obstacles or enemies without a frequent detection. Thirdly, high entity accelerations will improve the successful bypass rate which means a rapid adjustment on mobility helps avoiding the dangerous zone in the battlefield. Fourthly, enhance the entity detection ability or weaken the enemy detection ability will bring an improvement on successful bypass rate. This result suggests the importance of observation in the battlefield environment.

8. Conclusion

In this paper, we propose a topographic-awareness and situational-perception based mobility model with path optimization for tactical MANET to imitate the influence which terrain factors and enemy situations have on the dynamic characteristics of mobile entities.

Firstly, we constructed a formalized process to generate a random acceleration on nodes as the disturbance caused by small-scale topographic factors in the battlefield.

Secondly, we propose a terrain information based path optimization method with the ABC algorithm. We abstract the path planning as a constrained optimization of a multi-dimensional function to mimic the plan when the entities face large-scale terrain factors.

Thirdly, we improve the topographic-awareness bypass strategy to imitate the behavior when the entities without the terrain information face large-scale obstacles in the battlefield.

Fourthly, we establish an enemy situational-perception based avoidance strategy to simulate the behavior when the entity encounters enemies in the battlefield.

The synthesis of the four parts above comprehensively represents the dynamic characteristics of mobile nodes according to the awareness of the terrain factors and enemy situations in the tactical environment. In the future, we plan to evaluate different routing protocols with this mobility model so as to select and improve a protocol for military application in MANET. Our ultimate goal is to realistically imitate the mobility of nodes in tactical environment and precisely simulate the performance of MANET.

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