A DIGITAL STEREOPHOTOGRAMMETRIC SYSTEM

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Abstract

So far in all stereoplotters photographic images are used as data input, e.g. the data to be processed are stored in analog form. In a digital photogrammetric system digital image memories are applied instead of photographs. This concept leads to a new generation of stereophotogrammetric plotters.

In principle digital image processing systems can be used for stereophotogrammetric purposes too. Stereoscopic viewing of two digital data sets is easily to achieve by means of the anaglyphic method. For an operational system additional hardware components are necessary. In the first place three-dimensional control of the floating mark is essential because the movement of a cursor in two dimensions, which is standard in digital image processing, is insufficient. Secondly an automatic drawing table must be used in order to get graphical data output. Besides this all orientation and operation procedures can be handled by software.

Digital stereophotogrammetric systems offer a variety of advantages and the highest flexibility that one can imagine. Therefore digital stereoplotters will be of great importance for future development of photogrammetric instruments. An experimental system is being set up at the Technical University of Berlin.

Ein digitales stereophotogrammetrisches System

Bisher werden in allen Stereokartiergeräten photographische Bilder ausgewertet, d.h. die zu verarbeitenden Daten sind in analoger Form gespeichert. Ein digitales System entsteht, wenn man digitale Bildspeicher anstelle der Photographien benutzt. Dies führt zu einer neuen Generation von Stereokartiergeräten.

Grundsätzlich können digitale Bildverarbeitungsanlagen auch für stereophotogrammetrische Zwecke eingesetzt werden. Die stereoskopische Betrachtung von zwei in digitaler Form gespeicherten Bildern kann auf einfache Weise nach dem Anaglyphenprinzip erfolgen. Zur Stereokartierung sind jedoch zusätzliche Hardware-Komponenten erforderlich. Erstens muß die Bewegung der räumlichen Meßmarke in drei Koordinatenrichtungen möglich sein, da die bei digitalen Bildverarbeitungsanlagen übliche zweidimensionale Cursor-Bewegung nicht ausreicht. Zweitens muß ein digital gesteuerter Zeichentisch verfügbar sein, um die Meßergebnisse graphisch darstellen zu können. Im übrigen können alle Orientierungs- und Auswertevorgänge durch die Software gesteuert werden.

Digitale stereophotogrammetrische Systeme bieten eine Vielzahl von Vorteilen

und die denkbar größte Flexibilität. Sie werden deshalb für die weitere Entwicklung des photogrammetrischen Instrumentariums von zentraler Bedeutung sein. Ein experimentelles System wird am Fachgebiet Photogrammetrie und Kartographie der Technischen Universität Berlin aufgebaut.

1. Introduction

Conventional stereoplotters were set up of optical and mechanical parts exclusively. But during the last three decades more and more digital components were integrated in stereophotogrammetric systems.

In an early period the mapping systems became digitized, i.e. the manufacturers equipped photogrammetric instruments with digital components and computer-controlled drawing tables. By this development great flexibility, high quality and complexity of the graphical output and a large amount of operators comfort was achieved.

The latest state of development is the analytical plotter which was proposed as a future concept already in 1957 by HELAVA (3). Today analytical plotters are the standard in photogrammetric instrumentation. As is well known, in this type of plotters the relationships between the two-dimensional image coordinates and the three-dimensional model coordinates are solved by digital real-time computation. The analytical plotter concept introduces a large number of advantages, especially higher accuracy, greater flexibility and reduction of orientation time. These advantages combined with the benefits of computer-controlled drawing tables improved the applicability and efficiency of stereophotogrammetric systems to an extent which was inconceivable before.

But in all analytical plotters the data input is still achieved by means of photographic images, i.e. in analog form. Because digitization was a tremendous success so far, it suggests itself to continue this development and to replace the photographs by digital image memories. This results in a fully digital stereophotogrammetric system which is nothing else than the combination of photogrammetric principles with digital image processing techniques.

