DATA VISUALIZATION AND VISUAL ANALYTICS

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SPATIAL DATA AND GEOGRAPHY

OBJECTIVE

- To show spatial distribution of data
- To show relative positions of data components

- Thematic maps
  - Mapping to attribute data (quantitative and qualitative) on a map
  - Geometry linked to fixed geographical position

MAP DESIGN

- Projection
  - Map curved 3D objects to a place
- Scale
  - Reduction of a map to the available space
- Symbolization and themes
  - Equivalent to encoding with Visual Variables

SCALE

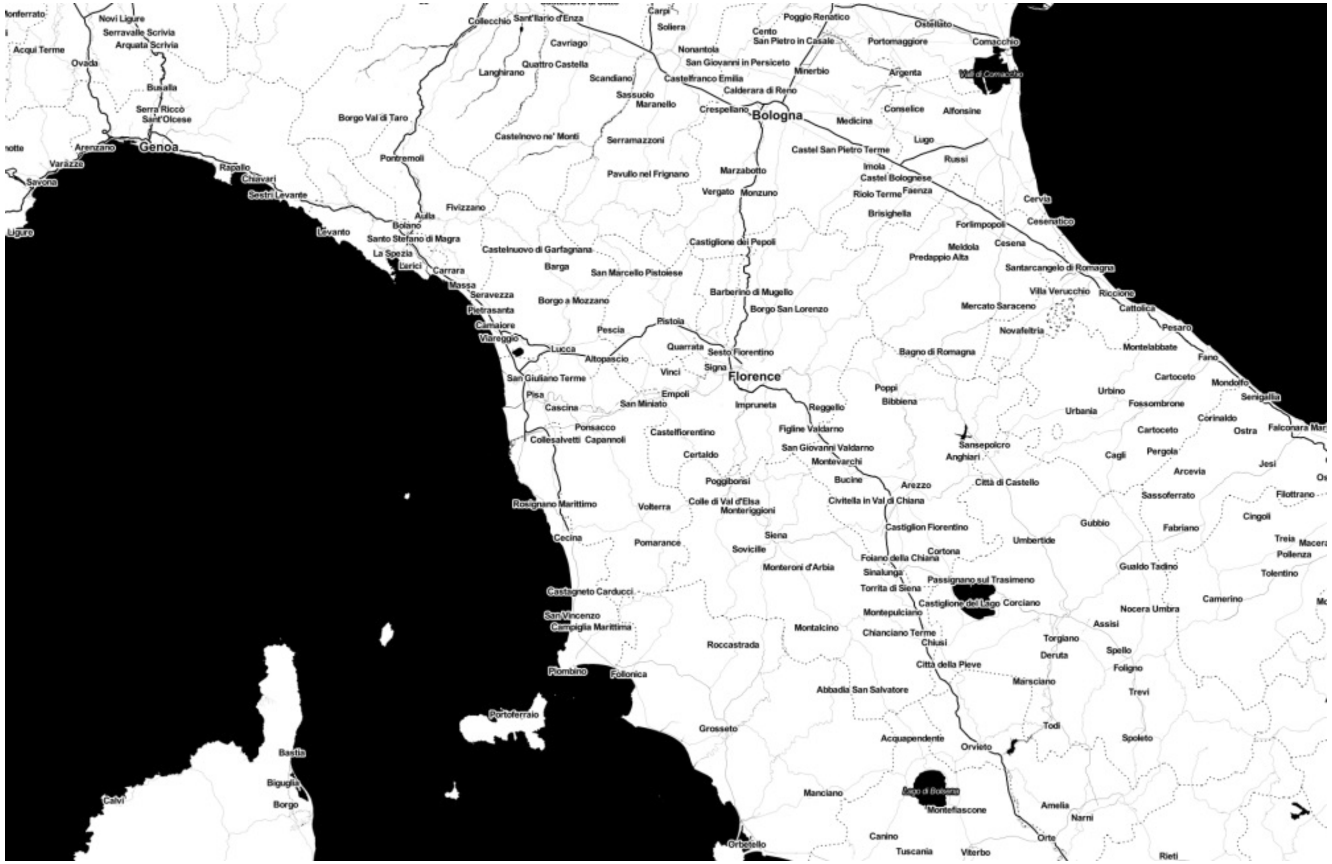
MAP SCALE

- Defines as the ratio between a distance on the map and the corresponding distance on the Earth
  - Usually expressed as verbal ratio
    - 1:100
    - Distance on the map is always expressed as one
  - The ratio is dimensionless
  - The larger the fraction, the greater the map's details

MAP SCALE (1:50,000,000)

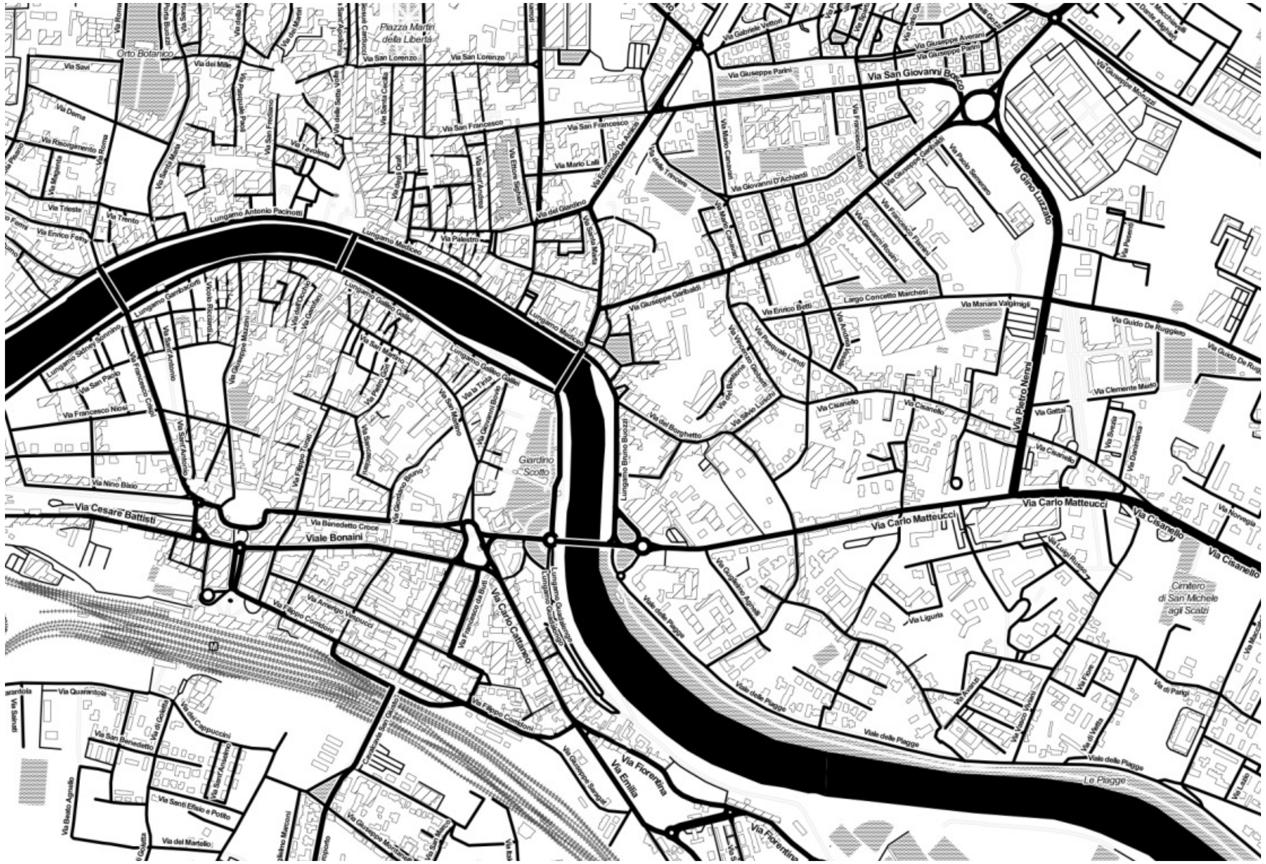
MAP SCALE (1:6,500,000)

MAP SCALE (1:1,500,000)

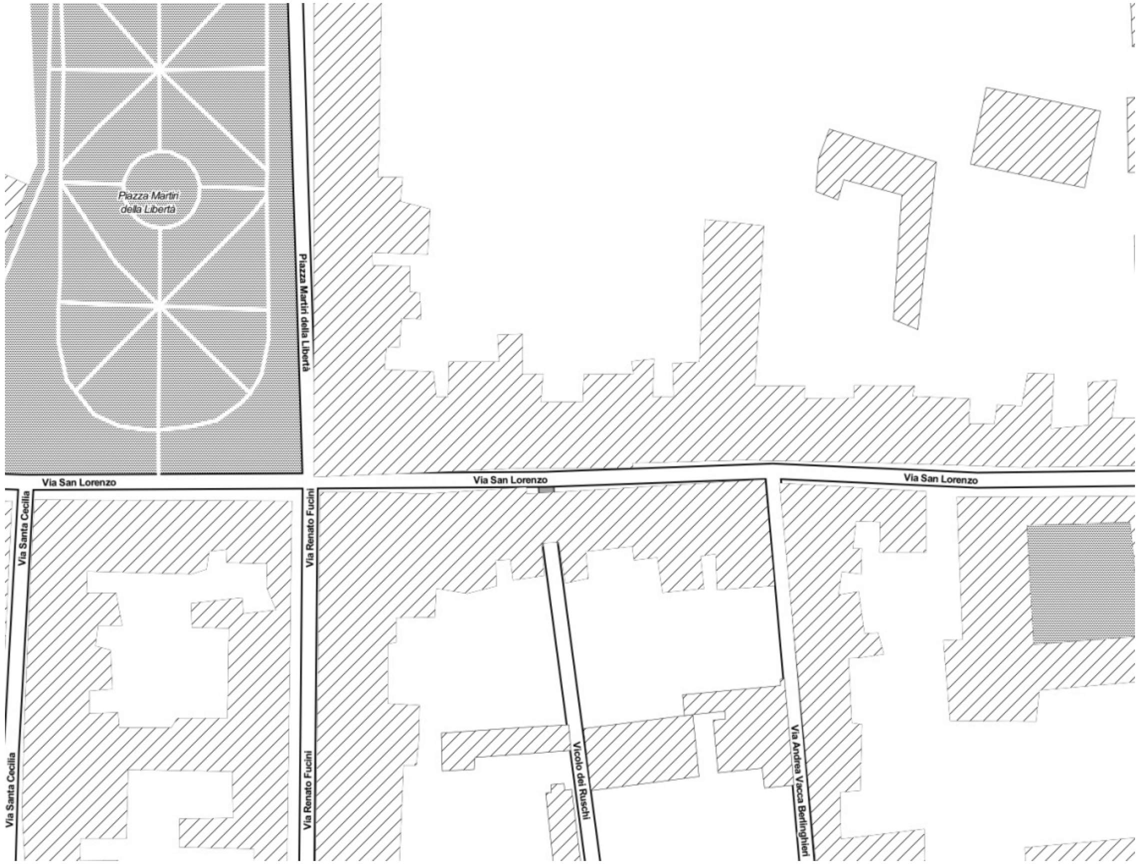


MAP SCALE (1:100,000)

MAP SCALE (1:10,000)



MAP SCALE (1:1,000)



PROJECTIONS

CARTOGRAPHY AS ART


L'EUROPE
DIVISÉE EN
TOUTTES SES RÉGIONS
ET GRANDS ESTATS
DRESSÉE,
Sur les Observations
Astronomiques
O C E A N
M E R   N O I R E
D'AFRIQUE
PARTIE


APHRICVM MARE


OCEANO
COSTA DELLA NOTTE
EUROPA
LIBIA
EGITTO
ASIA

THE NEW WORLD

- New challenges for geographers
- Since XVI century new methods to represent geography
- From plane to globe

BASIC COMPONENTS…

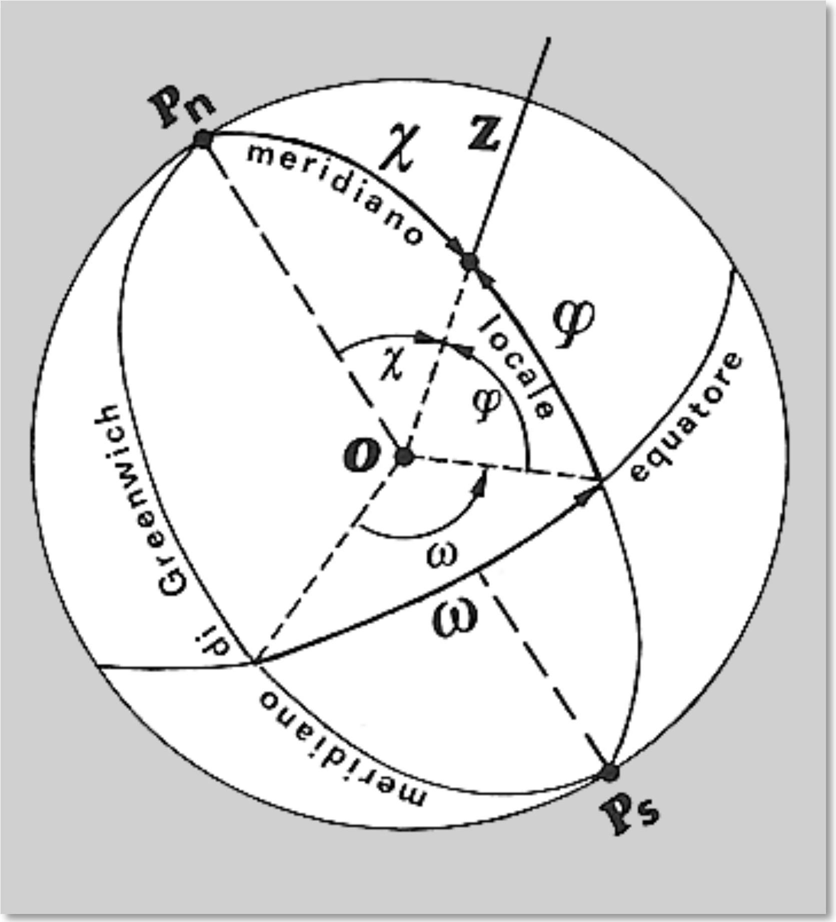
- A reference system
- A set of coordinates

REFERENCE SYSTEM

- Univocally determine a position in 3D (2D+1D)
- Need for a simple model:
  - Mathematically tractable: surface
  - Link to physical world
- Typical surfaces:
  - Sphere
  - Ellipsoid (spheroid)
  - Geoid

