Target Tactical Clustering Algorithm Based on Grouping Field

Na Hao, Kaixuan Chu, Tianqing Chang, Bo Zhang and Lei Zhang
Army Academy of Armored Forces, 100072, Beijing
adzygdshn@163.com, b1016938865@qq.com, cchangtianqing@263.net

Abstract. This paper proposes a target-based tactical clustering algorithm based on the grouping field. Inspired by the midfield theory of physics, the concept of gravitational force is used in the target tactical grouping of the armored unit level, and the concept of grouping field and grouping force is proposed. After acquiring the target identity, the state of motion parameters and the trend of the movement, the information of the identity attributes and state parameters of each target are fused and analyzed, the group field strength function is constructed, and a single target with a certain cooperation relationship in tactics is classified, forming tactical groups. Simulation results show the effectiveness of the proposed algorithm.

1. Introduction

The target tactical grouping is to cluster the targets with similar combat functions, similar intentions and close coordinate positions, and then conduct research on them. The purpose is to make inferences about their operational intentions based on clustering characteristics and cluster parameters. The most widely used is MacQuccn in 1967 proposed K-Means clustering algorithm. The algorithm finds out k clustering centers, divides the data in the dataset into k classes according to the distance relation, and adjusts the clustering center to minimize the sum of the square distances of the corresponding clustering centers in the dataset. The algorithm is simple and easy to implement, but it is sensitive to the initial value, and the number k must be specified manually[1]. In order to overcome the shortcomings of algorithms, scholars have studied the optimization of K-means clustering based on swarm intelligence. Literature [2] and [3] use artificial bee colony algorithm and particle swarm algorithm respectively to improve them and overcome the sensitivity of initial clustering center and easy to fall into the local shortcomings. Spectral Analysis[4] is widely used in clustering, pattern recognition and meshing. The method mainly uses the eigenvalues and eigenvectors to cluster the data in the dataset. Complex network clustering[5] has a wide range of applications in social networks, biometrics and the World Wide Web. In practice, it often happens that data points in a dataset belong to more than one class at a time. After the researchers' research, a fuzzy clustering method[6-7] has been proposed, such as FCM algorithm, FBBA algorithm, Gustafson-kessel algorithm, Gath-Geva algorithm. Hierarchical clustering is also a commonly used clustering method. Inspired by the midfield theory of physics, literature [8] proposes a hierarchical clustering method.

At present, there are few researches on armored tactical clustering algorithm. On the one hand, the traditional combat mode is based on commander's command, and there is less demand for this; on the other hand, the armored detachment target clustering needs to consider not only the target geographical position attribute but also the target feature attributes. Currently, the algorithm only considers the geographical attributes of the target itself, and the effect of direct use for
combat target grouping is not satisfactory enough. This paper combines the Voronoi diagram theory in computational geometry with the field theory in physics. Based on the FTASC algorithm\cite{9}, according to the characteristics of terrestrial armored targets, the radiation parameters are set according to the threat degree of different armored targets, and a clustering-based approach is proposed. Target tactical clustering algorithm to achieve armored team-level target tactical grouping.

2. The principle of grouping
Due to the tactical cooperation between multiple targets in the tactical group, the target position characteristics must have certain constraints in the spatial region, and there are some similarities between the target speed features. Based on this, the tactical clustering feature space can be constructed based on the obtained target state parameters, and the similarity measure function of the target in the tactical clustering feature space can be established to measure the characteristics of the target group. The standard of the metric function construction is to make the difference between the targets belonging to the same tactical group within a certain threshold range, while the targets belonging to different tactical groups have big differences.

A number of goals for each tactical group will inevitably have a core, that is, the group's command node. The synergy between command nodes and other targets in the tactical group can be vividly described as the attraction between objects with different masses in the gravitational field. Therefore, the concept of gravitation can be used in the objective tactical clustering of armored sub-team level. Make the following convention before grouping:

1. In battlefield space, our armor units will face multiple enemy targets that have certain tactical values.

2. The target will have some restraining effect on the other targets around it, and the scope of this restraining effect is limited. In the limited battlefield space around the target, the role of restraint is obvious. The space region is defined as the tactical grouping field. The restraining effect is defined as the tactical grouping force, referred to as the grouping force for short.

