TEACHING AND LEARNING PHOTOGRAMMETRY USING PC, CD-ROM AND PHOTO-CD

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ABSTRACT

The new tools like the advanced PC models, new storage media like CD-ROM and Photo-CD, equipment for stereovision as well as some professional software packages for image processing are described and their potential for photogrammetry in general and for learning software in particular is discussed. Some learning programs used at Aalborg university are described as well as some experiences with it. Furthermore, first experiences are presented from an exercise with a digital stereo-workstation as well as from the development of a learning program based on Photo-CD imagery.

1. INTRODUCTION

Photogrammetry did change a lot in recent years. This concerns the instrumentation and the methods. The development went from analogue to analytical and digital instrumentation and methods. These changes should reflect in the education. This concerns the contents, but also the forms (Höhle,1993a). One of the possibilities of adapting in the form to the new situation is **Computer-Assisted Learning (CAL)**. This means that the computer assists the teacher and the student in improving the learning and understanding. CAL can be used within the lectures and in the exercises, and in self-studies by the student. Presenting knowledge by dynamic pictures, giving tasks to solve, and checking the progress in learning are the elements of CAL. Learning by doing is an old and proven principle in education. With CAL it is applied in a unique manner (Höhle-&Stubkjær,1990),(Höhle,1993b). Considerable progress in computer hardware as well as in software gives photogrammetry good chances to be based on cheaper and easily available systems and services. This concerns mainly powerful PCs, CD-ROMs and KODAK's Photo CD services. A large amount of data and numerous sophisticated programs can be stored on CD-ROMs. Small format amateur photographs can be delivered by a local photoshop in digital form on a Photo CD. The advances in software concern the integration of multimedia which means that black&white or colour imagery, moving pictures, sound and speech are available to the authors of learning programs.

To teach and learn photogrammetry by means of PCs has been used for several years, for example at Aalborg University since 1988. Shortcomings in the first programs arised due to the quality of pictures at the screen and the limited amount of data. Other fields have already taken advantage of the new possibilities and came up with fine learning programs. In Remote Sensing several programs have been announced recently, for example 'DIRIGO' of the University of Maine (Ehlers/-Jackson,1990), 'SAR and Optical Sensor Data Set' of the National Space Development Agency of Japan (NASDA), 'RESEAT' of the Open University of the Netherlands (Nadolski,de Vries,1993). All of them include several satellite images. Furthermore, professional stereo-workstations are now also based on PCs and are reasonably priced, and can therefore be used with advantage in the education. It is the purpose of this paper to deal with these innovations with regard to teaching and

learning software. Furthermore, a current project at Aalborg University using some of these new means is presented. At the end of the paper experiences with some existing learning software are given as well as first experiences when using the new digital stereo-workstations in education.

2. THE NEW COMPONENTS IN PERSONAL COMPUTER HARDWARE AND SOFTWARE

2.1 Hardware

The technical progress in personal computers (**PC**) and their peripheral equipment is very rapid. It is combined with a drop in prices. The high rate of changes and the great variety in computers can, however, also be a problem. It is partially solved by new designs with compatibility to previous models and by simulation of various operating system in one machine (cross-platform compatibility). This trend is realized, for example, in the new PowerPC of Apple/IBM/Motorola. The most recent IBM- compatible PC's with Intel processors (486, Pentium) have higher processing speeds (100 Mhz) and large memory (32 Mb RAM and 512 Kb Cache). Special graphics adapters enable the display of highly resolved colour pictures at large-size screens. Peripheral equipment include optical discs, video tape cassettes and compact disc drives with high storage capacity. Microphones and loudspeakers can also be part of the computers. A large amount of data as well as programs can be stored on **CD-ROM** and read into the computer. This new storage device with a capacity of 600 Mb supports the application of sound, speech, images and film - the so-called multimedia - in the learning programs. Colour photography of small format cameras can be scanned by local photo shops and stored on Photo CDs. Up to 100 images of the 24 mm x 36 mm format can be stored in 5 different resolutions (see fig. 1). At multi-session **Photo-CDs** images can be added at a later date. A special drive can read both CD-ROMs and Photo-CDs.

