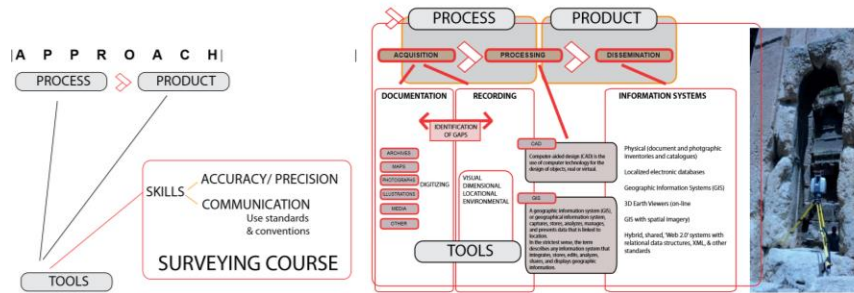


Lecture 1-ADMIN

- Surveying examples
 - Measured Drawings-Site plan/cross-section/floor plans
 - Conditioned Survey-construction materials
 - Energy Performance-lighting

Lecture 2-INTRO

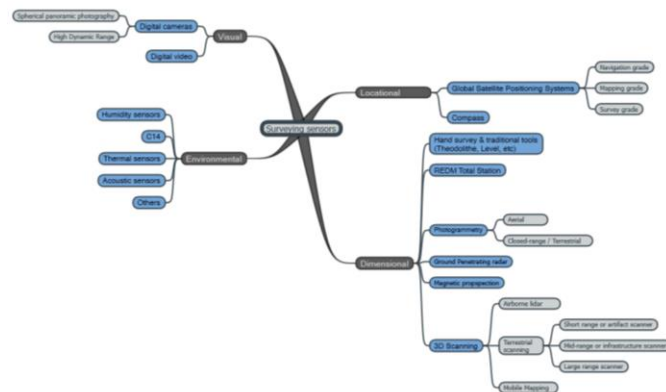


What level of detail is required?: What scale ?

| REGISTER RECONNAISSANCE SETTING / BUFFER | CATALOGUE PRELIMINARY PROPERTY | MONOGRAPH DETAILED FEATURES |
|--|---|--|
| ISSUES TO IDENTIFY | | |
| Location (centroid), accessibility, simplified significance assessment, type and history | Location (centroid), accessibility, significance, type, history, boundaries, buffer zone, management issues | Preliminary level information, detailed record of significance, condition (fabric, structure...), threats, phases of construction (history), spatial analysis, and other relevant detailed studies |
| ACCURACY EXAMPLE | | |
| Not to scale | Plans: average 10 cm - details: 2 cm. | Plans: average 2 cm - details: 2 mm. |
| SCALE (MEASURED PLANS) EXAMPLE | | |
| 1:10000 - 1:20000 | 1:1000 - 1:2000 | 1:10 - 1:200 |
| RECORDING TOOLS (MEASURED PLANS) EXAMPLE | | |
| SATELLITE IMAGES GPS NAVIGATION LEVEL DIGITAL PHOTOGRAPHY AERIAL PHOTOGRAMMETRY | GPS MAPPING LEVEL DIGITAL PHOTOGRAPHY EDM DEVICES | GPS SURVEY LEVEL DIGITAL PHOTOGRAPHY RECTIFIED PHOTOGRAPHY LASER SCANNING PHOTOGRAMMETRY |
| RESULTS EXAMPLE | | |
| Photographic report, Photo keyplan Initial condition survey, descriptive sketches | Measured drawings, Asset description/condition survey Observations, Photographic report | Measured drawings, Asset description/condition survey Observations, Photographic reports, extensive thematic plans |
| TIME FRAME | | |
| RECONNAISSANCE | PRELIMINARY | DETAILED |

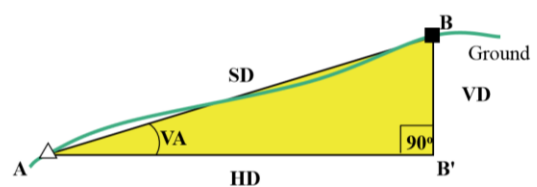
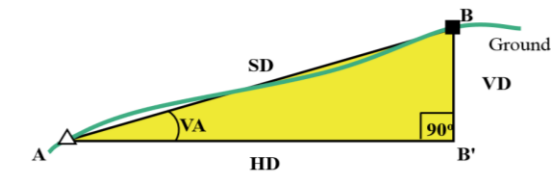
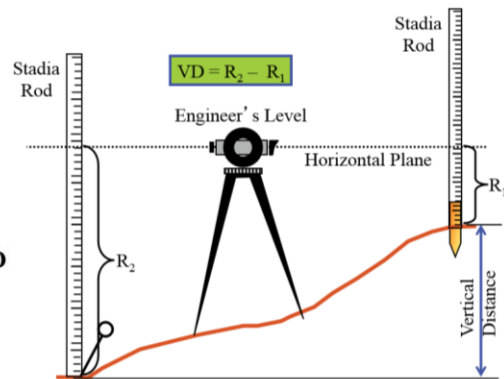
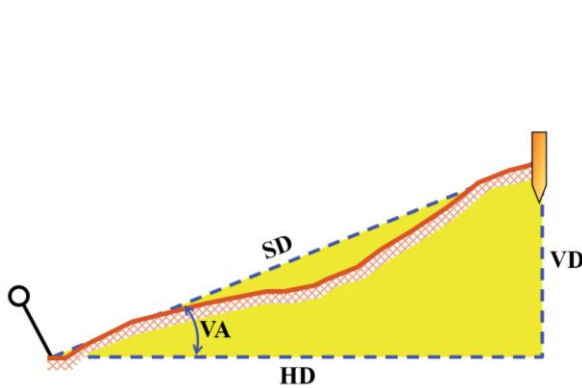
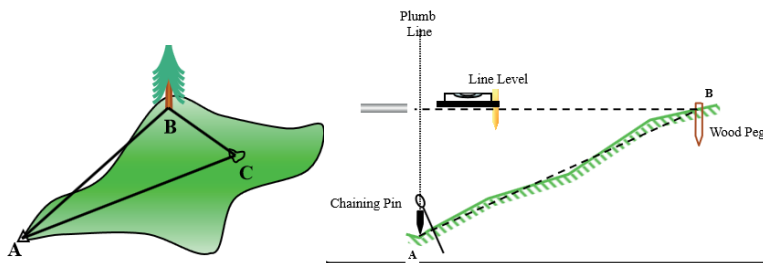
- Sources of error
 - Site/area
 - Artifacts-buildings aren't constant-they evolve, age and are modified over time forcing the user to pay attention to what time the data was taken
 - Environment-temperature, sunlight and cloud cover all play a role in accuracy
 - Tools/sensor
 - Device-rounding errors and calibration
 - Human-human error and bias-lack of experience
 - Provenance-without an attached record of how, why, where, how or with what and by who, accuracy is limited-transmitted
- Drawing Conventions
 - Cross-section-cut vertically
 - Plan sections-cut horizontally
 - Elevations-view from the ground from outside the building
- Tools
 - Reconnaissance-using field notes and sketches (paces, triangulation, height, span)
 - Digital Photography-context, location, detail
 - Reflectorless Electronic Distance Measurement Total Station (REDM)
 - Computer Aided Design (CAD)

- Global Navigation Positioning System (GNPS)
- Geographic Information Systems (GIS)
- Others-photogrammetry-3D scanning



Lecture 3-BASICS

- Geometry-geo means earth
- Trigonometry-trogo means triangle
- Field Measurements



$$HD = SD \cos(VA)$$

$$VD = SD \sin(VA)$$

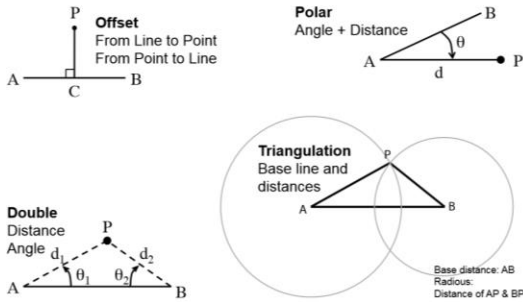
$$VD = \sqrt{SD^2 - HD^2}$$

$$VA = \tan^{-1}\left(\frac{VD}{HD}\right) \text{ or } VA = \sin^{-1}\left(\frac{SD}{VD}\right) \text{ or } VA = \cos^{-1}\left(\frac{SD}{HD}\right)$$

$$\text{Grade of AB} = \frac{\text{Rise}}{\text{Run}} \times 100 = \frac{VD}{HD} \times 100$$

$$\text{Grade of AB} = \tan(VA) \times 100 = \frac{VD}{HD} \times 100 = \frac{\sqrt{SD^2 - HD^2}}{HD} \times 100$$

