C R I S P

A SOFTWARE PACKAGE FOR CLOSE RANGE PHOTOGRAMMETRY FOR THE KERN DSR-1 ANALYTICAL STEREOPLOTTER

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ABSTRACT

A software-package for close-range photogrammetry for the analytical stereoplotter DSR-1 of Kern & Co. Ltd., Aarau is being developed. The program-system serves to process metric- and non-metric camera photography, which may exist in the form of single images, single stereo-models and image-blocks. In addition to common control point coordinates the system will use known terrestrial observations such as distances, angles etc..

ZUSAMMENFASSUNG

Ein Programmsystem für Nahbereichsphotogrammetrie wird derzeit für das analytische Stereoauswertegerät DSR-1 der Firma Kern & Co., Aarau entwickelt. Damit wird die Verarbeitung von Meß- und Nichtmeßkammeraufnahmen ermöglicht, die als Einzelbilder, Einzel-Stereomodelle und im Blockverband vorliegen können. Es wird die Möglichkeit vorgesehen, über die Paßpunktkoordinaten hinausgehende terrestrische Beobachtungen wie z.B. Distanzen, Winkel usw. zu verwenden.

1. 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 etc.).

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To materialize some of these promises of the analytical plotter technology one has to invest in sizeable software development efforts. This paper reports on an ongoing project to create a software system for the KERN-DSR-1 analytical plotter so that typical non-metric close range photography can be used for stereo mapping. The computer program is being denoted as CRISP, for close range imagery software package. The programming language is OMSI Pascal-2.

Single images, stereo pairs and small image blocks are the object of computer controlled measurements. In the event of a known interior orientation, conventional photogrammetric central perspective equations are used to reconstruct the exterior orientation of the cameras. If the interior orientation is unknown, as in the case of non-metric photography, then a collinearity formulation is used, either with 8 unknowns for a plane object, or with 11 unknowns with a non-plane object. The latter method is known also as a Direct Linear Transformation DLT (Addel-Aziz, Karara, 1971). The stereo case employs the DLT-solution as an approximation; a rigorous bundle method is used to consider all available observations, including the intersection of homologue rays.

The computation is performed in a robust manner solving first a least squares adjustment (L2-norm). If this solution is not satisfactory due to some gross errors, an adjustment by minimizing the sum of absolute residuals (L1-norm) follows (Fuchs 1980). This is a very powerful tool for detecting gross errors of heterogeneous size.

The KERN-instrument favors a user's participation in software development. Distributed processing with user-programabel processors provide great flexibility in adjusting or expanding existing system software to one's own needs.

We find that the implementation of non-metric camera stereo plotting on an analytical instrument is not a problem of conceptual rigor and intricate mathematics. It is much more a question of ergonomic man-machine interfacing and robustness of a software solution.

2. HARDWARE CONFIGURATION

The DSR-1 used in the current project is the standard configuration and consists of three digital processing units, which are denoted as P1, P2 and P3 (Chapuis, 1980). The overall configuration is illustrated in Figure 1. The units are:

Processor P1: DEC PDP 11/03L,
64 Byte - memory,
Dual-Floppy disk unit (0,024 MByte)
and RL01 hard disk.

Processor P2: DEC LSI/11, 24 kByte

Processor P3: Intel 8055, 4 kByte RAM.

