

PRINCIPLE AND IMPLEMENT OF MEASURABLE VIRTUAL REALITY (MVR) BASED ON SEAMLESS STEREO-ORTHOIMAGE DATABASE

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ABSTRACT:

The idea and concept of Measurable Virtual Reality (MVR) based on seamless stereo-orthoimage database is firstly put forward. The meanings and basic principle of MVR is discussed in this paper. Based on stereovision of human's eyes, the main idea of MVR is to generate a seamless Digital Orthophoto Quadrangles (DOQ) database from DEM and odd photos and generate additionally a digital stereo-orthophoto partner (DSP) from DEM and even photos, then a large area 3D virtual landscape environment can be formed without y-parallax. In such environment, the 3D measurement and analysis can be done under the interface of normal GIS or CAD systems without complex DPW. The 3D objects, such as houses, trees, cloverleaf junctions, geologic ruptures, and so on, which are not acquired during data acquisition at DPW, can be measured by end user himself. The project design in such 3D virtual landscape environment will be more intuitionistic and more realistic. The application fields and the prospects of MVR are also presented in this paper. At last, some experiment results of MVR are discussed.

1. Introduction

Virtual Reality is a rapid development research domain in recent years and has been paid extensive attention by more and more people (Jinde Liu and Wanjun Jing, 1997). The development of Virtual Reality reflects the human requirement. With the rapid development of computer technology and popularization of its application, the performance and ability of data processing of computer has been improved day by day. During the interaction between human and computer, people pursue the way of freedom and realization and hope to interact with computer in the habits of our daily life. By producing vivid vision image on computer screen or in the other environments, virtual Reality can make people feel in the real world and can do some operations and controls of the system like in our real life. At the same time, the system can give real-time and correct response to the operators. In other words, virtual reality provides a virtual world for people; however, it can give people the sense like in the real world. But for the restriction of the factor in hardware, software and algorithms, especially the hardware, virtual reality is not mature and has a long distance that people have expected (Stephen R Ellis, 1994).

Virtual Reality has been applied in many fields. In geographic fields, the simulations of terrain and cyber city are the aspect of virtual reality. Terrain visualization is a hot topic in GIS researches domain. At present, the methods for terrain visualization are mostly based on the acquired terrain models or 3D geometric models (such as DEM, the 3D model of buildings etc). The 3D geometric models are built with the computers after the observation point and direction are given, and then a series of operations as render, object hiding, illumination, texture and projection have been carried out to create virtual topographic scenes. Because it depends on the computer hardware support, it can't afford to build a lot of 3D models in large area. In addition, 3D geometric models must be acquired before rendering. So we have to spend a lot of time and much

money on data acquisition. At the same time, there are many unsolved problems, such as constructing complex 3D models, the real texture, and so on.

Stereovision model based on human's physiological parallax is the foundation of photogrammetry. The means of rendering real terrain and ground features at the moment of photography with stereoscopic equipment is also a style of terrain visualization. The advantages of stereo model based images are only to restore the parallax at the moment of photograph without the complex course of constructing models. But as the images from original photograph have vertical parallax, the stereo model after a serial of complex orientation operations is only set up by a photogrammetric operators who is specially well trained and the stereoscopic range is only limited to the small overlap range of one stereo pair. The neighbor stereo models are separate and cannot mosaic seamless stereo image database over a large area. The stereo model based epipolar line images is free from vertical parallax, it cannot also be mosaic together because of their different epipolar line directions, the stereoscopic range is also limited a pair of images. T.Blachut and S.Collins put forward the concept of stereo orthophoto pair in 1968 (Kraus, 1984;Deren Li, 1988; Deren Li and Zhaobao Zheng, 1992). The main idea is to construct stereo model using orthophoto and a specially made photo called the "stereo-partner". Orthoimage has seamless characteristic and can generate a seamless orthoimage database. So the thought of constructing large range seamless stereo modal across stereo pairs is put forward. In addition, the stereo model based on stereo orthophoto pair has measurement characteristics. So it is called Measure Virtual Reality (MVR).

