FROM HILL SYMBOL TO TERRAIN SIMULATION

------ The Evolution of 3D Relief Presentation

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Abstract: It is a difficulty and a focus of cartographic research to present three-dimension form of relief on map. The development of relief presentation reflects the improvement of cognition about natural environment and the progress of science and technology, and represents the progress of cartography. Reviewing the evolution of relief presentations is helpful for us to feel the history of cartography and foresee its future. The paper describes the evolution of 3D relief presentations and the related background of culture and technology as well as important persons chronologically.

Key words: Relief presentation; Pictorial symbolizing; Planimetric presentation; landscape simulation; Virtual reality

Map is the result that human search after the natural environment and the gist that people comprehend the element. Among all the factors of natural environment, relief is widely outspread and diversiform, it is a base of the other. Relief was rendered very precisely on one of the oldest maps which survives today ------ the representation of northern Mesopotamia, scratched into an earthenware plate, dating from about 2400-2200 B.C, and the map which was found in the grave of “Ma Wang-dui” in China, dating about 2000 years ago.

Relief is the variations in elevation of an area of the earth's surface[1]. Presenting relief on the plane is always a challenge of cartography. Cartographer Denis Wood said that “Everyone agrees with that hill is the most difficult to dispose on the map. ” He invoked David Greenhood’s words to say that a cartographer, “shows his real creativity only when he represents the 3D objects on the plane”[2]. Among all the factors of natural environment, relief is a 3D entity with length, width and height, the change of its shape is continuous and irregular, and its surface contains many minute structures. Only known and represented correctly, relief can be rendered nicely. Technology and art are both concerned here. Eduard Imhof ‘s viewpoint that being an technology and an art, map has a peculiar dual nature can be proved with the representation of relief[3].

With regard to the relationship between map and culture many scholars researched it deeply. In 1960s, Chinese cartographer Gao-jun pointed out that “map reflects the level of culture for a period

of time. Because it can not only manifest the degree of human cognition about the earth's surface and generalize the knowledge about Geoscience, but also show the basic status of art, aesthetics and printing technology at that time."[4] Denis Wood said also: map was a part of culture. He thought culture exerted a subtle influence on the cognition of map, for an instance, children could understand many maps inserted to books without legends[2]. Most of ancient maps of China had not legends, such as "HuaYiTu", "YuJiTu", but the meanings of the maps were clear.

The progresses of technology make people understand the world on the scientific viewpoints, explore the world with scientific methods, describe the world by advanced technology. To cartography, its significance is: it not only can deepen the people's cognition towards the natural environment, but drive the amelioration of map representation, and enrich the kinds of map. Let's look at the history of map, the information's carrier of map changed from stone, wood, paper and silk to disk and CD; the variety of map developed from handcraft to printed map and electronic map; the representation of map developed from hieroglyphy to abstract symbol then to simulation. All these changes embody the power of technology.

The idea and skill of cartographer is restricted by culture and technology at that time to a certain extent. But the cartographer's personal diathesis of art and creativity is the key to the development of map and its representation. A new representation and a new map variety are realized by a group of artistic and technical geniuses. Leonardo da Vinci and Eduard Imhof .etc are this kind of geniuses, their works stood head and shoulders above the other maps of the time, they made great progress in cartography.

1. The evolution of pictorial symbolizing

At the beginning of human civilization, because of lacking the whole understanding of natural environment, having no need of surveying and corresponding method, the describing of relief was limited at the range of movement, the terse and visualized pictorial symbolizing presentation of hill's side face was used at large. It can be divided into two kinds: one gives emphasis to the side figure of mountain, its effect looks like the silhouette of mountain from a viewpoint. Its characteristic is this method presents mountain chains not hill, and the figure of mountain is gotten from a certain direction. For example, the map found in the middle of Baja, California, North America rendered on the rock by aborigines of Indian used this presentation [4]. Because of the obvious constrains of this presentation, it's not common to be seen in the ancient maps yet, but in the modern chart, the map drawn with this presentation is usually used as attached drawing in order to present the land's figure watched from sea. The other gives emphasis to the symbol of individual hills, but a symbol is not always presented a hill. The characters of this presentation are: 1) it's just a sign, it meant there existed a hill[2]; 2)the symbol had the same shape, it presented the common characters of the hill in the side view; 3)the difference of the hill's shape incarnated by embellishment; 4)mountain and mountain chain were presented by the combination and arrange of the symbol. This presentation prevails for thousands of years , it was also used on the outline at present. But in the course of its development, this presentation evolved gradually into two aspects, the difference between these two

aspects showed by the form and arrangement of symbols.

