GAINING AN INSIGHT INTO THE METHODOLOGY OF INFORMATION SCIENCE INSIDE DIGITAL PHOTOGRAMMETRY

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ABSTRACT

With a powerful vigour digital photogrammetry is occupying the market at fast speed and being spread in mapping organizations over the world recently. It is one of technological outcomes in the age of knowledge economy and expresses the correct way on which photogrammetry has been pushed forward to automation. Using the fundamentals of information science one can profoundly analyse its technical route and developable prospects. The author makes an attempt to explain the geometric reversal of photographic beams from traditional photogrammetry newly under the case of digital photogrammetry so that one might realize a study of the methodology of information science in more details has a great signifacace for the further progress of digital photogrammetry in both theory and technology.

1 Introduction

During the past decade the photogrammetric technology underwent a revolutionary change what possessed the profound significance on its development. It is well-known that the foundation and evolution of the contemporary information science have promoted a full-scale growth of surveying and mapping. Using computer for a kernel hardware of the equipments of both image processing and cartographic production has entered the reality. Moreover, a great diversity of the geographic information softwares in successive upgrade guide the mapping procedure to automation. As a branch of surveying and mapping science which has relatively short history of growth photogrammetry has undergone three successive stages: from the earlier analog that progressed slowly through the analytical that began about 1970 into its current, truly digital state. The manufactories which provide users with digital photogrammetric workstations (DPW) recently come to the fore like bamboo shoots after a spring rain, and launch a keen competition in the international markets. A variety of new technical lectures, instrument demonstrations and exhibitions make the eyes of users can hardly follow the scenes in front of them, which show most brilliant future of digital photogrammetric technology.

However, the mathematical fundamentals of the stereophotogrammetry which utilizes the frame aerial metric camera for taking terrestrial photographs as the raw data do not change with the innovation in technological means. Creating new technical tools is usually aimed at saving much stress of operators in both physical and mental labour so that one can solve complicated problems better and easier. The traditional photogrammetric technology requires the operator of stereo-plotter to understand the geometry of perspective projection. Digital photogrammetry makes operators go round its tough conception through the sophisticated software system. Moreover, the excellent performance of digital system can meet the strict requirements of mapping units with better precision and efficiency.

The author makes an attempt to analyse certain theoretical questions in digital photogrammetry, illustrates how the principles of information science are embodied in digital photogrammetry with newly understanding the idea of the geometric reversal of photography. There is presented a challenge facing the current education of photogrammetry in this paper. It is proposed to discuss some problems in need of further research and prospects of possible solution.

2 Overriew of the basic methodology of information science

Since the beginning of the 1990s a powerful wave of information fever has engulfed the entire world. Information science, one of the interdisciplinary subject hierarchy which spans the field of both physical and social sciences, has made a remarkable progress under a boost of the technology growing at full speed. It comes into a basis of the theory of knowledge in the information era.

Information science is the one that makes a study of the information phenomena and their inherent communication laws. For a concrete explanation it is a subject that takes information as a target of exploration and adopts the moderm statistics for investigating the essence of information and the rules of its transference, the primary theory and technique that can be suited to develop the machinery of sensing,converting, transferring and controlling a variety of information, the fundamentals which research into the necessary equipment and system in order to implement the above-mentioned functions. The total purpose is to strengthen and extend the ability of human communication, especially that of intelligential activities.

The methodological framework of information science is composed of one method and two guidelines, namely the method of information analysis and synthesis, the analog guideline of behavioural functions, and the optimization guideline of system integration.

The method of information analysis and synthesis contains two parts of analysing and synthesizing information. The former lies in that it is in need of analysing the manners and characteristics of information linkage with focus on communication process of systems so as to explain its working mechanism from information instead of mass or energy when one analyses and recognizes the natural or the social systems. The latter is to use the principle and means of information science for setting up a reasonable communication process during integration of the man-made systems so that the operational goal of the assembly body is able to be accomplished.

