Geodetic Datum Transformation

What coordinates? Which system? Where is the point on the ground?

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Summary

- Geodetic datum
- Coordinate system
- Map projection
- Datum transformation
- Positioning error
- Practical issues relating to coordinate values

Geodetic Datum

The definition:

Geodetic datum is defined as

"A set of constants specifying the coordinate system for a collection of points on the Earth surface."

Definition of Geodetic Datum (local datum)

For classical geodesy, a local geodetic datum (e.g. HK80 geodetic datum) is customary defined by:

- latitude and longitude of initial point
- azimuth of a line from this point
- semi-major axis and flattening of the reference ellipsoid
- The deflection of vertical at the initial point (optional)

Definition of Hong Kong 1980 Geodetic Datum

Datum parameters of Hong Kong 1980 geodetic datum

- latitude and longitude of initial point
  - Old trig "zero"at the Observatory:

    Latitude 22^{o} 18' 12.82" Longitude 114^{o} 10' 18.75"
- azimuth of a line from this point
  - Trig 67.2 to Trig 94 : 292^{o} 59' 46.5"
- semi-major axis and flattening of the reference ellipsoid
  - Reference ellipsoid : International Hayford (1910)

    a = 6378388m f = 1/297

Local Geodetic Datum

A local geodetic datum is realised by

- best fitting the size, shape and location of the reference ellipsoid to the local region.

- Note : An ellipsoid is not a datum.

  Many countries have used the same ellipsoid but they are on different datum as they have different points of origin.

Definition of Geodetic Datum (global datum)

For satellite geodesy, a global geodetic datum (e.g. WGS 84) is defined by :

- Three constants to specify the origin of the coordinate system (x, y, z)
- The constants to specify the orientation of the coordinate system
- Two constants to specify the dimension of the reference ellipsoid (a and f)

Definition of World Geodetic System 1984

- The WGS84 is a geocentric reference system
  - The origin is the Earth’s center of mass
- The Z axis is the direction of the Conventional Terrestrial Pole for polar motion
- The X axis is the Intersection of the zero meridian and the equator
- The Y axis completes a right-handed, earth-centered, earth-fixed orthogonal coordinate system.

Definition of World Geodetic System 1984

- Parameters of the WGS84 ellipsoid
  - semi-major axis (a) : 6378 137m
  - flattening (f) : 1/ 298.2572235634

- WGS 84 was established by the Department of Defense of the USA (National Imagery and Mapping Agency)

Definition of World Geodetic System 1984

- WGS84 is realised by adopting the coordinates of stations around the world surveyed by **Doppler** satellite surveying technique.

- The origin of WGS84 is located at the Earth cente with an uncertainty of **1 to 2** meters

Definition of ITRF

- International Earth Rotation Service Terrestrial Reference Frame (ITRF) is a conventional terrestrial reference system

- It is defined and maintained by the International Earth Rotation Service (IERS)

Definition of ITRF

- The **origin, reference direction and scale** of ITRF are implicitly defined by the coordinates adopted for the observation sites (Fiducial Stations and terrestrial sites).

Definition of ITRF

- The coordinates of the observation sites are determined by high precision space measurement techniques (e.g **GPS**, very long baseline interferometry **VLBI**, satellite laser ranging **SLR**, and lunar laser ranging **LLR**).

- The origin of ITRF is located at the center of mass of the Earth with an uncertainty of **a few centimetres.**

Upgrade of WGS84

- WGS84 was defined in Jan 1987 using Doppler satellite surveying techniques
  - used as the reference frame for broadcast orbit on 23 January 1987
- WGS84 (G730), upgraded at the start of GPS week 730
  - used as the reference frame for broadcast orbit on 28 June 1994
- WGS84 (G873), upgraded at the start of GPS week 873
  - used as the reference frame for broadcast orbit on 29 January 1997

ITRF and WGS84

- The upgraded (refined) WGS84 (G873) has improved the accuracy of the position of the origin of the reference system

- WGS84 (G873) is now more closely aligned to the ITRF and the difference between these two systems is small.

