Geography 128 Winter Quarter 2017

Lecture 5:
What is Analytical Cartography?

What is Cartography?

Cartography - the science, technology and art of making maps.

Matthew Hampton, 2007, A Mosaic of Space, Time, and Order—The Portland, Oregon, Super Region

ClaudiaGraphics, http://www.claudiagraphics.com/pricemap.htm

Maps in the first half of the 20th Century

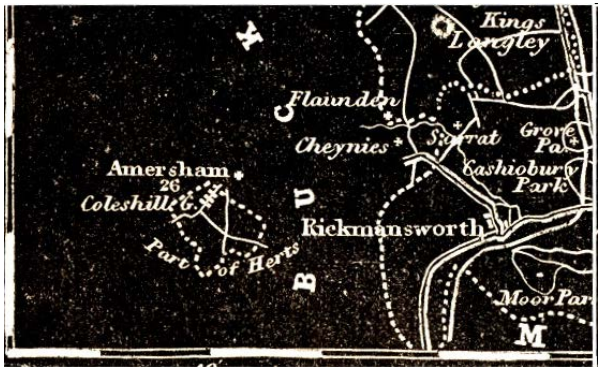
Normandy map, 1944

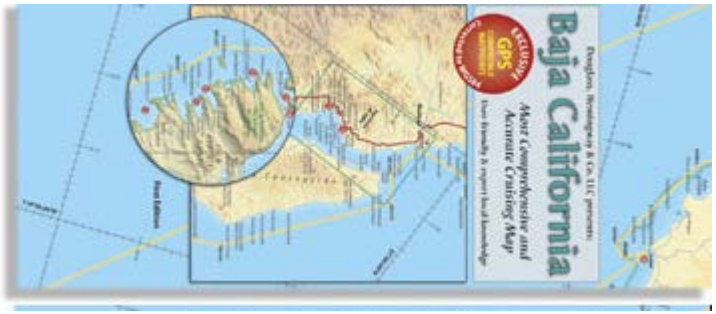
Technology: Manual drafting and layout,

Photo and Lithographic reproduction

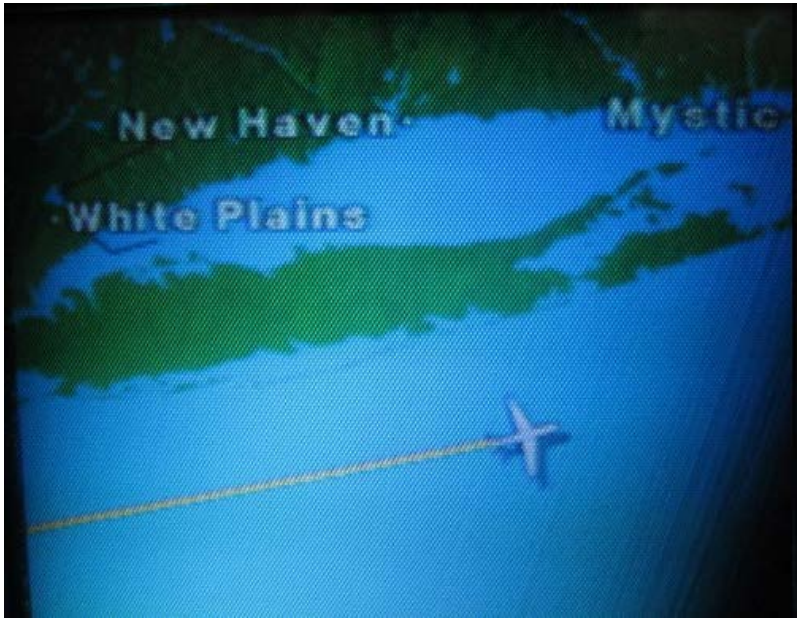
Distribution: Newspapers, books, magazine, sheet maps

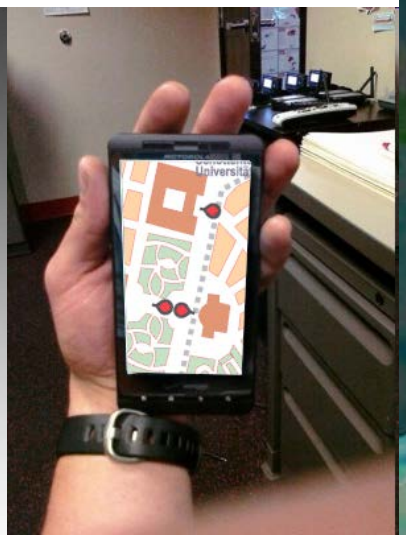
Lithography (Offset printing) and Photography





Now replaced by InkJet technology and LED displays/projectors





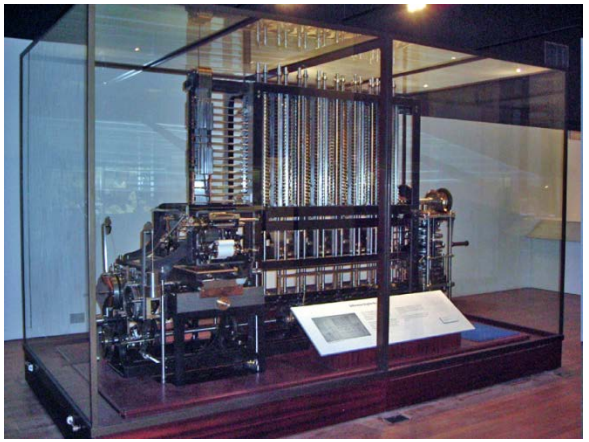
Origins of Computing

In a vivid demonstration of the power of his invention, Joseph-Marie Jacquard, using 10,000 punch cards, programmed a loom to weave a portrait of himself in black and white silk (above).