The information method runs through the entire proceeding of analysis and synthesis as well as knowledge and practice. It is the vital line of the information science methodology. For instance, people apply information analysis to expound a certain important mechanism of the logical thought in cerebrum, thus have designed the intelligent computers by means of the achievement of information science and technology. These machines can satisfy the parallel, object-oriented and knowledge-based processing.
As to the analog guideline of behavioural functions, that is to grasp rather functions than framework of a system for modelling the primitive system while integrating the artificial subsystems with the help of information synthesis.

This is an important implementing criterion of information synthesis. No matter how the structure is, it is considered to have achieved the goal of integration provided their performances are same or similar. As a matter of fact, there is not any similarity between computer and brain, but those have some analogous functions.

With regard to optimization guideline of system integration, that is to set off from the global consideration of a system, concentrate our attention on the interrelation among its internal individual parts and the connection between it and environment so as to ensure an optimum of the total performance of that system using information synthesis for integrating the man-made subsystems. This is another important implementing criterion of information synthesis. In fact, due to the relational complexity between the various components within a system the optimum of its each part, in general, does not guarantee the optimization of the entire system. Therefore, the integral optimization is a very important guideline.

3 The mathematical principle and digital technology of photogrammetry

Photogrammetry is mostly an engineering technology of obtaining reliable information about physical objects and the environment through processes of recordig , measuring and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena. Though the application of photogrammetry is broadening ceaselessly, the aerial topographic survey remains the most common field of this technology so far. Today, the camera is no longer the sole kind of sensors recording the ground images, but the aerial cameras still are the main tools to acquire the information on the earth surface because of the outstanding performances. It is well-known that the aerial camera is an optical instrument of the perspective projection which relies on the lens system. The expression of the ideal perspective geometry may be represented by a simple equation of the optical distances

$$\frac{1}{d} + \frac{1}{D} = \frac{1}{f} \quad (1)$$

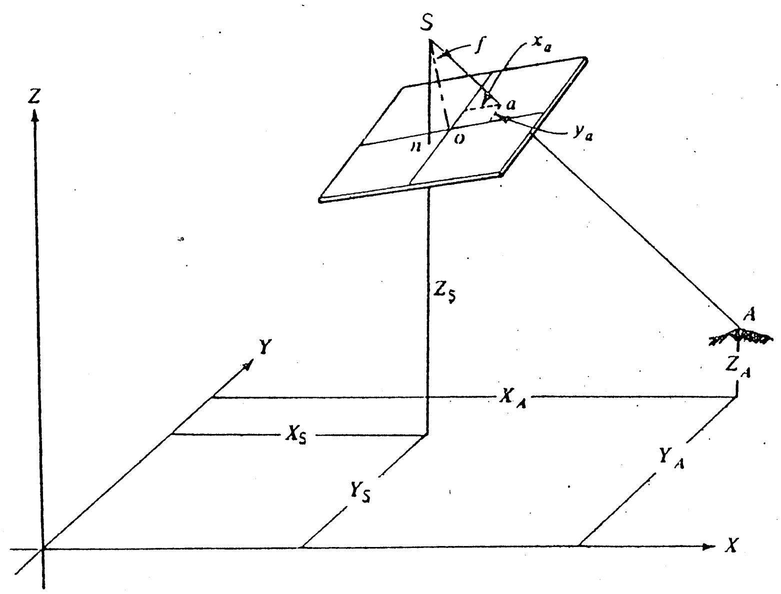

Figure 1 The *collinearity* condition.

where d is the image distance, D is the object distance, and f is the focal length. In the aerial photogrammetry we have to manipulate the relation of the perspective projection between the three-dimentional terrain surface and two-dimentional image plane (Figure 1). This geometric relation in the general text-books is often described via the collinearity equations such that for each point on a photograph two equations exist,

$$x = -f\frac{a_1(X-X_S)+b_1(Y-Y_S)+c_1(Z-Z_S)}{a_3(X-X_S)+b_3(Y-Y_S)+c_3(Z-Z_S)} \quad (2)$$

$$y = -f\frac{a_2(X-X_S)+b_2(Y-Y_S)+c_2(Z-Z_S)}{a_3(X-X_S)+b_3(Y-Y_S)+c_3(Z-Z_S)} \quad (3)$$

where f is the focal length of the camera; X_S, Y_S, Z_S are coordinates of the perspective centre of the lens in the object space; X,Y,Z are coordinates of point A in the object space; a_i, b_i, c_i $(i=1,2,3)$ are elements of the orthogonal matrix.

