M1: Introduction and Principles of Surveying

Module 1: Basic concepts of surveying

Introduction, Geoinformatics, Principles, Basic measurements, control networks, locating topographic details, topographic maps numbering and details

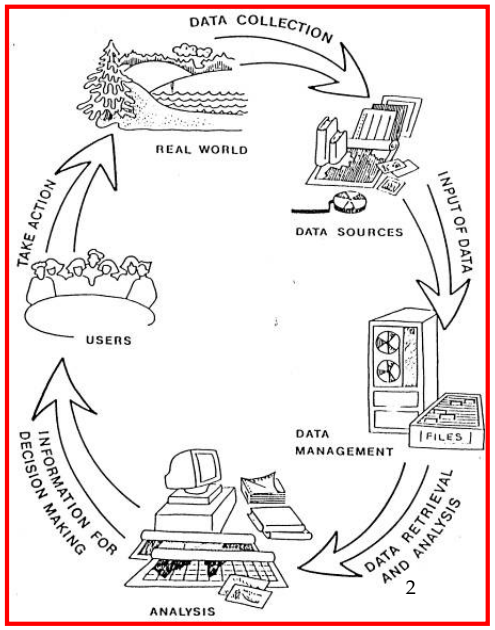
- Introduction
- Definition: Geoinformatics
- Divisions and classification of surveying
- Principles of surveying
- Basic survey measurements
- Topographical survey
- Map numbering systems: (i) I&AC series (ii) CIM series
- Symbols and colours for topographical maps
- References

Introduction: Geoinformatics/Geomatics/Geospatial Technology

Geoinformatics

System that provides information/data related to features on earth including land, water, and underneath and deals with:

- collection
- processing
- analysis
- display
- storage
- retrieval
- and updating of geoinformation.



Recognized fields of Geoinformatics

- Surveying/Geodesy
- Global Positioning System (GPS)
- Photogrammetry
- Remote Sensing
- Laser scanning (LiDAR: Light Detection and Ranging)
- Geographical Information System (GIS)
- Cartography

- Three stages:
  - Data collection
  - Data Processing
  - Data Analysis/Interpretation

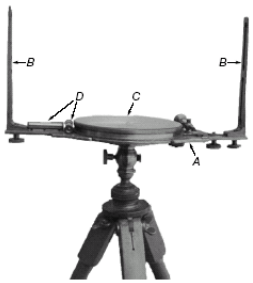
Conventional data collection procedures

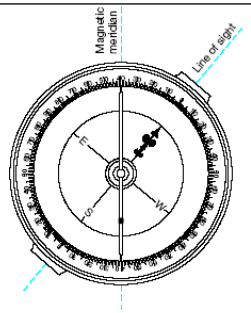
- Accurate knowledge of data pertaining to terrain surface and associated features (geoinformation) and the collateral data for planning and design of engineering projects.
- Field surveying methods considered as the only means to get reliable field data which have remained practically unchanged, even though considerable evolution has taken place.
- Conventional field surveying methods are
  - time consuming
  - weather dependent
  - expensive
- Hence, restrictive in use to only a few sites for detailed investigations in case of various alternatives

- End products of such surveys are maps:
  - topographic
  - cadastral or land revenue
  - thematic
  - special purpose engineering maps
- Survey of India (SoI) prepares topographic maps at 1:250,000, 1:50,000, 1:25,000 scale.
- Higher scale maps from state government or project executing authority.

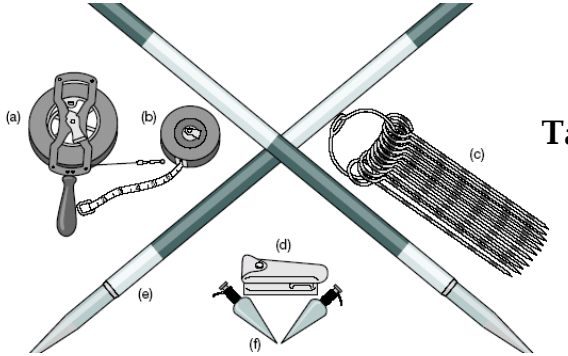
Traditional surveying measurements

Direction measurements:	Compass, Vernier or microptic theodolite
Distance measurements:	Chains, tapes, bands, subtense bar, tacheometers, range finders
Elevation measurements:	Levels, theodolites



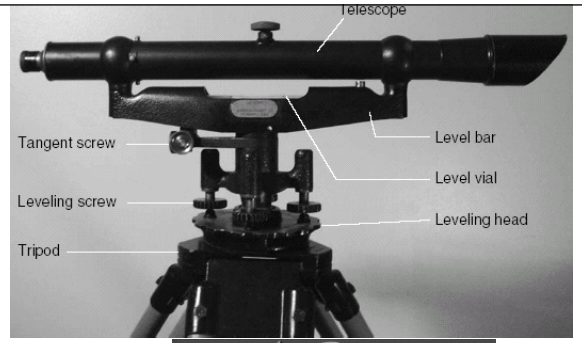


Surveyor's compass

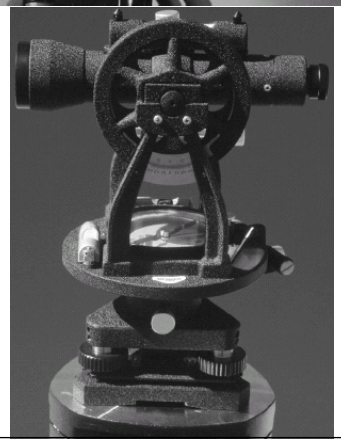


Taping/Chaining equipment

Earlier generation surveying equipment (Wolf and Ghilani, 2002)



Dumpy Level

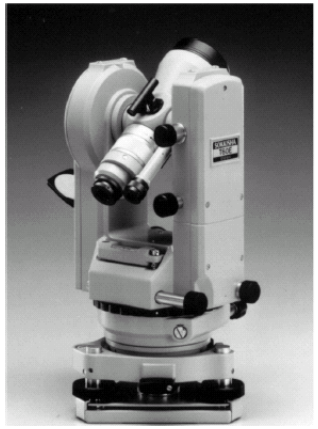


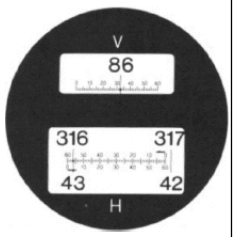
Theodolite/ Transit

Ref: Wolf and Ghilani, 2002

Microptic theodolites

Wild T-2 optical reading directional theodolite and reading system for the Wild T-2





Lietz T60E optical-reading repeating theodolite

Ref: Wolf and Ghilani, 2002

Changing scene

- Last four decades revolutionized measurement techniques in surveying.
- Highly sophisticated and advanced tools for distance, direction and elevation measurements
- Main reason: Improvements in
  - electronics
  - optics (larger resolution, magnification, less distortion)
  - more precise graduations
- Use of satellite sensors, use of computers, micro-computers
- Automation in instrumentation making data collection easier and fast.

Advancements in Field Instrumentation

- Electronic angle and distance measurements
- Laser-based surveying instruments and methods
  - Distance measurements
  - Alignment and deflection measurements
  - Vertical alignment lasers
  - Laser levels
- North seeking instruments and inertial systems
  - Compass devices
  - Gyroscopic devices
  - Inertial systems
- Satellite-based positioning systems
  - TRANSIT system
  - Global Positioning System (GPS), GLONASS, GALILEO, IRNSS
  - Satellite Laser Ranging
  - Satellite Altimetry
  - Very Long Base Line Interferometry (VLBI)

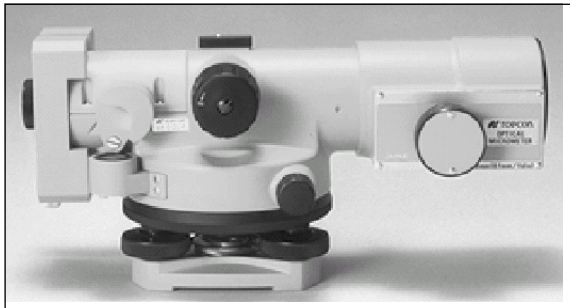
Electronic angle and distance measurements

- Electronic Theodolites
- EDMs
- Total stations
  - Mechanical
  - Motorized
  - Robotic/Auto-lock

Electronic angle and distance measurements

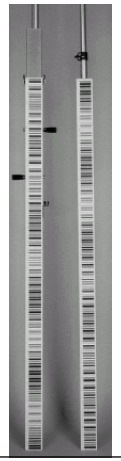
Topcon GTS 800 total station with internal data collector

Ref: Wolf and Ghilani, 2012

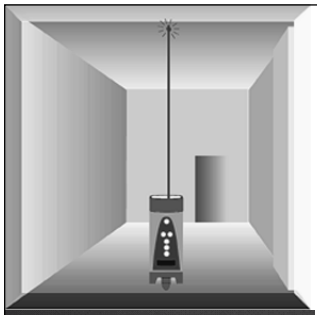


Automatic level with micrometer

Ref: Wolf and Ghilani, 2012



Digital level with staff



Reflectorless EDM

Ref: Wolf and Ghilani, 2012

Laser equipments

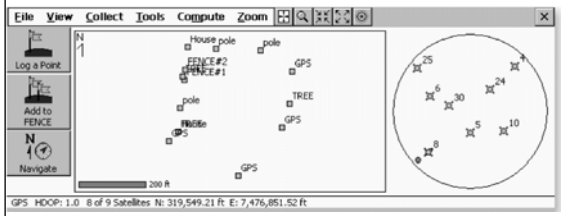
Sokkia LP30 laser plane level

Topcon PL-1 plumbing laser instrument

(a)

(b)

Pulsed laser instruments: (a) total station and (b) hand-held EDM instrument.



