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# The Integration of Planetary Science Simulation and Virtual Reality Geographic Information System

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***Abstract:*** *A method for constructing a measurable virtual reality environment based on the ground image of the planetary exploration patrol device and the high-resolution satellite image is proposed. According to the three-dimensional images acquired by the patrol at different azimuth angles and height angles, a 360°panoramic image is generated through cylindrical projection, automatic matching and seamless stitching. At the same time, the inverse calculation function from the panoramic image to the original image has been developed, allowing users to directly measure on the panoramic image, and obtain 3D terrain information from the original stereo pair. The three-dimensional measurable panoramic image is seamlessly integrated with the planet browser based on NASA's World Wind, which provides a measurable virtual reality environment for planetary exploration applications, and realizes the integration from the vertical view satellite image to the ground horizontal view patroller imagemeasurement. At the same time, combined with the current popular computer research fields of virtual reality and three-dimensional technology, it focuses on the application of virtual reality and three-dimensional visualization simulation technology in geographic information systems, and analyzes virtual dynamic simulation, three-dimensional space analysis, virtual geographic environment, and three-dimensional data acquisition. Basic issues such as processing, three-dimensional data structure and models, and discuss the development trend of VR-GIS and 3D-GIS.*

***Keywords:*** *Planetary Science Simulation; Virtual Reality Geographic; Information System*

## 1. Introduction

VR and 3D are one of the rapid development and very active technical fields in recent years. With the rapid development of computer technology, space technology and modern information infrastructure, geographic information system (GIS) serves as the link between the three, in the information The importance of the process of modernization is increasing day by day. VR and 3D technology have also become hotspots in the field of GIS research. GIS is combined with virtual reality technology and three-dimensional simulation technology to bring the virtual geographic environment into GIS, which can simulate and reflect the characteristics of geosciences, and the processing is related to geosciences. The attribute elements of GIS enable GIS users to manage and analyze spatial entity data more effectively in the virtual environment of the three-dimensional objective world. Satellite images and patrol ground images are widely used in planetary landing missions. High-resolution satellite images are used for global mapping and landing zone selection. The ground image of the patrol device provides more detailed landform and spectral information of the landing area, and provides technical support for scientific target selection and path planning. The visualization and measurement of satellite imagery and ground imagery and the digital products generated by them are indispensable tools for the implementation of planetary landing exploration missions. They can also be used for planetary scientific research, education and popular science.

In the field of earth observation and geographic information, virtual reality and virtual geographic environment technologies have been widely used in the visualization of spatial images and data. Academician Li Deren and others proposed the concept of measurable virtual reality, and used orthographic images and their stereo The matching film realizes MVR for visualization and three-dimensional measurement, and then proposes the concept of digital measurable image and uses it in geospatial information services. Geographic Information System (GIS) technology has been applied to planetary exploration research and mission implementation, such as the interactive network geographic information system planetary analysis database developed by the U.S. Geological Survey and the Mars network geographic information developed by Ohio State University. System. But in general, the

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research and application of GIS and virtual reality technology in the field of planetary exploration are still relatively small, and their key technologies and application potential are far from being developed.

## 2. Simulation and virtual reality technology

### *2.1 The development status and characteristics of VR technology*

VR technology is the product of the rapid development of contemporary information technology and integrated with other technologies. It is the most effective advanced human-computer interaction technology that simulates the behavior of people in the natural environment such as seeing, hearing, and moving. This kind of simulation has the most basic characteristics. That is, Immersion-Interaction-Imagination. VR is a science that integrates people and information. The purpose is to express information through virtual experiences. It is combined with a variety of disciplines, including artificial intelligence, cybernetics, computer graphics, databases, Human-machine interface technology, sensor technology, electronics, robotics, real-time computing technology, multimedia and telepresence technology, etc. The application of data gloves (DG), data suits (DS), data helmets (HID) and other equipment makes users It is easy to manipulate the virtual environment.

