Topic 13 : SPECIALIST AND NEW TECHNOLOGY

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PREVIEW

Introduction

This chapter deals with new and specialist technology. The engineer should have a knowledge of the principles and applications for these techniques, and be aware of their limitations. At this stage, the provision of these services is most likely to be by specialists in each field.

In addition this chapter lists some of the community's survey and mapping resources available to the engineer. These resources will often provide the data needed for feasibility studies and preliminary designs, if not the final design of works.

Objectives

After completing this topic you should be able to:

- understand the principles, applications and limitations of GPS and Photogrammetry
- recognise possible uses of existing survey and mapping resources available to the community.

Readings

Required: Read Muskett 5.9 Global Positioning System
6.7 Photogrammetry
4.6 EDM Developments

Note that some of the information in these sections is not up-to-date. This study guide provides an up- to-date supplement.

GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System is a three dimensional positioning system developed by the US Defence Department, which uses satellites orbiting the earth to fix positions anywhere on the earth. The system consists of a constellation of 21 satellites, plus three spares, orbiting at an altitude of 20,200 kilometres.

GPS will give results anywhere on earth, in any weather conditions. Five to nine satellites are "visible" at any place and time. Signal measurements from four satellites are required to fix position. Four additional signal measurements provide redundancy in the calculation of position, giving a better position fix and a measure of the error.

GPS receivers range in price and accuracy:

- Hand held receivers used for sporting and outdoor activities, sailing, etc. have an accuracy varying from 5 metres with good reception, to 100 metres under adverse conditions, and cost from $200 to $1,000.
- Geodetic receivers used for surveying have the capacity to calculate position using the data from two receivers. They cost from $5,000 to $80,000.
- Geodetic receivers used with one as a base station, and an acquisition time of 30 seconds, will yield an accuracy of (5mm ± 2mm per km of distance between them). This is an accuracy of 25mm for a 10 km radius circle.

Most GPS receivers are now multi-channel and can receive the signals from 8 to 12 satellites simultaneously.

The Principle

The 21 satellites move in orbits and their positions are continuously monitored and predicted. Orbit information is updated every eight hours. They broadcast corrected orbit information and a time signal from a precise atomic clock.

The GPS receiver on earth also has a clock, and measures the time taken for the broadcast signal to reach it. These time differences are converted to pseudo-ranges – pseudo because they include clock error. With signals from a minimum of four satellites it is possible to calculate position (x, y, z) and clock error.

Refinements

The position or orbit of each satellite will not be precisely known.

The passage of the signal through the atmosphere gives rise to errors in position as we will have an imperfect knowledge of the atmospheric parameters which affect the speed of radio transmission. These are principally, pressure, temperature and humidity.

To overcome this weakness in the system it is usual to employ two receivers, leaving one at a known point, as the base receiver and using the other to visit the points that are to have their positions fixed. If the roving receiver is within 200 km of the base receiver, the angle at the centre of the earth subtended by the two units is 1.8 degrees, and the angle subtended at the satellite is only 0.6 degrees. Thus the affects on the signal to both receivers will be the same and cancel out.

Positioning Methods

Different methods of collecting satellite data and processing it have evolved:

- Static – two units receiving data from the same satellites for a period of up to 30 minutes. This gives the greatest accuracy, but is slow.
- Rapid Static – more sophisticated processing techniques allow useful accuracies to be achieved by occupying the position for as little as 30 seconds. It necessary to maintain lock on the satellites, whilst moving from point to point, to achieve this rate of position fixing.
- Kinematic – this may be with one receiver only, which is continuously moving, as in a boat, car or train. Lock on the satellite must be maintained, and it is necessary to establish position initially in a static mode.

To obtain the best advantage of rapid static and kinematic modes in real time, the data from a base station receiver may be transmitted to the roving unit via an FM radio link. This restricts the area of operation to a few kilometres, but offers many advantages.

Problems

Cities

In cities it may not be possible to get a wide enough view of the sky to receive signals from sufficient well spaced satellites. The signal path may not be direct, but be reflected from the walls of buildings, giving rise to errors in range, and hence position.

