MAPPING TECHNOLOGY IN THE '90's FOR GIS APPLICATIONS TO IRRIGATION AND DRAINAGE

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ABSTRACT

Mapping technology, specifically photogrammetry and its related disciplines, has been extensively employed for irrigation and drainage engineering and management applications since becoming a practical tool in the post World War II era. The computer, space and information systems revolution of the '80's has radically changed the methods and potential for photogrammetric mapping applications. All aspects of photogrammetry have been affected including ground control surveys, aerial photography, stereo-restitution and map compilation, and cartography, the form in which maps are presented or published. The NAVSTAR Global Positioning System (GPS) satellites are used extensively to rapidly establish highly accurate ground for mapping projects. GPS is also used to improve aerial photography operations by providing an accurate flight line guidance system. Future GPS developments will permit instantaneous and highly accurate positioning of the aerial camera system at the moment of exposure. The analytical stereo plotting instrument developed and the close of the '50's is rapidly becoming the industry standard for the measurement and conversion of aerial photographs into highly precise maps and spacial data. The evolution of the personal computer and computer graphics has led to the "digital map" and the "digital terrain model" which in turn provides powerful management and analysis capabilities for geographically distributed data through the use of Geographic Information Systems (GIS).

DEVELOPMENT OF PHOTOGRAMMETRY

In order to better appreciate the dramatic changes which are taking place in the terrain information disciplines it helps to look back over the last 150 years to the beginnings of photogrammetry as a means of collecting terrain data. The first aerial photographs taken from hot air balloons in France in the late 1850's were more of a curiosity than of practical value. But within the next year Napoleon was using photos

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taken from balloons as a reconnaissance tool in preparation for battle. An just four years later an officer in the Union Army used photographs taken from a tethered hot air balloon to plot the position of enemy targets for artillery aiming.

The principals of perspective and stereoscopy which are so important in photogrammetric processes were developed and defined by an artist and an astronomer, both Germans, in the last half of the 16th century. But it was in the closing years of the 19th century that engineers and surveyors began to apply these to the photographs taken from either balloon cameras or terrestrial cameras in order to "precisely" determine positions of objects in the photos with respect to each other, and with respect to the location of the camera from which the photos had been taken, thereby giving birth to the discipline called "photogrammetry", the art and science of making reliable measurements from photography. These mathematical relationships still govern our discipline today.

Much significant work was accomplished by these early pioneers in terms of surveying and mapping, including the use of a photo theodolite, a combination of a camera and a surveying instrument, for surveys of the U.S. and Canadian boundary. In this same time period, the late 1890's and early 1900's, water related engineering projects were among the first to utilize this new discipline of photogrammetry. Reconnaissance mapping for the Lynn Canal and the Portland Canal in Alaska was prepare using a surveying camera in conjunction with a plane table.

But the invention of the aircraft was the first real breakthrough which spurred on the development of aerial photogrammetry as a mapping discipline. The first photographs known to be taken from an aircraft were taken appropriately by Wilbur Wright in 1909, with the earliest known application of aerial photos for mapping purposes being documented in 1913.

During both World War I and World War II military uses advanced the science of photogrammetry. The technologic revolution which followed saw improvements in optics and the mechanical systems for stereo restitution and measurement systems making photogrammetry a practical tool available to almost everybody.

During this period almost every discipline of natural science had its group of scientists developing applications of aerial photography to that science, soils, forestry, agriculture, geology geography and hydrology. Civil engineers began to use low level photography and stereo restitution to prepare large scale maps for engineering projects. Most major universities included some aspect of photogrammetry in their engineering, cartography or applied science curriculums and instituted significant research programs as well.

Agencies such as the Tennessee Valley Authority played significant rolls in the development of photogrammetric technology as well as application. A large photogrammetric survey of the entire Tennessee River Watershed was instituted prior World War II. Experience from this project and research by TVA lead to the first domestic production of instruments for the routine preparation of topographic maps from aerial photography. From the TVA to the extensive programs of the Bureau of Reclamation, water resource needs were a fundamental influence on the development of photogrammetry during its adolescent years.

TRADITIONAL USES OF PHOTOGRAMMETRY IN WATER RESOURCES

Before examining the changes taking place in photogrammetry in the '90's, let us review for a moment some of the traditional applications which have been made of the capabilities of photogrammetry since its acceptance as a commonplace tool for gathering and presenting terrain information.

Photogrammetry is both a qualitative and a quantitative discipline. Aerial photos can be used by themselves for the information they present about the character of the terrain. Landuse, soil and vegetation type, geology and drainage can be interpreted by knowledgeable users by what they "see" of infer from the photo evidence. Using specialized equipment photogrammetrists can make measurements in three-dimensional space of the terrain surface and the features thereon. These measurements can be converted to precision graphics, or maps. This is the quantitative aspect.