Jacquard's Loom 1805

Jacquard Loom in use

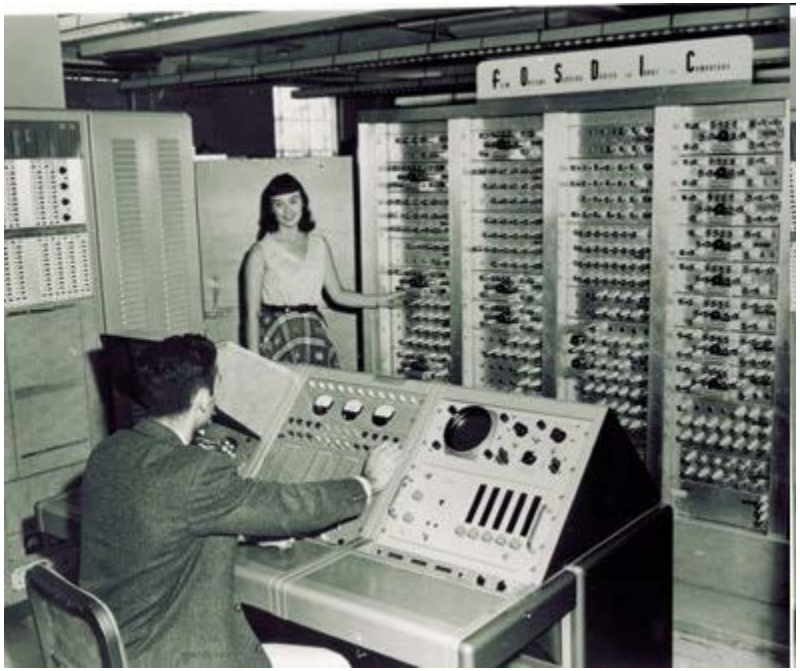
in India (Assam, January 2011)

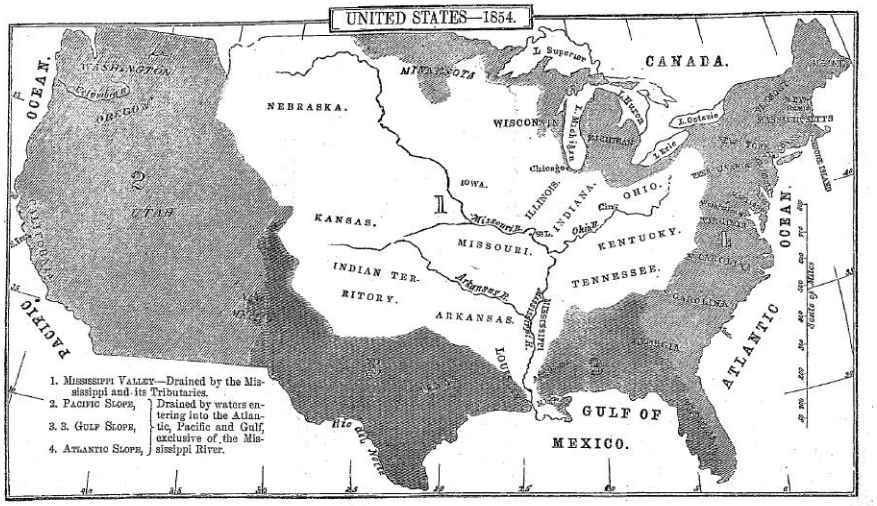


Charles Babbage: Difference Engine 1820s

Hollerith Tabulator 1890 Census

Census Mapping





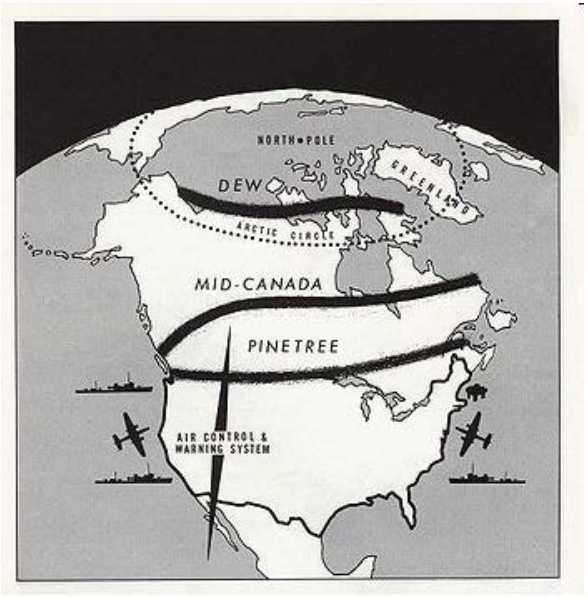
1950 UNIVAC

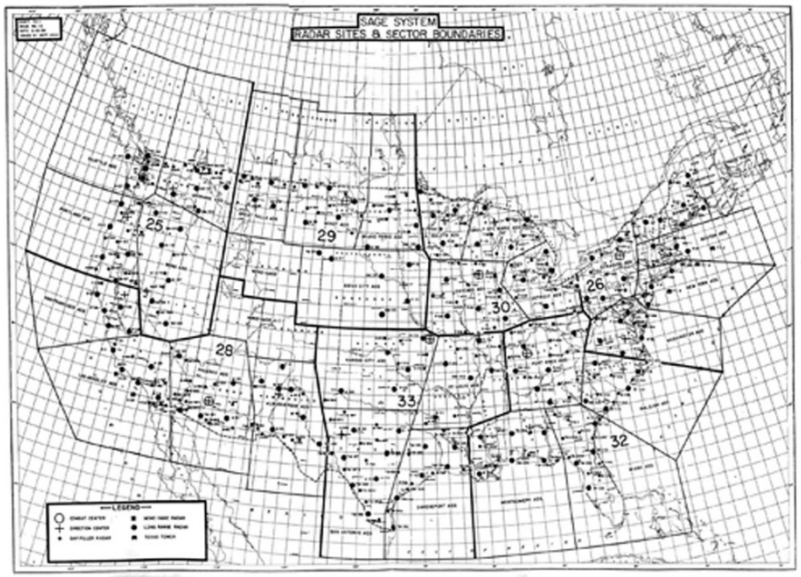
1980 GBF/DIME

1990 TIGER

Enter the Computer

- SAGE and the Cold War





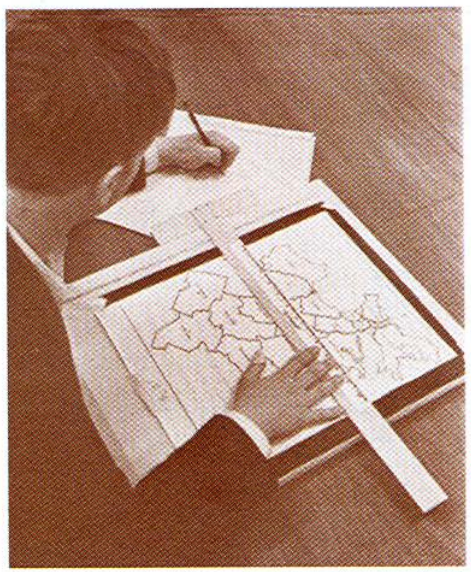
Developed by MIT Lincoln Laboratory, IBM and others.