2. What Is MVR?

MVR is put forward vs. Virtual Reality in geographic fields. Its definition is as follows:

MVR (Measurable Virtual Reality) is measurable Virtual

Reality(VR), which makes use of the principle of stereovision of human's eyes. It is based on DOQ (Digital Orthophoto Quadrangles) and so called Digital Stereo-orthophoto Partner (DSP). DSP is a production of additional image in which the x-parallaxes are artificially introduced according to DEM. A geometrically correct 3D landscape model will be obtained by means of the stereoscopic view of DOQ and DSP with the stereo observation equipments such as liquid crystal glasses and anaglyphoscopes in GIS or CAD platform. We can measure the height and position of interesting features during viewing stereo model without complex operations, including those features that didn't be measured during data acquisition at DPW. As the orthophoto images can mosaic a very large seamless image or create a seamless image database. So every body himself can seamlessly stereo-view and measure the whole stereo landscape model in a large area (not only within a stereo pair).

3. Why MVR?

The main features of MVR are the two aspects of Virtual Reality and Measurable Characteristic. The geometrically correct landscape modal constructed by DOQ and DSP has only x-parallaxes and is free from y-parallaxes. So the stereo model is set up very easily without complex orientation operations. As the orthoimage has good planimetric geometry accuracy, we also can measure the height and position of interesting features during viewing MVR model by means of an automatic image matching method.

The advantages of MVR are at least:

- 1) The remeasurement of DEM will provide correction and refinement of existing DEM. The blunders of original DEM can be easily detected by using MVR.
- 2) Those 3D objects, which didn't be or couldn't be measured by the data acquisition at DPW, such as height and form of trees, geological features, the height of houses and so on, can be done with MVR by end users at normal GIS or CAD environment.
- 3) The different designer and engineer who works at 2D GIS or map environment can direct work at 3D MVR environment.

4. The Basic Principle of MVR

In the field of photogrammetry and RS, digital differential rectification is a very mature technology at present, which mainly uses for the production of orthoimage. Digital orthoimage not only has correct planar position, but also hold abundant image information. However, it is only two-dimension, not including three-dimension information. Though that can partly meet the fault by means of overlaying contour on the orthoimage, it is impossible to substitute for stereoscopic view to obtain stereo sense. Therefore, we can artificially produce a so-called Digital Stereo-orthophoto Partner (DSP) vs. Digital Orthophoto Quadrangles (DOQ). DOQ and DSP are all together called Stereo Orthophoto Pair (Blachut, 1968,1976). The basic principle of MVR is based on stereo orthophoto pair. Figure 1 summarily shows the basic principle of MVR(Kraus,1984).

As shown in Figure 1, the coordinate z of the grid XY points forms digital elevation model. Figure 1a shows the diagram of making orthoimage, directly transforming the elevation of grid point to original photo according to collinearity equation to obtain image data for orthoimage.

In order to obtain stereo landscape model, the x-parallaxes are artificially introduced according to DEM and right image. The simplest method for parallax introduction is to use parallel ray with a certain angle between Z-axis (Figure 2b) to make a projection to DEM. The artificial parallaxes reflect the feature of terrain and form an auxiliary image, which can construct a stereo model with orthoimage. Figure 2 is a vertical plane diagram of projection; take the ground point P as an example, the height difference relative to the plane of projection is Z, p_0 is the ortho projection point of P and p_1 is the slope parallel projection point of P. Orthophoto is obtained by ortho projection and Stereo Ortho-photo Partner is obtained by slope parallel projection. The parallax P is obtained by stereo measurement, so it is obvious that