Also stereo-observation can be realized at PCs. An advanced system is called **CrystalEyes.** Two images are displayed quickly one after the other on the screen of the PC. The screen is observed by glasses which are made of liquid crystals. They open and close, each for itself, and with the same frequency as the images are displayed. Synchronization is controlled from the screen by means of infrared signals. Several persons can observe the imagery stereoscopically at the same time. When applying this additional hardware the PC can be extended to a photogrammetric stereo-measuring device. There are special print cards (frame crabbers), which digitize the signals of video-cameras and others which compress and decompress image data.

2.2 Software

The innovations in software are enormous and cannot be dealt with here in detail or completely. For our task, teaching and learning about photogrammetry, the innovations include operating systems, professional image processing software and authoring tools.

Operating systems

In the last few years new operating systems were introduced, for example Windows, System 7, OS-2, and NextStep. They support a graphical user interface, multiple windows, and multimedia.

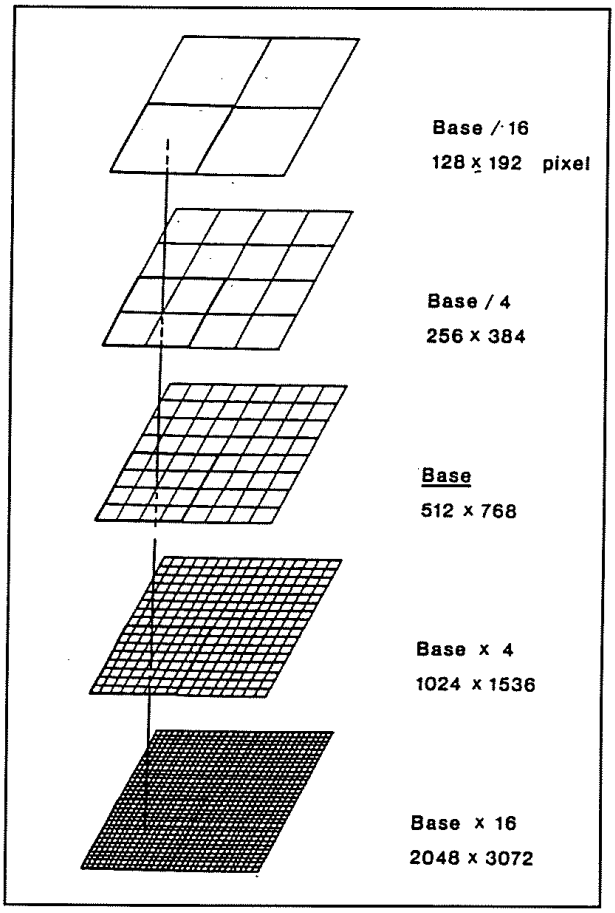

Fig. 1 KODAK Photo-CD. About 100 small format images can be stored on a compact disk in 5 different resolutions and with 16 million colours. The number of picture elements in this image pyramid changes by a factor 4 or 16 with regard to the 'Base' image.

System 7, the operating system of the Macintosh computer and its extension QuickTime, for example, controls films including sound and compresses images before storage.

Professional Software

There exists several professional software packages for PC's which can be used for teaching and learning photogrammetry. These are image processing programs, graphical programs and photogrammetric programs.

Image processing programs:

- 'Image' from National Institute of Health/USA
- 'Photoshop' from the Adobe Corp./USA
- 'Photostyler' from Aldus Corp./USA

All the mentioned programs can read images of various formats and transfer them to different formats, including compression. Furthermore, they can measure image coordinates, change the size, resolution, contrast, brightness and apply filters.