Solo data collector using Windows® CE operating system

Ref: Wolf and Ghilani, 2012

Global Positioning System

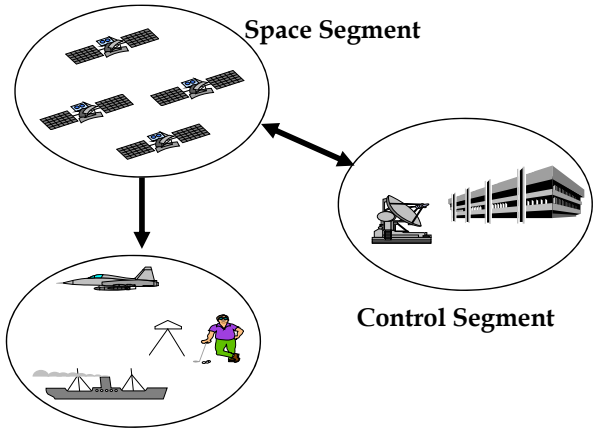
Ref: Wolf and Ghilani, 2012

NAVSTAR GPS segments

Navigation **S**atellite **T**iming **a**nd **R**anging Global Positioning System (GPS)

Comprises three major segments:

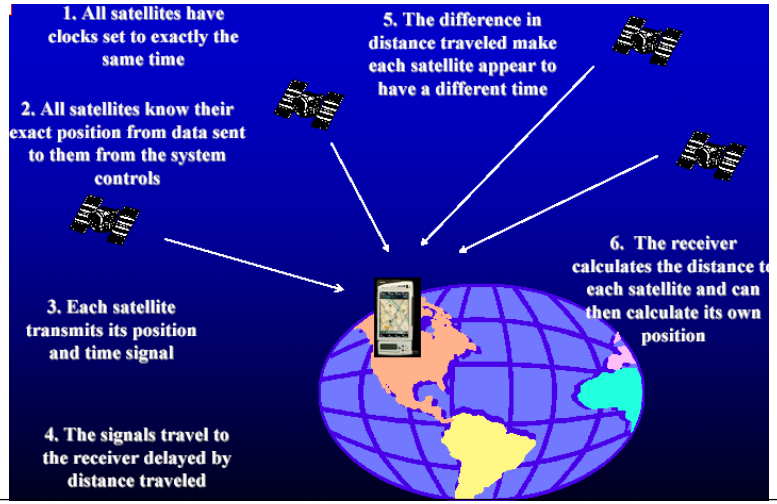
- Space Segment
- Control Segment
- User Segment



GPS Principles

6 basic steps and at least four (4) satellites required to solve four (4) unknown parameters:

Latitude-Longitude–Height-Receiver time offset



GPS Applications

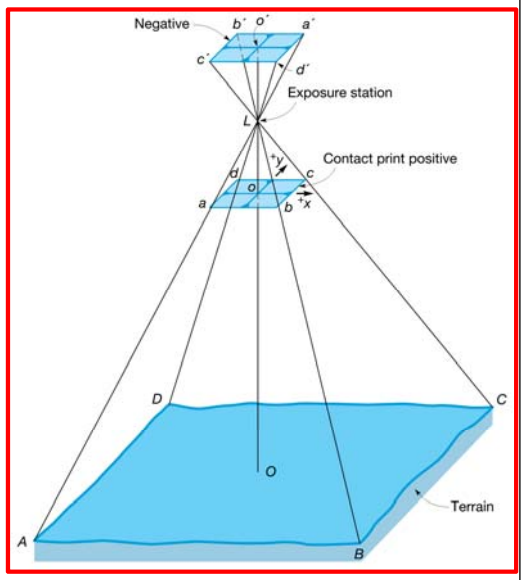
- Utility industry
- Natural resources
- Precision farming
- Civil Engineering applications
- Structural deformations
- Open pit mining
- Land and Marine seismic surveying
- Airborne mapping
- Seafloor mapping
- Vehicle navigation
- Transit system
- Retail industry
- Cadastral surveying
- Stakeout (waypoint navigation)
- Location based surveys (LBS)

Photogrammetry and Remote Sensing Technology

- Photogrammetry: well-established techniques for topographic map making.
- Many close range photogrammetric applications.
- Remote Sensing: for mainly thematic maps as a results of development in sensor systems and digital image processing.

Photogrammetry

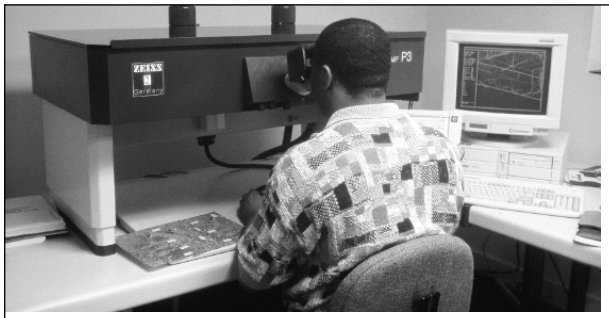
Art, science, and technology of obtaining reliable information about physical objects and the environment through process of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and phenomenon (ASP).



Developments

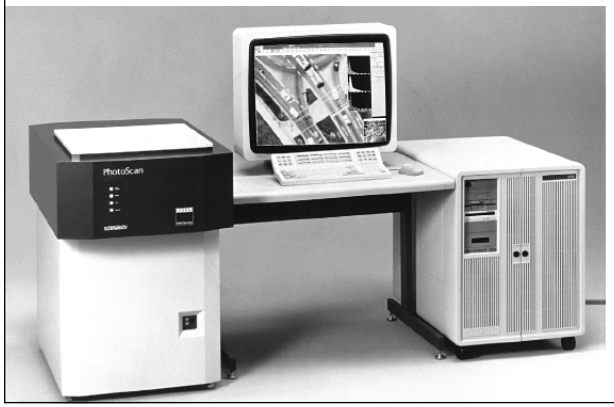
- Analogue photogrammetry
- Analytical Photogrammetry
- Digital Photogrammetry

Ref: Wolf and Ghilani, 2012



Zeiss P3 Analytical Plotter

Ref: Wolf and Ghilani, 2012



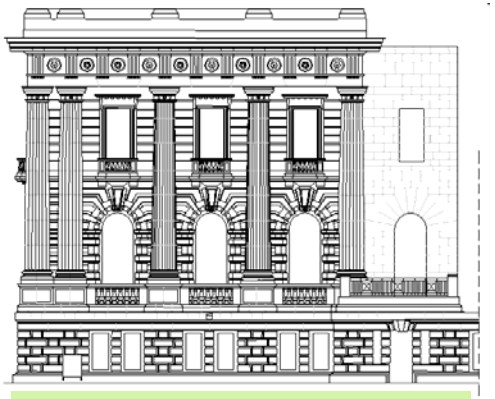
Zeiss/Intergraph PS1 PhotoScan

Digital stereoplotter

Digital Video Plotter DVP

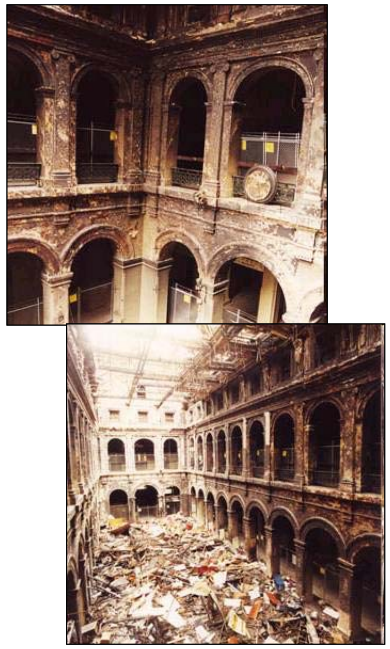
Ref: Wolf and Ghilani, 2012

Architectural Photogrammetry



Section of the Photogrammetric Survey of Parliament House in Melbourne. The survey of the whole Parliament House was completed in about twelve weeks by only one operator.