$$P = \tan \alpha \cdot Z = k \cdot Z \quad (1)$$

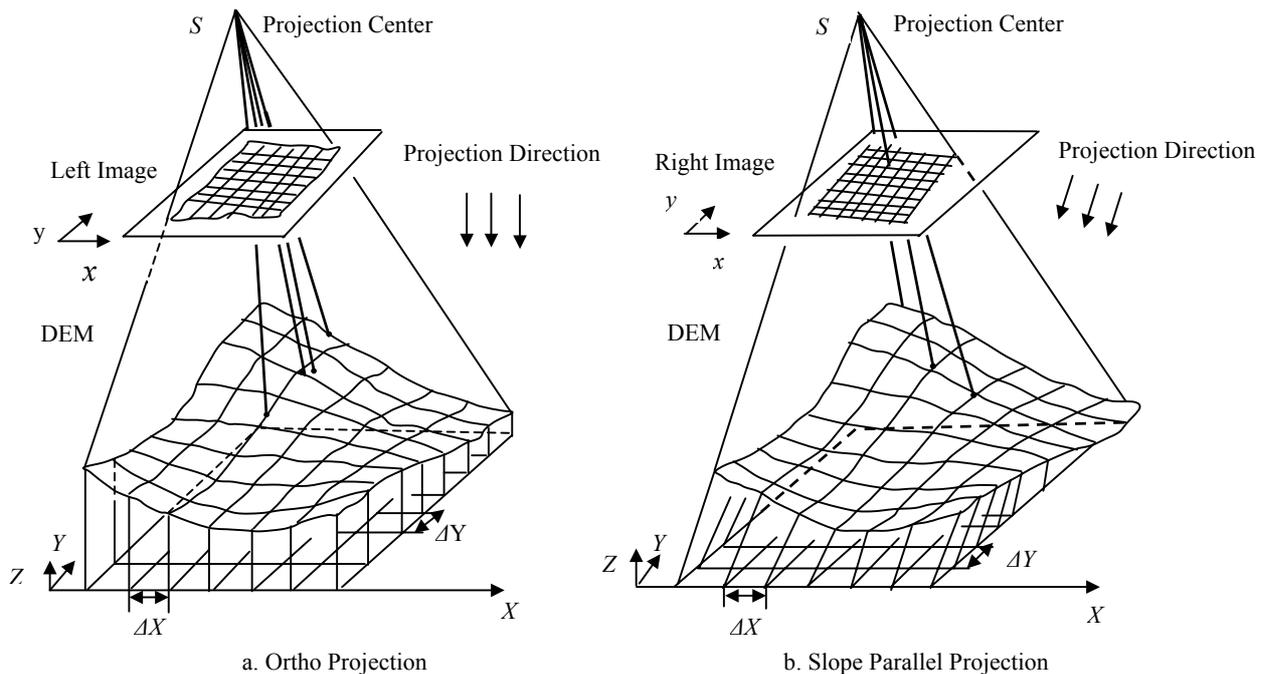


Figure 1 The Basic Principle of MVR

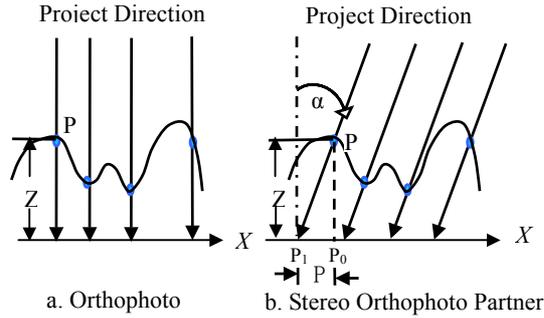


Figure 2 The Parallel Projection Method

As the direction of slope parallel projection parallel with XZ plane, there are only x-parallaxes between orthophoto and stereo orthophoto partner. Because they are generated from left and right photos of a stereo pair separately, it meets the prerequisite condition of stereo measurement and can provide not only planimetric correct position but also the height of ground point.

In order to make measurement, the angle α had better agree with the parallaxes of original stereo model, generally it is taken $\tan \alpha = \frac{B}{H}$, B is the base line of stereo model, H is the flight height.

The height difference relative to the reference plane can be calculated by the x-parallaxes measured from the stereo orthophoto pair divided by coefficient k and multiplied the denominator of photo scale. At last, the height is get after the height of starting point is added. The formula is as follows,

$$Z_i = \frac{P_i}{k} M + Z_0 \quad (2)$$

5. The Several Methods for Introduction of Artificial Parallax

An important advantage of MVR is the measurement of height information, therefore the correct introduction of artificial parallax should be a very important issue. Slope parallel projection above discussed is the simplest but not the best method; the other two more rigorous methods will be discussed in the following.

5.1 Logarithm Projection Method

The parallaxes introduced by slope parallel projection are linear function of height difference, which is not in accord with the parallaxes of original stereo model and can cause measurement problems. In order to overcome the measurement problems, logarithm projection is used to introduce parallaxes. The principle of logarithm projection is as shown in figure 3.