From the above agreement can be determined within the battlefield armored sub-team level target tactical clustering principles:

1. For a certain tactical group, there must exist a target that has obvious restraining effect on the other targets in the group, that is, it produces the largest grouping force.

2. Among the targets in the tactical group, some tactical coordinated actions will be adopted, and the targets are closely linked and the force of grouping is strong. Due to the different tactics between different tactical groups, the linkages will inevitably loose and will be weaker in the grouping forces.

3. The goal that does not belong to any tactical group belongs to a single goal, independence of action, the grouping force will inevitably be smaller.

3. Grouping field and grouping force
This paper proposes the concept of 'grouping field' and 'grouping force' for land armored targets, defines a function that characterizes the mechanism of action of the flocking field, and combines the flocking field with the grouping force. For armored team-level targets and tactical groups, due to the limitation of the number of team-level targets, the team tactical group has limited space within the battlefield. Therefore, the scope of the clustering field should be compatible with the scale of the battlefield control area at the tactical group. The range of influence produced by the divergence field, that is, the scope of the grouping force should be limited to the battlefield area of the tactical group at the detachment level. The force beyond this area should be significantly reduced. The improved Voronoi diagram is used to divide the tactical clustering feature space, and then the function mechanism function of the target tactical group clustering field is constructed.

Whether the multiple targets in the battlefield space can be divided into one tactical group is closely related to the degree of similarity of the groups in the target. Some features in the same tactical group among the various objectives must have the characteristics of high similarity. Because the targets in the same tactical group will maintain a relatively stable trend in the spatial range, the
position coordinate difference is within a certain range, and there is a high degree of similarity between the average velocity, the heading angle and the direction of the weapon barrel. Therefore, The target position coordinates \( x_i, y_i, z_i \), the target speed \( V_a, V_p, V_e \), the target heading angle \( \alpha_i \), and the target weapon pointing angle \( \beta_i \) as the eigenvectors. Considering that the state parameter of a single target in a tactical group is a function of a discrete time series, in order to ensure the stability of the target tactical grouping, the average value of the parameters over a period of time is taken as the value of the eigenvector. The target tactical clustering eigenvector is constructed as:

\[
O_j = [x_i, y_i, z_i, V_a, V_p, V_e, \alpha_i, \beta_i]
\]

The target tactical clustering feature space is a 7-dimensional space containing 7 characteristic indexes, denoted as \( QT \).

**Definition 1:** Feature Voronoi space area

For a certain battlefield space target set \( O \), \( O = \{O_1, O_2, O_3, \ldots, O_n\} \), any goal \( O_i \) of \( O \), its corresponding characteristic Voronoi area \( O_i^V \) can be defined as

\[
O_i^V = \{x \mid d(q, O_i) \leq d(q, O_j), O_i, O_j \in O, i \neq j, q \in QT \}
\]

All the corresponding Voronoi spatial regions of \( O_i \) constitute the Voronoi field of the target set \( O \). That is to say

\[
O^V = \{O_1^V, O_2^V, O_3^V, \ldots, O_n^V\}
\]

**Definition 2:** Recent Voronoi space domain target

For a battlefield space goal set \( O \), where \( O_i, O_j \in O \). If \( O_i^V \) and \( O_j^V \) have adjacent spatial surfaces, their relationship can be described as they act as each other’s closest Voronoi space target. Delaunay set is a collection of all its nearest Voronoi space domain targets, denoted as \( \text{NSD}(O_i) \).

