Cartographic Representation of the Abstraction of Reality (Part 1 & 2)

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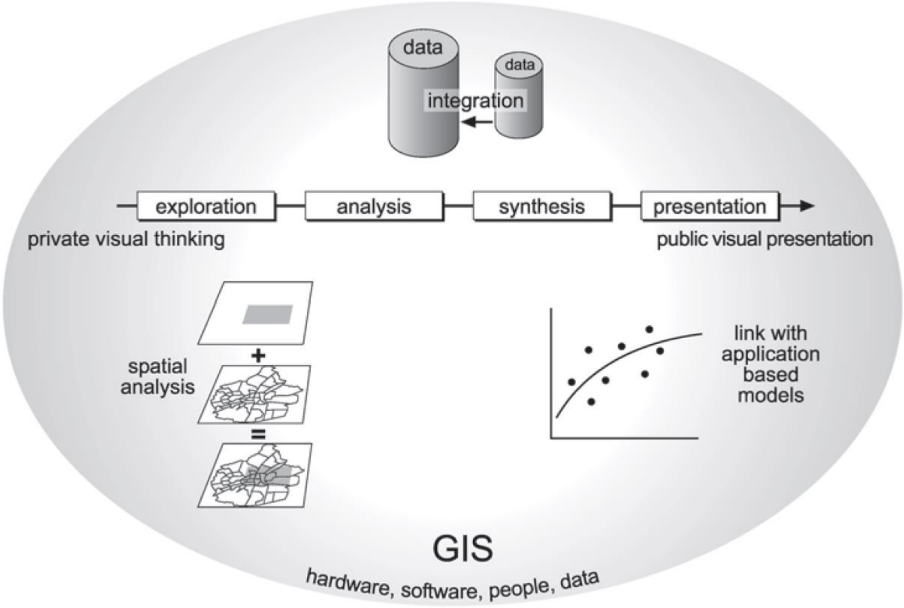
Cartography and GIS

- **Cartography** is considered as the *theory and practice of map-making and map use*.
- **GIS** is regarded as a *computer-based system* for *data input, management, manipulation and analysis, and displaying of spatial data* (*Aronoff, 1989, p.39*) *from the real world*.



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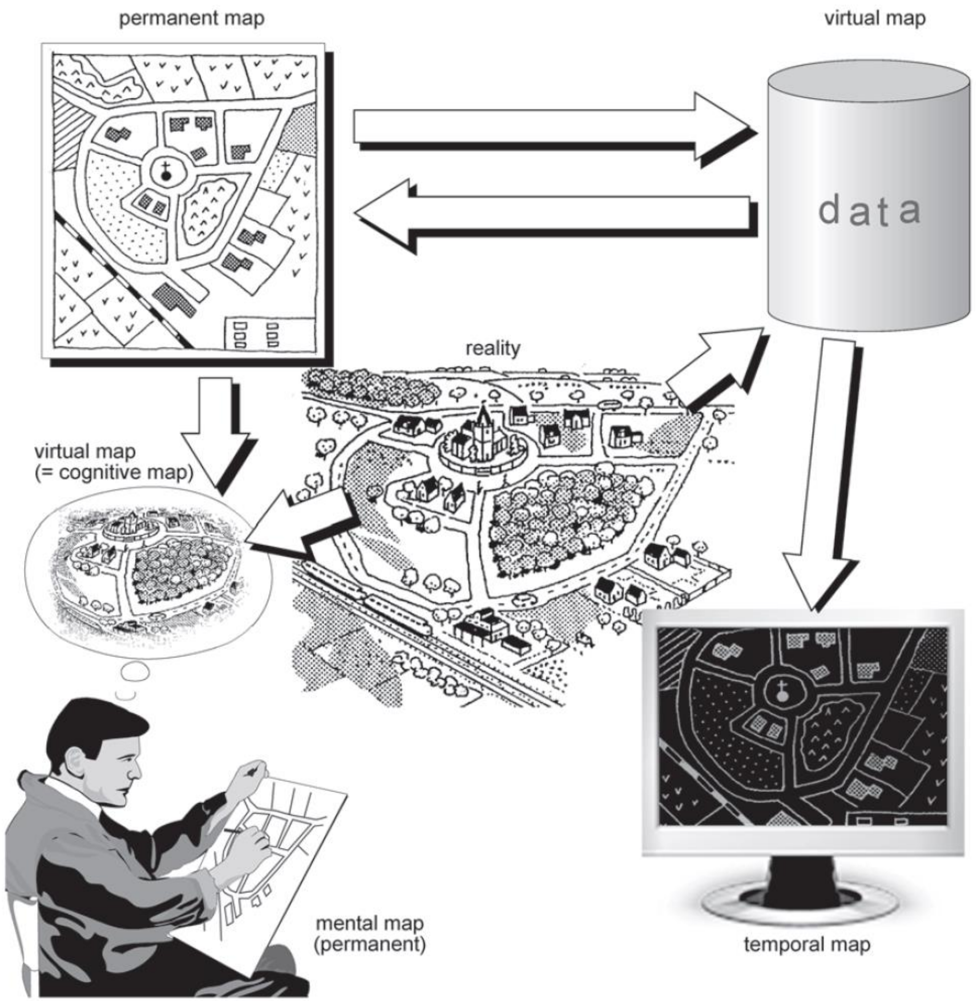
Examples of permanent, virtual, temporal and mental maps



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What type of questions can a GIS answer?

- Typical GIS questions answered by maps such as those used *to identify*, to *locate* or to *find geospatial patterns*.

