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# A Coordinate System for Aerial Frame Photography

**A standard system is desirable in order that calibration data may be determined and be applied unambiguously.**

Abstract: *Factors to be considered in choosing an image coordinate system are discussed. A system used for several years is described. The necessity to reach a consensus regarding which coordinate system to adopt is pointed out. The desirability to have some asymmetrical image area obstruction is indicated.*

The question of defining a unique rectangular coordinate system for aerial frame photography has recently been discussed at various meetings, for example, during the last Congress of the International Society for Photogrammetry in Helsinki and during the 1977 ASP/ACSM Annual Meeting. The reason for these discussions was the desire to define points contributing knowledge about the interior orientation of a camera in such a system. Some camera manufacturers use an image frame coordinate system, as do some camera calibration laboratories, for example, the Optics Section of the National Research Council in Ottawa. However, the system used is not standard, which causes unnecessary difficulties when comparing calibration data obtained for the same camera by different organizations.

Reference points used to define the interior orientation are the fiducial marks and, using the definitions adapted by Commission I (Data Acquisition) of the International Society for Photogrammetry, the fiducial center, the principal point of autocollimation, and the principal point of best symmetry.

When considering reseau cameras, which provide a larger number of reference points for the correction of image location errors within the photograph, one must differentiate between a back-projected reseau and a front-projected reseau. A back-projected reseau is obtained by installing into the magazine pressure platen a large number of small projection systems which project a mark through the film base onto the emulsion. This solution requires the determination of the relation between the reseau and the fiducial marks for each frame. A front-projected reseau results from marks placed onto the generally plane surface, facing the image plane, of the last lens element. It is, therefore, an integral part of the lens, obviating the need for extra fiducial marks.

The advancement in analytical photogrammetric methods requires the use of a standard image coordinate system for the correction of asymmetric image errors, for example, lens distortion (Figure 1) or film deformation (Figure 2), either by direct correction using a reseau or by an indirect correction using additional parameters during a block adjustment.

There are many ways of choosing a suitable system considering such factors as number and significance of measured and recorded digits, system origin, and operational convenience.

For automatic recording, the number of digits should be constant. If a stereocomparator with a resolution of 1 $\mu$m is used for measuring 23 cm by 23 cm photographs at their original scale, then six-digit counters will be required for the recording of any measured coordinate.

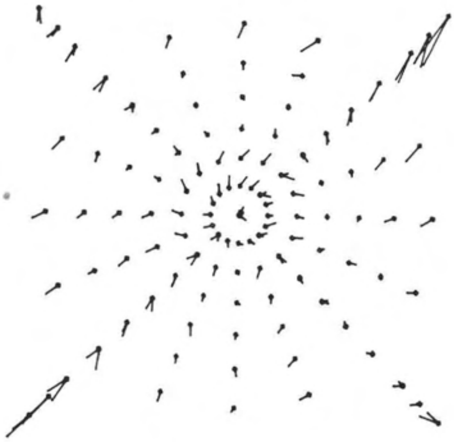

FIG. 1. Lens distortion values determined for the entire frame at once by comparing image coordinates with a three-dimensional bundle of rays.

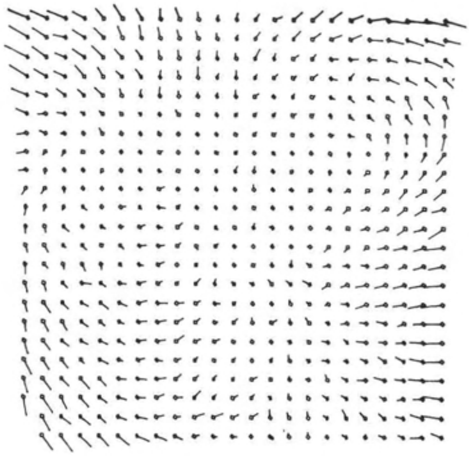

FIG. 2. Film deformation typical for reseau photographs taken with aerial cameras manufactured by Carl Zeiss Oberkochen.

The significance of recorded digits may be affected by word length limitations in electronic data processing equipment. For example, a two-byte integer number cannot be larger than $2^{15} - 1 = 32767$ and the mantissa of a four-byte floating point number cannot be larger than $16^6 - 1 = 16777215$. In the first example, the processing of the 1 $\mu$m digit recorded for 23 cm by 23 cm photographs would be impossible.

A change in sign requires the provision of an additional character for the registration of measurements and is, therefore, generally avoided by placing the origin of the image coordinate system outside the area defined by the image frame.

Operational convenience often leads to the selection of some round value for special parameters. For example, Wild Heerbrugg Ltd. uses 1000.000 mm for both coordinates of the fiducial center in their calibration reports. On the other hand, Carl Zeiss Oberkochen uses the values of 300.000 mm for both coordinates of the center point of the image carriage in their stereocomparators PSK I.

Economic considerations have resulted in approximately aligning the base of a stereomodel with one of the two frame directions. In the majority of cases, operational convenience has caused aerial cameras to be mounted into an aircraft in such a way that the film is transported approximately parallel to the direction of flight. This allows stereoscopic observation of the processed film with a mirror stereoscope without first cutting the film. Occasionally, when several cameras are mounted in an aircraft at the same time, one may be mounted in such a way that the film is transported approximately perpendicular to the direction of flight; in this case, successive frames can no longer be observed stereoscopically with a mirror stereoscope without first cutting the film.

