J ó z e f J. J a c h i m s k i, J a n u s z M. Z i e l i ñ s k i
University of Mining and Metallurgy
Al. Mickiewicza 30, 30-059 Kraków
Poland

DIGITAL STEREOPLOTTER FOR HISTORIC MONUMENTS RECORDING

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Abstract. It is hoped that PC-insatiable digital stereoplotter, equipped with several special functions indispensable or just advisable for easy evaluation of historic monuments and sites, would become a standard tool of restoration teams. The conditions of such a system design are discussed in the paper.

Key words:
Close_Range, Architecture, Restitution, Digitization, Instruments, Stereoscopic Processing Systems, Digital Stereoplotter Structure

1. Introduction

The explosion of analytical stereoplotters which took place at the ISPRS Congress in Helsinki in 1976 opened before photogrammetric science and practice the possibility of plotting numeric maps in real time in a continuous way. It was even possible to make use of photographs taken with nonprofessional cameras. Procedures have been developed which support the operator during evaluation.

However the analog nature of images made it difficult to automate the stages of plotting, thus the system of an analytic plotter was supplemented with a set of television cameras and later with CCD which gave access to the image around the measuring mark in the form of an electronic signal or in digital form. This facilitated an automatic analysis of images and allowed autocorrelation procedures to be introduced. Photogrammetry was becoming an universal, reliable and every less exclusive method owing to the computer support available to the operator during preparation and vectorization of the model.

Unfortunately the high price of analytic plotters was still making a true egalitarization of the method difficult.

Rapid development of personal computers in the late 80s was a big step on the road of reducing the elitarian nature of photogrammetry. In that time, on the basis of PC, we developed at the Department of Photogrammetry of AGH both the software for differential plotting of photographs (presented at the Congress in Kyoto) [Jachimski 1988] and the system for vectorisation of the content of a photograph on the screen. Our investigations into vectorization of stereoscopic models on the screen of the PC monitor were outdistanced by DVP [Agnard 1988, Gagnon 1990] successfully.

A true explosion of new system for vectorization of stereograms on the screen of a computer monitor took place at the ISPRS Congress in Washington in 1992 [Klaver 1992, Miller 1992, Jachimski 1992]. Excellent and very costly systems, which-permit the screen to be simultaneously observed by several persons, were and still are impressive. The stereoscopes used by the teams in Quebec and Cracow were replaced by the dynamic system Crystal Eyes and static polarizating oculars. This required, however, very costly computer solutions to be applied.

The excellent and complicated systems overshadowed the simple and cheap solutions based on the use of PC and mirror stereoscope. However it proved soon that much cheaper and simpler (and thus less perfect) systems DVP from Quebec and VSD from Cracow did not loose their popularity and that due to their price and utilization advantages they have found more and more new users, and student laboratories at universities have been equipped with multistation VSD networks.

The high cost of solutions adopted by Intergraph or Leica is a consequence of the necessity to visualize on the screen of a working station alternatively the left and right image of a stereogram and to operate with the same frequency of 50 - 100 Hz the viewing system which enables selective observation of the corresponding images with the left and right eye. In 1994 the firm Galileo-Sicam in Florence and the Technical University of Torino presented a static viewing system [Dequal 1994] based on the use of two monitors observed selectively correspondingly with the left and right eye through polarizating spectrales. The Italian system is considerably cheaper and at the same time not inferior to the dynamic system.

User's interest in digital autographs has not lessened and designs based on mirror stereoscopes have been ever wider introduced. For instance the firm Leica already distributes its excellent digital working station DPW 770 (Helawa) [Leica 1994a] in its dynamic-spectacles version and in the static version equipped with a mirror stereoscope (DPW 670 [Leica 1994b]). More and more copyrighted software packages for digital autographs based on PCs and mirror stereoscopes have appeared. Thus the concept of that system does not loose its attractiveness and software solutions based on standard computers can be developed and improved without any additional cost of hardware.

