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POINT POSITIONING USING LONG RANGE OBLIQUE PHOTOGRAPHY

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ABSTRACT

Long Range Oblique Photography (LOROP) is used to collect information about very distant areas. The obtained imagery is used mainly by photointerpreters to extract information about the dimensions of objects, or to perform a visual analysis of the imaged scenery in a qualitative manner.

A software system that is implemented in the so-called VIDARS photointerpretation workstation offers the tools to perform measurements in single images using the principles of rigorous analytical photogrammetry. This software is used for the current study. The photointerpreter is given the opportunity with the software to employ full analytical methods without a need of actually learning their principles. He subsequently will not only measure object dimensions but also determine the geographic location of targets of interest.

This paper presents the empirical accuracy that is achievable by applying proper photogrammetric methods to LOROP imagery. The influence of imaging geometry (i.e. camera position and attitude angles) on the absolute and relative accuracy of the measurements will be reported.

INTRODUCTION

Long Range Oblique Photography (LOROP) is mainly used by photointerpreters to measure dimension of objects on the ground. The measurement of absolute geographic positions was not included in routinely performed photointerpretation. To fill this gap a software system was developed to provide tools that allow the photointerpretor to determine point locations if necessary (see Leberl et al. 1985, Leberl et al. 1986). Gustafson et al. (1986) report about the accuracy of absolute and relative position measurements using the software system with the aid of some LOROP images taken under various conditions. As the paper shows an accuracy of 1 in 10,000 is achievable if the appropriate ground control data are available. More recently the question was brought up by photointerpreters of how accurate the camera position and attitude angles have to be known to allow a certain accuracy of absolute and relative position measurements. To find an answer to this question an empirical rather than an algebraic approach is used to illustrate the relation between erroneous camera position and attitude angles and relative and absolute positioning measurements in graphical form.

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ACCURACY OF ABSOLUTE POINT POSITIONING USING LOROP PHOTOGRAPHY

To determine the accuracy of measurements of geographic locations from LOROP photography the VIDARS software was used in an empirical approach. Certain values for camera position and attitude angles (orientation) were assumed. Errors in the geographic point locations occur due to changes of these orientation values; curves show the relation between the recorded errors and the orientation changes.

The parameters for the camera position and attitude angles were assumed to be typical of a LOROP application:

Flying height	15,000 meters
Depression angle16.5 degrees below horizon;	
Tip angle	0 degrees;
Focal Length of camera	66 inches.

The position in x and y, and the heading angle are irrelevant for the accuracy evaluation. For this particular example the airplane was assumed to fly north. The assumed imaging conditions are illustrated in figure 1.

The following sections discuss the influence of small changes of the camera position, attitude angles and image coordinates on the computed geographic position of a target location.

Roll Angle Accuracy

Position measurements are very sensitive to errors in the roll (depression) angle. In particular the measurements done in across track direction are strongly dependent on this error. The relation between coordinate errors occuring in across track direction and the changes in the roll angle is shown in figure 2. An accuracy of ±5m on the ground would typically require the roll angle to be known to within 6" or better.

Tip Angle Accuracy

An error in the tip angle of the sensor especially influences measurements made in along track direction. Figure 3 depicts the relation between along track measurements and tip angle changes. This is less critical than roll, typically by a factor 5.

Heading Angle Accuracy

Measurements of target positions are relatively insensitive to errors in the heading angle. Figure 4 illustrates the behavior of the positioning error due to inaccuracies of the heading angle.

Aircraft Flying Height/Terrain Height Accuracy

Errors in either the altitude of the aircraft or the assumed elevation of a point target on the ground have a strong influence on the accuracy of the geographic

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position. Larger errors occur in measurements made in across track direction (see figure 5). The errors are typically magnified by a factor of 3 or more.

Aircraft Along Track and Across Track Position

Erros of this type cause changes in the geographic position of a target at a 1:1 ratio.