In order to determine the coordinates of ground points in the object space, a minimum of two photographs which have a pair of overlapping images and the orientation parameters implicitly contained in collinearity equations must either be known or calculated. Essentially, it is necessary to consider the camera position in the object space (X_S, Y_S, Z_S), the orientation of its optical axis $(\varphi, \omega, \kappa)$ and the scale factor (λ).

The development of photogrammetry has undergone three successive generations from analog through analytical to now digital. Analog and analytical approaches are directly based on film (hardcopy) images. Digital photogrammetry is a generic description for a new form of photogrammetry based on digital (softcopy) images, as distinct from the formers. However, they all rely on the same mathematical principles of stereophotogrammetry.

Nowadays the digital imagery utilized by the photogrammetric operators in map production mainly remains the digital image files from what CCD-camera scans the original photographic films. The traditional frame aerial cameras remain the most popular airborne sensors as the data sourses of phtogrammetry. Consequently image scanning becomes a critical procedure in digital photogrammetry.

In the viewpoint of signal processing digital imagery is a sample of the image plane of the standard frame with a continuous changeable tone under the condition of maintaining an orthogonal coordinate system. A photograph may be regarded as an integrative population of the information source,and each pixel of digital imagery is a cell of spacial information decomposed or segmented according to sampling theorem. Computers are the prevailing tools good at processing a variety of the discrete pulse signals. Digital photogrammetry adopts computers as the kernel hardware equipment and uses the software package with a modular structure to execute the various operations of conventional photogrammetry. It is possessed of a strong potential of automation and can not be matched with conventional photogrammetry that demands the manual interference taking much time.

Digital differential rectification and orthophotos generation may be regarded as the most obvious examples of using information analysis and synthesis for operations of digital photogrammetry。Scanner converts the seamless photographic image of a whole frame into the discrete array of pixels with spacial topological relationship and grey level variation. This procedure is called sampling. The rectification algorithm corrects the geometric shape of pixel and reassigns the grey values to them. That is a resampling process. Eventually, those new pixels of the rectified array are pieced together to form an orthophoto in accord with the map projection under the coordinate grid.

4 The geometric reversal of photographic beams and an implementation of digital photogrammetry

As for a qualitative description of the stereophotogrammetric method many textbooks both domestic and foreign have cited the following impressive explanation about the geometric reversal of photographic beams.

" If two films of the left and the right of an aerial stereopair are put into two projector's magazines as same as the camera's ones, it will recover the elements of interior orientation. Afterwards, one manages to place these projectors respectively in the same orientations as the ones at the original moment of taking pictures according to their respective six elements of the exterior orientation. It is apparent that each pair of the conjugate rays should intersect at the corresponding ground point.

" In further speaking, one can reduce the photogrammetric base (B) in accordance with a specific scale, then use lamplight for illuminating the two films in order to obtain the beams of projective rays. It is not hard to be imagined that all of the conjugate rays from the two beams must intersect in pairs as well through several proper operations. All the intersection points of those conjugate rays will make up an optical stereoscopic model which is similar to the taken earth surface. If we measure the optical stereoscopic model of the ground by means of a stereoplotting instrument indoors, it will be possible of replacing the field surveying." (Li,1992)

