ANNUAL REPORT

A GEOREFERENCED AERIAL VIDEO IMAGING SYSTEM

By

Carol A. Johnston, Senior Research Associate
John Bonde, Supeivisory Applications Programmer

Natural Resources Research Institute
University of Minnesota, Duluth
5013 Miller Trunk Highway
Duluth, MN 55811

1993/94
Project No. 1673-189-6082

Prepared for:
Minnesota Technology, Inc.
111 Third Avenue South, Suite 400
Minneapolis, MN 55401

NRRI/TR-1994/42

A Georeferenced Aerial Video Imaging System

Annual Report for
Minnesota Technology, Inc.

Coordinators: Carol A. Johnston and John Bonde

Reporting Period: July 1, 1993 - June 30, 1994

Objectives:
The objective of this project is **to develop a system to georeference airborne video imagery using Global Positioning System (GPS) technology**. The system will make it possible for video images taken from an airplane to be used to make maps that could be interfaced with other data layers in a Geographic Information System (GIS). The uniqueness of the proposed system is its real-time georeferencing capability, which greatly accelerates the conversion of video images into a mosaiced, georeferenced digital database.

Background:
Airborne video has demonstrated promise as a rapid, low-cost means of acquiring imagery for a variety of ecological applications: fish and wildlife habitat, plant communities, phytomass determination, crop damage, weed infestations. The benefits of airborne video could be greatly enhanced, however, by combining frame-grabbed video images into a comprehensive, georeferenced database suitable for use in GIS, where the information could be integrated with other spatial databases and manipulated using the multitude of spatial analysis tools inherent to GISs.

This research is a collaborative effort between the Natural Resources Research Institute (NRRI) and Brimson Laboratories, a small business that provides contract programming and consultant services for computer software and applications design and development. Brimson Laboratories provided $9,250 of in-kind support for this project during this fiscal year.

Summary of Progress:

Work has been progressing according to schedule, and results are very promising. Our business partner, Brimson Laboratories, wrote a suite of programs for recording and processing video and GPS data using SMPTE codes (a motion picture industry standard) to time-stamp the video.

Test flights were done in the Duluth area, and included targets of known location (University of Minnesota football field, streets in the city of Superior, Wisconsin), as well as wetland study sites in the St. Louis River for which we have vegetation ground truth obtained under separate funding from the U.S. Department of Agriculture. Flights were done at different elevations, and under different cloud cover conditions.

Several initial equipment problems have been partially or complete solved. The initial video timing method used did not actually record SMPTE time code, but only simulated it using a much coarser technique of counting frame control pulses. This caused a decrease in video tape positioning accuracy with time since the video tape was last rewound. By using a Horita WG-50 device to dub the normally invisible SMPTE code directly on the tape, we were able to diagnose the problem and reprogram the controlling software to correct it.

Another equipment challenge has been the design of the camera mount. Our initial design allowed the camera head to wobble with vibration of the plane, which resulted in fuzzy video images. We are working on a new design in collaboration with the Duluth Technical College and the Department of Computer Engineering.

Several presentations about this project have generated a great amount of interest. In September 1993, Peter Berger (Brimson Laboratories) conducted a live demonstration at the Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling in Breckenridge, Colorado. A poster presentation by John Bonde and Peter Berger at the national GIS/LIS '93 Annual Conference and Exposition in November also generated a great deal of interest. Thirty-six people were sufficiently interested to leave their cards or other contact means, and many others stopped by. Interested parties included other researchers in addition to several potential industry users and/or partners. Potential application of the airborne video imaging system was also discussed with representatives of the DNR Division of Forestry Resource Assessment and the St. Louis County Land Department.

MTI Final Project Report: A Georeferenced Aerial Video Imaging System

Summary of Completed Project

A system was developed to georeference and mosaic aerial video images so that they could be used to make maps for geographic information systems (GIS). Airborne videography is low-cost means of rapidly acquiring large scale imagery, suitable for making maps of natural areas such as forests and wetlands. Airborne videography has the advantage that image acquisition can be timed to coincide with an event of interest (e.g., a flood, an algae bloom) at a spatial scale suitable for detecting objects as small as individual organisms (e.g., trees, geese), but the disadvantage that it is not inherently georeferenced (i.e., matched to ground coordinates). The system that was developed overcame this disadvantage by coupling airborne videography with Global Positioning System (GPS) technology.

