Lesson 2: The Devil is in the Data: Collection, representation, and modelling

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What will you learn from this course?

- Getting to Know Geospatial Data Models
  - Vector Data Model
  - Raster Data Model
- Georeferencing and Geocoding
- Sources of GIS data

Getting to Know Geospatial Data Models

- Basic concept of geographical data
- Basic geospatial data models
- Vector data models
  - Spaghetti data models
  - Topological data models
- Raster data models

Discrete Objects and Continuous Fields

- Two ways of conceptualizing geographic variation
  - The most fundamental distinction in geographic representation
- Discrete objects
  - The world as a table-top
  - Objects with well-defined boundaries

Discrete Objects

- Countable, persistent through time, perhaps mobile
- Human-made objects
  - Office buildings, houses, bus stops, etc
- Biological organisms
  - Animals, trees

Continuous Fields

- Properties that vary continuously over space
  - Value is a function of location
  - Property can be of any attribute type, including direction
- Elevation as the archetype
  - A single value at every point on the Earth’s surface
  - The source of metaphor and language
  - Any field can have slope, gradient, peaks, pits

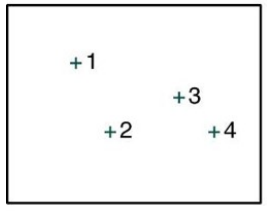
Basic Spatial Data Models

- Vector, implementation of discrete object conceptual model
  - Point, line and polygon representations
  - Widely used in cartography, and network analysis
- Raster, implementation of field conceptual model
  - Array of cells used to represent objects
  - Useful as background maps and for spatial analysis

Vector Data Models

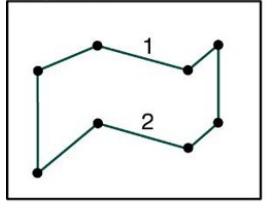
- Used to represent points, lines, and areas
- All are represented using coordinates
  - One per point
- Lines as polylines
  - Straight lines between points
- Areas as polygons
  - Straight lines between points, connecting back to the start
  - Point locations recorded as coordinates

Points



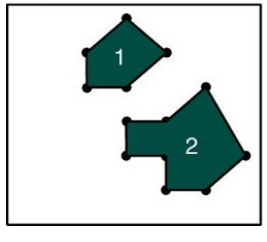
Point number	(x,y) coordinates
1	(2,4)
2	(3,2)
3	(5,3)
4	(6,2)

Polylines



Polyline number	(x,y) coordinates
1	(1,5) (3,6) (6,5) (7,6)
2	(1,1) (3,3) (6,2) (7,3)

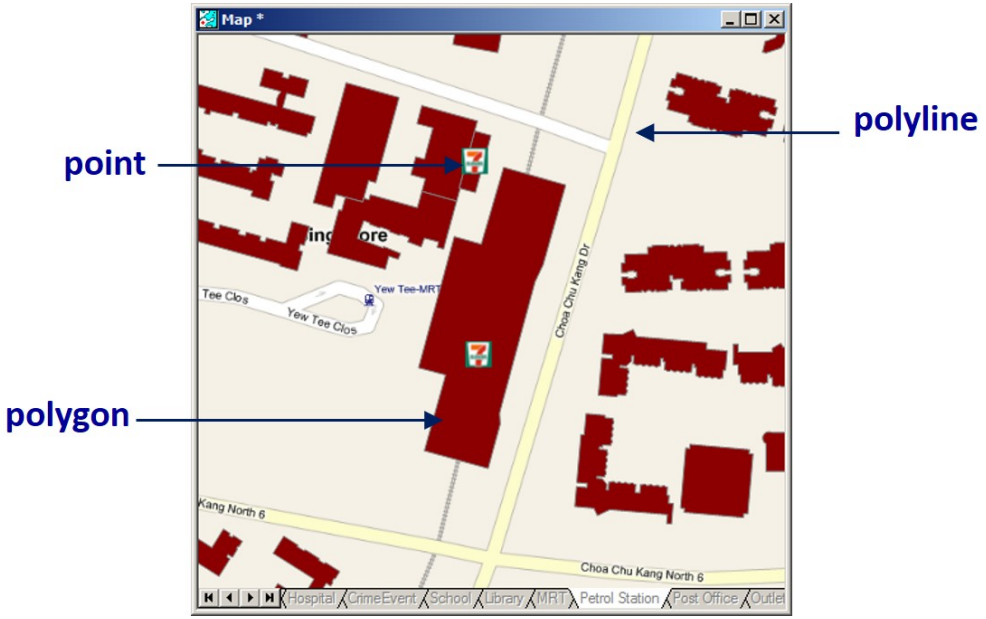
Polygons



Polygon number	(x,y) coordinates
1	(2,4) (2,5) (3,6) (4,5) (3,4) (2,4)
2	(3,2) (3,3) (4,3) (5,4) (6,2) (5,1) (4,1) (4,2) (3,2)

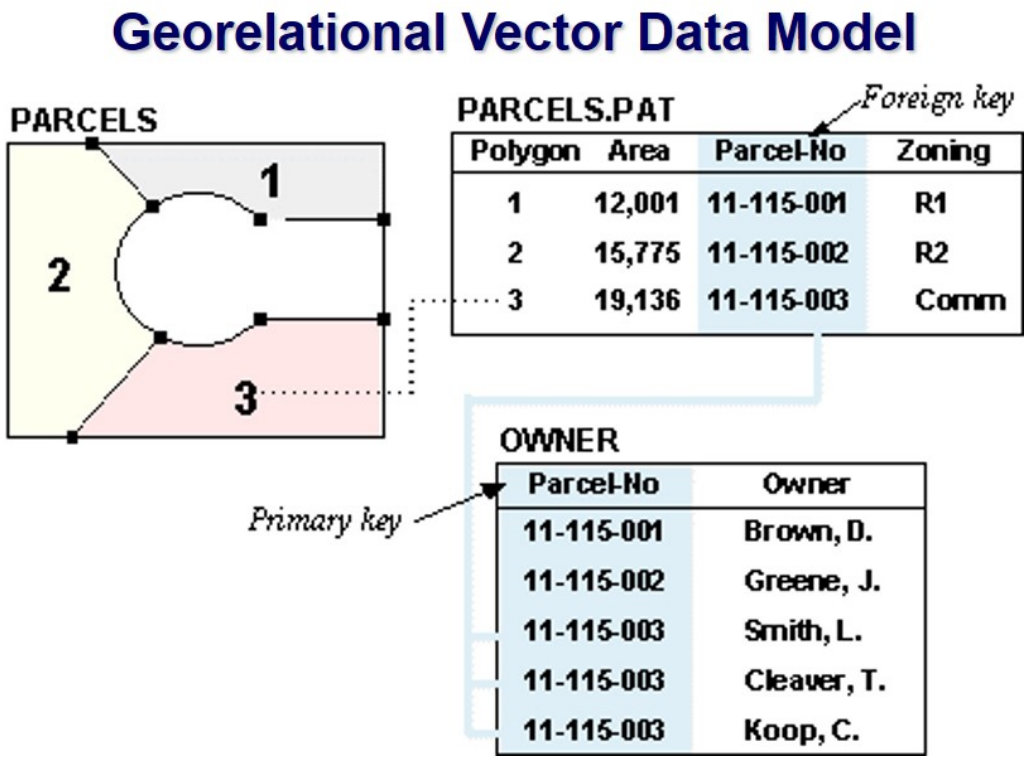
Vector Database

Building footprints are represented by polygon features, road reserves represented by polyline features, and convenient stores are represented by point features