Key Issues between Cartography and GIS

- Key issues between Cartography and GIS:
  - Cartography is concerned with *representation*
  - GIS is concerned with *analysis* of *spatial relationships*
  - GIS is a *product* of digital cartography development:
    - Which generated *georeferenced digital spatial databases*
    - These databases became the platform for data structures that could be *linked, processed, analysed* and *displaying results* in form of maps
- Aronof (1989, p.103) further notes that *while the main function of a cartographic system is to generate computer stored maps, the function of a GIS is to create information by integrating data layers to show the original data in different ways from different perspectives.*

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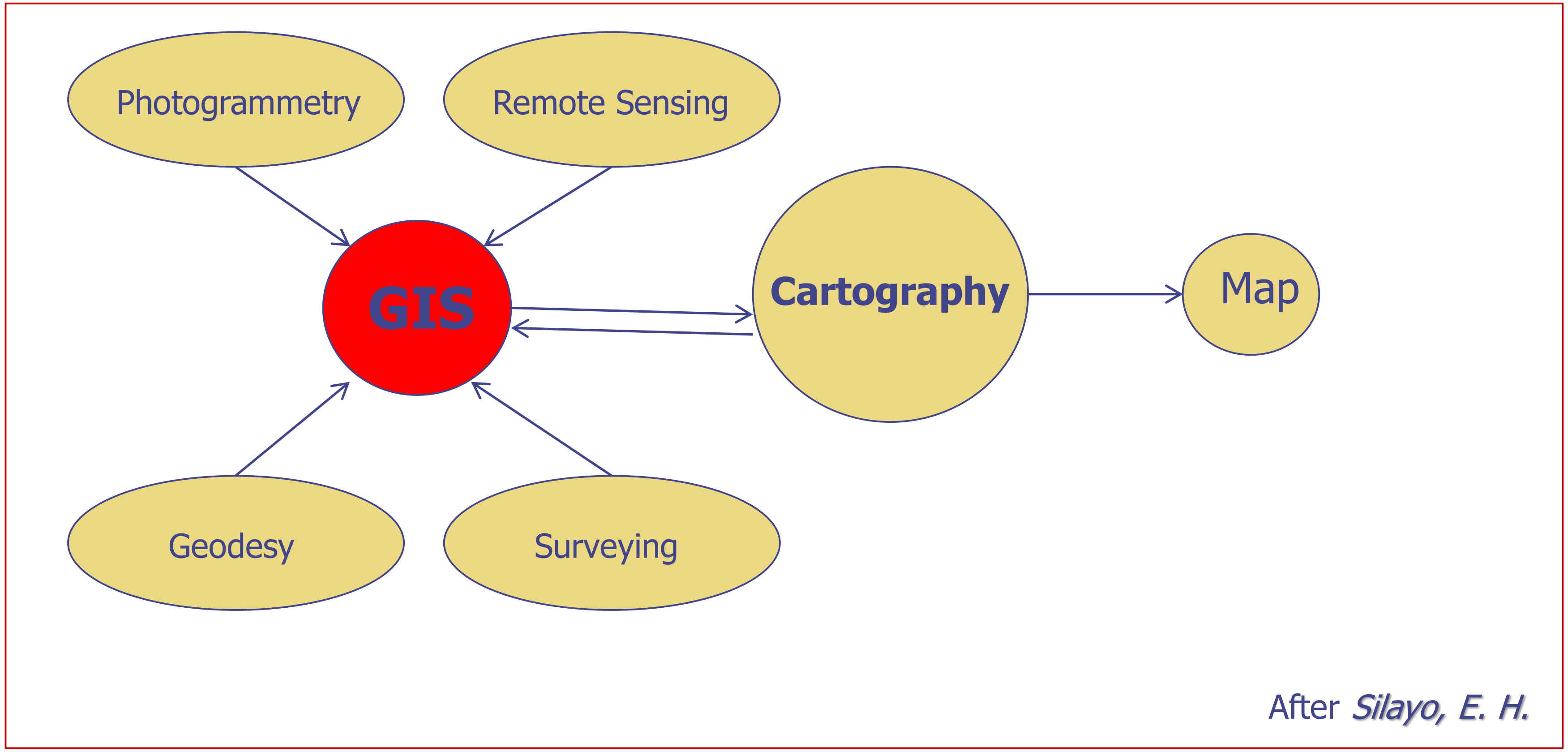
Cartography and GIS

- The *development of GIS* has made it possible for *anybody* who can operate a computer *to generate a map* from GPS data.
  - So *any GIS user* becomes *a mapmaker overnight*.
  - But **how are these maps produced?**
  - Dent (1993, p.19) stated that: *the possibilities today for maps without ethics are compounded by the proliferation of off-shelf computer programs allowing non-cartography trained persons to produce maps that may look good, but are **not** with any established professional standards or conventions.*
  - Bernhardsen (1992, p.215) observes that *GIS enables less skilled persons to produce maps but it has a drawback of permitting production of artless maps that are at best unattractive and at worst misleading.*

Cartography and GIS

- StatMap Web also observes that *Maps are a great way of displaying and analyzing statistical information but they need to be properly designed. This can be a tricky business until you know what you are doing and desktop mapping and GIS systems rarely provide much help. Most software packages will allow us to produce really bad and misleading maps.*
- Kraak and Omerling (1997, p.2) says *GIS allows users to produce their own maps even when they are unaware of cartographic grammar.*
- *Such maps may not transmit* the *intended meaning* to the *map user* at all.

GIS and the Mapping Sciences



- Information transfer *without maps* would be *cumbersome*

Cartographic Shortfalls in GIS

- A *GIS user not conversant* in *cartographic principles* may select:
  - *a wrong projection*
  - *inadequate content*
  - *wrong symbols*
  - *over- or under-generalise content*
  - *inappropriate scale*
  - *unsuitable layout*
  - *unsuitable colour*

- While a GIS system may be packed up with all the information possible on earth, a *graphic output* should be *purposeful* and therefore *selective*.