The following objectives were successfully accomplished: (1) develop hardware and software linkages between a GPS, video recorder, and laptop computer for acquiring video imagery and locational data, (2) develop semi-automated procedures for grabbing and georeferencing individual video image frames, (3) develop methods to minimize georeferencing distortion caused by aircraft roll, pitch, and yaw, and (4) use the system in a sample application to map wetland vegetation.

Technical Information

Objective 1: Develop hardware and software linkages between a GPS, video camera, and laptop computer for acquiring video imagery and locational data

The airborne equipment consists of a video camera head with 6 and 12 mm focal lengths (Panasonic GP-KR412 VHS), video recorder/player (Panasonic AG-7355 S-VHS), portable GPS (Motorola LGT1000), data radio, and notebook computer. The video signal was recorded on 1/2 inch video tape. After initial testing of this equipment from the hatchback of an automobile, the camera head was mounted in the bellyhole of a Cessna Skyhawk plane. Camera mounts were constructed and modified to compensate for vibration and orientation problems that were discovered during aerial testing. The camera head was mounted so as to be perpendicular to the ground during normal flight. The subcontractor, Brimson Laboratories, wrote software for recording in-flight GPS data and corresponding SMPTE codes (a motion picture industry standard for identifying video image frames) to the laptop computer.

Test flights were done in the Duluth area, and included targets of known location surveyed with GPS (University of Minnesota football field, streets in the city of Duluth, Minnesota), as well as wetland study sites in the St. Louis River for which vegetation ground truth data were obtained under separate funding from the U.S. Department of Agriculture. Flights were done under different cloud cover conditions, at altitudes ranging from 500 to 2,000 feet, on the following dates: 9/12/93, 9/23/93, 10/27/93, 7/14/94, 9/28/94, 10/27/94, 11/9/94.

GPS correction data for real-time differential processing were provided by a portable base station, established by positioning a Motorola LGT1000 GPS over a National Geodetic Survey (NGS) benchmark. Latitude, longitude, and elevation specifications obtained from NGS for the benchmark were programmed into the base station GPS. This GPS was linked to a UHF radio, which transmitted instantaneous correction data every 5 seconds to the airborne GPS. Power for the base station was provided by two 7 amp-hour 12VDC utility batteries, enough to run the GPS and radio transmitter for about 10 hours. The GPS, radio, and battery fit into a 10"x10"x10" wooden box for convenient carrying.

Several advancements in differential GPS (DGPS) have occurred during the lifetime of this grant which provide other options for GPS correction, such as the current availability of commercial FM-broadcast and U.S. Coast Guard DGPS service. However, this portable base station is still the most viable solution for GPS correction in the remote, unpopulated areas typically studied by ecologists. Real-time DGPS is preferable to "post-processing" DGPS because GPS problems such as satellite signal loss or base station failure are immediately known to the video system operator, and can be compensated for during the flight. Real-time DGPS also aids navigation: flight lines can be entered into the GPS as navigation routes, which reduces the risk of gaps in video coverage, particularly in featureless terrain.

Objective 2: Develop semi-automated procedures for grabbing and georeferencing individual video image frames

Post-flight processing was done with a suite of programs written by Brimson Laboratories and NRRI staff. Using the PC ARC/INFO GIS, the corner coordinates are calculated for two SMPTE-coded images each second, taking into consideration the lens field of view, the aircraft height above the terrain, the latency in the GPS data, and the roll, pitch, and yaw of the aircraft (see Objective 3). The flight path is then displayed in PC ARC/INFO, and the operator interactively clicks on a desired location to view areal extent of the image centered on that location. The operator clicks on a series of images in adjacent flight lines to produce a complete mosaic. The corner coordinates of the selected images are saved to a file, which is used to frame-grab the appropriate images using a 486 PC with a Truevision Targa+ frame-grabber connected to the Panasonic AG-7355 VCR. The frame-grabbing program automatically steps through the database, positions the video tape to each frame represented by the selected SMPTE codes, rasterizes the image, and stores it to disk in the ".LAN" format used by the commercially-available PC-ERDAS Image Analysis System. PC-ERDAS is then used to scale, rotate, and georeference the image according to the position information provided by the corner coordinates.

Objective 3: Develop methods to minimize georeferencing distortion caused by aircraft roll, pitch, and yaw

This was the most challenging of the technical objectives, and the greatest advance to result from this project, without which mosaicking of adjacent images would have been impossible. The problem is this: a GPS reading taken at the instant of video image acquisition represents the nadir of the aircraft, which is not necessarily the center point of the image. If the camera is in perfect vertical orientation relative to the ground, then the aircraft nadir is the center point of the image, and the only image distortion in flat terrain is radial distortion (ie., slightly smaller scale at the edges of the image). Gyroscope-operated camera mounts that are commercially available to maintain vertical camera orientation are prohibitively expensive for ecological research applications (~$65K). However,
with a fixed camera mount, aircraft roll or pitch causes the nadir to be off-center, and image scale to be distorted.