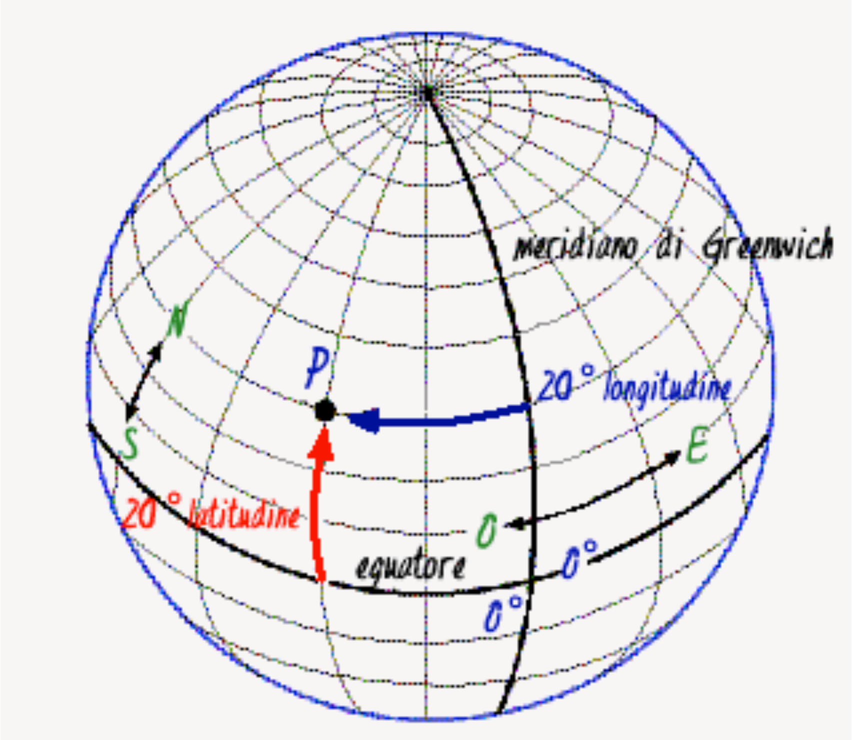
COORDINATE (2D+1D)

- Position relative to the reference system
- Angular coordinates
  - Longitude
  - Latitude
- Altitude as offset from the reference point



LATITUDE AND LONGITUDE

- Latitude: angular distance from equator
- Longitude: angular distance from central meridian

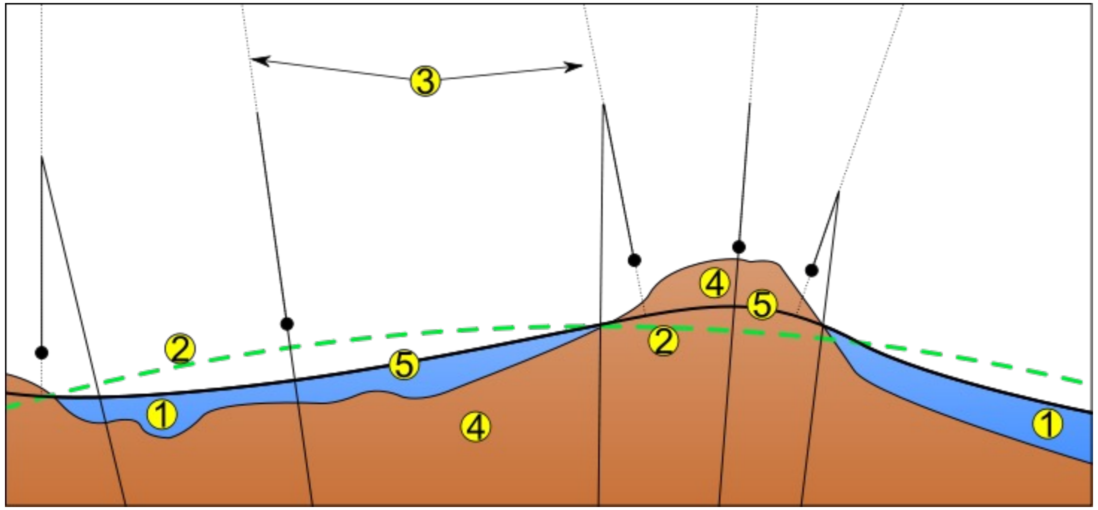


WHICH REFERENCE SYSTEM?

- Earth present a complex surface, results of gravity, magnetical forces and different densities
- Mathematic representation is very complex

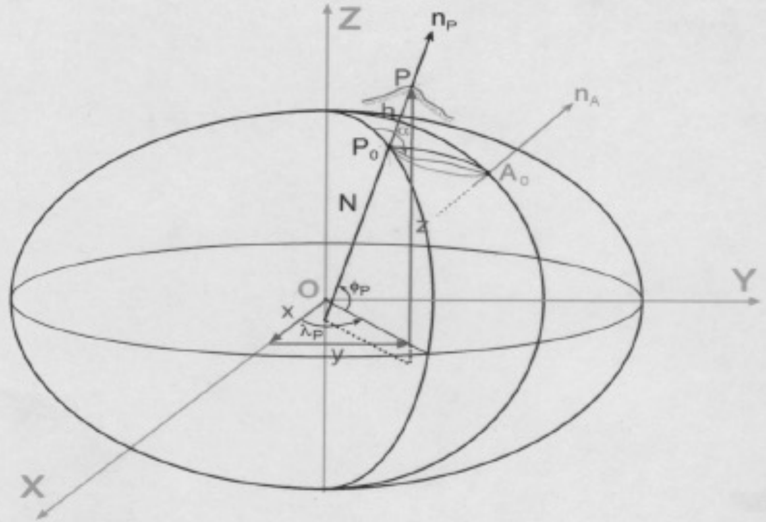
GEOID

- Geoid: surface where graivity is constant in each point
- Average surface of seas



WHICH REFERENCE SYSTEM?

- Ellipsoid: clear and easy mathematic definition
- Easy to define a position of a point in the space
- Low differences with the real geoid (~40m)

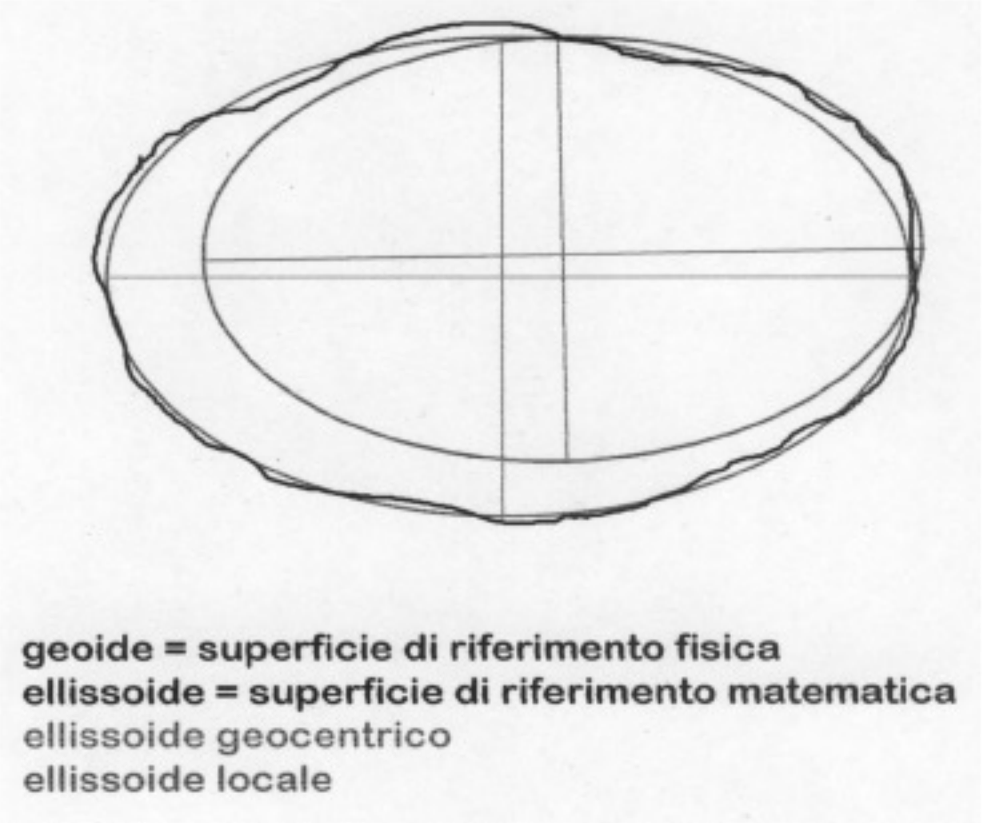


$$\frac{x^2+y^2}{a^2}+\frac{z^2}{b^2}=1$$

$$x=(N+h)\cos\varphi\cos\lambda$$
$$y=(N+h)\cos\varphi\,\mathrm{sen}\,\lambda$$
$$z=[N(1-e^2)+h]\,\mathrm{sen}\,\varphi$$

DATUM

- An ellipsoid is univocally determined by 8 parameters (named Datum)
  - 2 shape parameted:
    - Equatorial radius
    - Polar radius
  - 6 parameters for position and orientation



WHICH DATUM?

- Diffusion of GPS systems: WGS84 (World Geodetic System 1984)
- Many local cartograph systems use local defined datum
  - In Europe, datum ED50 (European Datum 1950, Ellissoide di Hayford) is largely used
- All datum can be mapped/translated to WGS84

PROJECTIONS

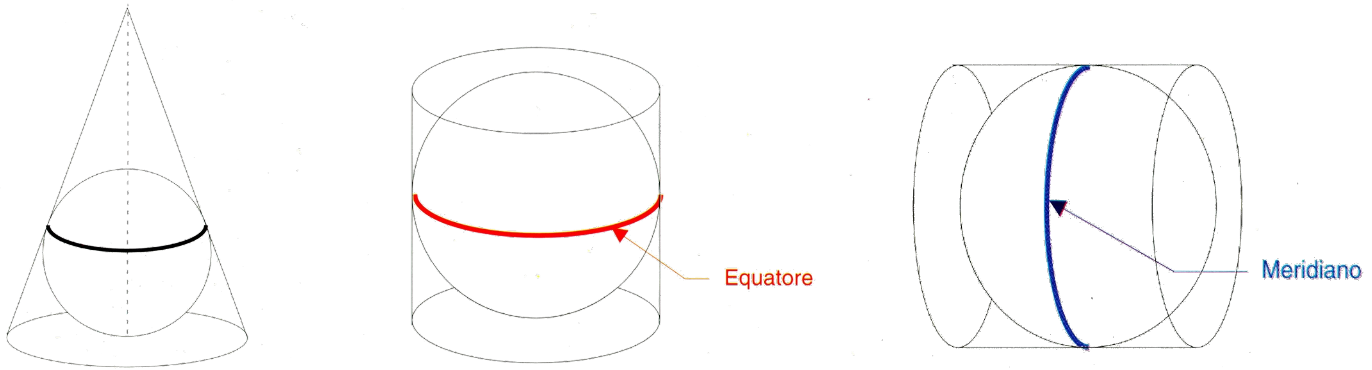
- Cartographic projections maps coordinates from the ellipsoid to the plane
- A direct mapping is not feasible without introducing deformations
- Families of mapping that preserve:
  - Angles (conformal projection)
  - Surfaces (equal area projection)
  - Minimizing both

PROJECTIONS

- Each projection assume a precise datum
- For example, UTM projection uses datum WGS84 and ED50

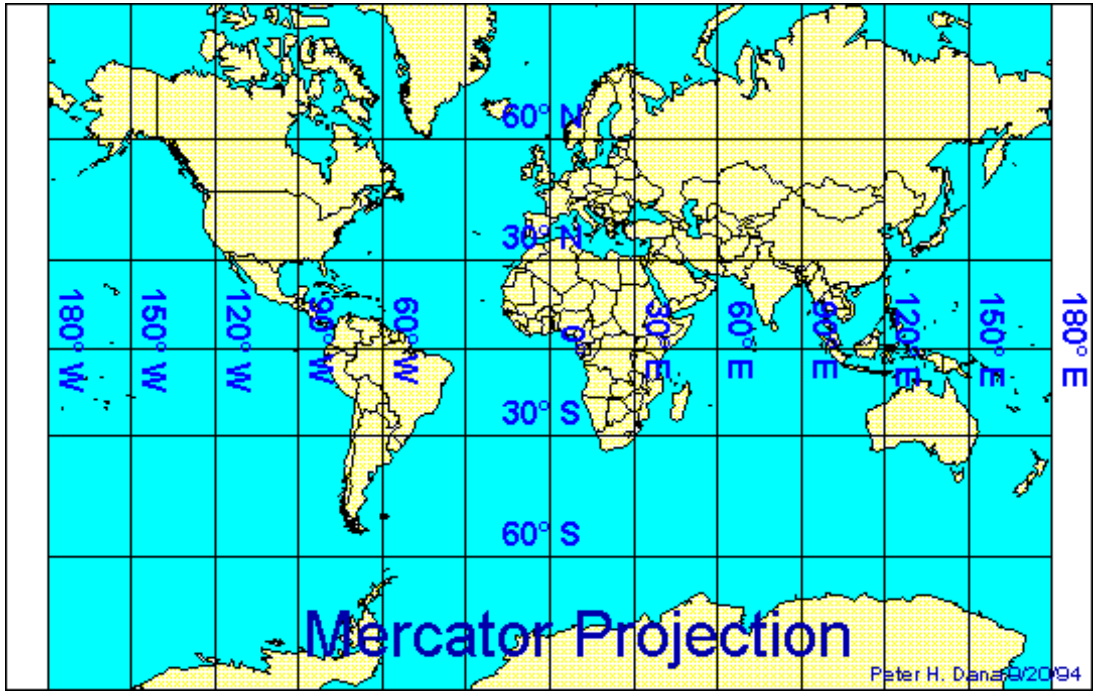
PROJECTIONS

- Three different types
  - Azimuthal: projection plane is tangent to a point on the earth
  - Conic: points are projected on a cone
  - Cylindrical: points are projected ona cylinder