**Definition 3:** Recent Voronoi space domain

At a certain target \( O_i \) in the optional battlefield space, the characteristic V-space region to which the target of the nearest V-space domain owned by \( O_i \) belongs forms a spatial region that forms the nearest V-space domain of \( O_i \) with \( O_i^V \), denoted as \( \text{DNV}(O_i) \).

**Definition 4:** Field strength function of the grouping field

An important principle to be followed in constructing the field strength function of a grouping field is to consider the area of the target feature Voronoi space as the applicable range of the target’s restraining effect. The restraining effect of each target spread outwards around its own position until Encouragement of other goals.

According to the above characteristics, we can establish the field strength of the sub-field as

\[
E_{\sigma_i} = k \frac{1}{d(O_i, q)^{2\sigma}} e_{\sigma_i, q}
\]

\[
\sigma = \begin{cases} 
1, & q \in \text{DNV}(O_i) \\
+\infty, & q \notin \text{DNV}(O_i)
\end{cases}
\]

where, \( E_{\sigma_i} \) is the target field strength of the subfields generated in the feature space, \( k \) is grouping field radiation parameters, \( q \) is any point in the feature space, \( d(O_i, q) \) is the distance between target \( O_i \) and point \( q \), \( \sigma \) is field strength parameters, \( e_{\sigma, q} \) is the unit vector of \( O_i \) to \( q \).

The selection of the group field radiation parameters \( k \) needs to be adapted to the target type. For different types of equipment selection of radiation parameters, using expert scoring method. The construction of the target type \( T_i \) and \( k \) corresponding relationship shown in Table 1.

| \( T_i \) | Main battle tank | Infantry chariot | Transport car | Self-propelled artillery | Light vehicle |
|---|---|---|---|---|---|
| \( k \) | 1 | 0.8 | 0.5 | 0.4 | 0.2 |
According to formula (1), we can express the grouping power between two targets

\[
F_{ij}(O_i, O_j) = E_i m_j = k \frac{m_j}{d(O_i, O_j) \sigma} e_{ij}
\]

(2)

where, \(m_j\) is the quality of \(O_j\), supposing the target is a unit of particle, so \(m_j = 1\), \(d(O_i, O_j)\) is distance metric function of target \(O_i\) and \(O_j\) in feature space, \(\sigma\) is field strength parameters.

4. Grouping algorithm

4.1. Principle of algorithm

According to the hypothesis, armored unit-level tactical clustering algorithm consists of the following two basic steps:

1. For each target in the battlefield space, obtain the target of the most recent space domain;
2. Choose a target that has greater containment power for other targets, that is, generate the target with the largest grouping field strength, and divide the targets of its recent space domain into a category to form a tactical group. The basic principle of the algorithm is as follows.

During the tactical grouping of armored unit-level targets, when a group of objects that interact with each other is a vector, and a target has a restraining effect on its surrounding targets, it will inevitably be adversely checked by other target directions, that is, There is a reverse group of forces acting on this goal. All the opposite direction restraints inevitably form a combined force in the space, and the target force generally appears in the opposite direction of the combinatorial force. The target can be considered as a tactical cluster center. The combined force at the tactical grouping center \(O_i\) in the grouping field is

\[
F_c = \sum F_{ij}(O_i, O_j)
\]

(3)

The angle between the combined force and the component force will have a certain impact on the tactical grouping. If the angle is smaller than 90°, the component force can enhance the effect of the combined force. If the angle is greater than or equal to 90°, then the component force will have a weaker effect on the combined force, which will cause grouping errors when the target is at multiple tactical group boundaries. Certain constraints must be set on the grouping algorithm.

4.2. Algorithm constraints

For the problem of wrong grouping caused by the target at the boundary of tactical group, we set the constraints on the size of grouping when grouping, as follows:

1. Select a target within the battlefield space as the center of the grouping, count the target of the nearest Voronoi space domain, and select all the targets whose angles of component force and combination force are less than 90° are expressed as CNS(O_i), which is:

\[
\text{CNS}(O_i) = \{ O_j | \theta(F_{ij}(O_i, O_j), F_c) < 90°, O_j \in \text{NSD}(O_i) \}
\]

Where, \(\theta(F_{ij}(O_i, O_j), F_c)\) is the angle of the forces.