Data Output and Cartography

- Cartography serves two (2) *major functions*:
  - It produces *graphics on screen* or *on paper* that *convey* the *results of analysis*
  - Other *database information* can be *generated* for *further analysis* or *use*

Maps as a Communication Tool

- People have communicated with one another since the beginning of time using *different forms of communication*.
- The *information exchange* can take place through:
  - Literacy
    - *words* (oral or written)
  - Numeracy
    - *tables*
    - *numbers* and *formulas* (in mathematics)
  - Graphicacy
    - *music* and *performing arts*
    - *pictures* and *photographs*
    - *graphic sketches* and *diagrams*
    - *cartographic presentations*

Maps as a Communication Tool

- Losses of information during cartographic processing:
  - at the first stage
    - not all the available information in *reality* is used
  - At the second stage, the *compilation of the map*
    - involves losses of information in the process of *generalisation*.
  - At the stage of map reading
    - information contained in the individual symbols is not always fully utilized because of the *insufficient cartographic training of the reader*.
  - At the interpretation stage
    - the chief aim of interpretation is the formation and expansion of ideas on mapped reality by enlisting the reader's prior *experience* and *knowledge*. But experience and knowledge *vary* from person to person. This subjective factor explains the possible variations in the *depth* and the *correctness* of *interpretation of reality* by *different users/readers*.

Maps as a Communication Tool

- Every map has a *specific communication objective*.
- In order to represent objects spatially in terms of *relationships, processes, functions, systems,* etc.
  - a *cartographic presentation* is the best
  - in most cases, the only possibility.

Maps as a Communication Tool

- Cartographic presentations *differ* from other kinds of communication for the following reasons:
  - because of the use of *mathematically derived process* of *transformation* called Map Projection
  - by the deliberate employment of a reduced form of representation through Scaling
  - by the *careful definition* and *delineation of concepts* called Symbolisation
  - through the *selection* and *simplification* of geographical reality according to scale and purpose called Generalisation

Maps as a Communication Tool

- A cartographic process makes it possible to transform a mapped part of reality into a two-dimensional (2D) spatial representation (the map) and thereby create a visual entity.
- This entity, whose contents are based on the **selection**, **generalisation** and **symbolisation** of facts, yields the desired map.
- A good map informs the map user through its scale-related spatial proportion and the selection and presentation of its contents.
- Since spatial awareness has always been one of the most important prerequisites of human life, cartographic representations can be seen to date back to the *earliest periods of man's known existence*.

The Language of Maps

- The ability to put information into and extract it from maps is termed Graphicacy.
  - the ability of a reader to extract full and accurate information is largely dependent on the skills and clarity of expression of the author, the mapmaker.
- The language of large scale maps is simple
  - Most reality could be drawn at their true plan size and shape as there is enough space among the details for drawing the features in full.

The Language of Maps

- When scale is reduced, cartography has to develop its own special language.
  - the skills of a cartographer are most needed
  - Useful information has to be shown as much as possible in an ever decreasing space and it must be clearly legible and comprehensible.
- This requires:
  - Selection
  - Generalisation
  - Symbolisation

Selection

- Selection in cartography means choosing:
  - which items of details to omit and
  - Which items to retain as scale decreases.

- The criterion used may be:
  - size or
  - importance of the feature.

- The choice of features will be affected by:
  - the purpose of the map or/and by
  - the editorial policy

Map Generalisation

- A **map** is an abstraction of reality; as such *not everything* in reality can be represented on the map
- But it should be able to assist the map reader to understand the *spatial form* and *structure* and to distinguish *important characteristics* of the phenomena represented.
- Thus, map generalisation requires:
  - Selection of features essential for *map purpose* and
  - Representation of them that is *clear* and *informative*
  - Both involve a *degree of information reduction*
  - Is dependent on scale and subjectivity

Map Generalisation

- The principal function of generalization is to **distinguish** between *important* and *unimportant* phenomena or events in a **reference space** in relation to the **map space available**
- **Three** (3) **levels** of the **transformation** of the Earth's surface can be recognised:
  - **Primary** (**geometric**; **x, y** surface)
  - **Secondary** (**semi-geometric**; **z** surface)
  - **Tertiary** (*generalization of data* from ***reference space*** to the *map space*, or **XYZ** → **xyz**).

Map Generalisation

- Factors which Influence Cartographic Generalization:
  - Scale
    - Scale determines the object size on the map
  - Source material
    - Source material must be ungeneralised otherwise correctly so
  - Special conditions for legibility
    - Special map reading conditions must be taken into account
  - Symbol specifications
    - It influences the degree of generalisation
  - Choice of colours
    - Pale colours require *wider lines* and *larger area symbols*
  - Technical reproduction capabilities
    - Take into account the available production and printing facilities

Semantic Generalisation

- It is concerned with the meaning and function of a map through the *identification of a hierarchical structure* in the geographical information
- **Two (2)** important hierarchs to generalisation are *classification* and *aggregation:*
  - 1. Classification
    - Hydrography
      - Rivers, lakes, etc.
    - Settlements
    - Lines of communication
    - etc.
    - Once data have been classified, *rules of selection* can be devised

Semantic Generalisation

- **2. Aggregation**
  - Is concerned with *composition of phenomena*
  - Which can further be subdivided:
    - A city is composed of *administrative districts* which are themselves further subdivided
    - It may be used in a *similar manner as classification*

Geometric Generalisation

- Geometric representation of geographical information may be subject to a wide range of modifications in the course of generalisation.
  - Thus, *boundaries of residential blocks may be left out* if they are too low on the classification hierarchy
  - Most modifications are as a result of trying to meet good cartographic symbolisation relating to:
    - Clarity and ease of visual communication

Displacement

- A road symbol at a smaller scale map would cover the buildings. Therefore the building symbols are displaced outside the exaggerated line. A road symbol is displacing buildings in generalization.
- Displacement Hierarchy
  - The following hierarchy could be suitable for Zambia:
    - Railways displace
    - Waterways.
    - Roads.
    - Buildings.
    - Vegetation.
    - Triangulation and other control points *remain always at their correct exact positions*.
      (Remember the primary transformation !)