The first trend followed the presentation on the ancient Babylon map (called hill symbolizing), the form of hill symbol looked like the regular and simple rounded dome. For the first instance, the symbol was arranged in row which was perpendicular to the axis of the valley, it's clearly limited by the range and way of movement. In the medieval (6th –15th century) effected by the style of the Gothic era, the hill symbol differed into heart-shaped, lancet-shaped and arch-shaped etc. These symbols were arranged by the perpendicular direction up and down with respect to the plane of map. This constituted a significant advance in graphic technique. Areal agglomerations of the symbols, either like fish scale or terrace, indicated extended mountain masses.

The second trend appeared at the Renaissance period, called "birds eye view pictorial representation". In the 16th century, topographic survey methods, with compass, measuring chain and measuring cart, were to replace simple reconnaissance and elementary compilations, prepared from travelers' tales. Scientists and artists were both interested in the exploring and knowing the nature environment. Leonardo da Vinci was a outstanding person of this period of time, he drew some Tuscany maps in 1502-1503, using the birds eye view pictorial presentation for the first time to show relief forms which were individual lifelikeness and whole concatenation and were close to reality. This was just a shortcoming of hill symbolizing. At the hill symbolizing, there were blanks among hill symbols, it made the absence of mountain's entire effects. Leonardo da Vinci's works was the important marker in the history of relief presentation in no doubt.

In the middle of 16th century, the woodcut and copper engraving brought Leonardo da Vinci's technique to its peak. By comparison, copper engraving took great effect on the planimetric presentation later. The ancient map of our country appeared at the stage of confusion of drawing and letter[4]. Our letters had the double meaning of letter and symbol, took the unique function on the presentation of relief.

Four xylographs were come up out of land in Fang Ma-tan , TianShui, GanSu province, in 1986, there were seven handcrafted maps on them, dating from about 238 B.C, and they are the oldest maps that survive today. Two mountains names were marked with different frames in size to show their ranks[6]. It's a method using letters to show the existence of mountain. In addition, the "ma Wand-dui maps" were unearthed in 1973,ChangSha, dating about 168 B.C. On the "garrison map" which was colored drawn, the combined method of the letter "山" written in seal character was used to show the orientation and direction of mountain symbolically. It's the intergradation of relief symbol from letter to symbol.

In the later maps, the presentation of relief tuned to mountain symbol too, and there were also two trends. One was the combination of individual symbol according to perspective to show the mountain's tend towards on the base of mountain symbol. It's almost same as European method at that time, such as "HuaYiTu "(1117), "GuangYuTu " (about 1555), "HuangYuQuanLanTu " (1718) etc. The other gave priority to landscape painting, all the ground objects were rendered as their true shape, no orientation was concerned here. In hilly country, the direction of map could be changed as random for the sake of avoiding envelop. The difference between Leonardo da Vinci's birds eye

view pictorial representation is that this method was short of the base of surveying, so it's difficult to distinguish it from landscape painting. Accordingly, some good maps were collected as famous painting [4].

2. The evolution of planimetric presentation

Geographic research and the techniques of trigonometric and topographical survey lead to further progress of cartography in the 17th and 18th centuries. Because of accuracy and density of surveyed points, it's possible to depict relief on the plane according to planimetrically principle. The Zuericher Kantonskarte,at a scale of 1:32,000,in 1667 was the first map used planimetric presentation. These maps presented an outstanding vertical view of the landscape, rich with natural colors and three-dimensional realism, and the technique was far and away from other maps at that time. But this gem of Swiss cartography did not influence the mapmakers of the time, as it was kept hidden away as a military secret. In 17th century, mountain symbolizing was the primary method of relief presentation.