Graphical programs:

- 'AutoCAD' from the AutoDesk Corp./USA
- 'Microstation' from Bentley Systems/USA

These two programs can be used for graphical-design, mapping, and 3D presentations. Images can be imported and used as background information. For example, one can map on top of ortho images and the result is a geometrically correct map.

Photogrammetric programs

- 'BINGO' from the University of Hannover/ Germany
- 'CAP' from Rollei/Braunschweig/Germany

The programs can determine object points by means of aerotriangulation, where geodetic and photogrammetric observations can be adjusted simultaneously. The second program is part of the Rolleimetric system, where multiple photos of an réseau camera are used to reconstruct an object. The measurements can be done in a digital comparator or after conversion into Photo-CD imagery also by a PC-based measuring program.

Various other useful programs on PCs exist for handling of Matrix calculations ('Mathlab') and for data bases ('dbaseIV'). Some of the programs are delivered on CD-ROMs together with various data sets and learning programs (tutors).

Authoring tools

When producing learning programs, one has several possibilities. One can start from scratch and use standard programming languages, such as Pascal,C or Prolog. For all of the languages there exist **toolboxes**, which include elements of the user-interface such as pull-down menus, input and message boxes, etc. A good help for the development of learning programs is an **application generator**. The user interface can be designed graphically and the source code of a selected programming language is generated automatically. A further possibility is an **authoring program**. They include routines for handling multimedia. A special hardware is often necessary and one speaks then of authoring systems. More details about authoring tools can be found in (SEFI,1991) and (Höhle,Stubkjær,1991).

3. TEACHING AND LEARNING PHOTOGRAMMETRY USING PCs

Personal computers can be used for teaching and learning in different ways. The teacher can demonstrate parts of the subject by means of the PC in the lecture room . The contents of the screen is usually projected onto a large screen so that a major group of students can see it. The student can use a learning program, also, in an exercise room together with his/her fellow students. At some universities a special PC room with many PCs has been established. Instruction and exercises can then take place under guidance of a teacher. But the student can also use the learning program at home on his own computer. Beside the special learning programs professional software and professional stereo-measuring systems, which are based on PCs, are used. These professional programs/systems can be supplemented with a learning program (tutor). Such a tutor for the well-known graphical program 'Microstation' was written at Helsinki Technical University (Laurema,1994). In the following some examples from Aalborg University are given.

3.1 ORTO

This learning program provides knowledge about orthophotos. It has sections about the basics of digital images, the manipulation with images and various applications of orthophotos. Especially the combination of orthophotos with vector maps and their integration into land information systems is a subject of learning. The presentation of knowledge is accompanied with exercises. For example, one can manipulate the brightness and contrast of the digital image and at the same time observe graphs for the transfer characteristics, relative and sum frequency (compare fig. 2).

Other tasks with respect to the basics on digital images contain the calculation of the data volumes at varying image parameters. A calculator and more information (formulas, text) can be displayed if required. The answer to the keyed-in solution is checked immediately and a statistics about the overall results can be printed out. The learning program which was produced in 1987 is easy to use. Only few keys are necessary for the operation and a help function is available in addition. The program requires an EGA/VGA graphics adapter. The program can therefore be used on low-cost IBM compatible computers. The texts within the program can easily be transferred to other natural languages. More details can be found in (Höhle&Stubkjær, 1990).