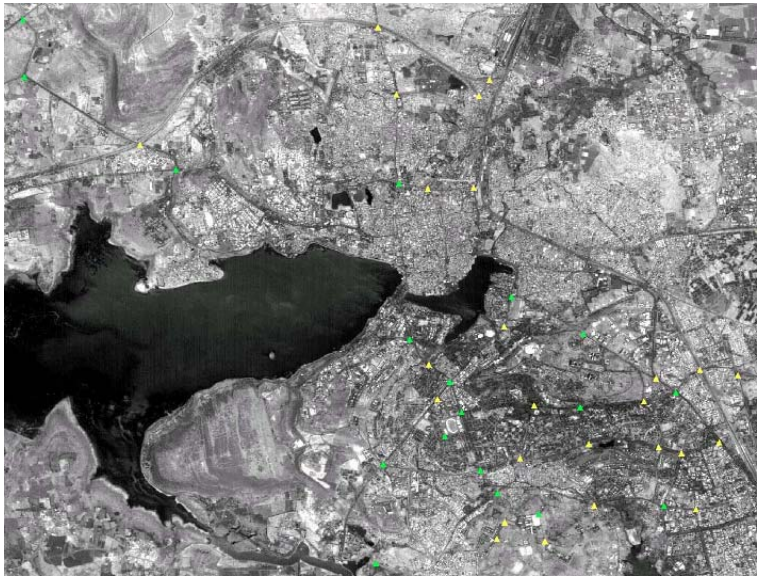
Photogrammetric Reconstruction



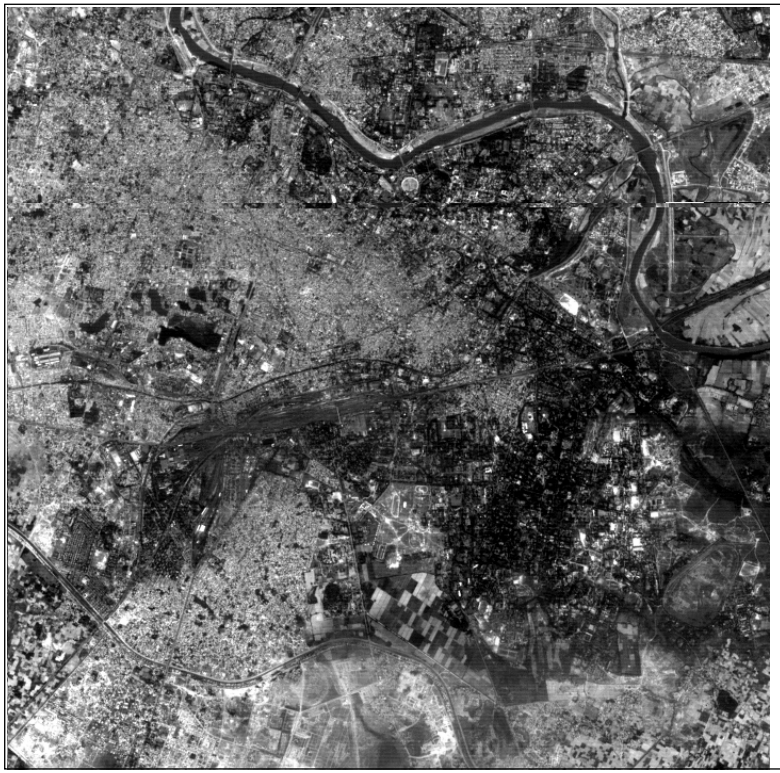
After a fire badly damaged the Postal Hall of Melbourne GPO on August 2001,a photogrammetric survey was undertaken to help in the reconstruction