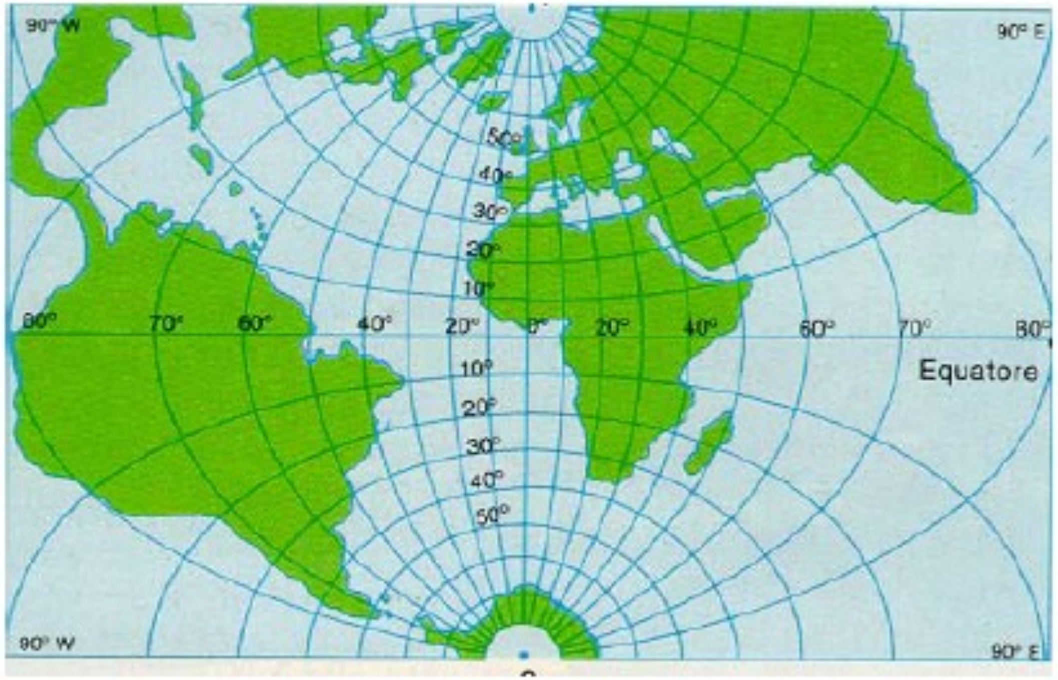
MERCATOR PROJECTION

- Cylindrical projections
- Cylinder tangent to equator
- Meridians are paralled
- Low distortion for tropical zones



UTM
(UNIVERSAL TRANSVERSE MERCATOR)

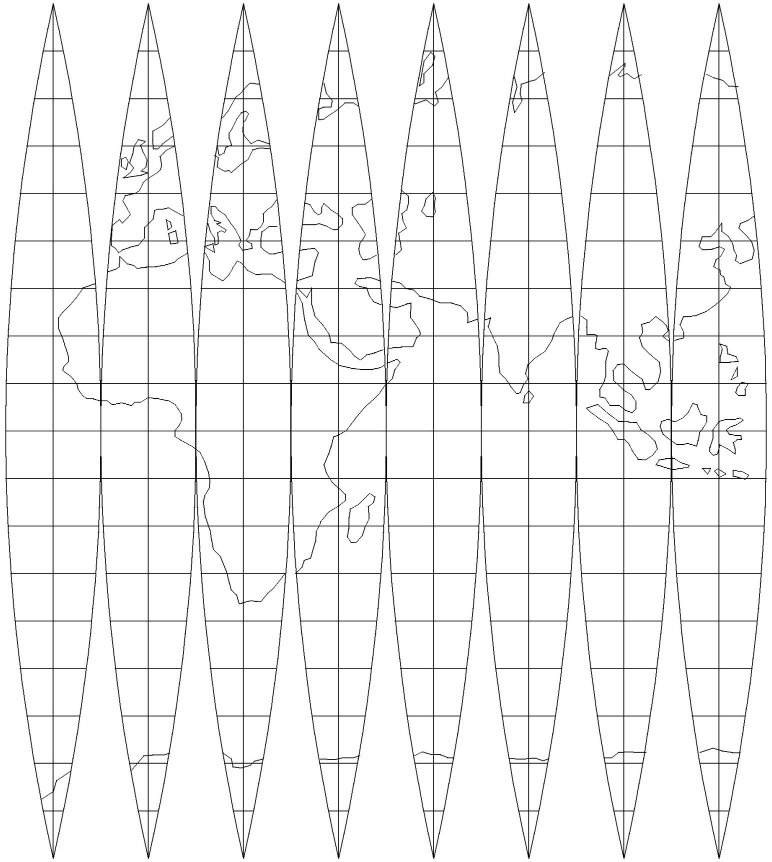
- Transverse Mercator Projection
- Cylinder tangent to one of the meridians
- Low deformation around the reference meridian



UTM PROJECTION

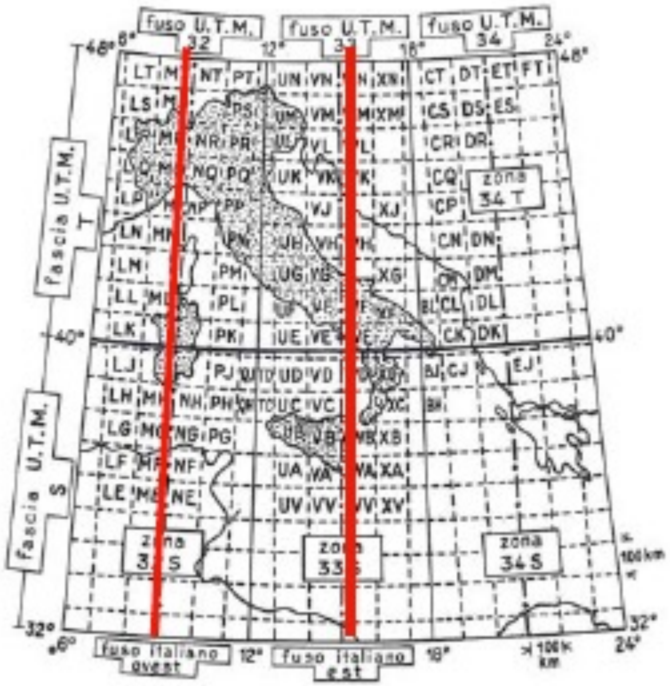
- Minimize distortion
  - Each projection is limited to a zone of 6 degrees
  - Central meridian is contracted by 0.9996
  - To ensure positive coordinates, each zone has a false easting origin at 500000 m on the east of central meridian
  - Projection is limited to latitudes between -80 N and +80 N

UTM ZONES



UTM ZONES IN ITALY

- Italy is covered by zones 32, 33 e 34



REFERENCE SYSTEMS: CATALOGUE

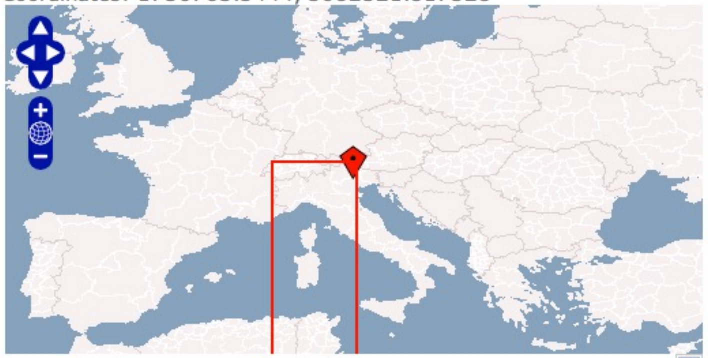
Spatial Reference — epsg projection 3003 - monte mario / italy zone 1

Home | Upload Your Own | List user-contributed references | List all references — Search

Previous: EPSG:3002: Makassar / NEIEZ | Next: EPSG:3004: Monte Mario / Italy zone 2

Link to this Page

Input Coordinates: 12.049609375, 45.8546875 Output Coordinates: 1736763.5444, 5082521.817528



EPSG:3003

Monte Mario / Italy zone 1 (Google it)

- **WGS84 Bounds**: 6.6500, 8.8000, 12.0000, 47.0500
- **Projected Bounds**: 1241482.0019, 973563.1609, 1830078.9331, 5215189.0853
- **Scope**: Large and medium scale topographic mapping and engineering survey.
- **Last Revised**: 2005-05-27
- **Area**: Italy - west of 12°E

- Well Known Text as HTML
- Human-Readable OGC WKT
- Proj4
- OGC WKT
- JSON
- GML
- ESRI WKT
- .PRJ File
- USGS
- MapServer Mapfile | Python
- Mapnik XML | Python
- GeoServer
- PostGIS spatial_ref_sys INSERT statement

http://spatialreference.org/

D3.JS REFERENCES

- d3.geo API reference
  - https://github.com/mbostock/d3/wiki/Geo-Projections
- topojson API reference
  - https://github.com/mbostock/topojson/wiki/API-Reference

CARTOGRAPHY IN D3

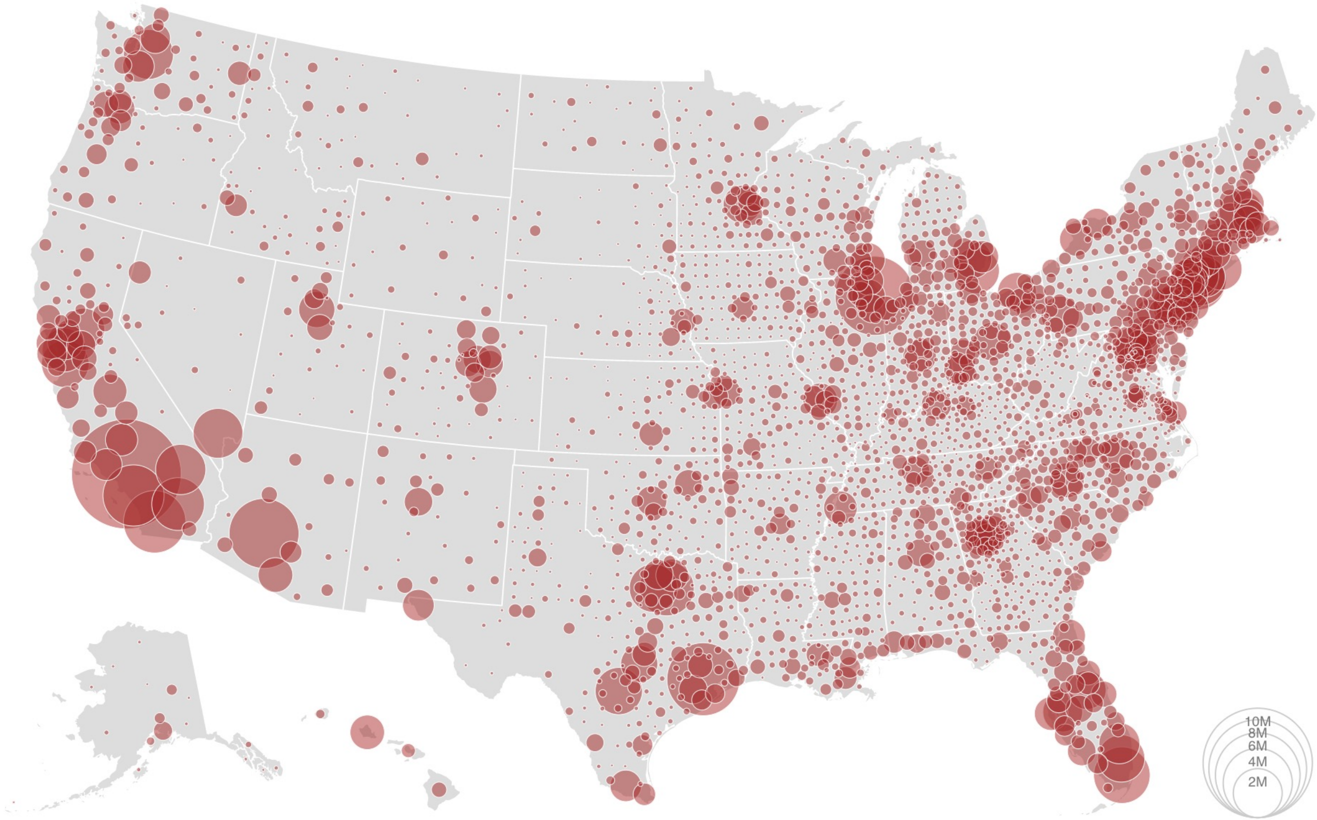
GEOGRAPHICAL DATA- GEOJSON

- Javascript based description of geographical objects
- Three main properties:
  - type (e.g. “FeatureCollection”)
  - crs (Coordinate Reference System)
  - features (list of objects located in the space)
- Each feature consists of:
  - type (e.g.“Feature”)
  - properties (key-value dictionary of attributes)
  - geometry (geometry that represents the object)

FROM GEO-DATA TO VISUALIZATION

- Mapping of geographical coordinates (longitude and latitude) to position on the screen
  - Definition of projection function based on scale, translation and rotation
  - module: d3.geo.projection
- Creation of mapping for each element (point) of the geometry
  - module: d3.geo.path

EXAMPLE: MAP OF PAINTINGS



https://observablehq.com/@d3/bubble-map

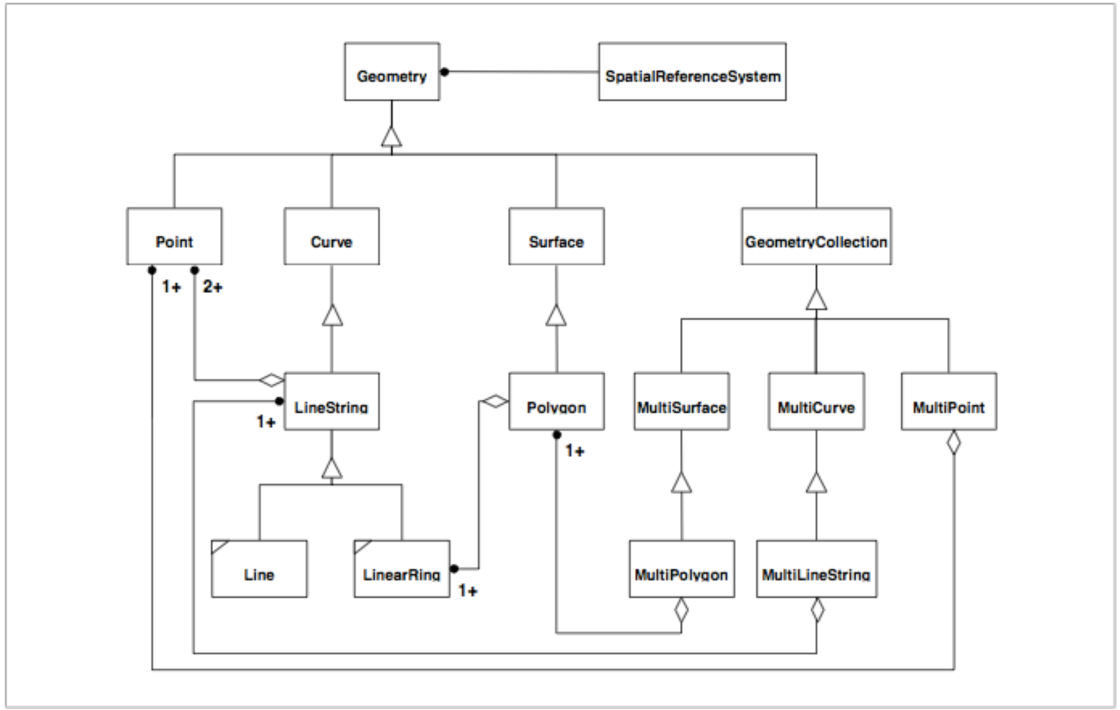
GEOMETRIES AND STANDARDS

OPEN GIS CONSORTIUM – OGC

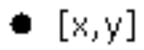
- Consortium to define protocols to transmitt territorial and geographic information