Image Accuracy

The image has internal accuracy limitations due to

- film deformation;
- errors due to lens distortions or scan limitations;
- refraction due to the atmosphere.

The refraction can be handled if a good model for the atmosphere is available. Effects of film deformation and lens distortions and/or scan errors can only be removed if precision fiducial marks relate the image details to time and scan/depression angle. There are still errors of roll rate compensation. They would only be removable if a roll and roll rate were known more precisely than the values implemented in the roll rate compensation.

This area of image accuracy is entirely in the hands of the camera manufacturer. Figure 6 is a curve that shows how the accuracy of the image coordinates relates to absolute position accuracy.

ACCURACY OF RELATIVE POINT POSITIONING USING LOROP PHOTOGRAPHY

A separate concern is the positioning of an object with respect to nearby other features. The absolute positioning error is simply a result of sensor position and attitude errors. The relative positioning problem depends on the distance to other points. For this purpose the assumptions for the camera position and attitude angles were the same as for the absolute positioning problem. As the results show the most critical parameters are again height and roll angle. Figures 7, 8 and 9 illustrate the relation between the accuracy of height, roll angle and image coordinates, and the occuring error in distance measurements. The curves show that a height error of ± 25 m causes an error of more than 10 m in distance measurements. It also can be seen (figure 8) that the roll angle has to be known to within 1′ or better to avoid distance errors larger than ± 10 m. Film and/or table errors of ± 15 μm lead to an error in the measured distances of approximately ± 2 m (figure 9).

CONCLUSIONS

The paper presents an empirical evaluation of errors in geographic target locations caused by erroneous camera position and attitude angles, and image coordinates. The study was performed independently for each parameter and curves relating errors and ocurring effects on the relative and absolute point position are shown. To determine the camera position and attitude angles with high accuracy

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various methods (e.g. CPNS, GPS, INS, Gyros) were proposed (Corten 1984, Grimm and Heimes 1984, Keegan 1984). According to studies performed in the past accuracies of the critical parameters height and roll angle of ±10 m for flying height and ±0.5° for the roll angle can be achieved. Through comparison with the curves shown in figures 2 and 5 for absolute positioning and figures 7 and 8 for relative positioning it can be seen that these values are not sufficiently accurate for high precision relative or absolute positioning.

An alternative to the above mentioned navigation methods is the simulatenous use of a vertically mounted metric camera. The metric camera could provide the accurate camera position and attitude angles derived from known ground control data. These parameters could then be used to perform relative and/or absolute position measurements on the simultaneously exposed LOROP imagery. This method leads to accuracies for the roll angle of several seconds of arc and for the flying height of ±1 m assuming high altitude flying at 15 km and using a wide angle camera. Comparing these values with the above mentioned curves leads to the conclusion that absolute positioning should be possible within ±5 m and relative positioning even below that.

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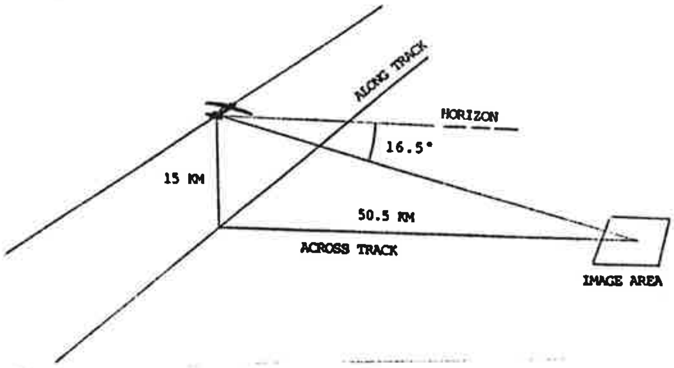

Figure 1. Assumed imaging conditions.