LISS3 FCC of Kanpur, IRS-1D

LISS3 FCC of Lucknow, IRS-1D

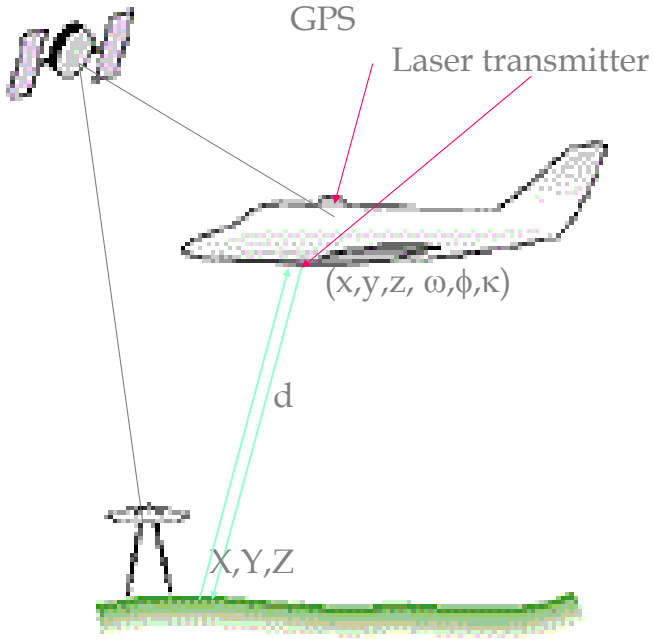


PAN image of Bhopal, IRS-1D

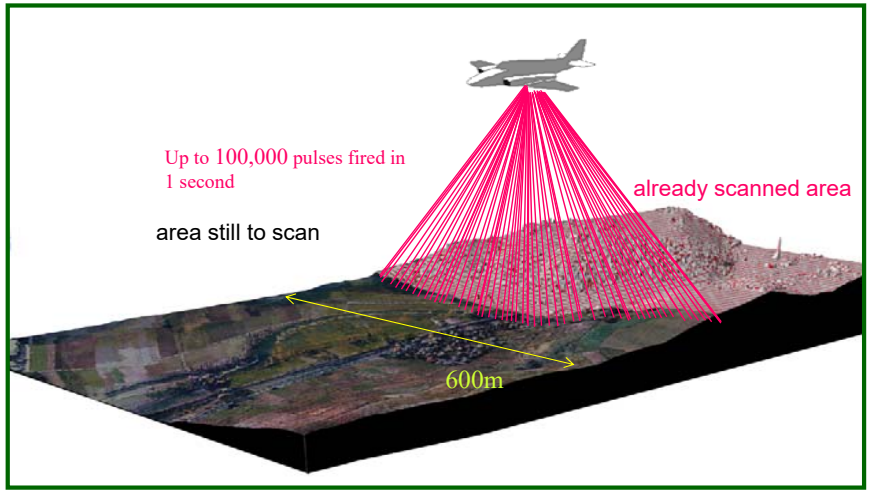


PAN image of Lucknow, SPOT

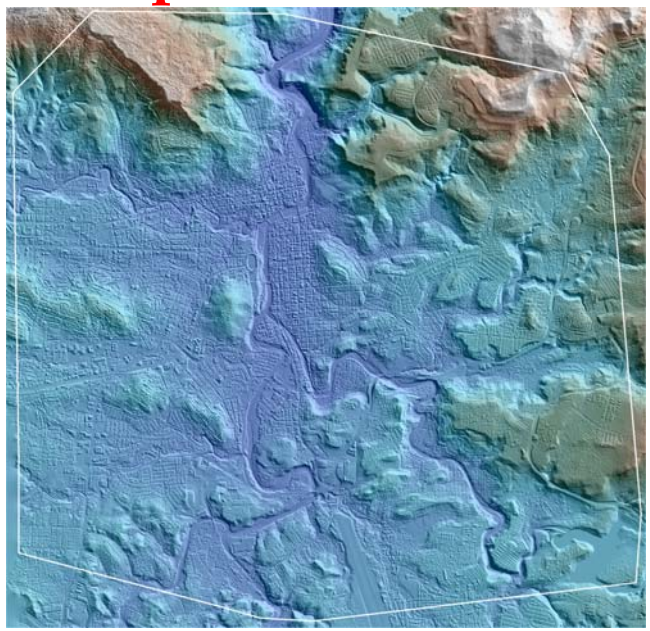
LiDAR Mapping



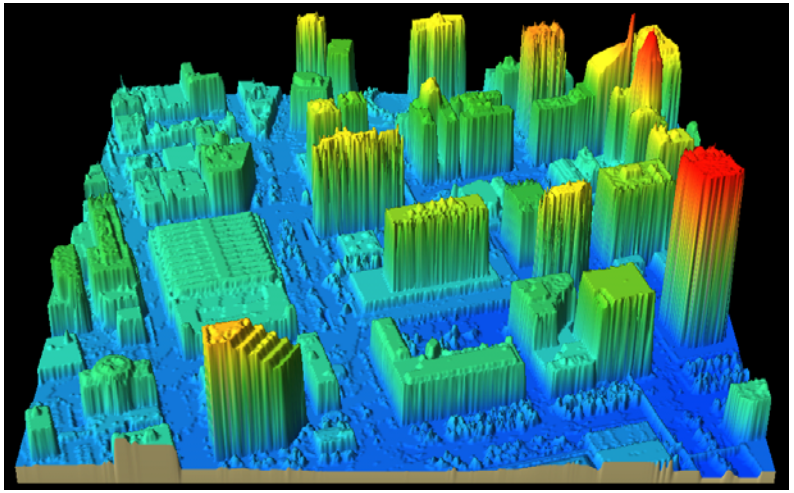
Principle of Scanning Airborne LiDAR



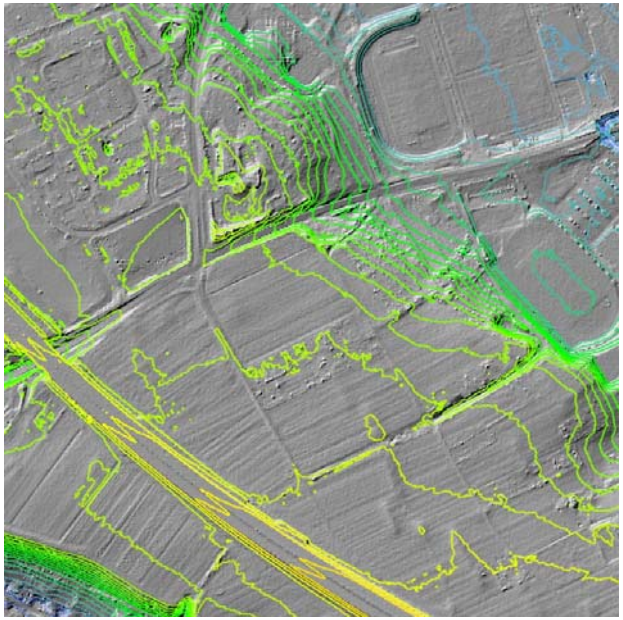
Data products: Colour plot of data



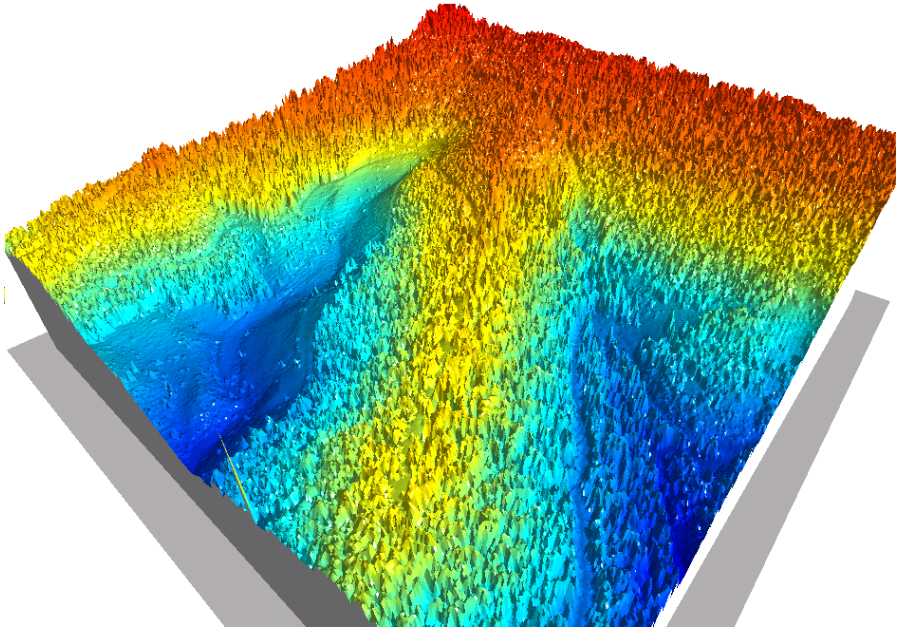
Data products: 3D city model



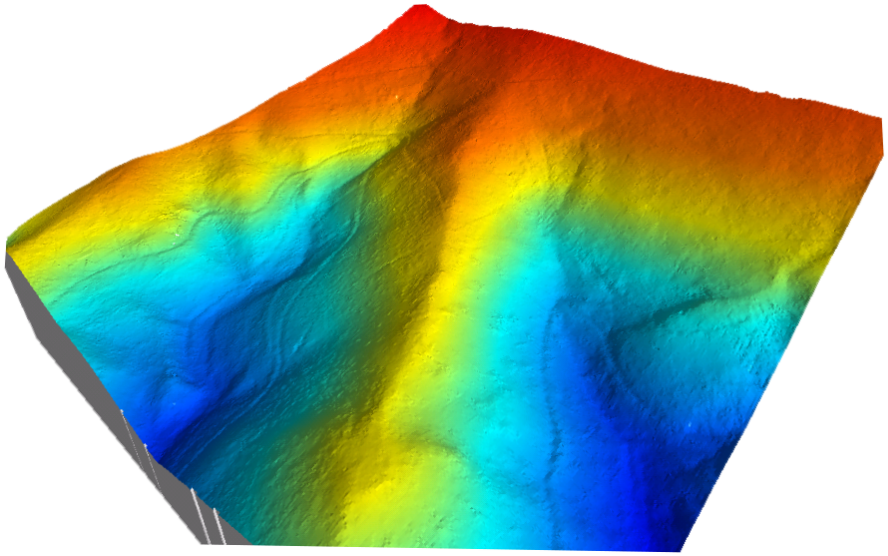
Data products: Contour maps



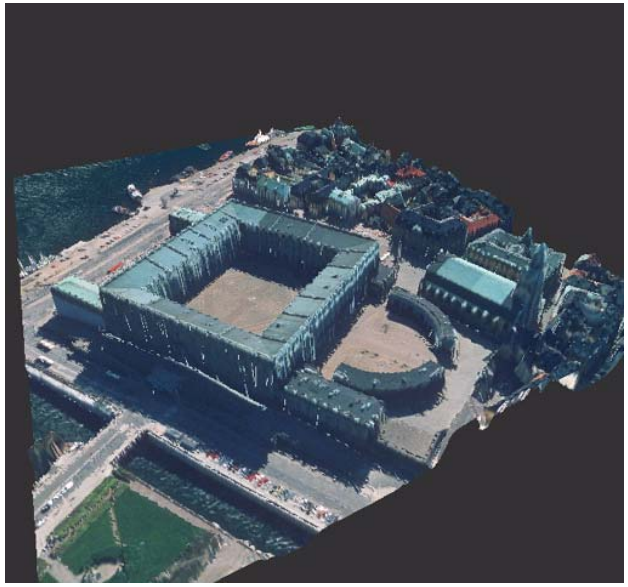
Data products: DSM



Data products: DEM or BEM



Data products: Photograph wrapped on LiDAR data



- Equipment
  - ILRIS3D from Optech
  - Nikon 200 camera for texture

Laser Scanning at Ajanta Ellora caves

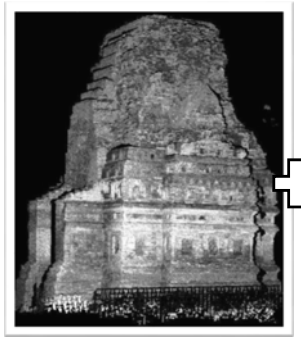
Data at 1st Position

Data with Image at 1st Position

Data at 2nd Position

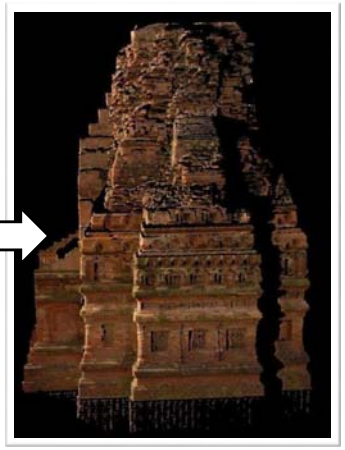
Data with Image at 2nd Position

Texture rendering

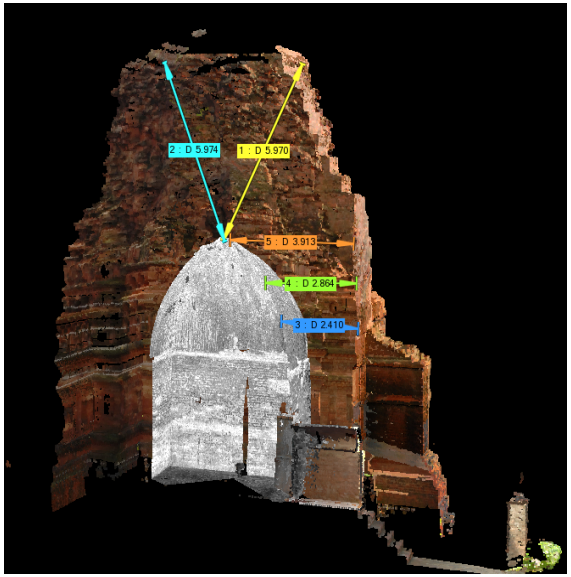


Point cloud

Image



Measurements with scanner data



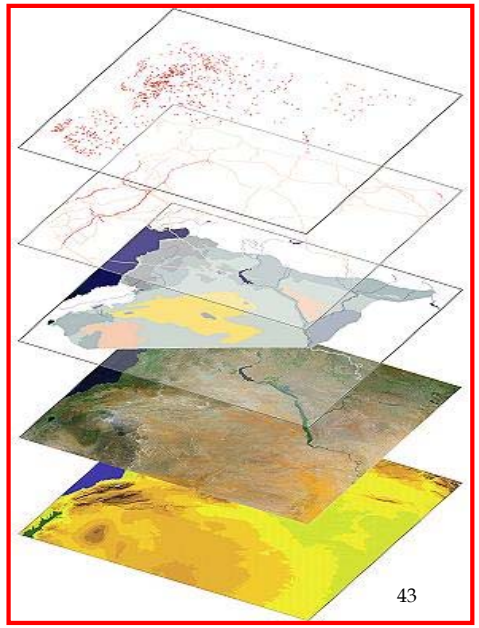
Developments in Computer based mapping, terrain modelling, and GIS