In the 18th century, France used advantaged method of geodetic survey and triangulation and precise leveling, compelted modern national triangulation for the first time, and copper engraving reached its highest stage of development. In support of this technique, Cesar-Francois Cassini de Thury and his son made the 1:86,400 scale French maps, and published between 1750 and 1815 (total 184 sheets) .Although these maps brought no progress in terrain representation, it did pave the way for a planimetric depiction of hills and mountains, through the accuracy of its other planimetric detail, so they were thought to be the most important map series. In the early 19th century, Swiss first turned side-view presentation into planimetric presentation, and completed of the 1:10,800 scale maps,total 16 sheets.

With the transition to planimetric presentation, a new problem of relief representation appeared. Firstly, people couldn't observe mountains from above, so nobody knew their true appearance; secondly, copper engraving could copy only line drawings in one color, so it's the only way to represent the continuous change of shade on mountain by line drawings; finally, the demands of geometry and content increased with the need of military and politics, the presentation of relief would have both 3D effects and orientation accuracy, and it should have no effects on other features on the map. In this case, the hachuring emerged as the times require in Europe. The hachuring described the shape of mountain by sets of short lines that were arranged along the mountain with regular intervals. It could be divided into two kinds: "slope hachuring" and "shadow hachuring". The first method rendered the hachuring lines on the base of change of slope, steep gradients appeared dark from the accumulation of heavy hachures, and gentle slopes with fine hachures appeared lighter. This method could represent the variety of slope, but the third-dimension impression was not strong. The latter rendered the hachures on the base of shade. Support there was a left illumination, on the illuminated slopes of the mountain lines were drawn very finely, and very heavily on the shaded slopes, and the slope lines were arranged with regular intervals. This method increased the third-dimension impression clearly, and the magnum opus at that time was topographic map of

Switzerland 1:100,000, called “Dufour map” also. This map series, of 24 sheets, is considered to be the finest and clearest map of any high mountain region to have appeared at that time. The hachuring was the most widely used relief presentation, until the middle of 20th century.

Contouring appeared almost at the same time with hachuring, they brought both on the base of surveying. In fact, when hachures map was made, the drawing of hachures lines was on the base of imaginary contours, two sides of every slope line were oriented at neighbor “contours”. But the real contour maps were produced in large scale after the appearance of photogrammetry, because it increased speed and accuracy of surveying.

The contour is also primarily ficticious in character, it’s not exist in reality. It does, however, possess the extraordinary advantage of recording and conveying, in a satisfactory manner, the geometric form of the terrain, elevation, differences in elevation, the angles and directions of slopes, and so on. But its shortcoming is evident: to be short of the 3D impression, to be difficult to understand. As contours produce such a poor visual impression of relief, what the cartographer could used to increase the 3D impression was changed the weight or color of the line. The regular methods were “thick and thin contour” and “light and shade contour”. The first way of former was increasing the line weight as elevation increases, contour with same elevation had the same weight. This method was easily to render, but the 3D impression was not enough. The second way was following the principle of shading, the more dark the mountain was, the heavier the contour was, every contour had the different weight in different place. This method had strong 3D impression, but it’s difficult to render. The “light and shade contour” followed the principle of shading also, the difference is dying a middle bright color on the map uniformly, on the illuminated slopes of the mountain contours were drawn in bright color, and in dull color on the shaded slopes, correspondingly the lines changed in thickness. These two methods appeared in the middle of 19th century, but because of the difficulty of drawing, there were only several countries which had advantaged technology such as Switzerland, France, used these methods to produce a little amount of maps.

In the year 1796,the Germany Alois Senefelder had invented lithography, and in 1840, it was employed in the reproduction of maps. This technique made possible the production of multicolored maps, and also drove the appearance of shading and hypsometric tinting. Shading is a method to describe the shade of mountain following the principle of illumination and perspective. The difference between this and hachuring is that this method can reflect the variety of shading by the continuous gray tones produced by ink, when original map for printing drawn. Lithography turns this color into microdot with different size, these microdots were very small, the human eyes are not aware of them, so produces the continuous effects of shading visually. Shading is the best relief presentation with 3D impression in planimetric presentation. Hypsometric tinting is a method that sets the different color on the different elevation zones according to a certain rule. With the change of color brightness, the hypsometric tinting can be divided into two principles “the higher, the lighter” and “the higher, the darker”; with the change of color, can be divided into “red & green color group ” and “natural color group”, etc. The rules mentioned above can be used compositely. The extraordinary advantage of hypsometric tinting isn’t in the 3D impression, but represents the

distributing rule of mountain elevation zones and lively effect of background.

