APPLICATION OF DIFFERENTIAL GLOBAL POSITIONING SYSTEM (DGPS)
INDEXING TO REMOTE SENSING PHOTOGRAMMETRY

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INTRODUCTION

In photogrammetry, radial displacement occurs when the point being imaged is not on the elevation of the mean datum. It is standard practice in photogrammetric mapping to provide 60% forward overlap and 30% side lap between adjacent photographs. Such overlap is often required as the aircraft is subject to altitude variations, tip, and tilt as the flight proceeds. Differential GPS is used to minimize 3-D positional variations and provide precise indexing of the photographic exposures. This paper reports on the application of differential GPS to scientifically map the "uplight" emanating from the Ames, IA area, which serves to provide preliminary photogrammetry for Iowa State University engineering students working on Aerial Integrated Platform (AIP) senior projects. The data and it's acquisition technique also serves as a model for low cost mapping of non-downward municipal and business lighting practices contributing to light pollution.

TECHNICAL APPROACH

The approach is simple and straightforward--fly at a fixed altitude of 9,000 ft above Ames, 10,000 ft altitude above mean sea level (MSL), under transparent atmospheric conditions, acquiring a series of overlapping still photographs. Each exposure covers a rectangular area of 1.32 km by 2.00 km. Each exposure overlap 49.9% with side lap of 15.9%. Given the terrain of the Ames area, which includes rivers at 880 feet altitude and high land at 1060 feet altitude, these degrees of overlap are sufficient to minimize radial distortion. One hundred and ten (110) photographs will be combined to create a large photometry map of Ames having an area of 125.4 km² (28.4 mi²). Normalcy to the ground is maintained by the camera operator making use of a circular bubble level and by minimization of street-light pattern convergence with respect to the frame of the camera’s viewfinder.

DATA INDEXING

Registration of the points in the air for exposures was achieved with the aid of DGPS giving an expected position accuracy in the range of 10-50 meters 2 drms.
Figure 1. Flight scan plan follows Universal Transverse Mercator (UTM) northing lines with image exposures determined by coordinates displayed with DGPS navigation equipment. Rectangle represents the area of one exposure.
REQUIRED EQUIPMENT

The required hardware for the preliminary photometry flight includes film, camera, and differential GPS (DGPS) read outs for both pilot and photographer.

A beacon receiver provides differential corrections in the RTCM SC-104 format from the USCG transmissions (Rock Island, IL and Alma, MN). The differential corrections allow both the Trimble and Garmin differentially ready GPS receivers to operate in DGPS mode providing 3-space accuracy on the order of 10 meters or better.

SCI’s beacon receiver has two independent receiver channels designed into the SBX-2 allowing it to continuously monitor all beacon signals available for a particular location. The receiver’s first channel tracks the primary station while the second channel continuously searches for other available beacons in the area. When the SBX-2 identifies a superior signal, it will automatically switch to that station without operator intervention. As backup a differential corrections pager receiver from DCI, which receives differential corrections from FM sub-carrier transmissions, was carried on the flights.

Both SBX-2 beacon receiver and DCI’s pager receiver provide differential corrections in parallel to the Trimble and Garmin GPS receivers. The Trimble was used by the photographer to determine points 3-space for exposing the film.

COMMUNICATION REQUIREMENT

The pilot and photographer can work independently and autonomously since each has all the navigational information required to carry out his function. However, as a check, when all eleven exposures for each east-west tier were recorded for a given northing, the photographer signaled the pilot that the tier has been completed and the pilot turned and aligned for another northing (east-west line). With the plane cruising at 140 knots exposures occurred every 13.9 seconds. Flight time was less than 1.5 hours, including the climb to 10,000 feet and the time for turns and exposures.

DETERMINATION OF EXPOSURE

The standard high quality 50 mm lens is capable of resolving more that 100 line pairs per millimeter at optimum aperture and critical focusing on fine-grain film. It is not unreasonable to assume that 10-30 line pairs per millimeter can be resolved at maximum aperture on T-Max P3200 film (ASA/ISO 3200) assuming that vibration of the aircraft can be isolated from the camera. This film resolution translates to about one meter of resolution on the ground.
Figure 3. One of one hundred and ten images, DGPS indexed, from the first flight. North is to the left and East is up in the image.

The inertial mass of the camera system coupled with the camera location at a structural nodal point of the aircraft structure provided sufficient isolation from the aircraft engine's vibration. This was one unknown resolved in the preliminary photometry flight.

Measurements have been made under residential street lights in Ames indicating that the illumination on the ground set at -2 stops would result in exposures of 1/30 second at f/1.4 aperture using ASA/ISO 3200 film. The dynamic range of the film is at least 7 steps (factors of two) providing a good range of light levels with normal residential street lighting being at the lower end of the scale.

SUMMARY

The first flight was achieved in June of 1998 with a second identical flight planned for late November of 1998 after the leaves have fallen. Follow-on flight are planned by the Iowa State University engineering students working on Aerial Integrated Platform (AIP) senior projects. Their flights will involve automated film exposure and visual computer graphic aids for the pilot.
The film for the first flight was digitized directly from the negatives. Positive prints were also made at a magnification of 11x to compare digital images with printed images. The digitization technique preserved at least 90% of the information available from the film and is considered adequate for creation of a calibrated database mosaic digital image. Three points from each image must be determined and used to scale and overlay the 110 individual images onto a geo-referenced grid. Once the final database digital image is created, additional calibration points (light sources) will be measured on the ground. A least squares fit of these calibration points will result in a final database digital image of calibrated luminosity.

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