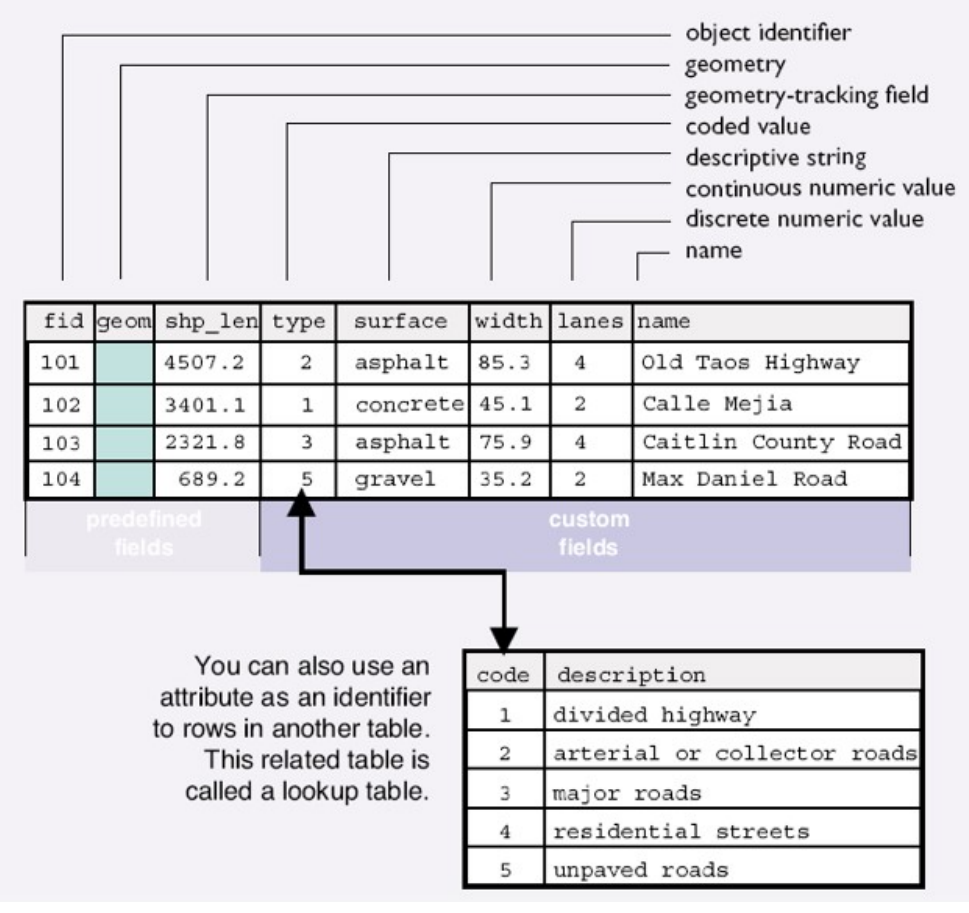


Georelational Vector Data Model

Stores spatial and attribute data separately in a split system: spatial data (”geo”) in graphic fields and attribute data (“relational”) in a relational database



Attribute Table



fid	geom	shp_len	type	surface	width	lanes	name
101		4507.2	2	asphalt	85.3	4	Old Taos Highway
102		3401.1	1	concrete	45.1	2	Calle Mejia
103		2321.8	3	asphalt	75.9	4	Caitlin County Road
104		689.2	5	gravel	35.2	2	Max Daniel Road

code	description
1	divided highway
2	arterial or collector roads
3	major roads
4	residential streets
5	unpaved roads

Types of Attributes: Numerical

10.0
23
8.63
-4.7

float

A float value contains one sign bit, seven exponent bits, and 24 mantissa bits.

double

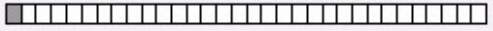
A double value contains one sign bit, seven exponent bits, and 56 mantissa bits.

-14
64
56
143

short integer

A short integer value contains one sign bit and 15 binary bits with a range of approximately –32 thousand to 32 thousand.

long integer



A long integer value contains one sign bit and 31 binary bits with a range of approximately –2 billion to 2 billion.

Graduated symbols

Any type of numeric value can be drawn with graduated symbols, which vary in proportion to a value.

Classified values

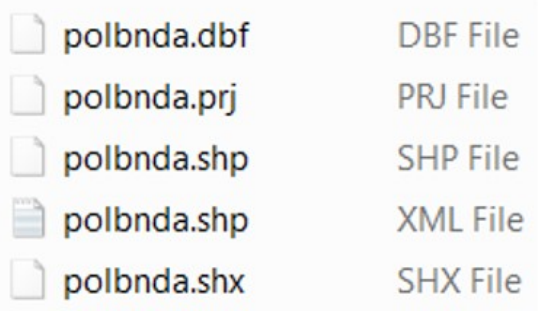
A classification is a statistical subdividing of the numeric values of a set of objects. Classified values are drawn with color ramps.

Other Types of Attributes

Sea Blvd Arkansas Red 45th **text**	A B C D E F G H I J Text values contain any number of characters. Each character is stored in a byte (8 bits). All text values in a field have the same number of characters with trailing blanks.	Description  Text shows names and other qualities of features.
12/1/61 1/30/ 7/16/97 **date**	Date values are based on a standard time format.	The date value is translated into the current day and time in the local time zone.
635432 **object ID** 689764	An object ID value is a long unique identifier generated in geodatabases.	Object IDs are used for database joins and establishing relationships between objects.
BLOB	BLOB values contain complex objects like images and video.	BLOB values let you add any kind of multimedia content to your geodatabase tables.

Vector Data File Format: shapefile

- A shapefile is a simple, nontopological format for storing the geometric location and attribute information of geographic features.
- Geographic features in a shapefile can be represented by points, lines, or polygons (areas).
- To find out more about shapefile, visit this link.



Limitation of shapefile

- It is proprietary (closed and controlled by ESRI).
- It’s a multifile format (.shp,.dbf.,.shx,.prj, encoding, other indexes, etc.) (everybody knows the problem with GIS newbies sending you solely the .shp... 😉).
- Attribute names are limited to 10 characters and only 255 attributes are allowed in .dbf.
- Limited data types. Data types are limited to float, integer, date and text with a maximum 254 characters.
- Unknown character set. There is no way to specify the character set used in the database.
- It's limited to 2GB of file size. Although some tools are able to surpass this limit, they can never exceed 4GB of data.

Limitation of shapefile

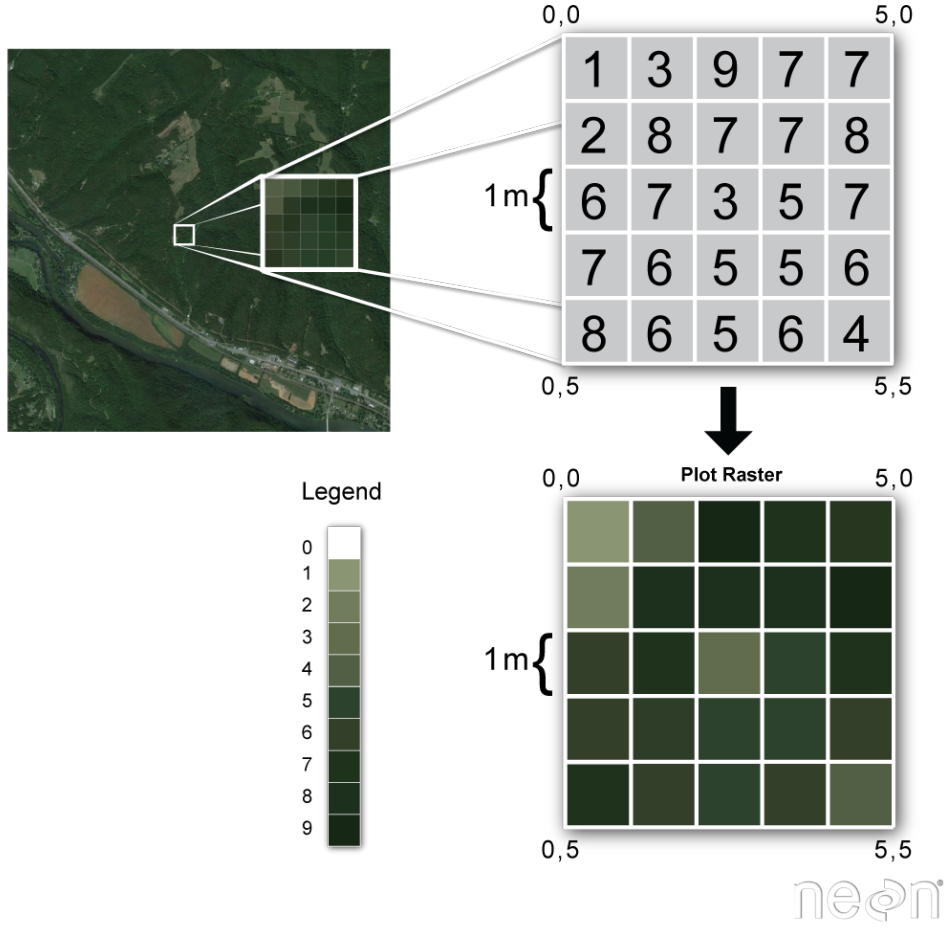
- Uses ESRI’s WKT. Can result in inconsistencies.
- Single geometry type per file. There is no way to save mixed geometry features.
- More complicated data structures are impossible to save. It's a "flat table" format.
- There is no way to store 3D data with textures or appearances such as material definitions. There is also no way to store solids or parametric objects.
- Projections definition. They are incompatible or missing.
- Line and polygon geometry type, single or multipart, cannot be reliably determined at the layer level, it must be determined at the individual feature level.

Other Vector GIS File Formats

- MapInfo TAB format - MapInfo's vector data format using TAB, DAT, ID and MAP files.
- Personal Geodatabase - Esri's closed, integrated vector data storage strategy using Microsoft's Access MDB format
- Keyhole Markup Language (KML) - XML based open standard (by OpenGIS) for GIS data exchange.
- Geography Markup Language (GML) - XML based open standard (by OpenGIS) for GIS data exchange.
- GeoJSON - a lightweight format based on JSON, used by many open source GIS packages.
- TopoJSON, an extension of GeoJSON that encodes topology.

