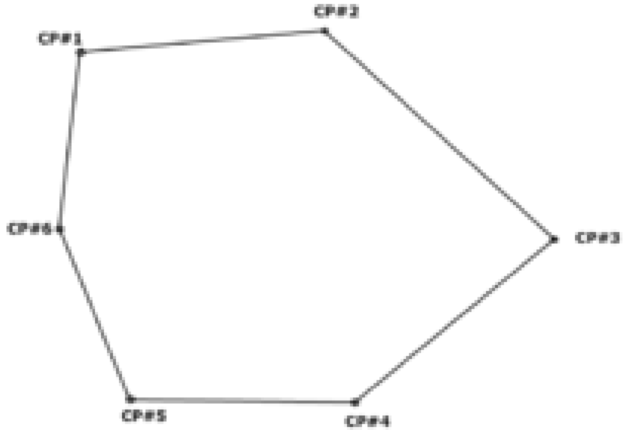
Control of Surveying

Control of surveying

- Regardless to the techniques and equipments, the basic principles of surveying are:
  - **1- Control**
  - **2- Economy and accuracy**
  - **3- Consistency**
  - **4- Independent checks**
  - **5- Safeguarding**

1- Control

- Any surveying process depends upon the establishment of a carefully measured control framework, which should encompass the whole area to be surveyed.
- Subsequent work is then fitted inside this framework and is adjusted to it.
- The accuracy of the control points must be known and better than the required to maintain high level of quality.
- If there is an extension for the survey area, a new framework must be established for it, not using the original framework.



2- Economy and accuracy

- It is important, before any survey operation is started, to weigh the accuracy against the time, resources and money available.
- To preserve the required accuracy, more checks and more observations may be performed.
- The accuracy will be the same or less than the accuracy of the control points.

3- Consistency

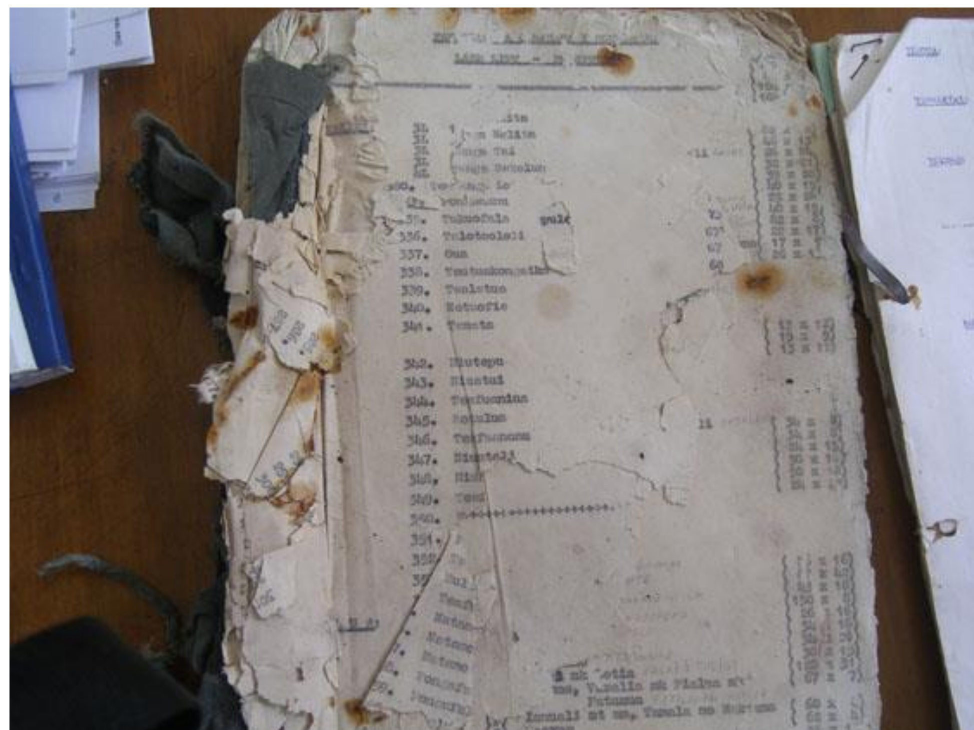
- The accuracy must be consistent throughout the survey covering all points.
- A certain standard of accuracy must be defined for the work and all stages of the survey must be designed to meet the requirements.