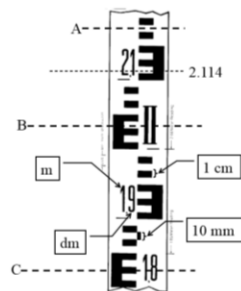
- Cosine law $a^2=b^2+c^2-2bccosA$
- Surveying is the art and science of determining the position of points near the surface of the Earth
- Types of Surveying
 - Plane Surveying-the surface of the earth is considered to be a 2D plane for all X,Y dimensions
 - Geodetic Surveying-the earth is considered to be a 3D ellipsoid for X and Y dimensions
 - Topographic, Hydrographic, Route, Property, Aerial, Construction, Final (as built)
- Tools
 - Levels-measure the height of distance points in relation to a bench mark
 - Slow speed, range is 0-25m, portable, very operable
 - Hand-tape measure, plumb bob, rod, level, drawing
 - Needs minimal training, labour intensive if high accuracy is needed, range is short
 - Total Station-TS065'' of angular precision, reflectorless range 400m
 - Time of flight device-laser, infrared-measures the time it takes for an object, article, acoustic or electromagnetic wave to travel a distance through a medium.
 - An electrical/optical instrument used in modern surveying
 - An electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read distances from the instrument to a particular point
 - Relatively quick but requires a skilled surveyor, precision depends on user and the surface(reflectiveness) ranges from 0-160m, relatively costly, but portable
 - GPNS-space based global navigation satellite system that provides reliable location and time information at all times and all places as long as there are four satellites that have an unobstructed line of sight
 - Range is in kms and can be accurate from cm to m based on the expense, can only be used outdoors and is quick
 - Navigation-grade GPS-map and absolute accuracy for 10m, not good for surveying or heights
 - Mapping-grade-map and absolute accuracy down to 1m, suitable for mapping but not site surveying
 - Survey-grade-cm relative accuracy, map and absolute accuracy to 100mm
- Measurements-distances, angles
 - Units
 - Length-mm, m, km
 - Angle
 - Degree, minute, seconds (ddd°, mm', s'')
 - Decimal degrees (XX.xxxxx)
 - Radians (rr.rrr)
 - Total Station (ddd.mmss) Pseudo Decimal
 - UTM
- Elements-points, lines, planes
- Location Methods



- Accuracy vs precision (accurate is on target, precise is close together)
 - Accuracy ratio-error/true measurement
 - Common-pacing 1/100
 - Transit and tape
 - Student 1/500-1/2000
 - Professional 1/3000-1/10000
 - Total station
 - First order 1/50,000
 - Second order 1/20,000
 - Third order 1/8,000
 - Fourth order 1/3,000

Lecture 4-LEVEL

- Levelling-measure the height of distance point in relation to a bench mark
 - The procedure used to find the elevation points and the difference in elevation between them
 - Elevation-vertical distance between a point and reference point, line or plane (datum)
 - Reference datum-mean sea level
 - Local reference-bench mark
- Differential levelling-determines the difference in elevation between points at a distance
 - Surveyors level and graduated rod
 - Rod can be read in feet or metres and is marked in m, dm, cm allowing estimations to the nearest 5mm (m.dm cm mm)
 - Made of wood, fibre-glass or metal

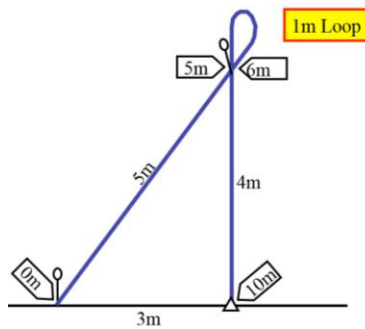


- Automatic level-self adjusting after an initial leveling using bull's eye bubble
- Digital level-sight on rod with bar code used to determine elevation and distance
- Tilting level-adjustment of the scope before each reading

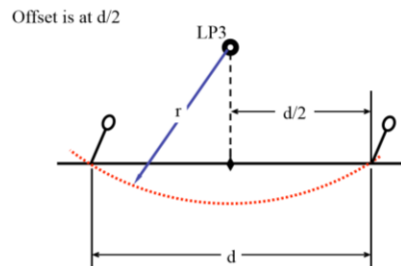
- Bench mark-permanent point of known elevation
- Temporary bench mark-semi-permanent
- Turning point-elevation transfer point
- Backsight-reading taken on a point of known elevation (+)
- Height of instrument-elevation of line of sight
- Foresight- reading taken on a BM, TP or TBM (-)
 - Known elevation+bs=HI
 - HI-FS=new elevation

Lecture 5-DISTANCE

- Distances
 - Indirect-scaling, stadia, subtense bar
 - Direct-pacing, odometer, EDM, tapes
- Tapes
 - Cut tape-first and last dm marked in cm and mm
 - Add tape-extra dm marked before 0, extra dm marked in cm, mm running backwards
 - Accessories
 - Plumb bob
 - Range pole
 - Tension handle
 - Chaining pins
 - Hand level
 - Clinometer-eye sight level, 45 degrees with roof of building
- Trilateration-measure two distances from two known points
- Triangulation-measure two angles from two known points
- 3-4-5 Method



-
- Swing method



○

Lecture 6-DISTANCE

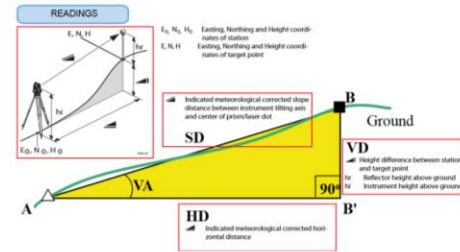
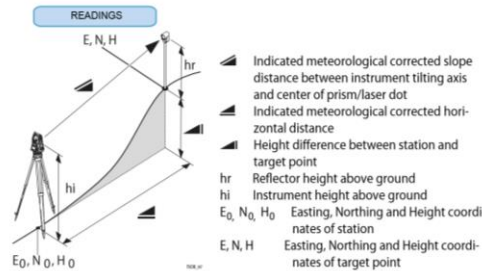
- Systematic taping errors
 - Slope, Erroneous length, Temperature, Tension and sag
- Random taping errors
 - Slope, temperature, Tension and sag, Alignment, Marking and plumbing
- Taping procedure
 - Zero, align, pull, plumb/level, mark, record
- Grade (%)= $VD/HD \times 100$
- Length Correction
 - D =recorded distance
 - T_n =nominal tape length
 - C_L =constant error
 - $T_A = T_n - C_L$ =actual tape length
 - $D_c = D(T_A / T_n)$ =corrected distance
- Temperature Correction
 - $C_t = \alpha(T - T_s)D$
 - α =coefficient of thermal expansion= $11.6 \times 10^{-6} \text{ C}^{-1}$
 - T_s =standard calibration= 20 C
 - T =temperature of tape during measurement
 - D =distance measured
- Invar steel tapes
 - Low thermal expansion, nickel-steel alloy
 - $\alpha = 3.6 - 5.5 \times 10^{-7} / \text{C}$
- Tension Correction
 - P_s =standard tension= 50 N
 - P =applied tension
 - L =Length of tape (m)
 - A =cross sectional area of tape (mm^2)
 - E =modulus of elasticity of steel= $200,000 \text{ N/mm}^2$
 - $C_p = \frac{(P - P_s)L}{AE}$
- Sag Correction
 - w =tape weight per unit length (N/m)
 - $C_s = \frac{-w^2 L^3}{24P^2}$
- Normal tension-tensile force applied to tape to compensate (eliminate) sag
- Taping procedure
 - Zero, align, pull, plumb/level, mark, record

Lecture 7-TOTAL STATION

- Electronic Distance Measurement
 - Modulated EM waves emitted and reflected back by prism
 - Response measured in terms of numbers of waves
 - Distance is calculated from information about the wave

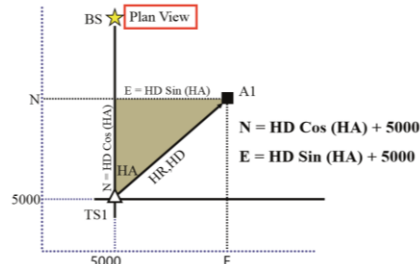
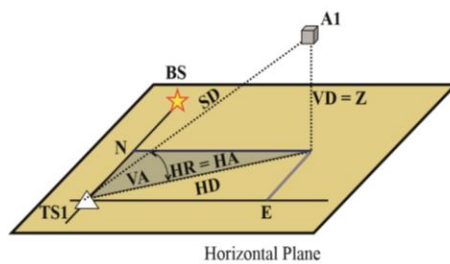
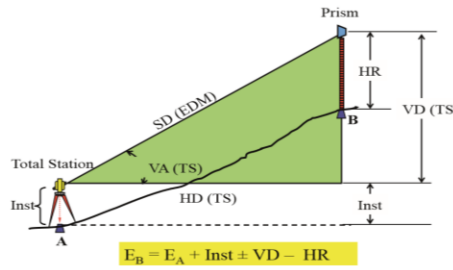
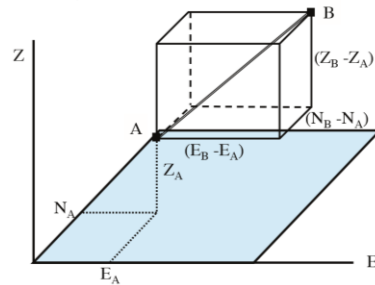
- Speed of light= $c=300000\text{km/s}$
 - Wave length= $\text{velocity/frequency}=\lambda=c/f$
 - Total distance is doubled-there and back= $SD=(1/2)(n\lambda+\varphi)=\text{slope distance}$
 - Instrument measures the number of times, n , and measuring the fraction, φ
 - Environmental affects
 - Temperature (1ppm/ C), pressure (0.5ppm/mmHg), moisture content(10ppm/mmHg)
 - Implicit Errors
 - Temperature (-1ppm/ C)
 - Pressure (+.3ppm/mmHg)
 - EDM's automatically correct for temp and pressure, corrections are negligible under 3km and depend on type/number of prisms
 - Range
 - No prism-100-400m
 - 1 prism-under 1km
 - 3 prisms-1.5km
 - 11 prisms-15km
 - Accuracy
 - Short-15mm+5ppm
 - Long-3mm+1ppm
 - Measuring time-1.5/3.5s
 - Battery-1400-4200 shots
 - Temperature- -20-50C
- Typical EDM
 - Range-1km to 10km
 - Accuracy- $\pm(15\text{mm}+5\text{ppm})$ at short range
 - Temperature range- -20 to 50 C
 - Measuring time is under 1.5 sec for short range
 - Automatically converts from SD to HD while the battery lasts from 1000 to 4000 points (4hrs)
- Leica TS06
 - Range of 3-3.5km with a single prism
 - Accuracy of $\pm(3\text{mm}+2\text{ppm})$
 - Measuring time is 0.8-2.4s with a precision of 1'' and battery lasts for 20 hours at 20 C
- Mini Prism
 - Reflect the signal transmitted by the EDM and is 360
- Total Station
 - Measures horizontal and vertical angles with the theodolite and distances with the distance meter at the same time so a 3D coordinate point can be deducted
 - Transmits and infrared wavelength to a prism, target or object and measures the time it takes for the light to bounce back to measure the distance
 - The reflectorless EDM can measure distances straight from a surface without a reflector and only requires one setup. With both measurements, angles and distances, it is possible to calculate the positions with trig