Raster Data Model

- Divide the world into square cells
- Register the corners to the Earth
- Represent discrete objects as collections of one or more cells
- Represent fields by assigning attribute values to cells
- More commonly used to represent fields than discrete objects
- What is raster data?, ESRI. A good read to learn the basic of raster data:



Raster Database

- All raster formats are basically the same
- Cells organized in a matrix of rows and columns
- Content is more important than format: data or picture?

Raster data

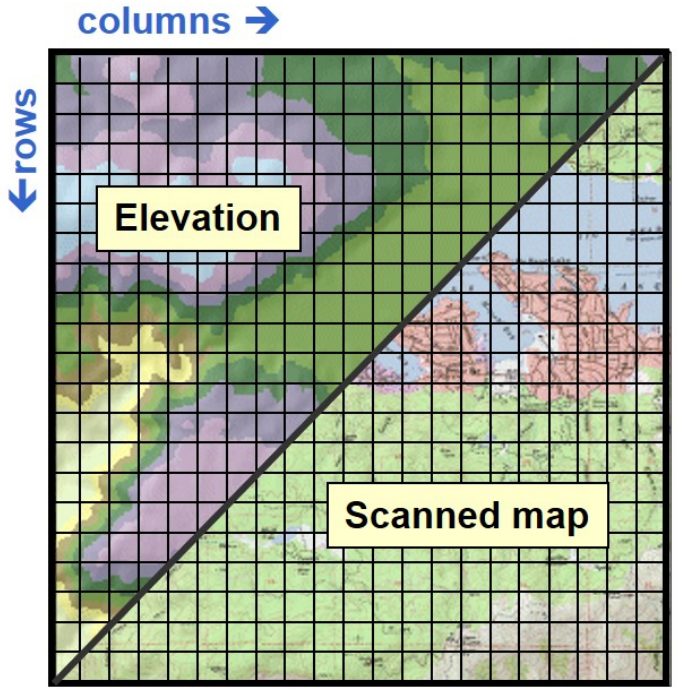
- Elevation
- Landuse codes
- Population density

Good for analysis

- Slope from elevation

Good for mapping

- Thematic layers
- Derivative products (like shaded relief)



Raster pictures

- Scanned maps
- Satellite images (unclassified)
- Photos of buildings

Good for mapping

- Backgrounds

Good for attributes

- Picture of house

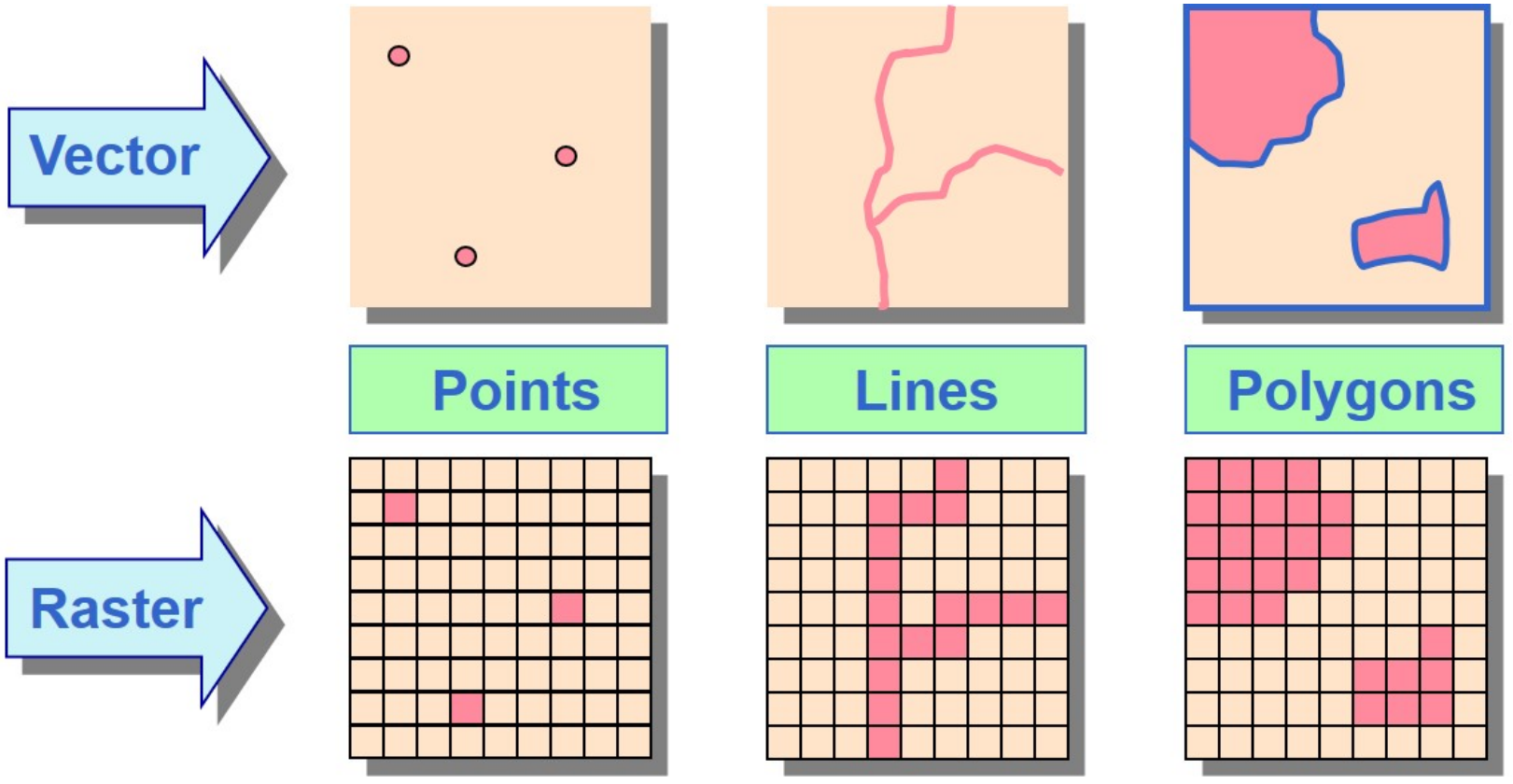
Bad for analysis

Characteristics of raster data model

- Pixel size
  - The size of the cell or picture element, defining the level of spatial detail.
  - All variation within pixels is lost.
- Assignment scheme
  - The value of a cell may be an average over the cell, or a total within the cell, or the commonest value in the cell.
  - It may also be the value found at the cell’s central point.

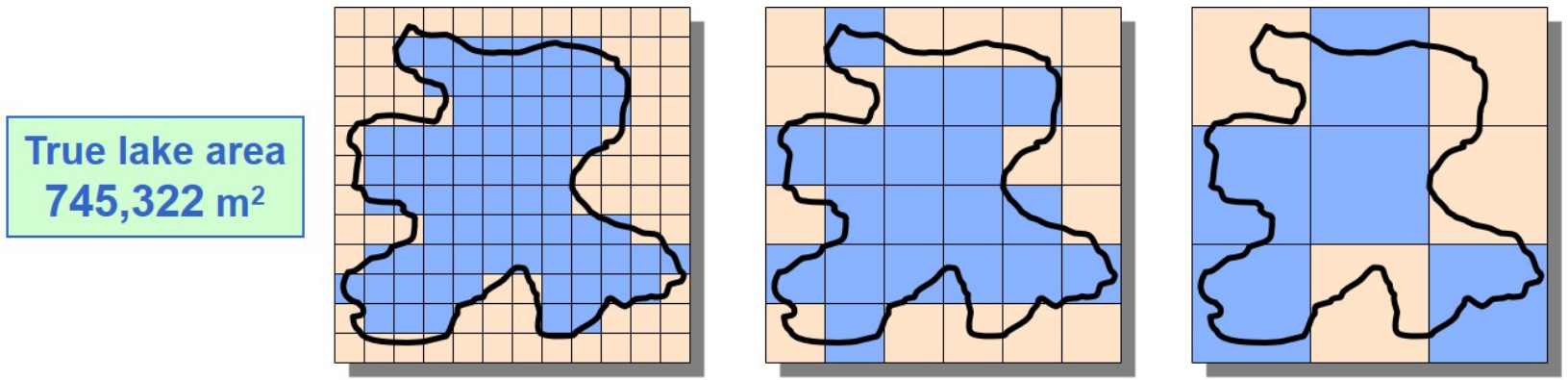
Features as raster

- Features lose uniqueness with raster representation a line becomes a collection of cells, not one feature)