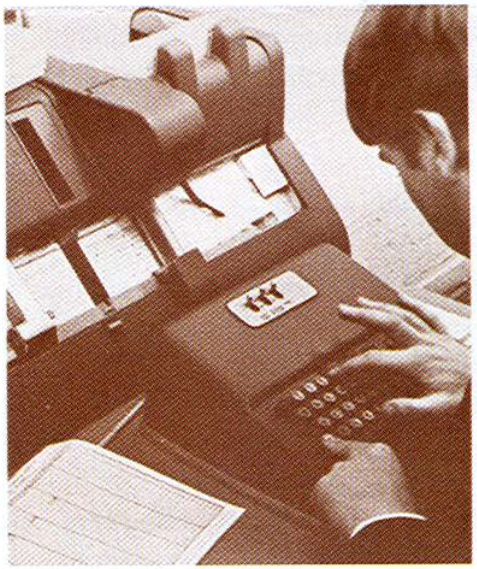
Operational in 1959

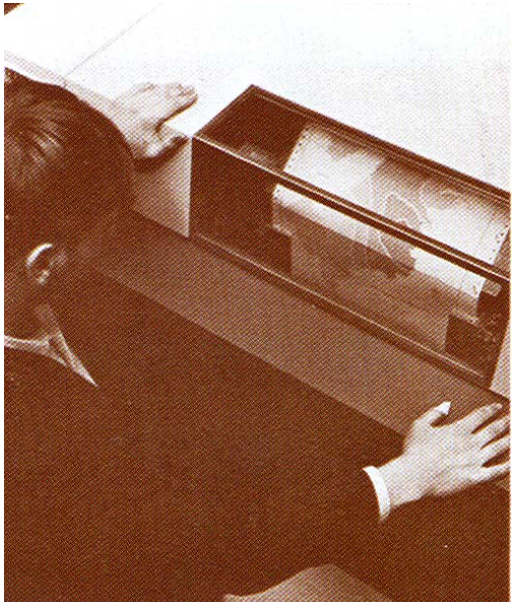
Part of North American Aerospace Defense Command (NORAD) until 1989

Servomechanisms Laboratory, under the direction of Jay Forrester (Systems dynamics)

