GIS's Roots in Cartography

Getting Started With GIS

Chapter 2

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MAP and ATRIBUTE INFORMATION

- **Data (numbers and text)**
- **store as files**
- **refer to them collectively as a database**
- **gather inform. about are referred to as attributes, (pictures, values, text...)**
- **individual data items as records**

GIS's Roots in Cartography

- ✓ **Maps and Attribute Information**
- ✓ **Map Scale and Projections**
- ✓ **Coordinate Systems**
- ✓ **Geographic Information**

The Elements of GIS

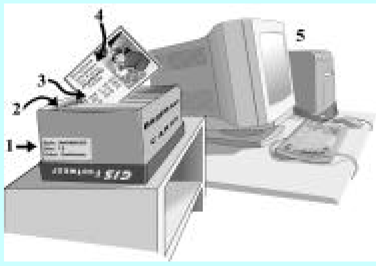


Figure 2.1 The Elements of a GIS. (1) The Database (shoebox); (2) The Records (Baseball Cards); (3) The Attributes (The categories on the cards, such as a batting average; (4) The geographic information (locations of the team's stadium in latitude and longitude); (5) A means to use the information (the computer).

Organizing Data and Information

- **Information can be organized as lists, numbers, tables, text, pictures, maps, or indexes.**
- **Clusters of information called data can be stored together as a database.**
- **A database is stored in a computer as files.**

The GIS Database

- **In a database, we store attributes as column headers and records as rows.**
- **The contents of an attribute for one record is a value.**
- **A value can be numerical or text.**

Flat File Database

	Attribute	Attribute	Attribute
Record	Value	Value	Value
Record	Value	Value	Value
Record	Value	Value	Value

- **Cartography** the science that deals with the construction, use, and principles behind maps and map use.
- the organisation, presentation, communication and utilisation of geo-information in graphic, digital or tactile form. It can include all stages from data presentation to end use in the creation of maps and related spatial information products." (F.Taylor)

Attributes have units

Cartography and GIS

- **Understanding the way maps are encoded to be used in GIS requires knowledge of cartography**
- **A map is a depiction of all or part of the earth or other geographic phenomenon as a set of symbols and at a scale whose representative fraction is less than one to one**

The GIS Database (ctd)

- **Data in a GIS must contain a geographic reference to a map, such as latitude and longitude.**
- **The GIS cross-references the attribute data with the map data, allowing searches based on either or both.**
- **The cross-reference is a link.**

Models of the Earth

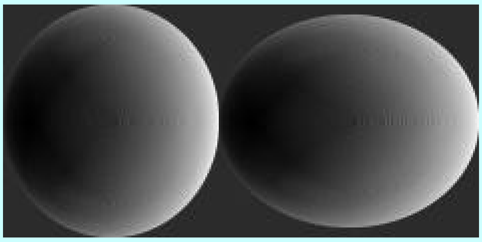
The earth can be modeled as a

–sphere,

–oblate ellipsoid

–geoid

Earth Shape: Sphere and Ellipsoid



Maupertius's Map

- River Tornio in modern Finland
- 14.3 km base line laid out on the ice
- Anders Celsius, Swiss physicist, was a member, and had suggested solution by direct measurement

Measuring the Ellipsoid

- Oblate ellipsoid predicted by Newton
- French Academy of sciences sent expeditions to Lapland and Peru (now in Ecuador) to measure the length of a degree along a meridian
- La Condamine sent to Mitad del Mundo
- Moreau de Maupertius sent to Tornio River Valley

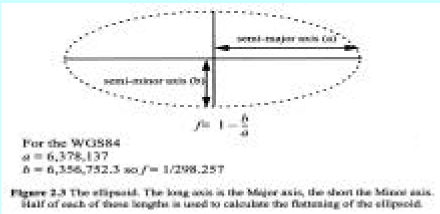
The Spheroid and Ellipsoid

- The sphere is about 40 million meters in circumference.
- An ellipsoid is an ellipse rotated in three dimensions about its shorter axis.
- The earth's ellipsoid is only 1/297 off from a sphere.
- Many ellipsoids have been measured, and maps based on each. Examples are WGS84 and GRS80.

