THE SUN-EARTH SPACE INFORMATION SYSTEM

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ABSTRACT:

Nowadays the object of Space Information System (SIS) is limited to the earth surface, and the large-scale sun-earth space does not been considered. In this paper, the research object of SIS is been extended, namely the object is been studied from the earth surface to the sun-earth space, and the concept of "Sun-earth Space Information System" is been proposed. It is the very important content of SIS. Considering the current theory and the research way of SIS, the possibility and the feasibility of applying SIS to study the Sun-earth space are been analyzed. In the last, the detailed research scheme is been given. Eventually SIS and Scientific Visualization are applied to visually model the three-dimensional Sun-earth space and the real three-dimensional environment is been set up.

1. INTRODUCTION

From the first satellite had been launched in 1957, the space times is coming to us. The development of space science for 40 years make us recognize the space environment is related with people's living and development, and it is very important as the same with earth, ocean and atmosphere. With the improvement of aeronautics and astronautics science and the development of military war situation, the sun-earth space environment becomes the most related environment with the human space activity. In this space environment, the activities of the sun, such as the solar flare and CME (Coronal Mass Ejection), influence and endanger frequently geomagnetic field, ionosphere and upper atmosphere, the satellite safety and human health. The space environment situation and its variety regulation become the concernment questions of space activity.

As compared with GIS (geographic information system) research in geography, the sun-earth space environment research is limited to the scientific calculation and mathematics processing to observational data. To describe better the solar-terrestrial space and show its entire situation and variety regulation, we can extend the research objects and fields of GIS to the entire solar-terrestrial space from ground, and apply the existing research ways and technology of GIS to the research of space object and space environment. And the solar-terrestrial space can be expressed by the prototype of "Digital Space", so that it can be better showing space, using space and controlling space for people.

Currently there is not good system framework about the entire solar-terrestrial space environment. And the research emphases are limited to the specialty of space aeronautics and space physics, and cannot meet the demanding of other fields to space application. To show the space by the way of visualization better, we must import new methods and technology to its research. At present, there is not much research about the entire solar-terrestrial space information system. So the system mainly includes SPENVIS-Space Environment Information System of Europe Space Bureau, U.S.A EWB-The Environment WorkBench and Space Radiation and so on. The software about the space environment includes NASA Living with a Star, Space Environment Effect System and National Space Weather Program. In this paper, it applies the conception, technology of GIS to the solar-terrestrial space research, and these new methods to the space environment research should improve the space studying level.

For convenience, it uses some Acronyms.

SIS: the Sun-earth Space Information System

GIS: Geographic Information System

VR: Virtual Reality

SciV: Scientific Visualization

2. THE CONCEPT OF SIS

The concept of SIS advanced on the base of GIS and the space environment technology, so it relies on the development of GIS methods and space environment research.

2.1 The Correlative GIS Technology

GIS, having geographic reference system information, is the tool to acquire, manage, process and display space information based on computer technology.(Li,2002) And its information usually was been divided into two kinds, namely, space information and attribute information. On compare with other information system, the basic concept of GIS is object's space situation, space distributing and space relation. The points, lines, areas and the implicit peculiarity, that are abstracted from space object, compose the basic cell of GIS. And the core of GIS is the management and analysis of space database. At present, the development of GIS more emphasizes the integration of many format data, the integration of GIS, RS and GPS. The space information analysis and simulation of GIS gives more methods to the other information.

2.2 The Sun-earth Space Environment

Developing the space environment research is the foundation of the development of space technology, and is the main ways of understanding space and utilizing space. And its research includes the static distributing of all space environment elements and the influence of sun and earth activity to the space environment. In our research, the space of space environment usually is the wide fields upper the a few kilometres from the ground.

The situation of the solar-terrestrial space environment is not static, but is the kinds of form, many time scale disturbances.

And the source of the space environment disturbances is sun. The solar activities directly influence the environment situation of earth space, and the high-energy radiation and particle flow, which caused by the sun eruption, can bring many earth physical effects around the earth. All kinds of solar activities mainly include solar flare, solar radio burst, Coronal Mass Ejection and high-speed solar wind streams. And the disturbances of the terrestrial space environment include geomagnetic disturbances, magnetospheric storm and substorm, ionospheric storm. The interplanetary disturbance includes interplanetary scintillation, interplanetary magnetic field variety and cosmic rays.

In our research, the solar-terrestrial space environment includes atmosphere, ionospheric plasma, geomagnetic field, high-energy electric particle (solar cosmic rays, earth radiation belt and galactic cosmic rays), space debris and meteoroid.