### *2.2 The key technologies of VR*

#### *2.2.1 Immersive interaction technology and device sensing technology*

Virtual reality allows participants to interact with objects in the virtual world using human natural skills and perception capabilities, making people immersive. The current interactive technologies mainly include: real-time three-dimensional computer graphics, large-view three-dimensional display, and head Tracking, hand and posture tracking, three-dimensional sound, tactile feedback and force feedback, three-dimensional position sensor, etc. are shown in Figure 1.

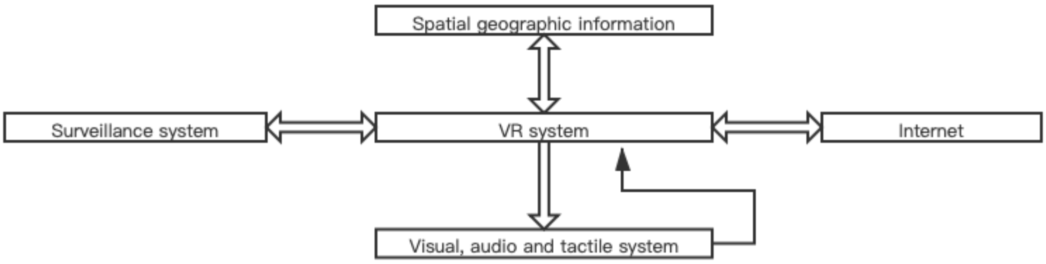


*Figure 1 VR system composition*

#### *2.2.2 High-speed computing power and computational complexity*

In VR, whether it is to simulate the high-speed motion of complex objects or the collision detection problem of complex moving objects, computers are required to have the ability to process data at high speeds, large-capacity storage, and strong networking characteristics.

#### *2.2.3 Smart Technology*

VR technology provides an environment of immersive interaction. Computers need to obtain information from various human activities, language and even expression changes. To correctly understand this information, artificial intelligence technology is needed to solve the problem. The current intelligent interface fields include: natural language Comprehension, language recognition, image recognition, text recognition and multimedia technology.

#### *2.2.4 Real-time graphic display system*

The perspective effect of the graphics display system makes the user feel real, and at the same time requires the computer to have a fast calculation speed and strong graphics processing in order to shorten the user's visual delay.

#### *2.2.5 Dynamic environment modeling technology*

The establishment of a virtual environment is the core of VR technology.The purpose of dynamic

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environment modeling is to obtain three-dimensional data of the actual environment, and to establish a corresponding environment model according to actual needs.Effective data acquisition is the key.

## 3. Application of virtual reality in planetary geographic information system

Nowadays, due to the rapid development of "3S" technology, more and more industries and fields are using geographic information systems (GIS) extensively to realize the scientific management of resource information and provide information services. Virtual reality and 3D visualization simulation technology are used in geographic information The application in the system will enable GIS not only to provide users with charts and data information, but also to manage spatial information while also managing information in the form of graphics, images, videos, audio, animation, etc., which is bound to greatly increase geoscience information. The performance ability of GIS has expanded the application field of GIS.

Combining virtual reality technology with the powerful spatial processing functions of GIS and multimedia technology, it can realistically reflect geological features in the virtual environment, making human-computer interaction more convenient, and users are immersed in a virtual environment created by a computer-supported GIS system In the virtual environment, interact with the virtual environment and get the same (or similar) feeling as the actual physical participation. Users can complete such things as navigation (moving viewpoint), selection, and manipulation in the virtual terrain, buildings, waters, and ecological environment. Interactive actions such as moving, zooming, rotating, etc.) and commands are displayed in front of the user through a stereoscopic visual device. At the same time, the three-dimensional audio equipment maps the parameter space (speed, state, type, etc.) of the simulated entity to the audio parameter space (pitch, tone, etc.) Volume, etc.), so that it is in a highly realistic audio-visual environment.