Position difference between reference frames

The positional differences

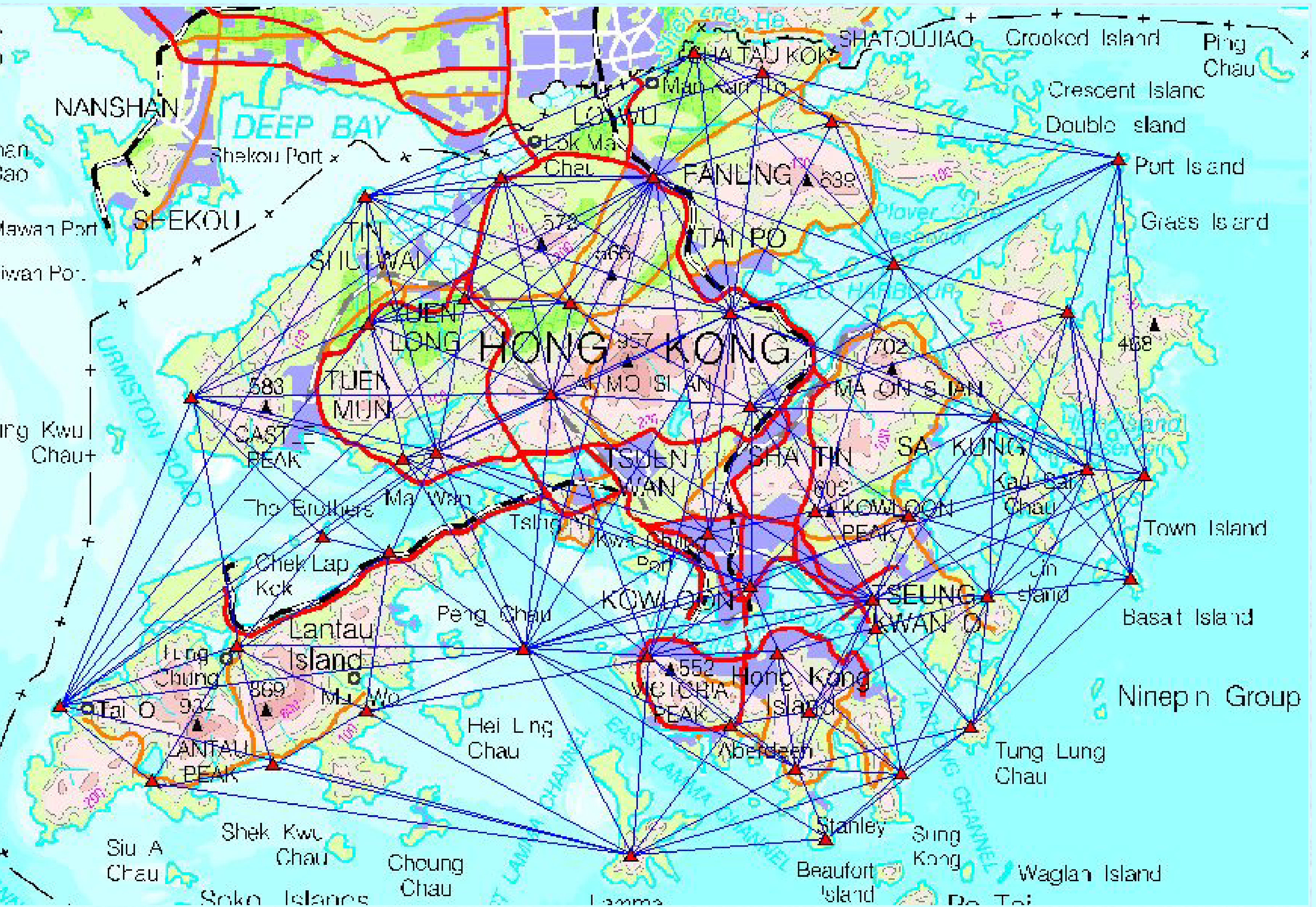
- between HK80 geodetic datum and WGS 84
  - about 200 m
- between WGS84 and ITRF 96 reference frame
  - about 2 m

1991 GPS Network

- The first GPS network of Hong Kong is surveyed in 1991
- The 1991 network used WGS 84 as the reference frame
- The origins point of the 1991 network is surveyed by the Special Team Royal Engineers (STRE) using Doppler satellite technique, the reference frame is also called STRE 91.