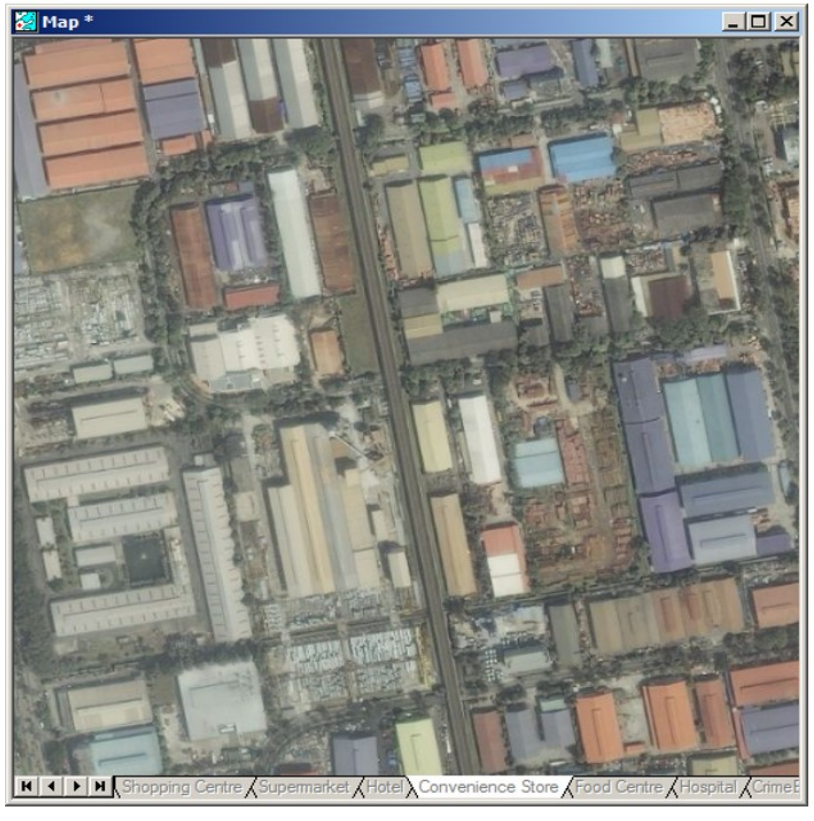


Raster Resolution

- Rasters always generalize spatial data
  - A function of cell size (smaller cells = higher resolution).
  - Impacts accuracy, processing speed, storage space.