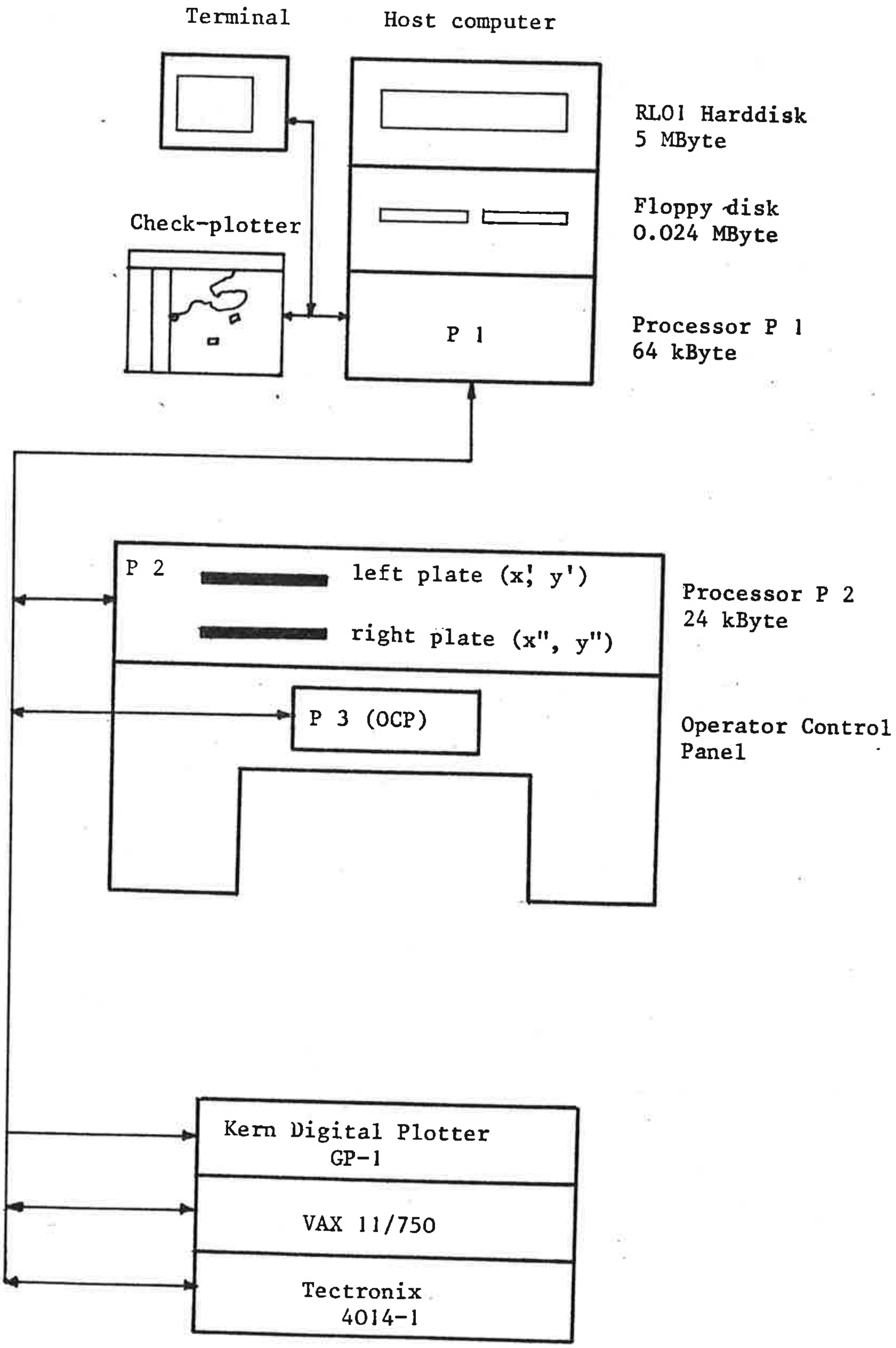

Fig. 1
Hardware configuration

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 a demand terminal for communication between operator and machine, line printer and a xy-check plotter. We decided to deviate from Kern's standard hardware configuration and to mainly rely 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. But we mainly employ the GP-1 as the general purpose vector hard copy device separate from the DSR-1. Therefore it is connected to our VAX 11/750 computer on which cartographic editing is done.

Processor P2 determines the positions of the two plate carriers in real-time at video rates of 50 times per second. P2 relates the model XYZ coordinates to the x' y' and x" y" plate coordinates. It therefore also considers distortion parameters.

Processor P3 controls the operator control panel (OCP); this is used for communication between the operator and the DSR-1. This communication is done by special function keys to be activated by the operator.