Precision of plotting performed with the aid of digital autographs depends mainly on the geometrical precision and resolution of digital images. Application of very precise scanners is sometimes difficult and costly. Thus research into the accuracy of popular scanners improved by introducing suitable geometrical corrections is developing wider and wider. The readability of details is decided by the resolution of digital images. Resolution of the order of 2400 dpi or even 1200 dpi can be practically satisfactory. However plotting is often performed on images with a resolution of 600 dpi because of the still existing difficulties in storing and making accessible large files of digital images (a 230 x 230 mm photograph scanned with a resolution of 600 dpi forms a file of 30 MB or of 120 MB in the case of a resolution of 1200 dpi). However it can be expected that the fast development of exchangeable magnetic and optical-magnetic hard discs will soon lead to an easy operation of even large files containing digital images.

All the existing historic monuments, such as: urbanistic complexes and single buildings, architectural details, furnishes, wall paintings and sculptures, as well as archeological excavations - all of them should be documented, also with proper surveying records. The surveying documentation scale depends on the object size and use, and can range from topographic scales to very large ones. The documentation must comprise drawings or numerical models which enable production of variety of projections, including developments, crossections, axonometric views and others.

Various techniques are used to survey historic monuments. For many cases photogrammetry could be very useful, but till present times it was recognized as very efficient but rather expensive method.

Very fast development of digital photogrammetry makes it potentially possible to apply analytical methods even without approaching a specialized photogrammetric laboratories. Well, but off shelf, equipped computer room makes the photogrammetric restitution possible. The use of highly specialized software and ordinary analogue and/or digital cameras make restitution feasible.

In such situation - when most difficult technological problems can be solved by computer software - photogrammetry becomes not only less expensive, but also much easier. It does not require high specialization and long training any more, and can be practiced even by non-photogrammetrist. It would be true, under condition, however, that the technology as well as equipment are properly adapted to be operated by non-professionalists..

The system named Video Stereo Digitizer was developed during recent years at the Dept. of Photogrammetry and Remote Sensing Informatics of our University. It can be implemented on the DOS operating personal computers of 386, 486 and better series, equipped with SVGA graphic monitor and mirror stereoscope to observe split screen stereopare presentation. VSD is, fast end efficient enough for the purpose it was designed for. Experimental works have shown good restitution accuracy, of aerial 23 x 23 cm stereopares, and even when utilizing aerial pictures taken with 6 x 6 cm photographic camera. Also plans of facades of historic church or vectorial documentation of sculptures were plotted with good result.

That type of a stereo restitution system, when equipped with properly designed specialized functions can suit also the non-topographic applications, namely the historic monuments documentation requirements. Being inexpensive, applicable on off-shelf hardware, easy and efficient in use, such small specialized digital stereoplotter can find room in many laboratories as a typical tool for historic monuments and sites photogrammetric recording by non-photogrammetrists, eg: conservationists and archeologists.

2. General outline of functions of a small digital stereoplotter designed for historical monuments and sites recording and some hints for the system construction

The recording of a historic sites is usually requested by a restoration team as a material for their studies and restoration design. Entire „as found" record comprises maps (1 : 500 to 1 : 200), vertical and horizontal cross-sections, facades, developments of vaults and walls, projections of domes (all that in the scale of 1 : 50 or even 1 : 20), and records of details (1 : 10 to 1 : 1). Archeological excavations need systematic periodical recording, to assure a proper documentation of successive layers which disappear one after another. This makes photogrammetry indispensable. In recording of historic monuments of architecture and art, and in recording of archeological sites photogrammetry has also very meaningful applications.

The modern methods allow for evaluation of pictures taken with any metric or nonmetric camera what makes much easier and broadens the range of applications. The demands for photogrammetric recording of historic monuments and sites is great and does not decrease [Waldhausl, 1992].