- Useful to record prominent features of the building but not measurements of complex surfaces
- Field Techniques
 - Point location, traversing, resection, offset measurement, layout or setting out-positions, area computation

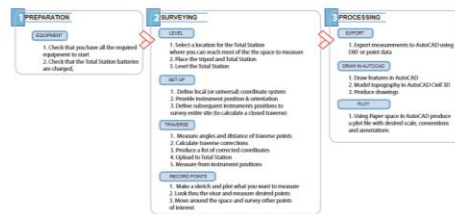


SLOPE DISTANCE BETWEEN TWO POINTS (3D)

$$SD_{AB} = \sqrt{(N_B - N_A)^2 + (E_B - E_A)^2 + (Z_B - Z_A)^2}$$

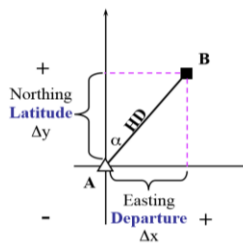


SURVEYING WORKFLOW: WORKING WITH A TOTAL STATION



- Traversing
 - Usually a control survey used for mapping, legal and engineering surveys. A series of established stations tied together by angle and distances. It can be open and closed.
 - Transverse serves for 1. Locate topographic detail for the prep of plans

- 2. Lay out (locate) engineering works
- 3. Process and order earthwork and other engineering quantities
- Computations-balance field angles, compute latitudes and departures, compute traverse error, balance latitudes and departures, adjust original distances and directions, compute coordinates of transverse stations and compute the area enclosed by a closed traverse



Azimuth = α

$$\text{LAT} = \text{HD} \cos \alpha$$

$$\text{DEP} = \text{HD} \sin \alpha$$

| SURVEYING PROGRAM | • TS06

1. Make a sketch
 - Make a detailed sketch of the area you want to measure with all the features and enough space to put Point ID corresponding with the measurements you will be making
2. Select Surveying program
 - Select Prog from the MAIN MENU
 - Select Surveying from the PROGRAMS menu
3. Define a new Job
 - Go to "Set Job" in Pre-settings screen
 - On "Select Job"
 - Scroll to New and hit enter
 - Scroll to Job and type your job name
 - Go to operator: insert your group number
 - (Setting the Job)
 - When done, hit "OK"
4. Set Station
 - Go to "Set Station" on the "Pre-Settings" screen
 - Insert Station number (a new screen will appear as the station is not found in your infernal memory) enter the first local coordinates:
 - East: 1000, North: 1000, Height: 100
 - Enter instrument height screen appears once the station coordinates have been entered. Enter the instrument height
5. Set Orientation
 - For your first orientation, you will use the "magnetic north", for this reason, go first to "Set orientation" in the "Pre-Settings" screen
 - Hit "Manual Angle Settings"
6. Surveying
 - In "Bearing" set to 0, and orientated the telescope of your Total Station towards the north with the help of the magnetic compass, when positioned press "Rec", now your device is orientated to bearing "north"
 - Define the new point that will be measured by typing on "PtID"
 - Make sure that the reflector height (hr) is correct and that you are using the correct reflector or non-reflector feature to measure the desired points in space.
 - Use the sketch you made to insert the point id where you have measured.

• For more information consult the Leica Manual, pages: 92 - 102

Lecture 8-CAD

- A digital drawing tool that has graphic primitives (lines, rectangles etc) arranged in a 3D coordinate system making it possible to change their location or scale.
- Drawing is stored in full size, the scale will be specified in the plot output which modifies the size of the view appropriate to the required scale and paper layout
- 2D and 3D

Point Density

To produce "as found" measured drawings a suitable density of points must be used, this depends on the complexity of the subject.

Line Weight

For the sake of clarity, different line weights are used in architectural conventions, as for example a heavier line should be used to show the "line of cut" inside the building. Decreasing line weights are used to indicate changes of planes in complex elevations. Bare in mind that scale will affect the line weight.

Text

Use an adequate font that provides clarity to measured drawings, mind the scale when selecting the height of text.

View

True orthogonal projections should be chosen that represents building views according to engineering/architectural conventions

Data Sources

CAD drawings are usually constructed from different sources of information, including previous documentation and on site recording. The use of layers can be useful to identify the origin of a measurement. This will ensure appropriate provenance data.

Scale

Although CAD allows producing different scales of measured drawings from a single CAD file, bear in mind that a survey is carried out for an specific level of detail.

Layers

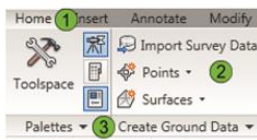
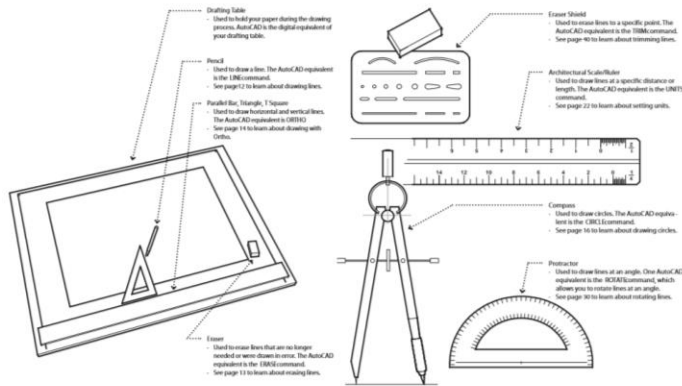
Layers allow separating information in CAD drawing using specified criteria. Different heritage information have published a layer structure guidelines.

Version control

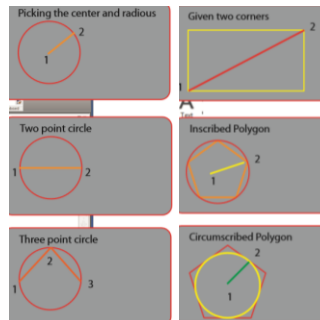
CAD drawings can be modified and updated easily, this can lead to confusion about the different versions of a measured drawings, make sure that layers indicate the date, when they have been drawn.

CAD

FEATURES



- 1 Tabs
- 2 Commands
- 3 Panel



- 3D polyline-command 3dpoly: allows drawing a grouped line through 3D space
- Snapping-allows you to pick corners, midpoints etc to create accurate elements
- Mirror-allows making irregular shapes from profiles
- Rotate-allows rotating around a base point or reference line
- Offset-allows to copy selected entities and place the copy at a specific distance from the original or through an existing position on another element creating a parallel or concentric copies of lines, polylines, circles, arcs or splines
- Scale-allows enlarging/reducing objects, keeping the proportions
- Layers-organize your drawings

Lecture 9-CONVENTIONAL DRAWINGS

Components drawings

- Details:
- 1:1
 - 1:5
 - 1:10

- Assembly:
- 1:5
 - 1:10
 - 1:20

Location drawings

- Site plan:
- 1:500
 - 1:200
 - 1:40

General location

- 1:50
- 1:100
- 1:200

- Ranges:
- 1:50
 - 1:100
 - 1:200

Maps, Town surveys & Block plans

- 1:100000
- 1:50000
- 1:25000
- 1:10000

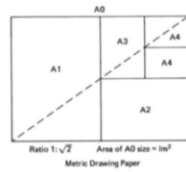
TABLE 9.1 Summary of Map and Plan Scales and Contour Intervals

| | Metric Scale | Foot/Inch Scale Equivalents | Contour Interval for Average Terrain | Typical Uses |
|--------------------|---------------------|--|--|---|
| Large scale | 1:10 | 1" = 1" | 0.5 m, 1 ft 1 m, 2 ft | Detail Detail Detail, profiles Profiles Municipal design plans Municipal services and site engineering |
| | 1:50 | 1/2" = 1', 1" = 5' | | |
| | 1:100 | 1/4" = 1', 1" = 8' | | |
| | 1:200 | 1" = 20' | | |
| | 1:500 | 1" = 40', 1" = 50' | | |
| 1:1000 | 1" = 80', 1" = 100' | | | |
| Intermediate scale | 1:2,000 | 1" = 200' | 2 m, 5 ft 5 m, 10 ft 10 m, 20 ft | Engineering studies and planning (e.g., drainage areas, route planning) |
| | 1:5,000 | 1" = 400' | | |
| | 1:10,000 | 1" = 800' | | |
| Small scale | 1:20,000 | 1:25,000, 2/3" = 1 mi | | Topographic maps, Canada and United States Geological maps, Canada and United States Special-purpose maps and atlases (e.g., climate, minerals) |
| | 1:25,000 | 1" = 400' | | |
| | 1:50,000 | 1:63,360, 1" = 1 mi | | |
| | 1:100,000 | 1:126,720, 2/3" = 1 mi | | |
| | 1:200,000 | | | |
| | 1:500,000 | 1:250,000, 1/3" = 1 mi | | |
| | 1:1,000,000 | 1:625,000, 1/6" = 1 mi 1:1,000,000, 1/8" = 1 mi | | |