Geoid

The satellites orbit about the centre of mass of the earth. Position and more importantly, height, are computed on the spheroid (the idealised shape of the earth). Heights for engineering purposes, especially gravity hydraulics, are required in relation to the geoid, which is the equal-gravity surface at sea level. This is an accidented (irregular) surface, whose shape is not completely known but our gravity models are now greatly improve. The desire to obtain useable geoid height from GPS has stimulated a lot of research in this area. The separation of the spheroid and geoid varies from place to place.

To check heights obtained by GPS, it is necessary to have both the GPS height and that obtained by ordinary levelling at a number of points throughout a project site. The more variations in the terrain, the greater the number of points required. Where the compatibility of corrected GPS heights and points from ordinary levelling is not good, data from these points can be used to set up a transformation algorithm to improve the GPS heights.

Applications

- Geodetic position control. The Australian survey network is being strengthened by use of GPS.
- Minor station positioning – control points for further survey work. Ground control for photogrammetry.
- Locating infrastructure for Geographic Information Systems (GIS).
- Detail surveys. This is subject to development. GPS cannot be used successfully in all situations. (Forests and cities)
- Off-shore positioning, ship and plane navigation
- Position and tilts of aerial survey cameras at the instant of exposure.
- Motor car navigation systems
- Road fleet monitoring and control. Ambulance, Fire Brigade, Police, Taxis, freight companies
- Hand held units for bush navigation, search and rescue.

Access to GPS Services

The following describes the situation in 1999, but the scene is constantly changing.

In the future, we can expect that all surveyors providing a consulting service will have GPS equipment, but this is not yet the case. The expense of geodetic receivers means that only the larger companies, and service companies set up specifically to provide GPS services, are equipped with geodetic receivers.

Survey education institutions and large service authorities also have receivers.
Most instrument manufacturers or their agents provide a hire service to get their particular equipment into the market place.

PHOTOGRAMMETRY

(*Terms shown in bold type, eg* **parallax** *are defined in a glossary at the end of this section.*)

The science and art of making reliable, three dimensional measurements of objects or sites from photographs of them.

Two photographs are needed to make three dimensional measurements. They are taken from different positions, chosen so that there is an appropriate **parallax** shift between images, which when viewed stereoscopically, is interpreted by the brain as a height difference, or difference in the third dimension.

Photographs can be taken as, or converted to digital images, and "viewed" by **machine vision**.

Aerial Photogrammetry

The major use of photogrammetry is map making from vertical aerial photographs. The maps are frequently in digital form.

The intent is to take photographs with the camera sighted truly vertical, but variations in the angle of the aircraft and accelerations make this impossible. Photographs are usually within 2 degrees of vertical.

Aerial photographs are taken in runs with each photograph overlapping the previous one by 60%, giving continuous stereoscopic coverage of the terrain, with a small safety margin of 10%. Where more than one run is required to cover an area, adjacent runs are overlapped by 20% to 30 % depending on the terrain.

The flying height from which the photographs are taken governs the scale of the photographs and the accuracy of the subsequent photogrammetric mapping in both position and height.

Aerial Survey Camera

This is a large **format** camera with fixed infinity focus, designed for mounting in an aircraft.

The format is usually 225 mm by 225 mm, and lenses of focal lengths 300 mm, 152 mm and 90 mm are in common use. The 152 mm lens is the most popular for engineering mapping applications.

Camera lenses have high **resolution**, low **distortion**, even illumination and a comparatively large aperture. The cameras are calibrated before use. Cycling time between exposures is a minimum of 1.5 seconds. A vacuum plate is used to hold the film flat during exposure. Microprocessors are used to control exposure and time between exposures.

Not surprisingly, they are expensive, with a price tag in the order of $500,000.

Ground Control

As the photographs are not truly vertical, and the exact height and position of the camera at the time of exposure is unknown , a means of relating them to the ground coordinate system (E,N,H) is needed. This is provided by ground survey.
For a pair of overlapping **stereo photographs** (60% overlap), it is usual to provide four control points with known position and height, one in each corner of the overlap area. This provides some redundancy (check) in the calculation of camera position and attitude for the two photographs.

