A Groud and Aerial BattleField Spatio-Temporal Data Unified Organize Model and Aplication

LI Feng, Li Qin, WAN Gang, CAO Xuefeng
Institute of Surveying and Mapping in Zhengzhou, Zhengzhou, China
E-mail: jueyun1020@126.com

Abstract. Aiming at the requirement of battlefield environment data model in joint operations, this paper proposed a groud and aerial battlefield spatio-temporal data unified organize model based on grid division. The thought of shere grid division is adopt to divide the space, and extend to the time dimension. Also, the spatio-temporal grid coding is designed. The field and object are combined to build the BSTD organization model, where the panet layer unit and panet volume unit are considered as the reference space separately to quantitatively describe the field, and the spatio-temporal grid coding is adopt to describe the space and time attributes of the objects. The relevant experiment is designed in paratroop tactics wargame simulation, and the results verify the feasibility of the model.

1. Introduction
With the rapid development of the science and technology, the range of military activities have been extended from the land surface to ocean, outer space, underground and undersea. The methods to get the environment information have made great progress in recent year. Therefore, it is possible to obtain the meteorological, electromagnetic and nuclear information in real time, which can form the massive BSTD ultimately. As the data origin from different departments, they have evident difference in spatio-temporal reference, data granularity, professional semantic, which greatly limit the capability. How to build the BSTD organization model, and accurately describe each element in strength, boundary, and change law, has become an urgent problem in battlefield environment science.

To simulate the comprehensive battlefield environment, the UAS develop the CTDB, define the TCDM, and make the SEDRIS to meet the requirement of the modular semiautomatic force simulation. Many universities of our country have done deep research on comprehensive environment simulation and terrain database, including the National University of Defense Technology, Beijing University of Aeronautics and Astronautics, and the Armoured Engineering Insititute. Liang et al. proposed the concept model of environmental factors, including natural and humanistic characteristics, which effectively describe the data of environmental factors based on SEDRIS, considering the classification principle in EDCS, Xie et al. built the object framework of marine and atmospheric environment based on SEDRIS, Liu et al. combined the object and field model to build the battlefield data model, according to which the database is carried out. Aiming at the requirement of battlefield environment data model in CGF decision, Dong et al. combined the grid and vector to build the battlefield environment database. Zhong et al. proposed a battlefield space modeling method based on space division, which can effectively describe the battlefield space.

This paper adopts the earth sphere grid division method to construct the groud and aerial BSTD organization model. The spatio-temporal grid division system is constructed based on space division...
and the extension to time dimension. The BSTD is effectively organized by combined the object and field. And the method is adopted in airborne flight path planning and site selection.

2. Battlefield space grid division

2.1. The thought of earth sphere grid division

The purpose of the sphere layer space grid is to describe the whole earth, and the sphere space is the abstraction of the earth space. According to certain rules, the sphere space is discretized into grid unit, which has unique code, than the process and mutual spatial relation of the geographic entities can be effectively described by several grid units, based on which the environment data can be effectively integrated and organized.

In the method, the geocentric coordinate system is the space reference, the earth center is the sphere center, the earth sphere is the starting surface, a series of concentric spheres are constructed by zooming the sphere in different scale. The concentric sphere is the sphere layer reference, the three-dimensional volume is formed by close the neighboring reference layer, which is also called shere volume reference. According to the sphere grid division model, the reference circle layer is divided into sphere grid unit, which is called as sphere grid. The neighboring sphere grid is closed into starting sphere volume, which can be divided into sphere volume with layer detail according to the octree rules in each layer.

The reference sphere layer division method is corresponding to the sphere grid division, where the hybrid sphere grid can be adopted. The basic thought is dividing the sphere into 6 basic surface with the same size, then dividing each surface according to the quadtree, to get the sphere grid unit with the same size. The sphere is divided into 2 spherical crowns and the middle zone by cutting using a planet, whose latitudes is 48.2. Then the middle zone is divided into 4 parts to get 6 basic surface with same size, which is coded using the number 0-5.

According to the octree rules, the sphere layer is divided into 4 equal parts, the circle layer radium is divided into 2 parts by the same distance, and the whole circle volume is divided into 8 parts, each of which is divided according to octree division, the results is shown in Fig. 1.

![Figure 1](image)

2.2. Extension to the time dimension

The battlefield elements is changing all the time, and the sample space description just reflect the statue at certain time, therefore it can not effectively organize the BSTD. The sphere space grid is just the discretization of the three-dimension space, and the space attribution is described by the discrete grids. Time is also the one dimensional data, same as the space. In order to effectively describe the time attribution, it is essential to discretize and code the time. Thus, the division is extended to time dimension based on space division, and the space grid and the space coding is combined to construct the spatio-temporal coding system.