Raster Resolution and Spatial Details

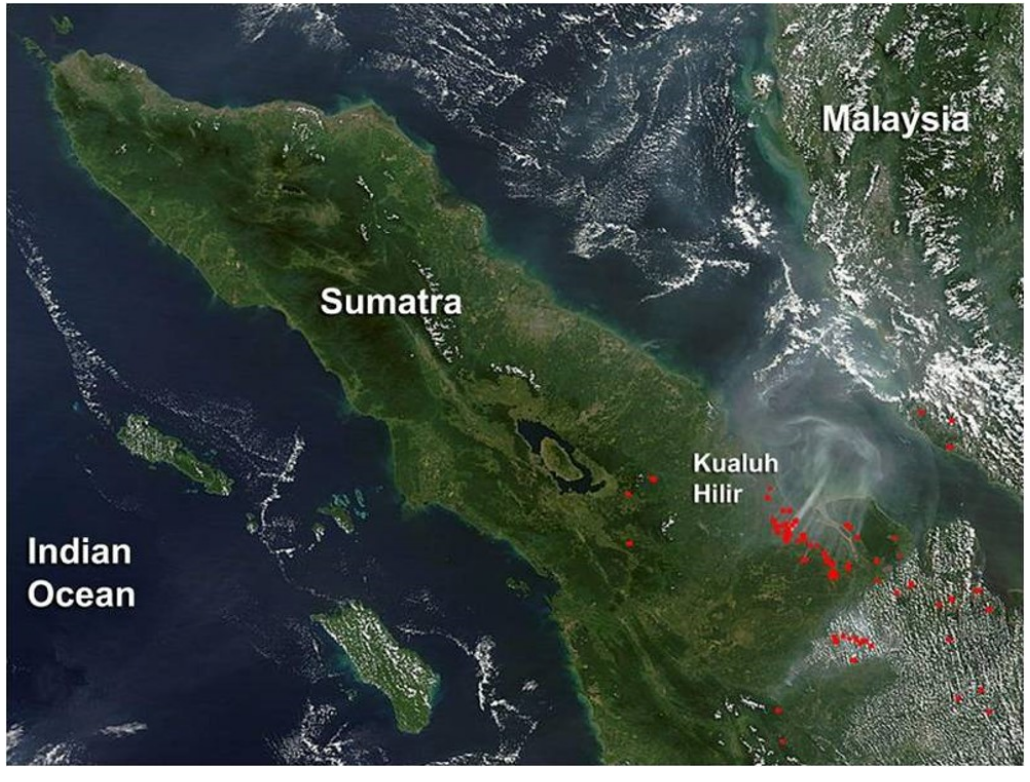


1:5000

1:500

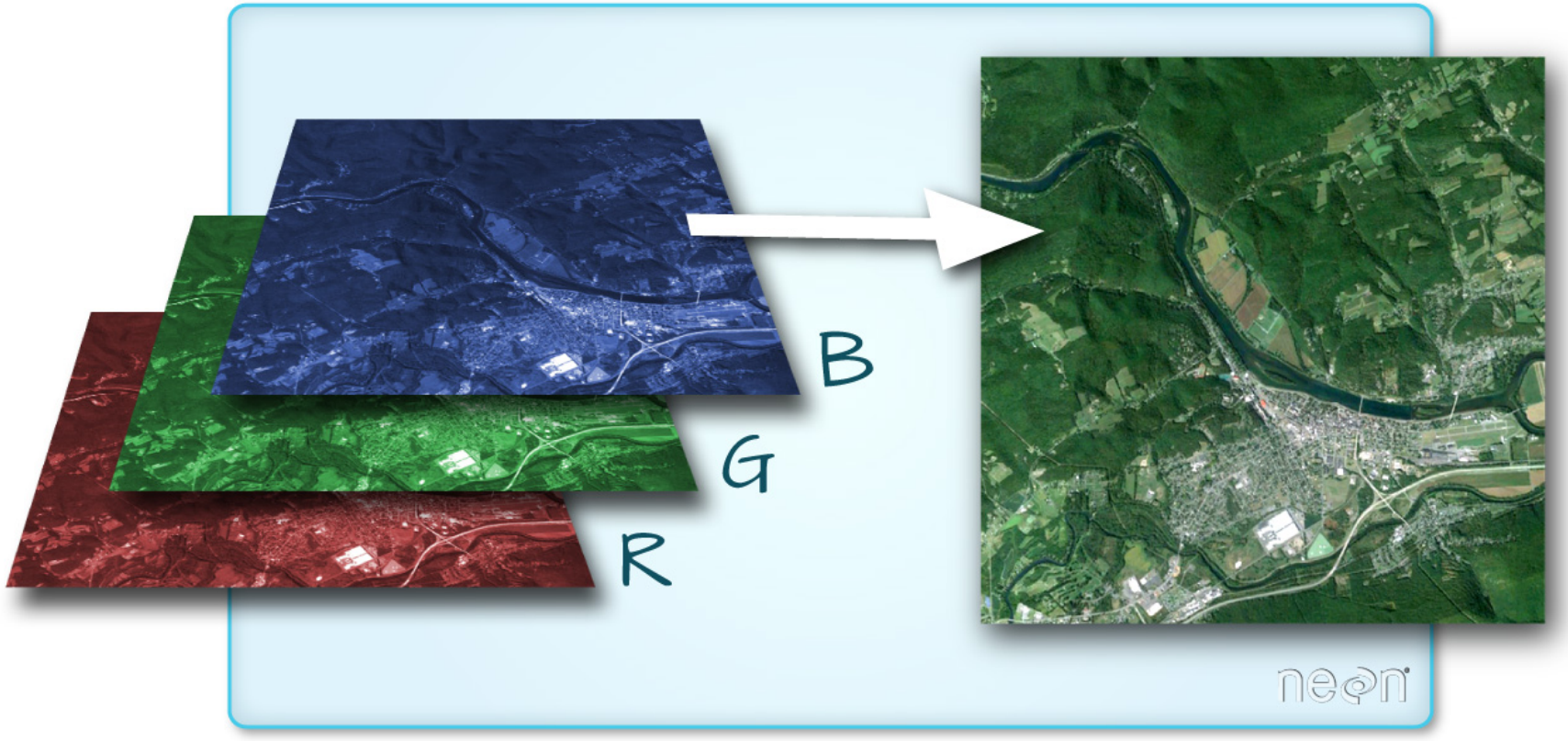
Raster Resolution and Spatial Extent

Small-scale satellite image



Large-scale satellite image

Multi-band Raster Data



Raster Data Format

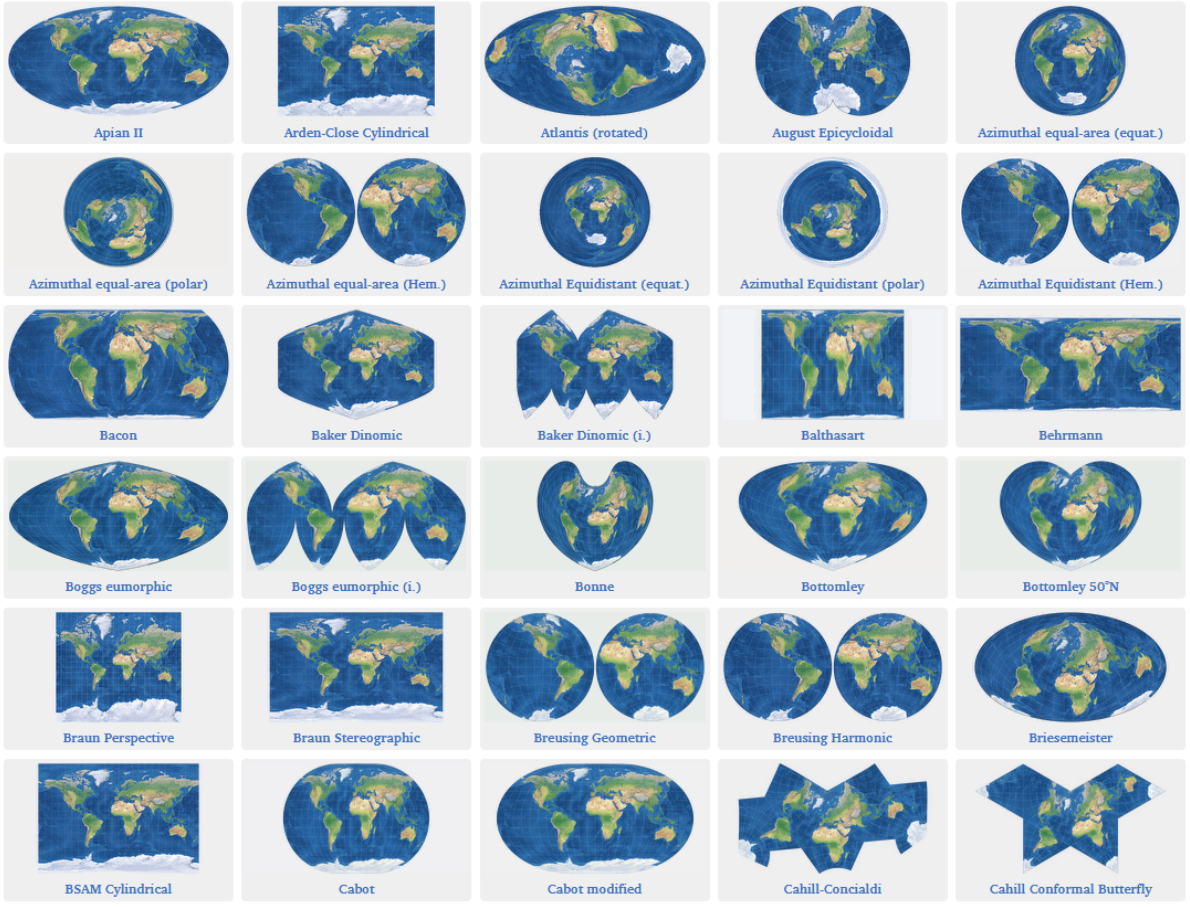
- GeoTIFF: TIFF variant enriched with GIS relevant metadata.
- JPEG2000: Open-source raster format. A compressed format, allows both lossy and lossless compression.
- BIL, BIP, and BSQ raster files: image format linked with satellite derived imagery, namely: BIL (Band Interleaved by Line),BIP (Band Interleaved by Pixel) and BSQ (Band Sequential) . To learn more about these three data types, read Fundamental of raster data, ESRI.
- ADRG: National Geospatial-Intelligence Agency (NGA)'s ARC Digitized Raster Graphics.
- Digital raster graphic (DRG): digital scan of a paper USGS topographic map.
- ESRI grid: proprietary binary and metadataless ASCII raster formats used by Esri.
- IMG: ERDAS IMAGINE image file format.
- ECW): Enhanced Compressed Wavelet (from ERDAS). A compressed wavelet format, often lossy.
- MrSID: Multi-Resolution Seamless Image Database (by Lizardtech). A compressed wavelet format, allows both lossy and lossless compression.

Unique Properties of GIS Data

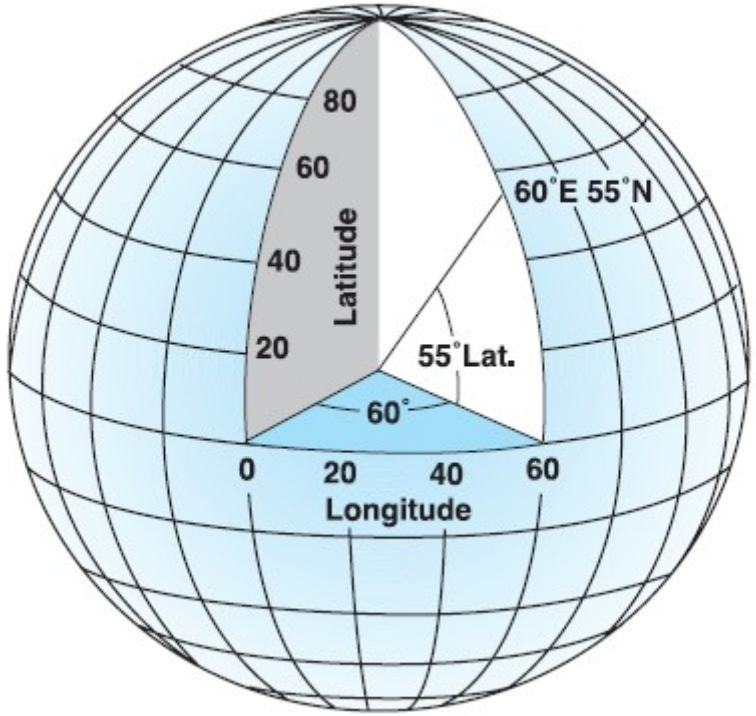
- Geographical reference
- Cartographic generalisation
- GIS data accuracy and uncertainty

Coordinate Systems and Map Projections

What is a coordinate system?



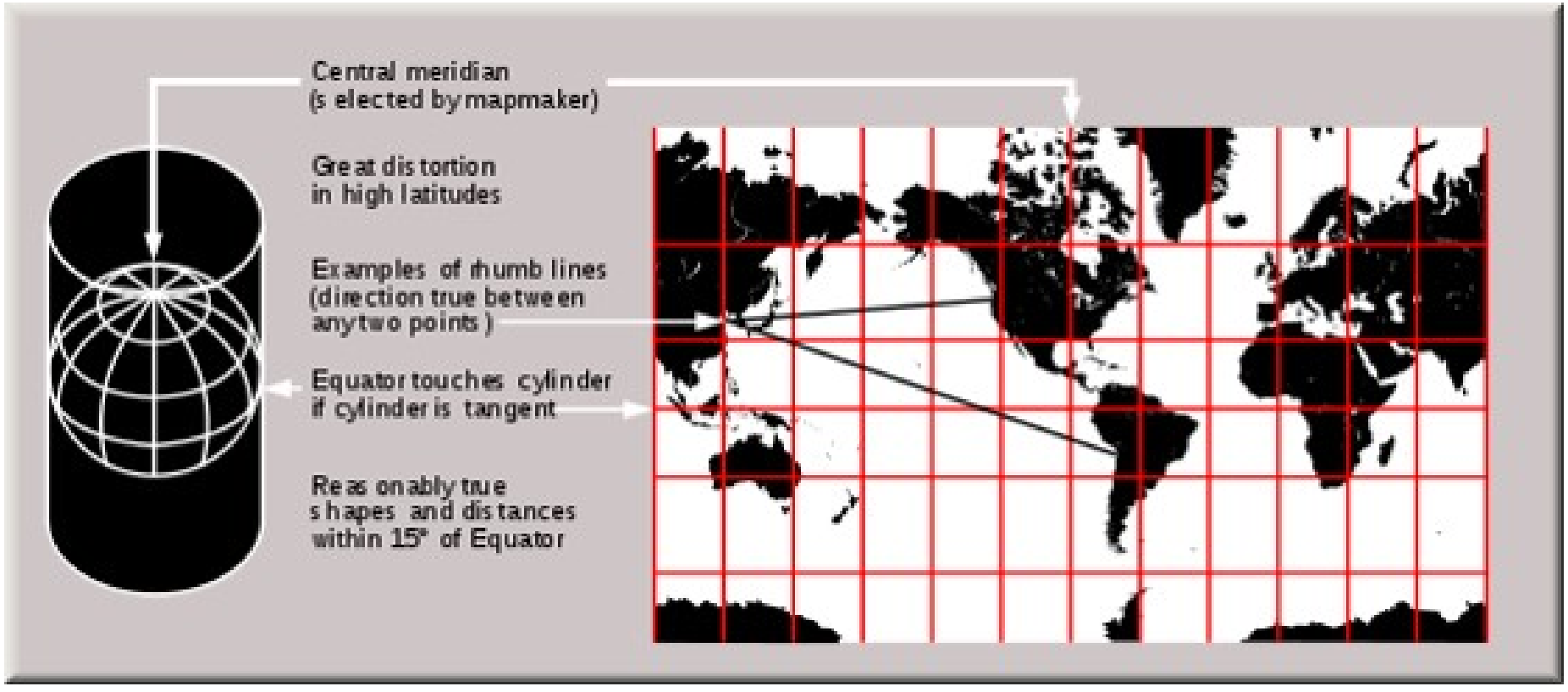
Geographical Coordinate Systems



Reference: http://en.wikipedia.org/wiki/Map_projection

Projected Coordinate Systems

- Based on a map projection such as transverse Mercator, Albers equal area, or Robinson.