Table B.2 STANDARD DRAWING SIZES

| Inch Drawing Sizes | | International Standards Organization (ISO) | | | ACSM ¹ Recommendations | | |
|--------------------|---------------|--|--------------|-------------|-----------------------------------|--------------|-------------|
| Drawing Size | Border Size | Overall Paper Size | Drawing Size | Border Size | Overall Paper Size | Drawing Size | Paper Size |
| A | 8.00 × 10.50 | 8.50 × 11.00 | A4 | 195 × 282 | 210 × 297 | — | 150 × 200 |
| B | 10.50 × 16.50 | 11.00 × 17.00 | A3 | 277 × 400 | 297 × 420 | A4 | 200 × 300 |
| C | 16.00 × 21.00 | 17.00 × 22.00 | A2 | 400 × 574 | 420 × 594 | A3 | 300 × 400 |
| D | 21.00 × 31.00 | 22.00 × 34.00 | A1 | 578 × 821 | 594 × 841 | A2 | 400 × 600 |
| E | 33.00 × 43.00 | 34.00 × 44.00 | A0 | 811 × 1,159 | 841 × 1,189 | A1 | 600 × 800 |
| | | | | | | A0 | 800 × 1,200 |

¹American Congress on Surveying and Mapping Metric Workshop, March 14, 1975. Paper sizes rounded off for simplicity, still have one-half characteristic.



- Need title block, bar scale, north arrow and dimensions

Lecture 10-CAD2

- Plotting drawing is the final output of the metric survey, therefore the info provided in it is of primary importance for the acquisition, storage, management, and retrieval of the info required
- Consider the following reference info prior to prepare a border, label and the thematic caption
 - Format-size for presenting the data, should contain single or multiple views with defined scales
 - Labeling-give info about orientation of the drawing, position, labels (title, scale, date, authors etc)
- Scale-metric scale is drawn without units usually, just in ratio, architects and engineers usually use mm
 - Drawing scale factor is a single number that represents the multiplier, normally 1/6, 1/20 or 0.5. the drawing scale factor for a drawing is the conversion factor between a measurement on the plot and a measurement in the real world
- Model space-draw features that were surveyed (hidden lines, phantom lines, symmetry lines, dimensions etc)
 - VPORTS command to create separate viewports
 - TILEMODE system variable switches between the model space tab and a layout tab
- Layouts
 - Can be changed without changing the location of the geometry, multiple layouts can be included within a single drawing
 - Model space is the only tab on the bottom that isn't a layout
 - Paper space represents a sheet of paper that you can organize the views you want to plot. Contain viewports that can display any part of your geometry at any scale
 - Floating viewports can display layers in different states than other viewports and can be any shape
 - To scale a viewport for plotting at 1:10 scale, type .1XP after issuing the zoom command
 - Paper space- once you are ready to present your drawing you need to create a layout in paper space which contains sheet border, title block, title block text, bill of materials
- Plot style- define the plotting specifications
- Topography-contour lines-close means steep slope
 - Straight means man-made
 - Every fifth line is labelled with an elevation

- Don't pass through buildings
- Deflect uphill at valleys and downhill at ridges

The Interface

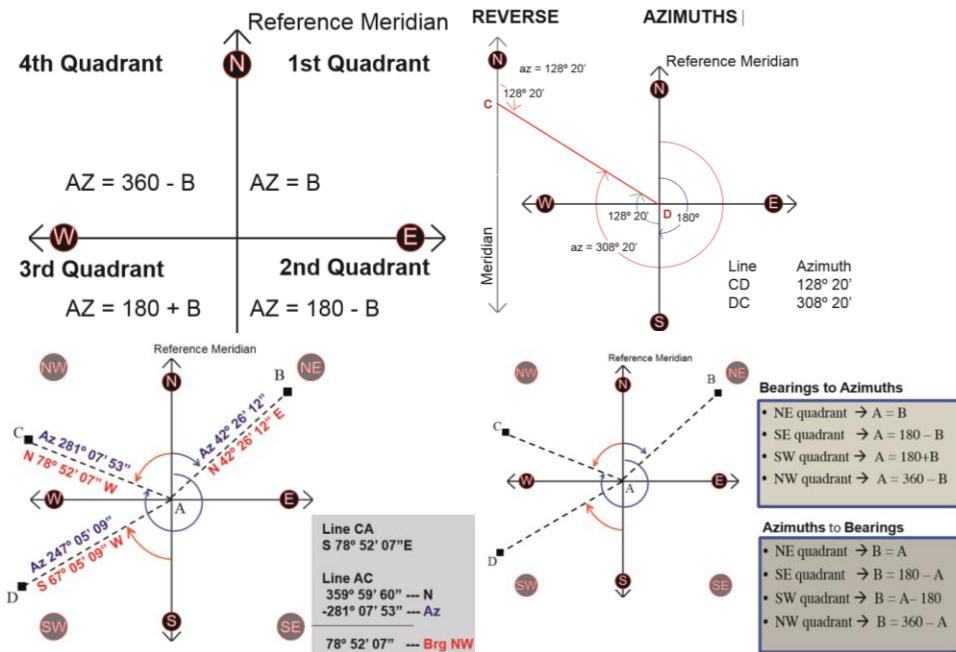
The standard interface is shown in the graphic below. Notice the following elements:

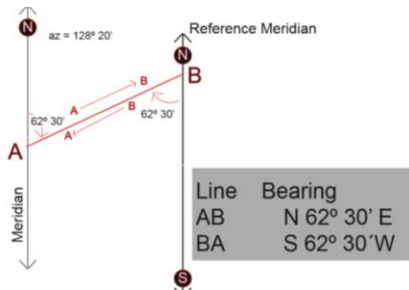
1. **The Graphic Window or Drawing Area:** This is the main window where the user inputs, modifies, and views visual data.
2. **Toolspace:** Toolspace is an integral component in the user interface for accessing commands, styles, and data. Use it to access the Prospector, Settings, Survey, and Toolbox tabs. Right-click each collection or item on these tabs to access commands.
3. **Ribbon:** The ribbon provides access for AutoCAD Civil 3D commands. Displayed at the top of the drawing window, the ribbon provides one location for commands, in an organization that provides the most-frequently used commands in the most accessible places.
4. **Application Menu:** Provides drawing-related commands, such as New, Open, Save, and Export to AutoCAD.
5. **Quick Access Toolbar:** The Quick Access toolbar displays frequently used tools. You can add ribbon buttons to the Quick Access toolbar
6. **InfoCenter:** The InfoCenter enables you to search for key words, enter a question for help, display the Communication Center panel for product updates and announcements, and display the Favorites panel to access saved topics. It also displays links to Help topics, RSS feeds, and product updates and announcements.
7. **Command window:** Also known as the command line or the text window, the command window enables user input using the keyboard for commands or numerical values. It also queries the user for information when required and reports data about the drawing.
8. **Status bar:** The status bar displays status information and includes some controls for changing the view.

-
- DTM: digital terrain model
- TIN: triangulated irregular network
- Breaklines: define terrain breaks, triangulation follows
- Surveying a topography: create transverse coordinates for your surveying network of fixed points, survey a grid of topographic points throughout the sight covering the entire area, identify and survey the breaklines, survey features of the sight; buildings paths etc

Lecture 11-TOTAL STATION 2

- Azimuth-horizontal distance measured clockwise from the north to the line, at the beginning of the line
- Bearing-acute horizontal angle measured from the north or south direction to the line. Shown as N30W is in the fourth quadrant





- Bearing are more commonly used, azimuths are easier for computer calculations, traverse angle adjustments computations are easier with azimuths
- Resection-a total station features used to determine the instruments position from measurements to known points, min of 2 max of 5, 10

1. Make a sketch
 - Make a detailed sketch of the area you want to measure with all the features and enough space to put Point ID corresponding with the measurements you will be making
2. Select Free Station program
 - Select Prog from the MAIN MENU
 - Select Free Station from the PROGRAMS menu
3. Look for your Job
 - Go to "Set job" in Pre-settings screen
 - On "Select Job" look for your Job
 - When done, hit OK
4. Set Accuracy Limit
 - Set the accuracy limits for the Easting, Northing and Height coordinates and the standard deviation angle.
 - Press OK to save the limits and return to the Pre-settings screen.
 - Select Start to begin the application
 - Press OK to return to the Pre-Settings screen
5. Sight to known points
 - Move your telescope and fix it to the known point
 - Enter the name of the station and the height of the instrument in the Enter station data screen and press OK.
 - Hit Alt
 - Hit know NextP to select the next known point
 - Move your telescope and fix it to the next known point
 - Enter the name of the station and the height of the instrument in the Enter station data screen and press OK.
 - Hit Alt
 - Move your telescope and fix it to the next known point
 - Enter the name of the station and the height of the instrument in the Enter station data screen and press OK.
 - Hit Alt
 - Hit know COMPUTE, to calculate and display the station coordinates, if at least two points and a distance were measured