Since 1912, China adopted the Christian era to represent the time. The sidereal time, ephemeris time, and atomic time are adopted in astronomy, weapons manufacture, and the christian era is widely adopted to describe the other military activities and environment elements. The start of the the christian era is the birthday of Jesus, before the start time is called as the "bc", and after that is "ad". In
the Christian era, the “year, month, day, hour, minute, second” is considered as the time unit to discretize the time, which is same with the space grid division. Different time units describe the layers in different level.

2.3. Spatio-temporal grid coding

In order to divide earth space into the sphere volume grid with different detail level, each grid must have the unique coding number, in which case, the space grid unit can be effectively described. The grid coding mechanism is the core of the space grid system, and it is the foundation of describing the attribution and mutual relation of grid units, and the premise of the code operation.

In the method of sphere grid division, there need 5 parts to identify a sphere volume unit, including the reference sphere volume, the division level, the starting sphere volume, the sphere radium, and the sphere grid. The sphere volume coding is consisted of the reference sphere volume coding, the sphere radium coding, the sphere grid coding, and the sphere grid coding is consisted of the division level, the row number and the column number. Therefore, the whole coding system is consisted of the reference sphere volume coding, the division level, the sphere radium coding, the basic surface number, the basic column number, and the row number. And the coding system can be represented as:

\[
\text{SolidCellCode} = (\text{DatumSphereID}, \text{RootSolidID}, \text{Level}, \text{RadialSegID}, \text{SphericalRowID}, \text{SphericalColID})
\]

Where \text{SolidCellCode} is the sphere volume coding, \text{DatumSphereID} represents the reference sphere volume coding, \text{RootSolidID} denotes the starting sphere volume coding, \text{Level} represents the division level, \text{RadialSegID} is the sphere radium coding, the \text{SphericalRowID} denotes the sphere grid row number, and the sphere grid column number is represented by \text{SphericalColID}.

Similar with the space grid, the time grid can be identified by the unique coding. The level coding, such as the year + month + day + hour + minute + second, can represent the time in different precision. Considering the habits in battlefield, the coding is like “YYYYMMDDHHMMSSIII”, where “YYYY” is the year coding, “MM” is the month coding, “HH” is the hour coding, “M’M’” is the minute coding, “SS” is the second coding, and “III” is the millisecond coding. The time coding is decimal coding with 17 numbers.

Combined with the sphere grid space coding, the spatio-temporal coding system can be designed as: spatio-temporal coding = space coding + time coding, the whole structure of the spatio-temporal coding is depicted in Fig. 2, where the yellow part is the space coding, the blue ones represent the time coding. The time coding can be set as 0, when the high precision of the time description is no need, for example, there is no need to record the second and millisecond coding when describe the thunderstorm areas, because the high precision of the calculation model is minute.

![Figure 2. structure of the spatio-temporal coding](image)

3. The battlefield data organization model based on grid division

3.1. data organization strategy of combining the field and object

Different elements in battlefield have different distribution characteristic and evolvement rules, according to which, the battlefield elements can be divided into field elements and object elements. The field elements have the continuous distribution, such as the elevation, soil type, the atmospheric temperature, seawater density, and the seawater velocity. This kind of data is the spatio-temporal distribution characteristics of certain attribution in battlefield, and it can be further divided
into two-dimension sphere elements and the three-dimension sphere volume elements according to the difference in time dimension. The object elements have the clear boundary, complete function and discrete distribution in space, such as the building, the three, and the fortifications. This kind of data is an independent individual in space, which can be divided into point, line, surface and volume object.

The sphere grid model is a method of spatial description, and the spatial attribution of object can be described by the grid unit coding and the subsidiary spatial coordinates. It can answer “where is?”, for example, the grid coding can describe the location and the range of the spatial points, lines, surfaces, and volume objects. The sphere grid model is also a spatial reference, and the battlefield elements can be effectively recorded and quantified based on sphere grid unit. Thus, it is convenient to adopt the sphere grid model to manage both the field elements and the object elements, the thought of organizing the battlefield environment data based on sphere grid model, is shown in Fig. 3.