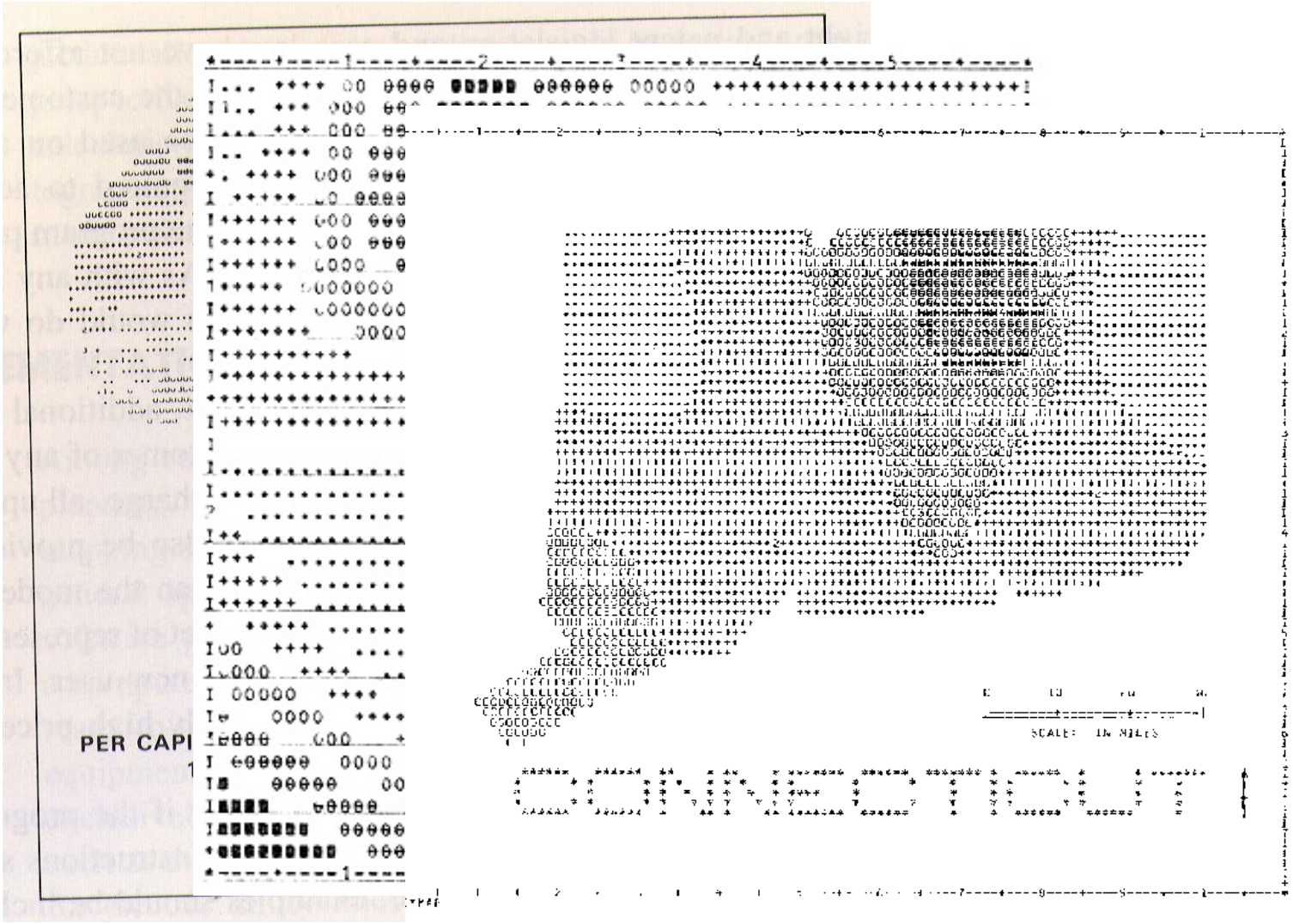
Early Computer Cartography







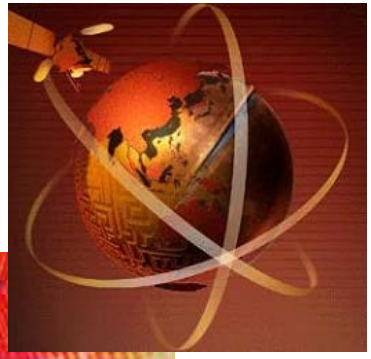
Early Computer-made Maps

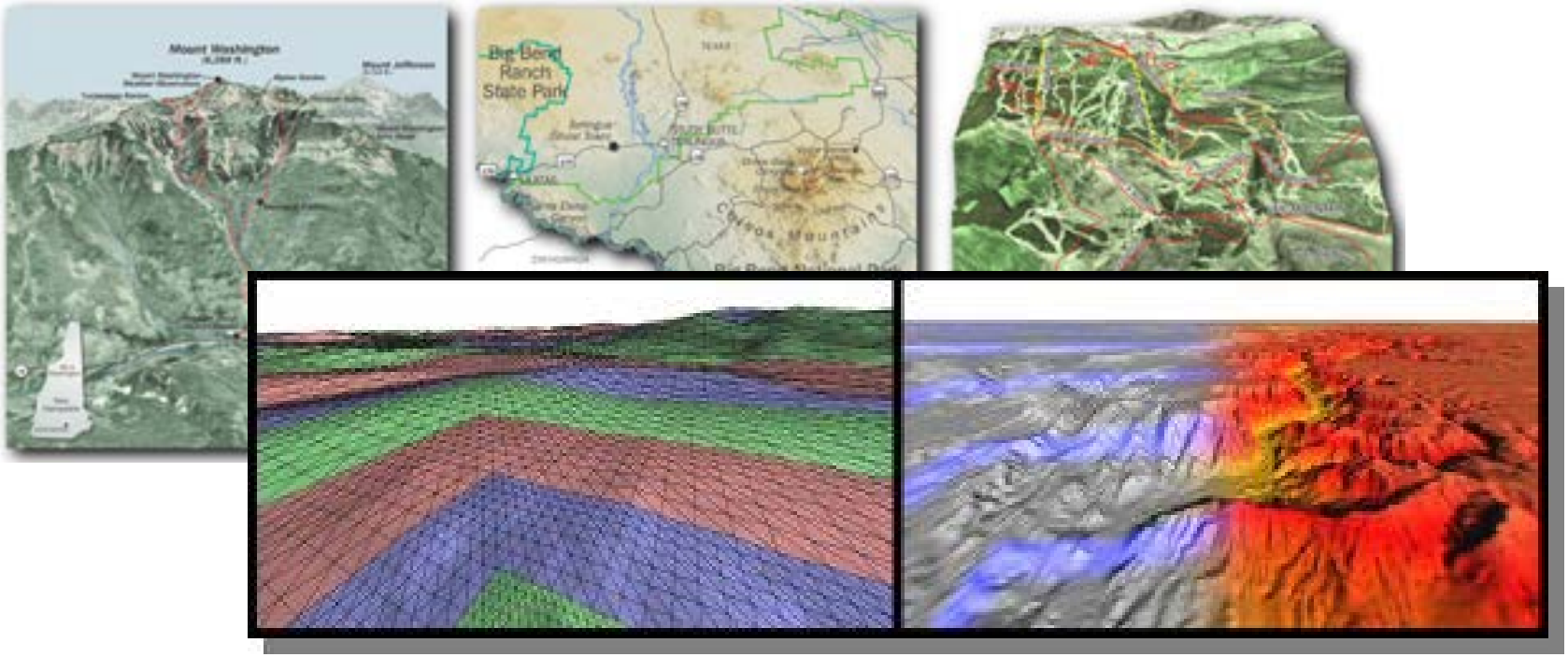


Evolution of Computer Cartography

What is Computer Cartography?

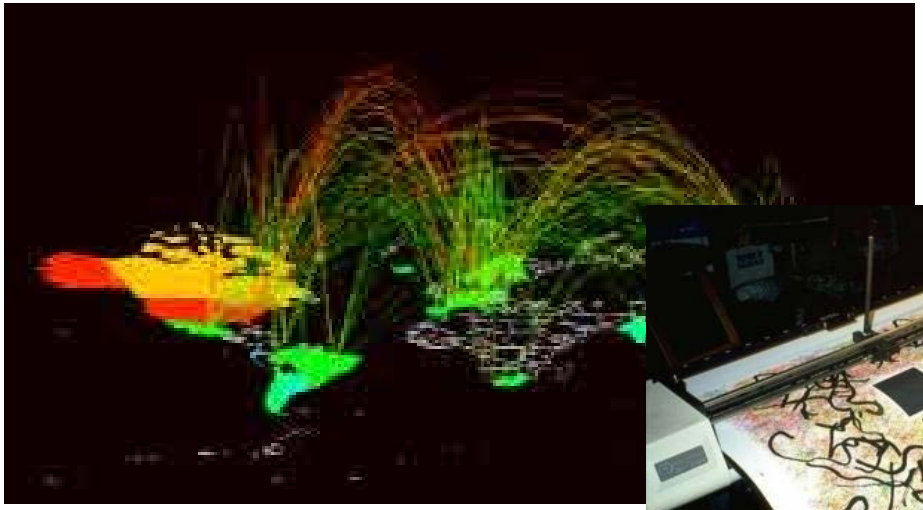
- Computer Cartography – the science, technology and art of making maps using computers and other new technologies





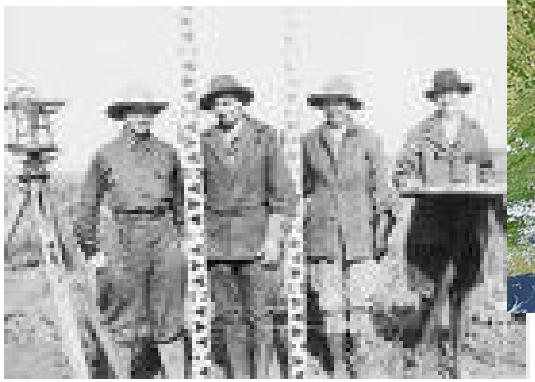
What have computers done to Cartography?
- Faster and Easier, even Cheaper

- Computer graphics for map drawing
- New survey technologies for map update



- Computer data transfer via mobile storage and networks for map sharing
- Computer printing technology for map production