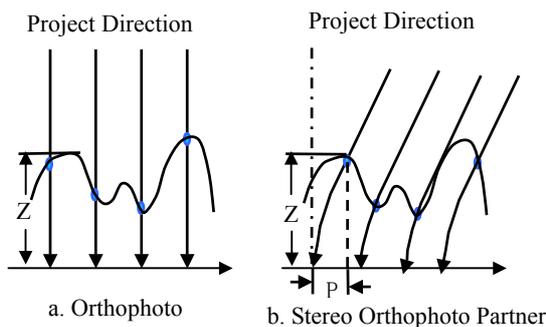


Figure 3 The Logarithm Projection Method

The parallax function of logarithm projection is:

$$P = B \cdot \ln \left(\frac{H}{H - Z} \right) \quad (3)$$

Where: B is base line of photograph

H is flight height

Z is the height of ground point

P is the parallax corresponding with the height of Z

In logarithm projection method, the height of ground point can be calculated by the following formula,

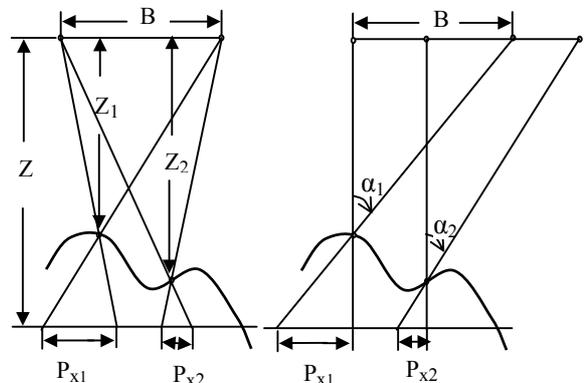
$$Z_i = H \left(1 - \exp \left(-\frac{P_i}{B} \right) \right) + Z_0 \quad (4)$$

5.2 Nonlinear Projection Method With Changing Angle

Though logarithm projection method can introduce the parallax in accord with the original parallax, the point of intersection between logarithm function and DEM must be solved by successive approximation. So it is considered that using other method to replace logarithm projection.

As shown in Figure 4, Figure 4a shows the parallaxes produced by the different height difference of ground point relative to reference plane during photography. Figure 4b shows two projection rays with the angle α_1 and α_2 for producing the same parallax with the parallax of original photograph. From the geometry relation in Figure 4, we can obtain,

$$\tan \alpha_1 = \frac{B}{Z_1} \quad \tan \alpha_2 = \frac{B}{Z_2} \quad (5)$$



a The Original Parallaxes b The Introduced Parallax Identical with Original Parallaxes

Figure 4 The Original Parallaxes and Introduced Parallaxes

Therefore, in order to accord with the original parallaxes during photography, Nonlinear Projection Method With Changing Angle is put forward for introducing parallaxes. Figure 5 shows the basic principle of this method; the angle of ray is changing with the height of ground point.

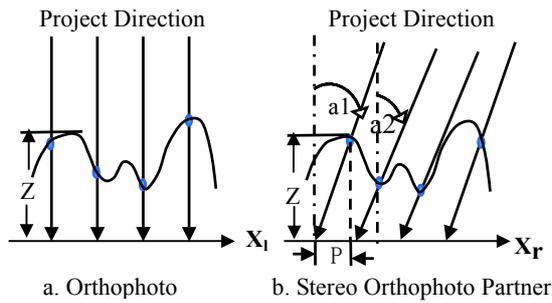


Figure 5 Nonlinear Projection Method With Changing Angle

The parallax function of Nonlinear Projection Method With Changing Angle is:

$$P = \frac{BZ}{H - Z} \quad (6)$$

The height of ground point can be calculated by the following formula,

$$Z_i = \frac{PH}{B + P_i} \quad (7)$$

6. How To Generate MVR?

The principle of MVR has been described above. As the stereo orthophoto pair is limited only a pair of photos. However, MVR requires seamless roaming and viewing the stereo model in a large area. So it should be considered the whole working area and meet the requirement of DOQ and DSP coming from left and right image while producing MVR. For this, the rule for producing MVR must be observed. Now, take three tripes with ten photos of each as a example to illusiarte the rule.