2. Design of a Digital Stereophotogrammetric System

Digital image processing has grown up to an efficient technique outside the photogrammetrists field of view. Its purpose is to transform a given matrix of densities which represents the input image to another matrix forming the output image. The transformation parameters can be chosen arbitrarily whereby the geometrical properties of the image as well as the radiometry, i.e. the densities or colors, may be changed. Furthermore one can combine data from several images in many ways with each other.

A great number of image processing systems is on the market and used for many different purposes of this type. But the periphery of these image processing systems is not sufficient for stereophotogrammetry. Three options must be added to the standard equipment.

In the first place the data of two images have to be displayed in such a way that stereoscopic vision is made possible. This can be achieved by many different methods as PETRIE (4) recently surveyed. The cheapest and nevertheless very effective solution is the application of an anaglyphic system. This principle, which is well known to photogrammetrists from optical projection plotters, can easily be realized by means of a color monitor, in which two images are displayed in red and green and viewed with the usual color filters.

Secondly for stereophotogrammetric purposes three-dimensional control of the floating mark is essential. Common image processing systems are equipped with a trackball or joystick which allows cursor movements in only two dimensions. Therefore an additional coordinate input is required so that the operator can move the floating mark through the stereomodel as usual. This may be achieved by the conventional combination of two handwheels and a footwheel or by other devices, e.g. a trackball and a handwheel.

Last not least stereophotogrammetric plotting needs a graphical data output. With regard to this requirement there is no difference to the analytical plotters. Therefore in principle any computer-controlled drawing table may be added to the image processing system.