Necessary field works require from the recording team some knowledge of photogrammetry, as the hand-survey, stereopairs, and various large scale shots which supplement the survey should meet not only the historic structure requirements but also the feasibilities of plotting techniques. Thus, beginning a new project, one foresees various kinds of drawings, their scales, and contents. Also the appropriate pattern of final presentation should be chosen at that early stage of each project..

One or more of the following patterns of presentation can be used for the final presentation of historic structure [Jachimski 1976]:

- linear drawing (vectorial presentation)
- linear drawing supplemented by photomosaic
- photomosaic supplemented by linear drawing
- photomosaic

Nowadays, the linear drawing is still a predominating pattern for the presentation of architectural record. Photomosaics are used rather rarely (due to the fact that the majority of architects is yet not used to it), but with a good result [Hokey, 1973, Wanot 1968]. Interesting experimental works on orthophotography proved the purposefulness of this technology for a certain type of historic objects.

The compiled patterns however, are most likely to become a future standard for monument presentation when utilizing the photogrammetric survey. This very useful combination of the linear drawing and photomosaic (rectified photography or orthophotography in various projections) can satisfy the accuracy demands and the minuteness of detail. The often expressed need for selective exposure of the most essential details of a structure is also assured. The editor of a record has a free choice of proportions when presenting the structure and can show a drawn constructional line on the background of photomosaic or, on the contrary, the picture of a detail can be exposed on the background of the drawing. A desire to make photointerpretation possible may prompt the editor to the very vast use of photomosaics. It should be considered, however, that due to the better geometric interpretability of stereopairs rather than single pictures, the usable linear accuracy of photomosaics is a degree lower than that of the drawing; on the other hand, the price of photomosaic does not depend upon the density of details to be shown, and therefore pictorial presentation may be for some monuments (e.g.richly decorated) much cheaper than the linear one.

Therefore a general rule can be adapted, that constructional lines of a structure should be presented rather in a vectorial manner, while decorative details can be very well presented as a half-tone insertions. In some cases [Jachimski 1975] it would be enough just to supplement a fotoplan of a facade with some plotted lines, just to better define openings or other constructional details.

A very interesting examples of combination of rectified photographic image and linear object representation ware presented at the ISPRS Washington Congress [Pallaske, 1992].

Presently available powerfull interactive photogrammetric work-stations provide for a very easy screen presentation of various combinations of vector and raster technique of object evaluation. That way the final selection of configuration of each portion on an object documentation can be verified visually, to the best benefit of the customers.

Present photogrammetric workstations are extremely universal and flexible - not all that flexibility is necessarily indispensable, however, for producing proper documentation of a historic monument. For those applications extremely important would be reasonable price of an efficient enough system, which would allow for photogrammetry direct application by various monument recording and restoration teams.

Let us try to determine the functions of photogrammetric workstations which are indispensable for historic monument recording.

As for the recording of monuments variety of cameras can be used - the devoted workstation must accept any metric or nonmetric pictures. To simplify the task we can assume that one of PC-instalable terratriangulation systems is available (eg.ORIENT), and therefore the discussed historic monuments documentation devoted workstation (HMDW) must just accept pictures having sufficient ground control information. This can be easily executed on PC as two-steps or one step orientation of stereopare furnished with interior orientation elements or as one step DLT orientation for those non-metric stereopares which were not initially processed within terratriangulation net.