The use of photogrammetry by the Tennessee Valley Authority to map the Tennessee River watershed for planning and evaluation of the Tennessee Valley projects has already been mentioned. The USDA Soil Conservation Service has been a large consumer of photogrammetric services to acquire photography for soil and land use mapping, the qualitative aspect, and for the preparation of large scale topographic maps for drainage basin erosion. drainage and runoff control planning and design, the quantitative aspect.

The US Army Corps of Engineers has been instrumental in the development of photogrammetry since its introduction in the United States and a major user of its capabilities for their may water resource related projects. All of the navigable waterways directories and River Book maps have been compiled by a combination of photogrammetry and hydrographic survey. During the 1970's and '80's the Corps, the Federal Emergency Management Agency (FEMA) and other agencies made extensive use of photogrammetry for the floodplain delineation and mapping program. Not only was photogrammetry used to make topographic maps of the flood plains, but it was also used to compile the cross sections of the flood plain surface, which when combined with below water cross section surveys formed the basis for flood routing calculations and determination of water surface profiles.

The US Bureau of Reclamation has used the services of photogrammetry for its extensive reservoir and canal system projects. Topographic maps of varying scales are used for reservoir delineation, and dam and recreation site design, strip maps for canal design. Cross sections of the terrain compiled by photogrammetric measurement along the centerline of canals, access roads, and across borrow areas are used for earthwork computation.

The conversion of simple aerial photo images into scale rectified photomaps and orthophotos is another photogrammetric process which has extensive application in irrigation and drainage. I have previously managed a project in Haiti where rectified photomaps were required for the delineation of landuse and ownership within a large agricultural delta area for the implementation of a major irrigation and drainage project for the rice and vegetable industry in the valley.

These examples indicate how photogrammetry has been used in traditional applications for water resource, irrigation and drainage applications throughout the last 40-50 years with the results being traditional photos, maps and cross sections for the most part.

PHOTOGRAMMETRY IN THE '90'S

The computer, space and information systems revolution of the '80's has had more impact on the mapping industry in a short time than any other factor in the history of the discipline. All aspects of what we do and the way we do it are being affected. This includes the ground control surveys necessary for accurate mapping, the aerial photography, the map data compilation process, and the cartographic completion process or the manner and form in which the map data is presented.

For example, five years ago the typical large scale map prepared by photogrammetry was drafted by scribing or engraving a negative copy which was then printed onto a sheet of photosensitive mylar. Some completed maps, less that 5 percent of all produced, were delivered in some form of computer data file. Today, it is safe to say that at least 95 percent of all the mapping produced is delivered in a digital computer graphics format. Hard copies of the mapping if they are furnished at all are most likely created not by scribing or ink drafting but by computer driven pen plotters and laser film writers.

Lets now take a look at the changes which are taking place in each area of the mapping process and what that will mean in terms of the possibilities for use in irrigation and drainage applications. The way things are done in photogrammetry, and in some cases the things that can be done are going to change radically.

Ground Control Surveys

Surveying capability has progressed over the years from the compass and chain, to the transit and tape, to the theodolite and electronic distance meter, to the total station of today. A colleague of mine working in the area of developing technology for surveying said about fifteen years ago, "Some day the surveyor will be able to walk around with a brief case in his hand and make measurements automatically." He was close. Though the accuracy is still limited, there are electronic receivers about the size of a pocket transistor radio or hand held calculator which will report and record its location and that of its user in latitude and longitude or other coordinates as it is moved about over a project area.

This capability for rapid positioning is based on the Department of Defense's NAVSTAR Global Positioning System satellites, commonly called simply GPS. A single GPS receiver recording signals from four or five of the NAVSTAR satellites will give its position on the ground to an accuracy of plus or minus 100, 20 or even 10 meters. This space age technology can be envisioned in a simplified manner as a resection survey to the unknown occupied location from the know position of the several satellites overhead at the time of the observations or measurements. Ultimately, a network of 21 satellites will give 24 hour a day capability anywhere in the world for position determination.

While the currently available precision for a single GPS receiver working alone is limited, when three or more receivers are operated simultaneously, originating on known triangulation stations, and proceeding in a systematic manner throughout a network of ground points to be surveyed, results having position accuracies in the range of 1:100,000 to 1:1,000,000 are commonplace.

Five years ago while performing GPS surveys it was necessary to place receivers on a point and to record data from the satellites for periods ranging from 30 minutes to over an hour. Now it is possible to achieve the same results in 15 to 30 minutes per point with thenew receivers just on the market within the last 6 months. These receivers and their associated data reduction and adjustment software have the capability of producing lessor orders of survey position accuracy, such as Second or Third Order, 1 part in 10,000 to 1 part in 50,000, when operated in different methods. Recently our survey crews determined the horizontal state plane coordinates of 80 points for a seven mile long project which was to be mapped at a scale of 1"=50' (1:600) within only 40 total staff hours for the crew. Also, with GPS no longer is it necessary to have line of sight visibility between the survey stations, only between the receiver and the satellite.