SFS – SIMPLE FEATURE SPECIFICATION

- Definition of an abstract data type:
  - Geometry

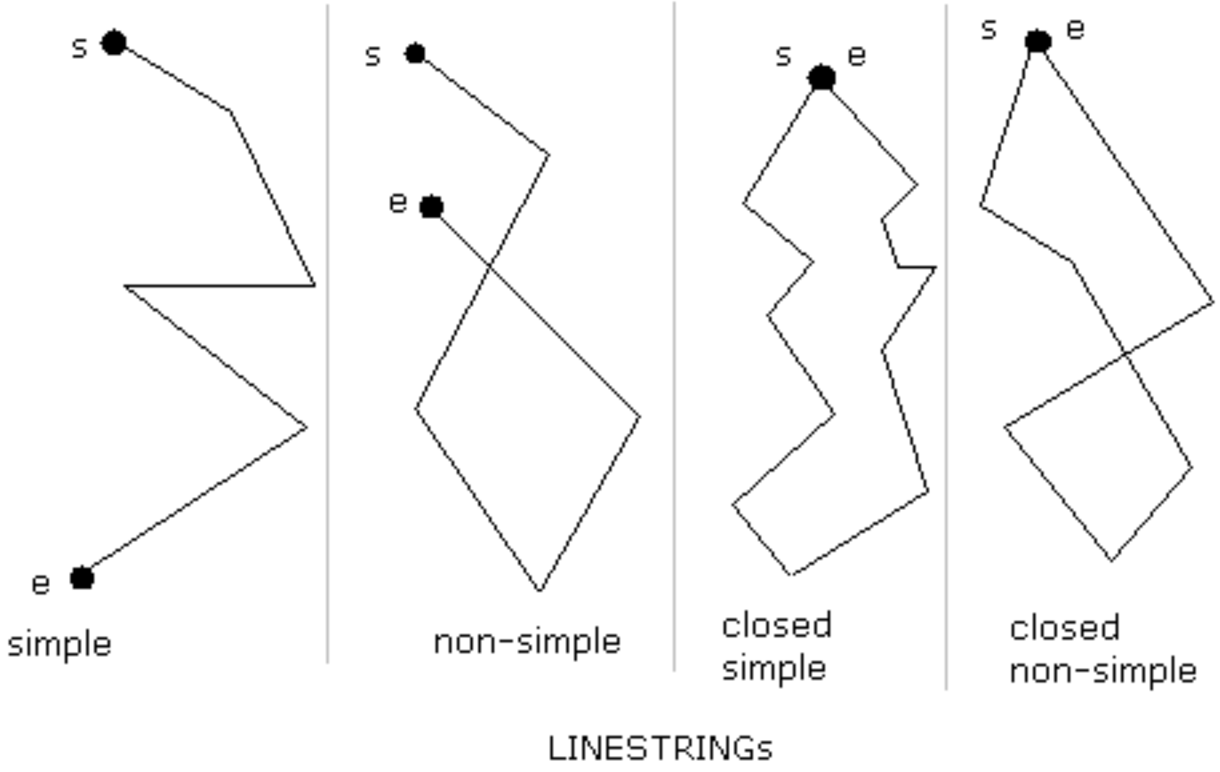


POINT

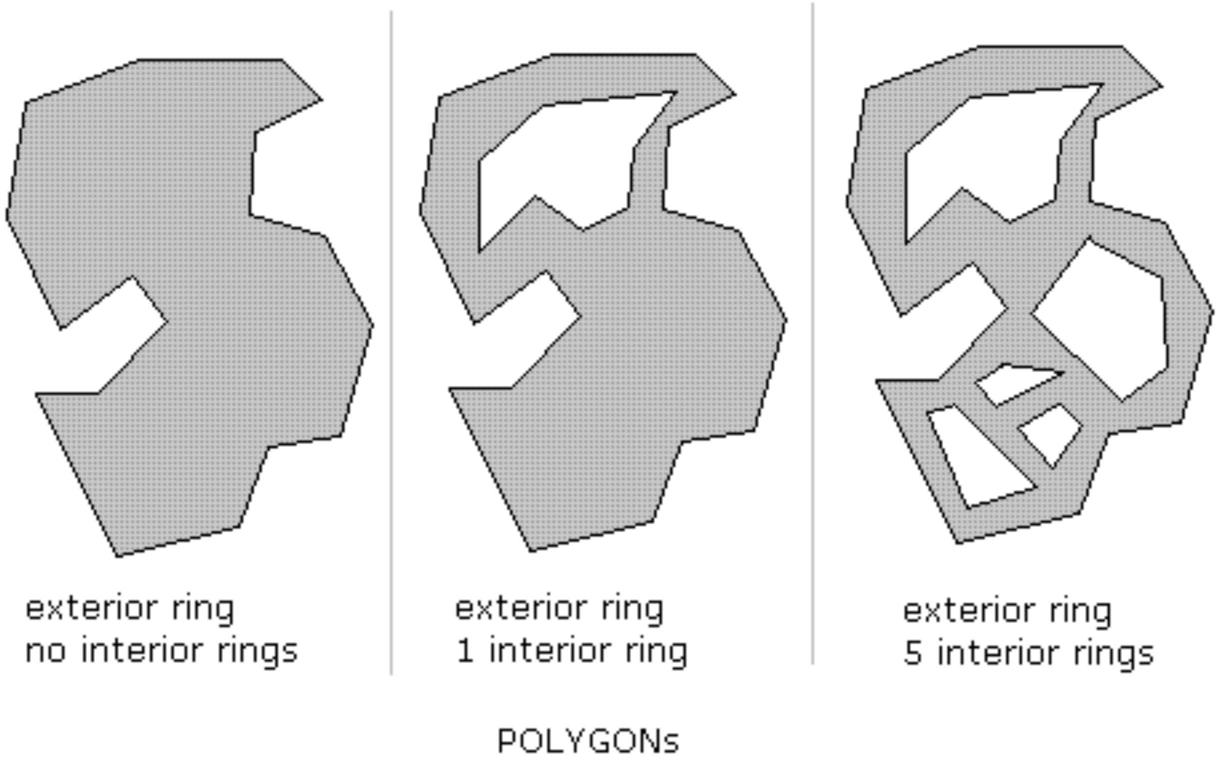


POINT

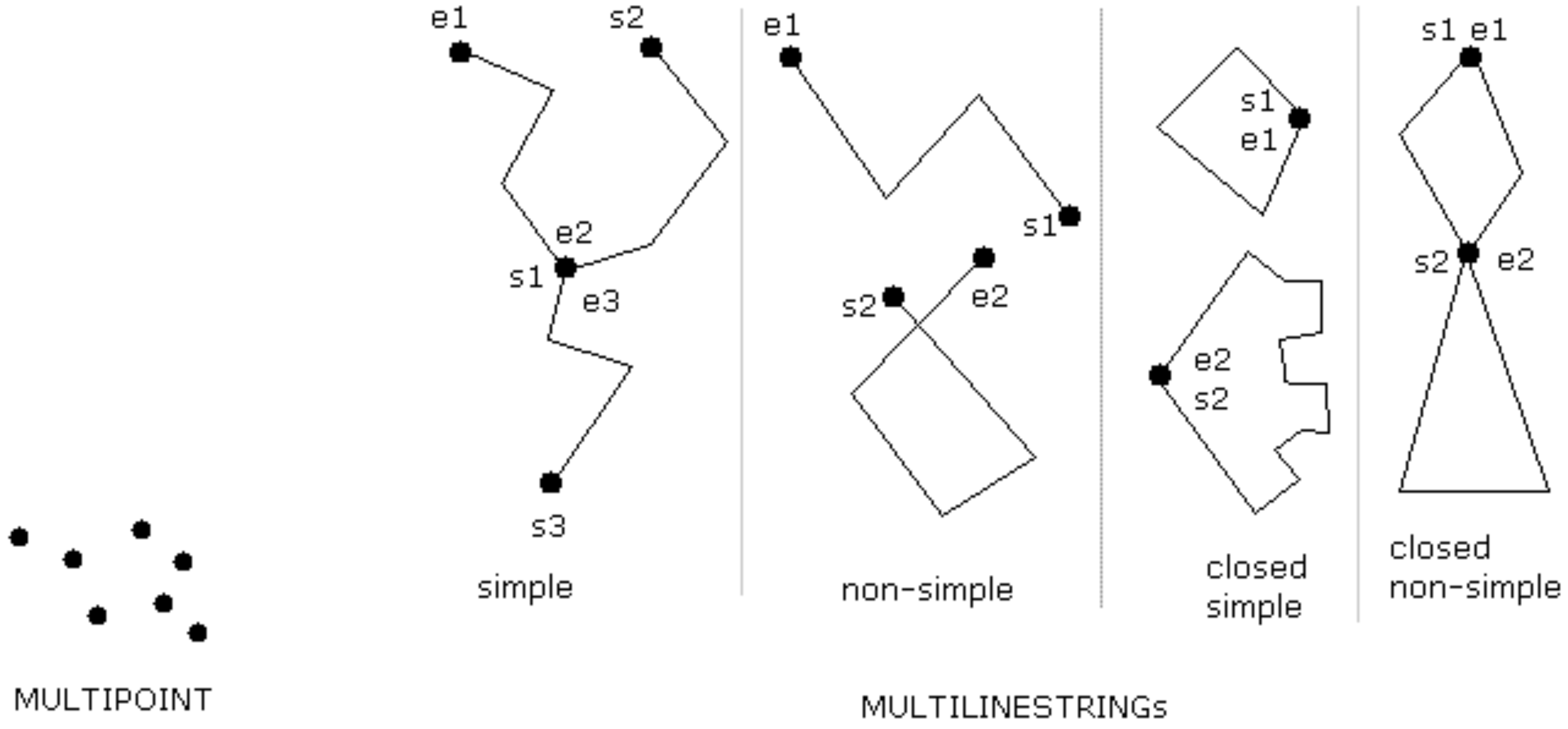
LINESTRING


s
e
simple
s
e
non-simple
s
e
closed
simple
s
e
closed
non-simple
LINESTRINGs

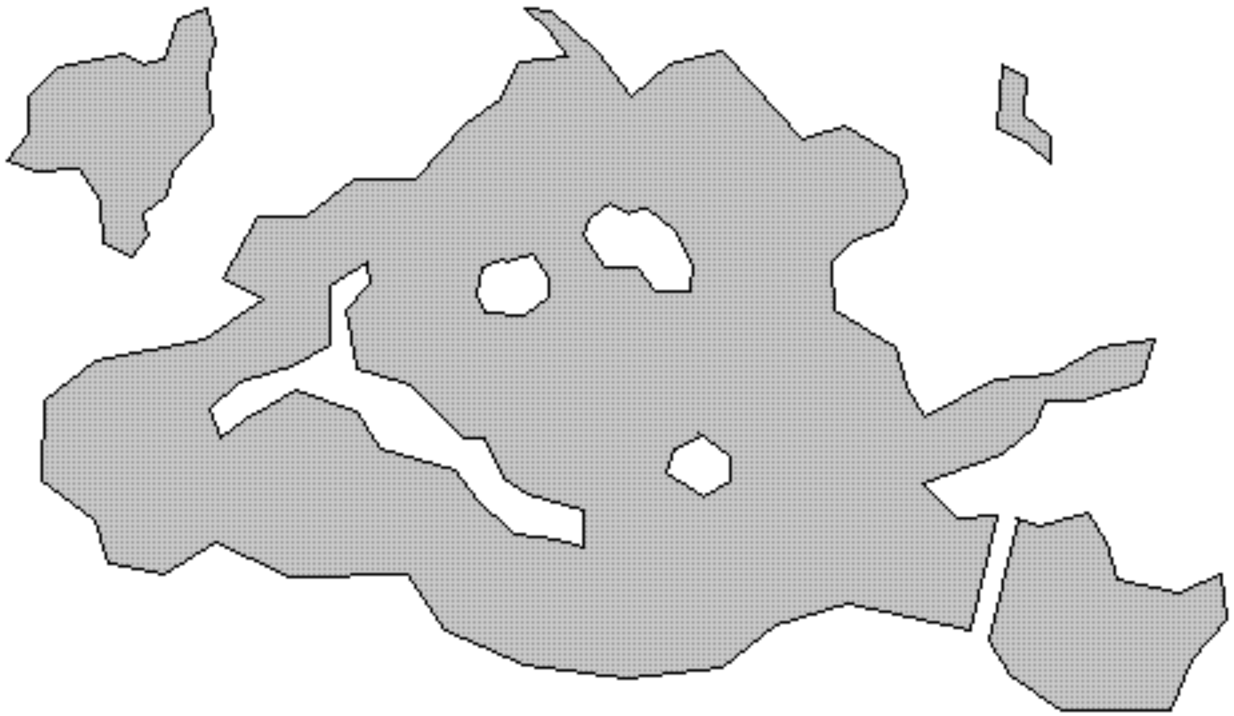
POLYGON


exterior ring
no interior rings
exterior ring
1 interior ring
exterior ring
5 interior rings
POLYGONs

