LEARNING DIGITAL PHOTOGRAMMETRY BY MEANS OF PERSONAL COMPUTERS

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ABSTRACT:

The new CAL program "Learning about digital photogrammetry" of Aalborg University is presented. The pedagogical and the technical concepts of "LDIP" are explained. One theme, the automatic measurement of réseau crosses and fiducial marks, is presented in more detail. Experiences from the development and the use of the finished parts of "LDIP" are discussed.

KURZFASSUNG:

Das neue CAL Programm "Lernen über digitale Photogrammetrie" der Universität Aalborg wird vorgestellt. Das dem Programm zugrunde liegende pädagogische und technische Konzept wird erläutert. Ein Thema, die automatische Messung von Réseau-Kreuzen und Rahmenmarken, wird ausführlicher behandelt. Erfahrungen von der Entwicklung und von der Benutzung der fertig gestellten Teile von "LDIP" werden diskutiert.

1. INTRODUCTION

When using digital imagery, the measuring process can be automated partially. However, the computer-based evaluation systems are rather sophisticated and the amount of data to be processed is usually huge (approximately 100 Mb per aerial image). This means that these systems are expensive, and they also change quickly. The education in photogrammetry at university level can neither afford all of the latest imaging and image evaluation systems nor buy it in considerable numbers for the training of a large number of students. This is where computer-assisted learning (CAL) comes into focus. The equal treatment of students, their active role in the learning process and their motivation to work with computers are some of the reasons for CAL gaining in popularity. Besides mass education, distance learning and self-study are good reasons for applying CAL. At Aalborg University CAL has been used since 1987, and various programs for PCs have been developed and used in the education of land surveyors (Höhle, J., 1992). Recently, new tools were introduced, for example more advanced personal computers and storage devices like CD-ROM as well as the Photo-CD services (Höhle, J., 1994). By means of these new tools a new development was started by the author. The program is called "Learning about Digital Photogrammetry" ("LDIP") and it deals with various processes in digital photogrammetry and image processing. It is the main purpose of this paper to present this new learning program and to demonstrate the power of the new possibilities for CAL in photogrammetry.

2. THE LEARNING PROGRAM "LDIP"

"Learning about digital photogrammetry" ("LDIP") is the title of a learning program currently under development at Aalborg University (see fig. 1). The contents will cover themes like rectification of imagery, generation of perspective views, correlation, compression techniques, and standard image formats.

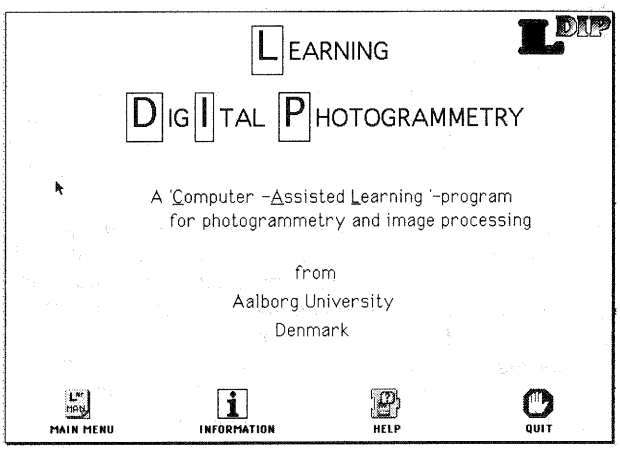

Fig. 1. 'Front page' of the CAL program "LDIP". The fields with the icons and text on the bottom line are used for controlling the program.

In the following, the pedagogical and technical concept and its realization is explained with the example of one theme. The presented information about this theme shall be described as well as the exercises to it. First the experiences, when using the programs at the surveying and mapping education shall also be mentioned.