Lithography made possible the combination of several relief presentations. Every presentation mentioned above has both advantage and shortcoming, to combine them organically can learn from others' strong points to offset one's weakness. In 20th century, the combination of several relief presentations was widely used, the magnum opus was the Switzerland relief map presided by E.Imhof, the Helvetian cartographer. E.Imhof was the first ICA chairman, he made great progress to the development of map in 20th century. He claimed that cartography should be divided into two kinds: the theoretical cartography and the applied cartography, gave emphasize to the status of art in cartography. He used colored shading and charcoal drawing to draw bare rocks successfully, and made the relief presentation of Switzerland on top of the world[8][9].

From 6th century to 17th century, the proportion of our nation had been more than 54% in great technology production on the world, but in 19th century, dropped to 0.4%[7]. it can be validated on the map. In Ming dynasty, Zheng He navigated to occident for seven times, the farthest place was south of African east coast, and entered to the Red Sea. B.Diaz founded the Hope after 53 years of Zheng He's final voyage (1486). Our nation was late near 100 years to the Europe of relief presentation from pictorial symbolizing to planimetric presentation, just at the end of Qing dynasty, hachuring appeared. Sometimes there were some maps used contour, but the craft was very coarse, so couldn't bring the influence to the relief presentation at that time. In our nation, using contour correctly was after 20th century.

3. The formation of landscape simulation

Pictorial symbolizing developed when planimetric presentation expanded fast and was used widely. On the contrary, because of the progress of technique, especially the progress of computer technique, with the help of planimetric presentation, the accuracy and effect of pictorial symbolizing made great progress, and now it has been a terrain simulation presentation which is a practical method to simulate the terrain vividly.

The best virtue of pictorial symbolizing is that it can present the relief with the viewpoint which people habited to, then improve the effect of watcher's cognition to the natural environment. In the middle of 20th century, in the course of improving the accuracy of pictorial symbolizing, there appeared three methods based on the contour projection transform ------ perspective pictorial symbolizing, axonometry pictorial symbolizing, and inclined contours. Perspective pictorial symbolizing follows the perspective to describe the relief. The perspective is a result of which represents three-dimensional objects and depth relationships on a two-dimensional surface. To graphics, the objects with same size will have different size on the plane, the nearer the objects reach to the viewpoint, the bigger, otherwise, the smaller. To shading, in the same condition of illumination, the nearer the objects reach to the viewpoint, the brighter, otherwise, the grayer. The landscape that was drawn according to perspective has a strong 3D impression as according to the visual habit. Axonometry pictorial symbolizing follows the axonometry projection to describe the landscape. The difference between it and perspective pictorial symbolizing is that to the objects with same size in the same illuminated condition, the size and shading of objects on the plane has nothing to do with

their place, that means the objects have the same size and brightness no matter how far it is from objects to the viewpoint. These two methods can present the orientation of mountain and the relative height accurately, but because there is no clue to survey the elevation and coordinates on the plane accurately, it is used only to reflect the topography. Inclined section symbolizing supports there is a group of parallel inclined section with same intervals, they intersect with ground in accordance with an angle, project the intersected lines to the plane, and form the pictorial map watched from inclined upside. This method can keep the place of mountain on the map, and has 3D impression to a certain extent, especially easy to deal with the relation with other objects shaped as line. But the 3D impression is relatively weak [10].

Since the 60s in the 20th century, the development of computer technology has brought great change to cartography, produced a series of theory and practical production, the important one is digital map. This kind of map that is saved in computer storage in the form of figure, has changed the production of map, the using of map, and the manifestation of map. There are many maps, can be classified to real map and virtual map, animated map and static map, planar map, three-dimensional map and virtual terrain environment [11]. Virtual terrain environment does be the developing direction of modern relief presentation.