Singapore Projected Coordinate System

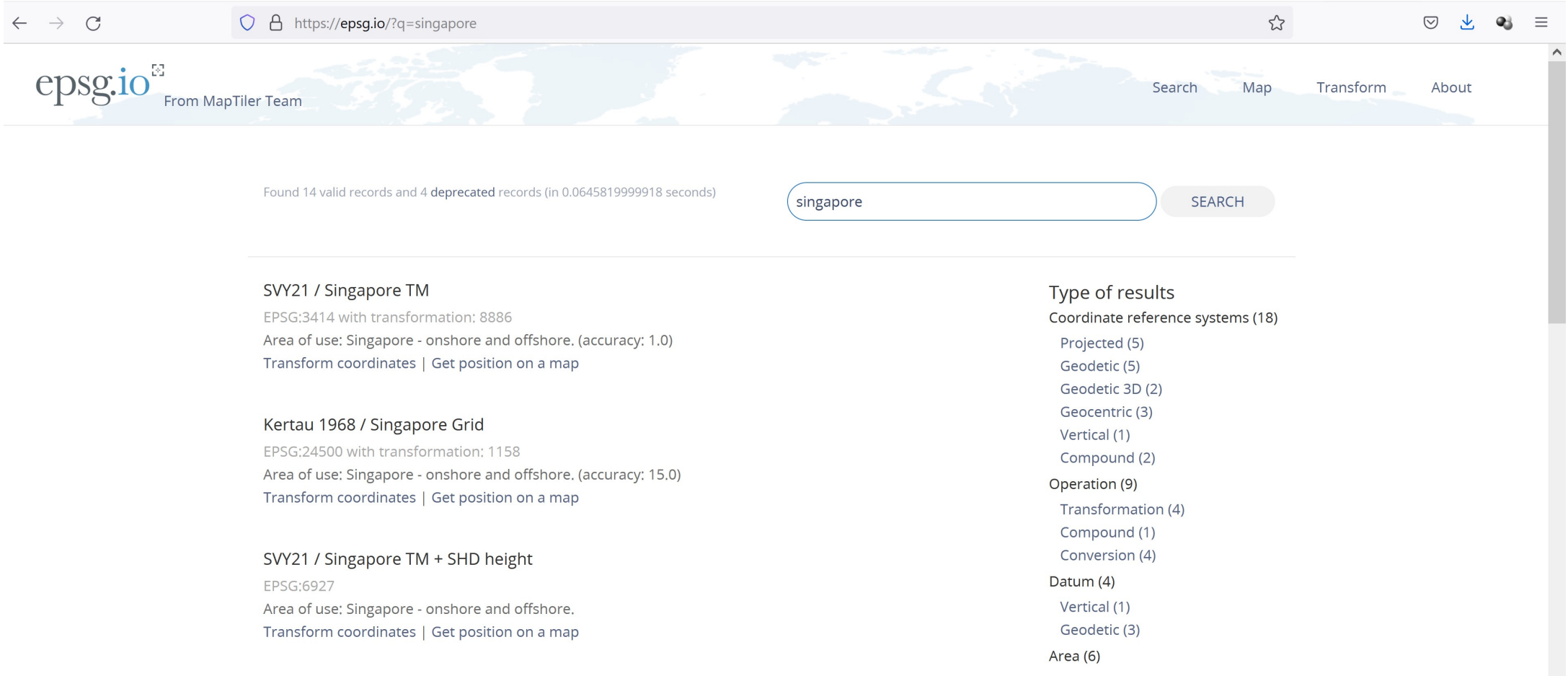
Old → **New**

Cassini-Soldner	Transverse Mercator
Spheroid: Revised Everest Datum: ASA(Kertau) Projection origin: 103deg 51 min 10.78 sec long 1 deg 17 min 15.08 sec lat	Spheroid: WGS-84 Datum: SVY21 Projection origin: 103 deg 50 min long 1 deg 22 min lat

- epsg.io provides a comprehensive list of country coordinate systems such as svy21.

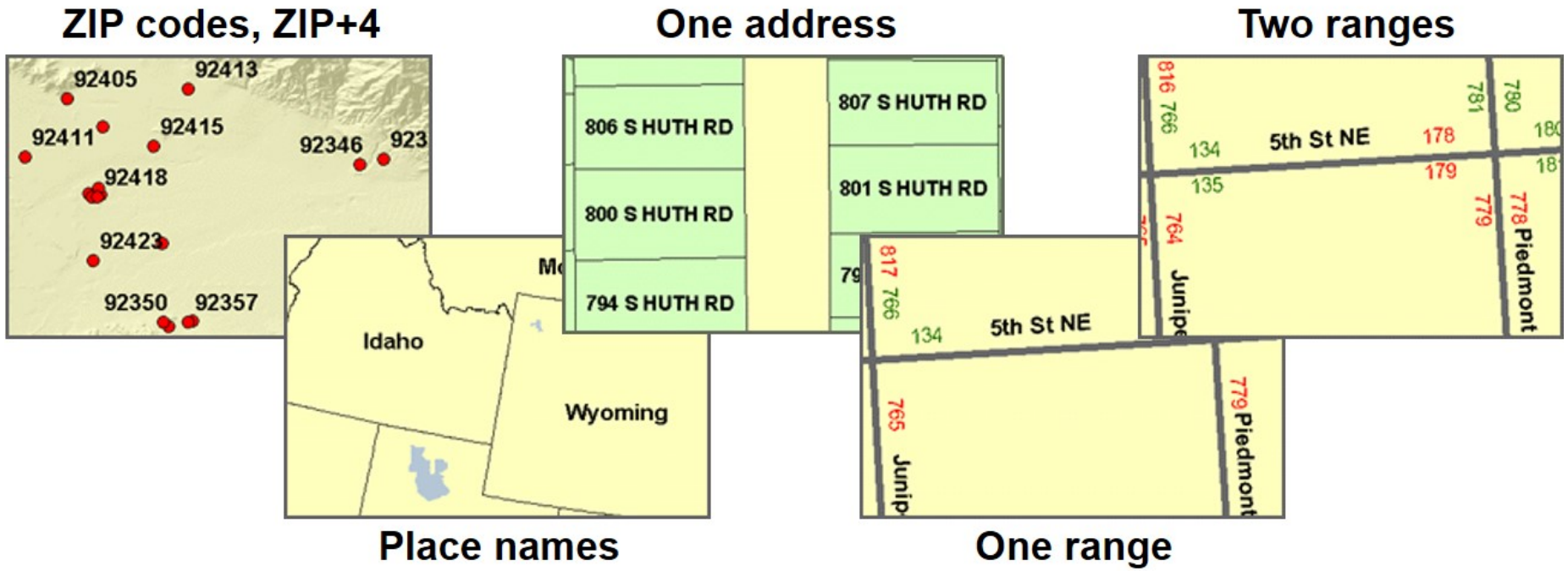
EPSG Reference System

Link to epsg.io



What is geocoding

- Reference data: features with address attributes Points, lines, polygons.