2.1 General description of the theme "Automatic measurement by means of correlation"

The evaluation of images starts with the measurement of fiducial marks. These are well-defined marks at the edges of the image. The connecting lines between the "fiducials" define the image coordinate system and its origo which is the principal point of the image. In order to reconstruct the image

coordinate system and the principal point one transforms the measured pixel coordinates into an image coordinate system given by the calibrated values of the fiducial marks. There can be 4, 8 or more fiducial marks that have to be measured. Other marks which have to be measured as well are réseau crosses, which are positioned on a glass plate inside a special camera, called réseau camera, and which are imaged together with the object. By means of these réseau crosses it is possible to detect image deformations or deficiencies of the used scanner and thereafter correct them. The mentioned marks or crosses are all well-defined, and their image matrix is known beforehand. It is called a template. By moving the template in steps of one picture element over the image one searches in the image for the imaged fiducial mark or cross. At each position of the template a correlation coefficient is calculated. The position where the correlation coefficient has its greatest value is the searched one. The accuracy of the determination is the size of one picture element. If subpixel accuracy is required, a least square adjustment has to be applied. A small shift of the template and two other parameters (which apply corrections in the greyvalues of the pixels) have to be calculated. This rather complex calculation leads to a positional accuracy which is about 1/10 of the pixel size. The measuring is completely automatic and fast.
The réseau camera is very handy and a pretty high accuracy can be achieved. Réseau cameras and réseau techniques are successfully used in industrial applications. (Dold, J. et al., 1993).

2.2 The pedagogical concept

When a theme is selected, the information about this theme (the so-called "knowledge") is presented. This occurs by means of screen images with text and figures. A text is written line by line on the screen, and additional information can be displayed when it is wanted. The attached figures are dynamical ones. The information is presented by small pieces so that it can be grasped. The sequence of the text lines can also be repeated. Several exercises ("tasks") are connected to the themes. The student is active and manipulates a figure or calculates values. The result of the "task" is sensed automatically or typed in the keyboard and immediately checked by the program. This immediate and neutral feed back is one of the main strengths of this CAL program.
The user interface is graphical and very simple. There are only few fields with their icons and texts to point to. The ones at the bottom line are used for the navigation through the program, the ones on the right side for the manipulation within the displayed screen image (compare the figure). They are started by means of the mouse or the track pad. A 'help' window informs about the next steps to be taken. A simulated pocket calculator can be used for the calculation of the results. The language in the texts is English only.

2.3 The technical concept

The prototype of "LDIP" uses Macintosh hardware, the models "2si" and "PowerBook 520". Both of them can be connected to a CD 300 drive in order to read imagery from a CD-ROM. The transportable PowerBook with a black and white screen can also be connected to a plasma screen (LCD) which enables the projection on a large screen in colour. The PowerBook can be upgraded to a PowerPC which then also makes possible the emulation of the DOS operating system so that PC programs can be used at a reasonable speed.
The software is written in Think Pascal and runs under the 'System 7.1'. This operating system contains also toolboxes with numerous functions for the development of CAL software such as pull down menus, input and message boxes, icons, image and sound facilities.

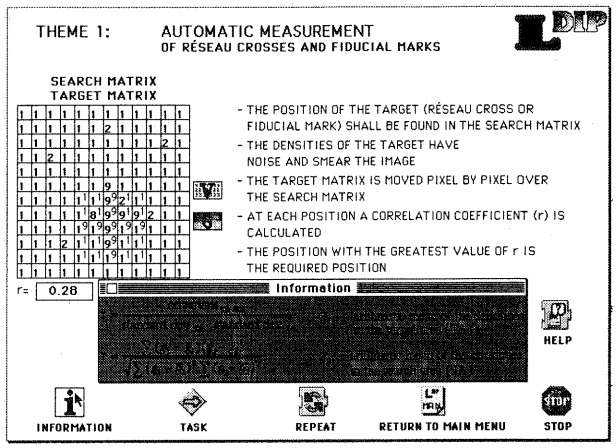

Fig. 2. Screen image for 'Knowledge' in the CAL program "LDIP". At this moment of the sequence *all* of the text lines and the additional information is displayed. The target matrix of 5 x 5 pixels is situated within the search matrix at the position where the correlation coefficient is r=0.28.

