UNIVERSAL ANALYTICAL PLOTTER SOFTWARE FOR PHOTOGRAPHS WITH PERSPECTIVE GEOMETRY (CRISP)

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ABSTRACT

A software-package for the Kern analytical plotter DSR-1 is presented. It serves with perspective photographs, irrespective of metric or non-metric geometry, handling single images or arbitrary multiple overlaps. In addition to common control points, the system also uses known terrestrial observations such as distances, angles, azimuths and height-differences. Conditions that some points are on a straight line and on a plane can be included. The program system also offers utilities such as digital mono- plotting or plotting in any arbitrary defined plane. Typical applications, apart from common cases of stereo-photogrammetry, are in close range work, in the use of amateur cameras and in special image arrangements.

INTRODUCTION

The advance of analytical plotters has created the possibility to address stereo plotting tasks that were previously not feasible. This concerns the range of focal distances, formats, presence or absence of fiducial marks, reseau, possible values of camera attitudes and variability in sensor projection geometries (x-ray, scanning, radar).

To materialize some of these promises of the analytical plotter technology one has to invest in sizeable software development efforts. We find that the implementation of a universal photogrammetric program system on an analytical plotter is not a problem of intricate mathematics. It is much more a question of ergonomic man-machine interfacing, robust numerical algorithms and robustness in operator-machine dialogues. The following will present the current status of the operational system CRISP (Close Range Image Set-up Program).

HARDWARE CONFIGURATION

CRISP has been written on the DSR-1 of the Graz Research Center. The analytical plotter consists of three digital processing units, which are denoted as P1, P2, P3 (Chapuis, 1980). The units are described in table 1.

Processor P1:	(host computer): DEC PDP 11/23, 64 k-Byte memory Dual-floppy disk unit RL01 Hard disk RL02 Hard disk (available also Winchester disk drive)
Processor P2:	DEC LSI 1103, 24 k-Byte memory
Processor P3:	Intel 8055, 4 k-Byte RAM

Table 1
Processing units of the Kern DSR-1
at the Graz Research Center

Processor P1 is the host computer. It is an independent unit and performs the transfer of data and programs between the microprocessors. It is the computer for application programs and serves as link to peripheral devices such as demand terminal, line printer and plotter. The periphery deviates from Kern's standard configuration. Plotting is mainly on a small A3-format plotter of Watanabe. The precision plotter Kern GP-1 that is normally combined with the DSR-1 can of course be used for precision plots instead of the small A3-format plotter. In our case the Kern GP-1 is the general purpose vector hard copy device and in connection with a VAX 11/750 computer. Also processor P1 is connected to a VAX 11/750.

Processor P2 determines the positions of the two plate carriers in real time at video rates of aprroximately 50 times per second. P2 relates the XYZ model coordinates to the x,y plate coordinates of the two plate carriers.

Processor P3 controls an operator control panel. This also can be used for communication between the operator and the DSR-1.

DISCUSSION OF SOFTWARE

CRISP consists of two main program systems, one for the plate processor P2 and one for the host computer P1.

Program for plate processor P2:

The plate processor program transforms the XYZ model coordinates into x,y plate carrier coordinates. This is done in a real time loop 50 times per second. On request the transformation XYZ -- x',y',x",y" can be chosen from three different methods:

* common rotation parameters
* Direct Linear Transformation (DLT) parameters
* numerical rectification of a single image

The program is also responsible for data transfer P1 between P2, for example:

* sending x,y image resp. plate (=machine) coordinates to P1
* sending XYZ model (micron) or object (meter) coordinates to P1
* driving the plate carriers to a certain image, model or object position
* receiving transformation parameter
* receiving camera parameters (like distortion)
* other functions.

The plate processor program runs in a stand alone mode without a so-called operating system and is written in Pascal. It is developed and tested on the host computer P1. This makes it very easy to study and to change the code. Every time when the DSR-1 is started the program executable module must be down-loaded from the host computer P1 to the processor P2.

CRISP Software on Host Computer P1:

CRISP follows the general rules for ergonomic man -- machine communication and provides:

* Operator friendly functions and procedures,
* Effective operator/machine dialogues,
* Help functions all throughout the program,
* Robustness in a statistical sense by detection of outliers,
* Robustness in the sense of guiding the inexperienced operator.