In order to numerically show the space environment elements, it needs some environment modes. And the environment mode transits all kinds of space environment process and phenomenal into the forms can be calculated, and describes by more concept and quantitative models. Based on the research and analysis to the current space environment modes, the static distributing space environment element modes include the following.(JIANG,2001) The atmosphere modes include MSIS, MET (Marshall Engineering Thermosphere), HWM (Horizontal neutral wind Mode) and CIRA (COSPAR International Reference Atmosphere) mode. The ionospheric plasma modes include IRI (International Reference Ionosphere) and Chiu model. The geomagnetic field mode includes IGRF (International geomagnetic Reference Field) model. The high-energy electric particle mode includes AE8&AP8 model. Also space debris and meteoroid have their own models. In addition, ISO/TC20/SC14/WG4 defines the standard about space environment models.

2.3 The Concept of SIS

To show better about the entire solar-terrestrial space environment, we consider all objects and its one other influences in space as the whole body, and form the concept prototype of SIS finally.

SIS is the scientific system based the space information science. It applies model space information theory to study information processing, data organizing, space modelling and digital expressing of the solar-terrestrial space objects and its space environment. Moreover, it uses SciV technology to three-dimension reproduction and visualization interactivity of space objects, including Aerospace vehicle, natural body and space debris and so on, and its environment. And it has some space analysis, communication analysis, as well as evaluation functions. The system flow chart in appendix

Its research objects are all objects in the solar-terrestrial space, and research range is the entire solar-terrestrial space, and research contents are space objects' visualization modelling and expressing. Certainly, it can be applied to study space objects' interactive influence.

3. THE NECESSARY AND FEASIBILITY OF APPLYING GIS TO SIS RESEARCH

3.1 The Necessary of Applying GIS to SIS

3.1.1 Studying Space itself

The space environment is the foundation of human from earth into space. Be compared with the ground environment, the space environment is more complex. Because the space environment includes many objects, involves large space scale and suffers more variation, describing the average distribution situation of the space environment looks very important. Especially, with the development of space technology, the space activities are more frequent. And the aerospace vehicles circle in different orbit space fields; the space environment should influence not only the aerospace vehicles, but also its material, apparatus, cabin equipment and cosmonaut in different degree. With the more development of space resource utilizing, people need the space weather to protect our space activities. Exploration, research, understanding and commanding the space environment condition and applying them to serve our space activities also become the necessary components in space utilizing.

3.1.2 Studying the Sun-Earth Space As the Entire Body

At present, more scientists gradually recognize the essentiality of studying the solar-terrestrial space system as the entire body. Although the solar-terrestrial space system is been divided into many fields, their mutual relation is very close and influence one other. The main character of the space environment around earth is affected by the energy condition and variation from the sun. All kinds of the space environment variation and all the space environment effect are sourced from the solar variety.

3.1.3 The Necessary of Applying GIS

Although GIS is mainly applied to geographic research, its aim and contents are expanded more fields and many theory, methods can be used in SIS. At present, the research about the solar-terrestrial space is immersed in physics, mathematics calculation and graphic visualization. How does we utilize these mathematics models for aeronautics mission and offer analysis and assistant decision-making functions, is becoming the stress of the current space environment research. Moreover, GIS technology is the important tools that can make the space environment model into spatial disperse, parameter and visualization. In other words, GIS offer two-dimension, three-dimension running frame by itself.(Li,2002) Because kinds of data have its difference time-space scale and survey methods, it should impose them into uniform geographic reference system in actual application. Thus they can be used in form of grid, polygon, line, points and so on. In order to resolve these problems, we need GIS to assist the solar-terrestrial space environment research.

3.2 The Feasibility of Applying GIS to SIS

3.2.1 Many Observation Data and Environment Models

With the advancement of observation, detection methods to the space environment, huge observation data are been accumulated. Using the related data and mathematic base, scientist work out the corresponding mathematic models about the space environment elements. The physical description to all kinds of the space environment elements becomes the time-space digital description. All kinds of historical data, index data and environment variety data about the space environment was been integrated into the standard database, such as Oracle8i, SQL Server. These data, same with the data in GIS, can be calculated to get the space data having space situation and time specialty by using some data models and transform. By these processing, we can construct the entire solar-terrestrial "Digital Space". With the improvement of science technology, observation

means, kinds of models should become more and more fine, accurate. And these advanced data models offer more reliable data for SIS application.