Geometric Generalisation

- Categories of geometric generalization:
  - Elimination of point, line and area geometry
    - Remove features that will create clustering of features
  - Reduction in the detail of lines, areas and surfaces
    - Rather than remove just simplify the detail of the feature
  - Enhancement of the appearance of lines, areas and surfaces
    - Smoothing and fractalisation
  - Amalgamation of lines and areas
    - Combing or merging originally distinct or entirely separate features

Geometric Generalisation

- Collapse of areas to points and lines
  - Reducing the dimensionality of an object to a geometric representation
- Enlargement or exaggeration of line and area objects
  - Exaggerate map features that have become too small to represent due to scale reduction
- Typification of line, area and surface objects
  - Communication of a representative form of an object which cannot be geometrically represented accurately
- Displacement of points, lines and areas
  - To avoid overlapping objects after exaggeration of other objects

Summary

- Map generalisation is a fundamental processes in graphic communication of spatial information.
- It is a subjective process in that the mapmaker must decide *what needs to be kept* and *omitted* from the map keeping in mind the map agenda.
- Its also important to note that generalisation is triggered by reduction in map space that arises due to reduction of map scale.

Symbol Design (Part 2)

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Symbolisation

- An unlimited variety of spatial data that is mapped is represented on maps by symbols.
  - The graphic symbol is an image chosen by the cartographer to represent data.
  - It is therefore the *most fundamental element* of the cartographic language and design.
- Symbols on a map are constructed to show clearly:
  - the precise geographic location of the feature they represent
  - the relationships existing among the symbols
  - the quality of the feature being represented.
- In addition:
  - all symbols must be identifiable without any extra effort or uncertainty, map user must identify each symbol easily

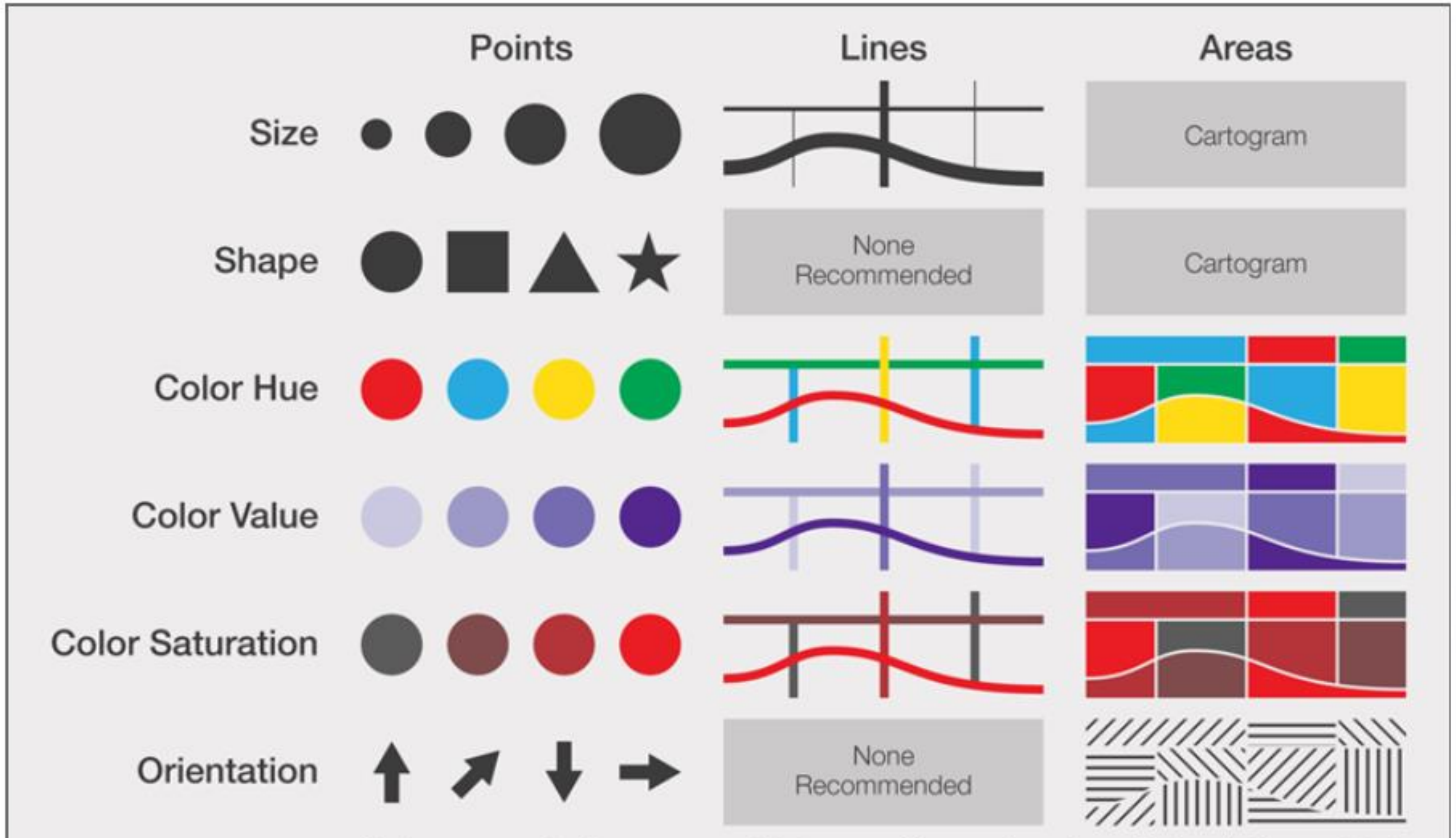
Classes of Symbols

- All symbols used in cartography can be classified in three (3) classes:
  - Point symbols
  - Line symbols
  - Area symbols
- Point, line and area symbols are always defined in the plane of the map by points which can be located with precision in **x** and **y**.
  - This location can be given a code number, be registered and plotted.
  - Computer Assisted Cartography is based on this principle.