Measuring the Ellipsoid (ctd)

- Maupertius reported a meridian degree as 57,437.9 toises (1 toise = 1.949 m)
- Meridian degree at Paris was 57,060 toises
- Concluded Earth was flatter at poles
- Measures were erroneous but conclusions were correct
- Published as "La Figure de la Terre" (1738)

Earth as Ellipsoid



	equatorial radius	polar radius	flattening
Clarke 1866	6,378,206.4 m	6,356,538.8 m	1/294.9787
1924	6,378,388	-	1/297
WGS84	6,378,137	6,356,752.3	1/298.257

Earth Models and Datums

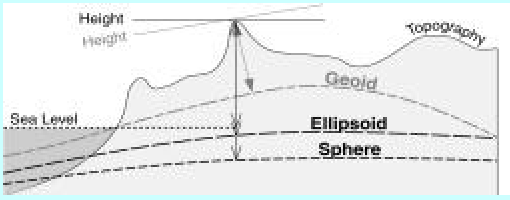


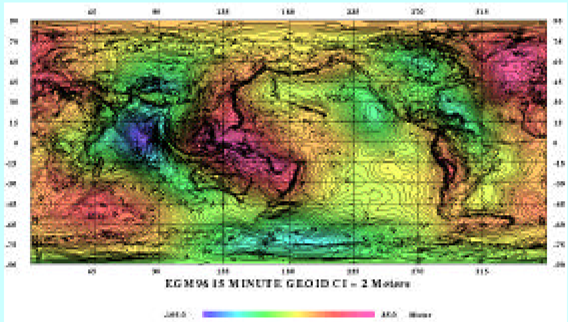
Figure 2.4 Elevations defined with reference to a sphere, ellipsoid, geoid, or local sea level will all be different. Even location as latitude and longitude will vary somewhat. When linking field data such as GPS with a GIS, the user must know what base to use.

An estimate of the ellipsoid allows calculation of the elevation of every point on earth, including sea level, and is often called a *datum*

The Datum

- **An ellipsoid gives the base elevation for mapping, called a datum.**
- **Examples are NAD27 and NAD83.**
- **The geoid is a figure that adjusts the best ellipsoid and the variation of gravity locally.**
- **It is the most accurate, and is used more in geodesy than GIS and cartography.**

Geoid



- **estimate of the ellipsoid *(datum)...***
- **datums have been calculated using the center of the earth as a reference point instead of a point on the ground as was the case before**
- **the world geodetic system 1984 (WGS84.)**

Map Scale

- **Map scale is based on the representative fraction, the ratio of a distance on the map to the same distance on the ground.**
- **Most maps in GIS fall between 1:1 million and 1:1000.**
- **A GIS is scaleless because maps can be enlarged and reduced and plotted at many scales other than that of the original data.**
- **To compare or edge-match maps in a GIS, both maps MUST be at the same scale and have the same extent.**
- **The metric system is far easier to use for GIS work.**

Scale of a baseball earth

- Baseball circumference = 226 mm
- Earth circumference approx 40 million meters
- RF is : 1:177 million

Geographic Coordinates

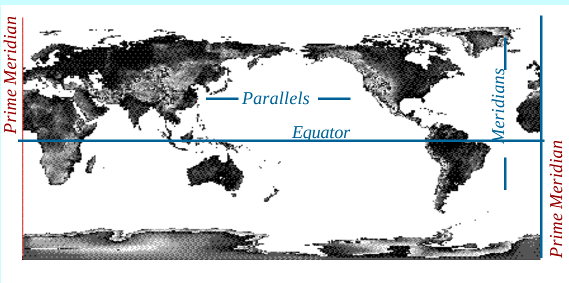
- Geographic coordinates are the earth's latitude and longitude system, ranging from 90 degrees south to 90 degrees north in latitude and 180 degrees west to 180 degrees east in longitude.
- A line with a constant latitude running east to west is called a parallel.
- A line with constant longitude running from the north pole to the south pole is called a meridian.
- The zero-longitude meridian is called the prime meridian and passes through Greenwich, England.
- A grid of parallels and meridians shown as lines on a map is called agraticule.