While GPS methods are producing extremely good results for horizontal positions, because of the geodetic survey principals which govern, the results for the vertical component or elevation are not as easily obtained nor as reliable or precise as the horizontal position component. Most surveyors are being conservative in the application of GPS for the determination of elevation for mapping control and are still using various types of differential leveling for this purpose. We have successfully applied GPS positioning to determine elevation for mapping having contour intervals of 5 feet (1.5 meters) or more. But we can expect this to improve further in the '90's.

<u>Aerial Photography</u>

A number of changes have taken place which improve the capability of photogrammetry as a result of improved photography. These include improved lenses on our

:ameras, both in terms of resolution capability and 'esidual image distortion caused by design limitations ınd manufacturing flaws. These improvements are a lirect result of computer aided design and computer ıided manufacturing. Films are being produced with ;reater resolution capability than ever before.

ıut there are several major changes in the overall :amera systems which are having profound effects on the :apability of photogrammetry and the methods of opera-:ion. One which is relatively common in most recently ıanufactured camera systems is called Forward Motion :ompensation or simply FMC. FMC causes the film to ıove in the camera, while the shutter is open for the ./100 or 1/200 of a second, at a velocity in the film ılane which is exactly relative to the speed of the ıircraft over the ground. This eliminates the blurring ıf the photo image caused by the motion which has been nherent in aerial photography since inception.

ınother recent development is a practical and opera-.ionally satisfactory gyro stabilized camera mount. ıecause of turbulence it is impossible to fly a photo ıircraft straight and level at all times. Gyro stabi-ized mounts have been tried by the military as far ıack as the '60's, but until the last year satisfactory ommercial models have not been available. The less ip or tilt present in a photo the less compensation is equire for geometric distortion in the mapping instru-ents, and the better the map which can result.

ut technology is on the verge of a two major break-hroughs for aerial photography and the mapping pro-ess. The GPS positioning system is the basis for one spect of change in aerial photography and subsequent apping. At present GPS receivers installed in air-raft are capable of providing precision airborne avigation and flight guidance along predetermined light lines. This will be of major consequence when erial photography is required over large undeveloped reas and in third world areas where existing maps are ot adequate to enable precision visual navigation.

ow level photography was required over the rice pad-ies in the river delta in Haiti which I mentioned reviously. It was impossible to rely on visual navi-ation because all of the land looked the same from the ir at 150 miles an hour. The solution to the flight ine location was to place tall guyed poles on the ends f each flight line with large colored flags which ould be visible to the flight crew. A similar techni-ue, placing large arrows made of plastic strips at the ends of the proposed flight lines, has been used by our crews for projects in the relatively featureless range land of the high plains region of Colorado. With GPS navigation exact flight line tracking can be achieved in situations like these by simply inputting the latitude and longitude of the flightline endpoints.

In a further application along the same direction, research is actively underway using GPS systems to record the precise position of the camera in the aircraft at the moment of exposure. For this purpose ground GPS receivers located at known control points record satellite data at the same time as the receiver in the aircraft coupled to the shutter of the camera. The coordinates of the camera position in three dimensional space can be determine fairly precisely, as with GPS surveys for the determination of ground control points. Research has demonstrated the technical feasibility to conduct photogrammetric mapping from aerial photography obtained in this manner with little or no ground control, but refinements are required to the GPS receiver antenna design for operational considerations and to the software and the technique before accuracies will be sufficient for practical application (Erlandson etal, 1991).

Over the years photogrammetrists have generally classified the imagery obtained from the air recorded directly on film through a camera lens as "photography", and that which is recorded on some sort of magnetic media by some type of electronic sensor as "remotely sensed data". Technology has now advanced to the stage that the possibility of recording an array of digital data in the form of pixels (picture elements) on a digital memory chip instead of a piece of photosensitive film is not only feasible but a reality. Recently my wife and I had our picture taken for our church directory, and a moment afterward viewed the photo on a high resolution computer terminal. As with the GPS positioning, only refinements are needed before this will become a practical method of "photography" for photogrammetric applications.