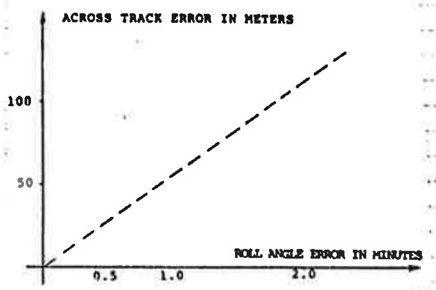

Figure 2. Roll angle accuracy versus accuracy of across track positioning.

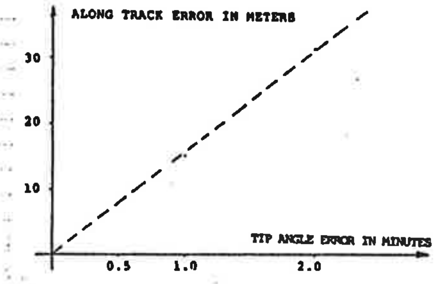

Figure 3. Tip angle accuracy versus accuracy of along track positioning.

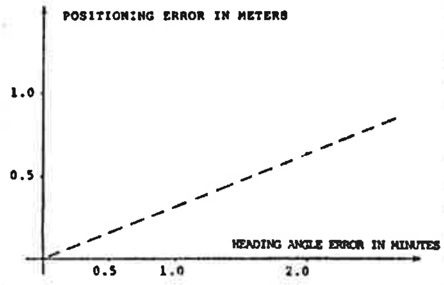

Figure 4. Heading angle accuracy versus accuracy of point positioning.

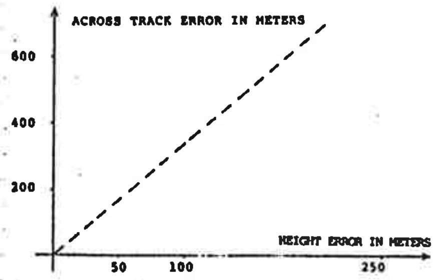

Figure 5. Height accuracy versus accuracy of across track positioning.

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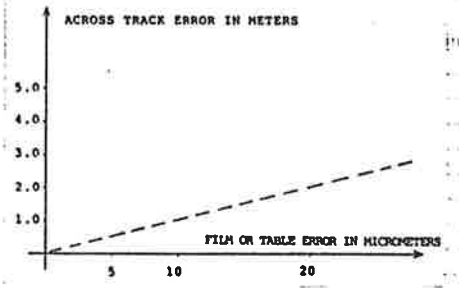

Figure 6. Image accuracy versus accuracy of across track positioning.

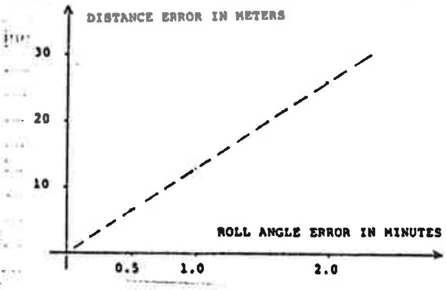

Figure 7. Roll angle accuracy versus accuracy of distance measurement.

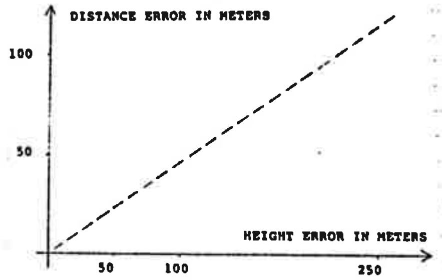

Figure 8. Height accuracy versus accuracy of distance measurement.

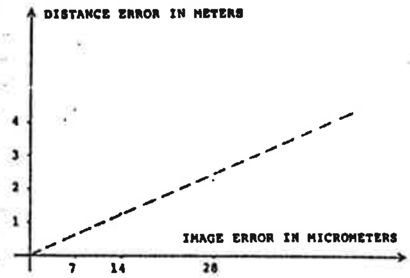

Figure 9. Imgage accuracy versus accuracy of distance measurement.

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