All image data shall be stored on an assembled CD-ROM which has to be produced from imagery originally stored on various media and at various formats. The image data is loaded from an attached or integrated CD-ROM drive or from various discs if CD-ROM drives are not available.

2.4 Description of the use

2.4.1 Automatic measurement of réseau crosses and fiducial marks: Five text lines for this theme are displayed sequentially, they are coordinated with the attached figure. In this dynamic figure a target matrix moves over the search matrix and the correlation coefficients are displayed at each position (see fig. 2). The grey values of the two images (search and target area) can be displayed as numbers or as shades of grey. With the field "INFORMATION" the formulas for the correlation coefficient can be displayed in addition. Also, the different parameters in the formula are then explained in detail. All this information is necessary for carrying out the related exercise (task 1.1). For this purpose, the field "TASK" has to be activated.

2.4.2 Automatic measurement - task 1.1: The best fit of two density profiles (target and search area) has to be found, first manually by moving the target area over the search area. The user clicks either on the icon "RIGHT" or "LEFT", whereby the target area moves in the selected direction. At the position of best fit a correlation coefficient has to be calculated. The pocket calculator can be used for the computation. If the student has forgotten the formula for the computation of the correlation coefficient, the icon "KNOWLEDGE" is clicked on which leads back to the screen image with the formula. The computed value has to be typed in the keyboard and is displayed at the input window. If the result is correct, the program will indicate it by writing and saying "CORRECT!" In the other case the written and spoken answer are "WRONG!". By means of the icons "NEXT TASK" or "RETURN TO MAIN MENU" the student can proceed. **2.4.3**

Correlation in the subpixel range: The basic information about this theme is presented by means of four text lines and two figures (see fig. 3). The sequence of the text lines can be repeated or stopped. Additional information such as formulas and explanation of the parameters is displayed when clicking on the field "INFORMATION". The exercise is started by pointing to "TASK". The contents of the theme covers the correlation within a profile, which means the target matrix is shifted in one direction only. This topic is easier to understand than correlation in two dimensions. It serves here as an introduction, but has in itself practical application for height determinations.

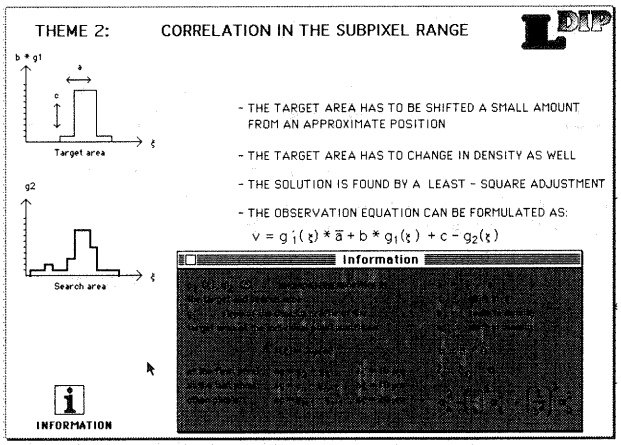

Fig. 3. Theme 'Correlation in the subpixel range' from the CAL program "LDIP". At this moment of the sequence all text lines are displayed as well as the additional information (in smaller print). The sequence of the text lines can be restarted by activating the field 'REPEAT'.

2.4.4 Correlation in the subpixel range - task 2.1: This exercise requires to find the coefficients of the observation equations which have to be read from the attached figure and set into the matrix and the vector areas. Thereafter the calculation of the normal equations is started and can be watched. The precise position of the target area and its accuracy have to be calculated by the student again. He or she uses the integrated pocket calculator for this purpose (see fig. 4). The results have to be entered into the keyboard and they will be displayed at the premarked result windows. All input values are analysed and commented by the program.