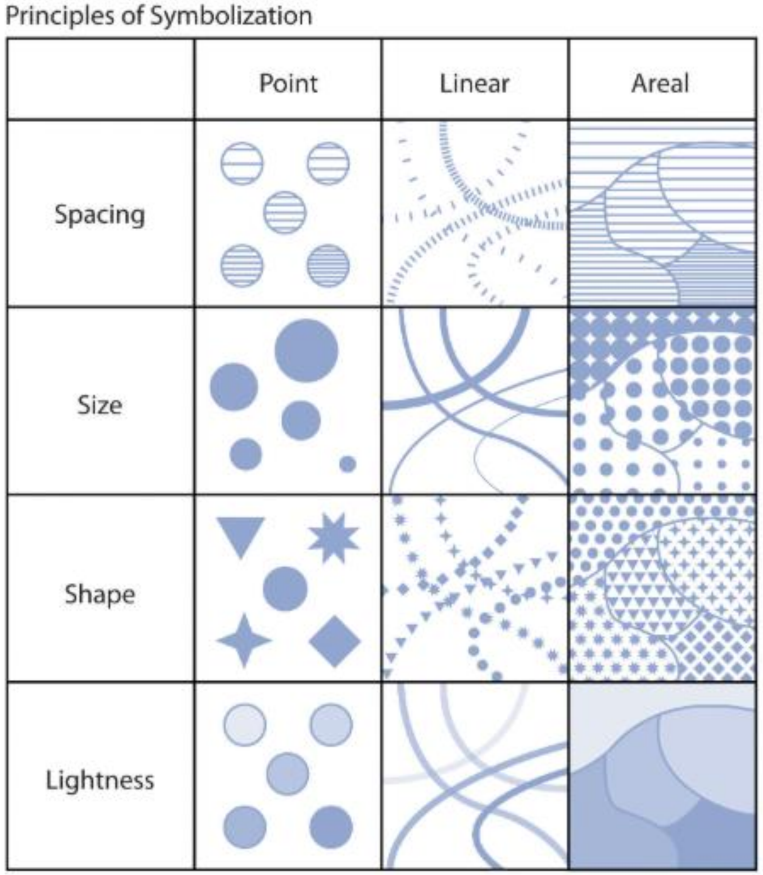
Graphic Elements in Symbolisation

- Differences in positions among data is the primary purpose of the map
  - but if this was all, a map would not be necessarily readable
  - In order to represent the different data in meaningful way, we must vary the appearance of graphic symbols.
- The different variations that can be used are:
  - size
  - texture and structure
  - value or lightness
  - grain
  - hue (colour)
  - orientation
  - shape

Graphic Elements in Symbolisation



Cartograms, or value-by-area maps, distort geographic areas based on a single variable associated that area, (e.g., the size of a county is proportional to its population density).



Size

- Symbols vary in size when they have *different dimensions*
  - such as diameter, width or area
  - Usually the larger a sign, the more important the feature is thought to be.
- Variations in size are almost unlimited.
  - only limitation is the aptitude of the eye to perceive certain minimum thresholds of linear or area size differences.
- The size of the symbol will depend on two (2) factors:
  - The minimum size at which it can be perceptible
  - The size required to demonstrate its level of importance

Size

- Limits of Visual Perception
  - A map should be readable without difficulty, in normal light, by a user having normal vision.
  - To ensure the legibility, a map designer must take the following criteria into consideration:
    - Threshold of perception
    - Threshold of separation
    - Threshold of differentiation

Size

- **Threshold of Perception**
  - This is the minimum size of a graphic element which can be seen with a naked eye under normal circumstances.
  - In the practical work the following standards are normally used:
    - Point
    - Line
    - Full square
    - Empty square
- **Threshold of Separation**
  - This is the minimum distance between two (2) graphic elements which can be observed with the naked eye under normal circumstances.
  - In practice this is 0.2 mm for parallel lines.

Size

- **Threshold of Differentiation**
  - This is the minimum difference between two (2) graphic elements or between two (2) symbols of nearly the same size which can be observed with the naked eye under normal circumstances.
- In order to follow this rule, one should avoid:
  - shapes which are too similar
  - the use of tint screens which are too similar
  - sizes too similar for symbols of the same shape.
  - It is important to respect this limitation of differentiation in cartography, and especially in the thematic mapping.

Size

- The threshold of perception and separation are very important in generalization, particularly in topographic mapping.
- Example of size demonstrating importance:
  - Main road 0.60 mm
  - Secondary road 0.30 mm
  - Other roads 0.15 mm
- Differences in line widths must be perceptible differences which can be detected by the map user

Texture and Structure

- Some simple graphic elements can be distributed inside a point, line or area symbol.
- Texture (Spacing)
  - refers to spacing of a series of dots or lines that are components of a symbol.
  - Texture can be coarse or fine, and when it becomes *very fine* it may be difficult to distinguish *from* value.
- Structure
  - refers to the regular spatial arrangement of simple graphic elements inside a symbol.

Value or Lightness

- Value or lightness is the variation in intensity of light perceived by eye as shades of grey, *varying* from white to black.
- Through a size variation of the graphic element and consequently a space between them, a variation in value is obtained.
  - Value is thus the relation between the surface covered by graphic elements and the white space between them expressed in percentages:
    - a white surface corresponds to 0%
    - a surface is 50% when there is an equilibrium between white and black (or other colour)
    - A surface is 100% when the elements cover the entire surface.
      - It is said to be **saturated**.

Grain

- The grain is a size variation of the graphic elements, points and lines, spread over a surface.
  - The relation of the graphic element (dot or line) to white background (= value) remains constant.
  - It is expressed in dot or line/cm (international) or dot or line/inch (UK)
- Flickering Effect
  - Whenever the graphic elements are in equilibrium with the white background (value = 50%), a vibration or flickering effect is produced.
  - Especially when the graphic elements are big enough to be perceived separately, the flickering effect appears.
  - The eye then flickers between the white and the black elements of similar importance. This gives a disagreeable appearance and should be avoided.

