SURVEYING TO DETERMINE COORDINATES

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A coordinate system is a method for identifying the location of a point on the earth. Most coordinate systems use two numbers, a coordinate, to identify the location of a point. Each of these numbers indicates the distance between the point and some fixed reference point, called the origin.

The Projected coordinates of a point are a pair of numbers that define its exact location on a two-dimensional plane. Recall that the coordinate plane has two axes at right angles to each other, called the $x$ and $y$ axis.

The abscissa is another name for the $x$ (horizontal) coordinate of a point. Pronounced "ab-SISS-ah" (the 'c;' is silent).

The ordinate is another name for the $y$ (vertical) coordinate of a point. Pronounced "ORD-inet".
Surveying to determine coordinates

Before, going into the subject of “Surveying to determine the coordinates”, we will go through the principles of Surveying:

1. **Working from whole to the part.**

2. Economy of accuracy:

3. Consistency of accuracy:

4. Independent checks

First one is the basic principle that is being employed in all types of survey work. According to this principle, while surveying in fairly extensive areas, first a system of **control points** is to be established. The positions of these points are to be fixed with a **high standard of accuracy**. In between these points the work can be carried out by less accurate and less expensive methods. The idea of working in this way is to prevent accumulation of errors.

On the other hand if the reverse process is followed and the survey is made to expand outwards, it will generally be found that minor errors become highly magnified and the process becomes uncontrollable at the end.
Control Survey is an accurate survey carried out to determine co-ordinates of selected points of a region forming a basis for more detailed surveys.

IMPORTANCE OF SURVEYING TO DETERMINE COORDINATES:
1. For subsequent detail survey.
2. For doing any project survey.
3. For Geo-referencing of Maps.
4. For Photogrammetric work.
5. Acquisition of ground control point coordinates (GCPs) are particularly important for geometric correction of high resolution satellite images.
**Surveying to Determine Coordinates**
(Classification of Coordinates)

Even though there are many types of Coordinates, here we are discussing the classification meant in context to Surveying.

The Co-ordinates are classified depending on the Projection

1. Geographic co-ordinates
   (Non-projected coordinates)
2. Projected co-ordinates
   a. Rough assumed coordinates
   b. Projected coordinate
   c. ECEF coordinate.

The Co-ordinates are classified depending on the surface

1. Horizontal control co-ordinates
   (2D Control / x,y axis control)
2. Vertical control co-ordinates
   (Z-axis control only)
3. Full control co-ordinates
   (3D Control / x,y & z axis control)

**ECEF** (acronym for *earth-centered, earth-fixed*), also known as **ECR** (initialism for *earth-centered rotational*), is a geographic and Cartesian coordinate system and is sometimes known as a "conventional terrestrial" system. It represents positions as X, Y, and Z coordinates. The point (0, 0, 0) is defined as the center of mass of Earth, hence the term **geocentric coordinates**.
2D coordinates for surveying can be determined by measuring horizontal distances and horizontal angles. This type of survey is often referred to as HORIZONTAL CONTROL. These positions can be referenced by parallels or plane coordinate axes. Because they are used as a framework for other surveys, these surveys must be precise and accurate. These surveys provide a network of monuments or points on the ground that can be used as the control for any other surveying project, such as a boundary or construction survey.

The advantages of using a horizontal control survey is that lost monuments can be replaced accurately, surveys can be cordinated, more than one network station can provide a check to the work, and a reduction in the cost of the project can be achieved. Most horizontals should (and will) be connected to the control network.
Surveying to determine the Z coordinate is carried out by measuring horizontal distances and vertical angles. This type of survey is often referred to as VERTICAL CONTROL. A vertical control survey determines elevation with respect to some reference datum i.e., sea level. These surveys are also used as a benchmark upon which other surveys are based and high degree of accuracy is required. These surveys are useful for tidal boundary surveys, route surveys, construction surveys and topographic surveys. In a vertical control system, at least two permanent benchmarks should be used, but more may be required depending upon the needs and complexity of the project. These projects are needed for the construction of water and sewer systems, highways, bridges, drains, and other major town or city infrastructure. These surveys can be done alone, but are often done in conjunction with a horizontal control survey.
A 3d coordinate determination, create a framework around which other surveys can be adjusted. These 3d coordinates are used for accurate mapping projects in the construction of underground utility systems, roadways, power lines, tunnels, and many other high precision projects.

Global Positioning technology including Static GPS, Real Time Kinematic (RTK) and Differential GPS to provide high precision solutions for determining the coordinates.
SURVEYING TO DETERMINE COORDINATES

Even though several methods to determine the coordinates for surveying, the main methods are by:

1. Triangulation
2. Trilateration
3. Traverse (Theodolite/EDM/Total Station)
4. GPS (Global Positioning System) or GNSS (Global Navigation Satellite System)

Theodolite

Digital Theodolites

TOTAL STATION
Triangulation

Triangulation is the process to establish a framework of 3d coordinates over a large area by observing the three angles of a triangle formed by the lines joining the three apex stations with the help of base line measurement.

These 3d coordinates are further supplemented for densification of controls using lesser order method of observation.