### *3.1 The concept of a measurable virtual reality environment*

Figure 2 shows the structure diagram of the measurable virtual reality environment. Its core components include a three-dimensional measurable panoramic browser and a planet browser based on World Wind. Among them, the three-dimensional measurable panoramic browser is used to browse and measure the 360 °panoramic image generated by the ground stereo image pair after cylindrical projection, automatic matching, seamless stitching, and image uniformity. The realization of the measurement function can be divided into the following steps: (1) Select the target point to be measured on the panoramic browser; (2) Back to the original stereo image pair from the cylindrical panoramic image coordinates, and find the point in the Corresponding pixel coordinates on the original stereo image pair; (3) Perform least-squares matching on the stereo image pair, and after obtaining the inner and outer orientation elements of the image, perform forward intersection to calculate the three-dimensional coordinates of the point. The World Wind global browser provides a platform for the visualization of digital elevation models and digital orthophotos. At the same time, the path of the patrol can also be superimposed on it. The two browsers are seamlessly connected to achieve an integrated measurement from the vertical view to the horizontal view.

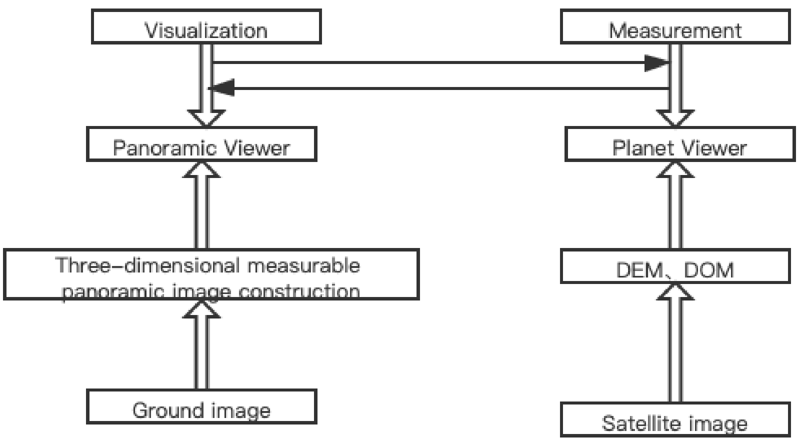


*Figure 2 Conceptual diagram of MVE*

***3.2 Data***

The ground image experimental data used in this article comes from Mars ground images taken by Pancam mounted on Mars Exploration Rover, MER. The baseline of the stereo panoramic camera is 30 cm, the image size of each camera is 1024×1 024 pixels, the main distance of the camera is 43 mm, the pixel size is 12 μm, the field of view is 16.8°×16.8°, and it has multiple spectra Band. The panoramic camera and the navigation camera are mounted on the high-precision gimbal together, which can achieve 360 °azimuth angle and ±90 °pitch angle rotation. The data used in the experiment are the Pancam stereo image pair resampled by the epipolar line and the derived 3D point cloud data. After epipolar re-sampling, the three-dimensional image pair eliminates the upper and lower parallax, which reduces the search range of the same-name point from two-dimensional to one-dimensional when the three-dimensional image is matched, which improves the reliability and speed of matching. After the three-dimensional point cloud data is matched between the stereo image pairs to obtain the points with the same name, the forward intersection calculation is performed according to the external orientation elements (position and posture) of the camera. Images and 3D point cloud data can be downloaded directly from the MER Analyst's Notebook website (http://an.rsl.wustl.edu/mer/mera/mera.htm). These data are automatically generated by Jet Propulsion Laboratory, JPL's Multimission Image Processing Laboratory, MIPL) through its software pipeline. The image resampled by the epipolar line is called the FFL file; the 3D point cloud data file is called the XYL file, and the epipolar line is aligned according to the stereo image. The resampled left image is the index and stores the ground coordinate X, Y, and Z values of each pixel in the local coordinate system of the work area. Figure 3 shows

***3.3 Measurable panoramic image construction***

Automatically constructing large-scene, high-resolution panoramic images is a research hotspot in the field of computer vision in recent years, panoramic images provide a large field of view that a single image does not have, and users can get a better sense of immersion.