Instruments for Photogrammetry

Analytical instruments currently in use employ binocular optical trains for viewing the photographs, or the images are projected on a computer monitor and viewed through shuttered spectacles so that the left eye sees the left image and the right eye the right image. The "projection" is done by computer in real time at approximately 50 Hz. The use of computers has allowed a great sophistication in photogrammetric process, giving higher accuracy, flexibility and higher productivity.

State-of-the-art digital photogrammetry using machine vision opens up the possibility of co-processing more than two images, and further enhancing accuracy and productivity. (Systems requiring viewing by a human operator are limited to the number of eyes of that operator. People with two heads would be invaluable in photogrammetry.)

Photogrammetric Products

The basic product for many years has been the plotted contour map, be it for a standard series of topographic maps at say 1:25000 with 10 metre contours, or special maps to suit engineering projects, where scale, contour interval and map content are tailored to project needs.

The plotted map has now been largely superseded by digital products. Data can now be supplied in a variety of formats to suit the user's requirements.

A much used method is to format data as a drawing in one of the popular CAD systems, or as a **digital terrain model (DTM)**, which can be interrogated to provide data suited to changing design requirements.

For example: If data was provided as longitudinal sections and cross sections for an intended road centre line, and the it proved necessary to change the position of the centre line, the data would be at best difficult to use, and at worst useless. If the data is provided as a strip DTM, longitudinal sections and cross sections for any alignment within the strip may be obtained from the DTM.

Data can also be provided as an orthophoto or orthophotomap. A photograph is a perspective view of the terrain, all features are viewed from one point.

A map is an orthogonal view of the terrain, that is, it is seen as if the observer is vertically above each and every point, or expressed another, the point of observation is at infinite distance, and all rays from the observation point to terrain features are parallel.

An orthophoto is one in which the image geometry has been changed to make it like a map. Most are prepared from digital images, and the process of making an orthophoto is carried out by calculating the correct or map position of each **pixel**. The orthophoto can be supplied as a picture plot or as digital data for viewing in one of the many computer imaging systems

The orthophoto transfers the onus of interpreting the aerial photograph from the photogrammetrist to the user. In areas of little cultural detail, the orthophoto may provide more information than a map, but in developed or built up areas it may be difficult for the user to discern all the details properly.

Aerial Photogrammetry Applications

- topographic mapping from 1:25,000 scale with 10 m contours down to 1:100,000 with 40 m contours
- large scale special purpose mapping, including feature surveys for engineering projects
- 1:500 maps with 0.5 m contours for sewer reticulation design
- 1:2500 base maps with 1 m contours
- 1:5000 strip maps for preliminary design of highways, pipelines, railways etc.
- profiles and cross sections
- digital terrain models – surfaces defined by random or ordered series of points with three dimensional coordinates
- cadastral (property boundary) surveys
- flood plain maps and sections for hydrology
- volume monitoring for land fill, quarries, stockpiles
- monitoring change

All of these products can be supplied as hard copy plots or as digital data.

Accuracy

The position accuracy of photogrammetry is in the order of 30 μm (30.10^{-6}m) at the scale of the photograph.

Height accuracy is 1/5000 to 1/6000 part of the flying height.

Contours are usually prepared from aerial photographs where the flying height is 1000 to 1200 times the contour interval.

Examples:

Large scale maps/digital data for land development or freeway design. (Field survey levels required on critical points such as existing drains to be crossed and existing paved surfaces to joined to.)

Photograph scale 1:4000, flying height 600 m. A stereoscopic overlap pair covers 360 m by 630 m.
Contour interval 0.5 m. Contour accuracy (1 sigma) 0.1 m

Position accuracy 30 μm on the photograph, equivalent to 0.12 m on the ground

Topographic mapping and digital data. 1:25,000 map, 10 m contours

The use of 1:40,000 scale aerial photographs is proposed. Six stereoscopic overlap pairs are needed to cover a standard 1:25000 mapsheet of 0^{o} 07’ 30” of latitude by 0^{o} 07’ 30” of longitude

Required plan accuracy (1 sigma) 0.2 mm on the map, equivalent to 5m on the ground and 125 μm on a 1:40,000 aerial photograph.

For 1:40,000 scale and 152 mm focal length lens, the flying height is 6080 m.

Contour interval that could be prepared from these photographs is $^{6080}/_{1000} = 6$ m.