3. SPECIFICATIONS FOR THE CLOSE RANGE IMAGERY SOFTWARE PACKAGES CRISP

3.1 Applicability

CRISP is currently being developed to initially address taskes that encompass variations in:

(i) Types of photography;
(ii) Imaging configurations;
(iii) data processing.

ad (i): Types of photography:
CRISP aims at the possibility to process the following types of images:

* Metric camera photography of various formats with known inner and exterior orientation.
* Photographs with partially known inner orientation.
* Non-metric photographs with no information of inner and exterior orientation.
* Image composites, where several individual smaller images are combined to form a composite image for evaluation. We envisage to work in the analytical plotter with several stereo-models simultaneously.

ad (ii): Imaging configurations:

In close-range photogrammetry various image acquisition arrangements are common. CRISP addresses the following configurations.

* Single cameras (e.g. amateur photograph of car-accident where one can assume that the scene of interest is a plane, namely a road surface);
* Single stereo-pair with arbitrary exterior orientation
* Blocks of images:
  strips
  common blocks (consisting of several strips)
  other blocks such as e.g. a series of images presenting all sides of a single object, or repeated exposures of the same object (multiple overlap).

ad (iii): Data Processing:

The analysis of the data in close-range photogrammetry is very diverse and specific to each case. The end product will mostly consist of coordinates in the object coordinate-system, such as of individual points, of digital vector data such as contour lines, and of shape descriptions such as lengths, slopes, digital height models.

Organisation of CRISP:
The block diagramm in Figure 2 illustrates the main flow of operations in CRISP.

A path exists from (to) the initialisation/project - formation module to (from) any other module of the system.

In the event of a single image task, a single photo stage only will be used with binocular observation of this one stage. The stereo case uses both plate carriers in the conventional way. Also the block is essentially an expansion of the stereo-comparator concept.

In all cases a bundle adjustment is the ultimate method of relating image, image pair and block to the object data. However, preliminary computations are needed. In the single image case, a DLT or 2-d collineation model is used to generate approximations of inner and exterior orientation parameters; the same applies to stereo data if no inner orientation is known. Otherwise the approximations result from a space resection with 3 points for a single photograph, or a relative/absolute orientation for the stereo model.

The image block is conseptually a set of stereo models to generate precise image coordinate measurements and approximations for the unknowns.

In the case of a single image or stereo model set-up with known camera, inner and exterior orientation, the preliminary and bundle adjustment steps do not apply. Instead one directly proceeds to stereo plotting after establishment of the inner orientation.