representative fraction	Map Distance	Ground distance
1: 400,000,000	400.000 m	400 km.
1: 40,000,000	40.000 m	40 km
1: 10,000,000	10.000 m	10 km
1: 1,000,000	1000 m	1 km
1: 250,000	250 m	
1: 100,000	100 m	
1: 50,000	50 m	
1: 24,000	24 m	
1: 10,000	10 m	
1: 1,000	1m	

coordinate pair , coordinate, coordinate systems

The problem is a flat map of all or part of the earth's surface is necessarily on a map projection.
Something has been distorted to make the surface flat, usually scale, shape, area, or direction.

Geographic Coordinates



How complex a shape the earth is?

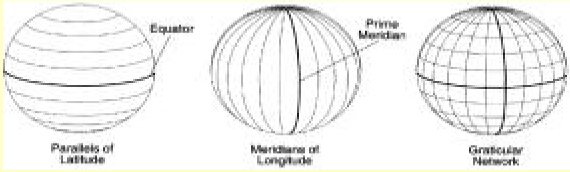
...however, many of the systems are perfectly adequate, indeed extremely well suited for work with GIS.

geographic coordinates

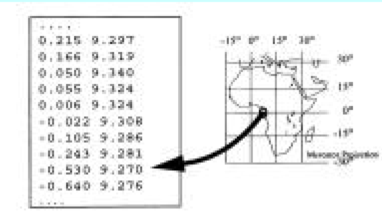
- *universal transverse mercator* (UTM) coordinate system favored in many mapping efforts;
- the *military grid* system, an alternative form of the UTM that has been adopted in many countries outside the United States
- for world mapping; and the *state plane* system, the basis of most surveying practice in the United States
- other systems might be met in the GIS world and the implications of using these systems.

Referencing location on the earth's surface

- latitude and longitude reference system

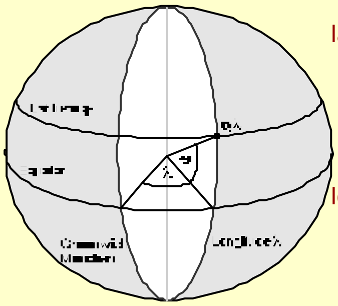


Geographic Coordinates as Data



Data Bank I listing of the coordinates of the coastline of Africa. Format is geographic coordinates in decimal degrees.

Referencing location on the earth's surface



latitude φ

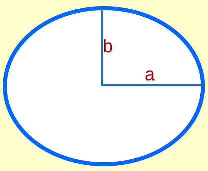
angle from the equator to the parallel

longitude λ

angle from Greenwich meridian

Cartographic Concepts

Reference Ellipsoid



Ellipsoidal Parameters

a - semi-major axis
b - semi-minor axis
f = (a-b)/a - flattening

used to establish a datum: reference point for large scale mapping

Map Projections

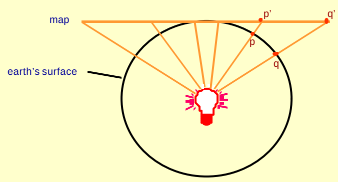
- Curved surface of the earth needs to be "flattened" to be presented on a map
- projection is the method by which the curved surface is converted into a flat representation.