Our small HMDW must provide though a resolution good enough to interpret and survey even very small details of historic monuments. It is obvious that high resolution of digital image (that of 2000 dpi to 4000 dpi) requires not only a lot of disk memory, but also quite powerful screen graphics. The on screen image visualization must be so designed, that on medium screen format (14”-15”) must be visible large enough portion of the surveyed monument to allow for proper general interpretation, and, at the same time, the details must be presented with a very high resolution (what requires a lot of the screen pixels). That dilemma can be solved the same way as in other systems by providing small portion of high resolution image in a zoom window with the smaller resolution image in the background. If it is steady image based system (dynamic floating mark instead of scrolled image), it can function with no need for very powerful screen memory. To provide the operator with an easy approach to the image portions which are out of the screen, there would be enough to use a large RAM. In the RAM memory the image portions fitting the screen size (or part of it) would be stored (virtual screen) to provide very fast image change and visualization of portions close to the actually visible ones. The RAM of course can not be big enough to accommodate full stereopare images. Therefor such a rotary system must be adopted, that the RAM stored image portions always surround the portion currently visible on the screen. After several RAM pre-stored image portions have been used, the RAM stored images must be rearranged; that requires some extra time, but with relatively large RAM does not have to happen too often. Not only the main scale image exchange on the screen relies on the PC RAM in such system design. Also the zoom window can use the image portions taken from the image pyramid (which could also be ZOOM-ed on purpose).

So, in proposed solution the universal-use RAM rather then the screen memory is used, what allows to use typical off-shelf PC sets with hardware flexible for other programs. The proposed HMDW uses image pyramid in which the highest resolution image is predestined for ZOOM-window, one of intermediate images is used as a basic full screen visualized image, and the pyramid top image of smallest resolution should fit a half screen size and be used for the free selection of working stereopare portions (those which are visualized for evaluation). It is obvious that behind the relatively large RAM (not smaller than 8 MG) would have to be a big hard disc available. To easy deal with many high resolution images (one 6 x 6 cm image requires for true colour at 2000 dpi some 75 MG memory) it would be advantageous to furnish the PC system with exchangeable hard disks of short data transfer time rather than magneto-optical or similar diskettes.

Altogether the above system may work perfectly, but being based in a large extend on the PC/RAM, it does not go well with windows operation system on the middle size PC-computers. But lack of the common user friendly communication system would make our HMDW difficult to learn by all those users majority accustomed to use windows operation system. Therefore intermediate solution must be adopted, and an extra programmed user friendly communication system similarly operated as „windows" should be introduced. Of course such a windows-like interface would not have all the features typical for real windows operating system but would use less RAM. It would provide though, an easy enough communication with the HMDW program. Easy - because working on principles well know to the majority of users.

The system stereovision working on principle of steady image split screen stereo perception is probably the most easily fitting the natural fizjological men vision system, and - no doubt - the least expensive at present.

The system must be easy to operate, not only from the point of view of communication with program, but also from the point of view of stereo-operation. One of the basic problems here would be free selection of the most proper floating mark control coordinate system. The following coordinate systems can be here distinguished for our purpose: the spatial fiducial coordinate system, the leveled spatial fiducial coordinate system and the above system after transformation to parallelity with the field coordinate system (but keeping not changed the name of axis closest to the camera axis - this would assure the model depth control connected all the time with identical mouse key or other generator of impulses, e.g. P-cursor). The operator of the system should have also approach to the special temporary coordinate system, which being defined „on purpose" would suite to ease the operator's work (e.g. the coordinate system parallel to the tilted facade, or polar coordinate system which fits a dome parameters, [Jachimski 1975] etc).

The system must be easy to operate also from the point of view of plotted documentation peculiarity. Historic buildings, and other buildings even more, have many repeatable features: windows, door, ornaments etc. The HMDW system can and should be equipped with subroutines which will allows to build a pattern for each building repeatable feature and with a system which will allow for an easy implementation of repeatable elements spatial representation to the historic monument digital model created in the computer memory (such a system would be also used to build and implement conventional signs on maps, if map production would be occasionally performed eg. for historic urban studies).

Usually historic monuments are plotted with the use of several stereopares, which partially overlap each other. A vectorial monument evaluation portions taken from adjoining stereopares should match each other in double recording strip. To ensure the full awareness of matching actions undertaken by operator, the HMDW system should provide simultaneous observation of both matched stereopares along the overlapping strip. The floating mark being operated in selected fotogrammetric coordinate system connected with one stereopare is automatically properly located also on the second one via field coordinates of its position. The operator can decide about the optimal evaluation of a detail analyzing simultaneously matching of vectors with both spatial images.

