OUTLOOK ON THE DEVELOPMENT OF DIGITAL PHOTOGRAMMETRY ----FROM DIGITAL PHOTOGRAMMETRIC WORKSTATION (DPW) TO DIGITAL PHOTOGRAMMETRIC SYSTEM (DPS)

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ABSTRACT:

Through the stages of Analogue and Analytical, the photogrammetry has entered the digital photogrammetric era completely. Digital Photogrammetric Workstation (DPW), which was born in digital photogrammetric era, has been widely used in practice and it also pioneers a wide field being used photogrammetric technique. But we should notice that both from the design concept of DPW to practical application or from operating procedure to production workflow, DPW is affected by the traditional photogrammetric concepts, especially by analytical plotter. With the development of computer science and digital photogrammetric technique, it urges us to design a new system for digital photogrammetry, and the new system must contain two main parts: Automation and Interactive, which can make full use of the potential of "Human" and "Computer" to promote the production efficiency. The new system also should be a management system instead of purely a production system.

1. A BRIEF REVIEW OF THE DEVELOPMENT OF PHOTOGRAMMETRY

Whether Analogue, Analytical or Digital photogrammetry essentially they are a subject of science and technology, which reconstructs the spatial geometric model of objects from its image and then make some measurements and recognition. But in different stage it has much difference in research contents, characteristics, and instruments for production and task management. For Analogue Photogrammetry, many kinds of analogue instruments, based on the precise optical and mechanical plotters, were adopted; for Analytical Photogrammetry, analytical plotter and ortho-projector, which integrate precise optical mechanism with computer science were adopted; and for Digital Photogrammetry, all the functions are highly integrated into a computer, which bring on the DPW. Essentially, DPW is a software system and deals with the digitized image, so DPW is also called softcopy digital photogrammetric workstation.

The whole development of photogrammetry is rather the procedure of computer applying in photogrammetry. In the 1930s, the stage of Analogue, V. Gruber, the famous German photogrammetrist, said: "Photogrammetry is a technique which can avoid computation", which fully indicates the characteristics of analogue plotter. It should be pointed out that the analogue plotter itself actually is an analogue calculator because it simulates the geometrical reverse course of photograph. But it has completely changed while steps to analytical stage. In the analytical stage, computer not only does most of the calculation work as aerial triangulation, block adjustment but also solve collinearity equation in real time to form the "Digital Guide-Rod", which can control a stereocomparator to form a analytical plotter. But whether in analogue photogrammetry or in analytical photogrammetry, manual observation is still needed, while in digital photogrammetry stage, the task for computer is not only calculation but also recognition and observation to replace the manual work of operator, such as recognition of fiducial marks and homologous points etc., which can boost the automation capability of photogrammetry.

This situation also affects the relationship between the system designer and scientific researcher/teacher. In the early stage of analogue /analytical photogrammetry, system design is the original driven force for development of photogrammetry. The most important research task is to design various new analogue instruments and once there come up a new type of instrument the only thing for scientists or college professors to do is some principle discussion or test on the new instrument in library to make knowledge of its capability. While in digital stage things have been thoroughly changed, the main task for system design is "Calculation by software" (A.Gruen, 1996), so digital photogrammetry has enlarged the field for teaching, scientific research, production and application of photogrammetry.

2. DIGITAL PHOTOGRAMMETRIC WORKSTATION (DPW)

Since 1990 digital photogrammetry has made a rapid development, DPW has been widely used and more and more workstation appears. Prof. Christian Heipke made a very good review and analysis on DPW's present status (C. Heipke, 2001). Some DPWs in fact are analytical plotter for processing digital image and generally most of them need much manual work.

From the development point of view, this kind of DPW isn't real digital photogrammetry because the essential difference between digital photogrammetry and analytical photogrammetry doesn't lie in whether it can process digital image or not. The core of digital photogrammetry lies on whether it integrates digital photogrammetry with computer science such as digital image processing, pattern recognition and computer vision etc. and whether it realizes fully automatic/semi-automatic operation or not. For example, enable easily handling functions

like Inner orientation, automatic aerial triangulation, DEM collection, orthoimage generation, automatic / semi-automatic feature collection, etc. The ideal status is to make all the basic operation as a "Black Box" so the operator needn't have too much knowledge about photogrammetry (Ir Chung, 1993), only in this way, the digital photogrammetry can gain widely application in different domain.

Now the powerful automatic DPWs are mainly from Autometric, LH System, Z/I Imaging, Erdas, Inpho and Supresoft (C. Heipke, 2001). The automatic function can be divided into three types, i.e. semi-automatic mode, automatic mode and full-automatic mode. To semi-automatic mode, it works interactively by operator and computer. To automatic mode, it needs operator input various parameters and make some definition previously to ensure a good result. But to full-automatic mode, it completes work by computer. Obviously, few functions can realize full automatic at the present time. Generally speaking, it still stays in semi-automatic and automatic mode. But it should be noticed that the parameters input in automatic mode depends on the experience of operator. So while running the DPW in automatic mode, the important element to evaluate whether DPW will be robust or not lie on the amount of inputted parameters and experience of the operator. A good automatic system should have such features: fewer parameters and less sensitive to parameters. For example, in VirtuoZo system there only need two parameters in DEM Automatic Generation Model: window size of image matching and interval of parallax grid, which is easy –to- handle and also the system isn't very sensitive to the parameters.