Map Projections

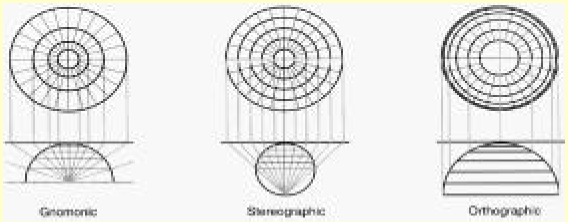
- defined as a mathematical function to convert between the surface location on the earth and the projected location on the map
- conversion from a geographic (spherical) reference system to a planar (Cartesian) system;
  e.g., lat/long -> x/y

Map Projections

- **we can literally think of it as a light source located inside the globe which projects the features on the earth's surface onto the flat map**



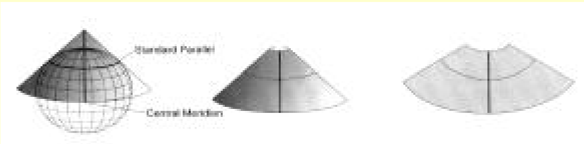
Azimuthal Projections



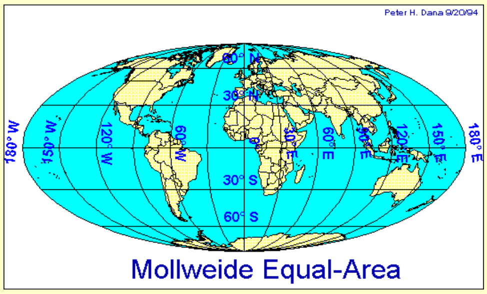
Azimuthal Projections Aspect

Cylindrical Projections

Conic Projections



Equal area projections



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Distortion in Map Projections

- some distortion is inevitable
- less distortion if maps show only small areas, but large if the entire earth is shown
- projections are classified according to which properties they preserve:
  area, shape, angles, distance

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Conformal projections

- preserve the shape of small features
- show angles (bearings) correctly
- useful in navigation

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Equal area projections

- area on the map is proportional to the true area on the earth's surface
- required when area measures are made
- popular in GIS

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Equidistant projections

- represent the distances to other locations from either one or two points correctly

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Compromise projections

- do not preserve any property, but represent a good compromise between the different objectives
- e.g., Robinson's projection for the world

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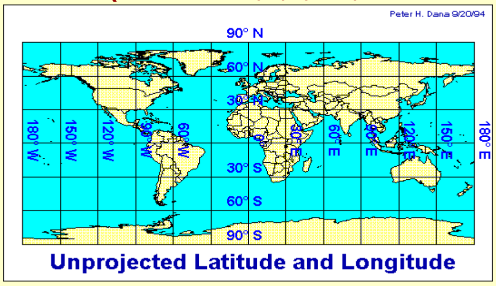
Lat/Long can also be represented in planar form

(but is not technically a projection)



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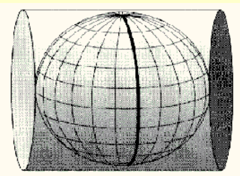
UTM



- Universal Transverse Mercator
- cylindrical projection with a central meridian that is specific to a standard UTM zone
- there are 60 zones around the world

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Parameters required for projecting a map

- latitude of origin
- central longitude (meridian)
- spheroid/datum
- false easting/northing (., an offset to avoid negative numbers)
- map units
- always record all information included on a map sheet!

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UTM

- coordinates are usually measured in meters from the central meridian (x) and the equator (y)
- minimal distortions of area, angles distance and shape at large and medium scales
- very popular for medium scale mapping

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The concept of scale

- scale is the ratio between distances on a map and the corresponding distances on the earth's surface
- e.g., a scale of 1:50,000 means that 1cm on the map corresponds to 50,000cm or 0.5km in the real world

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The concept of scale

- scale is essentially a ratio or representative fraction
- small scale: small fraction such as 1:10,000,000
  shows only large features
- large scale: large fraction such as 1:25,000
  shows great detail for a small area

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Map Projections

- **A transformation of the spherical or ellipsoidal earth onto a flat map is called a map projection.**
- **The map projection can be onto a flat surface or a surface that can be made flat by cutting, such as a cylinder or a cone.**
- **If the globe, after scaling, cuts the surface, the projection is called secant. Lines where the cuts take place or where the surface touches the globe have no projection distortion.**

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The concept of scale

- "small scale" versus "large scale" often confused
- e.g., large scale models in climatology operate on large areas
- best to say "cartographic scale" or "geographic scale"