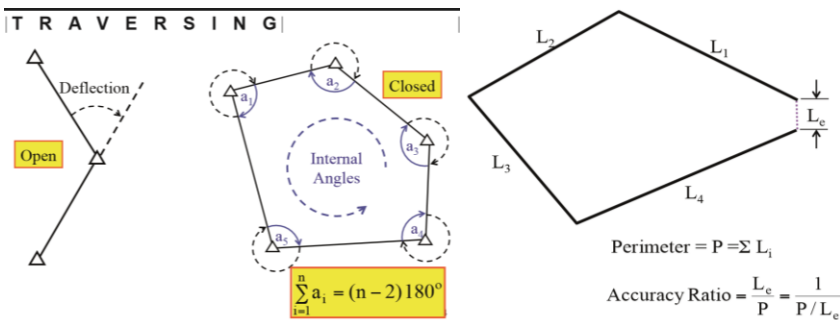
The Total Station will display the calculated station coordinates. The final computed results are Easting, Northing and Height coordinates of the present instrument station, including the instrument height. Also, standard deviations and residuals for accuracy assessments are provided.

6. Now you can survey from this new position, follow the surveying part

• For more information consult the Leica Manual, pages: 111 - 117

Lecture 12-TRAVERSE

- Control surveys to locate topographic detail, layout engineering works, as-built
- Open traverse-highways closed traverse-boundary, construction



$$\sum_{i=1}^n a_i = (n-2)180^\circ$$

| Station | Field angle | Arbitrarily balanced | Equally balanced |
|---------|----------------|----------------------|--|
| A | 101° 24' 00" | 101° 24' 00" | 101° 24' 12" |
| B | 149° 13' 00" | 149° 13' 00" | 149° 13' 12" |
| C | 80° 58' 30" | 80° 59' 00" | 80° 58' 42" |
| D | 116° 19' 00" | 116° 19' 00" | 116° 19' 12" |
| E | 92° 04' 30" | 92° 05' 00" | 92° 04' 42" |
| | 538° 119' 00" | 538° 120' 00" | 538° 118' 120" |
| | = 539° 59' 00" | = 540° 00' 00" | = 540° 00' 00" |
| | Error = 01' | Balanced | Balanced |
| | | | Correction/angle = $\frac{60}{5} = 12''$ |

- Northing is latitude, easting is departure
- Error of closure
 - Calculate interior angle-sum of angles-(n-2)180

- Adjust interior angles. Calculate Az/Brg
- Calculate lat/dep for all lines (sign)
- Add lat/dep with proper sign
- Linear error
- Perimeter= $E^2=(\text{sum of lat})^2+(\text{sum of dep})^2$
- Accuracy ratio is E/P

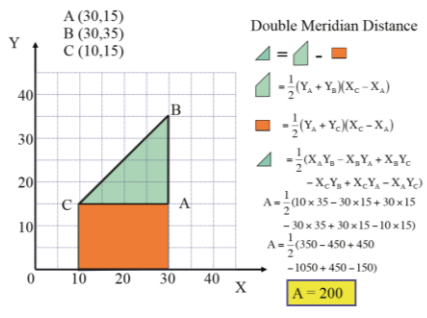
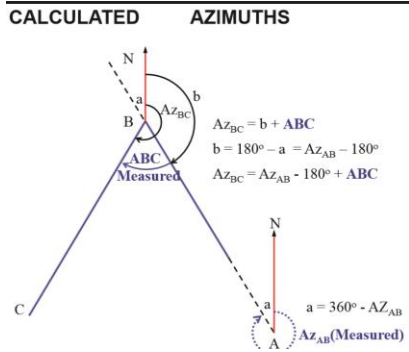
| Course | Distance (ft) | Azimuth | Bearing | Latitude | Departure |
|---------------|---------------|------------|--------------|------------------------------|------------------------------|
| AE | 350.10 | 152°46'12" | S 27°13'48"E | -311.30 | +160.19 |
| ED | 579.03 | 64°50'54" | N 64°50'54"E | +246.10 | +524.13 |
| DC | 368.28 | 1°10'06" | N 1°10'06"E | +368.20 | +7.51 |
| CB | 382.20 | 262°08'48" | S 82°08'48"W | -52.22 | -378.62 |
| BA | 401.58 | 251°22'00" | S 51°22'00"W | -250.72 | -313.70 |
| $P = 2081.19$ | | | | $\Sigma \text{ lat} = +0.06$ | $\Sigma \text{ dep} = -0.49$ |

$E = \sqrt{\Sigma \text{ lat}^2 + \text{dep}^2} = \sqrt{0.06^2 + 0.49^2} = 0.49$
 Precision ratio = $\frac{E}{P} = \frac{0.49}{2081.19} = \frac{1}{4247} \approx \frac{1}{4200}$

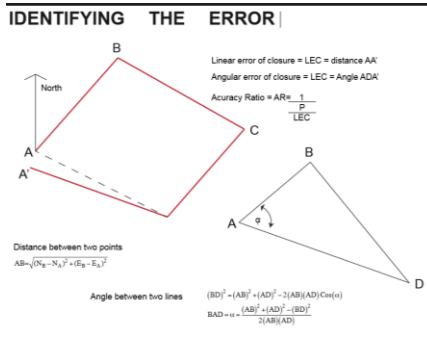
ERROR CALCULATIONS

| Line | Angle | Adj Angle | Dist | Azimuth | Lat | Dep |
|---------|----------|-----------|-------|----------|---------|---------|
| AB | 60.6875 | 60.7044 | 20.65 | 331.8767 | 18.212 | -9.734 |
| BC | 64.1086 | 64.1256 | 21.95 | 216.0022 | -17.757 | -12.903 |
| CA | 55.1531 | 55.1700 | 19.59 | 91.1722 | -0.401 | 19.586 |
| Sum | 179.9492 | 180.0000 | 62.19 | | 0.054 | -3.050 |
| Ang Err | 0.0508 | 0.0000 | | | | |
| Lin Err | 3.050862 | | | | | |
| A.R. | | 1/20 | | | | |

Ang Err = $180.0000 - 179.9492 = 0.0508$
 Correction = $\frac{0.0508}{3} = 0.0169$
 Adj Angle = Angle + Correction = Angle + $\frac{\text{Ang Err}}{n}$
 Lat = Dist * Cos(Az)
 Dep = Dist * Sin(Az)
 Lin Err = $\sqrt{(\Sigma \text{Lat})^2 + (\Sigma \text{Dep})^2}$
 $A.R. = \frac{1}{\frac{\text{Lin Err}}{\text{Lin Err}}}$



Lecture 13-TSTRAVERSE



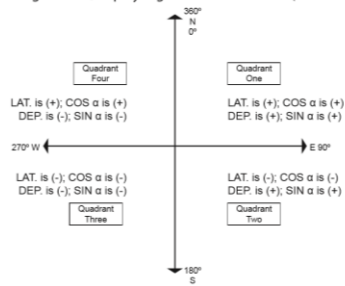
READINGS TABLE

| PIID | East (E) | North (N) | Height (Z) | hi | hr | Line | HD | SD | VD | HZ | V |
|------|----------------------------|----------------------------|----------------------------|----------------|-----------------|------|------------------|------------------|------------------|------------------|-----------------|
| A | 100.00 | 100.00 | 100.00 | h _A | h _{rA} | AB | HD _{AB} | SD _{AB} | VD _{AB} | HZ _{AB} | V _{AB} |
| B | Coord of B obtained from A | Coord of B obtained from A | Coord of B obtained from A | h _B | h _{rB} | BA | HD _{BA} | SD _{BA} | VD _{BA} | HZ _{BA} | V _{BA} |
| C | Coord of C obtained from B | Coord of C obtained from B | Coord of C obtained from B | h _C | h _{rC} | BC | HD _{BC} | SD _{BC} | VD _{BC} | HZ _{BC} | V _{BC} |
| D | Coord of D obtained from C | Coord of D obtained from C | Coord of D obtained from C | h _D | h _{rD} | DC | HD _{DC} | SD _{DC} | VD _{DC} | HZ _{DC} | V _{DC} |
| A | Coord of A obtained from D | Coord of A obtained from D | Coord of A obtained from D | h _A | h _{rA} | AD | HD _{AD} | SD _{AD} | VD _{AD} | HZ _{AD} | V _{AD} |

Coordinates from DC should be equal to AB
 Observations from stations
 Traverse Course

LATITUDE & DEPARTURE

Algebraic signs of Lat/Dep by trigonometric functions (α is the azimuth)



COMPASS RULE

• Rule to distribute the errors in LAT/DEP. The compass rule distributes the errors in LAT/DEP for each of the traverse course in the same proportion as the course distance is to the traverse perimeter.