4- Independent checks

- Every survey operation should be subjected to checks.
- It is preferable to employ a system of self-checking process.
- If self-checking was not possible:
  - New approach for measurement (i.e. measuring from the other side of a line)
  - Taking extra measurements
  - Using different method or technique

5- Safeguarding

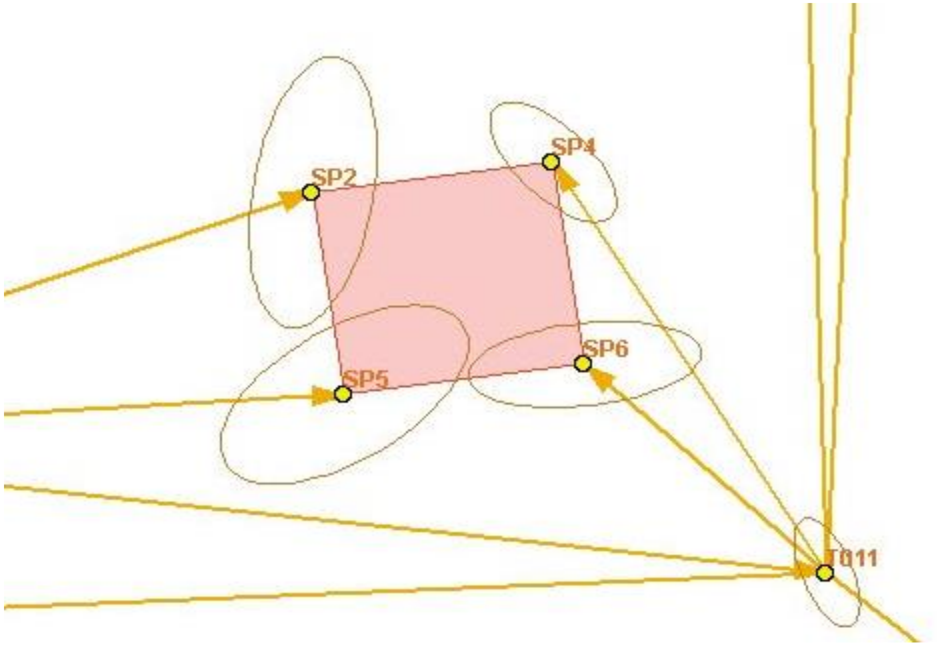
- The engineer must take precautions to ensure that his/her work is preserved for the future and that records of the work is properly kept.
  - BM must be permanent and easy-to-replace
  - The work must be done is such away that is understandable by others.