MULTIPOINT, MULTILINESTRING



MULTIPOLYGON



MULTIPOLYGON

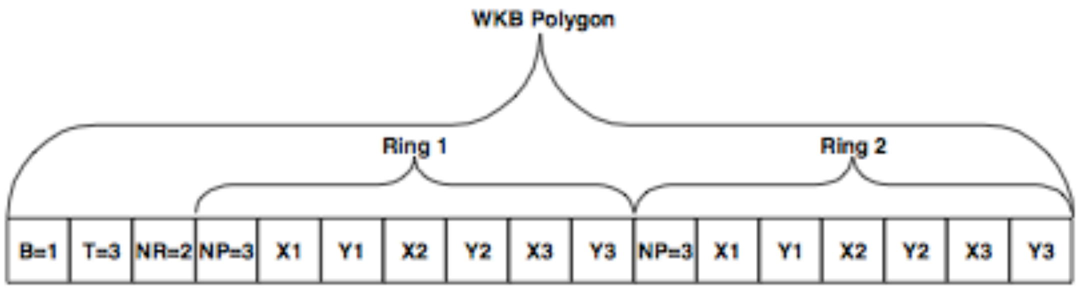
WKT – WELL KNOWN TEXT FORMAT

- POINT(123.45 543.21)
- LINESTRING(100.0 200.0, 201.5 102.5, 1234.56 123.89)
- POLYGON((101.23 171.82, 201.32 101.5, 215.7 201.953, 101.23 171.82))
- POLYGON((10 10, 20 10, 20 20, 10 20, 10 10),(13 13, 17 13, 17 17, 13 17, 13 13))
- MULTILINESTRING((1 2, 3 4), (5 6, 7 8, 9 10), (11 12, 13 14))
- MULTIPOLYGON(((0 0,10 20,30 40,0 0),(1 1,2 2,3 3,1 1)),((100 100,110 110,120 120,100 100)))
- GEOMETRYCOLLECTION(POINT(1 1), LINESTRING(4 5, 6 7, 8 9), POINT(30 30))

WKB – WELL KNOWN BINARY FORMAT

- Compact representation
- Useful to store geometries on DBMS

```
WKBPolygon {
          byte           byteOrder;
          uint32         wkbType;                          // 3
          uint32         numRings;
          LinearRing     rings[numRings];
}
```



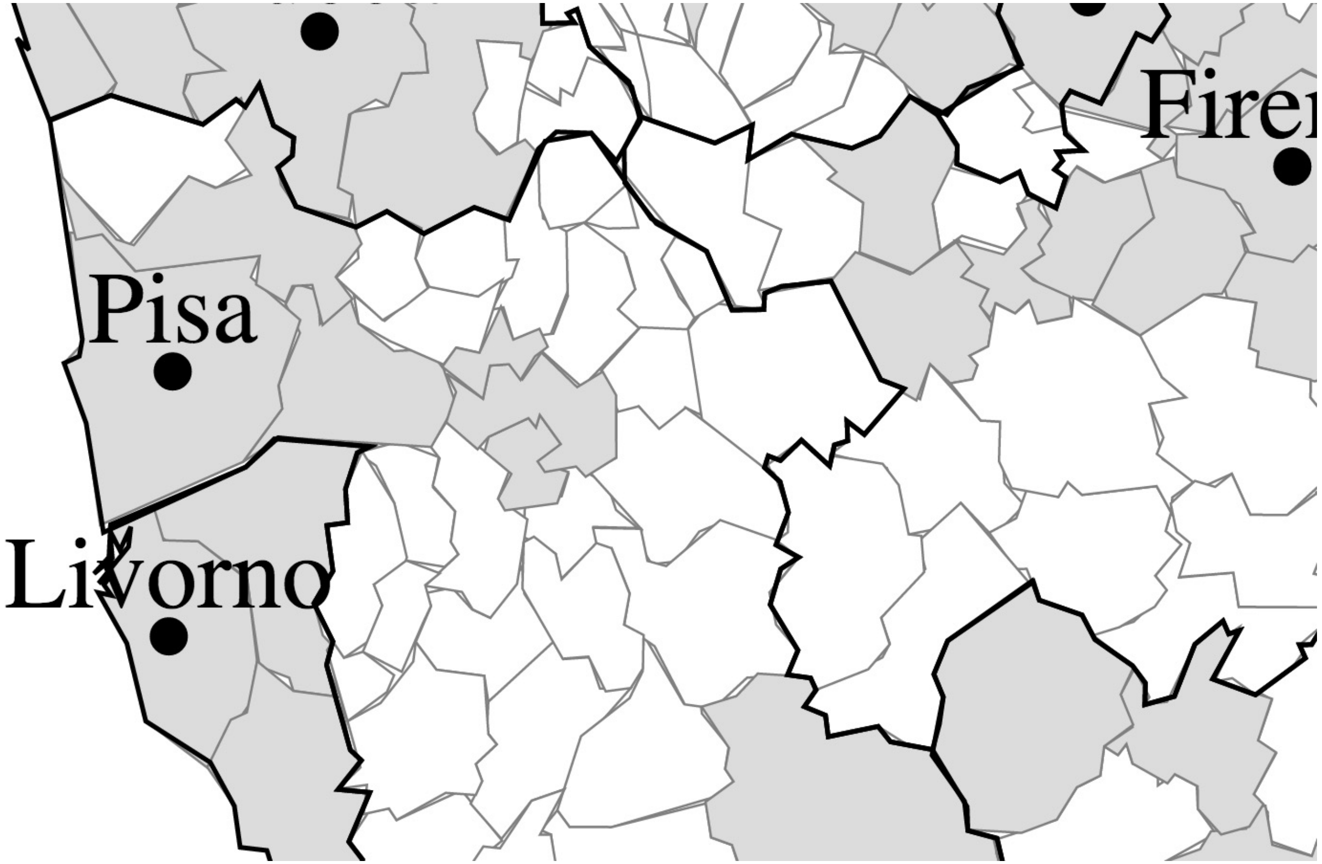
GEOJSON FORMAT

```
{ "type": "FeatureCollection",
  "features": [
    { "type": "Feature",
      "geometry": {"type": "Point", "coordinates": [102.0, 0.5]},
      "properties": {"prop0": "value0"}
      },
    { "type": "Feature",
      "geometry": {
        "type": "LineString",
        "coordinates": [
          [102.0, 0.0], [103.0, 1.0], [104.0, 0.0], [105.0, 1.0]
          ]
        },
      "properties": {
        "prop0": "value0",
        "prop1": 0.0
        }
      },
    { "type": "Feature",
       "geometry": {
         "type": "Polygon",
         "coordinates": [
           [ [100.0, 0.0], [101.0, 0.0], [101.0, 1.0],
             [100.0, 1.0], [100.0, 0.0] ]
           ]
       },
       "properties": {
         "prop0": "value0",
         "prop1": {"this": "that"}
         }
       }
     ]
   }
```

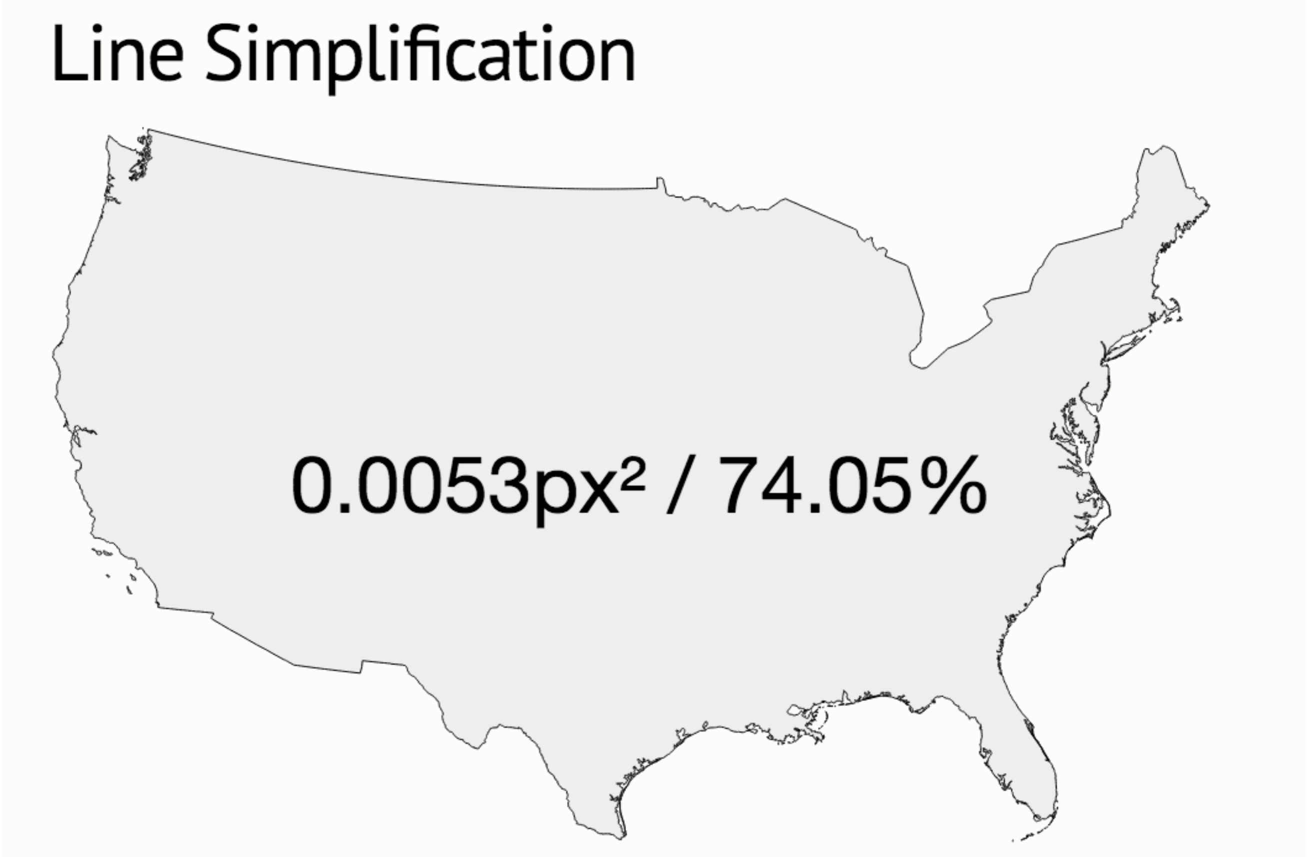
TOPOJSON

- Extends GeoJSON and encodes topology
- Shared lines are represented as arcs
- Reduce redundancy and decrease file size
- Topology can be exploited in specific applications