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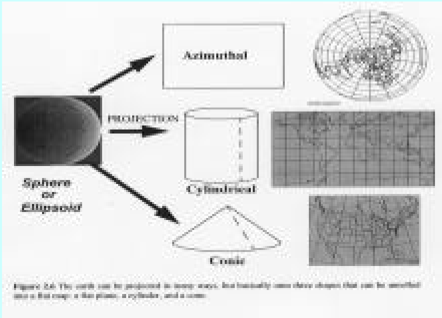
Map projections



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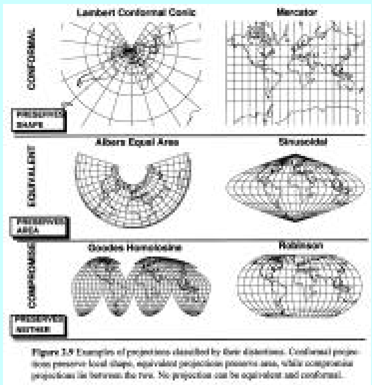
No flat map can be both equivalent and conformal.



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The concept of scale

- scale shows not only how features are shown but also what features are shown
- e.g., large scale map of 1:25,000 may show individual houses
  smaller scale map of 1:500,000 shows only points representing villages
- importance of generalization.

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Map Projections (ctd)

- Projections can be based on axes parallel to the earth's rotation axis (equatorial), at 90 degrees to it (transverse), or at any other angle (oblique).
- A projection that preserves the shape of features across the map is called conformal.
- A projection that preserves the area of a feature across the map is called equal area or equivalent.
- No flat map can be both equivalent and conformal. Most fall between the two as compromises.
- To compare or edge-match maps in a GIS, both maps MUST be in the same projection.

Coordinate Systems

- A coordinate system is a standardized method for assigning codes to locations so that locations can be found using the codes alone.
- Standardized coordinate systems use absolute locations.
- A map captured in the units of the paper sheet on which it is printed is based on relative locations or map millimeters.
- In a coordinate system, the x-direction value is the easting and the y-direction value is the northing. Most systems make both values positive.

Standard parallels

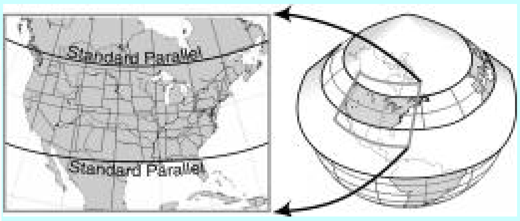

Figure 2.7 Standard Parallels. The conic projection cuts through the globe, and the earth is projected both in and out onto it. This is a secant conic projection. Lines of true scale, where the cylinder and sphere touch become standard parallels.

UTM

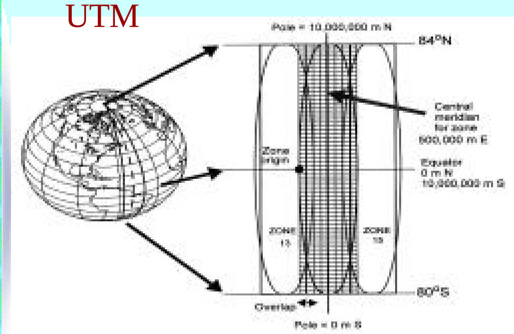

Figure 2.12 The Universal transverse Mercator coordinate system

Secant map projections

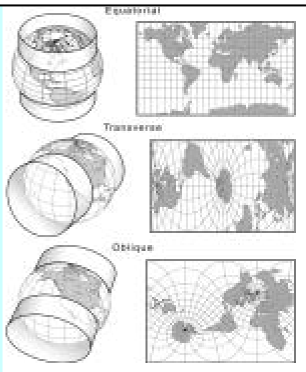

Figure 2.8 Variations on the Mercator (Pseudocylindrical) Projection shown as secant. Top: Equatorial. Middle: Transverse. Bottom: Oblique.