2. Summarize the reverse groupings suffered by the cluster centers and calculate their average

Sort all the target groups in the CNS(O_i) of the grouping center by the grouping power of the grouping centers, remove the minimum \([N/2]\) targets, sum the grouping forces of the remaining targets, and average them, expressed as \(E(F)\), \(N\) is the nearest target number of Voronoi space domain, \([\ ]\) means rounding.

3. Determine the target of tactical grouping objects
The target of the tactical grouping target must meet: The target grouping group has a grouping force greater than \( \frac{E(F)}{5} \). The set of goals that satisfy the condition is denoted as \( \text{NS}(O) \), which is \( \text{NS}(O) = \{O | [F_0(O, O)] > \frac{E(F)}{5}, O \in \text{CNS}(O)] \) \)

4.3. Algorithm Description

According to the above basic principle, given a battlefield space target set \( O \), armored unit-level tactical clustering algorithm can be described as follows:

Step A: For each target \( O \) in the grouping target set, calculate its characteristic Voronoi space area and generate \( \text{NSD}(O) \); and obtain the combined force of the grouping forces \( O \) received.

Step B: Generate \( \text{NS}(O) \) for target \( O \).

Step C: Calculate the combined force of the reaction force of the grouping force of each target in the target set. Select the target of the maximum combined force \( O \) as the tactical grouping center, and classify all the targets in the \( \text{NS}(O) \) as \( O \) which is marked as "grouped."

Step D: Select the non-clustering target \( O \) in \( C \), and assign \( \text{NS}(O) \) to \( C \), until all the targets are marked as "grouped" to generate a target tactical group.

Step E: Calculate the number of targets contained in the set \( C \). When \( \text{Count}=1 \), indicating that only one target is included and the target is an independent target.

Step F: If there are no targets in the statistical target set \( O \) that are included in the tactical group, look for new tactical grouping centers in these targets and perform Step C ~ Step E again until all targets are clustered or become independent targets.

5. Simulation example

In order to validate the tactical clustering algorithm and tactics recognition method proposed in this paper, we use Matlab2014a software to write the simulation program and simulate the computer with the frequency of 1.6GHz CPU and memory 2G.

(1) Battlefield Environment

In the \( OXYZ \) coordinate system, set the simulated area size of 1km \( \times \) 1km \( \times \) 800m undulating flat terrain environment, as the target sports venue.

(2) Scale of Troops

Set the target number of enemy targets by unit size. At a certain moment, the target location of the target units in the battlefield space is shown in Figure.1, and each target is displayed by a diamond logo.

(3) Target Tactical Clustering Algorithm Simulation

We observe that the enemy's target cluster eigenvectors are shown in Table 2. Among them, the heading angle and the pointing angle of the weapon are all based on the positive direction of the Y-axis and rotate clockwise to be positive.

| Target | \( \vec{x} \) | \( \vec{y} \) | \( \vec{z} \) | \( \vec{V_x} \) | \( \vec{V_y} \) | \( \vec{V_z} \) | \( \vec{\alpha} \) | \( \vec{\beta} \) |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1      | 198    | 385    | 20     | -5     | 15     | 0.1    | -18    | -10    |
| 2      | 245    | 510    | 22     | -2     | 18     | 0.2    | -6     | -12    |
| 3      | 400    | 410    | 23     | -2     | 15     | 0.2    | -8     | -5     |
| 4      | 490    | 620    | 21     | 0      | 21     | -0.1   | 0      | 10     |
| 5      | 590    | 780    | 25     | 2      | 22     | 0      | 5      | 15     |
| 6      | 703    | 620    | 20     | 1      | 30     | 0.1    | 2      | 10     |
| 7      | 600    | 520    | 25     | 2      | 24     | 0      | 5      | 10     |
According to the target cluster eigenvector in Table 2, the characteristic distances among the targets are solved as shown in Table 3.