Virtual terrain environment is an interactive, present terrain circumstance made of the technique of virtual reality on the base of digital map. The user can immerse the lively environment by the way of natural interaction through certain equipment for watching. The difference of traditional map used is that user is an actor not a spectator.

Virtual reality called artificial environment also, is a high tech simulated system produced by computer. It is a general and perceivable environment given priority to visual including hearing and feeling also, and user can watch, operate, touch and check in this artificial environment through certain equipment, and be personally on the scene[10]. The production of virtual reality is the result of people's pursuing to real scene and the development of computer.

The technology what is very important to the production of virtual reality should be run down to the middle of 19th century[12]. In 1824, Peter Roget found the after image in human visual system, and calculated the time of after image. This great discovery became the foundation of movie and TV image, and it's a physiological gist of virtual reality's 3D impression also. In 1833, the cameraman invented stereoscopic display in order to make photography attract more people. By using the glasses, the watcher's left eye and right eye can see left and right images that were shot twice or by the double lens and double negatives camera. This way can make people establish the physiological 3D impression, and have intense effect on the depth of field, modern technology of virtual reality used this idea too. In 1889, Edison invented kinetoscope, it made people found the dynamic scene was more lively and exact on the environmental describing. In 1941, the signal of TV broadcast formally. TV made the seeing and hearing system widely distribute. And the more important is it leaded to the appearance of telepresence, that means people will be personally on the scene through the video camera from which is far away.

In 1968, Douglas Engelbart invented mouse by which people can interact with computer, after

that the user-oriented man-computer interaction appeared. In 1966, Ivan Sutherland invented the first HMD joined with computer. Through this element, the watcher can't see the computer, but enter entirely to the environment produced by computer. In 1985, Jaron Lanier organized the VPL Co., this is a realm of virtual reality, it not only brought forward the concept of virtual reality, but made the data glove------which was used to man-computer interaction. Today, HMD and data glove have to be hardware symbol of virtual reality. In 1988, NASA assembled the first virtual reality system ------ VIEW(Virtual Interface Environment Workstation) used these techniques. This system included a computer, a data glove, a HMD and a speech recognition system, user can see the 3D scene, hear the 3D sound, order and snatch at the virtual objects which were produced by software [13].

The research of virtual reality needed a great deal of outlay, the U.S. Department of Defense devoted a lot of outlay (it is called the cradle of virtual reality), so the production was used in military affairs. For more than ten years, virtual reality has been used in many fields, such as weapon design and experiment; plane, tank, ship drive training; powerful weapon operate training; command training and campaign simulation, gotten a great deal of military and economic benefit [14][15]. So, the U.S. Department of Defense has ranked it as main training tool in the 21th century.

Virtual reality uses for terrain simulation and finally becomes a relief presentation is a certain result of the deepening of human cognition to natural environment and the development of technology. At the beginning of the appearance of virtual reality, the sensitive cartographer has been on to that the function of map will be expanded supported by this advanced technique. Academician Gao Jun began to pay attention to the development of virtual reality in the middle of the 80s, and took the lead in using virtual reality to battlefield mapping support [16]. He pointed out that "from traditional map to electronic map & information system supported by database and then to battlefield virtual reality supported by environment information system will be a safeguard mode up to technique and logic"[17]. With his advocating and mastering, our army's virtual battlefield environment building started at high level, and has gotten a series practical productions, the research and training of our army's terrain simulation has reached the advanced level in the world [18].

4. Conclusion

From above we can see, for centuries, the presentation of relief wandered among reality, accuracy and calculation. Among all the relief presentation, no one can meet all the three requests except terrain simulation. Not only this, terrain simulation can also "be entered", interact, user will have the real feeling about the environment, then improve the effect of environmental cognition.