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-------------------------------------------------------------------------
FZG Graz, Austria                          CRISP help for digitizing data
-------------------------------------------------------------------------

GENERAL SYNTAX OF COMMAND FOR DISTANCES:
  Command/Option-1/Option-2   or  Command Option-1 Option-2

COMMAND  = What is to do ? (3 characters):
  DEL-(delete),  REM-(remeasure),  DIG-(digitize),  EXI(T)-(exit)
OPTION-1 = 3 characters or distance number (-9999...+9999)
  ALL    - perform the command with all distances (DIG/ALL not allowed)
  number - perform the command with specified distance.
OPTION-2 = 3 characters
  number - do it with a specific distance point (e.g only station point)
  ALL    - do it with all distance points (station and target point)
  empty  - do it with all distance points (station and target point)

For example: distance with number 1000 ( -9812 --> 1234)
       DIG/1000/1234 ... digitize target point 1234 (e.g -9812 not visible)
       DEL/1000      ... delete distance with number 1000
       REM/1000/ALL  ... remeasure all distance points in distance 1000
-------------------------------------------------------------------------
To CONTINUE press -RETURN-
-------------------------------------------------------------------------
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Figure 1.
Example of a help function display

Individual dialogue can be extensive for the inexperienced operator (see figure 1) or it can be shortened if the extensive support is redundant.

Short Description of CRISP Modules:

Various elements of the modular program system are reviewed in the following.

a.) Point management: This allows input, deleting, inserting, listing and correction of object space control points. The module accepts points with X and/or Y and/or Z coordinates.

b.) Observation management: This allows input, deleting, inserting, listing and correction of terrestrial observations. Types of observations to be considered are distances, angles, azimuths, differences of heights and conditions that certain points are on a straight line or on a plane.

c.) Camera management: Module for input and editing camera parameters.

d.) Project definition: Module for the operator to define the kind of images and other project parameters which exist in a specific project. Images can be metric or non-metric. Multiple overlaps are feasible, e.g. an image can have more than one stereo-partner.

e.) Project status report: This program part writes the status and all available results of the project on an ASCII-file, which can be printed or checked with the editor.

f.) Single images: This serves to set up single images. It includes inner orientation, numerical rectification.

g.) Stereo images: For setting up a pair of stereo images one has an inner orientation, DLT, and 3-D space resection of the individual images and relative as well as absolute orientation. Here also all available observations and constraints on object data can be digitized. Observations which span over several models and control points which are only visible in one image are allowed.

h.) Bundle adjustment: All images defined for this project are included in a bundle adjustment. For the solution of the adjustment the method of conjugate gradients is used.

i.) Utility programs: So far this includes the capability to plot in XY, XZ, YZ planes or arbitrary planes defined by three points.

All redundant equation systems are solved in a robust manner. First a least squares adjustment (L2-Norm) is employed. If this solution is not satisfactory due to some gross errors the operator can enter an adjustment by minimizing the sum of absolute residuals (L1-Norm). This is a very powerful method for detection of gross errors of heterogeneous size (Fuchs 1982).

EXAMPLE OF A STEREO PAIR WITH NON-METRIC AND METRIC IMAGES

A small example of CRISP is the set up of an unconventional stereo pair. Details are described in table 2, the photos are shown in figure 2.

Left Photo:	Amateur photo (Canon A-1) format 24 * 36 mm approximately 50 mm focal length
Right Photo:	Metric photo (Wild P32) format 60 * 90 mm fiducials known, focal length 64.06 mm

Table 2: Data of the stereo pair used in our example.

The model was set up in the following way:

(a) Inner orientation of the photographs,
(b) Determination of parameters of the amateur photo using the DLT solution,
(c) Relative orientation,
(d) Absolute orientation,
(e) Bundle adjustment including
    7 full (XYZ) control points,
    One Z control point,
    Two distances,
    Condition that some points are on a straight line.

The plot was obtained from the A3-format check plotter connected with the DSR-1 (figure 3). The resulting data are also stored on an ASCII plot-file. The file can be transferred to the VAX 11/750, edited and finally plotted or scribed with a general plot editor program on the GP-1.

The time for setting up of the model was about 18 minutes for an expierenced operator.