VirtuoZo DPW is an achievement based on the research project "Fully Digital Automatic Mapping System", advanced by Professor Wang Zhizuo of Wuhan Technical University of Surveying and Mapping in 1978, the honorary member of ISPRS. At the beginning, VirtuoZo SGI workstation version released in Gold Coast, Australia, 1994. It was regarded as a DPW of the characteristics of innovation (A.Stewart Walker & Gordon Petrie, 1996). In 1998, Supresoft Inc. released its PC version.

3. OUTLOOK OF DIGITAL PHOTOGRAMMETRY (DIGITAL PHOTOGRAMMETRIC SYSTEM)

In fact, DPW is a processing system cooperated by "operator and Computer". But up to now, the DPW is more likely used as a photogrammetric "Instrument" instead of a real computer system, whether the DWP researcher, developer or user. Now, while in considering the DPW as a "man - machine cooperative system", one should realize the difference of operation between the traditional way and DPW, i.e. the difference of working mode between human operator and computer, so that one can consider the construction of DPW and its development in a sense of "System" instead of "Instrument". Following are some of the problems should be improved.

1) Now, requirement of the traditional operation may not fit digital photogrammetry because the operating steps have become "blur" in digital photogrammetry. Now it much more emphasizes integration. For example, the purpose of the traditional aerial triangulation is to calculate the coordinates of pass points, which will be the control points of absolute orientation in next operation. So it needs to select three pass points in the triple overlapped area. Affected by it, some DPW system now is to select pass points according to the "point group" at the standard point position in aerial triangulation (Eija. Honkavaara, 1996). But to the system of AAT (Automatic Aerial Triangulation) of Supresoft, in considering the uniform requirement of the post procedure, it add large numbers of pass points in the edge of the model, which conduces to generating DEM, especially DEM mosaic.

2) The specification of the traditional photogrammetry also may not fit the digital photogrammetry. For example, in relative orientation, it requires the maximum residual parallax less than 10 μm, which is limited by maximum residual parallax while measuring 6 points by the operator at the standard point position for relative orientation on analytical plotter. But for digital photogrammetry, only measuring 6 points at the standard position is hard to realize automation of DPW. In general, there are two ways to select enough points, one is to select points according to "point group" at each of the 6 standard position, the other is to select lots of points distributing evenly in the image pair. VirtuoZo adopts the later, which makes the relative orientation points up to 100-200. Obviously, the maximum residual error presented above doesn't suit that of DPW.

3) On intelligence, operator is much more intelligent than computer. So DPW is led by the operator to complete the work during the whole course. For example, operator opens a project/object/file, do some processing and then the computer will fulfill the order from the operator. That's the so-called "automation". In this sense, the whole DPW is a set of "interactive system". On the capability of "recognization", operator is much more intelligent than computer, such as recognizing types of ground objects (building, road, forestry etc.), control point, gross error etc. So DPW presently is rather the same as analytical plotter on feature collection: manual working mode or semi-automatic mode led by the operator.

4) Computer has more remarkable capability to remember the current process than operator does. Human has better capability of memory than computer in a whole, but to a certain part, it is just on the contrary. For example, computer can remember each point and its possible homologous point in the whole stereo image pair, but it is impossible for operator to remember it. So based on such a character, VirtuoZo adopts "optimum matching " in the whole image pairs instead of "single point matching" by operator.

5) For transferring the task of " recognition" into the task of "calculation", computer has much better capability of processing than operator. For example, measurement of homologous point, a task of " homologous point of recognition" in DWP (or computer stereo vision) can be converted to a task of "image matching". It needs about 0.5 second for an operator to measure a point, while for computer, the matching speed can reach as high as 100-1000 point/second (may include some gross errors). Namely, the former has lower speed but higher accuracy; the later has higher speed but lower accuracy. Making full use of this characteristic, there comes up AAT of VirtuoZo, an efficient automatic aerial triangulation software which integrates the speedy and efficiency image matching algorithm of VirtuoZo and the remarkable gross error detection capability of block adjustment software PATB (online).

6) As computer can keep working all day and all night without break, the running software will never be tired or bring up error because of tiredness. But to operator, it is impossible to work like a computer without break and of cause the tiredness will cause mistakes. So we can see that computer has much higher efficiency and lower costs, which is also the basic

purpose of Digital photogrammetry, to promote working efficiency and reduce the cost.

7) There are two running modes for DPW: one is "man and computer" (interactive), the other is "computer only" (automatic). But at present, DPW doesn't distinguish the difference between the two modes so it can't completely implement the efficiency.

According to the presentation above, the future design of DPS should be:

1) DPS should consist of several computers and proper software to form a full digital photogrammetric system by network.