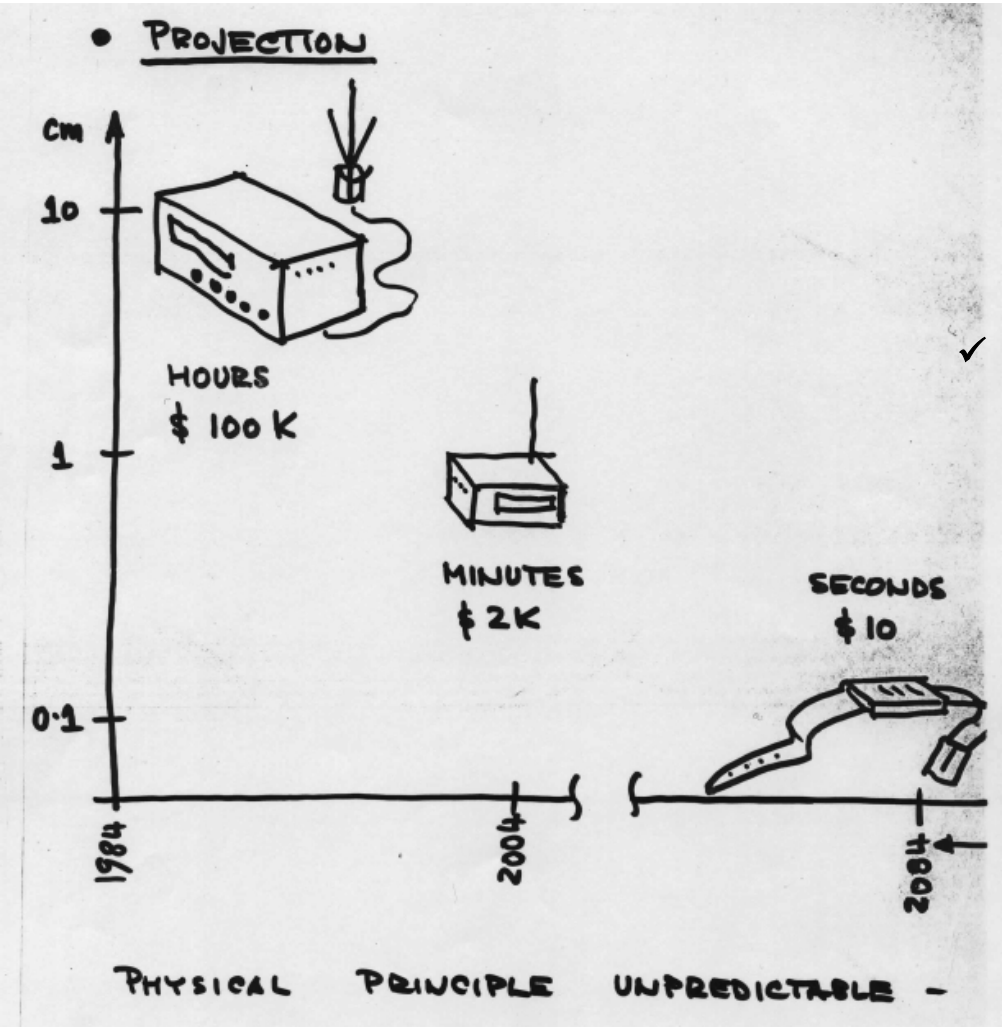
What have computers done to Cartography? - More Accurate and More Precise



- New survey technologies increase the accuracy of geographic information

- Computer graphics and plotting/printing vs. manual drawing
- Computers enable more significant digits – more precise

Dru Smith: NGS on the future of geopositioning

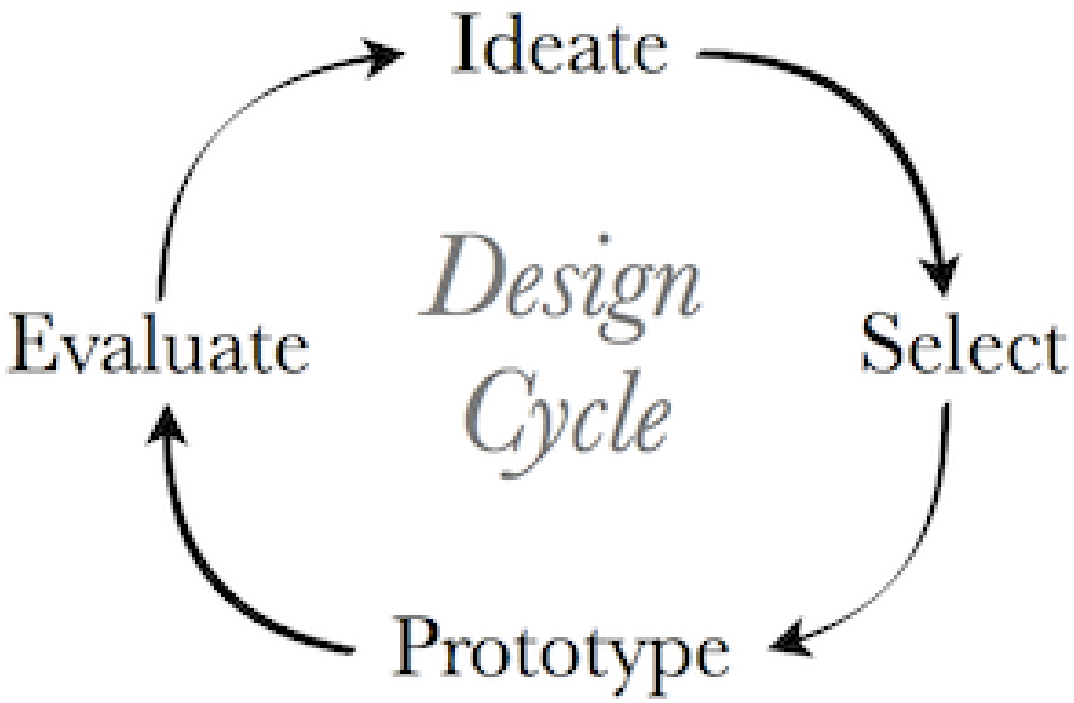


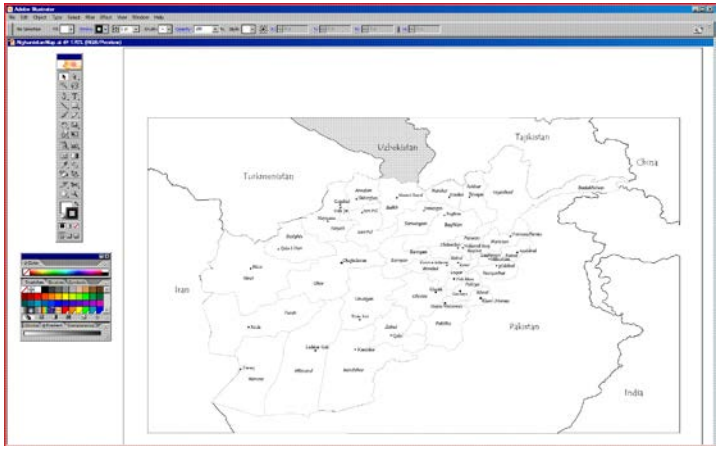
Richard Langley on the Future of GPS

"2004: $2000 and *a few minutes gets you 1 cm*..."