3.2.2 GIS Offers Many Methods to Resolve Problem

Almost all of environment problems relate to space dimension.(Li,2002) The basic unit composed environment simulation and other factor correlative with the environment simulation all have specialty of spatial distributing, and these spatial distributing effectively influence the environment elements interactive process and spatial process dynamic evolvement. And processing to spatial distributing, spatial relation and spatial process is GIS advantage. The relation between the environment simulation and GIS is obviously. Integrating GIS and the environment simulation in the way of technology, research contents and methods have extensive application foreground.

At present, some large GIS software Corp. develop many module of GIS, such as MapX, MapObject and MapXtreme. (ESRI, 1996) These COM built on the base of OLE, can be used for any programme language that bear COM technology. Thus they give all programmers convenience. So applying GIS into SIS research has feasible technology base and can be acquired by GIS software level.

3.2.3 The Application of SciV and Graphics technology

Three-dimension visual simulation is a new type of simulation technology formatted by combining the computer visualization and systemic modelling technology. Essentially, it uses the mode of graphics or image to track, calculate and final- process for the simulation calculation processing. At the same time, modelling and simulation to objects by this way have the following benefits, for example, rapidness, high efficiency, intuitionist and visualization.

Because the data calculated from the solar-terrestrial space environment elements is huge, these surveyed data can be calculated to form 2D, 3D or more dimension data sets. This data sets includes huge complex information that cannot easily understand and analysis. The visual technology of the data sets can translate the no-visual information into visualization by the way of graphics and image, so it opens out the inner meaning that contained in the data sets.

For visual processing of the data sets, it not mainly refer the precision image that be fit with the data accuracy, but construct and render the graphics and image that can easily understand its regulation or more information. We can observe and analyze the inner character from the graphics and image. In conclusion, the essential of visualization is a kind of information simulation.

4. STUDYING THE SUN-EARTH SPACE ENVIRONMENT BY THE METHOD OF GIS

4.1 The Research Object of SIS

Based on the graphic environment character, the geographic data mainly is three or more dimension, its database should be the three dimensional database corresponding.(GONG,2001) The geographic data have many kinds; the natural data includes terrain, physiognomy, geology, ocean and lower atmosphere and so on. The anthropogeography includes building, road, establishment and population. These data have its own character. For instance, the geology data mainly shows the static three-dimension space, but the ocean data shows the dynamic four-dimension space.

In the research of SIS, it makes the space environment as the application background as similar as the ground environment in GIS. And the Aerospace vehicle, the main object running in the space environment, is corresponding with the human activity, the main body in the geographic activity. The aerospace vehicle runs in the complex space environment, they changes data and transmits information with the ground control centres through the space environment. The space environment model's goodness directly relates the working performance and life of the aerospace vehicle.

But the research object of SIS is the dynamic four-dimension time-space data that includes all kinds of aero crafts, space environment and stars, and it is different from the two-dimension or three-dimension entity.

4.2 The Approach to Express SIS by GIS

4.2.1 Build "Digital Space" by the way of Digital Earth

The Vice President envisions the Digital Earth as a multi-resolution, three-dimensional representation of the planet into which vast quantities of data can be embedded.(A.GORE) A key goal is to move beyond the current desktop metaphor for user interfaces into a more natural, immersive environment that will facilitate navigation and interaction.

The vision looks something like this: Go into virtual orbit around Earth. Zoom in on any part of the planet and grab a detailed view of a road system, vegetation and weather, even an image of a single house or garden. Flick a virtual wrist, and you can even know the political layout of the community, all in 3-D.

" Digital Space", namely, creating "The space object and environment more dimension system" and real reproduction of the space environment and the space objects is similar to "Digital Earth" in many design idea and technology. But it has some difference with "Digital Earth" from the research object, the time-space specialty, the data management model, framework models, showing and output.

Referring the theory and technology of "Digital Earth" and considering enough the time-space specialty and data more-dimension of "Digital Space", we can integrate the entire space information to create "Digital Space". In this framework, we study the concept, contents and key technology of "Digital Space" and the relative theory system.

4.2.2 Organise Spatial Environment Data by GIS Data Model

The geographic space objects have four kinds of characteristic;(WANG, 2001) the space situation, property, spatial relation and time specialty. As to SIS, its objects have the similar characteristic.

According to the geometry position and space dimension specialty, the geographic space objects can be classified to five kinds, namely, point, line, area, surface and volume. In the SIS, all kinds of the space environment information are mainly line, surface and volume. Especially, the volume data model is the main data model in the solar-terrestrial space environment.

The space object's property is the geographic meaning data or variable related with the space objects. And it used to express the objects' inner character and the semantic definition of the space objects. In the solar-terrestrial space environment, there are many properties for only one space environment element. For example, the variables about the upper atmosphere that has definite spatial position have some properties, such as the atmospheric temperature, the atmospheric density, the atmospheric pressure and so forth.