![Figure 3. The battlefield environment data organize model](image)

The point, line, surface, and the volume elements can be described by the spatio-temporal coding, where the spatial position and range is described by the space coding, the time attribution is described by the time coding, and the level and neighboring relation of the grid unit can be the index of the object elements. The field elements in two dimension sphere can be quantified with the reference of the sphere grid, and those in three dimension sphere can referring the sphere volume grid. The scale attribution of the battlefield elements can be described by the level relation of the sphere grid model.

### 3.2. The grid coding description of the object elements

There are two purposes to adopt the sphere grid model to manage the object elements. One is to describe the spatio-temporal attribution of the environment object as a whole, the other is to describe the spatial distribution and the evolution characteristics of the environment objects in detail. In order to achieve the goal, the object coding structure, consisted of the spatio-temporal coding and the object coding, is essential to be designed. The whole spatio-temporal coding is described by the whole spatio-temporal coding, and the internal spatio-temporal coding of the environment objects is described by the spatio-temporal coding set. The object structure based on the circle grid model is shown in Fig. 4, where the target ID is the identical mark of the environment object, which is formed according to other information system.

![Figure 4. Object coding structure](image)
describe the spatio-temporal information, such as the spatial distribution and the time evolution. Also, it can be adopted to search the internal elements and make a judgement on spatio-temporal relation of the environment elements.

3.3. the grid organization of the field elements

The field elements can be effectively managed by adopting the spatial grid unit to record the attribution. The two-dimension and three-dimension sphere field elements can be organized separately by the sphere grid and the sphere volume grid.

The two-dimension sphere elements, such as the elevation, slope, soil, the land type which is distributed in the earth surface, can be quantified based on the sphere grid unit. In the process, each unit records the element value, which is also called as the data record with time coding, representing the element value in different time. Many battlefield elements can be described based on the sphere grid unit, such as the elevation, the remote sensing image, the slope, the soil, the land type, the earth surface weather, the visibility, and the shaded degree.

Some elements are spread in certain sphere volume in earth, such as the air temperature, humidity, visibility, seawater temperature, salinity, density and the sound velocity, which could be considered as the three dimension sphere volume field data. And the data can be quantified based on the sphere volume grid unit, each grid unit record the element value.

The whole space is divided into underground, the undersea, in the air, the mix of ground and air, the mix of water and air, according to the material in the volume grid unit, and the material is also the basic attribution of the grid. With the refinement of partial levels, the sphere grid model can effectively simulate the real battlefield.

Some sphere volume units are filled with gas, such as the air, the mix of the ground and air, and the mix of the water and air, many attributions of these elements need to be quantified, including the atmospheric temperature, humidity, visibility, wind speed, wind direction, cloud, special weather phenomena.

Some sphere volume grid units are filled with liquid, such as the water volume, the mix of the ground and water, and the mix of the air and the water. The attribution of the field elements, need to be quantified, include the water temperature, salinity, density, the sound velocity, fluid velocity and the fluid direction.

4. Application and analyze

In order to verify the validity and the practicability of the model, the proposed model is applied in paratroop tactics wargame simulation. The BSTD of the system can be divided into 7 parts, include the elevation data of the task area, with the 2 meter resolution produced by the digital map, on a scale of 1:10000, the slope and the slope direction information produced by the elevation data, the shaded degree, soil, and the land type extracted from the digital, the three dimension building data by manual model, the aerocraft information received in real time, the electromagnetic environment information produced by the electronic countermeasure model, and the meteorological data received from the meteorological model.

Different battlefield elements are organized in different methods, for example, the elevation, sensing image, slope, soil, landform, and the shaded degree can be organized by the sphere grid model, and the sphere grid unit is considered as the reference to quantify the environment elements, the atmosphere, and the electromagnetism can be organized by the sphere volume grid model, and the sphere volume grid unit is considered as the reference to quantify the elements, the building and the aerocraft in low altitude can be described by the spatio-temporal grid coding. Experimental results demonstrate that the proposed model can effectively support the flight planning of the helicopter, the selection of the airborne area, and the construction of the battle efficiency evaluation model. Application results are shown in figure 5. The figure 5-a is helicopter landing terrain location analysis, figure 5-b is helicopter penetration path planning.
5. Conclusion

Aiming at the multi-dimensional battlefield data support of the paratroops in joint operation, a ground and aerial BSTD organization model is proposed. The space and time are both divided into grid, and the spatio-temporal grid coding model is designed, based on which, the environment elements is organized by combining the field and the object. The model is applied in the paratroop tactics wargame simulation, the experimental results demonstrate that the model can effectively describe different kinds of data in battlefield with high efficiency. Further research on the multi description of the BATD and the conversion of field elements and object ones is still needed.

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