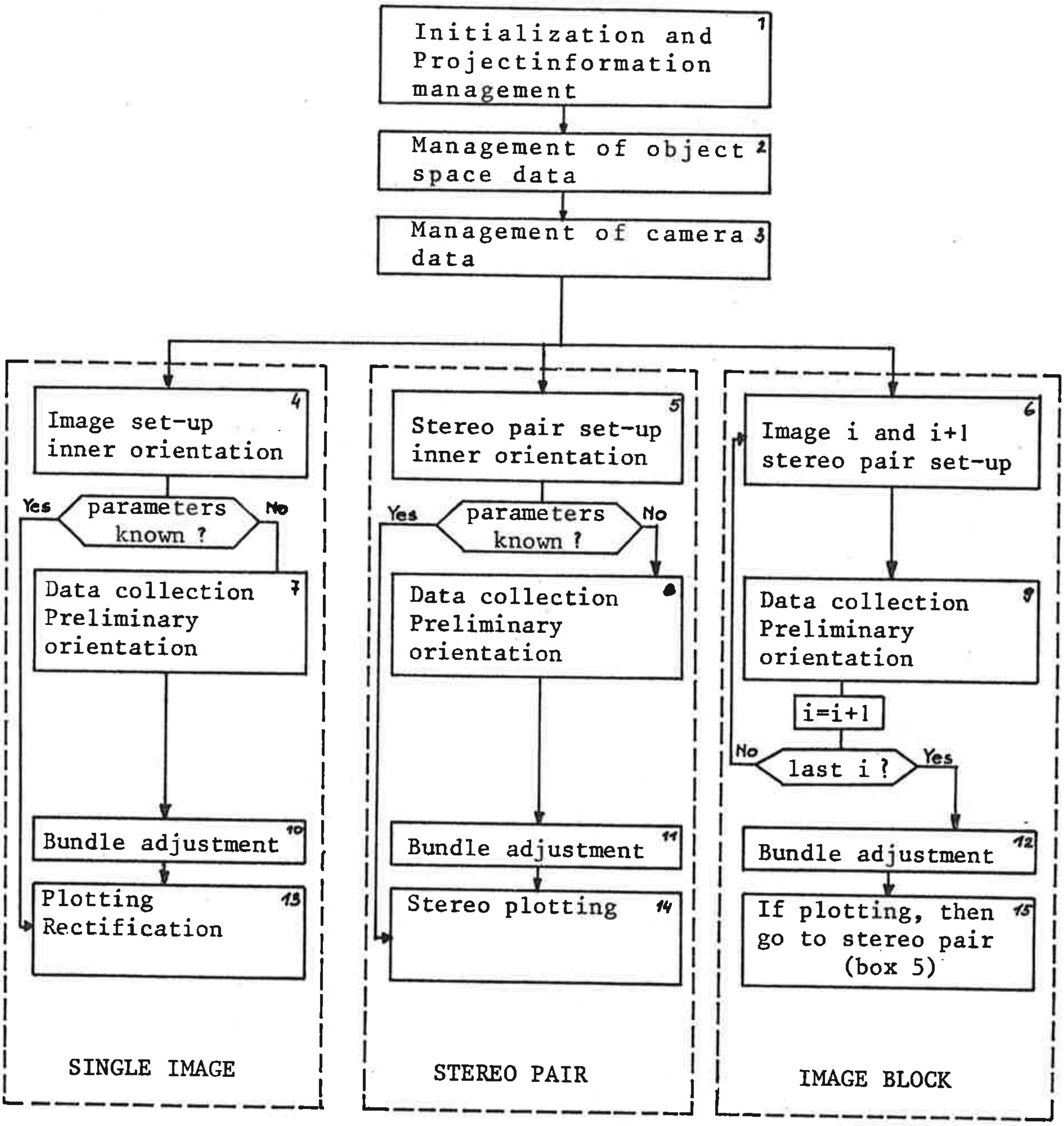

Fig. 2
Block diagram of CRISP-components and flow of operation

CRISP follows the general directions for the communication between the operator and the DSR-1 and is designed to provide:

* Operator-friendly functions and procedures,
* Effective operator/machine dialogues,
* Short and clear information at the operator control panel,
* Detailed information at the demand terminal (if necessary),
* Help functions, whenever it is desired
* Robustness in a statistical sense by detection of outliers
* Robustness in the sense of guiding the inexperienced operator.

4. DISCUSSION of CRISP modules

4.1 Initialisation/Projectinformation management

This program module controls the input of various data on a project that is being done. The man-machine communication is guided by the host computer P1.

The following categories of information are being processed:

* Project information such as name, area, size etc.;
* Date, Operator;
* Dimensions (metric, english);
* Modelconfiguration (single image, single stereo model or block);
* General purpose information block about the project. This can be the name and address of a customer, the desired completion date, accumulated working hours, operators working on this project, company information about this project etc.).

4.2 Object space data management

Again the man-machine communication is only guided by the host computer. Two different cases are considered:

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. Kinds of observations to be considered are distances, angles, azimuths, differences of heights, conditions that certain points are on a straight line, conditions that points are on a circle.

4.3 Camera management

Module for editing camera parameters

4.4 Image set-up

(a) Single Image.

In the image set-up module the relationship is established between the plate carrier coordinate system and image coordinates. If fiducial marks or a reseau are available, then this will be used for a proper inner orientation. If no elements of the inner orientation are known then arbitrary reference points (at least two) need to be measured. Depending on the number of fiducial marks, grid or reference points three different transformations are possible:

linear conformed (Helmert) 4 parameter,
affine (6 parameter),
bi-linear (8 parameter).