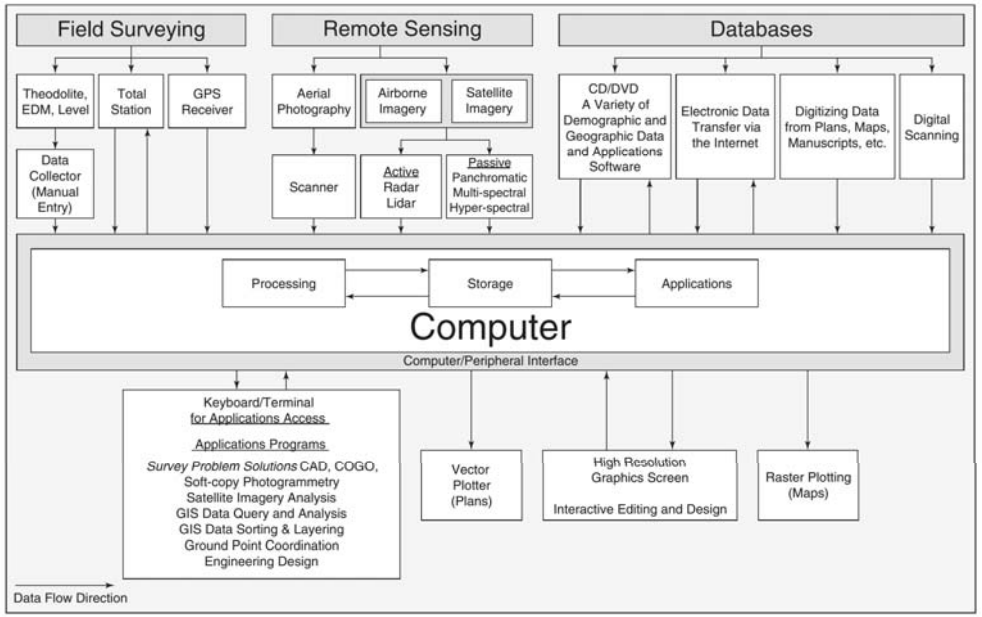
- Digital mapping or automated cartography
- Digital Terrain Modelling
- Geographic and Land Information System

Conceptual framework for operational GIS

Selected layers in a GIS:

- Digital elevation model
- Satellite image map
- Land use map
- Infrastructure
- Utility maps
- Other layers of interest





Geomatics data model: Data collection, processing, analysis, design, display in GIS environment (Kavanagh, 2012)

Surveying

Focus of present course.

- Art or science of determining relative positions of points
  - on
  - above or
  - beneath the surface of earth
- By means of direct or indirect measurement
- Of distances, directions and elevations – three most important observables.

Primary divisions of surveying

(a) Plane Surveying

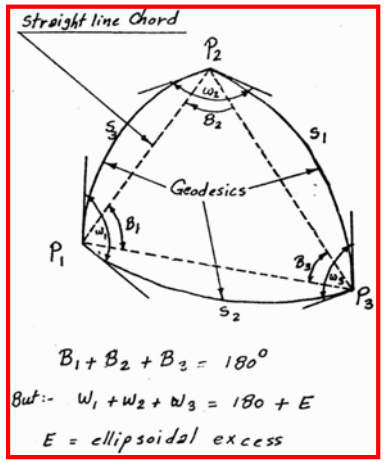
(b) Geodetic Surveying

(a) Plane surveying

- Mean surface of earth considered as plane and spheroidal shape neglected.
- All triangles formed by survey lines are considered as plane triangles.
- Level line considered as straight and plumb/vertical lines are considered parallel.

(b) Geodetic surveying

- To determine precise position on earth surface, of a system of points which form control stations to which survey of lesser precision may be referred.
- Shape of earth accounted for.
- Surface lines are curved and triangles are spherical triangles.
- Geodetic survey includes:
  - work of larger magnitude
  - higher degree of precision



Classification of surveying (Ref: Rampal)

(A) Nature of field survey

1. *Land survey*

(a) Topographical survey

Horizontal and vertical locations of points by linear and angular measurements to plot natural and man made features.

(b) Cadastral survey

To fix property lines, calculations of land area, or transfer of land property, to fix boundaries of municipalities, state and federal jurisdiction.

(c) City survey

For city works like construction of street water supply system, sewers, etc.

2. Marine or hydrographic survey

For water bodies for navigation purpose, water supply, harbour works and determination of mean sea level (MSL).

3. Astronomical survey

To determine, absolute location of any point, or location of any line on the surface of earth. Requires star observations.

Other classification

(B) Survey objective	(C) Instrument used	(D) Scale of survey
• Engineering survey • Military survey • Mine survey • Geological survey • Archeological survey	• Chain survey • Triangulation • Theodolite survey • Traverse survey • Tacheometry • Plane tabling • Photographic • Aerial	• Large scale: 1: 100 to 1:10,000 • Small scale: 1:10, 000, 1: 250,000

Land survey

(A) Control	(B) Detail
1. **Horizontal (planimetric)** • Triangulation • Traverse • Astronomical • Linear • Graphical • Photogrammetric • Electronic	1. **Horizontal (planimetric)** • Plane table • Tachometer • Chain • Aerial survey
2. **Vertical (height)** • Spirit leveling • Trigonometric level • Barometric Level • Height traverse	2. **Vertical (contouring)** • Tachometer • Clinometer • Barometer • Spirit level

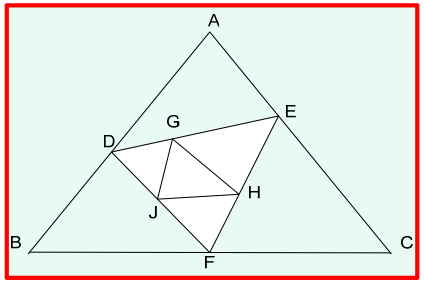
Basic principles of Surveying
Ref: Arora

1. Working from Whole to Part

- First establish a system of major control points and fix them with high accuracy.
- Minor control points can be established by less precise methods and details can be plotted using minor control points, by running minor traverse etc.
- Prevents accumulation of errors which otherwise would expand to greater magnitudes if reverse process followed.

- Why?
  - more number of measurements in part to whole
  - more errors due to propagation of errors

- Three points A, B, C form part of a framework ABC.
- Relative position of these points established with high accuracy by measuring AB, BC, CA.
- Interior triangle DEF can be established with relatively lower accuracy by measuring DE, EF, and FD.
- Framework GHJ can be established with still lower accuracy by measuring GH, HJ, and JG.

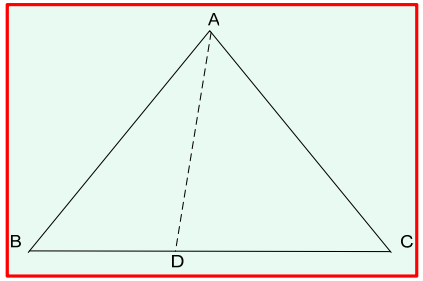


2. Choose the survey method most suitable for the purpose

- Highest accuracy is possible with modern surveying equipment. But use the method that is commensurate to accuracy requirements, cost and time involved.
- Relative standards of linear and angular accuracy should be consistent.

3. Adequate provisions of checks

- Very important to provide checks due to possibility of errors in all measurements, recording observations, computing, and plotting.
- As far as possible, self-checking mechanisms should be there.

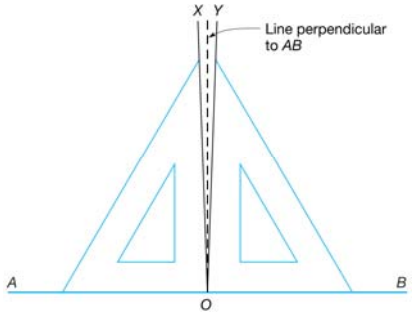


Check line AD indicates error if plotted distance AD on plan does not match the one measured in the field.

4. Careful recording of data

- Field data to be recorded carefully, nothing should be left to memory.
- Field record to be accurate, clearly written, and properly arranged.
- Use of notes, sketches, description advisable.