Firstly, the photos is encoded along stripe direction as shown follows.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30

- Denotes making DOQ using odd number photo
- Denotes making DSP using even number photo

Figure 6 The Data Organization of MVR

According to the above way of data origination, the steps of generating MVR are as follows.

Step1: Digital Orthophoto Quadrangles (DOQ) generated from left image (1,3,5) and DEM

Step2: Image database generated from DOQ to construct a large seamless area through digital mosaic.

Step3: Digital Stereo-orthophoto Partner (DSP) generated from right image (2,4,6) and DEM using above method

Step4: Automatic retrieve of stereo orthophoto pair from DOQ and DSP image databases

Step5: Using liquid crystal glasses /Anaglyphoscopeto to observe and measure continuous real 3D object by using image

matching software.

In order to measure the height of ground details, the DSP should be produced by the methods of logarithm projection or nonlinear projection with changing angle that can achieve better measurement precision. In the case of the area with little ground features, the slope parallel projection may be used, however, the slope angle should be the tangent of base line and flight height and the flight height should equal the average height of the stereo model. If the height doesn't be care about, DSP can be produced by simple slope parallel projection, which may be used for image stereoscopic interpretation.

7. The Application Fields and Prospects of MVR

7.1 The Advantages of MVR

Simply compared with the product of orthoimage, there are many advantages of the stereo model formed by MVR.

1. The convenience of orientation and measurement. As DOQ and DSP have the same scale and no y-parallaxes, it is convenient for the operation of model orientation. The height calculation can be accurately solved according to formula of parallax introduction. So stereoscopic view and measurement can be performed without knowing a lot of knowledge of photogrammetry

2. The whole process of observation and measurement doesn't need professional skills. The non-photogrammetry experts and engineers can easily learn and use MVR to solve their own problems.

3. The Measurement of MVR can be at any GIS or CAD environment. At present, the advanced PC can equip with corresponding stereo display and measurement instrument.

4. The stereo model formed by MVR is the best medium for photogrammetry to cooperate with other disciplines, such as engineering design, planning, forest, geology etc. Non-photogrammetry operators can acquire their wanted information by themselves with very simple stereo measurement equipment through MVR.

7.2 The Application Fields and Prospects of MVR

At present, MVR can be applied but not limited in the following aspects:

1. The map of forest and vegetation diseases and insect pests. The tree and vegetation can be precisely classified in the stereo observation using the MVR formed by color infrared image, including directly measuring the height of vegetation.

2. The area evaluation of used farmland. MVR can help identity the classified edge of land and directly measure the area in stereo environment. It is very good for researches on the shape of the earth's surface and water loss and soil erosion.

3. The preliminary plan of traffic line. Ortho photo is the foundation of traffic line planning, which can spend short time and less money. MVR can really reflect the condition on the spot and form a large-scale seamless stereo model, so it is very convenient for interpretation, selecting line and measuring vertical plane.

4. Selecting lines for electric power system and making the map

of vertical plane

MVR provide a virtual stereo seamless geometry model, which can precisely make measurement on the ground surface and are very convenient for selecting lines for electric power system and making vertical plane.

5. Map Revision.

MVR can be immediately produced as long as there is DEM database. It is availability for revising the ground features and the little change in height. It is proved through experiments that ortho photo is more convenient for map revision then original photo. However, MVR can make out more 50 percent ground features by stereo observation (Kraus, 1984).

MVR can be regard as a bridge to communicate between photogrammetry and other disciplines. The terrain surface of nature is complex and changeable. So it is very arduous tasks for providing service only by photogrammetry workers, and furthermore, the requirements are different for different fields. For example, forest branch may be interested in the height of trees; planning branch may be interested in the height of houses; geologic branch may be interested in the height of geologic ruptures. If the stereo model formed by MVR is taken as a new

digital product, the geologist, the forester, the planner, the engineer or any other user of aerial photograph can easily use the accurate stereo model by himself over the whole project area.

8. The Experiment Results and Conclusions

According to above principle, two test area with different image scale are taken. The parameters of the photo are shown in Table 1.