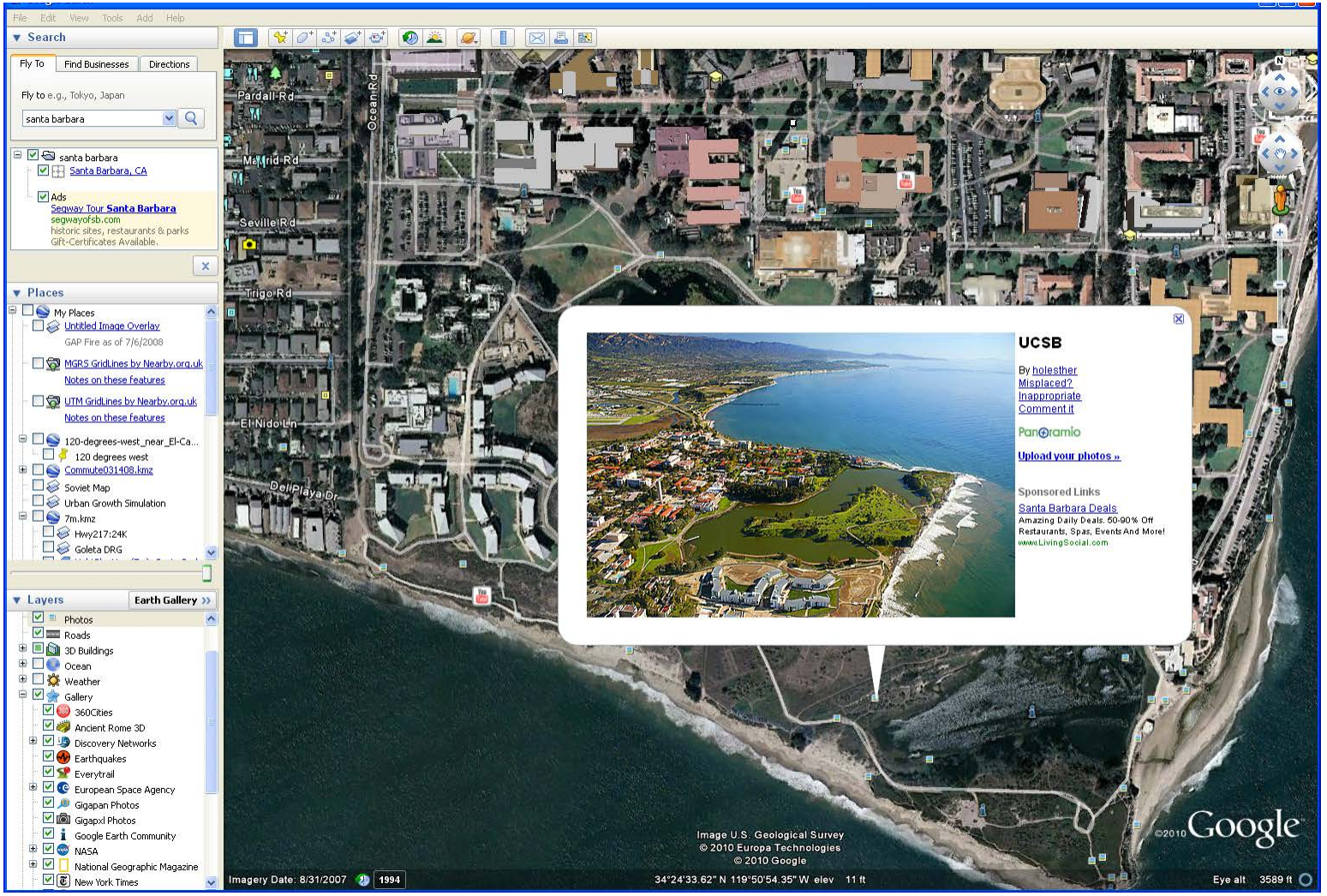
"2084: $10 and *a few seconds gets you 1 mm*..."

What have computers done to Cartography?
- The Design Loop!!





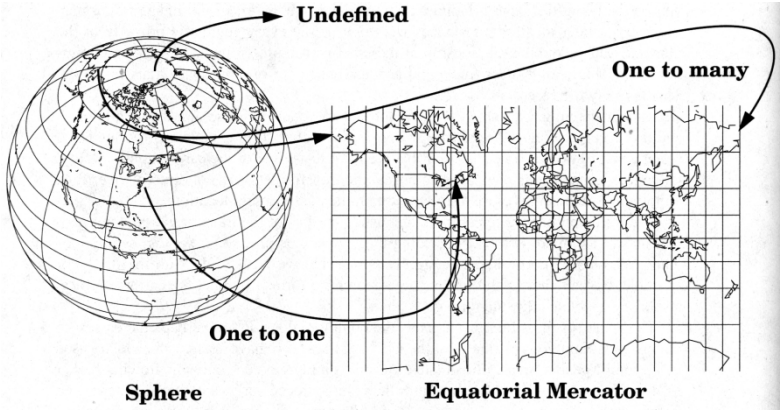
What have computers done to Cartography?
“The democratization of cartography”
- Anyone can do Cartography?

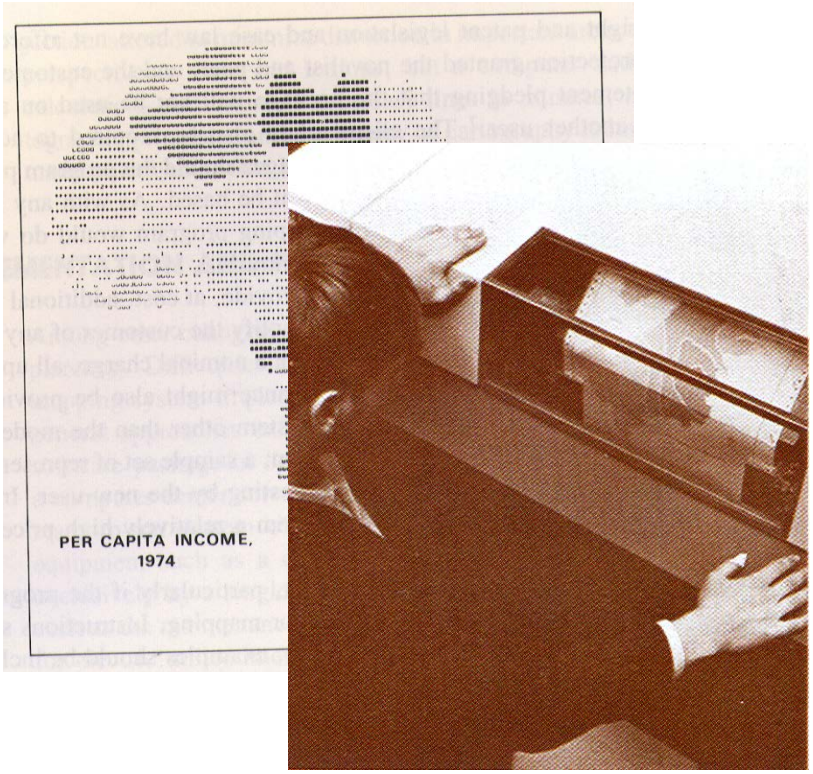


What have computers done to Cartography?
BUT anyone can do Cartography!

What have computers done to Cartography? - The birth of Analytical Cartography & GIS

- Born in the 1960s and 1970s
- From technological focus to theoretical focus





- The early Geographic Information Systems are more like computer mapping programs plus a few data management functions.