The 1:40,000 scale is suitable for the mapping using very conservative criteria. (Note that considerations of feature identification also affect this decision.)

Photogrammetry will be cost effective only on large projects, or where the amount and complexity of detail to be included on the map is great. Cost comparisons between photogrammetry and field survey methods should always be made for engineering applications, as the dividing line between the use of the two technologies changes with developments in survey and photogrammetric instruments and techniques.

Features surveyed by photogrammetry will tend to be more faithfully recorded as to detail, because of the ease of gathering data points, but with a lower overall point accuracy than is obtained by field survey.

Terrestrial and Close Range Photogrammetry

In terrestrial and close range photogrammetry the camera is no longer airborne, but mounted on a tripod, either singly or in pairs. A static object can be photographed with a single camera used successively in two positions. A moving object, or one subject to change must be photographed by two cameras instantaneously. In this latter case two cameras mounted on a bar either 600 mm or 1200 mm long are frequently used.

The distance between the cameras, is a function of the size of the object, the distance to the object, and the accuracy required. Camera formats vary from the size of the aerial camera 225 mm by 225 mm (rarely) to 60 mm by 60 mm. Larger formats give greater give greater accuracy. The angle of coverage of the lens is in the range 60 to 90 degrees. Applications of terrestrial and close range photogrammetry include:

- mapping vertical or near vertical faces
- geological mapping of dam abutments
- dams and structures surveillance
- measurement of mechanical plant and components
- car body prototypes
- car seat design (Renault)
- ship propeller for conformance with design profile

- plant pipework "as constructed"
- deformation of structures
- building façade measurement, elevation drawings, sections
- recording heritage sites, buildings, mines, aboriginal rock art
- measurement of underwater structures, corrosion on oil production platforms at depths of 100 m. Pairs of cameras deployed by a remotely operated vehicle (ROV) to photograph welds and joints. measurements of corrosion pitting to an accuracy of 0.3mm
- forensic applications, traffic accidents, crime scenes
- medical applications, growth monitoring, malformation, corrective surgery
- boat and ship hulls, aircraft fuselages, wings etc.

Advantages

- non contact, for difficult or dangerous sites
- records the whole scene, photographs can be re-visited to obtain additional information found necessary by study of the initial data
- records irregular or intricate detail where manual point by point method would be too time consuming.

FURTHER READING

Atkinson, K B (ed.) 1980. *Developments in Close Range Photogrammetry*. London: Applied Science Publishers.

Burnside, C D 1985. *Mapping from Aerial Photographs*. 2nd edn. Oxford: Blackwell Science.

Wolf P R 198? *Elementary Photogrammetry* 2nd edn. New York: McGraw Hill

American Society of Photogrammetry (ed) 1980 *Manual of Photogrammetry* 4th edn. Falls Church Va.: American Society of Photogrammetry

GLOSSARY AND DEFINITIONS

digital terrain model (DTM)	a surface defined by a series of points whose positions are known by three dimensional coordinates (x,y,z). The DTM may be either ordered, where the points are in a regular grid for position (x,y) and z is random or more usually random, where all three ordinates are governed by the shape of the terrain.
distortion	Change in position of an image caused by errors in the design or manufacture of a lens
format	Size of negative for a particular camera
machine vision	Process of image matching or recognition by computer matching of individual **pixel**s making up the image
parallax	An apparent shift in the position of an object image in relation to its surrounding images, caused by a shift in the position of the observer
pixel	the smallest digital unit of a digital image. Usually identified by its matrix position and given a value indicating its colour or brightness.
resolution	The ability of a lens to register changes within an subject. Measures in line pairs per millimetre or by modulation transfer function
stereo photographs	A pair of photographs covering at least in part the same object or site, taken from different positions so as to provide a three dimensional view of the object under appropriate viewing conditions.

TOTAL STATIONS

A Total Station is the combination in one instrument of the functions of:

- Electronic Theodolite
- Electronic Distance Measuring Equipment
- Data recording hardware and software

Some total stations include a microprocessor for data manipulation, minor calculation and format conversion.

The theodolite and edm share the one telescope so only one pointing is necessary.
Data recorded includes horizontal circle, vertical circle, height of prism, slope distance, and codes for point description. Thus all the information required for a survey can be recorded electronically in the instrument and down loaded to a PC for reduction and plan production.