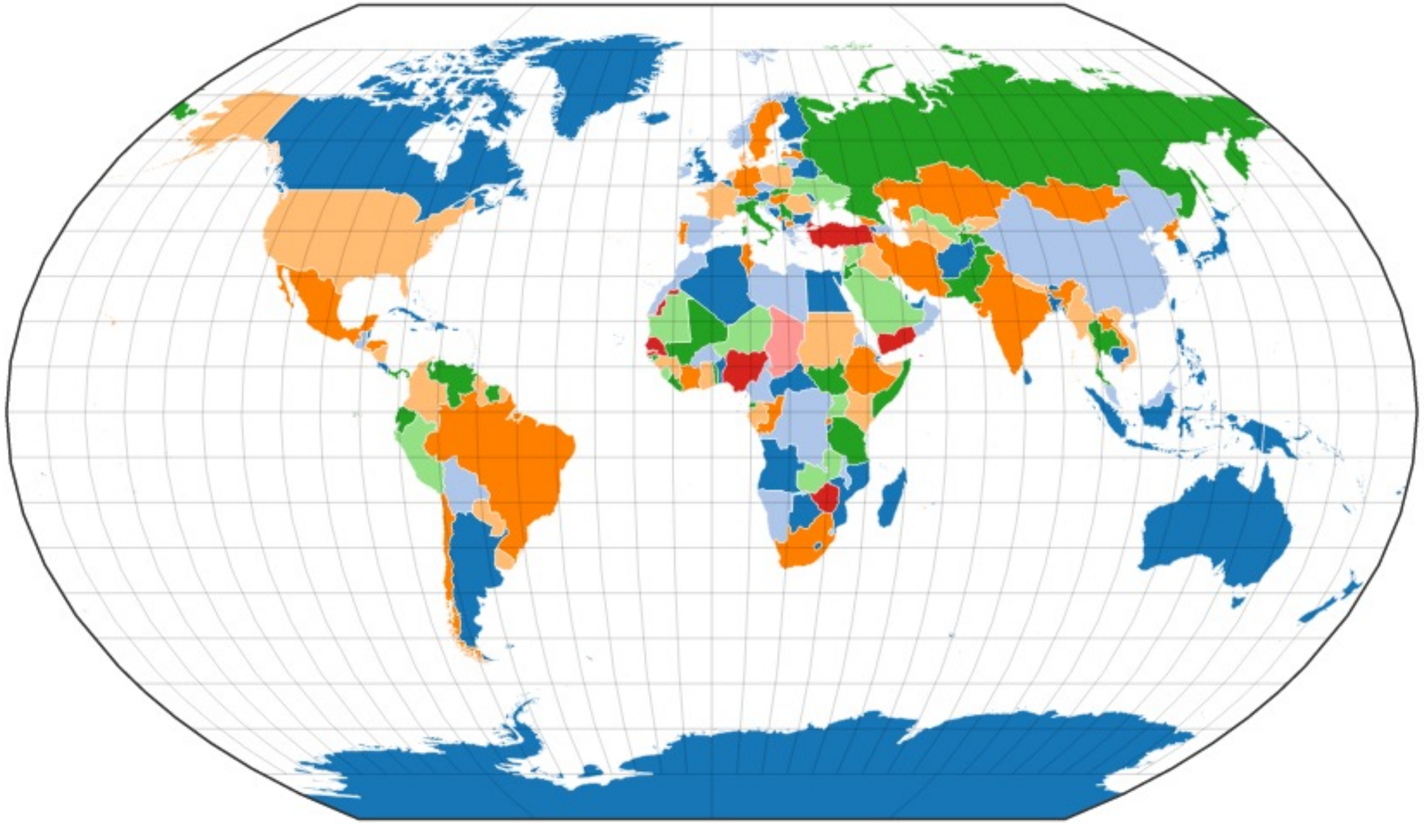
EXAMPLE, WITHOUT TOPOLOGY



LINE SIMPLIFICATION

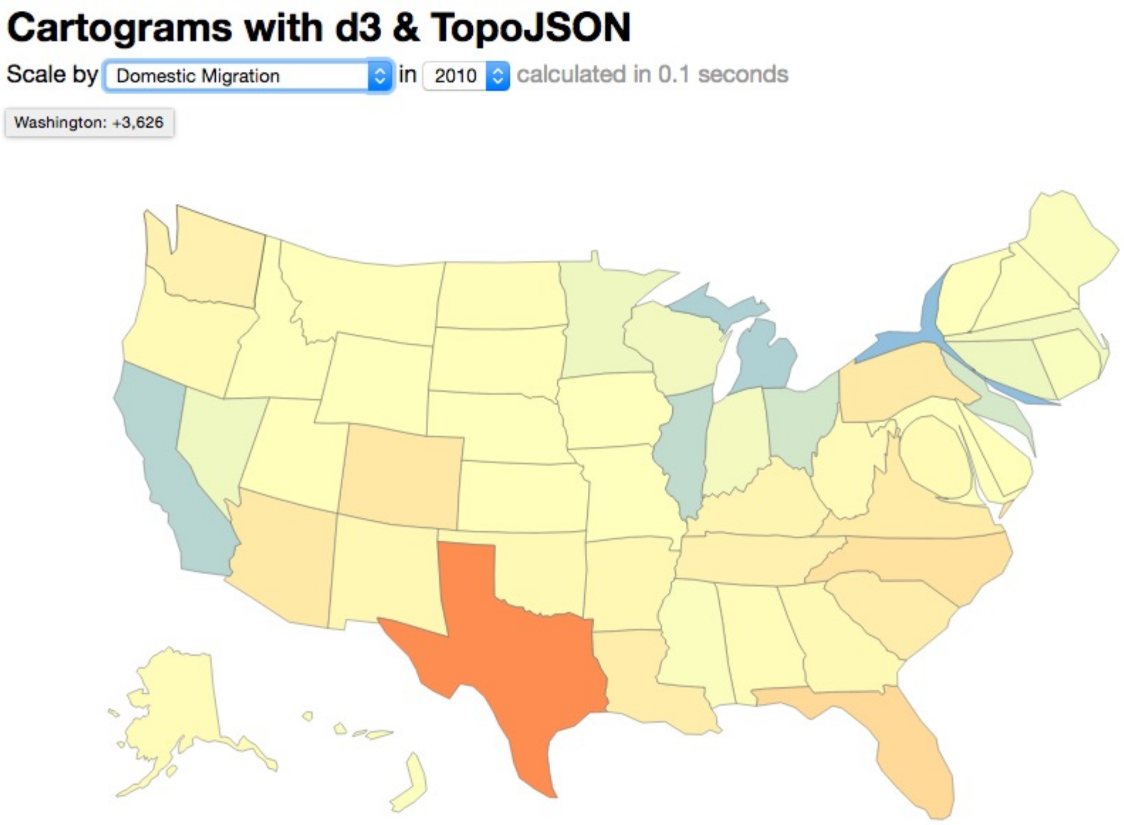


COLOR MAPPING



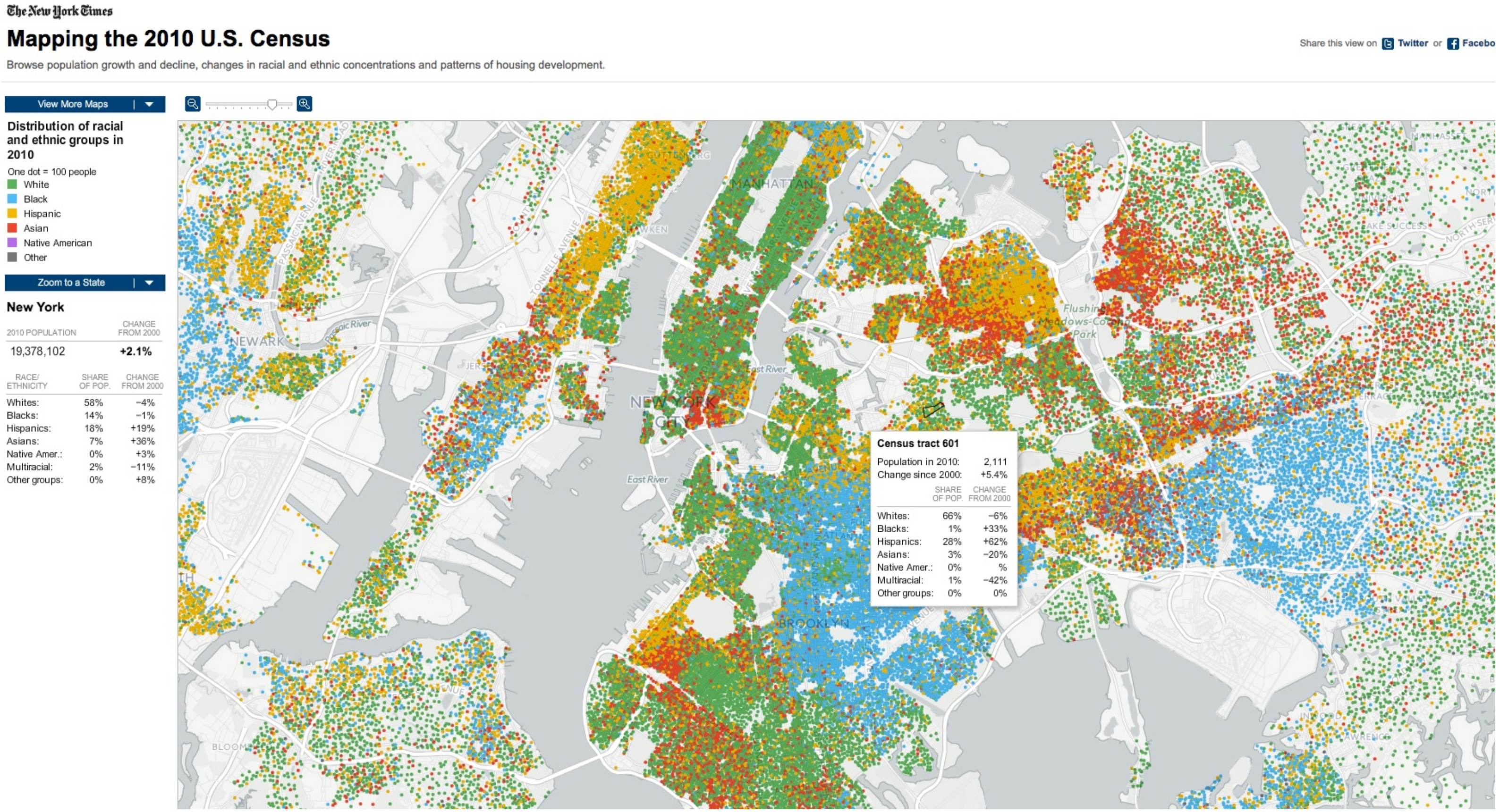
http://bl.ocks.org/jasondavies/4188334

CARTOGRAMS



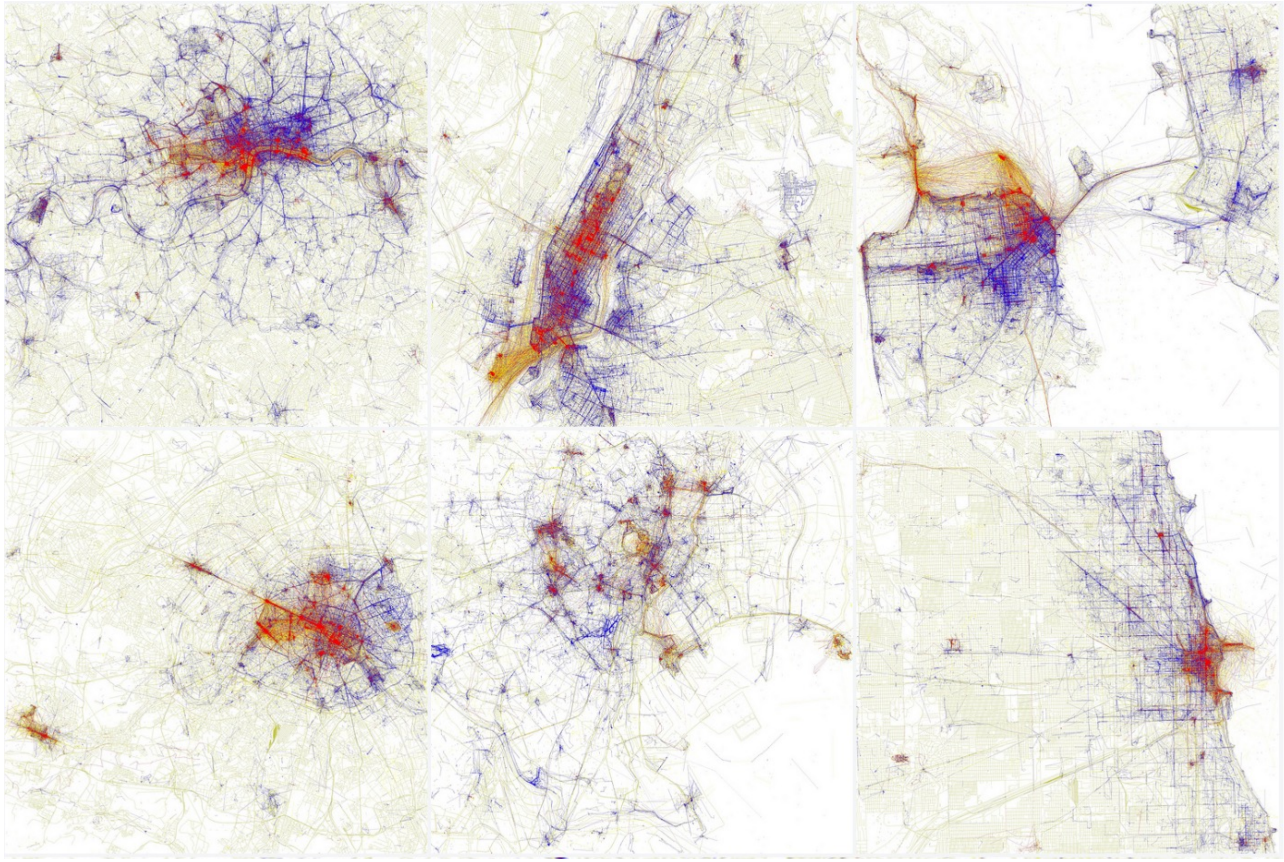
http://prag.ma/code/d3-cartogram/

DOT DISTRIBUTION



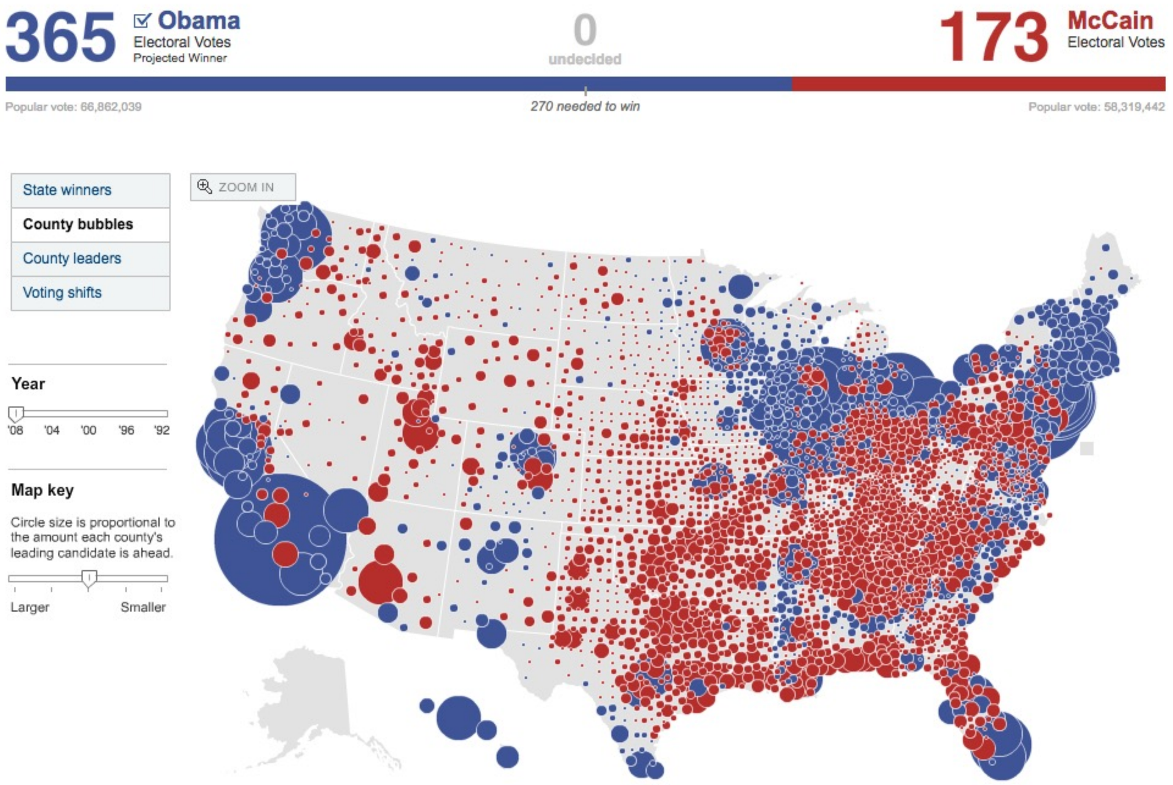
http://projects.nytimes.com/census/2010/map

LINES DISTRIBUTION



https://www.flickr.com/photos/walkingsf/albums/72157624209158632

GRADUATED SYMBOL MAP



http://elections.nytimes.com/2008/results/president/map.html

TILE MAP SERVER

TILE MAP SERVER

- An efficient solution to publish maps on the web
  - Complexity in space (rather than in time)
  - Used by many providers:
    - Google Maps, Bing, Yahoo Maps, OpenStreetMaps
- Maps is generated once for all level of zoom and then sliced into tiles
- A map for a finite set of zoom levels

Tile Map Server (2)

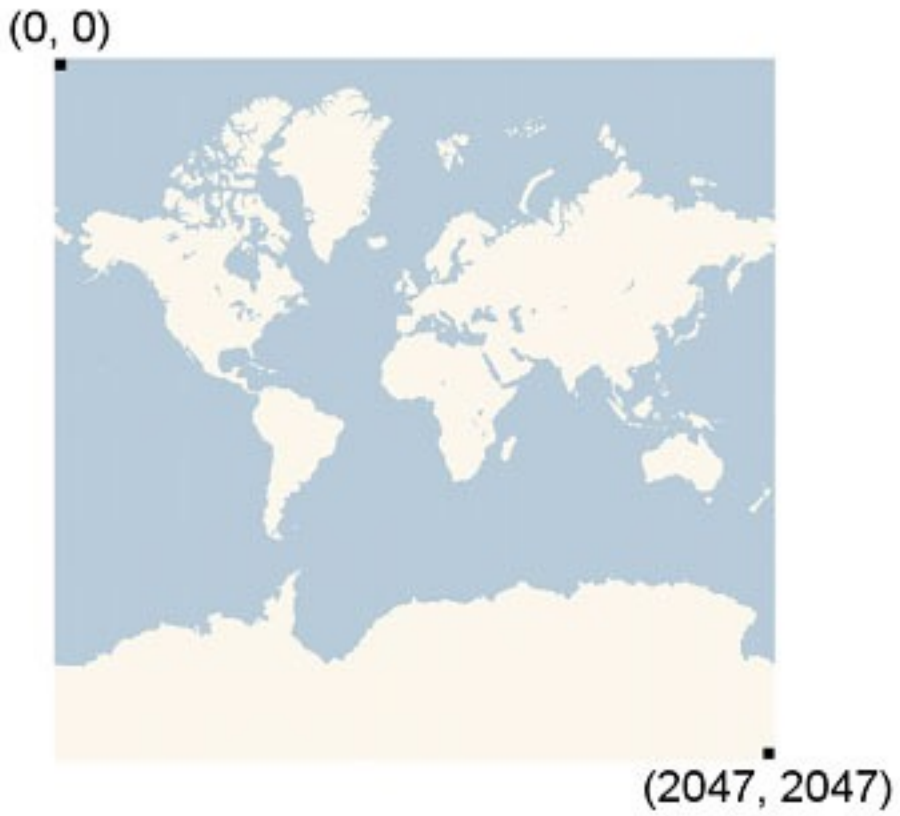
- To simplify coordinate mapping: cylindrical projection
- Two main reference systems:
  - Sphere Mercator (53004)
  - World Mercator (54004)
- Mercator Cyndric projection
  - Meridians are parallels
  - Conformal (preserves shapes)
  - Preserves directions