The stereo model can be observed with crystal glasses or anaglyphoscopeto. The following two experiment results are a part of the whole stereo model and the stereo model can be directly observed with anaglyphoscopeto. All kinds of ground features can be really viewed during stereoscopic observation. At the same time we can roam the whole stereo model across stereo pair and measure the height of interested ground features with stereo mark. It is sufficiently proven the feasibility and prospect of MVR.

As the content of this paper is limited, the measurement accuracy of MVR will be discussed in another paper.

Table 1 The Parameters of Photography

	Test I	Test II
Principle Distance	153.710mm	152.400mm
Photo Scale	1:25000	1:8000
Format	23CMX 23CM	23CMX 23CM
Photo Type	Grey	True Color
Pixel Size	25um	50um
Average Flight Height	4225m	2090m
Resolution of DEM	12.50m	5m
Resolution of orthoimage	1m	0.5m
Data Range	Two Strips and Three Stereo Model of Each Strip	Five Strips and Five Stereo Model of Each Strip

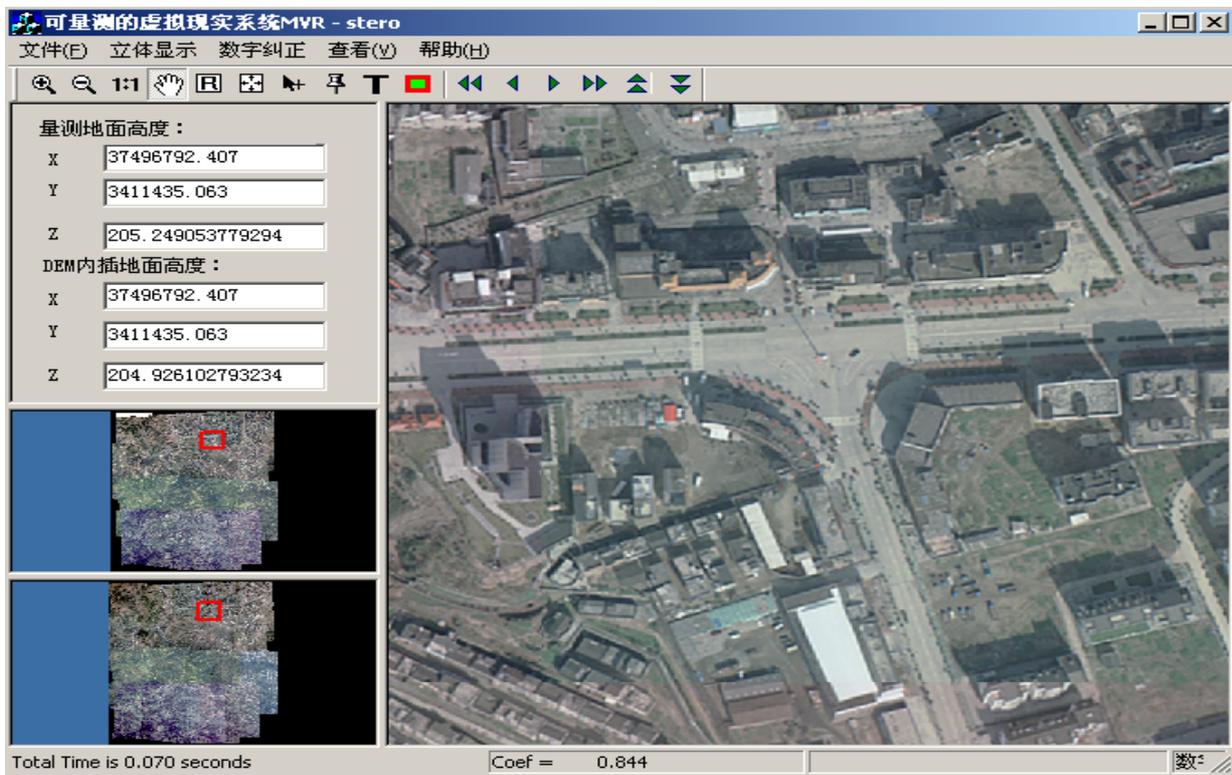


Figure 7 System Interface of MVR



Figure 8 a Test Area I: Guangxi Province in south China



Figure 8 b Test Area II: Three Gorges Project Area

Figure 8 The Experiment Results

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