### Table 3: The distances among target features

| Target | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1      | 0   | 1.06| 1.04| 2.24| 2.76| 2.25| 2.44| 2.42| 3.00| 2.88|
| 2      | 1.06| 0   | 0.53| 2.18| 2.35| 1.83| 2.09| 1.63| 2.22| 2.27|
| 3      | 1.04| 0.53| 0   | 1.93| 2.06| 1.53| 1.82| 1.47| 2.05| 2.04|
| 4      | 2.24| 2.18| 1.93| 0   | 0.82| 1.09| 0.74| 1.87| 2.05| 1.59|
| 5      | 2.67| 2.35| 2.06| 0.82| 0   | 0.78| 0.48| 1.55| 1.51| 1.13|
| 6      | 2.25| 1.83| 1.53| 1.09| 0.77| 0   | 0.65| 1.12| 1.29| 1.06|
| 7      | 2.44| 2.08| 1.82| 0.74| 0.48| 0.66| 0   | 1.29| 1.35| 0.94|
| 8      | 2.42| 1.63| 1.47| 1.87| 1.55| 1.12| 1.28| 0   | 0.63| 0.82|
| 9      | 3.00| 2.22| 2.05| 2.05| 1.51| 1.29| 1.35| 0.63| 0   | 0.62|
| 10     | 2.88| 2.27| 2.04| 1.59| 1.13| 1.06| 0.94| 0.81| 0.62| 0   |

Enemy target is the main battle tank, then \( k = 1 \). For \( \text{NSD}(O) \), which generates the target \( O \), the following processing is performed in the simulation. The \( k \) targets whose distance metric function \( d(O_i, O_j) \) in the feature space between the target \( O_i \) and the \( O_j \) is the smallest form the \( \text{NSD}(O) \) of the target, and the value of \( k \) is the same as that of the local team. In the simulation example, the enemy unit contains 10 targets, and the \( k \) value of 3 is more appropriate, corresponding to the rank tactical units. The field strength variation \( \sigma \) is 1. \( e_{O_i} \) is the unit vector, and the value is 1. The force of grouping among targets can be calculated as shown in Table 4.

### Table 4: Grouping force among targets

| Target | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1      | 0   | 0.90| 0.92| 0.20| 0   | 0   | 0   | 0   | 0   | 0   |
| 2      | 0.90| 3.54| 0   | 0   | 0   | 0   | 0   | 0.38| 0   | 0   |
| 3      | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0.46| 0   | 0   |
| 4      | 0   | 0   | 0   | 0   | 1.48| 0.84| 1.81| 0   | 0   | 0   |
| 5      | 0   | 0   | 0   | 1.48| 0   | 1.68| 4.41| 0   | 0   | 0   |
| 6      | 0   | 0   | 0   | 0   | 1.68| 0   | 2.35| 0   | 0   | 0.90|
| 7      | 0   | 0   | 0   | 1.81| 4.41| 2.35| 0   | 0   | 0   | 0   |
| 8      | 0   | 0   | 0   | 0   | 0   | 0.79| 0   | 0   | 2.52| 1.50|
| 9      | 0   | 0   | 0   | 0   | 0   | 0.60| 0   | 2.52| 0   | 2.58|
| 10     | 0   | 0   | 0   | 0   | 0   | 0   | 1.14| 1.50| 2.58| 0   |

Based on the above calculation results, a tactical clustering algorithm is run and tactical clustering is carried out on the target of the contingent tank. The result is shown in Figure 2.
6. Conclusion

The simulation results show the effectiveness of the target-tactical clustering algorithm based on the clustered field proposed in this paper, which can quickly and accurately achieve target tactical clustering at the armored unit level and provide an important basis for further obtaining the tactical intent of the enemy and assessing the threat level of the enemy target.

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