Hue or Colour

- On printed maps, variations in hue between red, yellow, green, blue etc., which the eye can perceive when looking at symbols are not produced by using particular simple graphic elements, but by changing the printing ink used on the map.
- What is colour? The sensation of colour can first be defined as a physical phenomenon.
- The colours used on a map are components of the light of the sun.
  - Coloured light is composed of light particles, *photons*, each one moving with a different wavelength.
  - Solar light appears to be white, when it is made up of all its components together.

Hue or Colour

- The components of solar light can be separated from one another in a well-defined sequence:
  - violet-blue 410 nm
  - blue 450 nm
  - green 510 nm
  - yellow 560 nm
  - red-orange 600 nm
  - red 650 nm

  - The wavelengths from 410nm - 670nm (nanometres) corresponds to a visible zone of the solar spectrum or electromagnetic spectrum.

Hue or Colour

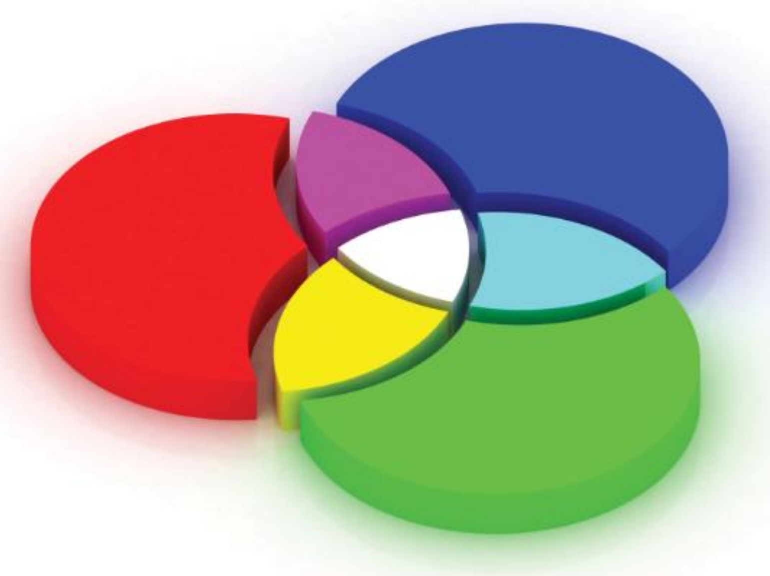
- Primary colours
  - Some hues are called as primaries.
  - All other colours may be created by a suitable mixture of them.
  - A primary colour is not a pure spectral hue, but like all non-spectral hues, it is a combination of wavelengths in which one portion is dominant.
- Additive Primaries
  - Blue
  - Green
  - Red

Hue or Colour

- If three circles of blue, green and red light are projected on a white screen, the superposition of:
  - red and green = yellow
  - green and blue = cyan
  - blue and red = magenta
  - red, green and blue = white

- This is called an additive synthesis.

  - A colour-TV functions by additive synthesis.



Hue or Colour

- Subtractive Primaries
  - Colours on a paper result from pigments being applied to the surface, which, when *illuminated by white light* **absorb** or **subtract** some of the *wavelengths*.
- The subtractive primaries are:
  - cyan (greenish-blue)
  - magenta (purplish red)
  - yellow
- Most colours can be created by a subtractive mixture of these pigments.
  - This process is called subtractive synthesis.

Hue or Colour

- Printing systems of coloured images such as maps are based on subtractive synthesis.
- The so called "4-colour" printing system, uses subtractive primaries plus black (also called process colours)
  - this is the most common printing system for multicolour images.

Hue or Colour

Colour terminology

- Colours can be differentiated in terms of their **hue**, **value** (or lightness) and **saturation**.

Hues	Y	yellow
	O	orange
	R	red
	P	purple
	V	violet
	B	blue
	G	green
Lightness	W	white
	L	light colour
	D	dark colour
	S	black
Saturation		pure colour
	GY	neutral grey

Hue or Colour

- Colour, Value and Saturation
  - All colours can be subjected to variations in their value (lightness) i.e., they will appear lighter or darker, depending on the percentage of the screen which has been used.
  - Pure colours (without any white) are said to be *saturated*.
- It is not possible to distinguish more than:
  - three degrees of saturation of yellow,
  - four or five degrees of green, or orange-red
  - six degrees for red and
  - up to eight degrees for blue and violet.

Hue or Colour

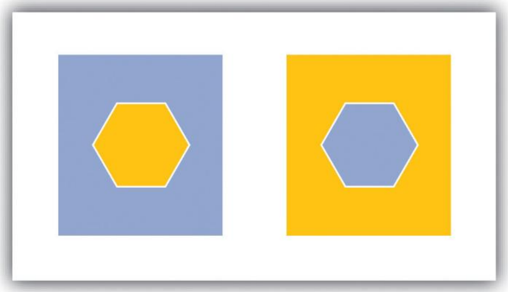
- Perception of the Brightness of Colours
  - The colour of an object or map element will be perceived by the eye according to the amount and the composition of light shining on it.
  - If the object or map is observed in incomplete light, the original colour of the object will be modified.
  - For instance, yellow and red map elements will appear grey in an orange electric light.

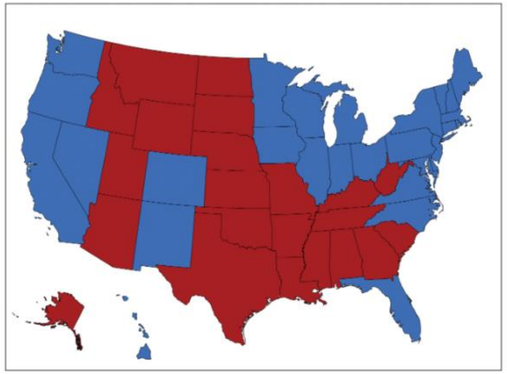
- When selecting colours in a map designing process, artificial light conditions should be taken into consideration.
  - The intensity of light will also influence the perception of colours.
    - colours with a long wavelength (yellow to red) appear *brighter* under intensive light and *softer* under subdued light (at dusk).
    - The effect is opposite for colours with a short wavelength (blue to violet).