Two approaches were used to accomplish this objective: (1) construction of a stabilized camera mount for maintaining vertical camera orientation, and (2) use of a GPS capable of precisely measuring aircraft attitude. The camera mount was designed by the two REU students who worked on the project in 1994, both from the University of Minnesota, Duluth: Richard Poole (Department of Industrial Engineering) and Mark Tupa (Department of Electrical and Computer Engineering). The mount was motor-driven, with two-axes of motion to correct for aircraft pitch (the orientation of the wing axis) and roll (the orientation of the fuselage axis from propeller to tail). Absolute encoders recorded the orientation of the camera, Gyro-Chip piezo-electric gyroscopes detected camera and aircraft movement, and high-power amplifiers boosted the aircraft's 12 volt power supply to power electric motors on the gimbals. A prototype was made by the NRRI machine shop.

The second approach was to test a GPS capable of precisely measuring aircraft attitude, the Ashtech 3DF ADU GPS receiver system, which consists of four GPS antennas mounted to each wing and the front and back of the fuselage. This system worked well, but was expensive ($20K), and required FAA approval for mounting on the aircraft. Procedures were developed using software written for PC ERDAS 7.5 to use these attitude data to automatically rectify, convert to a common scale, and mosaic together adjacent frame-grabbed video images into one georeferenced file.

Objective 4: Use the system in a sample application to map wetland vegetation

Graduate student Carol Sersland performed this analysis, and details are provided in the paper she presented at the 15th Biennial Workshop on Color Photography and Videography in Resource Assessment (Sersland et al. 1995). The June and September 1994 images were co-registered to make a multi-date composite. The two images were then layered using the routine LAYERSTACK in Imagine to produce a six band image. Training signatures were defined in the Signature Editor with ERDAS Imagine's Area of Interest/Seed Properties, and merged until the maximum separation between classes was achieved. A supervised classification with the maximum likelihood decision rule was applied. Classification accuracy was about 60%, which is comparable to the levels of accuracy obtained using more expensive multi-spectral videography.

Dissemination of Results

Two publications were written describing results of this project, both of which are accessible via the Natural Resources GIS Laboratory World Wide Web home page:

http://www.nrri.umn.edu/gis.html

These papers were presented at two national conferences. Five additional presentations were made at national and state GIS and Landscape Ecology conferences (see below).

Publications Resulting from this Research

Johnston, C.A., C.A. Sersland, J. Bonde, D. Pomroy-Petry, and P. Meysembourg. In press. Constructing detailed vegetation databases from field data and airborne videography. Proceedings of the Third International Conference/Workshop on Integrating Geographic Information, Santa Fe, NM.

Sersland, C.A., C.A. Johnston, and J. Bonde. 1995. Assessing wetland vegetation with GPS-linked color video image mosaics. pp. 53-62. In Proceedings of the 15th Biennial Workshop on Color Photography and Videography in Resource Assessment. American Society for Photogrammetry and Remote Sensing, Bethesda, MD.

Other Presentations Resulting from this Research

Bonde, J.P., C.A. Johnston, and P. Berger. 1995. Using GPS to georeference aerial video imagery (poster). 10th Annual U.S. Landscape Ecology Symposium. Minneapolis, MN.

Bonde, J.P, C.A. Johnston, and P. Berger. 1994. Using GPS to speed the process of creating GIS databases from aerial video imagery (poster). 5th Annual Conference of the Minnesota GIS/LIS Consortium. Minneapolis, MN.

Berger, P., J. Bonde, C.A. Johnston, and D. Updegraff. 1993. A GPS-Linked airborne video system for georeferencing GIS databases of natural areas (demonstration). Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling. Breckenridge, CO.

Bonde, J.P., C.A. Johnston, P. Berger, and D. Updegraff. 1993. GPS-Linked airborne video system for georeferencing GIS databases of natural areas (poster). GIS/LIS '93. Minneapolis, MN.

Johnston, C.A., A. Bamford, J. Schubauer-Berigan, and S.D. Bridgham. 1993. Using GPS/ GIS to analyze spatial variation of wetland processes. GIS/LIS '93. Minneapolis, MN.