The time specialty manifests the space object's variable with time change. For SIS, All kinds of the space environment elements change with time, including instant variable and long period variable. And besides, the space environment elements' models must input the time dimension to be calculated.
The spatial relation includes topological relation, order spatial relation, metric spatial relation and so on. For SIS, the solar-terrestrial space was been considered as a whole body. All kinds of space environment elements have one other relation; especially they have strong relation with sun. And the space environment elements' distributing is also order.
The common sort method to the spatial object in GIS is layer and level. For instance, the physiognomy can be sorted to river, road, building, pipeline, etc. And river can be classified different level. For SIS, the space environment can be sorted by altitude to atmosphere, ionosphere, geomagnetic field, radiation belt, etc. And every level has many sub-style sorted by variable.

4.2.3 Showing Dynamic Transformation Applying time-space Data Model

Already there are many design methods about the time-space data model. For instance, time as an additional property data, time as n new dimension, object-oriented methods and so on. At present, the main data models include Time-slice snapshots, Base Map with overlay, Space-time composite, etc. According the space environment elements' distributing and time specialty, we can adopt one model or methods, also can advance the new model based on them.

4.2.4 Visually Express the Three-dimension Space

Applying the old terrain three-dimension visualization technology, we can arrange space position by some space environment element' property to form the data set similar with DEM (Digital Elevation Model), and render the three-dimension scene by OpenGL. At the same time, we add time as its other dimension. Thus, these models in simulation mostly represent the dynamic sconces and computer motion.
For getting the whole visualization effect, we can directly form more dimension data sets based on the physical and mathematic models. In these setss, the space dimension was been divided to cube body with the same border, and the property of every point is the space environment element' every parameters, such as the atmospheric density, the atmospheric temperature, the electron density and ion density. For achieving the more dimension data sets' visualization, we should redescribe and plot by the data structure for the data sets, and set up corresponding geometry model, then form the three-dimension visualization image for any space environment element' property, through serials of the three-dimension visual processing including projection transform, window reduce, light model, colour adjustment and showing. Because there are many properties in every space environment element, we only adopt layer showing, transparency, translucency folding and alternation switch, etc. showing methods to get every space environment elements' visualization effect.
There is a test image to show three-dimension visualization about the space, figure 1.

4.2.5 Space Analysis and Assistant Decision-making

In GIS, spatial analysis is the space data analysis technology based on the position and configuration property of the

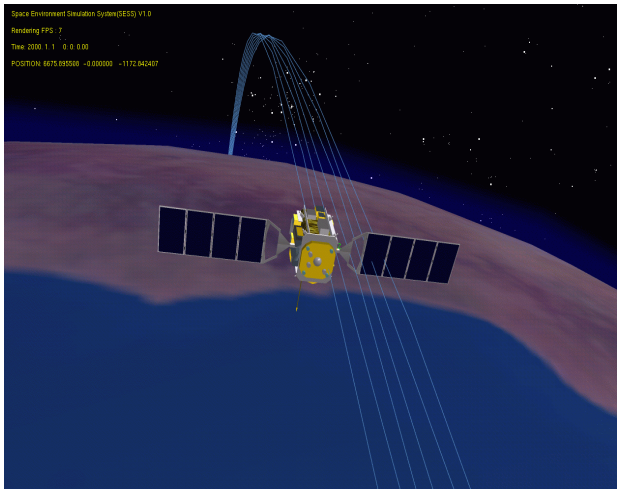

Figure1 three-dimension visualization about the space

geographic objects, in order to find and transmit the spatial information. According to the application order, there are many analysis methods, such as network analysis, overlay analysis, buffer analysis and the most short path analysis. In SIS, we can analyze the aerospace vehicle circuit by referring the spatial analysis models in GIS. For example, through calculating the space environment elements' property at some time and position, based on the correlative buffer analysis model, we can get the setss that affect on the aerospace vehicle, and control it not into the dangerous region. In conclusion, Combining the practice mission and GIS application analysis, we can advance the aerospace vehicle circulating safety.

5. CONCLUSION

In this paper, based on the research of GIS technology and the solar-terrestrial space environment, we extend the research field and object in GIS to the entire solar-terrestrial space and advance the concept of SIS-The Sun-Earth Space Information System. Later, It demonstrates that application of GIS to the space environment is feasible, and gives the concrete methods to resole the space environment problem by GIS. It not only extends the application of GIS, but also brings new method and way to study the space environment. But it only the simple research that apply GIS to study the Sun-Earth Space Information System, and there are many problems waiting for us to resolve.

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APPENDIX: THE SIS FLOW CHART