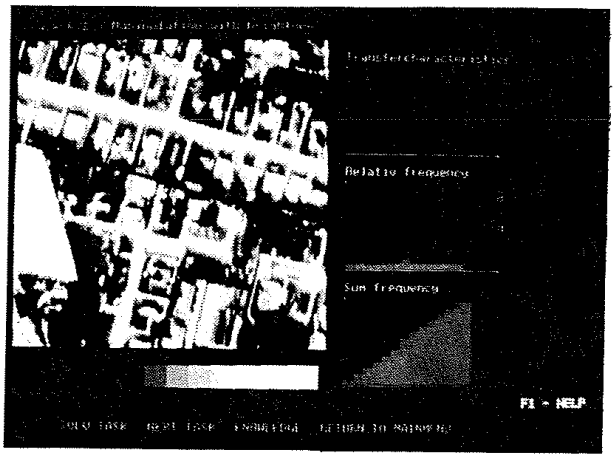

Fig. 2 Screen image of an exercise in the learning program 'ORTO'. Brightness and contrast of the ortho image (on the left side) shall be changed by the student. At the same time he or she observes dynamically changing image parameters: number of greytones (greywedge below image), average greytone and standard deviation (numbers), transfer characteristics, relative and sum frequency (graphs at the right side). There is a menu for operations (lower line) and a help function (hot key F1).

3.2 ANALYT

The purpose of this learning program is to train in analytical photogrammetry. In contrast to the previous program 'ANALYT' is an open program. This means, the source code can be inspected, changed and compiled. Running of the programming can be stopped or intermediate results can be observed. The presence of the Integrated Development Environment of the programming language (Pascal) is, therefore, necessary. In this way the programming of the formulas for orientation and object determination and the calculation according to different methods can now be inspected and the logic of the formulas can be followed. The exercises were accompanied by picture-taking with a terrestrial camera, surveying of control points and measuring of photographs in an analytical stereoinstrument. More details can be found in (Höhle,1992).

3.3 DiAP

The learning of digital photogrammetry can be done when using a professional digital stereo-workstation. Such a PC-based system was introduced by the Canadian firm International Systemap Corp. in 1992. This so-called **D**igital **i**mage **A**nalytical **P**lotter (DiAP) uses 'CrystalEyes' for the stereo-observation and a 3D-mouse or handwheels and footdisc for the control of the measuring mark or images (compare fig. 3).

The computer is a standard PC (with an Intel 80486 processor with 32 Mb RAM), a graphical adapter with two 'fields' of 1024 x 768 pixels, each pixel with 256 colours , a 1.4 Gb harddisk and a 2 Gb tape unit (DAT). The system software is written in MDL, which is based on the graphical software 'MicroStation'. The images are stored on disc and portions of it are read into the Graphic adapter by means of decompression/compression software ('Turbo-charger'). The stereo model or the individual images can be observed with zoom functions and measured by means of a selectable measuring mark. When panning through the stereomodel in X,Y and Z, the images will move according to the equations of collinearity. The exterior orientation can be determined by a bundle adjustment where also weights can be applied. Mapping can be carried out by 'Microstation' functions. Special packages for photogrammetric applications are available, for example for mapping, DEM data collection and triangulation. If the photographs have considerable longitudinal tilts a resampling of the images is recommended, and a special program can be acquired. At DiAP only black & white imagery can be used.

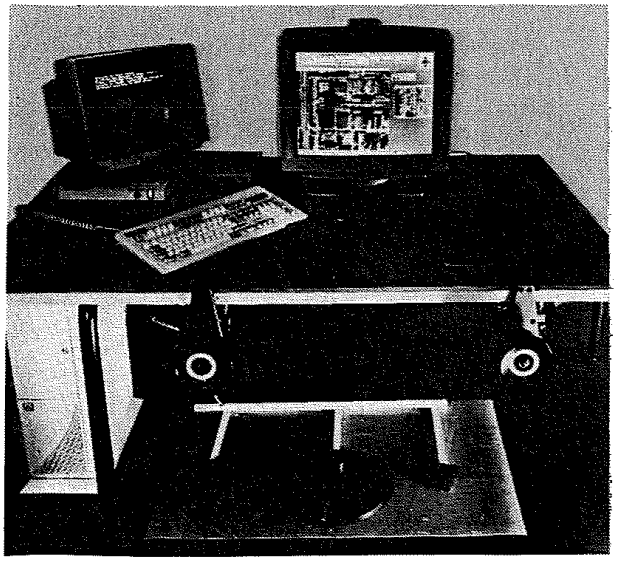

Fig. 3 PC-based digital stereo-workstation 'DiAP'. Two digital images are alternately displayed on the screen and observed stereoscopically by means of the 'CrystalEyes' glasses. The images or the measuring mark are controlled by a 3D-mouse or by handwheels and footdisc.