Photogrammetric Measurements and Restitution

Computers, scanners, digital computer graphics systems as they have developed in the '80's have changed the way we are now converting photos to maps. The projection and optical mechanical stereoplotters which have been the mainstay of the mapping equipment for the last 40-50 years have been almost completely replaced by computer controlled instruments. Instead of the stereo image of the photographs being optically and mechanically projected into a plane of reference for measurement, the spacial orientation and relational measurement of the two photos forming a 3-dimensional stereoscopic view are performed analytically hundreds of times each minute on a continuous basis as the operator views the photos and moves about in the view. At AeroMetric Engineering for example, twenty out of our twenty-eight instruments are of the analytical type, whereas only three years ago the ratio was the opposite. The analytical stereoplotters provide many refinements and options in the mapping process. For example, the effects of imperfections in the camera lens can be programmed into the plotter which will then be removed analytically and differentially as the operator maps from different portions of the photo. Likewise the radial displacement effects of atmospheric refraction can be eliminated, as can the warping effects of earth curvature. The computer can remember the orientation parameters for each photo which has been set up and used for mapping. If the operator needs to reset a model, all that is necessary is to enter the photo identification number.

More significant however for some water resource applications is the capability of being able to program the instrument to cause the operator to take measurements of the ground surface at finite locations. This is particularly advantageous for the collection of profiles across flooplains for flood flow calculations. Given the location of the endpoints and deflection points along the desired cross sections, when input into the analytical instrument's computer, the operator's field of view will be moved precisely along the line connecting the ends and deflection points so that the elevation and distance along the line can be measured and recorded in the system's computer.

In a similar manner the instrument operator can program the system to "drive" him to finite spaced grid value locations to in order to measure a grid elevation model, or along evenly spaced profiles for a terrain profile model.

The most significant change in the last five years is the transition from the mechanically drawn map manuscript and manual drafting to computer-aided drafting (CAD) systems. The affordability of fast, powerful personal computers and workstations, and the availability and widespread implementation of user-friendly CAD systems, such as Intergraph's MicroStation® and Autodesk's AutoCad® has allowed the photogrammetrist to use digital computer graphics to create the maps of the '90's.

The use of these CAD systems, analytically compiled terrain data, and the advent of high resolution photo scanning instruments has also made possible the digital orthophoto. Many of you may have used orthophotos as a map base in your irrigation and drainage projects because of the advantages they offer, showing the photo image of the ground in an exact scale representation, with superimposed reference grid, and perhaps also the contours or other information. These orthophotos can now be prepared analytically and presented in digital image format for use with CAD systems.

GEOGRAPHIC INFORMATION SYSTEMS AND MAPPING

There is quite possible not a single scientist or engineer working in the areas of resource applications and management that has not heard of geographic information systems or GIS. What is a GIS? It is quite simply an assemblage of computer hardware and software which provides for the management of information which is geographically distributed in its nature through the use of digital computer data bases related to digital computer graphics. Some GIS systems provide capability to do relational queries, perform relational analyses and create complex reports and maps from different types of data stored in the data bases.

For example the two papers preceding this one on the program dealt with GIS applications, and imagery or mapping (Podmore and Wagner, 1992; Fredericks and Labadie, 1992). During another conference this last summer three papers dealt with GIS applications in hydrology (Shamsi, 1992; Vieux, 1992; Jones and Nelson, 1992).

GIS is becoming a powerful tool enabling questions to be asked and answers to be created which were not previously possible. The state of the art capability in photogrammetry is able to provide the digital maps and digital terrain data which are fundamental to a GIS.

Photogrammetry in the '90's is able to provide maps and map data in forms and formats not previously available. Concepts such as map scale and accuracy no longer have the same meaning in CAD or GIS systems as they previously had with hard copy maps. CAD systems allow the user to change scale upon desire. Therefore, it is more important to be concerned with positional accuracy f mapped data, level of detail and content rather than ap scale for CAD and GIS applications. Knowing the ccuracy requirements and intended use the professional hotogrammetrist can design the mapping process to meet he specific GIS users needs.

n the past is has been usual to think of the presentation of terrain data in the form of a topographic map ith the surface configuration and relief depicted by ontours at some preselected interval. In computer-ided design and GIS systems contours are no longer ecessarily needed, nor are they necessarily the best ay to express topography foranalysis and modelling. onsequently, the photogrammetrist is doing less and ess "contouring", and more and more terrain modelling. nstead of mapping points of equal elevation along a ine, the technicians may compile randomly distributed pot elevations which depict the land surface, called ass points, with three-dimensional line strings along iscontinuities such as crests, breaks in slope and the xis of drainages, called break lines. These terrain odels can be used to model drainage and irrigation anals, or floodplains for flow analysis (Vieux, 1992; ones and Nelson, 1992), and can be used to model res-rvoirs for the calculation of stage storage tables.

apping technology in the '90's is able to provide more ata and different types of data than ever before. It s the primary source of the geographic base map for IS systems. Much of the data needed for irrigation nd drainage systems design and management can be rovided through photogrammetry more effectively to eet the water resource challenges of the '90's.

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