8.9 A Concept for a Future Ground Control Data Set for Image Correction

Ralph Bernstein
IBM Scientific Center
Palo Alto, CA 94304

ABSTRACT

Strips of ground control can be established with current and future satellite sensors. These can provide precise and reliable geometric references for locating and correcting satellite image data and to support temporal image registration. This paper briefly describes the concept and approach for implementing this data base called a Ground Control Strip, and recommends additional work. The advent of new solid state imaging systems, in particular the linear array detectors (pushbroom sensors), make this new concept particulary attractive and practical.

INTRODUCTION

Image data suffers from some degree of geometric error. The error sources are due to sensor characteristics and imperfections, to satellite attitude perturbations, and to orbit decay and eccentricity effects. The external geometry of a satellite can be determined from star trackers, horizon sensors and gyro-compasses, inertial platforms, and ground reference or control points. Geometric errors are currently precisely determined and corrected by the use of ground control points, which are typically 32x32 pixel subimages used to establish image geometric errors (Bernstein, 1975,1976, and Niblack, 1981).

A ground control point is a subimage which includes natural or cultural features used to establish a ground reference point to support image correction and registration. These features are selected to have the characteristics that they can be precisely located in the image and on the maps. Digital ground control points have been used for about a decade. These have replaced "film chip" ground control points commonly used in electo-optical image processing systems. Given a sufficient number of ground control points, a scene can be corrected to sub-pixel image accuracy (see Fig. 1). It is apparent from Figure 1 that many GCP's, high resolution data, and sub-pixel registration algorithms are needed to obtain high image geometry accuracy.

The problem with using conventional ground control points is that the features are initially selected and stored manually, and periodically manually updated. This operation is time-consuming, expensive, and error prone. In addition, features that are commonly selected are those preferred by the human eye, and not necessarily those that are best for machine registration.

Paper Presented at the NASA Registration and Rectification Workshop, Leesburg, VA., Nov. 17-19, 1981.

Linear array sensors have been proposed to support earth observation applications (Welch, 1971, Thompson, 1979, Tracy and Noll,1979, Wight, 1979, Colovocoresses, 1979). This note dicusses how these sensors can implement a new approach to establishing a world-wide network of ground control called a Ground Control Strip (GCS).

MOTIVATION FOR NEW APPROACH

Motivating factors for a new approach to ground control were identified at the NASA Registeration and Rectification Workshop and are summarized:

Higher Resolution Ground Control Data - Users and analysts have determined that the accuracy of establishing ground control is closely related to the resolution of the source data. Thus it is advantageous to obtain and use higher resolution data for establishing ground control.

Higher Accuracy Source Data - Due to spacecraft structure bending and vibration, even star trackers will not provide sufficiently accurate external orientation data without additional information such as angular displacement sensor data. The use of sensor coupled data has the advantage of direct and close coupling of the data used for image correction with the data to be corrected. There are no static or dynamic errors associated with using coupled image data.

More Ground Control Data - Users have indicated that more ground control data is needed, and should be made available to the user community. This approach directly constructs a large geometry control data base during mission operation.

Compatible Sensor and Ground System - The sensor and the ground system should be designed as an integrated system. With this approach, the sensor system is designed in order to improve ground processing operation efficiency and image accuracy, which may reduce mission system costs.

CONCEPT

This concept deals with the development and use of a continuous strip of ground control used to determine the sensor orientation relative to the earth. Assume a linear array sensor system with differing resolution elements such as that shown in Figure 2. The detector arrays consist of variable size detectors, with higher resolution data in the center of the image swath. While the sensor is on, the detectors "sweeps" the earth in the direction of the satellite track, providing a contiguous strip of higher resolution data (eg., 7.5 m) used for the GCS. The higher resolution data can be combined to provide normal linear array data. Over a period of time, strips of data are acquired that are wrapped around the earth and covers the earth in the vicinity of the subsatellite point. This strip of data, after editing and ground location, can than serve as the geometric reference for subsequent image location, correction, and registration. Clearly, the acquired data must be initially ground located, mosaicked, and edited.

It is apparent that satellite roll and pitch can be accurately determined with the GCS approach. To determine yaw accurately, it may be necessary to use an "out-rigger" network of ground control data. This question will involve a complete error analysis with a particular set of conditions.

SIZE OF DATA BASE

A preliminary analysis of the data base indicates that the ground control strip concept is practical from the point of view of the data storage requirements.