To create conditions for the simultaneous plotting of overlapping areas, the system must use the screen splitted to four portions. In most cases it would be convenient to have it split vertically again (eg. for plotting a building corner from two perpendicular stereopares). Sometime, however, the overlapping zones will be horizontal rather than vertical and for that cases the screen must be split to the regular four quarters. With non-scrolled images and dynamic floating mark such a multipurpose split-screen operation is possible even on standard PC-s.

The overlapping zones matching function create an peculiar observation environment which can be used also when multi-image control points survey is concerned during preparatory terratriangulation stages. Up to four pictures matching portions can be surveyed simultaneously. In cases when there is more than four overlapping pictures, the operator can select one of them as a reference picture, and can visualize remaining 3 pictures sets one after the other, keeping the reference picture on the screen.

The results of control points multipictorial selection should be marked on the pictures (artificial temporary sygnalisation - similar to pinholes made with PUG on photographs - but non destructive for the digital image), to create pass-points for further processing.

Use of standard PC-s is limiting to certain extend the broad survey automatisation, specially when it is understood as a mass survey procedure. For selected terratriangulation points though, and in some other monument evaluation cases an automatic correlation subroutine would be very advisable. It would be implemented as two or three independent functions constructed with the use of different algorithms, just to use more developed but more time consuming ones only in the-most difficult matching cases, while other points would be autocorrelated with the faster but less sophisticated subroutines.

Except of autocorrelation procedures there is another possibility of semi automatization by automatic evaluation of edges of contrasting image zones which would be hand-indicated by operator. That method provides a high subpixel accuracy of line location on digital image [...], and could be used for semiautomatic control-point survey when they are defined as a two lines section. If fast enough, that type of subroutine could be used also as an semiautomatic tool supporting plotting (for that purpose a less dens line automatic analysis would give sufficient accuracy in a shorter time).

The proper vectorial representation of a monument selected lines (edges) can supplement a photoplan of facade or other decorated surface of the object. Also photoplan portions can be implemented to fill some zones of vectorial representation, where the monument is densly decorated or has many very small details which do not necessarily need vectorisation. To build such a mixed representation of a monument, one could use another program for differential rectification of images. On the other hand the resampling itself it is an easy subroutine. It would be probably much more difficult and time consuming to transfer rectification control data from HMDW to other system, just to produce resampling, and then to transfer photoplan again to HMDW to merge it with the vectorial representation, than to build all the product stages in one system. Therefore we consider HMDW as a small workstation which can be used also for rectification of selected portions of images. The advantage coming from such a solution would be also great when more complicated rectification in spatial projections are performed (egs vault, dome).

3. Closing remarks

An as found recording team, or just the monument revitalisation team which prepares monument recording, all of them would profit from a flexible use of photographic pictures during monument evaluation to produce some inventarisation documents. The broad use of photogrammetric methods would be beneficial only when it does not require big investment and long training. A small digital stereo plotter which incorporates several other useful functions could be an excellent toll for such applications, but it must be operated with user friendly, windows-like interface which would lead the user, step by step, to produce required record. Such a working station should accept scanned images taken with standard 60 x 60 mm or 24 x 36 mm cameras which could be precalibrated in specialized photogrammetric laboratory. For scanning the standard middle resolution scanners could be used, but only if they are precalibrated, and scanned images precorrected with the use of special image-quality and image-resolution adjustment program. The research concerning such procedures is in progress and it is anticipated that there will not be the necessity to use in future those very expensive photogrammetric scanners to get proper stereoplotting results.

The Authors believe, that small PC-instalable digital workstations which incorporate stereoplotting system will be in future utilized by restoration teams as a standard recording equipment. Our efforts are aimed on such a workstation development.

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