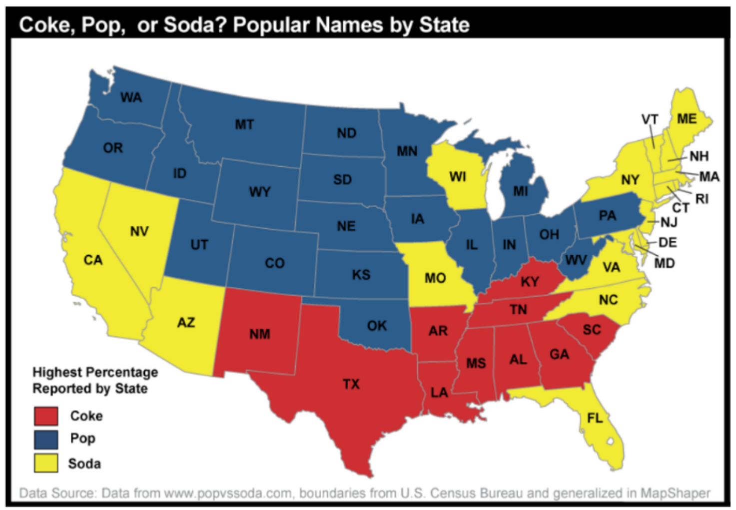
Hue or Colour

- Psychological Aspects of Colour
  - The feeling and sensations which a map reader experiences when looking at colours have always been consciously or not, *a guide for map makers*.
- Connotative colours
  - are those which remind the reader of the colours found in nature (green for forest and vegetation in general, blue for water, etc.).
- Warm colours
  - (red, yellow) are used in order to represent those elements of the map which have to appear more important or higher.
- Cool *colours*
  - (blue, violet) represent less important or weaker elements.

Hue or Colour







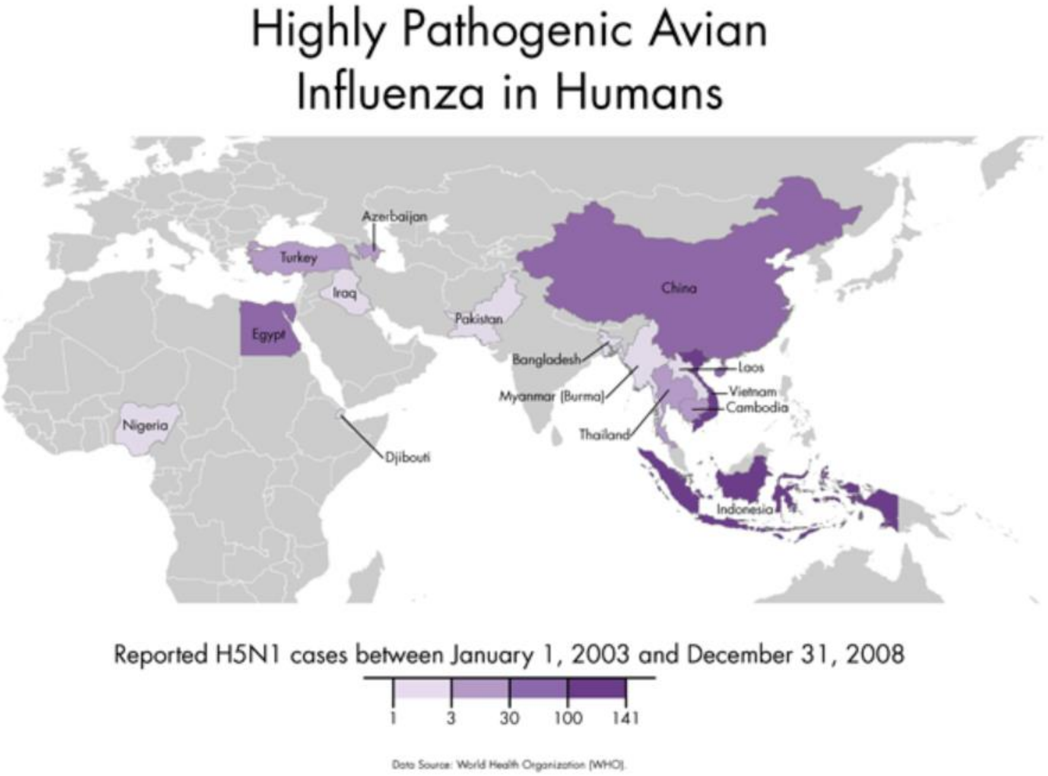


Figure 3.10: Reported H5N1 Cases (Avian Flu) Per Country from January 1, 2003 to December 31, 2008.

Credit: Created by Paulo Rapolo.

Hue or Colour

- **Colour Appearance Systems**
  - Each of the three (3) characteristics of colour varies continuously, and all colours can therefore be arranged as a three-dimensional (3D) colour appearance system.
  - A number of colour-appearance systems have been developed, e.g. CIE, Munsell, and Kirschbaum systems.
- **CIE-system (Commission International de l'Eclairage)**
  - is based on instrumentation and the mathematical analysis of the physical characteristics of light.
- **Munsell system**
  - is based on the human perceptual reaction to light and its colours.

Hue or Colour

- The Kirschbaum system
  - is an oblique double cone.
  - Its central axis (W-S) is the grey scale with black at the bottom and white on the top.
  - Every horizontal layer contains all of the colours of equal lightness.
  - The hues Y-O-R-V-B-G-GY are arranged in the form of an oblique diameter, called a colour circle.
  - Within this model colours may vary continuously, but may also be split up into steps so that each colour sample differs from its neighbours by a noticeable amount.

Orientation

- It is possible to express differences between symbols by their orientation.
- This variable can only be used on the graphic elements or on linear symbols
  - which restricts its possibilities.
- Orientation can be used so that each orientation represents a different group of information (human type, vegetation species, etc).
- Orientation is the only visual variable which can provide effective representation of all dynamic phenomena: directions, movements, attractions, migrations.