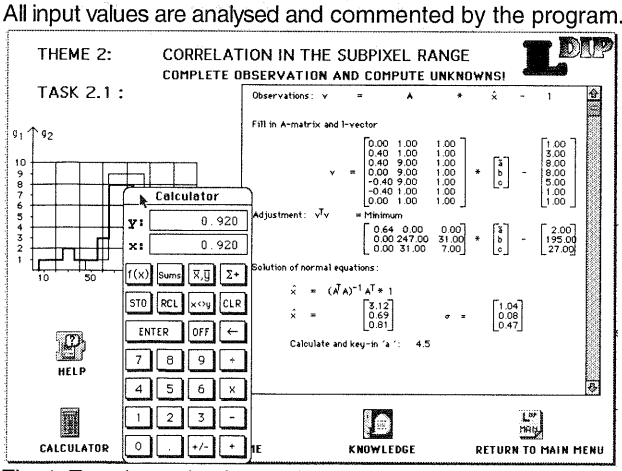

Fig. 4. Exercise to the theme 'Correlation in the subpixel range - one dimension'. The unknowns of the correlation are determined by an integrated calculator.

2.4.5 Automatic measurement of real réseau images: The theoretical treatment is now supplemented with practical réseau images. The presented knowledge contains again a sequence of lines of text, dynamic figures, formulas and recommendation of literature to read (compare fig. 5). They are presented in various levels.

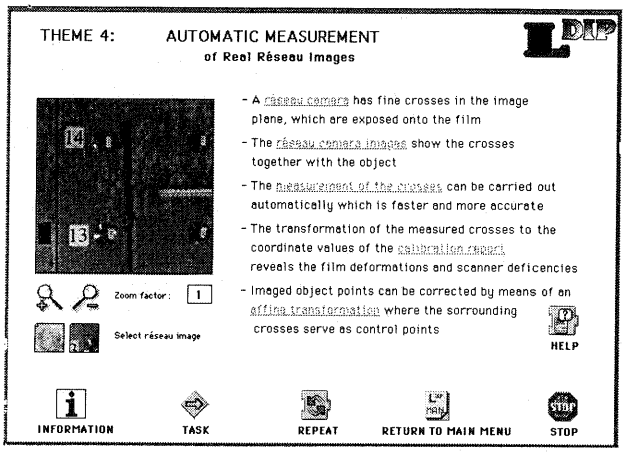

Fig. 5. Screen image for the theme 'Automatic Measurement of Real Réseau Images'. All the text lines are displayed by now; additional information will be shown when 'clicking' on the underlined key-words. A hypertext window will then display more text, formulas, figures or recommended literature. The image at the left side of the screen can be interchanged and zoomed. The selectable images are taken from project work.

Additional information is received by activating either the keywords in the text or an icon. A hypertext window appears which can be shifted to another place, if it hides information. The exercise with real réseau images starts with adjusting the template in size, rotation and geometric resolution (pixel size) to the crosses of the réseau image. The first two crosses are measured by pointing at the approximate location. By means of the derived transformation parameters the measuring can now occur automatically. The speed of measurement and the setting accuracy is displayed. Various sets of transformation (affine or projective, with all crosses or with four surrounding crosses) are carried out, and the residuals at the crosses are displayed. The results demonstrate the advantages of the réseau camera.