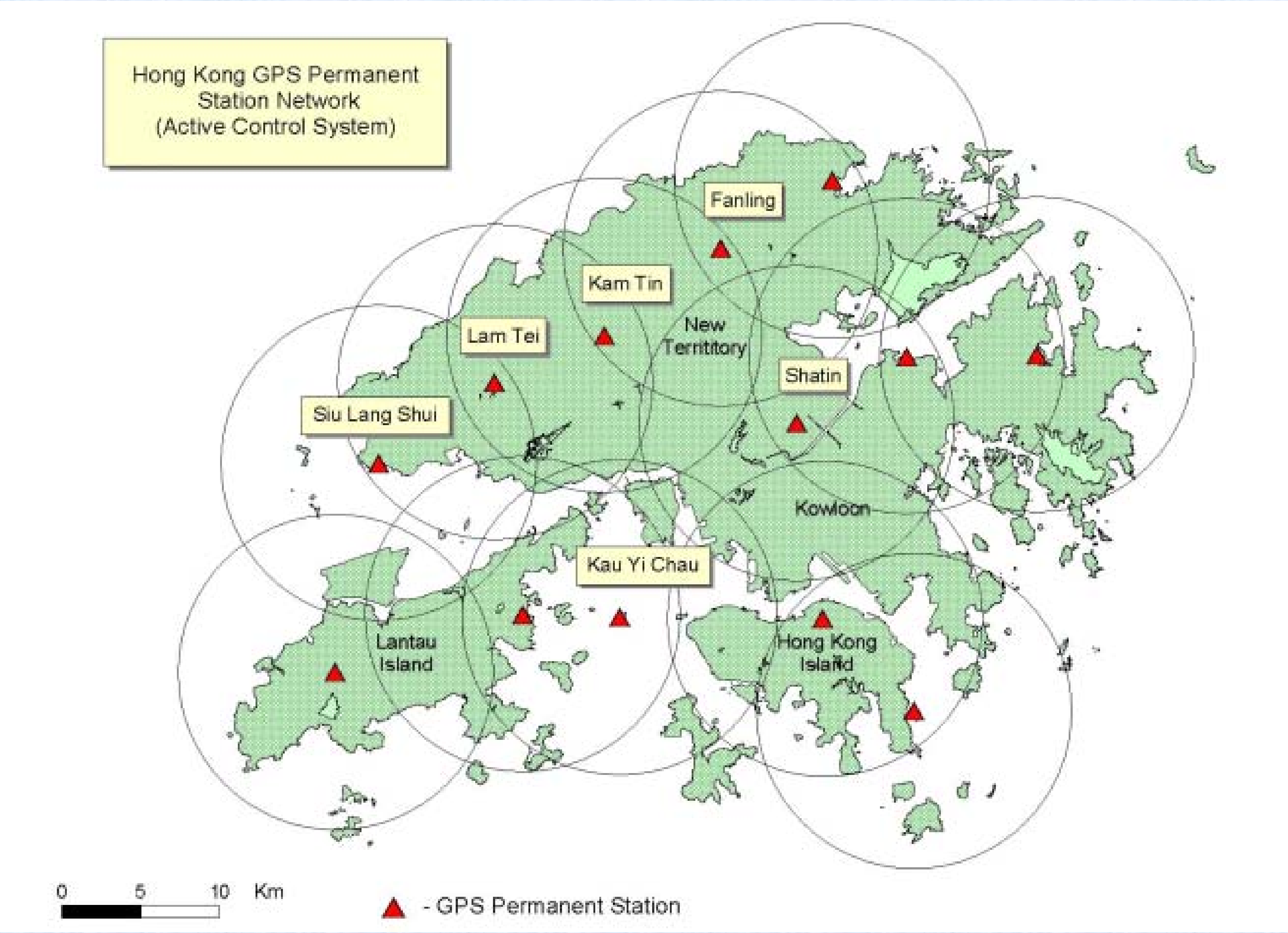
2000 GPS Network

- The 2000 GPS network improves and densifies the 1991 network.
- The Hong Kong Satellite Positioning Reference Station Network (SatRef) serves as the Active Control System
- Both the 2000 network and the Active Control System adopt ITRF 96 as the reference frame