***3.3.1 Panoramic image stitching***

Image preprocessing, under normal circumstances, the plane on which the rover stays will have a certain slope, resulting in the tilt of the horizon on the acquired , so that the stitched panoramic image appears wave-like distortion. Therefore, it needs to be corrected by the external orientation elements of the image.

$$\begin{cases} x' = x\cos k - y\sin k \\ y' = x\sin k + y\cos k \end{cases} \tag{1}$$

Where: x, y are the pixel coordinates of the original image; x′, y′ are the pixel coordinates of the corrected image; k is the rotation angle along the optical axis.

***3.3.2 Panoramic image measurement***

The panoramic image generated by splicing is only a two-dimensional cylindrical projection image. The realization of the three-dimensional measurement function is to obtain the position of the original stereo image through the inverse calculation of the panoramic image coordinates, and use the original stereo image to realize the measurement function.

The panoramic image coordinates are inverted back to the image after cylindrical projection.First, by reading the project file information, calculate the horizontal field of view ρ occupied by each pixel of the panoramic image.

$$\rho = \frac{W}{H_{\mathrm{fov}}} \tag{2}$$

Where: W is the width of the panoramic image; $H_{fov}$ is the horizontal field of view of the panoramic image; I $(x_p, y_p)$ is a point on the panoramic image; I′ $(x_c, y_c)$ is the corresponding image on the image after cylindrical projection point.

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$$\left.\begin{aligned} x_c &= \frac{\sin\theta\cos r}{d}x_p - \frac{\sin\theta\cos p\sin r}{d}y_p + \sin p\sin r\cos\theta \\ y_c &= \frac{\sin\theta\sin r}{d}x_p - \frac{\sin\theta\cos p\cos r}{d}y_p - \sin p\cos r\cos\theta \end{aligned}\right\} \quad (3)$$

## 4. Seamless integration of panoramic browser and world wind

World Wind is an open source virtual planet browser developed by NASA. In addition to earth data, World Wind also provides data on the moon, Mars, Venus, and Jupiter . The user can browse, pan, and zoom on the planet of interest. The data in World Wind is managed in XML format, and you can freely superimpose your own images, DEM, DOM, rover path and other data by writing XML files.

Based on the HiRISE stereo satellite image of the Mars rover landing zone, high-resolution DEM and DOM are generated and superimposed on the surface of Mars according to the latitude and longitude. In order to increase the rendering speed of World Wind, the image is managed hierarchically by building a pyramid. In each layer, the image is divided into 512×512 pixel tiles and indexed by the file name. Other data, such as the path diagram of the rover, can be added to World Wind in KML format.

The seamless integration of the panoramic browser and the planet browser is realized through image data and coordinates, in which the satellite-fixed global coordinates used in satellite images and the local coordinates of the landing zone used in ground images are converted in real time. As long as you click on the planet browser within a certain distance of the panoramic image site, the panoramic browser will be activated and the panoramic image will be displayed.

## 5. Conclusions

VR-GIS and 3D-GIS research still have great difficulties in three-dimensional data acquisition, data model and data structure, large data volume processing and storage, three-dimensional visualization, and three-dimensional spatial analysis. Geographical science uses virtual reality and three-dimensional technology not only. It can better promote oneself, deepen the level of theoretical research, and realize the interactive development between theories and applications of geographic science. In this paper, based on the characteristics of planetary landing patrol detection, a method based on ground panoramic images and satellite images is proposed. The virtual reality environment construction method is to automatically stitch the ground image into a measurable panoramic image, use the panoramic browser to directly perform three-dimensional measurement on the panoramic image, and seamlessly integrate the three-dimensional measurable panoramic image with the planet-based browser. The integrated measurement from the vertical viewing angle satellite image to the ground horizontal viewing angle patrol image.

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