The highest level of virtual reality is the virtual environment is same as real environment, so the user is difficult to distinguish them. But there must be a very long time to reach it. In this degree, the research about terrain simulation is just at beginning. In the future, terrain simulation will make progress in these aspects: 1) the way of stereoscopic observing will improve greatly, the way now we used need stereoscopic display or HMD, it is trouble to user. The new techniques such as auto stereoscopic observing liquid crystal display and hologram offer user an evident spatial scene without any additional elements [19]; 2) the research about DSM according with the need of virtual

terrain simulation will make great progress then be used in practical. Now, there are some grand evolvements in multi-resolution modeling, model simplification and multi-resolution surface description, it has come true that terrain simulation with macro vector data interact displaying of real-time on PC [20] [21] [22]. 3) a research system will be built with the influence of terrain simulation technique. The system will make use of all kinds of production of surveying and mapping to terrain simulation, provide mapping safeguard to kinds of applications. For example, a research system for battlefield terrain simulation is coming into being, battlefield environment supported by high tech will be built for military command and training.

Reference

[1] Surveying and Mapping Dictionary Compiling Committee. Surveying and Mapping Dictionary [M]. ShangHai: ShangHai Dictionary Publishing House, 1981.

[2] Wood, D. Writer, Wang Zhi-hong, Translator, The Power of Map [M], BeiJing: Social Science Publishing House of China, 2000.

[3] Imhof,E.. Cartographic Relief Presentation, Walter de Gruyter. Berlin. New York.1982.

[4] Gao Jun. The Discussion of the Evolvement Characters of Mathematic Features and Presentation of Our National Map [J]. ACTA Geodaetica et Cartographica Sinica, 1963(2).

[5] Woodward,D. &Lewis, G.M..The History of Cartography. Vol. 2, University of Chicago Press, 1998.

[6] Gao Jun. The Compendium of Chinese Map History [M]. ZhengZhou: Teaching Materials of Institute of Surveying and Mapping, 1998.

[7] Jia Feng-shan, Tang Ming. The Problem of Joseph. Lee and the Answer. The Newspaper of PLA[N]. 2000. 11. 15 The 11th edition.

[8] Imhof, E. .Tasks and Methods of Theoretical Cartography. Cartographica, Monograph, No. 19. 1977.

[9] Gao Jun. The Theoretical Cartographic Research In Europe [J]. Military Mapping, 1982(2).

[10] Gao Jun, Xia Yun-jun, You Xiong, etc. The Application of Virtual Reality on Terrain Environment Simulitation [M]. BeiJing: The PLA Publishing House, 1999.

[11] Gao Jun, Cartography In 21th Century [C]. Proceedings of Institute of Surveying and Mapping Foundation 50's. ZhengZhou: Institute of Surveying and Mapping, 1996.

[12] You Xiong. The evolution of Virtual Reality [C]. Proceedings of Institute of Surveying and Mapping Foundation 50's. ZhengZhou: Institute of Surveying and Mapping, 1996.

[13] Pimental. K. & Teixeira.k. . Virtual Reality, 2nd Edition, Intel Windcrest McGraw-Hill, 1994.

[14] Jia Yan, Wu Man-dian, Wang Hai-lin. Virtual Reality Open The Door of Future Military Revolution [N]. Newspaper of PLA, 2000, 11, 15. 11th Edition.

[15] Jane's Training and Simulation System (1997 - 1998). Guildford & Kings Lynn. 1998.

[16] Gao Jun, The New Way of Battlefield Spatial Cognition ------ Virtual Reality and Mapping Safegaurd [J]. Military Mapping, 1994(3).

[17] Gao Jun, You Xiong. The Application of Virtual Reality on Military Mapping and Training

Simulation [J]. Journal of Institute of Surveying and Mapping,1996(2).
[18] Gao Jun, Visualization in Geo-Spatial Data [J]. Engineering of Surveying and Mapping, 2000(3).
[19] Kirschenbauer, S. & Buchroithner, M.F. . “Real” 3D Technologies for Relief Depiction. Ottawa ICA/ACI 1999- Proceedings/Actes. PP. 975-981.
[20] Chen Gang. A Research on Multi-resolution Surface Description and Real-time Rendering for Virtual Terrain Environment[D]. ZhengZhou: Institute of Surveying and Mapping in Information Engineering College, 2000.
[21] Xia Qing. Technology Research on Battlefield Terrain Simulation System [D]. Institute of Surveying and Mapping, 1998.
[22] Wan Gang. Research on Object Modeling Technology in Virtual Scene Realistic Simulation [D]. ZhengZhou: Institute of Surveying and Mapping in Information Engineering College of PLA, 2000.