TILE MAP SERVER (3): SCALE

- Hierarchy division of plane
- Every tile (any zoom) has a fixed dimension: 256x256
- Each zoom level increases (doubles) the number of tiles
- At level 1: only 4 tiles

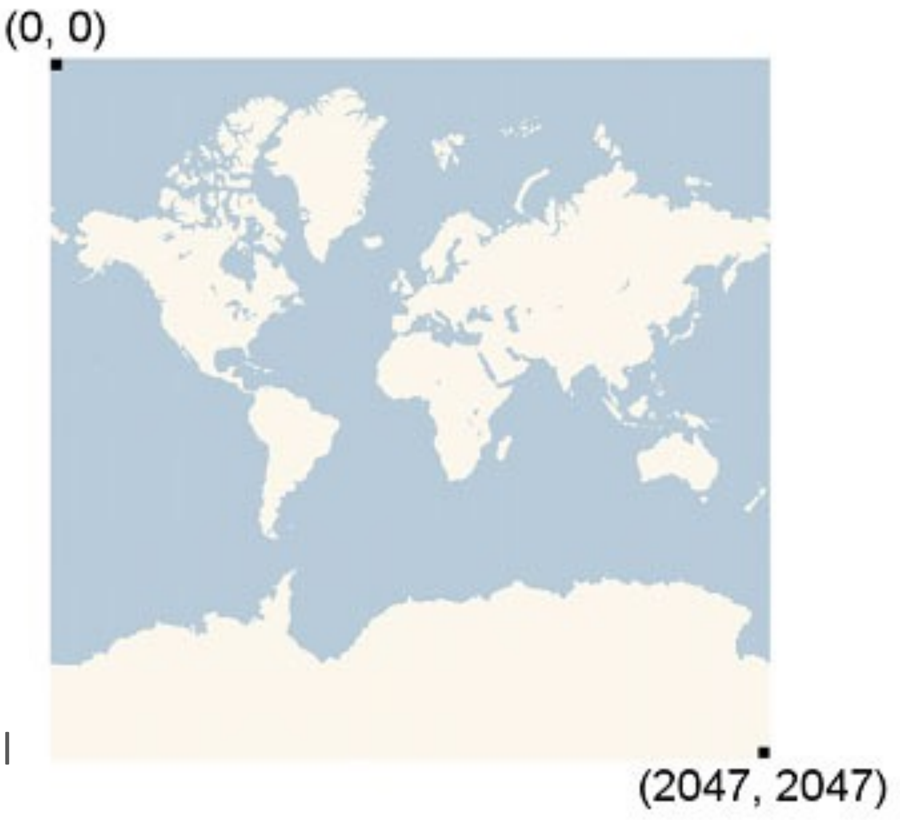
TILE MAP SERVER (4): SCALE

- At each zoom level, the number of tiles increases
  - Every tile at level n generates 4 tiles at level n+1
- At level n tiles cover 256 * 2^n pixel
- For example, at level 3 map has a side 256 * 2^3 = 2048 pixel



TILE MAP SERVER (5): COORDINATES

- Given coordinate (lat,lon) and zoom level n, how to determine position on the image?
- Which tile correspond to coordinate?



pixelX = ((longitude + 180) / 360) * 256 * 2^level

pixelY = (1 – log(tan(Latitude)+ sinh(Latitude)) / pi))/2 * 256 * 2 ^ level

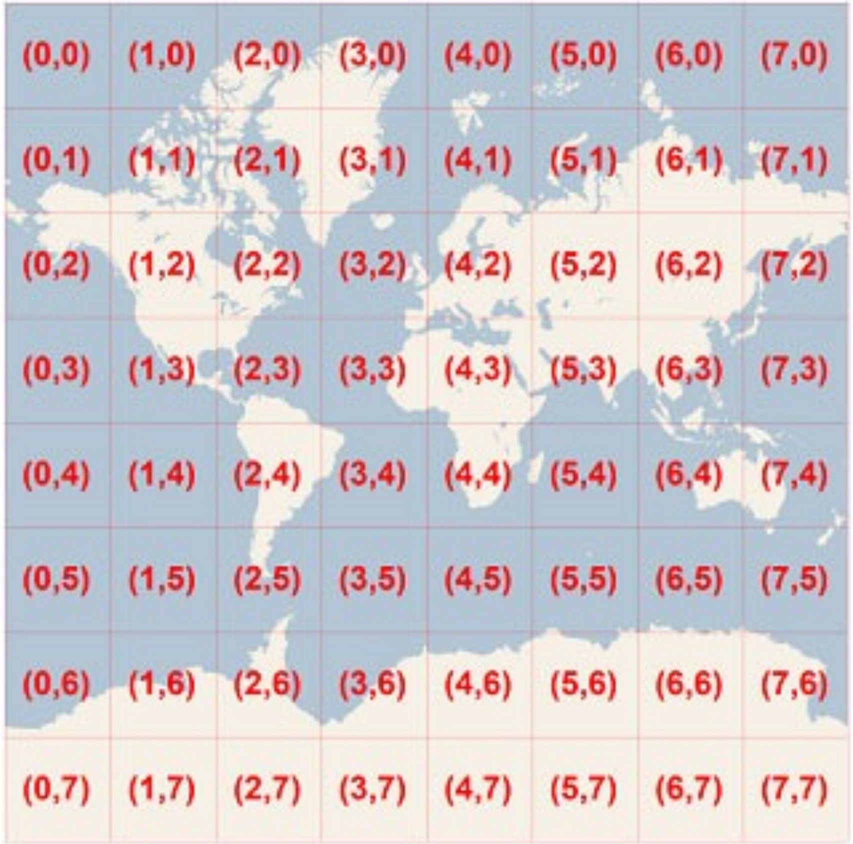
TILE MAP SERVER (6): TILE NUMBER

- Given pixelX e pixelY
- Which tile contains that pixel?

tileX = floor(pixelX / 256)

tileY = floor(pixelY / 256)

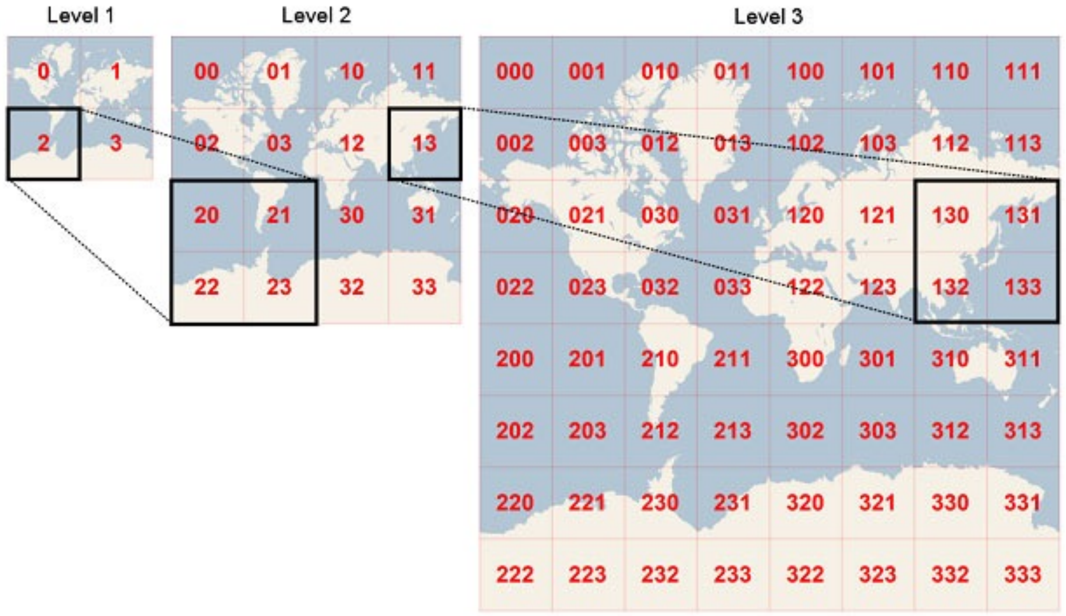
- URL to tile:
  - /zoom/tx/ty
  - quadkey



http://otile2.mqcdn.com/tiles/1.0.0/osm/1/0/0.png

TILE MAP SERVER (7): QUADKEY

- Used by Bing
- Length of the key corresponds to the zoom level



tileX = 3 = 011
tileY = 5 = 101
quadkey = 100111 = 2134 = “213”

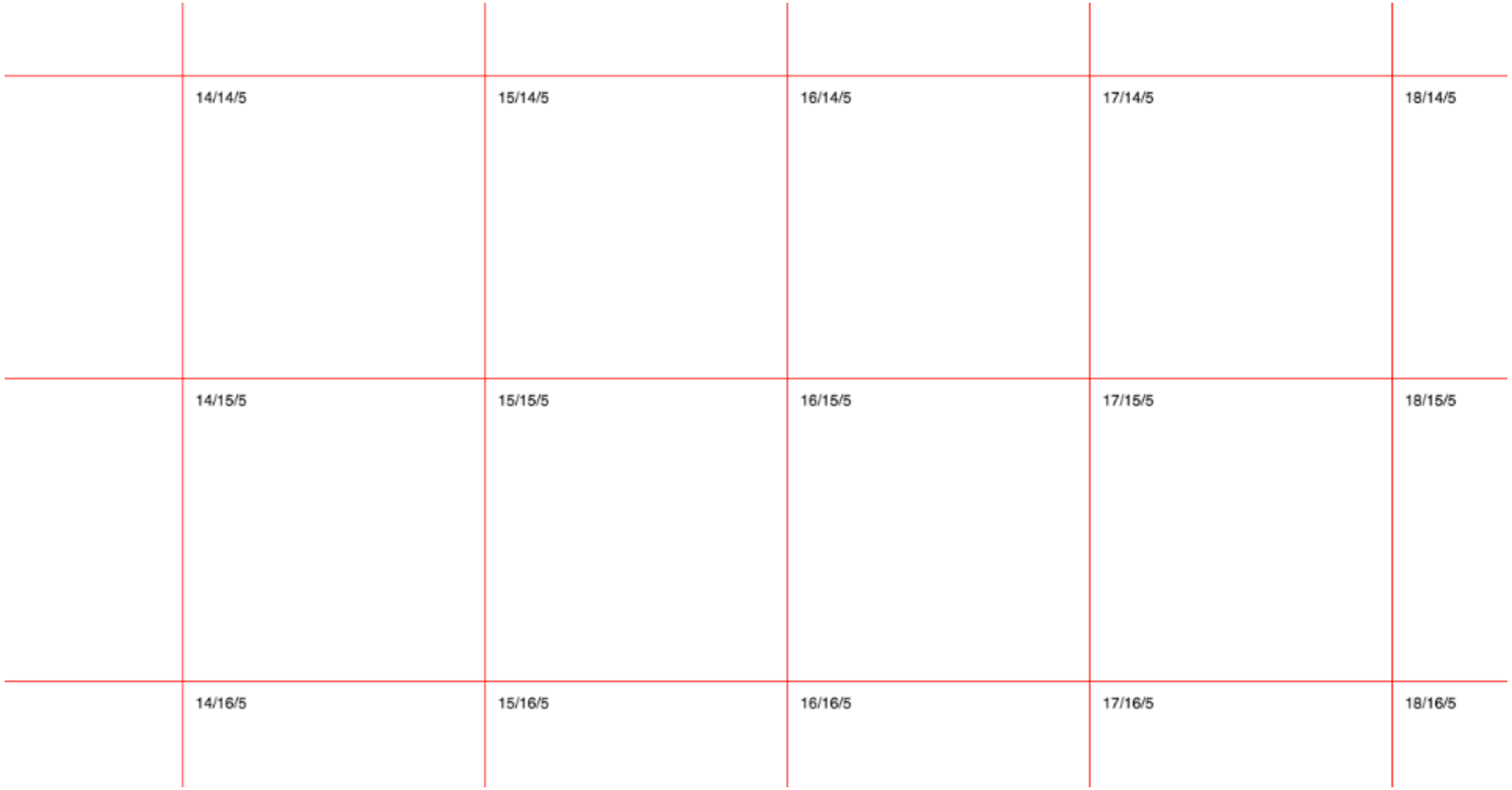
TILE MAP SERVER (8): ZOOM IN

- Given a tile a zoom level n
- Successive tile at level n+1 are:
  - 2x,2y
  - 2x+1,2y
  - 2x,2y+1
  - 2x+1,2y+1

/3/4/2.png


Sea
Archangel
Finland
Norway
Vaasa
Sweden
Petrozavodsk
Tampere
Bergen
Helsinki
St. Petersburg
Oslo
Stockholm
Vologda
Estonia
Kristiansand
Yaroslavl
Tver
Latvia
North Sea
Denmark
Malmo
Baltic Sea
Moscow
Lithuania
Minsk
Smolensk
Gdansk
Hamburg
Berlin
Bryansk
Belarus
Netherlands
Poland
Brest
Voronezh
Germany
Kiev
Belgium
Kraków
Lvov
Kharkiv
Luxembourg
Czech Rep.
Munich
Slovakia
Ukraine
Austria
Hungary
Restov
France
Switzerland
Moldova
Slovenia
Croatia
Romania
Krasnodar
Sevastapol
Constanta
Serbia
Marseille
Italy
Adriatic Sea
Kosovo
Black Sea
Bulgaria
Barcelona
Naples
Albania
Samsun
Naltchik