10 km

2000 GPS Network



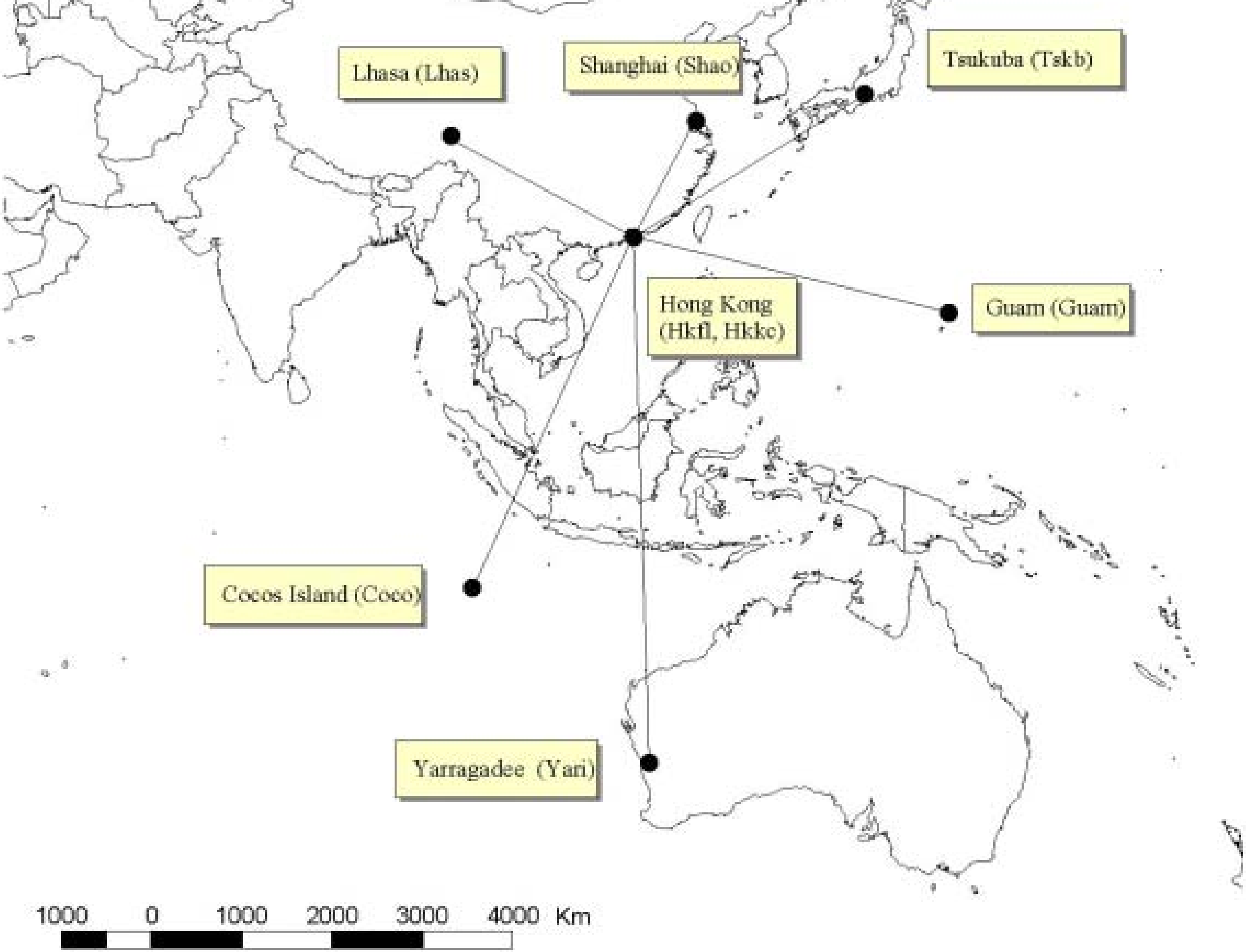
Layout of Active Control System

Connection of 2000 GPS Network to ITRF96

- Ties 2000 GPS to ITRF96
- Based on 2 months continuous GPS data
- Baseline length
  - 1200 to 5000 km

Connection 2000 GPS Network to ITRF96

- 2 Hong Hong GPS Reference Stations
  - Fanling, Kau Yi Chau
- 6 Global IGS Stations
  - Cocos Islands (Indian Ocean)
  - Guam (Pacific Ocean)
  - Lhasa (Western China)
  - Shanghai (Eastern China)
  - Tsukuba (Japan)
  - Yarragadee (Australia)



Linking Hong Kong datum to ITRF system

Coordinate System (3-Dimensional)

- Geodetic coordinates
  - Latitude, φ
  - Longitude, λ
  - Ellipsoidal height, h
  - Note : need definition of the reference ellipsoid
- Users
  - Cartographers (for mapping of the Earth)
  - Mariners (for navigation)
  - Geodetic Surveyors (for geodetic survey of large areas)

Coordinate System (3-Dimensional)

- Cartesian coordinates
  - x, y, z
  - Note : no need to define the reference ellipsoid
- Users
  - Space geodesists (describe the position of the Fiducial station of the reference frame)
  - Space scientists (describe the position of satellite orbit)
  - geodynamic scientist (monitoring of crustal deformation)

Coordinate System (2-Dimensional)