Compass Rule: calculation of course error of Latitude

$$\frac{C \text{ lat } AB}{\sum \text{ lat}} = \frac{AB}{P} \rightarrow C \text{ lat } AB = \sum \text{ lat} \times \frac{AB}{P}$$

Compass Rule: calculation of course error of Departure

$$\frac{C \text{ dep } AB}{\sum \text{ dep}} = \frac{AB}{P} \rightarrow C \text{ dep } AB = \sum \text{ dep} \times \frac{AB}{P}$$

- C lat AB = correction in LAT AB
- $\sum \text{ lat}$ = error of closure in LAT
- AB = distance AB
- p = perimeter of traverse

- C dep AB = correction in LAT AB
- $\sum \text{ dep}$ = error of closure in LAT
- AB = distance AB
- p = perimeter of traverse

Lecture 14-FINAL PROJECT

Lecture 15-CAD AND TOTAL STATION

- Topographic surveys are preliminary surveys used to locate the horizontal and vertical positions of natural and constructed surface features in a defined geographic area. Such features are located relative to one another in the field by tying them all in to the same control line or control grid, or through the direct positioning techniques common to satellite positioning field surveys. Additionally topographic spatial detail positioning can be conducted using remote sensing surveys
- Most natural features are not precisely defined themselves therefor aerial or satellite imaging can be used
- Breaklines are joined coordinated surface points that define changes in slope, such as valley lines, ridge lines, the tops and bottoms of slopes, ditch lines and the tops and bottoms of curbs

Lecture 16-TS04

C A L C U L A T I O N S

| Field | Description |
|------------------------|--|
| To known Closing Point | To close a traverse to a known closing point. Use when setup on an unknown station and only the coordinates of the closing point are known. 1. Input the data for the point. 2. Measure to the closing point. 3. The results are displayed. |
| At known Station only | To close a traverse at a known station only. Use when setup on the closing station and the coordinates for it are known. 1. Input the data for the closing station. 2. The results are displayed. |
| Leave open | To leave the traverse open. There is no last traverse station. 1. The results are displayed. |

Select an option, from the CLOSE TRAVERSE menu to proceed to the TRAVERSE RESULTS screen.

CLOSE TRAVERSE ...

F1 At known Station to known Closing Point
 F2 To known Closing Point
 F3 At known Station only
 F4 Leave open

F1-F4 To select menu item.

| Field | Description |
|---|--|
| At known Station to known Closing Point | To close a traverse at a known station to a known closing point. Use when setup on the closing station, and the coordinates for the station and the closing point are known. • If this method is chosen a distance measurement is mandatory. 1. Input the data for both points. 2. Measure to the closing point. 3. The results are displayed. |

Lecture 17-CAD03

- Plotting steps: set drawing units to meters, define layers, make a paper sheet, make a title block, define attributes, make a plot style, make a page layout and import the title block and borders defined, plot the file into a PDF

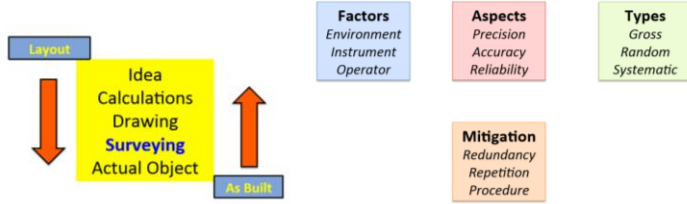
Lecture 18-CAD04

Lecture 20-SURVEYING APPLICATIONS

- Surveying-topography and geomatics
 - Art and science of determining the position of the objects on, below and above the surface of the Earth

- Position is determined by the measurements of distances, elevations, and angles
- Types: cadastral, land title, boundary, archeological, as-built/layout, bathymetric, geological, hydrograph, plane, geodetic, forensic

Measurement Errors



- Typical grades-stairs 55%
 - Ramps 10%
 - Sewers 2%
 - Railways 1%
 - Roads 1%-8%
- Field procedure-measure, specify, determine, select, calculate, stake

Example

$T = R \tan(\Delta/2)$
 $T = 300 \tan(53.8/2) = 152.2 \text{ m}$

$C = 2R \sin(\Delta/2)$
 $C = 2(300) \sin(53.8/2) = 271.5 \text{ m}$

$L = 2AR \frac{\pi}{360^\circ}$
 $L = 2(300) \frac{53.8}{360} = 281.7 \text{ m}$

$\delta = \left(\frac{\text{arc}}{L}\right) \frac{\Delta}{2}$
 $= n \left(\frac{\pi}{180}\right) \frac{\Delta}{2}$

Geometry

$y = ax^2 + bx + c$
 $a = \frac{g_2 - g_1}{2L}$
 $b = g_1$
 $c = E_{BVC}$

Given:

- L = Length of Vertical Curve (Specified)
- Ch_{PVI} = Chainage of break point
- E_{PVI} = Elevation of break point
- g_1 = Approach grade
- g_2 = Exit grade
- $y = ax^2 + bx + c$ Equation of curve

- #### Calculations

 - **Determine:**
 - Curve parameters
 - $a = (g_2 - g_1) / (2L)$
 - $b = g_1$
 - $c = E_{BVC}$
 - Elevation of beginning/end of Vertical Curve
 - $E_{BVC} = E_{PVI} \pm g_1(L/2)$
 - $E_{EVC} = E_{PVI} \pm g_2(L/2)$
 - Chainage of beginning/end of Vertical Curve
 - $Ch_{BVC} = Ch_{PVI} - L/2$
 - $Ch_{EVC} = Ch_{PVI} + L/2$

Calculations

Low/High point

 - $x = -g_1 L / (g_2 - g_1)$
 - $y = ax^2 + bx + c$

Chainage of low/high point

 - $Ch_{L/H} = Ch_{BVC} + x$

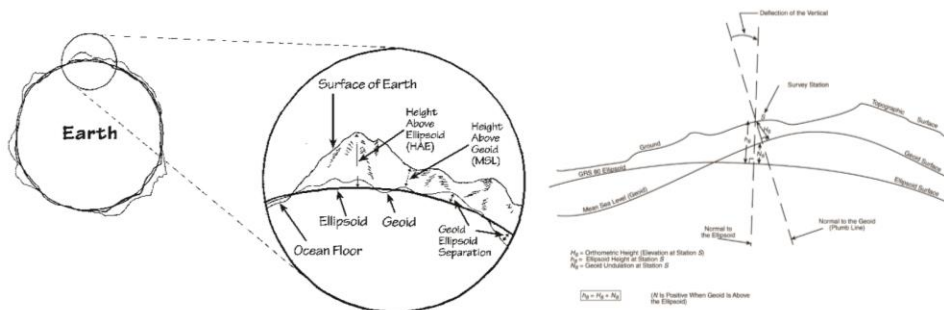
Elevation of low/high point

 - $E_{L/H} = E_{BVC} + y$

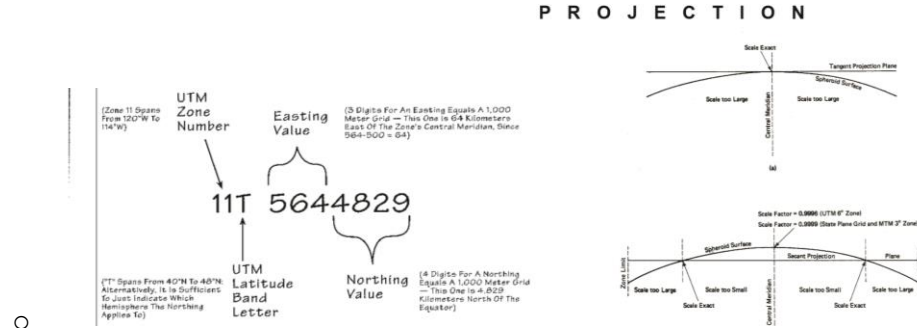
Elevations along

 - Tangent $E_{sta} = E_{BVC} + g_1 x$
 - Curve $E_{sta} = E_{BVC} + y$
 - Offset between Curve and Tangent = Tangent E_{sta} - Curve E_{sta}

Lecture 21-GNSS



- Types of coordinates
 - Angular-3D Latitude and longitude
 - Rectangular-2D universal transverse Mercator and military
 - Grid size determines the precision of the coordinate e.g 10m size gives precision to nearest 10th



- Global positioning system is a space-based global navigation system that provides reliable location and time info in all weather at all times and anywhere on Earth that there is an unobstructed view of four or more satellites.
 - Navigation-grade GPS
 - Map and absolute accuracy to ~10m, good for finding location in relation to maps and relocating sites, bad for heights and site survey
 - Mapping-grade
 - Map and absolute accuracy to 1m can be achieved in real time or if post-processed, suitable for 1:2500 scale but not site survey
 - Survey-grade
 - Map and absolute accuracy to 100mm can be achieved in real time or if post-processed
 - 5-10m is a stand alone GPS \$100
 - 1-3m is a DGPS with code corrections \$3000
 - Submeter to subfoot is a DGPS with phase corrections \$6000
 - Cm phase corrections from \$15000
- Positioning techniques
 - Code measurements
 - GPS-pseudo-range navigation
 - Differential GPS or DGPS
 - Code corrections, carrier phase measurements, post processing, realtime (phase corrections)
 - Augmented services
 - Ground base augmented services
 - Satellite base augmented services
 - Assisted GPS and high sensitivity GPS
- GDOP-geometric dilution of precision
 - Tied from each corner not just one so more accurate
- Stand alone GPS is not a good way because the ionosphere causes delay in deflection in the ray which affects the location

- Differential GPS is when you have an error sent to both receivers due to the ionosphere: a reference receiver that knows its position sends a corrected coordinate to the rover receiver
- Errors occur from clock errors, ionosphere slows down the signal, multipath, bouncing, less than 7 satellites

TOOLBOX: EQUIPMENTS

GPS (Navigation grade)

Although not cheap, thanks to the precision of the record the topographic accuracy is much that inherent. The RTK/PPK application is standard. A data cable to connect to the computer will be required.