4. TEACHING AND LEARNING PHOTOGRAMMETRY USING PC AND PHOTO-CD

The general advantages of the Photo-CD in photogrammetry are described first. A CAL program under development by the author is described thereafter.

4.1 Use of Photo-CD in photogrammetry

The huge capacity of a Photo-CD combined with the fact that one can get digital colour images at low costs enables the user to collect
various images and to establish an image library. The Photo-CD format can be read by various low-cost image processing programs, such as 'Photo-shop', 'Image', etc. The use of smaller formats (up to 120 mm width) restricts the application mainly to terrestrial photogrammetry. The availability of different resolutions for one and the same image enables one to adapt to the capacity of the computer and the graphical processor or to the requirements for speed or quality. One can assume that Photo-CDs together with PCs will have also some practical applications in future. For example, geological mapping has been carried out by terrestrial photography for many years in Greenland (Dueholm, 1992). Architects use terrestrial photogrammetry for surveying facades. Photo-CD imagery can be used with advantage in 3D mapping (compare Höhle, 1994). The application of the Photo-CD in CAL for photogrammetry is obvious because it offers new possibilities and does not need expensive equipment.

4.2 The learning program "LDIP"

"Learning about digital Photogrammetry" ("LDIP") is the title of a learning program, currently under development at Aalborg University. The contents cover themes like rectification, generation of perspective views, correlation, compression techniques, and standard image formats. The image material is stored on a self-assembled Photo-CD, it includes 35 mm amateur photography, 60 mm x 60 mm réseau photography and 4" x 5 " photography of a photogrammetric camera. The user

interface consists of several general functions ('initialize', 'knowledge', 'tasks', 'calculator','help', etc.). 'Knowledge' contains the theory and facts about the mentioned themes, which is supplemented by exercises ('tasks'). For example, correlation will be explained in detail. One of the attached tasks requires the measurement of a réseau cross. The réseau camera image is loaded and several measurement have to be carried out, both manually and automatically. The derived standard deviations will show the differences in quality between automatic and manual measurements. The prototype program is written in Think Pascal and runs on Macintosh computers under the operating system 'System 7' and in connection with the Apple CD 300 drive. "LDIP" is supposed to run on the IBM PowerPC as well. Fig. 4 shows a screen image for an exercise in "LDIP".

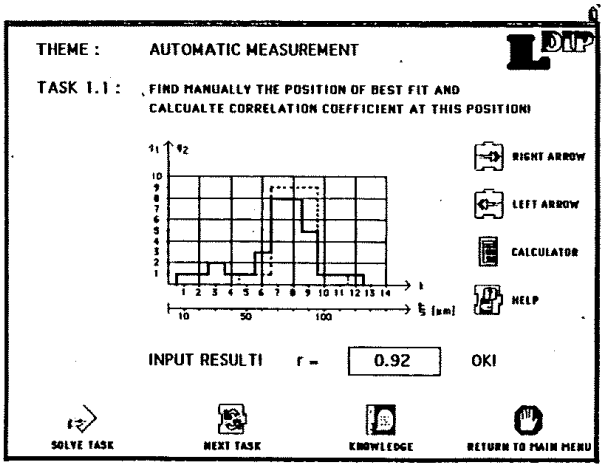

Fig. 4 Screen image of an exercise in the learning program "LDIP". Within the theme 'Automatic measurement' the best fit of two density profiles (target and search area) has to be found. First manually by moving the target area (dashed line) over the search area. Thereafter, at the position of best fit, the correlation coefficient (r) has to be calculated by means of a 'calculator'. If the result is correct, the program will indicate it by writing "O.K." on the screen.