Shape

- Variations of shape or form, not to be confused with the shapes of areas, consist of changing the outline of the symbol.
- These variations only apply to point symbols or, in certain circumstances, to line symbols, and never to the outline of an area symbol, as this outline represents a geographic location and thus cannot be changed.
- In order to express shape differences within area symbols:
  - the only possibility is to introduce graphic elements or point or line symbols at regular intervals across these areas.
  - Their shape remains the same throughout a particular surface area but may vary from area to area, each shape representing a particular category of data
  - this type of symbol patterns are very common in topographic maps

Shape

- The forms used in cartography are called pictorial or representative when they suggest, in a general way, the real shape of the features represented.
- Geometric shapes such as squares, circles and triangles are commonly used in thematic mapping, especially representing statistical data.

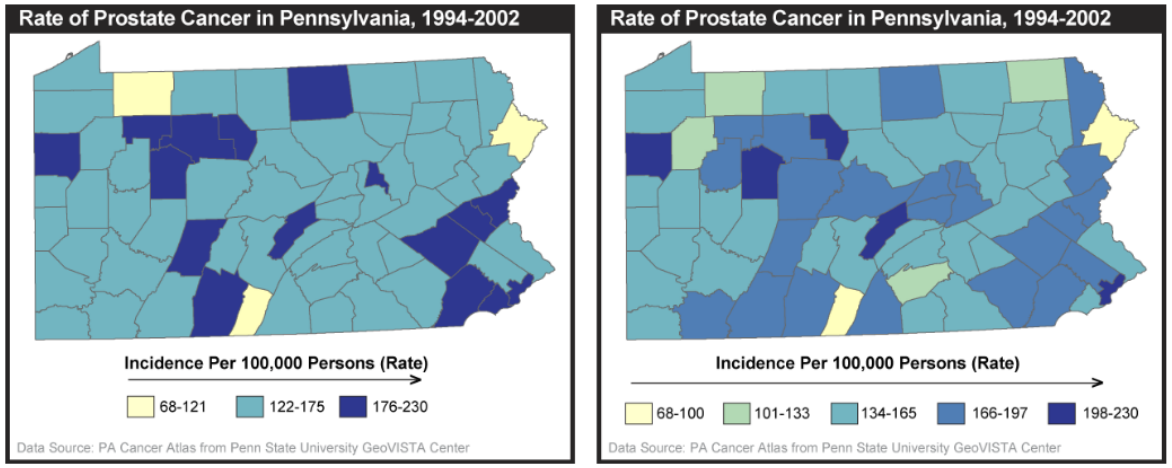


Figure 3.6: Incidence rate of prostate cancer per 100,000 persons per county in Pennsylvania, visualized using three classes (left) and five classes (right).

Credit: Jennifer M. Smith, © The Pennsylvania State University; Redesigned after PA Cancer Atlas from Penn State University GeoVISTA Center.

Symbol Perception

- Four (4) types of visual perception properties:
  - Associative Perception
  - Selective Perception
  - Ordered Perception
  - Quantitative Perception

- Visual variables may have one or more of these perceptual properties

Symbol Perception

- Do all symbols look of similar importance?
  - If yes then the symbol has an Associative Perception
- Can distinct groups of symbols easily be separated?
  - If yes then the symbol has a Selective Perception
- Can any specific order be recognised?
  - If yes then the symbol has an Ordered Perception
- Can the order be specified by amounts?
  - If yes then the symbol has a Quantitative Perception

Associative Perception

- A visual variable is called associative if spontaneously all symbols represented by that variable are seen as of equal importance
- Such a group of symbols has a homogeneous appearance such that no one symbol stands out above the others
  - Form, orientation, colour and texture* are associative
  - Value, size and grain are NOT associative

Selective Perception

- A visual variable has a selective perception if spontaneously all symbols differentiated by that variable can be arranged in distinct groups
  - Value, size, orientation, texture and grain are <u>selective</u>
  - Form is <u>NOT selective</u>

Ordered Perception

- A visual variable has an ordered perception if spontaneously all symbols differentiated by that variable can be placed in an unambiguous order
  - E.g. Low – high, least – most important
  - Value, size and texture are <u>ordered</u>
  - Orientation, colour, form and grain are <u>NOT ordered</u>

Quantitative Perception

- A visual variable has a quantitative perception if spontaneously all symbols differentiated by that variable may be separated from another by a distinct amount
  - E.g. B is 2 times A and C is 3 times A
  - Only size has a quantitative property
  - All other variables are NOT quantitative

Types of Information and their Perception Property

- A particular type of information is represented by visual variables with a particular perception property.

- Nominal Information = Associative/Selective
- Ordinal Information = Ordered
- Interval Information = Ordered
- Ratio Information = Quantitative

Types of Information

- Qualitative Information is measured on a nominal measurement scale
  - This measurement scale gives information on the different nature/identity of things
  - E.g. Arable land, pasture, built up area, forest

- Ordered Information is measured on the ordinal measurement scale
  - This measurement scale gives information with a clear element of order though not quantitatively determined
  - E.g. Hamlet, village, town, city, conurbation

Types of Information

- Quantitative Information gives information about specific amounts
- It is measured on either interval or ratio measurement scales
- The Interval measurement scale ranks data and the interval between the data is quantitatively determined
  - However the zero point is arbitrary e.g. Temperature
- The Ratio measurement scale ranks data on a quantitative scale using an *absolute zero point*
  - E.g. Number of employees, production figures

Systematic Approach to Symbol Design

- Analyse the information
  - Has it got a clear spatial component
  - Its dimensional property (point, line, area)
  - Its organisational structure
  - Its measurement level (nominal, ordinal, interval, ratio)
- Select visual variables with corresponding perceptual property
- Compose the most appropriate symbols
- Combine the symbols into the map