Since the initiation about the beginning of the twentieth century and the continuation till a decade ago, the traditional photogrammtry was adopting the optical or the opto-mechanical methods to embody the train of thought. Those technological tools do not need any complicated calculation so that it is intuitive and understandable easily to students from the teaching point of view. In spite of those instruments are designed and manufactured more and more delicately from generation to generation, the most obvious defect is their low operating efficiency and limited accuracy. In the 1970s computer was adopted by analytical photogrammetry as a vital part so that the spacial intersection of corresponding image rays or mechanical guide rods could be realized by means of image measurement and numerical computation. Each airphoto of stereopair in an analytical plotter is laid levelly on the picture carrier all the time though it may not be an ideal image of the exact vertical photography. There are no longer those operations of tilting the primary optical axis and setting up the photogrammetric base what are necessary for the geometric reversal in analog plotters. The program for solving equations of photogrammetric condition has been described as the " numerical guide rods ". Although this kind of guide rods has never any physical structure similar to the prototype of the geometric reversal it fits into the analog guideline of behavioural functions in information science. The reason is out of the fact that the output results from a computer terminal are able to be equivalent to the ones of converting the readings from the corresponding scales of an analog plotter. Of course, it is indispensable for the binocular monitoring of an operator via the sophisticated observation system. Besides the stereoscopic effect sensed by visual observation after the perfect orientation in an analytical plotter, the computer software can also create the digital elevation model (DEM) what is not visible to the naked eyes. The DEM is both a data file and a spacial signal sample of the earth surface with the continuous fluctuation. One can manage to make it visualization on a screen at the various views according to some requirements of the visual analysis, or print out the perspective graphs and the contour maps using a diversity of plotters.

Having evolved on the basis of analytical photogrammetry, digital photogrammetric systems retain a lot of the merits of the numerical algorithms, but they no longer use airphotos for the source data of the direct measurement. After digitalization on a scanner airphotos are converted into the primitive data files which can be inputted into the memories of a computer for manipulation. Digital photogrammetric workstation (DPW) executes a necessary treatment for the primitive data and the other ancillary data just as a common image processing system compiles and manipulates remotely sensed data or recorded values from any eleotronic instruments. In reality, photogrammetry and remote sensing have started going on the near routes by means of information technology for some thirty years. DPW has removed the stereocomparator together with an opto-mechanical part for the binocular observation. In order to watch the stereoscopic imagery promptly appearing on the screen one can wear a pair of the stereo viewing spectacles such as the active LCD shuttering eyewear or the passive polarized glasses so as to obtain an undulatory feeling of the relevant area. All the necessary operations are accomplished by calling for the different program packages according to the functional menus. In that case the spacial forward intersection by an idea of geometric reversal is implemented through the digital image correlation or registration. It may be thought quite abstract. However, it has reduced much stress of the operators during monitoring and made an encouraging step towards photogrammetric automation. Digital mapping and object extraction from digital image data by DPWs will depend on interactive human intervention for a long time, but the interactive operations on image workstation can be effectively supported and speeded up by the automation of various elementary functions and processes. Also, all tools for graphical data processing and complex editing functions can be used which help, in addition, to turn interactive modes of operation into more efficient procedures. The modular programming structure of application softwares and the various functions of database management in digital photogrammetry can make DWPs provide at least the performance of the previous level of the best analog and analytical plotters with considerably faster and cheaper operations under the optimization guideline of system integration in information science.

5 A challenge to the current photogrammetric teaching

It is a well-known reality that information science is progressing with each passing day and computer technology is quickly on the upgrade one generation after another generation, which have become the motive power to propel photogrammetry forward. Today, the domain of photogrammetric application has broken through a traditional circle of surveying and mapping and gone into wider industrial area. Training and fostering the photogrammetric professionals become indispensable for the constructional cause in every nation over the world. Digital photogrammetry has been successfully accepted by many developed countries as the prevailling mode of operation due to its high efficiency of production. Several world-famous corporations manufacturing photogrammetric apparatus such as Leica have abandoned conventional opto-mechanical instrument-based photogrammetry and decreased the production of analytical stereo plotters in order to push a full digital series of products into the global markets at a powerful thrust.

The specialized teaching of photogrammetric technology aims at not only training a new generation of the young technicians but also spurring on the old experts to refresh their knowledge. At present the students who major in photogrammetry have been generally offered some additional courses in information technology but most of photogrammetric textbooks are often revised quite slowly . There are some out-of-date contents what are almost intact so far. Furthermore, those methods of operation which have been abolished for ages by the mapping agencies are still inculcated by teachers into students at the cost of time. In the early days of 1980s, although the densification of points with computer programming was already popular in the photogrammetric organizations the teachers of some colleges continued explaining the graphic radial triangulation with a poor accuracy to students. At that time a great diversity of the precise stereo-plotters were not seldom seen in the map-making organizations, analytical plotters were also increasingly exploited in operatios, but there were quite lots of pages in the photogrammetric textbooks at home and abroad that explained the principle and usage of multiplex yet. Many graduates who are just in the employment of photogrammetric divisions have to face a challenge to the renewal of their knowledge.