**Principle of Triangulation:** If all the three angles and length of one side of a triangle are known, the length of the remaining two sides can be computed by a well known formula of trigonometry (Sine rule) i.e.,

\[
\frac{\text{Sin } A}{a} = \frac{\text{Sin } B}{b} = \frac{\text{Sin } C}{c}
\]
Triangulation

Simple Chain Triangulation

- Simplest and quickest method.
- Used for lower order surveys
Triangulation
Polygon Triangulation
Depending upon the purpose, time, accuracy and nature of the country, a triangulation series may consists of various geometrical figures. But, at present determining the coordinates by Triangulation is completely obsolete and is replaced by GPS.
Trilateration is a method of surveying in which all the three sides of a triangle are measured. No angular observation is made.

Sides of a triangle are measured by following instruments EDM instruments, Total Station and or GPS.

After applying the corrections, the measured distances are converted into horizontal distances on the reference surface of the spheroid / ellipsoid.

The three angles are deduced using the simple trigonometrical cosine formulae, and able to determine the 3d coordinates.
Trilateration

\[ \cos A = \frac{b^2 + c^2 - a^2}{2bc} \]
\[ \cos B = \frac{c^2 + a^2 - b^2}{2ca} \]
\[ \cos C = \frac{a^2 + b^2 - c^2}{2ab} \]
Drawbacks of Triangulation & Trilateration

Triangulation and Trilateration method of surveying in which inter-visibility between the stations is essential.

Both the methods require huge working force.

Consumes much time for surveying.

Accurate care should be taken while surveying.

Several Mathematical computations are involved to **determine the coordinates of the points**.

Getting instant coordinates is not at all possible.

For the above reasons both the methods are obsolete now a days and are replaced by GPS Surveying.
Traverse is the method of determining the 3d coordinates along a pre-defined route by means of establishing a series of connected lines joining the traverse stations. These lines are called traverse leg and their lengths are measured by means of tape, EDM instrument, and Total Station and their directions are measured with respect to reference line.

**Traverse angle:-**
The horizontal angle subtended at the Traverse Station of observation between the Back Traverse Station and Forward Traverse Station is called Traverse angle.

Distance and angle are the two essential elements for the determination of 3d coordinates.
Traverse Surveys

**IMPORTANCE OF TRAVERSE**

Traverse is very much essential while determining the coordinates at the places where there is no provision of erecting GPS i.e., the sky is not open. Example: Wooded areas, Jungle areas.

The reference line may be:
- True North i.e. Meridian line
- Grid North line
- Magnetic North line
- Any arbitrary reference line.
Types of Traverse

A traverse may be classified as
(i) closed traverse
(ii) open traverse

Closed traverse: - A traverse which starts from a known station and closes on to another known station or on the same station is called closed traverse.
Types of Traverse

**Open traverse:** - A traverse which starts from a known station and does not close on to another known station or on to the station but left hanging is called open traverse.

Ideally, a traverse should always be a closed traverse whose starting and closing points should be different and not to be the same point.
Different formulas used in Traverse

Sum of interior angles = \((n-2)180^\circ\)

where \(n\) is no of stations.

Sum of exterior angles = \((n+2)180^\circ\)

where \(n\) is no of stations.

\[
\text{Difference in Easting} = D \cdot \sin \theta, \quad \text{where } D \text{ is the projection distance and } \theta \text{ is bearing.}
\]

\[
\text{Difference in Northing} = D \cdot \cos \theta, \quad \text{where } D \text{ is the projection distance and } \theta \text{ is bearing.}
\]

\[
\text{Difference in height } h = D \cdot \tan \theta, \quad \text{where } D \text{ is the horizontal distance and } \theta \text{ is vertical angle.}
\]
SURVEYING TO DETERMINE COORDINATES
(Determining Z coordinate)

Accurate Z coordinate can determined by only leveling. Even though Z coordinate can be established by triangulation/traverse/GPS the heights are obtained by mathematical computations and are not so accurate.

GPS provides Z coordinate with reference to WGS-84 ellipsoid and Z coordinate is known as ellipsoidal height and its reference in not MSL. After applying geoidal undulation correction also the Z coordinate is nearly equal to MSL, but not so accurate to match with it.

Now a days to obtain accurate Z coordinate, bar coded Digital levels (example: Leica DNA 03) are used, which can give the Z coordinate up-to forth decimal of a meter i.e. 1/10 the mm and every reading is recorded digitally.
**Principle of Leveling:** The horizontal line of sight is established with the help of an instrument, called level. Graduated scales known as staffs are normally used to determine the altitude difference.

Let height of A = \( H' \)
Height of level surface \( ab \) = \( H' + Aa \)
Height of B can be obtained by subtracting \( bB \) from the height of level surface \( ab \) i.e. Ht of B = \( H' + (Aa - bB) \), where \( (Aa - Bb) \) is the difference of two staff reading.

By successive readings, heights of other points can be established. **Digital Level** records all readings digitally, with the help of Modern bar coded staves.
CONTROL SURVEY BY GPS
(Full control – 3D)

- Consumer Grade GPS
- Survey Grade GPS
- Use of two receivers
- instead of just one (CORS
- CORS Continuously Operated Receiver Stations.
Control Networks

Why is it necessary to have a common countrywide coordinate system?