5. Principle of reversal



Basic survey measurements

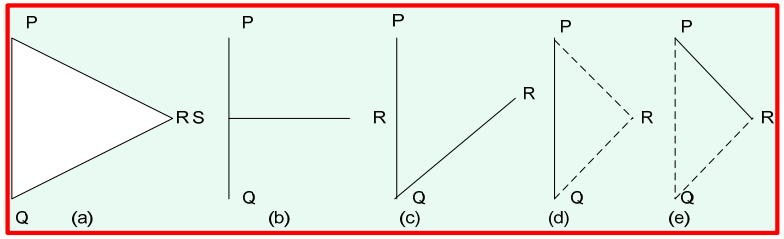
- Four basic measurements:
  - Horizontal distances
  - Vertical distances
  - Horizontal angles
  - Vertical angles

- Direction measurements: Compass, Vernier/microptic/electronic theodolite, total stations
- Distance measurements: Chains, tapes, bands, subtense bar, tacheometers, range finders, laser distance measurements, EDMI
- Elevation measurements: levels (automatic, digital), all theodolites

Locating a point

Point location in horizontal plane by measurements from two reference points:

Relative positions of points to be surveyed, should be located by measurement from at least two points of reference, the positions of which have already been fixed.



Examples:

a) Cut arcs PR & QR to get R, used in intersection (chain surveying and plane table, trilateration).

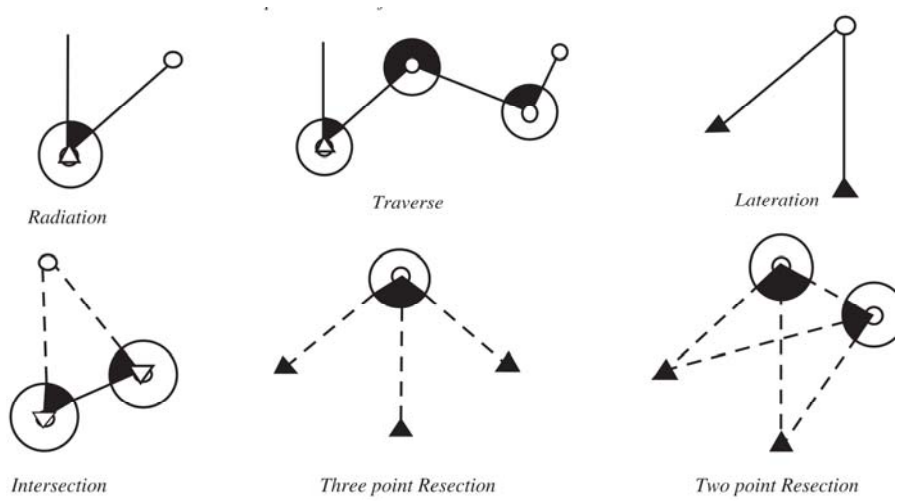
b) Drop perpendicular from R on PQ to get PS & SR, (define details).

c) Measure QR & angle PQR to locate R, (traversing).

d) Measure angles RPQ & RQP, (triangulation).

e) Measure angle RQP & RP (traversing and plot of minor utility).

Principal Methods of Fixation in two dimension



- **Position fixing in horizontal plane by**
  - Intersection
    - Intersection by angles: triangulation
    - Intersection by distances: chain survey, trilateration
  - Radiation: measurement of distance in a given direction
  - Traversing: measuring angles and distances
  - Resection: if position of three points A, B, and C is known, position of third point can be located by measuring angles (Plane table)
- **Position fixing in vertical plane by**
  - Ordinary spirit leveling
  - Trigonometric leveling
  - Barometric leveling

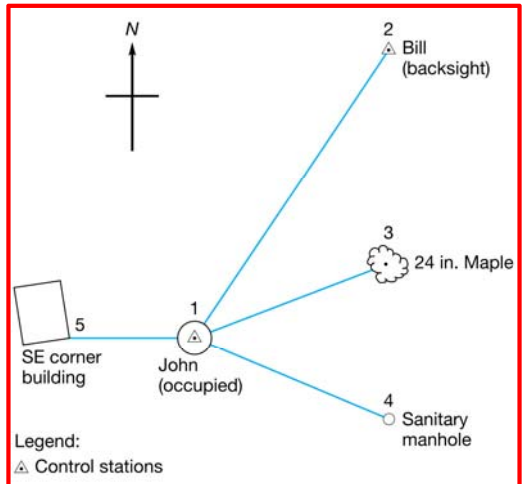


Figure 16–5 Radiation survey from control traverse.

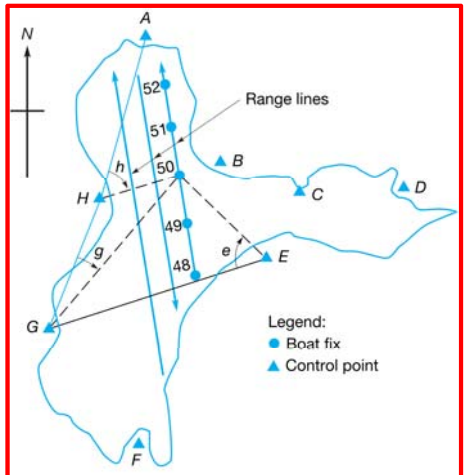
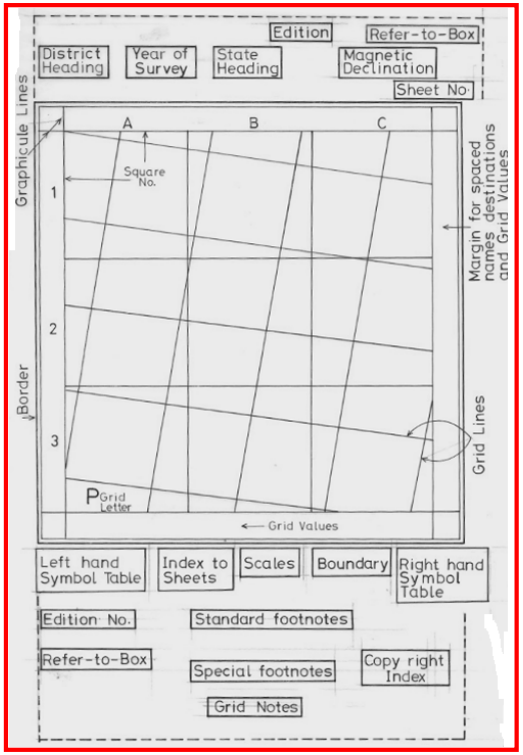


Figure 16–15 Angle intersection procedure for locating boat fixes along range lines.

Position fixing by Radiation and Intersection (Ref: Wolf and Ghilani)

Topographical survey

- Topographical survey can be defined as science of measuring physical features of earth surface and representing them in the form of map.
  - Large scale 1:5000 to 1:20,000
  - Medium 1:25000 to 1:250000
- All topographical maps are on medium scale.
  - Topographic maps: Maps between 1:20,000 to 1:250,000.
  - Geographical maps: Maps between 1:250,000 and below
  - Cadastral maps: Maps at 1:1,000
  - Large scales for building plan, special surveys, projects or project site plan.

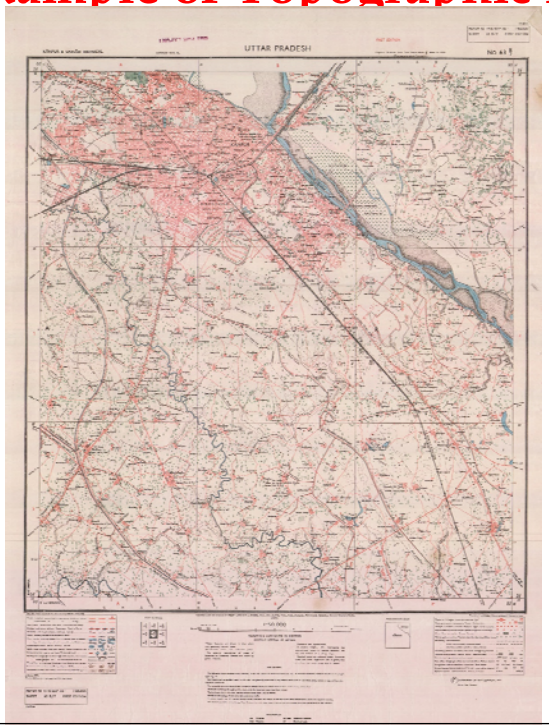


Layout of Topographical map (Rampal, 1991)

General features of topographical maps

- General maps at large and medium scale depicting all important features including relief.
- Contain graphical representation of selected man made and natural features of plot of earth surface plotted to a definite scale.
- **Characteristic**: Portrayal of shape and elevation of terrain (USGS).
- Plotted on sufficiently large scale to enable individual topographical feature to be identified on the ground, by their shape and position.
  - Topographical maps will have man made features, natural features shape and size of terrain (contours).

Example of Topographic map



Utility of topographical maps

- Civil administration
- Planning, design and execution of Engineering projects
- Management of decision making policy
- Idea regarding forests, existing irrigation system, drainage pattern, telecommunication links, etc.
- Soil patterns
- Planning entertainment spots
- Mountaineering

Symbols and colors used in Maps

Black	Name of places, spot heights of BM, graticule lines, dry chambers or sand in river bed.
Vermillion red	All man made features.
Green	Vegetation, forests, unsurveyed tree.
Yellow	Cultivated area.
Blue	Water bodies.
Brown	Sand dunes, barren areas having very small coverage in the form of shrubs.
Burnt sienna	Contours.

If forests, etc. (large size vegetation growth) give a dotted boundaries of black & give light green wash to it.