What is Analytical Cartography?

- Tobler (1966) – “solving cartographic problems”

- Tobler (1976) – “mathematical and analytical parts of cartography that remain independent of technology”

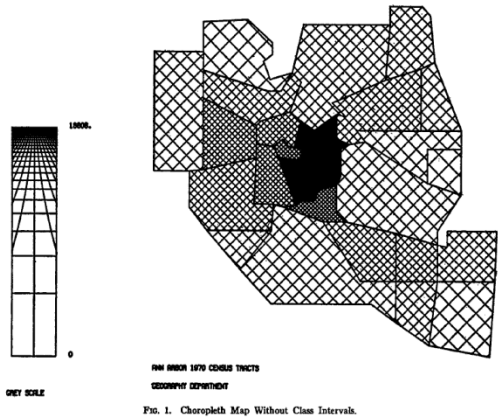
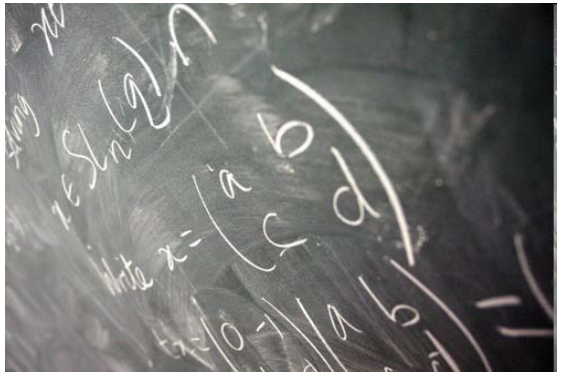
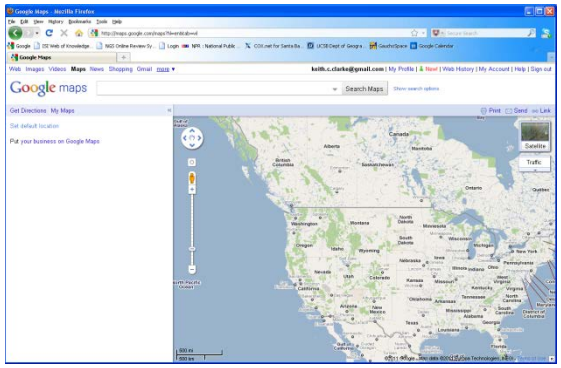


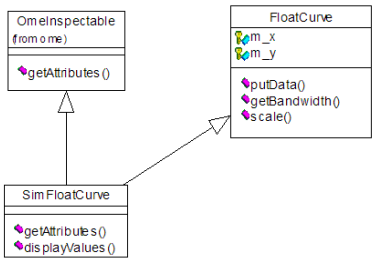
Fig. 1. Choropleth Map Without Class Intervals.

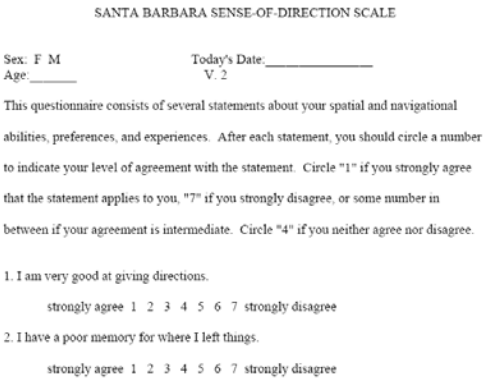
Methods of Analytical Cartography

- Computer science
  - Data base science
  - Computation
  - Logic and programming
- Mathematics and Statistics
  - Matrix theory
  - Set theory
  - Algebra
  - Trigonometry
  - Topology
  - Spatial statistics
- Cartography
  - Map data
  - Transformations
  - Representation
  - Symbolization
  - Layout and design
- Psychology
  - Map reading and interpretation
  - Navigation and route finding
  - User design









SANTA BARBARA SENSE-OF-DIRECTION SCALE

Sex: F M Today's Date:_____
Age:_____ V. 2

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.

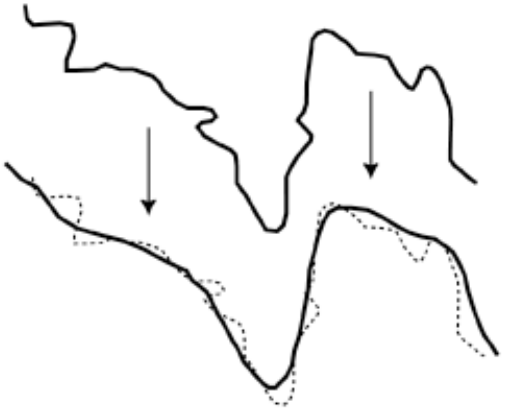
strongly agree 1 2 3 4 5 6 7 strongly disagree

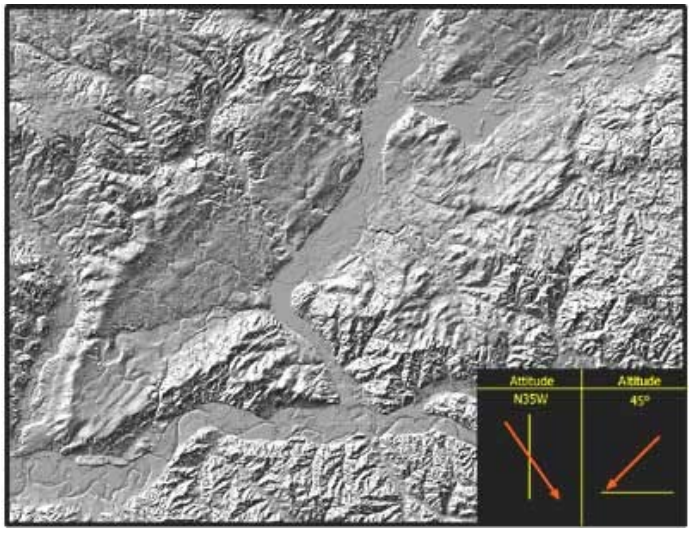
2. I have a poor memory for where I left things.

strongly agree 1 2 3 4 5 6 7 strongly disagree

Typical Topics in Analytical Cartography

- Map Transformation
- Sampling
- Critical Features
- Map Generalization
- Shape Analysis
- Data Models and Structures
- Analytical Visualization
- A lot more …





Review of Applications by W. R. Franklin (2000) in Special Issue of Cartography and GIS on Analytical Cartography

Applications of Analytical Cartography

Wm Randolph Franklin

ABSTRACT: Several applications of analytical cartography are presented. They include terrain visibility (including visibility indices, viewsheds, and inter-visibility), map overlay (including solving round-off errors with C++ class libraries and computing polygon areas from incomplete information), mobility, and interpolation and approximation of curves and of terrain (including curves and surfaces in CAD/CAM, smoothing terrains with over-determined systems of equations, and drainage patterns). General themes become apparent, such as simplicity, robustness, and the tradeoff between different data types. Finally several future applications are discussed, such as the lossy compression of correlated layers, and just good enough computation when high precision is not justified.