Types of control survey

- 1- Horizontal control
- 2- Vertical control

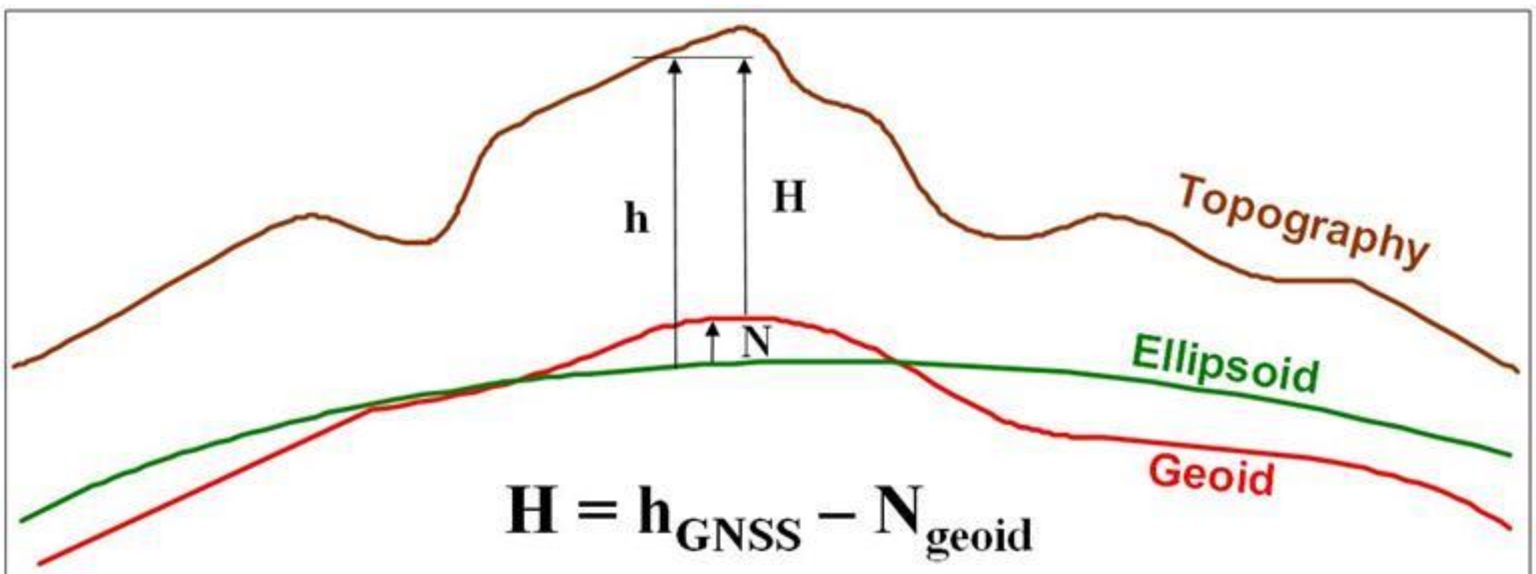
- **1- Horizontal control:** is used to describe all forms of control of position whether they are expressed in terms of Easting and Northing or Longitude and Latitude.



Methods of horizontal control

- **1- Astronomical observations:** used to determine longitude, latitude and azimuth at individual points by making observations to the sun or other stars.
- **2- Satellite observations:** used to determine the position of any point using different methods and techniques (i.e. GPS and GLONASS)
- **3- Triangulation:** provides a network of triangles over the area using angle and distance measurements
- **4- Trilateration:** similar to triangulation, but the only observation is distance measurement.
- **5- Traversing:** provides a line of points, fixed by bearing and distances starting at a known point and closing on the same or another known point.

- **2- Vertical control:** is used to describe all forms of control of height or altitude corresponding to the horizontal control, to determine the 3D position of any point.
- The methods of vertical control:
  - 1- Levelling
  - 2- Trigonometric levelling
  - 3- precise levelling (three wire levelling)
- Vertical control must be based on an accurate framework of heights.