<http://www.gps.gov.au/gps/rtk/rtk.html>

<http://www.gps.gov.au/gps/ppk/ppk.html>

Metec tape

Type measure to take corner corners to define the scale of the object

Digital camera

A digital camera with sufficient resolution and accuracy with a wide lens will be able to cover most of the site with fewer photographs.

Alternatively, it is possible to get a camera equipped with GPS and/or a real-time GPS patch per unit.

Computer

PC/MAC equipped with internet access in order to install the software and upload - process the images taken

Drawing material

A notebook and pencils to make sketches of the site, indicate the points, which are measured, and eventually the positions from where the photographs are taken.

Earth viewer

A 3D Earth Viewer (e.g. Google Earth) with spatial imagery, for example Google earth (http://earth.google.com/), downloaded the base location of the software application you need the free version only.

GIS software

ARC/INFO and other software used to collect GIS information online and transfer to the computer

Carrying capacity

Enough items and ability to transport to normal carrying capacity and safety equipment

Lecture 23-24-3D SCANNING AND BIM

- 3D scanner is a device that collects 3D coordinates of a region of an object surface automatically and in a systematic pattern at a high rate in (near) real time
- Can record high numbers in a very short time with high accuracy but needs line of sight
- Has long range, safe, non-contact, accessible, fast
- Terrestrial Scanners
 - Dynamic scanners
 - Mobile scanning, roads/highways, cities
 - Static scanner
 - Long range-(150-1000m)
 - City modeling, mining
 - Cm accuracy, 500000-1000000pt/sec
 - Mid range-(1-180m)
 - Construction, geology, architecture, historic places
 - Mm accuracy, 100-1000000pt/sec
 - Short range-(0.5-2m)
 - Body scanning, medicine, artifacts, crime scenes
 - Sub mm accuracy, 100pt/sec

MEASURING USING AN ACTIVE APPROACH: LIGHT (LASERS)

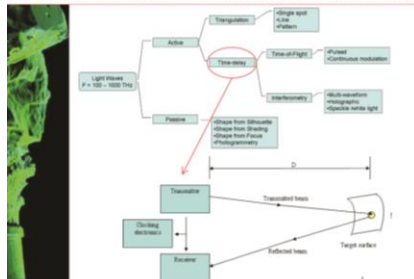


Table 1. Laser scanning techniques used in cultural heritage management activities

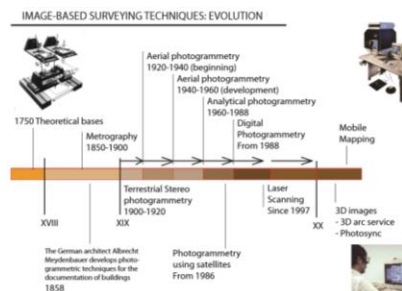
| scanning system | use | typical accuracy / operating range |
|---|---|---|
| rotation stage | <ul style="list-style-type: none"> • scanning small objects (that can be removed from site) • to produce data suitable for a replica of the object to be made | 50 microns / 0.1m-1m |
| triangulation-based artefact scanners | <ul style="list-style-type: none"> • arm mounted • scanning small objects and small surfaces • can be performed on site if required • can be used to produce a replica | 50 microns / 0.1m-1m |
| | mirror/prism | sub-mm / 0.1m-25m |
| terrestrial time-of-flight laser scanners | <ul style="list-style-type: none"> • to survey building façades and interiors, resulting in line drawings (with supporting data) and surface models • can be used to produce a replica | 3-6mm at ranges up to several hundred metres |
| terrestrial phase-comparison laser scanners | <ul style="list-style-type: none"> • to survey building façades and interiors resulting in line drawings (with supporting data) and surface models - particularly where rapid data acquisition and high point density are required | c 5mm at ranges up to 50-100m |
| airborne laser scanning | <ul style="list-style-type: none"> • to map and prospect landscapes (including in forested areas) | 0.05m+ (depending on the parameters of the survey) / 100m-3500m |
| mobile mapping | <ul style="list-style-type: none"> • to survey highways and railways • for city models • to monitor coastal erosion | 10-50mm / 100-200m |

(adapted from Barber, DM, Dallas, RWA and Mills, JP 2006 Laser scanning for architectural conservation, J Archit Conserv. 12, 35-52)

| feature size | example feature | point density required to give 66% probability that the feature will be visible | point density required to give a 95% probability that the feature will be visible |
|--------------|----------------------------------|---|---|
| 10m | large earth work | 3500mm | 500mm |
| 1m | small earth work/ditch | 350mm | 50mm |
| 100mm | large stone masonry | 35mm | 5mm |
| 10mm | flint galleting/large tool marks | 3.5mm | 0.5mm |
| 1mm | weathered masonry | 0.35mm | 0.05mm |

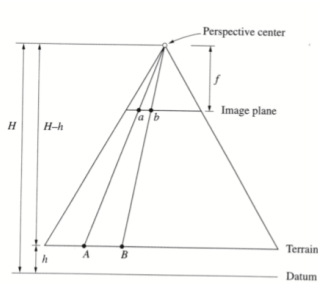
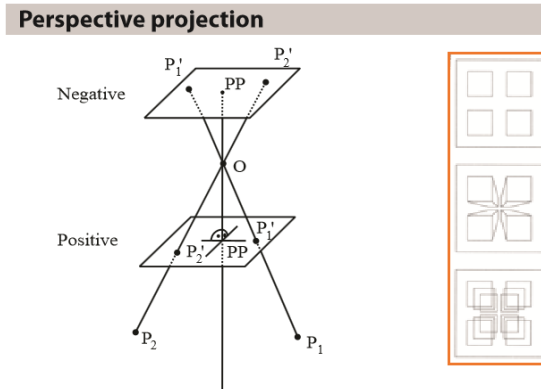
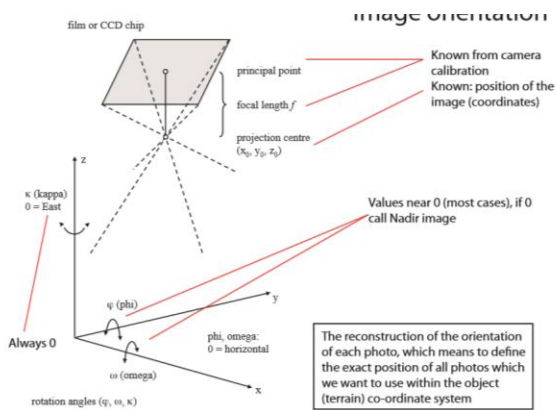
- Constraints
 - Surface reflectiveness, temperature, distortion from vibration
- Resolution is defined as the distance between two subsequent measured points and thus determines the density of points in the point cloud
- Define deliverables-planning-recording—registration/processing-modeling
- When scanning avoid creating shadows to enlarge the amount of info to be gathered
- Merging scans
 - Direct
 - Setting the device over a known point
 - Leveling, centering, and orientating the device
 - Requires existing or new control network and a total station
 - Geo-reference possible by GNSS device or other terrestrial positioning
 - Indirect
 - Target to target
 - Placing and scanning target's positions
 - Geo-reference possible by measuring targets with T.S. GNSS or other terrestrial positioning
 - Cloud to cloud
 - Clouds need to be scanned with 30% overlap
 - Geo-reference possible by measuring points of interest with T.S. GNSS or other terrestrial positioning
- Prepare the data for export by removing disconnected and noisy points by meshing
- Parametric modelling uses parametric constraints to define and easily modify part features, and to create relationships between these features in order to create intelligent part models to be created to assembly models

Lecture 25-PHOTOGRAMMETRY



- Factors-focal length

- Aerial is used by architects and civil engineers (to produce as-built records of buildings or document their condition), archaeologists (to facilitate analysis of historic buildings), surgeons (plastic surgery), police departments (documentation of traffic accidents and crime scenes) - involves a camera, tripod, and software
- Photogrammetry
 - Position, Orientation, Shape
 - based on
 - photochemical conventional photography)
 - photoelectrical (digital photography)
 - Size
 - OBJECTS
 - Digital points determination: 3d coordinates
 - Drawings (analogue) - planimetric detail and contour lines
 - Geometric models (digital) - transfer to GIS or CAD
 - Images (analogue or digital: ortho, rectified photos 3D photomodels
- Stereoscopy creates an impression of depth and is the capability of the human binocular visual system to perceive depth when presented with the images from the left to the right eyes. The brain interprets the parallax in a way conceptually similar
- Parallax is the apparent displacement in the position of an object when viewed or photographed from different vantage points
- An orthophoto or orthophotograph is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same lack of distortion as a map