Similarly for large cultivation area, the boundary is not dotted but area is given yellow wash.

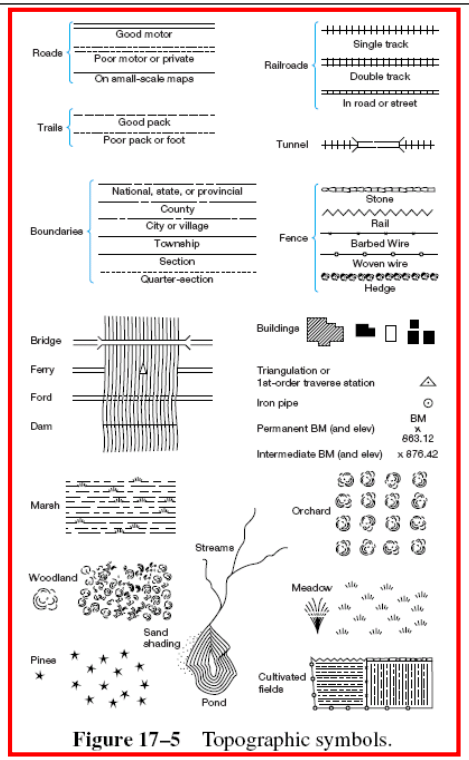
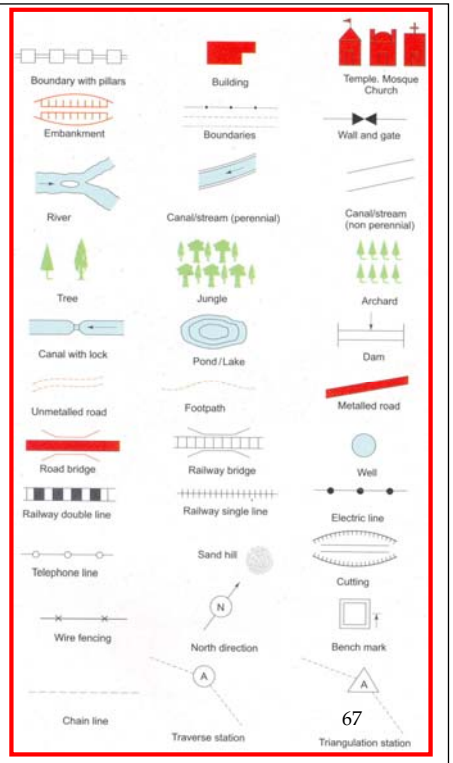


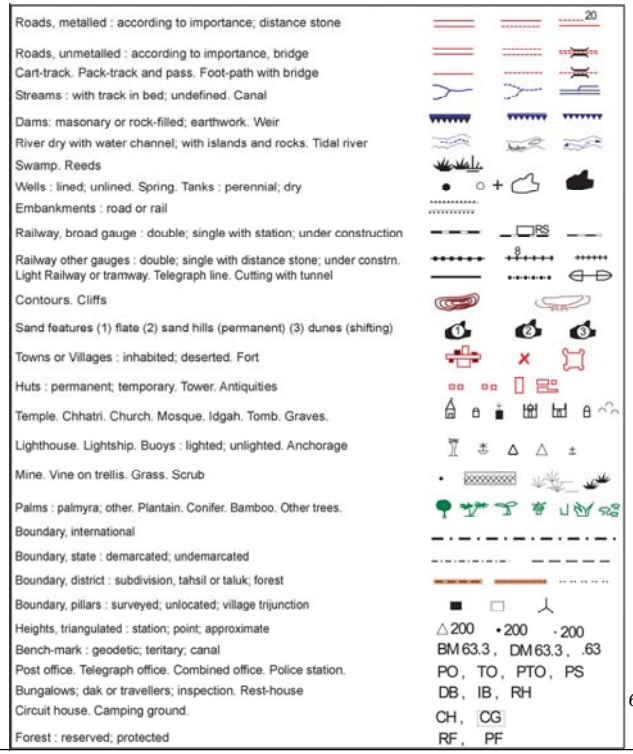
Figure 17–5 Topographic symbols.