5. SOME EXPERIENCES

5.1 ORTO

This learning program has been used by the author since 1988 in the education of the Danish land surveyors at Aalborg University. Some experiences with the program are already reported in (Stubkjær, Höhle,1993). The recent experiences with the 5th and 7th semester students, who get basic training in photogrammetry and image processing, are positive also. The exercise with some of the parts takes place with 10 students at a time in the department's 'PC-bar', and does not last much longer than one hour. The program is handed out and some students repeat or continue at their own computer. 'Orto' was also used at other educational institutions, e.g. at the Faroe Islands, Spain, England. The simplicity in using the program, its error-free run and the easy transfer to other languages have contributed to its success.

5.2 ANALYT

The program was used so far 1992 and 1993 of the 8th semester of the Danish land surveyor education. The exercise took place again in the 'PC-bar' and lasted about 1.5 hours. One teacher can guide a group of ten students alone. The results of the calculations can be presented also graphically, which improves the understanding. The 'open' programs stimulate to

continue with own programming and take some of the mysteries out of analytical software packages.

5.3 DiAP

The Laboratory for Photogrammetry and Surveying at Aalborg University acquired 2 DiAP systems in 1993. The first exercise with 34 students took place in spring 1994. The practical training included a complete orientation of the stereopair as well as mapping a part of the model. The used imagery at a scale of m_b=5550 had a pixel size of 22 µm. The amount of data to be handled was therefore 2 x $(230/0.022)^2$ x 2^{-20}=208 Mb. The display of the single image is done with 1024 x 1536 pixels, the stereo-pair, however, is displayed, however, with 1024 x 750 pixels. With the zoom-in function a portion of the image is displayed, which allows for a more accurate pointing. The fiducial marks, the points for relative orientation and also the control points (after a first calculation of the exterior orientation by means of 3 points) come into the display window automatically and also relatively fast. The pointing is carried out by means of the mouse-controlled measuring mark. Glasses were not used in the orientation procedures. At the interior orientation the 'Affine transformation' was applied, and at the exterior orientation the 'Bundle adjustment'. The obtained root mean square errors (RMSE) were usually less than ½ pixel (11 µm) at the interior orientation and about 1 pixel (or 22/152=0.015 % of the flying height) at the height control. The achievable accuracy depends on the pixel size and the quality of the scanner used for the digitizing of the photography.

The mapping of portions of the model occurred with functions of µStation software. The glasses as well as the handwheels/footdisc were used for this part of the education. The observation of the stereomodel is pretty comfortable, the progress of the mapping can be followed by other students or the teacher and errors in tracing and in height setting can immediately be detected.

5.4 LDIP

The use of the Macintosh computer together with its CD-ROM drive gave the author many new possibilities when developing "LDIP". First of all, the user interface could be designed more elegantly than in the previous programs (ORTO,ANALYT). Pictograms and texts could be used and the program is controlled by 'mouse click' only. The amount of the usable data or the size of the program is no longer a problem when storage on CD-ROM or Photo-CD is applied. The higher computing speed allowed to solve larger computational tasks, for example correlation by least square adjustment.

6. CONCLUSION

Teaching and learning photogrammetry by means of CAL have got many new tools. Many new educational programs (teachware) will be created in the next future. Professional programs are often delivered (or marketed) on CD-ROMs; these programs can be integrated into the CAL software. Own photography can be digitized and stored on a Photo-CD at low costs. It can be used as slides or image data for interpretation or measurement tasks. PC based digital stereo workstations can be used with advantage in the education of photogrammetry. The usual difficulties

with the stereo-observation do not exist with these systems, and the communication between student and teacher are easier. In CAL software, the user interface can be designed more friendly now. The higher speed allows animation, colour photography and larger computational tasks.

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