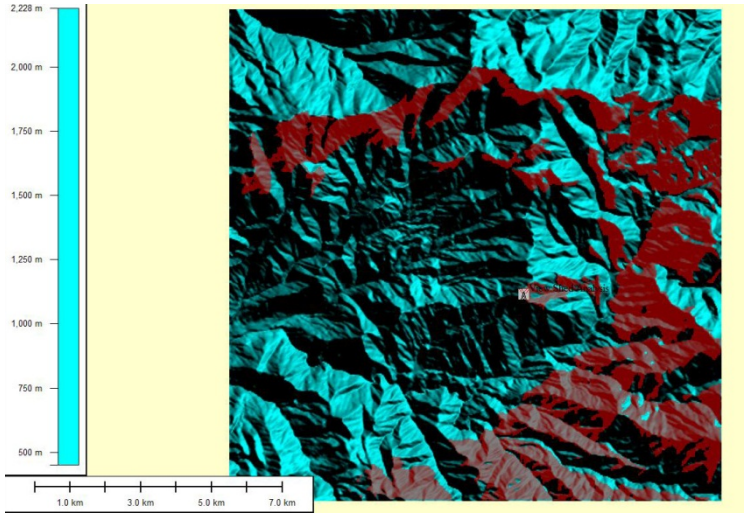
Introduction

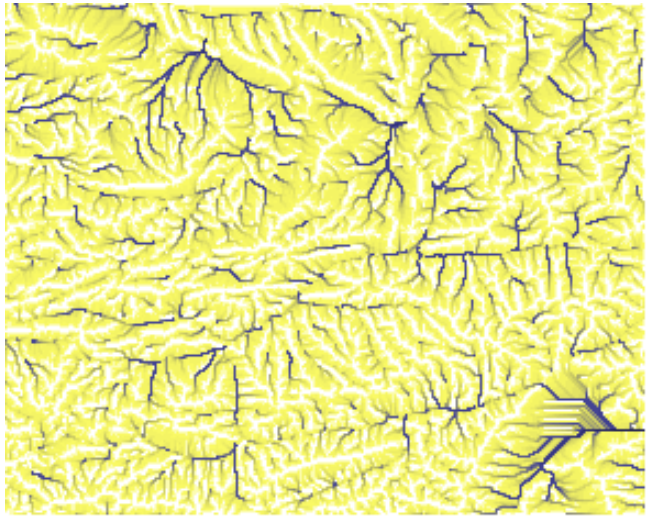
Analytical cartography's progress has been distinguished since *mathematikoi* measured the circumference of the Earth, (Aristotle 350BC), which may have happened before 2600 B.C. (Stecchini 2000). Throughout its history, it has relied on, and even forced the development of applied mathematics. Today, techniques developed in computer science enable its advance.

results. The paper also describes how the CAD/CAM community handles curves and surfaces. It also discusses terrain elevation interpolation, including using the solution of an over-determined system of equations, with Matlab, to cause greater smoothness and to infer local peaks inside topmost contours. The discussion also summarizes drainage determination. Some common themes become apparent, including the interplay between theory and application, and factors in data structure and algorithms design, such as the importance

Franklin’s Topics

- Terrain visibility
- Map overlay
- Calculation with partial information
- Mobility and routing
- Interpolation and approximation
- Representing curves and surfaces
- Interpolation on terrain surfaces
- Surface flow





Franklin’s themes

- Interplay between theory and applications
- Algorithm and data structure design principles
- Robustness in computations and solutions
- Interoperability

Franklin's Future Applications of Analytical Cartography

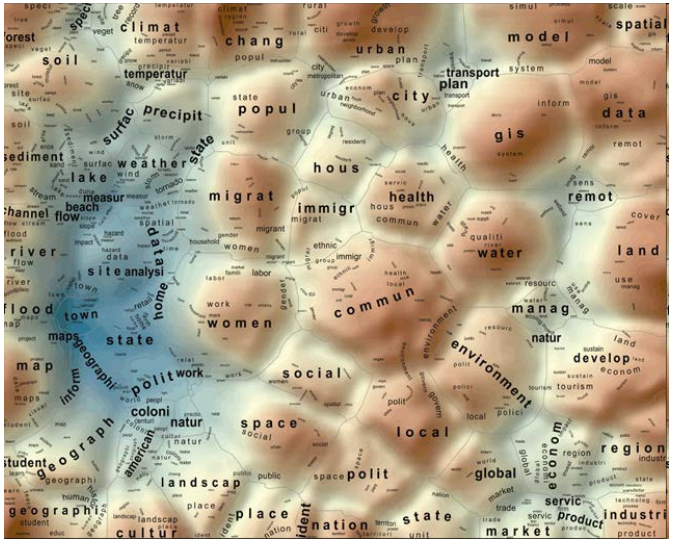
- *The best method for representing terrain*
- *Can we represent the terrain by the features that people would use to describe it?*
- *Conflating data across layers, e.g. topography and hydrology*
- *Dealing with true 3D, e.g. for geology*
- *Establishing error bounds on output as a function of approximations in the algorithm and uncertainties in the data* is *critical*
- *Consider "just good enough" computation, or, how do we tum input uncertainty and output sensitivity to our advantage?*
- *Finally, an open theoretical issue is why some simple algorithms, which have intolerable worst-case times, work so well in practice (e.g. Dykstra)*

Computer Mapping Fragments

- Geographic Information Systems
- Geographic Information Science
- GeoComputation
- Geospatial data
- GeoVisualization
- Visual Analytics
- Remote Sensing
- Image processing
- GeoAnalytics
- GeoWeb
- GeoSensor

Trends

- Integration and interoperability
- Mobile
- Ubiquitous
- Web enabled
- Interactive
- Animated



Finally

- BOTH analytical AND computer cartography are necessary
- Technology and theory
- Current technology IS the computer
- Technology a moving target
- What information in Geography 128 will be technological history in 5-10 years?

$$x = \lambda$$

$$y = \ln\left(tg\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)\right)$$

Analytical cartography

- The mathematical and analytical parts of cartography that remain independent of technology that applies to both paper and online maps and their digital databases
- Defined in term of its development, origins, scope and conceptual content and applications
- Flexible approach to GIScience and GeoComputation
- Now has books, journal special issues, classes
- Bridges Cartography and Computer Science