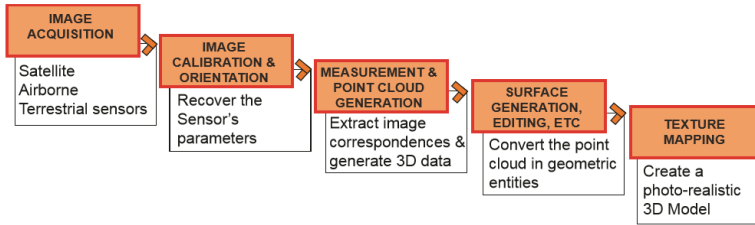
Vertical images over flat terrain have a simple characterisation of scale.

$$scale = \frac{ab}{AB}$$

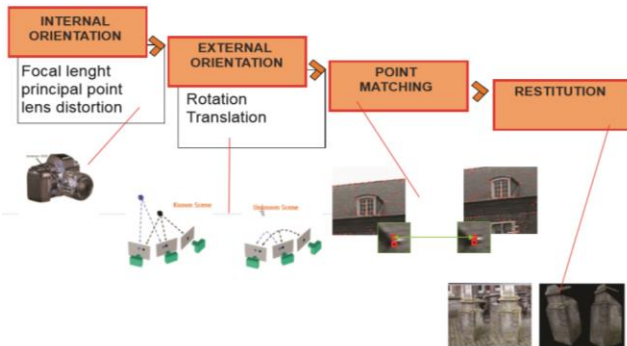
The scale can also be expressed as:

$$scale = \frac{f}{H-h}$$

For actual images the concept of scale becomes more complicated. For tilted or oblique photos, scale varies point by point and in each point it varies with direction (see analogy with cartography).



PHOTOGRAMMETRY | The collinearity equations



The fundamental characteristic of frame imaging is that the perspective centre, the image point, and the corresponding object point all lie on a line in space. This line can be expressed as vector components in the image space coordinate system or as a vector components in the object space coordinate system.

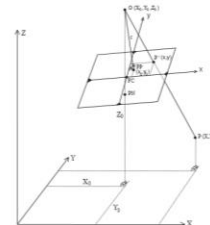
For each object point exists only one image point. An image point can be generated by one infinity of object points.

$$x - x_0 = -\frac{m_1(x - X_0) + m_2(y - Y_0) + m_3(z - Z_0)}{m_1(x - X_0) + m_2(y - Y_0) + m_3(z - Z_0)}$$

$$y - y_0 = -\frac{m_1(x - X_0) + m_2(y - Y_0) + m_3(z - Z_0)}{m_1(x - X_0) + m_2(y - Y_0) + m_3(z - Z_0)}$$

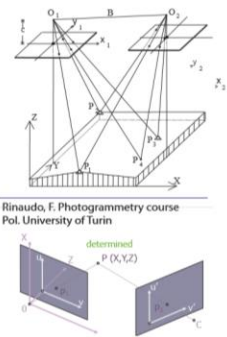
$$X - X_0 = (z - Z_0) \frac{m_1(x - x_0) + m_2(y - y_0) - m_3(z - Z_0)}{m_1(x - X_0) + m_2(y - Y_0) - m_3(z - Z_0)}$$

$$Y - Y_0 = (z - Z_0) \frac{m_1(x - x_0) + m_2(y - y_0) - m_3(z - Z_0)}{m_1(x - X_0) + m_2(y - Y_0) - m_3(z - Z_0)}$$



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PHOTOGRAMMETRY | Resection: two images bundle solution



bundle solution

Also unknown object points can be used in this case, each point introduces 3 new unknowns (the object coordinates) but 4 new equations, so they contribute to the global redundancy of the solving system.

At least three known points have to be found in order to solve the problem of the orientation of exterior orientation parameters of the stereo-pair.

For each point of known coordinates 4 equations can be written. All the used points must be imaged on the two images

$$\eta_0 = f \frac{Z_0}{Z_0 - Z_0} = f \frac{Z_0}{Z_0 - Z_0}$$

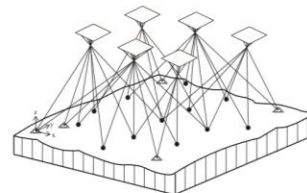
$$\eta_1 = f \frac{Z_0}{Z_0 - Z_0} = f \frac{Z_0}{Z_0 - Z_0}$$

$$\eta_2 = f \frac{Z_0}{Z_0 - Z_0} = f \frac{Z_0}{Z_0 - Z_0}$$

$$\eta_3 = f \frac{Z_0}{Z_0 - Z_0} = f \frac{Z_0}{Z_0 - Z_0}$$

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PHOTOGRAMMETRY | Bundle adjustment



The bundle block adjustment considers the single image as the elementary component of the block. The analytical model are the collinearity equations. Each point generates at least 6 equations and define three unknowns (its coordinates). Each ground control point generates 2 equation for each image and do not add unknowns.

Photogrammetric triangulation (PT) has been a major factor in improving the economic feasibility of photogrammetric mapping.

Without PT every stereomodel needs at least 2 XY and 3 Z control points requiring expensive ground surveys. PT allows the simultaneous determination of the orientation parameters (both interior and exterior in case of bundle block method) and of the coordinates of a set of points (the points) used in order to run PT.

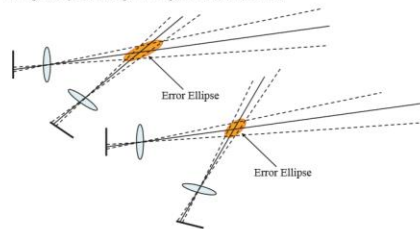
Bundle Block Adjustment (BBA)

It is based on the collinearity equations and allows the determination of the true accuracies. It is the only way to manage in a unique solution images coming from different types of camera. BBA allow also the determination of interior orientation parameters

PHOTOGRAMMETRY | Bundle adjustment

DIGITAL PHOTOGRAMMETRY: BUNDLE ADJUSTMENT

Using multiple convergent images (PHOTOMODELER)

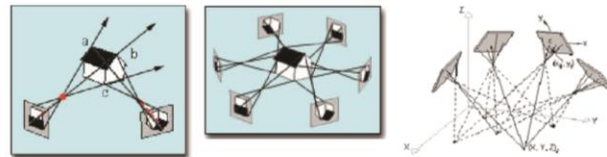


The degree of convergency of images is important to minimize the ellipse errors in the epipolar geometry of each of the photographs and corresponding images

PHOTOGRAMMETRY | Bundle adjustment

DIGITAL PHOTOGRAMMETRY: BUNDLE ADJUSTMENT

Using multiple convergent images (PHOTOMODELER)



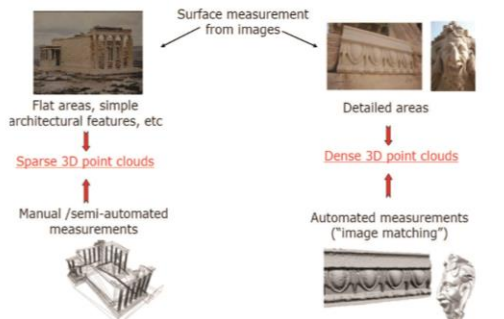
The photograph's geometry is used to select homologous points in the different convergent images. The software calculates the position by aims of the epipolar geometry projected on the sensor: intersecting lines are projected. Multiple images are used

- Fix your focal length (no zooming)
- Use a tripod to be able to use longer shutter speed and get more exposure to improve image detailing
- Take a convergent bundle of photographs covering the entire object to record

- Check the photographs to see if they are oblique and convergent
- Load photographs and start finding homologous points and mark in at least 3 photos

PHOTOGRAMMETRY | *Reconstructing the scene*

3D Reconstruction



- Structure from motion (SfM) is a range imaging technique; it refers to the process of estimating three-dimensional structures from two-dimensional image sequences which may be coupled with local motion signals. It is studied in the fields of computer vision and visual perception. In biological vision, SfM refers to the phenomenon by which humans (and other living creatures) can recover 3D structure from the projected 2D (retinal) motion field of a moving object or scene
- Creation of 3D models from multiple images
 - Based on multiple (tangential) images of a scene, the software performs:
 - Automatic matching of images
 - Automatic computation of camera calibration
 - Automatic dense matching for depth map generation 3D model
- Accuracy
 - Resolution: the higher the resolution of the images, the better chance of achieving high accuracy because items can be more precisely located
 - Camera Calibration is the process of determining the camera's focal length, format size, principal point, and lens distortion. There are a number of ways of obtaining this camera information and using a camera fully calibrated in PhotoModeler will give the best results.
 - Angles Between Photos: points and objects that appear only on photographs with very low subtended angles (for example a point appears in only two photographs that were taken very close to each other) have much lower accuracy than objects on photos that are closer to 90 degrees apart. Making sure the camera positions have good spread will provide the best results.
 - Photo Orientation Quality: during processing, PhotoModeler computes the location and angle of the camera for each photo - this is called Orientation. One factor that contributes a lot to the accuracy of projects is an accurate orientation for every camera position. The orientation quality improves as the number of well-positioned points increases and also as the points cover a greater percentage of the photograph area.
 - Photo Redundancy: a point's or object's position is usually more accurately computed when it appears on many photographs - rather than the minimum two photographs.

- Targets: the accuracy of a 3D point is tied to the precision of its locations in the images. This image positioning can be improved by using targets. PhotoModeler uses the image data to sub-pixel mark the point and this increases the precision of its placement and hence the overall accuracy of the point's computed 3D location.
- Drone, kites and balloons are ways to get aerial photos