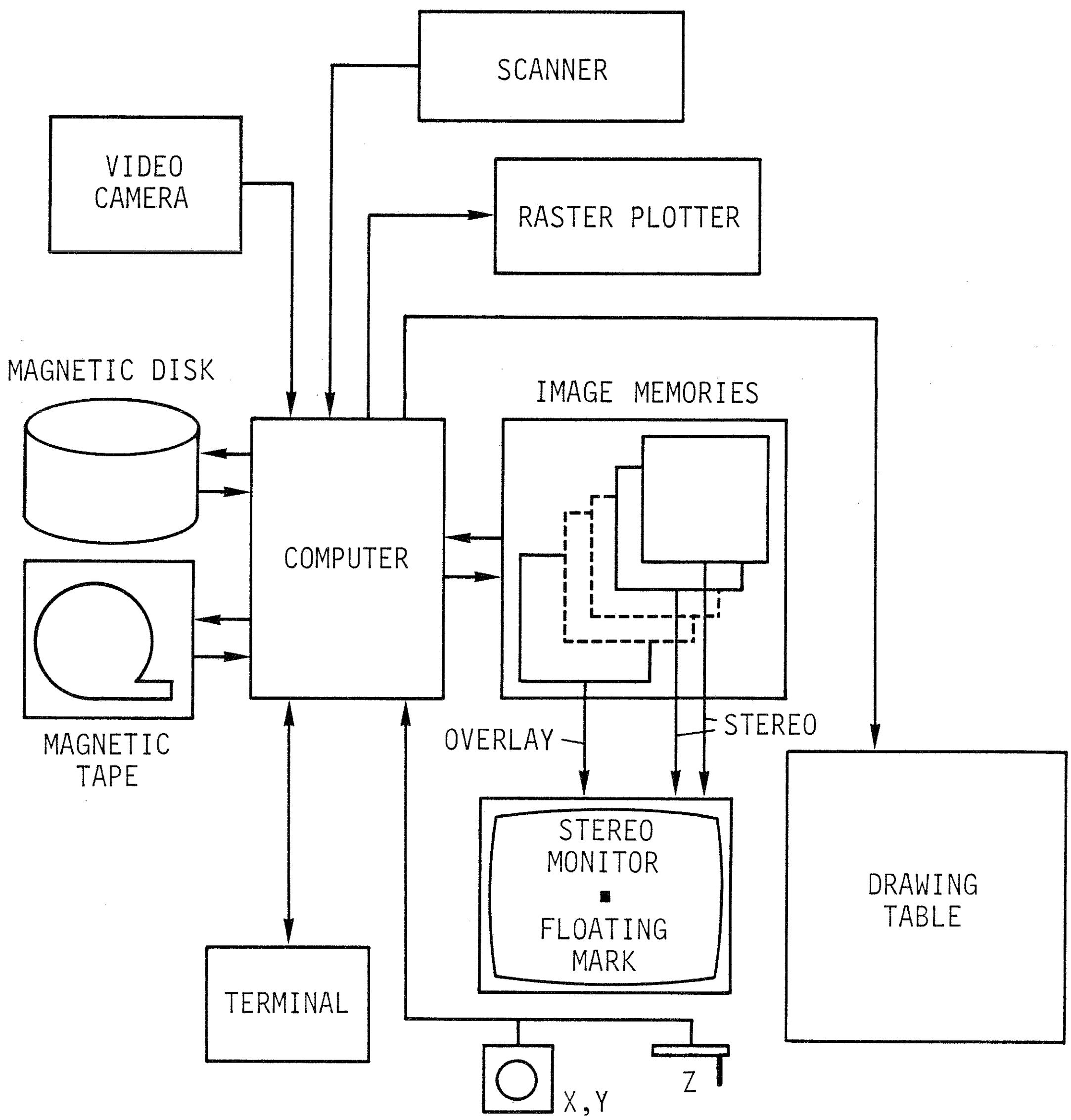

Fig. 1 Components of a digital stereophotogrammetric system

Thus the hardware components as scetched in Fig.1 will form a digital stereophotogrammetric system. A scanner respectively a video camera is used to convert photographs into density matrices. Moreover the central computer is equipped with a magnetic tape unit to read already digitized image data, and with a disk drive for mass storage purposes. The image data to be processed actually are stored in the image memories and can be displayed stereoscopically on a color monitor. This monitor, the x, y and z control and the terminal for communication with the computer form together the interactive working station to operate the system. The output may be plotted either in graphical form by means of a computer-controlled drawing table or in photographic form (e.g. as orthophotos) by a raster plotter.

3. Operational Aspects

The operator working with a digital stereophotogrammetric system has to fulfill pretty much the same functions as with an analytical plotter. But the system itself is based on quite different operation procedures.

With regard to the interior orientation of the images two cases must be distinguished. The image data to be compiled may be digitized from photographs taken with a metric camera or they may be acquired by a scanner or video system and directly recorded in digital form. In the first case the fiducial marks or the reseau crosses must be used to determine the interior orientation as usual. The reason for this is that the pixel matrix is not identical with the system of image coordinates. In the second case the inner orientation depends completely on the calibration of the data acquisition system. The pixel matrix itself serve as the system of image coordinates so that the interior orientation is determined without an additional source of error by just introducing the calibration data.

To perform the relative orientation several solutions may be considered. Of great promise is the transformation of one image data set in such a way that the pair of image data is reduced to the normal case of stereophotogrammmetry. The parameters for this transformation can be calculated by a least-squares adjustment using a sufficient number of orientation points. In some special cases, e.g. for plotting convergent images, the transformation of both image data sets into an adequately defined system of model coordinates may be preferable.

Absolute orientation of the stereo model based on ground control points is performed in the same way as in analytical plotters.

After completion of the orientation procedures the operator uses the system in a way which is very similar to conventional stereoplotting. He moves the white (or black) cursor as a floating mark through the three-dimensional stereo model by means of the control units for x, y and z. These movements may either be plotted in real-time on the drawing table or recorded in digital form. Furthermore data may be collected in profiles, rasters etc. Therefore also orthophoto production or similar tasks can be accomplished.