The correction of asymmetric image location errors requires that the image coordinate system be defined with reference to the image frame, that is, one axis will be approximately parallel to the direction of film transport and the other perpendicular to it. Once the system has been defined, it should be maintained disregarding the relationship between film transport direction, i.e., camera mounting orientation and the direction of flight.

Figures 3 to 5 show the layout of films exposed with three different types of cam-

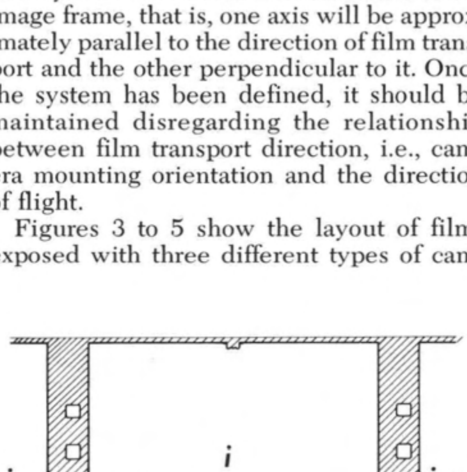


FIG. 3. Layout of a negative film (emulsion down) exposed in aerial cameras manufactured by Carl Zeiss Oberkochen, showing the proposed coordinate system.

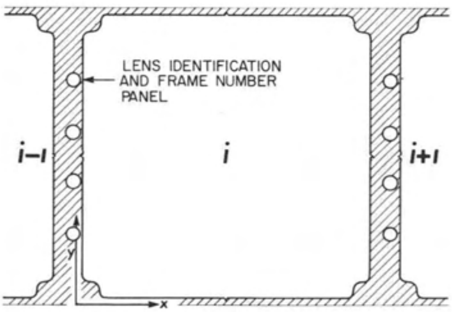


FIG. 4. Layout of a negative film (emulsion down) exposed in an RC8 aerial camera manufactured by Wild Heerbrugg, showing the proposed coordinate system.

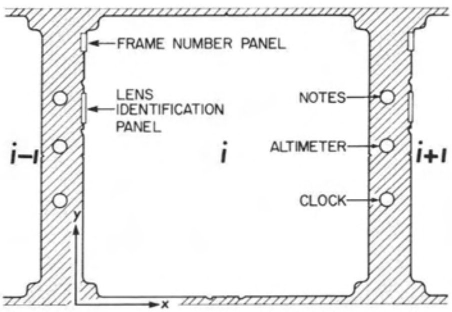


FIG. 5. Layout of a negative film (emulsion down) exposed in an RC10 aerial camera manufactured by Wild Heerbrugg, showing the proposed coordinate system.

eras, each equipped with four fiducial marks. These camera types are also available with front-projected reseaux. In this case, the fiducial mark obstructions disappear from the layout; otherwise the layouts remain unchanged.

For several years the author has used the following plane rectangular image coordinate system in his investigation of asymmetric image errors (Figures 3 to 5). The primary axis, $x$, is approximately parallel to the direction of film transport and is defined exactly by either the fiducial marks or, when available, the front-projected reseau. The $x$-values increase towards the end of the film roll. This direction is always indicated by the increasing frame numbers. The secondary axis, $y$, is positioned at 90° in a counterclockwise direction to the primary axis when looking towards the back of the lens cone from the magazine position, or at a positive photograph with emulsion up, or at the original negative photograph with emulsion down. The origin is placed just outside the format at the lower left corner, as indicated in Figures 3 to 5, in such a way that the value in both $x$ and $y$ of 120 millimeters is obtained for either the fiducial center or the center point of a front-projected reseau for a 23 cm by 23 cm format.

This image coordinate system has proven to be very efficient in the development of computer routines which relate any point measured within the area limited by the image frame to reseau points. The reseau point measurements are labelled inside the computer according to the reseau point locations in order to save space and speed up searching.

Even if a consensus regarding the most suitable image coordinate system cannot be reached, it is desirable that a camera frame provide some asymmetrically located obstruction inside the frame area proper in order that the orientation of a frame photograph with regard to the film direction always can be positively established without regard to the original film, the auxiliary marginal imagery, or any particular annotation procedure. The two frames shown in Figures 3 and 5 provide for such an obstruction which is extremely useful for an operator in deciding the position a plate should occupy in a comparator or plotter. The image frame displayed by Figure 4 does not include an asymmetrically located obstruction inside the image area. It is, therefore, impossible to properly orient a photograph with such a frame for the correction of asymmetric image location errors if the auxiliary marginal imagery is cut off.

The proposed solution may not be convenient for all types of frame imagery used photogrammetrically, in particular for photographs lacking any well-defined image reference marks.

It is hoped that this short report will initiate a more forceful discussion of the pros and cons of rectangular image coordinate systems and eventually lead to a standardization of such a system.

## REFERENCE

1. Carman, P. D., Recommended Procedures for Calibrating Photogrammetric Cameras and for Related Optical Tests. Adapted by Commission I of the International Society for Photogrammetry, September 1960, and reaffirmed since during each of the following Congresses (1964, 1968, 1972 and 1976). *International Archives of Photogrammetry*, Vol. XIII, Part IV, Amsterdam 1961.