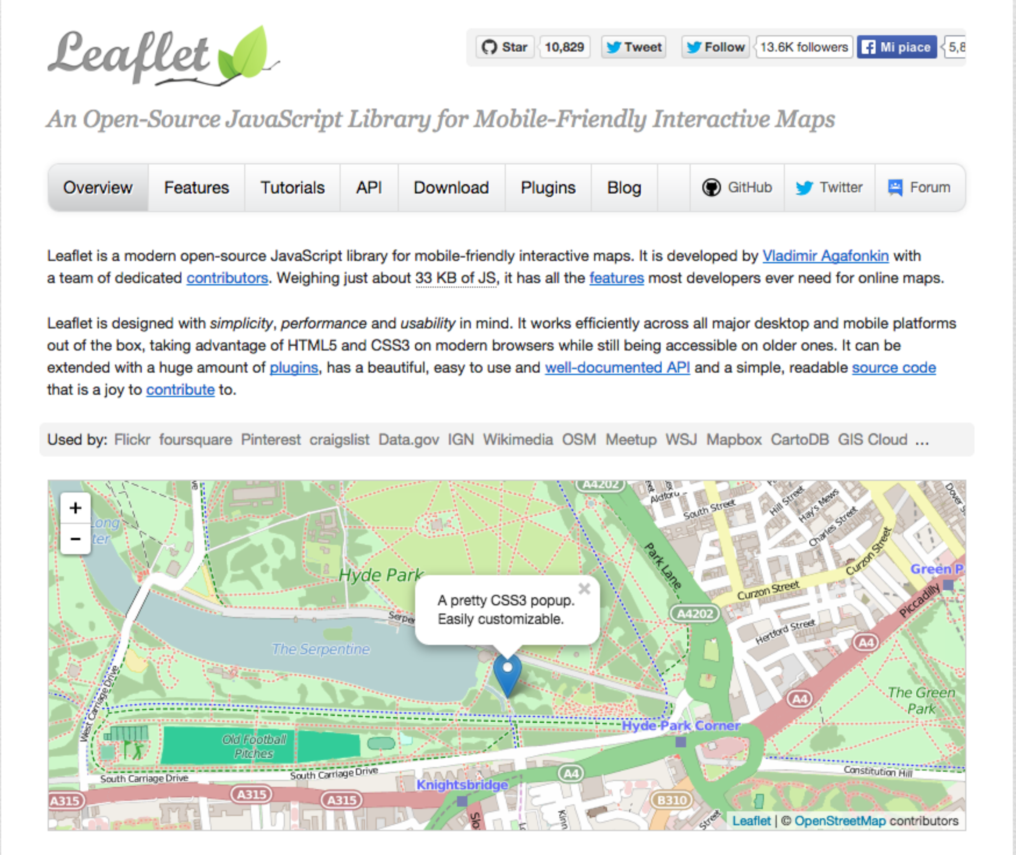
TILE VIEWER EXAMPLE



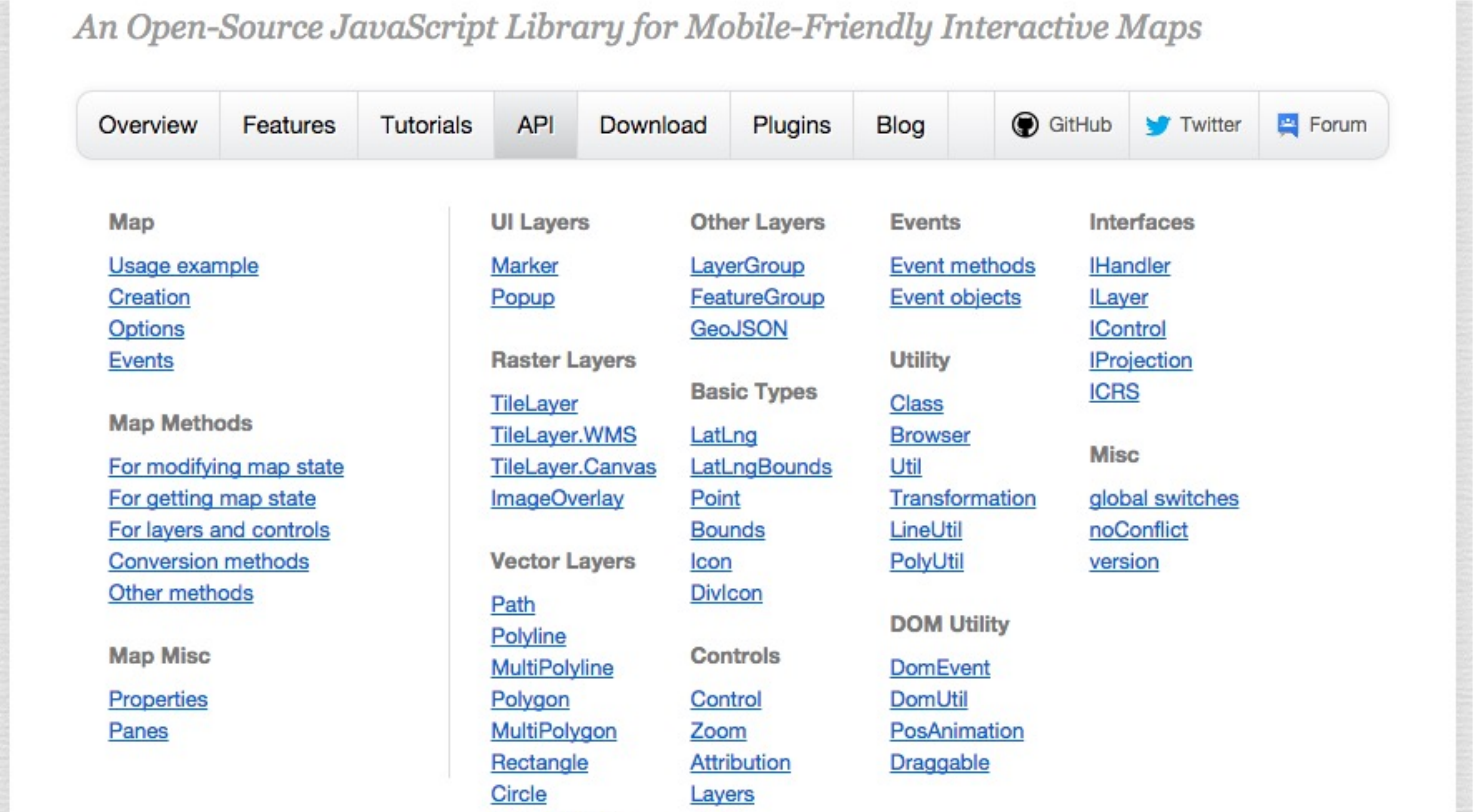
https://bl.ocks.org/mbostock/f9f91fd9148bdc5aa6db

TILE SERVICES

LEAFLET.JS


Leaflet
Star 10,829 Tweet Follow 13.6K followers Mi piace
An Open-Source JavaScript Library for Mobile-Friendly Interactive Maps
Overview Features Tutorials API Download Plugins Blog GitHub Twitter Forum
Leaflet is a modern open-source JavaScript library for mobile-friendly interactive maps. It is developed by Vladimir Agafonkin with a team of dedicated contributors. Weighing just about 33 KB of JS, it has all the features most developers ever need for online maps.
Leaflet is designed with simplicity, performance and usability in mind. It works efficiently across all major desktop and mobile platforms out of the box, taking advantage of HTML5 and CSS3 on modern browsers while still being accessible on older ones. It can be extended with a huge amount of plugins, has a beautiful, easy to use and well-documented API and a simple, readable source code that is a joy to contribute to.
Used by: Flickr foursquare Pinterest craigslist Data.gov IGN Wikimedia OSM Meetup WSJ Mapbox CartoDB GIS Cloud ...
Hyde Park
The Serpentine
A pretty CSS3 popup. Easily customizable.
Hyde Park Corner
Knightsbridge
The Green Park
Curzon Street
Park Lane
Old Football Pitches
South Carriage Drive
Leaflet | © OpenStreetMap contributors

LEAFLET.JS - APIS



LEAFLET.JS

- A valid tool to provide tile-based maps
  - Open Source
  - Open Data (http://tools.geofabrik.de/mc/)
  - Free
- Easy to use API
- Lightweight lib (only 64k)
- Support mobile applications
- Alternative to Google Maps (http://flink.com.au/tips-tricks/27-reasons-not-to-use-google-maps)

FREE TILES PROVIDERS

- OpenStreetMap
  - Some issues for high traffic services
- MapQuest Open License
  - Free, by attribution
  - Special configuration for heavy usage
- MapBox
  - Free tier
  - Customizable design (see next slide)
  - Same family as Leaflet.js

COMMERCIAL TILE PROVIDERS

- CloudMade
  - Mirror of OSM data till few years ago
  - Leaflet was born here
  - $30 per 1M tiles
- MapBox
  - Free for low traffic
  - $30 for 900k tiles

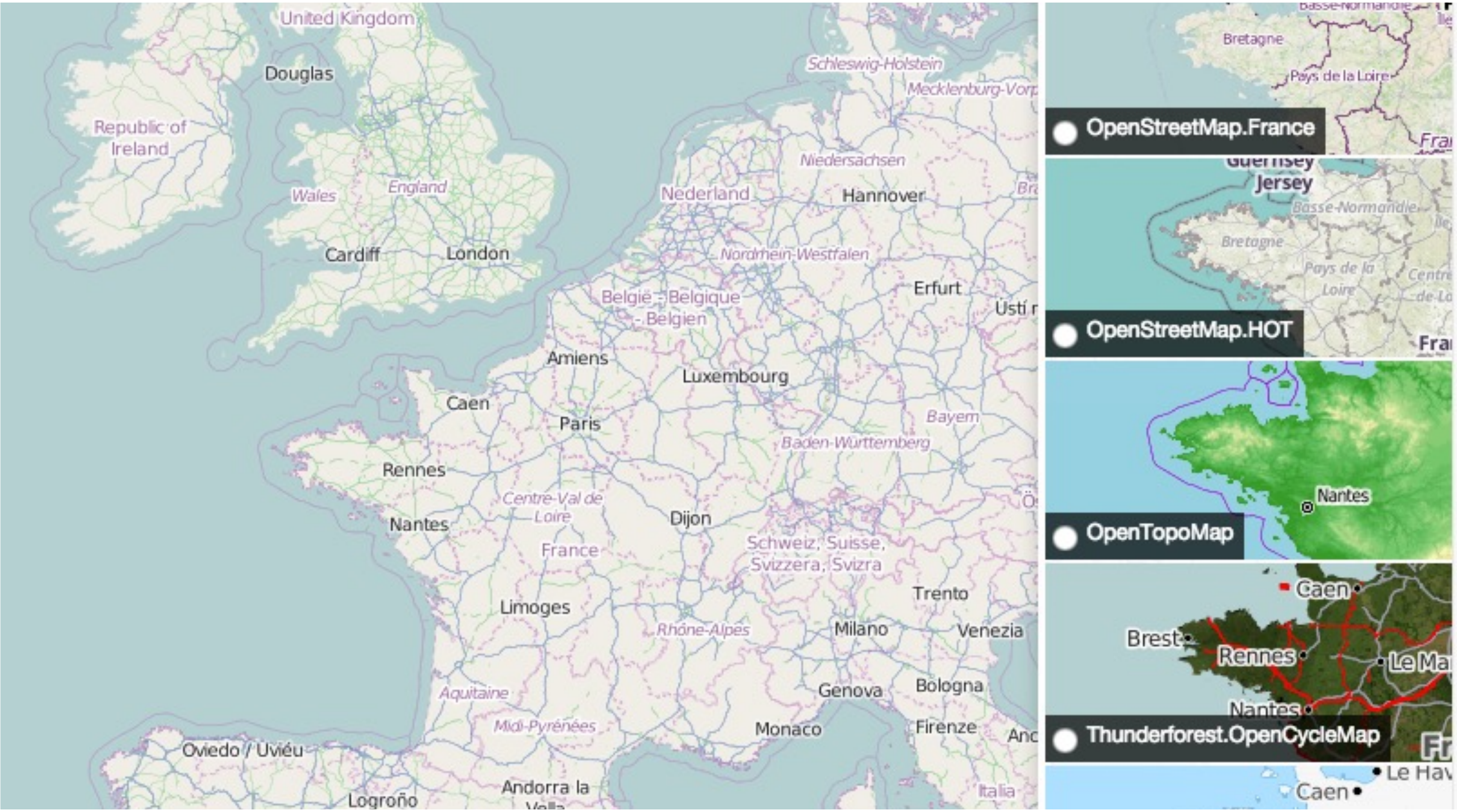
EASY TO INSTALL/USE

- HTML (Setting the stage)
  - Link CSS (via CDN)
    - `<link rel="stylesheet" href="http://cdnjs.cloudflare.com/ajax/libs/leaflet/0.7.3/leaflet.css" />`
  - Link JS (via CDN)
    - `<script src="http://cdnjs.cloudflare.com/ajax/libs/leaflet/0.7.3/leaflet.js"></script>`
  - Create a div to contain the map
    - `<div id="map"></div>`
  - Set height for the container
    - `#map { height: 180px; }`

EASY TO INSTALL/USE

- Create an object to handle the map
  - `var map = L.map('map').setView([51.505, -0.09], 13);`

TILE MAP PROVIDERS



http://leaflet-extras.github.io/leaflet-providers/preview/

http://maps.stamen.com

MARKERS AND GEOMETRIES

- var marker = L.marker([51.5, -0.09]).addTo(map);
- var circle = L.circle([51.508, -0.11], 500, {
    color: 'red’,
    fillColor: '#f03’,
    fillOpacity: 0.5
  }).addTo(map);
- var polygon = L.polygon([
    [51.509, -0.08],
    [51.503, -0.06],
    [51.51, -0.047]
  ]).addTo(map);

INTERACTIONS

- marker.bindPopup("Hello world!
I am a popup.").openPopup();
- circle.bindPopup("I am a circle.");
- polygon.bindPopup("I am a polygon.");

EVENT HANDLING

- ```
  function onMapClick(e) {
      alert("You clicked the map at " + e.latlng);
  }
  ```
- ```
  map.on('click', onMapClick);
  ```

- ```
  var popup = L.popup();
  ```
- ```
  function onMapClick(e) {
      popup
          .setLatLng(e.latlng)
          .setContent("You clicked the map at " + e.latlng.toString())
          .openOn(map);
  }
  ```
- ```
  map.on('click', onMapClick);
  ```
  ```

OTHER EXAMPLES

- Mobile app
  - http://leafletjs.com/examples/mobile.html
- GeoJSON
  - http://leafletjs.com/examples/geojson.html
  - http://geojson.io/
- Tutorials
  - http://leafletjs.com/examples.html