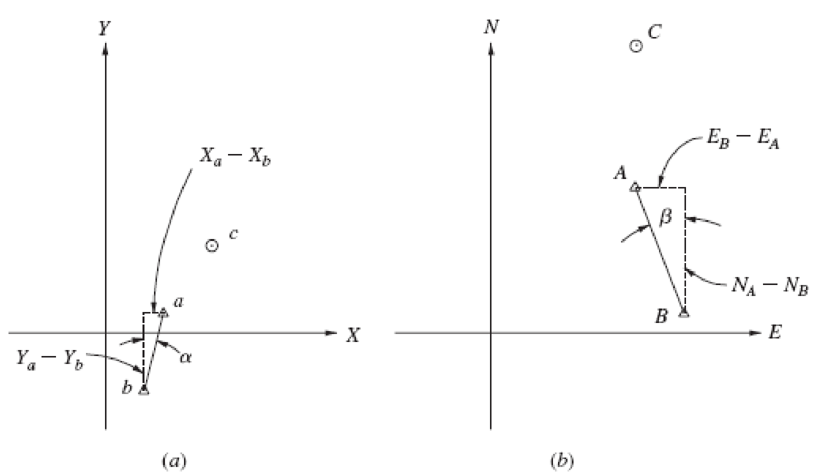


Coordinate transformation

- Sometimes coordinates need to be transformed from one coordinate system to another. For example transforming coordinates from an arbitrary coordinate system to a final system.
- It is required to find the parameters of the coordinate transformation to convert the coordinates from one system to another. For this purpose, the coordinates of some points must be known in both systems.
- The coordinate transformation can involve any of the following or the combination of the following parameters:
  - **Scale factor:** Distance between two points might not be equal in both coordinate systems. It is expressed as a multiplication factor
  - **Rotation:** The two major axes of one coordinate system might be inclined at a specific angle to the two major axes of another coordinate system
  - **Translation:** A shift in the origin of one coordinate system to another either in X direction, Y direction or both
- **Scale factor:** If the lengths of lines *ab* and *AB* are unequal, the scales of the two coordinate systems will be unequal. The scale of the *XY* system is made equal to that of the *EN* system by multiplying each *X* and *Y* coordinate by a scale factor *s*. The scaled coordinates are designated as *X*' and *Y*'. By use of the two control points, the scale factor is calculated in relation to the two lengths *AB* and *ab* as:

$$s = \frac{AB}{ab} = \frac{\sqrt{(E_B - E_A)^2 + (N_B - N_A)^2}}{\sqrt{(X_b - X_a)^2 + (Y_b - Y_a)^2}}$$

(a) Arbitrary XY two-dimensional coordinate system. (b) Ground EN two-dimensional system.



- **Rotation**: If the scaled *X'Y'* coordinate system is superimposed over the *EN* system so that line *AB* in both systems coincides. An auxiliary axis system *E'N'* is constructed through the origin of the *X'Y'* axis system parallel to the *EN* axes. It is necessary to rotate from the *X'Y'* system to the *E'N'* system, or in other words, to calculate *E'N'* coordinates for the unknown points from their *X'Y'* coordinates. The *E'N'* coordinates of point *C* may be calculated in terms of the clockwise angle θ by using the following equations:

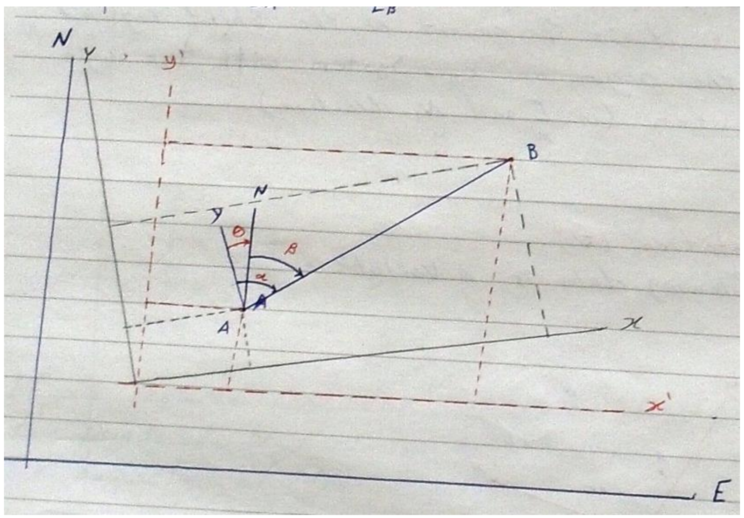
$$E'_C = X'_C \cos\theta - Y'_C \sin\theta$$