A special feature of great importance is the fact that digital correlation techniques can easily be applied to image data in the normal case of stereophotogrammetry. This means that stereocompilation may be performed in the usual way by an operator as well as by digital correlation procedures. The change from one mode to the other can be carried out at any time.

It might be informative to have a look on the data flow in such a system. The information content of the data in the digital image memories can be effectively used by two closed loops (Fig.2). Either the image data are displayed stereoscopically to an operator who moves the measuring device and controls this movements through the first closed loop. Or the data are directly used for measurements by digital correlation in a second loop which is completely integrated in the digital system.

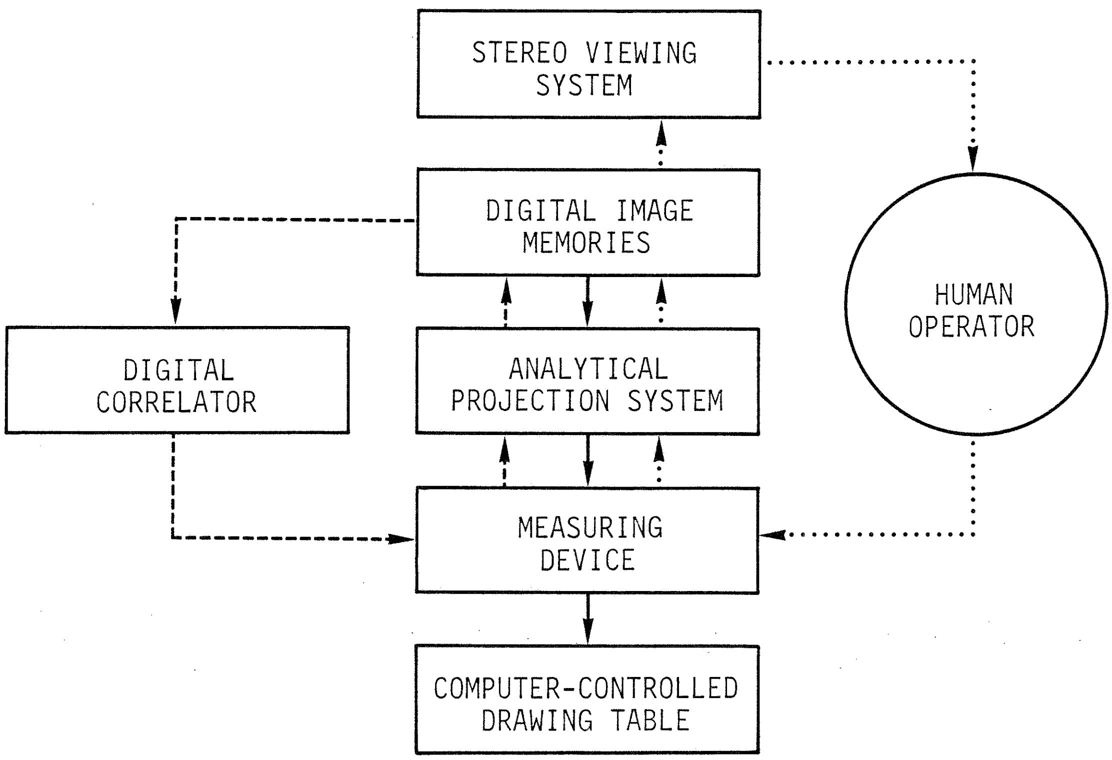

Fig. 2 Data flow in a stereophotogrammetric system with digital image correlation

Another feature of the digital concept which is not available in conventional photogrammetric systems is the possibility of using the graphical overlay for storage of the data already collected. Points, contour lines etc. measured by the operator may be superimposed on the image as one chooses. This allows to check what is already done and if it is done correctly. As already mentioned by CASE (2), superposition is a prior condition for revision of previously collected data or maintenance of digitized maps, which can be transformed into the display coordinate system and superimposed to the stereo-model. In a subsequent step, correction and editing functions for revision purposes will be integrated in the photogrammetric system.