As an engineering course the theoretical teaching of photogrammetry is usually matched with the relevant practices to the lectures. Most of the practical exercises are conducted by means of instrumental operations. Analog plotters can give a good intuition to students for understanding the fundamentals of the space intersection. Due to the complexity of the instrumental structure with more operative freedoms, however, it is necessary for students to take much time on exercises in order to have a better grasp of the operative skills . Students would be hard to comprehend the farreaching significance of the contemporary information science for guiding photogrammetric development even though they were familiar with the performances of those instruments of facing retired destiny. It should manage to make students not only do the moderate exercises on analog and analytical plotters but also have the sufficient opportunities for handling digital photogrammetric equipments. In this way, it is possible for students to recognize profoundly how information science can promote progress of photogrammetry and focus their attention on a trend of the future development.

6 Discussion and conclusion

Photogrammetric engineering is one of the technical outcomes since mankind entered the industrial era.It progresses together with the evolution of the industrial society. The transit of analytical photogrammetry to digital photogrammetry is a successful breakthrough of technology in the turning period from the post-industrial society to the information society. We all know that the traditional photogrammetry radically has nothing to do with information technology, but it may contain a certain rational idea what is in accord with the methodology of information science as well. In this paper we have simply described the application of the fundamentals of information science to analytical photogrammetry and digital photogrammetry via a few examples. Although the experts who are being engaged in development of photogrammetric technology may not have made an intensive study of the radical principles of information science, they do utilize the methodology of information science consciously or unconsciously in practice. It is under the guidance of this methodology that photogrammetrists are able to have rushed out of the traditional mode of the instrumental design according to the optomechanical structure and found a feasible way to the photogrammetric automation.

Any digital photogrammetric systems, regardless of running on image workstations or based on advanced PCs, all are the highly integrated, specialized in-information systems using computer as a kernel hardware. These equipments put the complete photogrammetric expertise into the utility softwares, consequently bring in the basic methodology of information science as well. Automatic generation of digital elevation models by image correlation has been realized. Digital contouring and feature extraction from digital image data have also entered the initial stage of partial automation. Advent and improvement of GPS technology will open up a hopeful outlook for the automatic digital aerial triangulation which has been the focus of the photogrammetric development of many researchers.

No doubt, automation is one of the most important conditions by which an integral optimization of the digital photogrammetric system can be implemented though the standards of integral optimization has not been specified clearly yet. A further improvement on the geometric resolution of sensors and scanners should be the proposition that guarantees the resultant accuracy of digital photogrammetry. It is worth to consider utilization of the artificial intelligence technology for raising the operational efficiency of digital systems. In the view of author, it will be beneficial to photogrammetrists if they carry out an intensive research on the methodology of information science so as to enhance their manifold abilities to handle the new problems in photogrammetric technology by making good use of that methodology. Moreover, the methodology of information science will be sure to play an important role in directing digital photogrammetry how to take part in integration of RS, GIS and GPS, as well as in construction of the digital Earth's framework.

References from Journals:

Ackermann, F., 1996. Digital Photogrammetry: Challenge and Potential. Photogrammetric Engineering and Remote Sensing, 62(6),pp679.

Krzystek, P., 1999. Automatic Aerial Triagulation: Conceptual aspects and new investigations. Inpho GmbH, Stuttgart, Germany.

References from Books:

Li Deren and Zhen Zhaobao, 1992. Analytical Photogrammetry. The press of surveying and mapping, Beijing, China.

I,S,M. International Systemap Corp., 1997. The Fundamentals of Digital Photogrammetry. Vancouver, B.C. Canada.

Zhang Renlin., 1993. The Fundamentals of Information Theory and its Applications in Geoscience. The Xian Cartographic Publishing House, Xian, China.