- Projection grid coordinates
  - Northing, N
  - Easting, E
- Users
  - Land Surveyor (for boundary survey)
  - Civil Engineer (for construction works)

Map Projection

Purpose of map projection

- To represent a 3-D spheroid into a 2-D flat surface
- To allow computation in a simple 2-D coordinate system

  (Computation, such as distance between points, is excessively complex when expressed in spheroidal formulae)

Map Projection Parameter

Map projection of the Hong Kong 1980 grid system

- Projection name : Transverse Mercator
- Reference ellipsoid: International Hayford (1910)

  a= 6378388m f=1/297
- Scale factor along Central Meridian : one
- Geodetic coordinates at the projection center

  trig "two"at Patrick Hill

  Latitude 22^{o} 18' 43.68" Longitude 114^{o} 10' 42.80"
- Hong Kong 1980 grid coordinates at projection center

  Northing, 836694.05N Easting, 819069.80E

Datum Transformation

Transformation model

- Seven Parameters Transformation
  - three translation parameters (dx, dy, dz)
  - three rotation parameter (θx, θy, θz)
  - one scale factor (s)

- the transformation computation is based on the 3 -D Cartesian coordinate system

Transforming geodetic coordinates to projection grid coordinates

Transforming geodetic coordinates (in ITRF or WGS84) to HK1980 grid coordinates involves 3 steps

- Convert geodetic coordinates to Cartesian coordinates
- Carry out Seven Parameters Transformation (scale, shift and rotation)
- Perform map projection computation using Transverse Mercator projection formulae

Transforming geodetic coordinates to projection grid coordinates

Important notes

- Always use the correct transformation parameter corresponding to the associated reference frame.

Positioning Error

Measurements are subject to error

- Position is described by two elements
- The coordiantes: (x,y,z) or (φ, λ) or (N,E)
- The error of the coordinates : (σx, σy, σz) or ($\sigma\varphi$, $\sigma\lambda$) or (σN, σE)
- It is not uncommon to have different coordinates of the same point if we re-measure the point.

Reasons for having different coordinates

- The coordinates difference is within the expected error range :
  - No need to worry. It is normal.
- The coordinates difference exceeds the expected error range :
  - Is the control points based on a different **survey origin**?
  - Is there is any **systematic error or blunder** due to equipment defects, observation problem and computation mistake?

GPS survey accuracy and terrestrial survey accuracy

- GPS survey error :
  - Error in GPS measurement : 1-2 cm
  - Error in GPS control point, (e.g. reference station) : about 5 mm
- Terrestrial survey error
  - Error in total station measurement : 1-2 cm
  - Error in title survey control point
    - accumulation of error due to control breakdown :

      main trilateration, minor triangulation, main traverse, minor traverse, first generation of title control, second generation of title control, third generation of title control, forth generation of title control, ………….

      ………… : error can accumulate up to a few cm

Mixing of new control with old control points

I have one new control point surveyed by GPS and two old control points surveyed by total station, can I use these points together to run a traverse?

- In this case, the control points are used for controlling the traverse. If the consistence of these points can meet the accuracy standard of the traverse (say 1: 7500 for cadastral survey), they can be used together for running the traverse.
- You should carry out the normal procedure of “check origin” to check the consistence of these three points. If the results are acceptable, use the points together.

Survey of boundary features

I have surveyed some boundary stones and house corners. The positional relationship between these points remain unchanged as compared to the lease survey results done 20 years ago.

However when I compared the old survey results with the new results, I find that the coordinates of the points have shifted by several cm . What should I do?

- For boundary survey, the important boundary evidence is the position of the original or reliable monuments on the ground. The position of the reliable monuments do not change even after 20 years.
- The coordinate differences may be caused by the fact that a different survey origin is adopted. However, it does not affect our decision on the position of the boundary line on the ground.

Using GPS to survey control points separated by a short distance

I have surveyed three control points using GPS. The accuracy of the established points has met the accuracy standard (1 to 2 cm). These points are separated by 20 meters. As the lines between the points are short, the angle between the points (observed by total station) and the computed angle (using coordinates) does not match. What should I do?

Using GPS to survey control points separated by a short distance

Answer:

- To improve the relative accuracy between the points, we can include the directly measured angle (by total station) in the least squares adjustment when we compute the GPS survey results. This method is call inner-constraint. By doing this we can make the final coordinates agree with direct field measurements (which should be very accurate because the line is very short).
- In order to avoid mistake in setting the constraint (i.e. the field measurements), we should observe two sets of measurements (repeated measurements) to reduce the chance of having blunder.