The EDM is usually of infrared type, measuring the distance to a prism, but the latest instruments can be switched over to a low power LASER which allows measurements without a prism.

This is especially useful for measurements to inaccessible or dangerous points. Low power (for safety) restricts the range to approximately 80 metres.

If the beam is interrupted, the measurement displayed will be wrong.

Some instruments have a tracking facility and can be operated from the prism end by one person.

COMMUNITY RESOURCES

The community invests funds in survey type resources for the planning , development and management of the environment. These resources may be a suitable source of base data for your engineering project and should be considered before commissioning new, and probably expensive, surveys for your project.

The resources fall into three categories:

1. Maps, both printed and digital electronic.
2. Land data bases
3. Aerial photographs

MAP PROJECTIONS – WHAT YOU SHOULD KNOW

Maps are drawn or calculated on a map projection, which is an algorithm for representing the curved surface of the earth on a plane surface, or a simply curved surface which can be developed from a plane. Map projections are complicated by the fact that the earth is not spherical, but spheroidal or ellipsoidal. The earth is approximated by an oblate ellipsoid of revolution, where the minor (polar) axis is 42.77 km smaller than the equatorial diameter. The equatorial radius of the earth is accepted as 6378.160 kilometres for mapping purposes. (fig. 13.1)

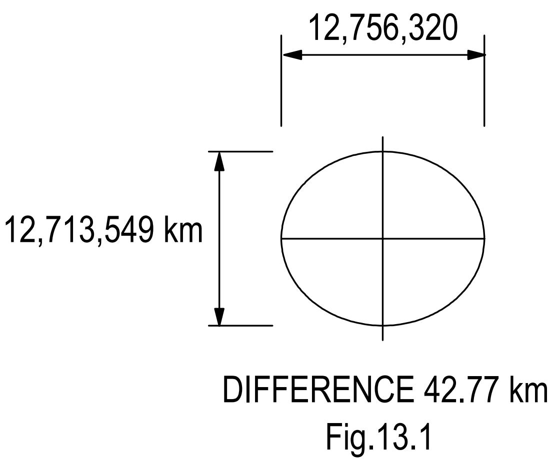

Fig.13.1

A cone and a cylinder, either circular or elliptical, are surfaces which can be developed from a plane. Both of these are used for map projections.

Mercator's famous map of the world is projected onto a cylinder which contacts the spheroid along a single great circle, the equator. As you move further from the equator, the distance between the spheroid and the cylinder increases, and so do the distortions in the map, as the section in figure 13.2a shows. Figure 13.2b shows the similar situation for a cone.

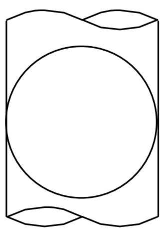

Fig.13.2a

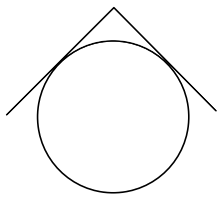

Fig.13.2b

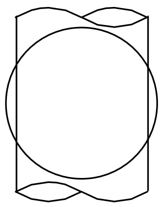

Fig.13.3a

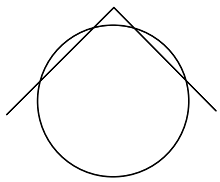

Fig.13.3b

The distortions of the map projection can be reduced by arranging the surface to intersect the spheroid, as shown in figures 13.3a and 13.3b.

The map projection used in Australia and many other countries is the Universal Transverse Mercator projection. The spheroid is projected in 6 degree sectors of longitude, onto a cylinder which intersects the spheroid surface. A new cylinder is used for each 6 degree zone. Projecting only a small section of the spheroid at a time reduces the distorts to a manageable amount.

On the Map Grid Australia, distances at the centre of a zone are smaller than ground distances by a factor of 0.9996, and at the edges of a zone they are larger by a factor of 1.0004.

Map Grid Australia coordinates in metres repeat in easting at distances of approximately 668 km at the equator and 526 km at the latitude of Melbourne.