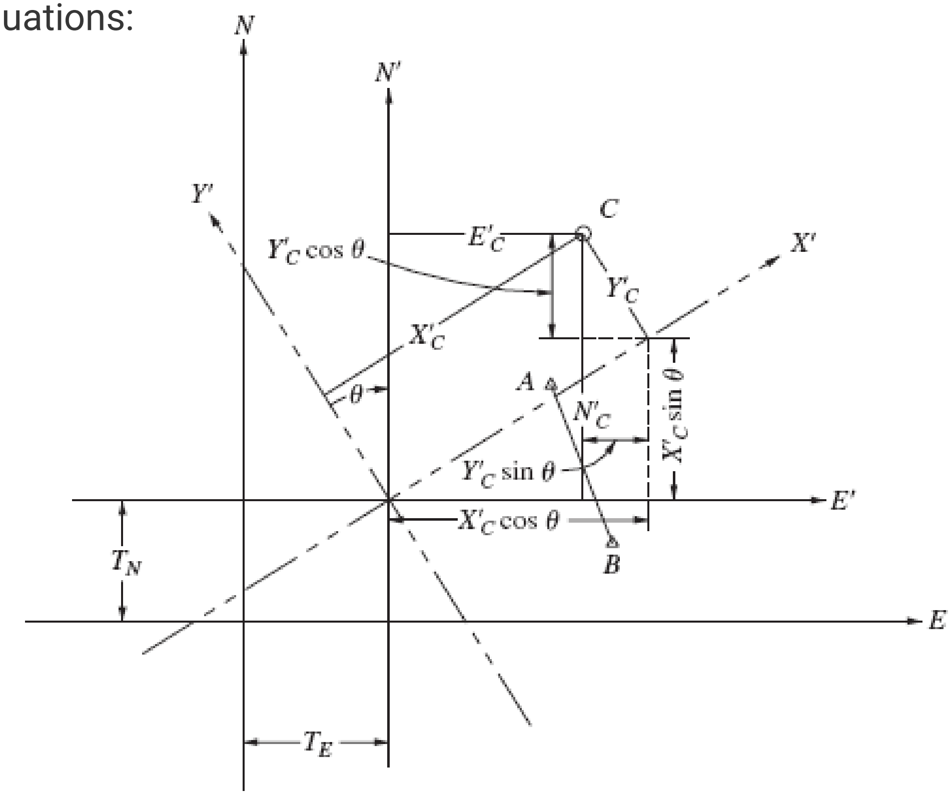
$$N'_C = X'_C \sin\theta - Y'_C \cos\theta$$

$$\theta = \alpha - \beta$$

$$\alpha = \tan^{-1}\left(\frac{X_a - X_b}{Y_a - Y_b}\right)$$

$$\beta = \tan^{-1}\left(\frac{E_B - E_A}{N_A - N_B}\right)$$





- **Translation:** The final step in the coordinate transformation is a translation of the origin of the *E'N'* system to the origin of the *EN* system. The translation factors required are T_E and T_N. Final *E* and *N* ground coordinates for points *C* then are:

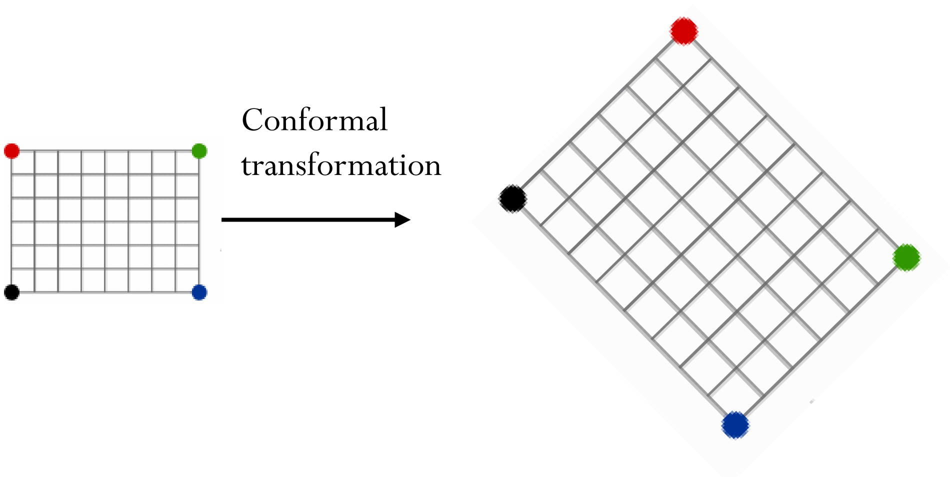
$$E_C = E'_C + T_E$$

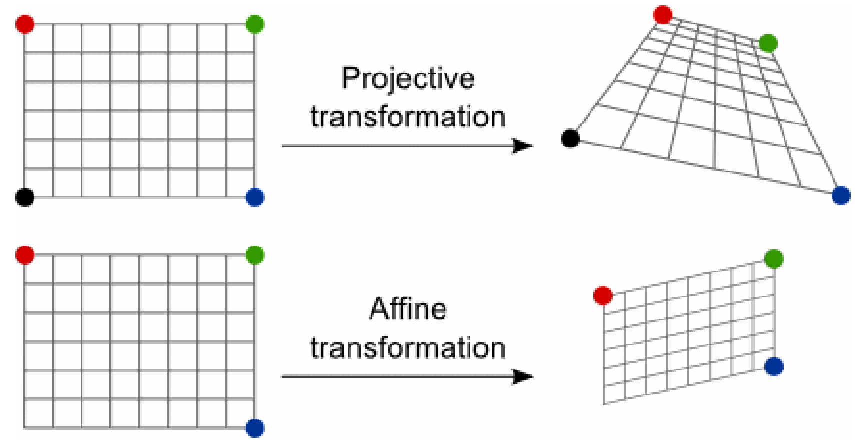
$$N_C = N'_C + T_N$$

$$T_E = E_A - E'_A = E_B - E'_B$$

$$T_N = N_A - N'_A = N_B - N'_B$$

- <u>**Three types of coordinate transformation:**</u>
  - A **projective transformation** shows how the perceived objects change as the observer's viewpoint changes. Projective transformations do not preserve parallelism, length, and angle.
  - **Affine transformation** is used for scaling, skewing and rotation. Affine transformations, unlike the projective ones, preserve parallelism.
  - A **conformal transformation** is one in which true shape is preserved after transformation





Example

a and *b* the arbitrary and ground coordinates of points *A* through *C* are as follows:

Point	(Arbitrary Coordinates) *X*	(Arbitrary Coordinates) *Y*	(Ground Coordinates) *E*	(Ground Coordinates) *N*
A	632.17	121.45	1100.64	1431.09
B	355.20	-642.07	1678.39	254.15
C	1304.81	596.37		

$$s = \frac{\sqrt{(1678.39-1100.64)^2+(254.15-1431.09)^2}}{\sqrt{(355.20-632.17)^2+(-642.07-121.45)^2}}$$

$$= \frac{1311.10}{812.20} = 1.61425$$

It is required to compute the coordinates of point *C* in the ground *EN* system.

Solution

1. The scale factor is calculated .

The arbitrary coordinates are then expanded to the *X'Y'* system, which is equal in scale to the ground coordinate system, by multiplying each of the arbitrary coordinates by the scale factor. After multiplication, the *X'Y'* coordinates are as follows:

Point	(Scaled Coordinates) *X'*	(Scaled Coordinates) *Y'*
A	1020.48	196.05
B	573.38	-1036.46
C	2106.29	962.69

$$\tan\alpha = \frac{632.17-355.20}{121.45+642.07} = 0.362754 \qquad \alpha = 19.9384°$$

$$\tan\beta = \frac{1678.39-1100.64}{1431.09+254.15} = 0.490892 \qquad \beta = 26.1460°$$

$$\theta = 19.9384° + 26.1460° = 46.0845°$$

2. The rotation angle, calculated

obtain *E'* and *N'* coordinates. The solution in tabular form is as follows (with $\sin\theta = 0.720363$, and $\cos\theta = 0.693597$):

Point	X' cos θ	Y' sin θ	X' sin θ	Y' cos θ	E'	N'
A	707.80	141.23	735.12	135.98	566.57	871.10
B	397.70	-746.63	413.04	-718.89	1144.32	-305.84
C	1460.92	693.49	1517.29	667.72	767.43	2185.01

3. The translation factors T_E and T_N are calculated next,

$$T_E = E_A - E_A' = 1100.64 - 566.58 = 534.07$$

also $$T_E = E_B - E_B' = 1678.39 - 1144.32 = 534.07 \qquad \textit{Check!}$$

$$T_N = N_A - N_A' = 1431.09 - 871.10 = 559.99$$

and $$T_N = N_B - N_B' = 254.15 + 305.84 = 559.99 \qquad \textit{Check!}$$

By adding the translation factors, the final transformed E and N coordinates of point C are obtained

$$E_C = 767.43 + 534.07 = 1301.49$$

$$N_C = 2185.01 + 559.99 = 2745.01$$