2.5 Some experiences from the development

The development of "LDIP" occurred in the usual steps design, programming, testing, and documentation.
The design of the program comprises the screen images for 'Knowledge' and 'Task', the user interface and the program structure. The screen images are designed according to the technical contents, here "Automatic measurement ". The practical exercises also determine the amount of information which has to be presented in 'knowledge', for example the formulas, the figures, their expressions, etc. Computational tasks should not be too lengthy. Parts of the computations will run automatically and intermediate results are displayed. The user interface was designed according to standards established in previous CAL programs by the author. For example, the operation has to be as simple as possible. The sequence at the normal use of the program as well as all possible manipulations had to be specified for the programmers. Programming of the "LDIP" software was split into 'user

interface' and in 'computation'. For the first programming task, detailed knowledge of and experiences with the toolboxes were necessary. Such information can be gained from the books "Inside Macintosh" which are also delivered on a CD-ROM. Parallel with the programming, the testing of the finished modules took place. The efforts for careful testing are considerable but they are well invested. When running the program, some problems occurred due to insufficient memory at the PowerBook. 4 Mb of RAM proved to be sufficient, but no other programs should be loaded into the memory. The runtime version of the "LDIP" prototype has about 250 kbytes. The development efforts of the prototype version are about 150 hours of programming; design, testing and documentation efforts are not included. On the whole, the development efforts are relatively high. They can only be justified if the program can be used several times.
The production of a CD-ROM is planned to be carried out on a multi session CD-ROM writer and all the images will be in the TIF format. The image data are originally stored by means of a Photo-CD, a DAT cassette or 3.5" discs. The format of the original data was partially in Photo-CD format (YCC) which has to be converted by means of the program "Photoshop".

2.6 Experiences from the use

The use of the program is twofold. The first use is a presentation in the lecture room together with an overhead projector.

The quality of the presentation depends on the applied plasma screen (LCD). The used one, Telex 6001, makes possible the presentation in colour, even though the PowerBook 520 has a black and white screen only. The light intensity at the projection can be a problem at larger audiences and at bright lecture rooms.

The second use, in an exercise room with 12 Macintosh computers, model LC475, is carried out by one teacher only. He himself uses 1 Macintosh LC475 together with a LCD and an overhead projector. The students did not have experience with Macintosh computers beforehand. The exercise with the contents explained in section 2.4.1-2.4.4 of this article takes about 1.5 hours. At this computer model it was necessary to emulate the Motorola processor 68030 instead of the built-in 68040 processor in order to run the execute file of "LDIP".

3. CONCLUSION

CAL in digital photogrammetry requires a large amount of data and complex calculations. The new personal computers with their high processing speed and large internal and external storage capacity (such as CD-ROM) as well as the Photo-CD services make a new type of learning program possible. These CAL programs include speech, image libraries and programs with heavy calculations. The user interface is simpler and more attractive due to icons, sound and various windows. The efforts for development are relatively high and require detailed knowledge of toolboxes as well as good programming experience. There are also very advanced author programs available which will ease the production of good CAL programs for authors with less experience in programming.

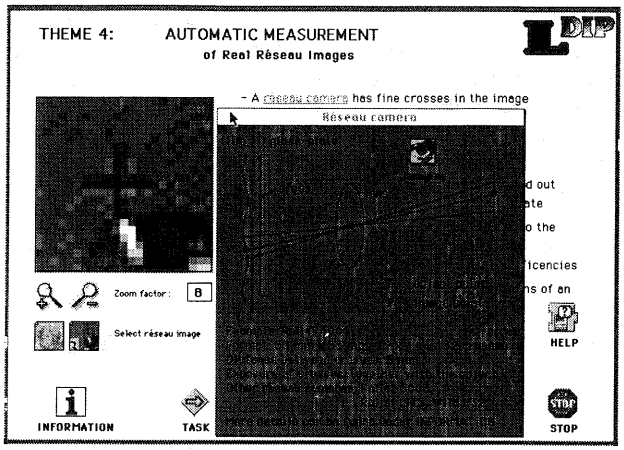

Fig. 6. Second level of information about réseau cameras. The new figure is a dynamic one. By clicking on the icon "IMAGING", three imaging rays run from right to left and hit the film at three points: the image point p' and two imaged réseau crosses. A third level of information can be displayed; this hypertext window contains related literature.

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