Imposing a rectangular grid on each zone creates the concept of grid north, which is coincident with true north only along the centreline of the zone. Fig. 13.4 shows the grid aligned to north, but all the meridians in the zone run to true north, but are not parallel to the grid.

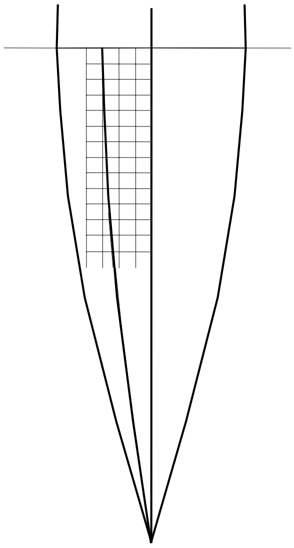

Fig.13.4

MAPS

Land Tenure or Cadastral Maps

Parish System

Each colony produced plans of the original Crown subdivision of the land, known as Parish Plans. The Colony of Victoria was divided into counties and further subdivided into parishes, according to the English model.

Parishes were divided into Portion or Sections and Crown Allotments.

This system is still used today for the legal description of land.

Later subdivision by private land holders resulted in Lodged Plans of Subdivision (LP's) and now Plans of Subdivision (PS).

The legal description of a piece of land might read:

> "….being lot 12 on Plan of Subdivision Number 34136, and being parts of Crown Allotments 31 and 32^{E}, Section IV, Parish of Keelbundora, County of Bourke."

Cadastral Maps

All states now produce cadastral maps which show the major subdivision pattern on a modern map base.

In Victoria:

- rural land holdings are shown on a base of the 1:25000 map series.
- urban land holdings are shown on a series of "base maps" at scale 1:2500. This series covers the whole of greater Melbourne, and every other city, town or township in the state.

Similar arrangements apply in other states.

Topographic Maps

Topographic maps show natural and man-made features by point symbols and line symbols, and the shape of the earth's surface, usually by contours.
The Commonwealth Government, through AUSLIG have produced a map series at scale 1:100,000 with 20 metre contours, and from this series at 1:250,000 and 1:1,000,000 have been derived.

Larger scale maps are produced by the states. A series of 1:25,000 topographic maps is universal, and some states also produce 1:50,000. Victoria uses 1:50,000 for outdoor leisure maps.

Base maps which show roads and some property boundaries are produced at scales of 1:10,000, 1:5,000 and 1:2500 with contours varying from 10 metres to 1 metre vertical intervals.

All the topographic and base maps are produced from aerial photographs, but they do not necessarily show all the information that may be gleaned from the photographs. There is a standard specification for each map series.

Thematic Maps

Maps showing particular themes are produced by both state and commonwealth governments.

The most common to engineers is the geological maps, but there are also maps of rainfall, population, primary production etc.

Land data bases

LANDATA is an electronic index of land holdings and land holders in Victoria. Information can be obtained from a variety of inputs such as owners name, street address, plan reference, certificate of title volume and folio, map grid coordinates.

Municipal councils have databases linking the maps of their areas with land ownership and rating.

Other data bases are strictly “land” data bases. A major example is the Facilities Information System established by Melbourne Water. It contains details of water reticulation, sewerage and drainage in electronic form

Aerial photographs

The state government has taken aerial photographs of Victoria in a more or less systematic way since the 1950’s. The scale of the aerial photographs varies from 1:10,000 over Melbourne, to 1:40,000 over rural areas. Aerial photography is flown for special projects, such as highway/freeway development (Geelong Road upgrade), and City Link.

There is an electronic index to this aerial photography. The site to be searched may be specified by:

- map grid coordinates
- Melway reference
- Parish and crown allotment.

Details of the latest, all, or a certain epoch, of aerial photographs may be extracted from the index.

SUMMARY

The Global Positioning System is a tool for economically providing both position and height in a global system for engineering, subject to some limitations.
Photogrammetry can be used to provide mapping over large areas, in either hard copy or digital form. It can also be used for a variety of measuring tasks, with the accuracy scaled to the application.

Total Stations have become much easier to use and provide a rapid survey tool that is cost effective. New instruments allow one-person operation.
There is a wealth of survey and mapping data, provided by government as part of its community service obligations, which is suitable for investigations and preliminary designs.