4. Questions of Data Processing

Using turnkey image processing systems for stereophotogrammetric purposes is coupled with one main problem: processing of the entire stereo model is only possible by dividing the images into small subregions. The size of these subregions depends on the capacity of the frame buffer of the system. Displaying the actual part of the image must be organized by the user's program. Of course, routing data from the disk drive of the host system, where the stereo images are stored, to the refresh memories is time consuming and stresses the bus of the computer system. This means reduction of efficiency.

At present this problem could be diminished by using four image refresh memories of an image processing system for storage of two partly overlapping stereo pairs. Swapping between them leads to the advantage that reloading one memory set can be handled in the background while the operator is observing the contents of the actual image memory set.

Nevertheless it is necessary to provide a powerful facility for the interchange of data between display memory and external data sources. Further developments must result in a system which is equipped with a private background memory, especially a winchester disk drive which could be adressed as virtual memory by the image processing system and which allows high speed transfer rates.

As in the previous chapter already described, the cursor of the image processing system is used as floating mark. For stereo compilation this floating mark may be fixed in the centre of the display screen. In this case, which is analog to the traditional mode of stereoscopic measurements, the image movement is realized by the scroll capability of the image processing system. For accurate measurements by the operator a digital enlargement of factor two may be useful. If a large amount of details to be collected is already visible on the screen, optionally a second mode (moving floating mark and stationary image) is offered to the operator. In both cases one image has to be moved relative to the stereo partner in order to define the spatial position of the floating mark in the stereo model, which once again means scrolling of the images. The value of the x-parallax which could be determined by one-dimensional correlation indicates the hight of the object point.

5. Characteristics of a Digital Stereophotogrammetric System

The concept of an entire digital stereophotogrammetric plotter leads to a system which offers a variety of advantages bejond those already achieved by the introduction of analytical plotters.

Since the digital system works without moving parts the measurements are independent from mechanical devices. Furthermore no calibration problems arise because the coordinate systems, the flatness of the images etc. are determined perfectly by mathematical definitions. Limitations with regard to accuracy performance will only depend on the calibration of the data acquisition system.

The flexible combination of stereocompilation by a human operator and digital image correlation has already been mentioned. For many applications this combination will be extremely useful, particularly because tiresome and time-consuming monotonous measurements may be performed automatically.

Moreover it must be stressed out, that the combination of a digital system with high resolution video cameras may lead to an entirely new concept of photogrammetry, which is "on-line photogrammetry" in the strongest sense: stereo measurements may be performed in real-time because no photographic process does interrupt the data flow from data acquisition to data processing.

On all accounts a digital stereophotogrammetric system is more flexible and more powerful than common instruments. A system designed for photogrammetric purposes will be capable to perform all functions of analog instruments such as rectifiers, comparators, stereoplotters, dodging instruments or orthoprojectors. This means that a digital stereophotogrammetric system as a unique tool could be used for universal tasks and will overcome the needs for a variety of instruments necessary today.

6. Conclusion

It is obvious that a completely digital stereophotogrammetric system offers a variety of advantages and leads to a new generation of photogrammetric instrumentation.

At the Technical University of Berlin an experimental system for stereophotogrammetric purposes is under development. The aim of the authors is to get experience in realization of the digital concept by using a commercially available image processing system. The main hardware components at the Department for Photogrammetry and Cartography are an image processing system IP 6432 of DeANZA Systems Inc., a VAX 11/730 of DIGITAL EQUIPMENT Corp. as host computer and for graphical output a computer-controlled drawing table KERN GP 1.

At present a software package for stereophotogrammetric needs is being developed. First investigations are made for the solution of the paging concept for image roaming, for the implementation of stereo-correlation algorithms and for realization of relative and absolute orientation.

7. References

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