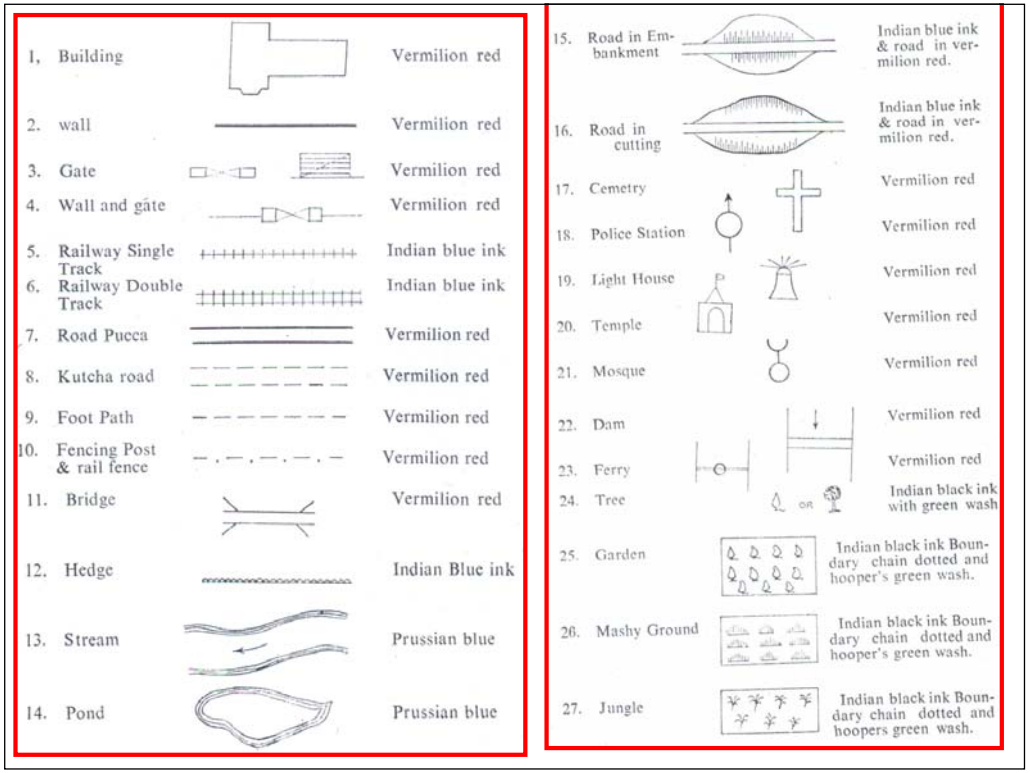
Ref: Anderson and Mikhail

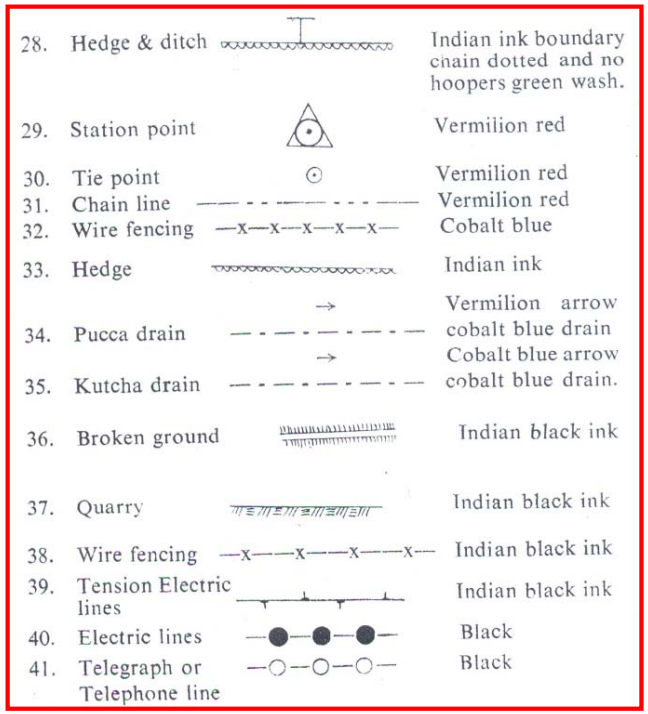


Ref: SoI symbology NCERT Text Book on Geography

SoI symbology





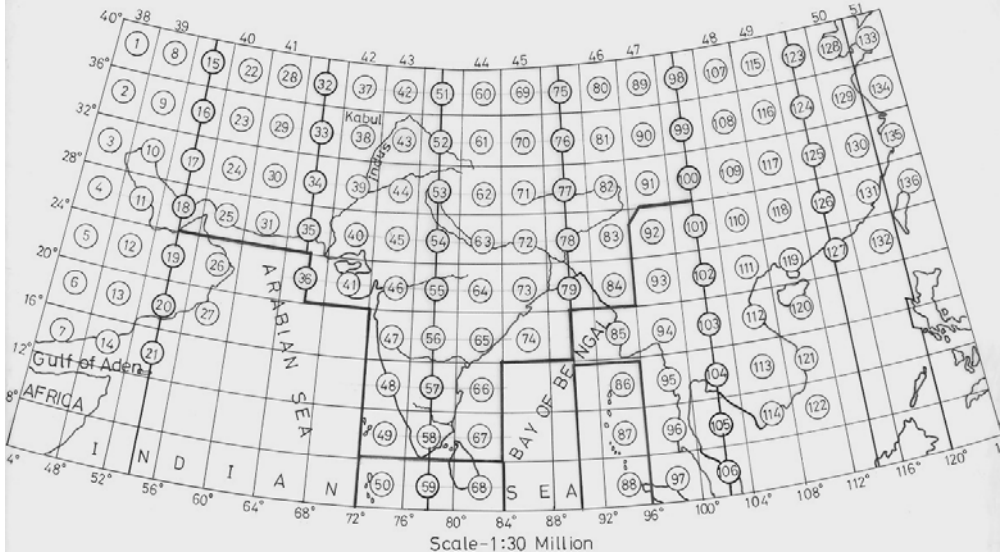


Map numbering system

1. I &AC (India and Adjacent Countries)
2. CIM (Carte International du Monde)

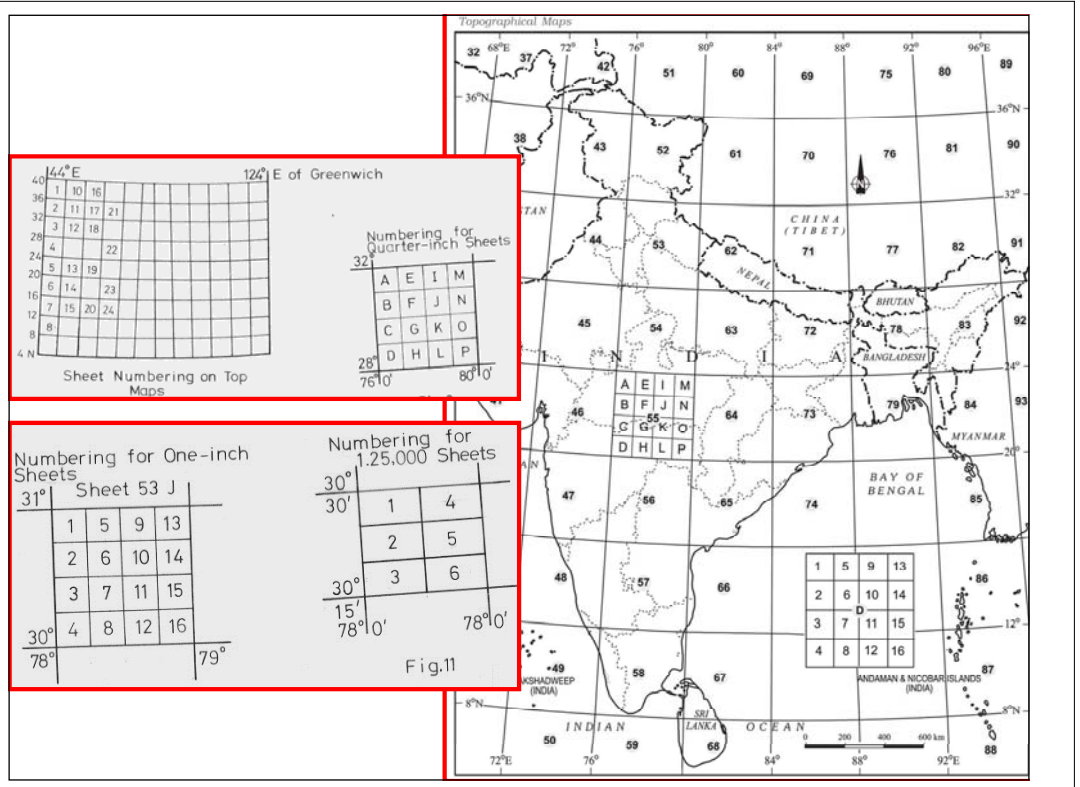
1. India and adjacent countries series

- British surveyors developed this for Indian subcontinent for the range:
  - Latitude 4°N - 40°N Longitude 44°E - 124°E
- Each sheet was on 4°x4° scale with 1:1M scale and had a unique number allotted from top-to-bottom.
- Limitation
  - No number was allotted for area lying in sea and the next number was given to area on land.
  - Map catalogues have been issued by SOI for these sheets covering land masses.



Index to the maps of India (Rampal, 1991)

Indian subcontinent range: Latitude: 4°N - 40°N Longitude 44°E - 124°E; Each sheet on 4°x4° scale with 1:1M scale with unique number allotted from top-to-bottom.



A	E	I	M
B	F	J	N
C	G	K	O
D	H	L	P

Level I: 4° x 4° sheet on 1: 1M scale

Level II: 1° x 1° sheet on 1: 250,000 scale,

(16 parts: A to P, CI: 100 – 200 m

1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16

Level III: 15′ x 15′ sheet on 1: 50,000 scale

(16 parts: 1 to 16), CI: 20 m

NW	NE
SW	SE

Level IV: 7.5′ x 7.5′ sheet on 1: 25,000 scale (Four parts: NE, NW, SE, SW); earlier numbered as 1 to 6. CI: 10 m

New scheme

1	4
2	5
3	6

Old scheme

Present Survey of India practice is to divide 1:25,000 sheet into 4 parts rather than 6 parts.

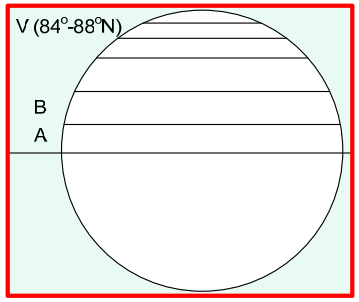
- Example:

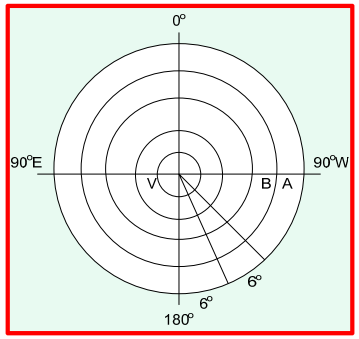
If we say that a point has coordinates (18°35′N & 88°37′E), it means that the point will be in a sheet as shown below:

1. 50 on 1:1M (50 from SoI catalogue)
2. 50J on 1:250,000
3. 50J/10 on 1:50,000
4. 50J/10/SW on 1:25,000

CIM series

- Earth is divided in north (N) and south (S) hemisphere. This system does not consider whether area lies on land or sea. All the areas are numbered irrespective of their location.
- For latitude:
  - Each map sheet is on scale 1: 1M and divided in groups of 4° latitude each up to 88°N starting from 0° and each belt is numbered as A, B, C_ _ _ _ and V (*i.e.* from 84 –88°N).
- For longitude:
  - Each sheet divided in longitude of 6° each starting from anti-meridian i.e. 180° towards west and numbered as 1, 2, 3, 4 etc.





I: Large grid 4° x 6°, scale 1: 1M

20°N

A	B	C	D	E	F
G	H	I	J	K	L
M	N	O	P	Q	R
S	T	U	V	W	X

16°N

60°W 66°W

Example:

I: For map sheet number NE20

- 4° x 6° sheet (scale 1:1M)
- N represents in northern hemisphere
- E represents its latitude
- 20 represents longitudinal range

II: Smaller grid 1° x 1°, scale 1: 250,000

Place having coordinates 18° 35′N and 63° 42′W will be in sheet J with code NE20/J

20°N

A	B	C	D	E	F
G	H	I	J	K	L
M	N	O	P	Q	R
S	T	U	V	W	X

16°N

60°W 66°W

III: Smaller grid 30′ x 30′, scale 1: 125,000

- Each grid of 1° x 1°, is further subdivided into four parts each of 30′ x 30′, scale 1: 125,000.
- Place having coordinates 18° 35′N and 63° 42′W will be in second quadrant (II) with code NE20/J-II

19°N

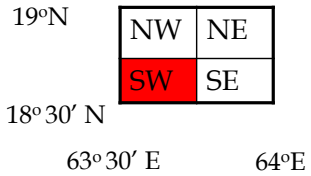
I	II
III	IV

18°N

63°E 64°E

IV: Smaller grid 15′ x 15′, scale 1: 62,000

- Each grid of 30′ x 30′ is further subdivided into four parts each of 15′ x 15′, scale 1: 62,000, although it should have been 1: 62500 but for conversion sake we use 1: 62,000.
- This scale is more suitable to plot and nearer to the original scale in FPS system (1″ = 1 mile, 1: 63360).



Place having coordinates 18° 35′N and 63° 42′W will be in SW quadrant with code NE20/J-II-SW

Summary

1: 1M	Lat 4° x Long 6°	NE20
1:2,50,000	Lat 1° x Long 1°	NE20/J
1:1,25,000	Lat 30′ x Long 30′	NE20/J-II
1:62,000	Lat 15′ x Long 15′	NE20/J-II-SW

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