Coordinate Systems for the US

- Some standard coordinate systems used in the United States are
  - geographic coordinates
  - universal transverse Mercator system
  - military grid
  - state plane
- To compare or edge-match maps in a GIS, both maps MUST be in the same coordinate system.

UTM zones in the lower 48

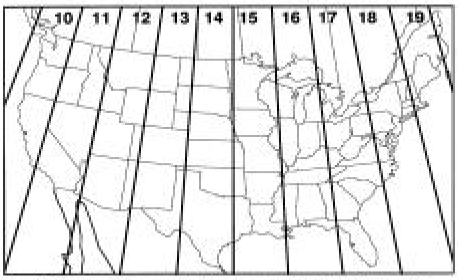

Figure 2.11 Universal Transverse Mercator zones in the 48 contiguous states.

Geographic Information System

Geocoding: the conversion of spatial information into computer-readable form

- **data:** on geography, descri... s of locations on the face of the earth, data by t... ocation and the location by the data
- **database:** maps
- **geocoding: (georeferencing)** latitude, longitude
- **link** the map with the attributes in the form of numbers

data are now more useable, because if we have the capability of mapping in GIS, we can place any information on a map.

GIS Capability

- **A GIS package should be able to move between**
  - **map projections,**
  - **coordinate systems,**
  - **datums, and**
  - **ellipsoids.**

GEOGRAPHIC INFORMATION

- **the map component is very large (*Volume*)**
- **geographic data is *dimensionality***

points, lines, areas

- **the attributes associated with a geographic feature**

level of measurement*: nominal, ordinal, interval* and *ratio*

Geographic information

- **Characteristics**
  - **volume**
  - **dimensionality**
  - **continuity**

- ***Nominal* data are those that simply assign a label or class to a feature, such as a mine shaft or a ski resort.**
- ***Ordinal* features have a rank assigned to them, such as the sequence used for highways on maps of Jeep trails, unsurfaced roads, single-lane roads, two-way roads, state highways, and interstate highways.**

- ***Interval* values** are those measured on a <u>relative scale</u>, such as elevations on a datum (based on mean sea level, an arbitrary zero point) or survey locations measured by pace and compass without a geodetic control.

- ***Ratio* values** are measured on an <u>absolute scale</u>, such as coordinates on a standard system or computed measures such as total precipitation.

geographic information is *continuity*

- **contour maps** continuous distribution
- **choropleth maps** discontinuous distribution (tax rates)

Continuity is an important geographical property (surface elevation)

Continuous variables in GIS, often called *field variables*

Building complex features

- Simple geographic features can be used to build more complex ones.
- Areas are made up of lines which are made up of points represented by their coordinates.
- Areas = {Lines} = {Points}

Properties of Features

- size
- distribution
- pattern
- contiguity
- neighborhood
- shape
- scale
- orientation.

Areas are lines are points are coordinates

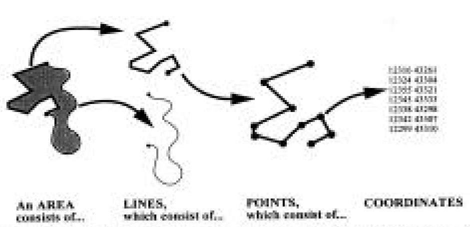

Figure 2.16 Geographic information has dimension. Areas are two-dimensional and consist of lines, which are one-dimensional and consist of points, which are zero-dimensional and consist of a coordinate pair.

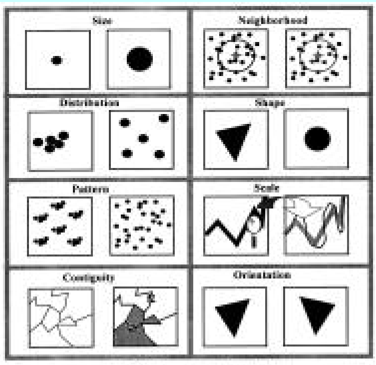

Figure 2.17 Basic properties of geographic features.

GIS Analysis

- Much of GIS analysis and description consists of investigating the properties of geographic features and determining the relationships between them.

Coming next….

Maps as Numbers