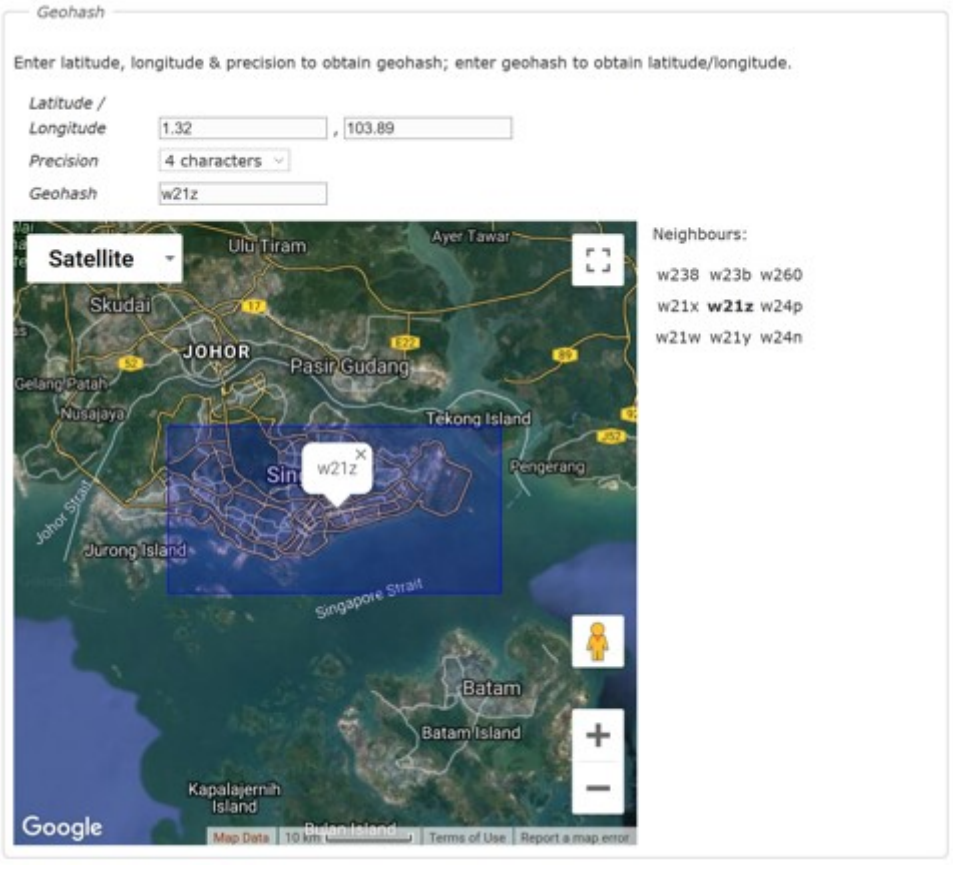


Source: http://en.wikipedia.org/wiki/Geocoding

GeoHash

- GeoHash is a public domain geocode system invented in 2008 by Gustavo Niemeyer.
- For more information, visit this link and

GeoHash of Singapore

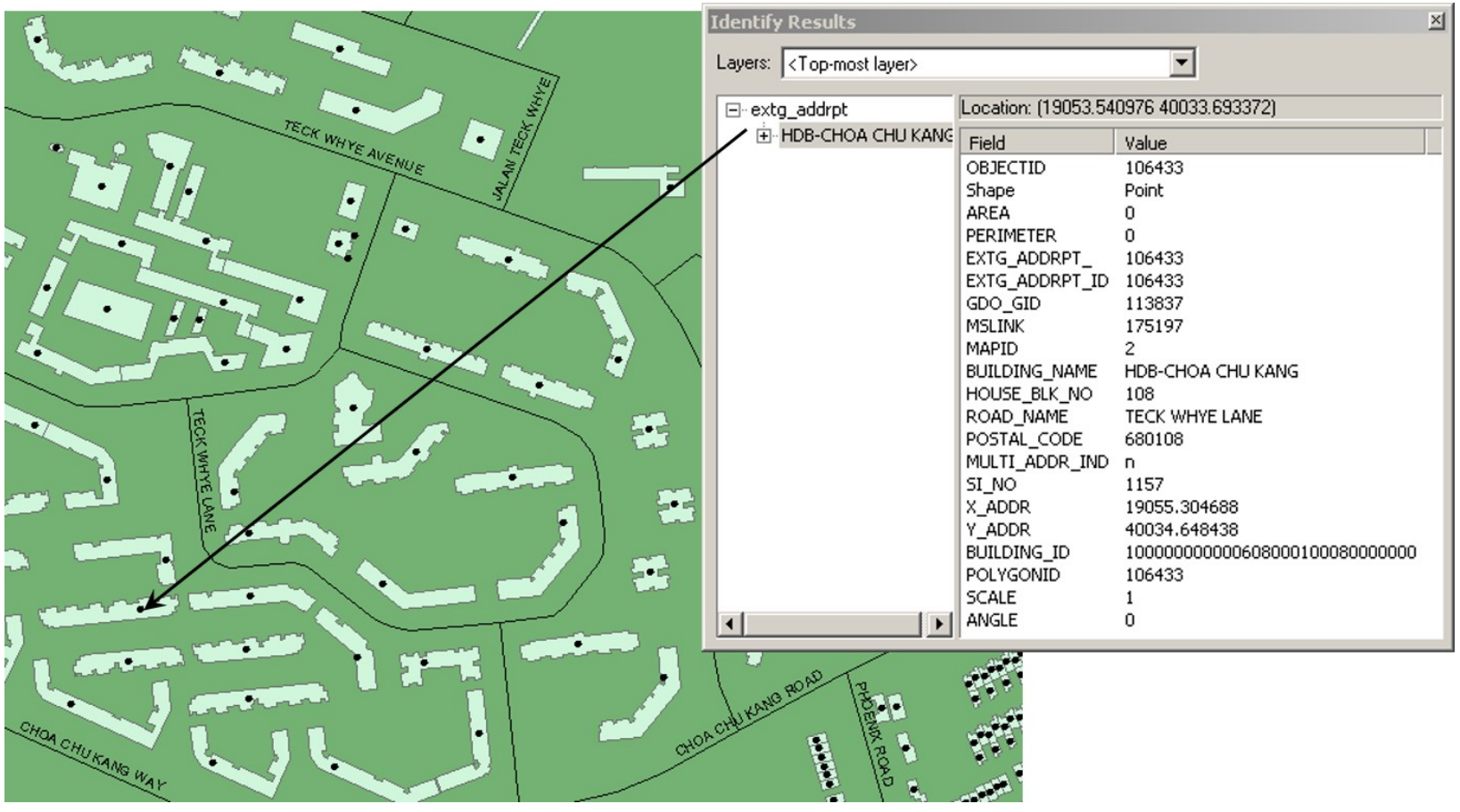


Source: https://www.movable-type.co.uk/scripts/geohash.html

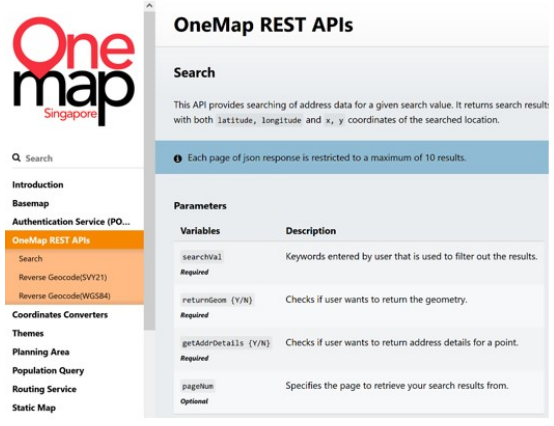
Geocoding in Singapore: SLA's Address-Point Data

			C	D		F
1	POI_NAME	E	POI_TYPE	POI_GROUP	POI_ADDRESS	POSTCODE
2	Ang Mo Kio		polyclinic	NHG	Block 723 Ang Mo Ki	560723
3	Bukit Batok		polyclinic	NHG	50 Bukit Batok West A	659164
4	Choa Chu Ka		polyclinic	NHG	2 Teck Whye Crescent	688846
5	Hougang Po		polyclinic	NHG	89 Hougang Avenue 4	538829
6	Jurong Poly		polyclinic	NHG	190 Jurong East Avenue 1	609788
7	Toa Payoh P		polyclinic	NHG	Block 2003 Lorong 8 Toa Payoh	319260
8	Woodlands		polyclinic	NHG	10 Woodlands Street 31	738579
9	Yishun Polyc		polyclinic	NHG	100, Yishun Central	768826
10	Bedok Polyc		polyclinic	Singhealth	Block 212 Bedok North Street 1 #03-147	460212
11	Bukit Merah Polyclinic (Singhealth)	SGH02	polyclinic	Singhealth	Block 163 Bukit Merah Central #04-3565	150163
12	Clementi Polyclinic (NHG)	SGH03	polyclinic	Singhealth	Block 451 Clementi Avenue 3 #02-307	120451
13	Geylang Polyclinic (Singhealth)	SGH04	polyclinic	Singhealth	21 Geylang East Central	389707
14	Marine Parade Polyclinic (Singhealth)	SGH05	polyclinic	Singhealth	Block 80 Marine Parade #01-792	440080
15	Outram Polyclinic (Singhealth)	SGH06	polyclinic	Singhealth	No.3 Second Hospital Avenue	168937
16	Pasir Ris Polyclinic (Singhealth)	SGH07	polyclinic	Singhealth	1 Pasir Ris Drive 4 #01-11	519457
17	Queenstown Polyclinic (Singhealth)	SGH08	polyclinic	Singhealth	580 Stirling Road	148958
18	Sengkang Polyclinic (Singhealth)	SGH09	polyclinic	Singhealth	2 Sengkang Square #01-06 Sengkang Communi	545025
19	Tampines Polyclinic (Singhealth)	SGH10	polyclinic	Singhealth	1 Tampines Street 41	529203