For the Landsat-D satellite mission, the following orbital parameters apply (NASA, 1981):

Repeat Period:	16 days
Orbits/Repeat Period:	233
Trace Spacing:	172 km

The cross-track orbital drift will be approximately 455 m RSS (1-sigma). This corresponds to about 25 Landsat-D pixels drift 90% of the time. If one assumes a ground control region four times wider or a 1820 m wide strip encircling the globe used for ground control, and a 7.5 m resolution ground control data base, and further since the oceans cover about 75% of the earth, than the total ground control strip data base would be:

$$\text{Data Base} = \frac{455\text{x}4 \text{ m x } 233 \text{ orbits x } 40\text{x}10^{6} \text{ m/orbit}}{7.5 \text{ m/pixel x } 7.5 \text{ m/pixel}} \text{ x } 0.25$$

$$= 7.54 \text{ x } 10^{10} \text{ pixels}$$

Thus, the Ground Control Strip data base requirement is within the capacity of current mass memory systems, and a full earth data base could easily fit within ten high density tapes.

TIME TO ACCUMULATE DATA BASE

The orbit repeat period for the Landsat-D mission is 16 days. Due to cloud cover, and the possible need for data over differing seasons, the time to accumulate the GCS data base would become larger. Assuming that 50% of the time cloud cover can exist in a particular area, there would statistically be a minimum time of seven 16-day periods or 112 days in order to have 99% of the area covered. There are certain areas over the earth where the persistence of cloud cover may require up to several years prior to cloud free acquisition.

ADVANTAGES OF APPROACH

There are a number of advantages of this approach:

Automatic Collection of Reference Data - The strip of ground control is automatically collected and stored. This minimizes the need for manual ground control selection.

High Resolution Control Data - The use of high resolution data in the region of ground control provides the needed resolution to support precise external geometry determination and image correction.

High Density Ground Control - The contiguous data provides a dense data set for image location, correction, and registration. This dense network is an improvement over the relatively sparse network of ground control currently in existence and allows for automated alternative area selection.

Decreased Sensitivity to Cloud Cover - The continuous and extended data set available with this approach should result in a lower sensitivity to cloud cover. When cloud cover occurs and is detected, alternate nearby cloud-free ground control data can be selected and used to establish the geometic parameters. In fact, the continuous nature of the data coupled with the stability of new satellite, such as the Landsat-D (0.01 degrees and 10^{-6} degrees/sec) should allow for long segment and perhaps orbital geometric models and correction parameters to be determined.

Multi-Mission Capability - The Ground Control Strip, having high resolution characteristics, should be useable for other missions with sensors of similar spectral characteristics.

FUTURE WORK

The following needs to be done to adequately assess the value of this approach:

Error Analysis - An error analyis of the approach needs to be performed, assuming a set of satellite attitude and orbit characteritics and sensor parameters. The Landsat-D attitude control system characteristics, and a variable set of sensor resolution paramet··rs should be used to predict the resultant image geometric characteristics. A statistical analysis of cloud cover would be necessary in order to determine the available amount of ground control.

Data Management Analysis - A detailed analysis of the data acquisition, selection, editing, storage, and retrieval of the data needs to be considered. Since this concept involves the use of a larger data set than previously considered, this analysis is particularly important.

Cost Analysis - A study to assess the cost of this approach needs to be considered. The cost savings resulting from the automation of the compilation of ground reference data may be partially offset by the increased cost associated with data storage, processsing and management.

CONCLUSIONS

A concept has been proposed that may improve the correction of remotely sensed image data from satellites. This approach may reduce the time and costs associated with building a ground control point library system, and would result in a larger and higher resolution data base to support image preprocessing. The new data, called a ground control strip is practical with todays storage and processing technologies, and could be developed for the next generation earth observation satellites. The design of the sensor system should be done in conjunction with the ground system, as the parameters are inter-related. Study efforts are necessary in order to adequately assess and evaluate this concept.

REFERENCES

Bernstein, R., "All-Digital Precision Processing of Landsat (ERTS) Images", Ralph Bernstein, NASA Contract NAS5-21716 Final Report, April 1975.

Bernstein, R., "Digital Image Processing of Earth Observation Sensor Data", IBM Journal of Research and Development, Vol. 20, No. 1, January 1976

Welch, R., "Acquisition of Remote Sensor Data with Linear Arrays", Photogrammetric Engineering and Remote Sensing, Vol. XLV, No. 1, Jan 1979.

Thompson, L.I., "Remote Sensing Using Solid-State Array Technology", Photogrammetric Engineering and Remote Sensing, Vol. XLV, No. 1, Jan 1979.