Many engineering tasks cover a large area (highways, bridges, tunnels, channels, land registry, etc.), where the common coordinate system (reference system) should be available.

The Control Network provide us with the coordinate points given in the same reference system (coordinate system).

Thus measuring the relative positions of unknown points using these provided coordinate points, the coordinates of the new points can be computed in the same reference system.
Possible consequences of using inconsistent reference systems
Determining the Number of Ground Control Points (for surveying)

Selection of number of Control Points:

As a general rule, it has been laid down that for an area of 40cm X 40cm on the scale of survey, the number of control points should be 20 to 40. In addition, adequate control points also need to be established on the four flanks of the area of ground survey. The reason being it will facilitate the surveyor to fix his positions on the plane-table board for subsequent ground survey by plane tabling (PT) method.
Determining the Number of Ground Control Points 
(for ortho-rectification of imagery)

The first step in obtaining GCPs for use in orthorectification is determining the number of control required for your area of interest. In general, one has to collect at least 10 GCPs to have extra control to toss out if it is of low quality and/or use for accuracy testing; and if you can collect more than 10 points, by all means please do!

More GCPs are required: (1) as your area of interest grows in size; (2) in areas with lots of terrain change; and (3) if you have multiple overlapping images to orthorectify.

Here is an equation you can use to help determine the number of GCPs to collect:

Number of Control = 10 + (Area Covered in Square Kilometers / 25) + (2 x Number of Overlapping Scene Edges)

So if you had a polygon that is 150 sq km with two scenes that overlaps at a single edge, then you would want to collected at least 18 GCPs. Please keep in mind this equation is just a rule of thumb and is definitely not accurate in all cases, for example if the area is very mountainous.
NATIONAL GCP LIBRARY
(http://www.surveyofindia.gov.in/files/pdf/63_meta%20data.pdf)

To obtain the list of GCP.s from National GCP Library login to http://www.surveyofindia.gov.in/files/pdf/63_meta%20data.pdf

Note: In the near future, that is on completion of the third phase of Nation GCP Library state cadastral department can use the Control Points from GCP Library and they can be part of Nation Mapping
Datum transformation from Geographic to ECEF and vice versa online

http://www.oc.nps.edu/oc2902w/coord/llhxyz.htm

Latitude, Longitude, Height to/from ECEF (X,Y,Z)

This converter uses N latitude and E longitude. Heights are in meters, and are ellipsoidal heights. There is no geoid model included. The WGS 84 ellipsoid is used.

Enter either:
- Latitude, Longitude, and Height, or
- Earth Centered, Earth Fixed (ECEF) x-y-z values in km
- And press the conversion direction desired.
- Answers appear in the text box below the input.

The current values in the input fields are used. Blanks are treated as zero.
(If you enter latitude-longitude-height and press the wrong button with the x-y-z fields blank - you get the earth center location in LLH.)

Latitude 17.426811  Longitude 78.371441  Height 485 meters

ECEF - X km  ECEF - Y km  ECEF - Z km

LLH to ECEF  ECEF to LLH

ECEF from Latitude, Longitude, Height (ellipsoidal)

X : 1227.069 km
Y : 5962.723 km
Z : 1898.099 km
Datum transformation from Geographic to UTM and vice-versa online
http://www.synnatschke.de/geo-tools/coordinate-converter.php

<table>
<thead>
<tr>
<th>Geographic Tools :: Coordinate Conversion / Datum Transformation</th>
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</thead>
<tbody>
<tr>
<td><strong>Geographic coordinates (Latitude, Longitude)</strong></td>
</tr>
<tr>
<td><strong>Hemisphere</strong></td>
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<tr>
<td>Latitude:</td>
</tr>
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<td>Longitude:</td>
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<td>78</td>
</tr>
<tr>
<td><strong>UTM Coordinates</strong></td>
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<tr>
<td>Zone/Sector:</td>
</tr>
</tbody>
</table>

*Datum: WGS84/NAD83

Magnitude of total shift (WGS84 vs. NAD27): N/A

*Instructions*

1. Enter the GPS coordinate and the desired datum in one of the columns above.
2. Select the hemisphere, if you want to convert Lat/Long values into UTM.
3. In case of datum transformation, select the desired datum in the target column(s).
4. Press the convert button.

*Note: The datum transformation is an approximation and works for the continental US (CONUS), Alaska and Canada only, because it uses the Molodensky equation and fixed shift parameters for those areas.*
TO OBTAIN GEOIDAL UNDULATION VALUE
(Online – example)

Online geoid calculations using the GeoidEval utility

Position (ex. «16.78 -3.01», «16d46'33"N 3d0.6'W»):
17.5 78.5

Select action:
Submit  Reset

Geoid height:

lat lon = 17.50000 78.50000 (17°30'00"N 078°30'00"E)
geoid heights (m)

EGM2008 = -76.3442
EGM96 = -76.5810
EGM84 = -76.0815
Questions?
Thanks for your attention !!!