2) DPS should assign Automation mode and Interactive mode to different computers. The former is Master computer, which can work all the day, but the later are Slave computers, which only work 8 h/d, so it will promote whole efficiency of the DPS. To those computers, the system requirements are different, for Master computer, it should have high processing speed, large memory and large disk space because it will save the data of image, intermediate result, and the final result of the whole mapping area. The system requirements of Slave computers are similar like DPW, which is only for work based on models and map sheets. The whole structure of DPS is shown as figure 1.

3) DPS is not only a producing system but also a managing system for photogrammetry. With the development of computer, especially the capacity of exterior memory, data amount of photogrammetric system has become larger and larger. To the color image, while scanning aperture with 14 μ m, the original data of an aerial image can reach 1G, the whole amount of data including intermediate and the final data will be as large as 2-4G. How to manage the process and the huge amount of data becomes more and more important in photogrammetry.

4) DPS doesn't work by models as the traditional procedure in DPW. For example, the selected point in aerial triangulation can't stand on the top of trees, but "recognition of trees" must work with the extraction of DSM (digital surface model), which indicates that aerial triangulation, image matching and ground object recognition are tied up and they are hard to separate strictly.

5) The software of DPS also should be classified as automation (or automatic) and interactive (or semi-automatic) because up to now, there still haven't an ideal module, which completely meet the requirement of automation for any terrain condition. For example, to the relative orientation module, about 99.9% of them can realize automation, but in some cases it still needs manual work. Even the DEM generation of open area, which is regarded as a full automatic area, also needs some manual work. So each module of DPW should be divided into two parts: automation and interactive, which will be installed on the Master computer and Slave computer separately. The relationship between functions and computers are shown in Tab. 1 (marked with √, means automation part; marked with ⇔, means interactive part, and marked with □, means none.).

	Master	Slave
Production Management	√	□
Aerial Triangulation	√	⇔
DEM(TIN & GRID)	√	⇔
Vector data capture	√	⇔
Map / model join	√	□
Orthophoto & mosaic| & Dodging	√	□

Table 1. Relationship between function and computer

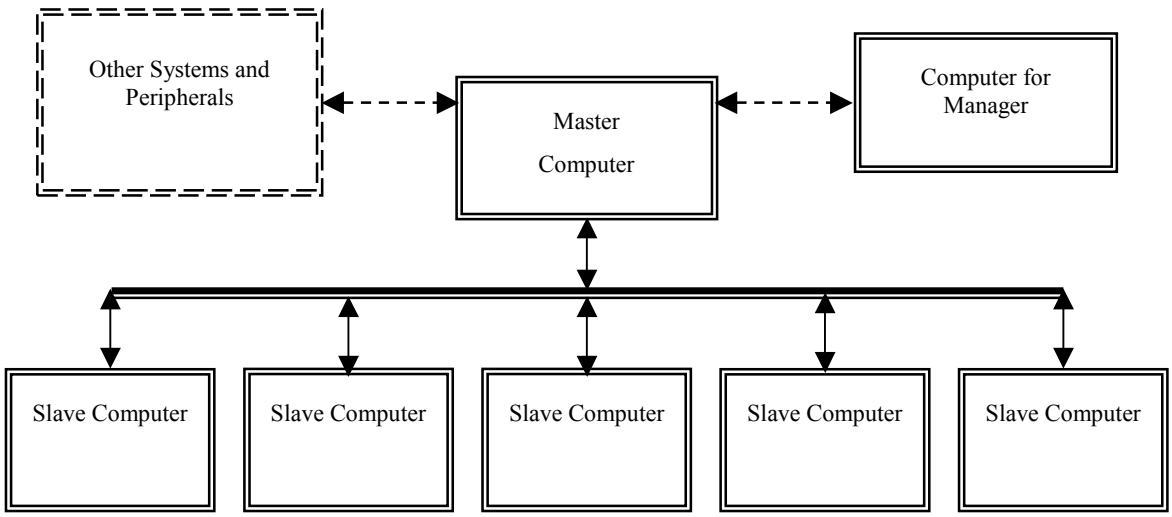

Figure 1. DPS Structure

4. CONCLUSION

The future development of photogrammetry is as follows:
1) Further development of automation of digital photogrammetry. Automatic DEM generation needs further development. Automatic feature collection is only at the beginning stage and semi-automatic is still the main direction for it.

2) Expand the application domain for digital photogrammetry. It includes image and map matching, digital photogrammetry and map updating, data processing of digital photogrammetry and remote sensing, digital close range photogrammetry, digital photogrammetry and city modeling etc.

3) Further develop the integration of photogrammetry and GPS, GIS, such as the integration of CCD and GPS to form the mobile mapping system.

4) Develop from DPW to DPS.

In this article, it doesn't introduce details of the first three items, it emphasizes the development direction of DPS instead, and it is also the inevitable result of DPW development. In fact, it can be said that DPS is the second generation of DPW, which is very important to the production, management, operating of photogrammetry and also it will promote the work efficiency.

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