Structure of SLA's Address-Point data



SLA Onemap Geocoding API



Usage:

```
/commonapi/search?searchVal={SearchText}&returnGeom={Y/N}&getAddrDetails={Y/N}&pageNum={PageNumber}
```

Examples:

With optional variables:

```
https://developers.onemap.sg/commonapi/search?searchVal=revenue&returnGeom=Y&getAddrDetails=Y&pageNum=1
```

Sample Response(Only 2 Results):


```
{
   "found":5,
   "totalNumPages":1,
   "pageNum":1,
   "results":[
      {
         "SEARCHVAL":"INLAND REVENUE AUTHORITY OF SINGAPORE (IRAS)",
         "BLK_NO":"55",
         "ROAD_NAME":"NEWTON ROAD",
         "BUILDING":"INLAND REVENUE AUTHORITY OF SINGAPORE (IRAS)",
         "ADDRESS":"55 NEWTON ROAD, SINGAPORE 307987",
         "POSTAL":"307987",
         "X":"28983.7537272647",
         "Y":"33554.4361084122",
         "LATITUDE":"1.31972890510723",
         "LONGITUDE":"103.842158118267",
         "LONGTITUDE":"103.842158118267"
      },
```

Geocoding options for QGIS users

- Geocode Tools of MMQGIS plugin.

Sources of GIS data

- Field surveying
  - Conventional land surveying
  - GPS surveying
- Digitising
- Remote sensing
  - Airborn
  - Satellite
- Digital data
  - Internet map services
  - Open Data.gov

Field surveying

Land surveying

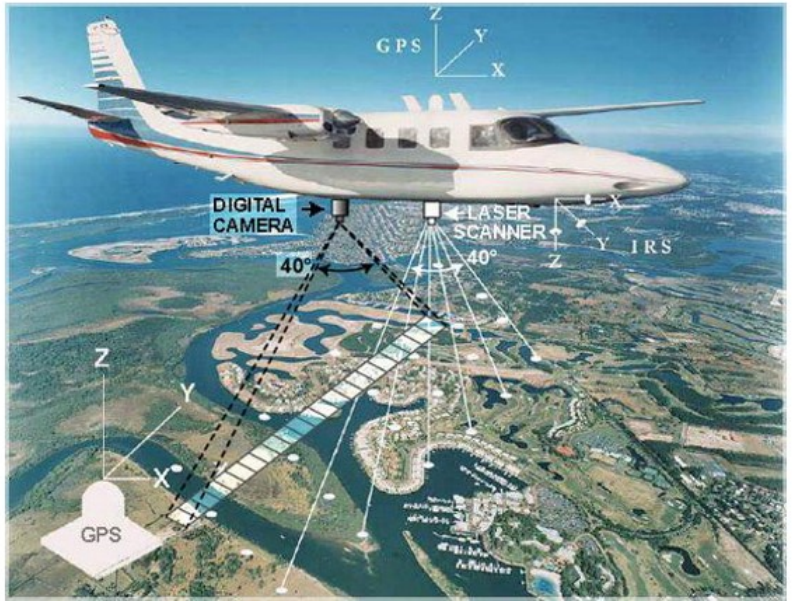
GPS surveying

Mobile mapping

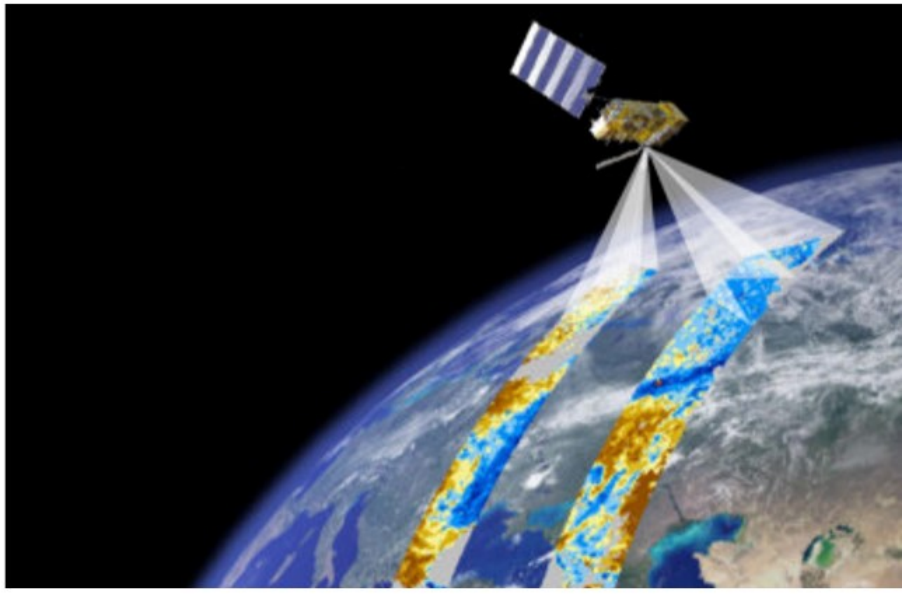
Digitising

Remotely Sensed Data

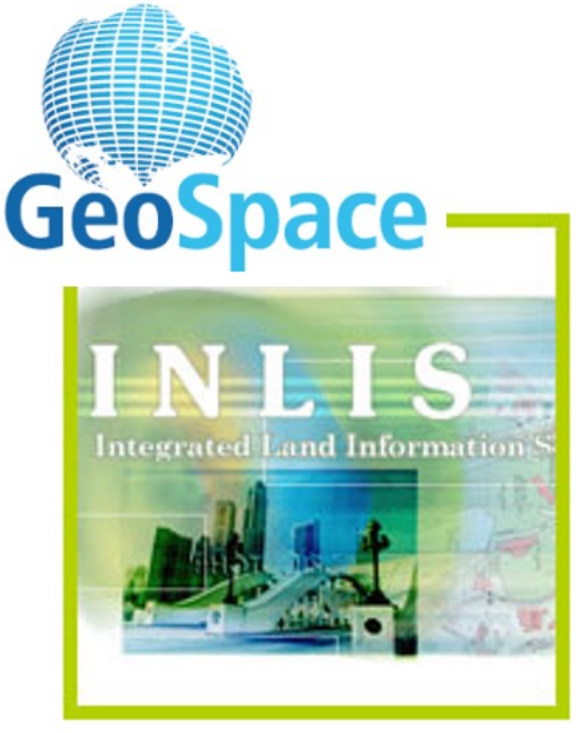
Airborne



Satellite



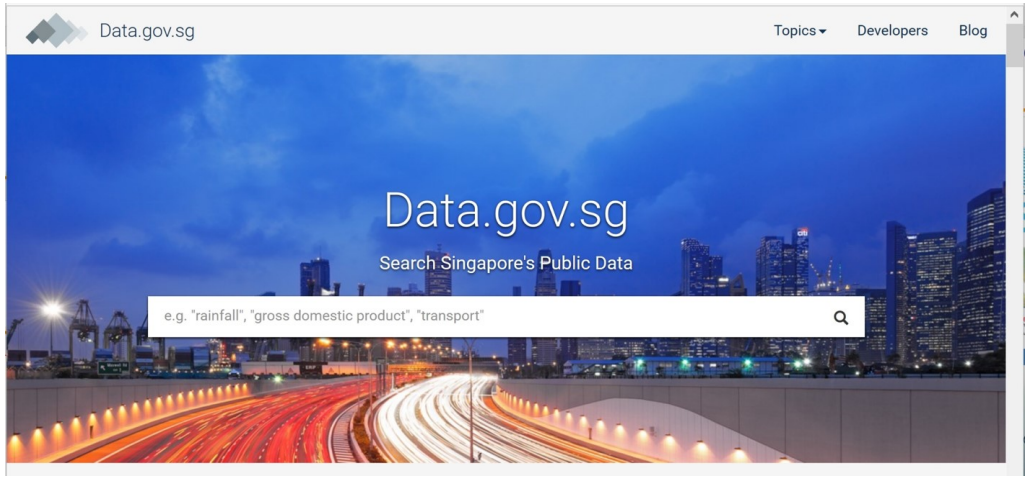
Geospatial Digital Data from SLA



Reference: http://www.asiageospatialforum.org/2011/proceeding/pps/leekim.pdf

Geospatial Digital Data from Open Gov

data.gov.sg



LTA DataMall

OpenStreetMap (OSM)

- To learn more about OSM Singapore, visit this link.
- To obtain the latest OSM extract for Singapore, visit this link

Open Global Digital Data

Natural Earth

GDAM: Global Administration Boundary Maps