Fiducial marks may be of two types: single points and crosses. For lens and film deformation a mathematical model is chosen as described by Karara (1979).

(b) Stereo Model

This is an application of the single image set-up routine to the left and right plate carrier (even with different camera types).

(c) Block

This can be in the first instance a repeated application of (a). In excess of this however, one may

- have several photographes on each plate carrier; this can be of interest with small format data.
- have for each photograph a different camera.

4.5 Data collection and preliminary orientation

(a) Single Image

Here several cases have to be considered, including plane, and non-plane objects.

* Plane object and unknown inner orientation:
  At least 4 points (defined in the plane) are necessary to solve the collinearity equations. This case is also known as the numerical rectification of a single photograph.
* Plane object and known inner orientation:
  At least 3 points must be available. A space resection is used to determine approximate values for the exterior orientation.
* Non-plane object and unknown inner orientation:
  At least 6 points with their X, Y, Z coordinates are needed. Approximate values for inner and exterior orientation are calculated using the DLT-method.
* Non-plane object and known inner orientation:
  At least 3 points with X, Y, Z coordinates must be available: A space resection is used to determine approximate values for the exterior orientation.

(b) Stereo model:

Here two camera types are possible again: Cameras with no inner orientation, no or partly known exterior orientation (at last 6 control points). Cameras with known inner orientation; no or partly exterior orientation (at least 3 control points).

For cameras with known inner orientation the approximate values for exterior orientation are calculated for the left and right image using a space resection with 3 points. For cameras with unknown inner orientation approximate values for inner and exterior orientation are calculated with the DLT method.

(c) Block:

The same types of cameras as described for case (b), single stereomodel, can be processed. Approximate values for inner orientation (if unknown) and exterior orientation are determined in the same way.

In at least one model of the block 6 control points (when inner orientation is unknown) or 3 control points (when inner orientation is known) must be available. This minimum of data is necessary to get initial values for orientation for the entire block.

4.6 Bundle adjustment:

If additional information (e.g. more control points than necessary, additional terrestrial observations) is available then a bundle adjustment is processed for all three cases (single image, single stereo model, block). All available measurements are entered in the bundle adjustment; e.g. also points will be used that are not in the model area, but still visible on one image.

If the bundle adjustment with least squares provide inacceptable results, so that a suspicion of gross errors exists, the program can run through a gross error detection procedure. It is then possible to correct or to delete errouneous information and to run again through the least squares solution.

4.7 Plotting:

(a) Single image:
This will be plotting of the situation in the X Y-plane (rectification). But a link to future monoplotting systems, i.e. when a digital terrain model exists, will be established.

(b) Stereo model:
This will be plotting of conour lines, collecting data for a digital terrain model and of planimetry. It is intended selectively offer the capability to plot in other planes than XY, eg. XZ, YZ or other planes defined by 3 points.

(c) Block:
The block consist of several stereo models. Plotting therefore is as in (b) from individual stereomodels. In the flow chart of Fig. 2 a pointer exists to link the block method with plotting from individual stereopairs. Generally, plotting will be very specific to the user's problems. Individual application programs have to be developed.

5. CONCLUSION

Work on CRISP began in mid-1981 and currently is under progress (April 1982). The scape of CRISP is ambitious since it encompasses the entire range of photogrammetric plotting cases from single image to stereo model and image block. Both metric and non-metric photography are the object of measurement. Central considerations are on the robustness of the solutions in both a statistical sense (gross error detection) and with respect to inexperienced operators. Generally, close range photogrammetry applications are rather specific to each case. A general purpose software package is therefore difficult to realize. However, essential elements exist such as computation of inner orientation of approximate values of exterior orientation, point and parameters management etc. It is these common elements that can be meaningfully implemented in close range photogrammetric imagery software package for an analytical plotter.

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