Tracy, R.A., and Noll, R.E., "User Oriented Data Processing Considerations in Linear-Array Applications", Photogrammetric Engineering and Remote Sensing, Vol. XLV, No. 1, Jan 1979.

Wight, R., "Sensor Implications of High Altitude Low Contrast Imaging", Photogrammetric Engineering and Remote Sensing, Vol. XLV, No. 1, Jan 1979.

Colvocoresses, A.P., Multispectral Linear Arrays as an Alternative to Landsat-D", Photogrammetric Engineering and Remote Sensing, Vol. XLV, No. 1, Jan 1979.

NASA, "Landsat-D Applications Notice, Landsat-D, Oct. 1981.

Niblack, W., "The Control Point Library Building System", Photogrammetric Engineering and Remote Sensing, Vol. XLVII, Dec. 1981.

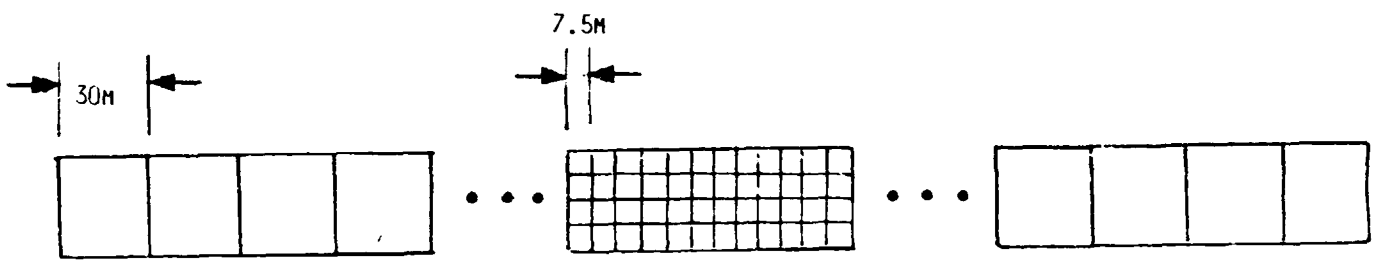

Figure 1. Imbedded Ground Control Strip Footprint

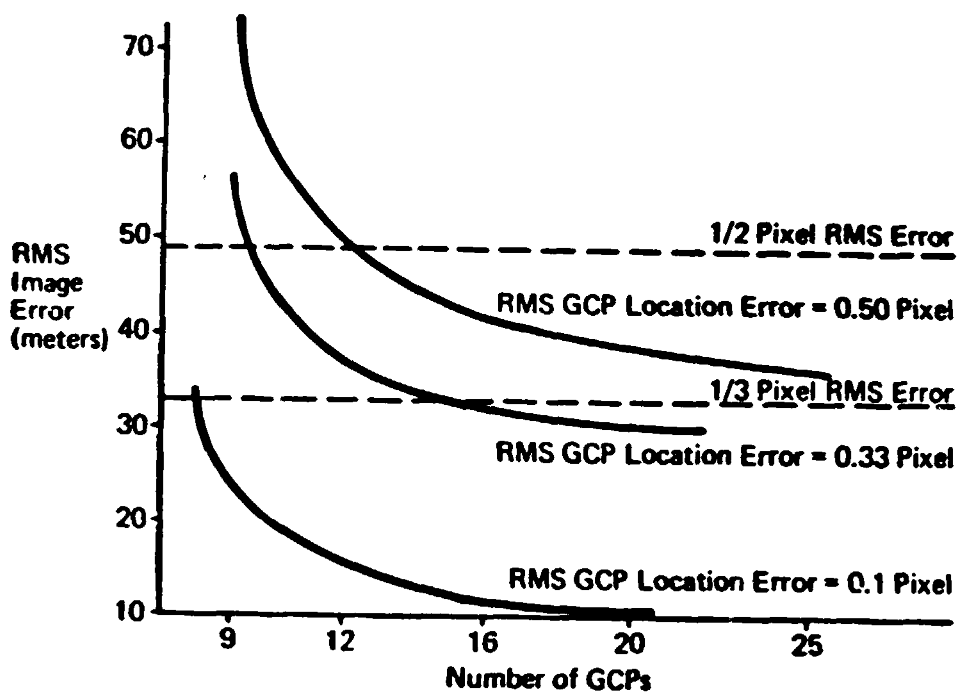

Figure 2. MSS Image Absolute Error As A Function Of The Number Of Ground Control Points