CONCLUSION AND FUTURE PLANS

The Kern DSR-1 favors the user's participation in software development. Distributed processing with user-programmable processors provide great flexibility in adjusting or expanding existing system software or even independently creating one's own system. All programs of CRISP are written in Pascal. Pascal is easy to learn and has a

powerful code which is easy to read. This is important when developing complicated plate processor programs such as for radar-, strip camera images etc. Current plans are to create also plotting systems for non-perspective imagery. One effort addresses radar (Raggam and Leberl, 1984).
Two other projects are development of program systems for SPOT and MOMS satellite images.
It is expected that this type of work will help to fullfill - for the system concerned - the promise that analytical plotters have held since their early days.

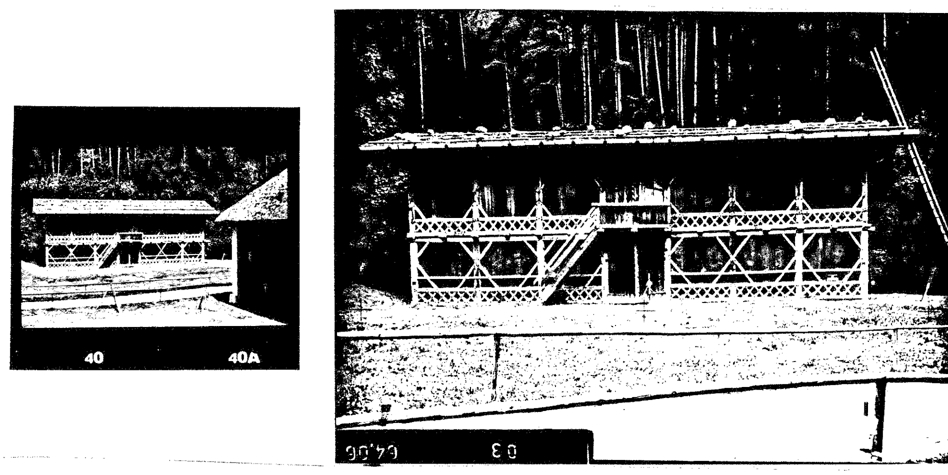

Figure 2: Unconventional stereo pair consisting of a metric and non-metric image. Non-metric (left) with a Canon A-1, metric (right) with a Wild P32 camera.

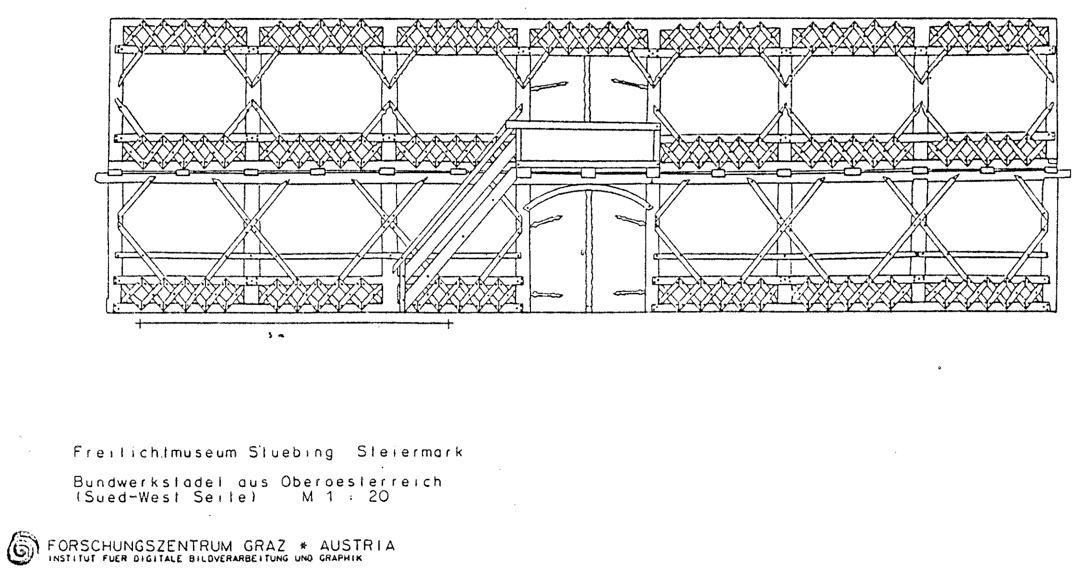

Figure 3: Plot generated from the photographs of figure 2.

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