Outline

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- Preludes to the Golden Age
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  - Statistical theory, technology
  - Inventions in statistical graphics & cartography
- Exemplars of the Golden Age
  - Graphic vision of Charles Joseph Minard
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  - Statistical atlases
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Data visualization: thematic maps & statistical graphics

- Different ‘visual language’, but common goals:
  - Exploration: show trends, reveal patterns in quantitative or qualitative info
  - Analysis: aid in synthesizing, generalizing or testing patterns
  - Presentation: stimulate thought, convey conclusions, argue a point

Snow (1855)  Galton (1863)  Minard (1869)

Data visualization: Diffusion of ideas

- Those who developed thematic maps often not cartographers

Dupin (1826): literacy in France   Galton (1881): travel time from London
Data visualization: Diffusion of ideas

- Those who developed data graphics often borrowed from cartography
  - Halley (1701): contour map -> Lalanne (1843): contour diagrams of soil temp

Data visualization: Diffusion of ideas

- Graphical inventions often applied to maps
  - Playfair (1805): pie chart -> Minard (1858): pie map

Context: Milestones Project

www.math.yorku.ca/SCS/Gallery/milestone

Milestones in the History of Thematic Cartography, Statistical Graphics, and Data Visualization

- An illustrated chronology of innovations by Michael Friendly and Daniel J. Denis

Project goals:
- Comprehensive catalog of developments in history of data visualization
- Tool to study themes, antecedents, influences, patterns, trends, etc.
Milestones as a graph

1800-1849: Beginning of modern data graphics

1801: Pie chart, circle graph invented- William Playfair
1819: First modern statistical map (illiteracy in France)- Charles Dupin
1843: Wind-rose (polar coordinates)- L. Lalanne
1844: variable-width, divided bars, area ~ cost of transport- C. J. Minard

1850-1900: Golden Age

1855: Dot map of disease data (cholera)- John Snow
1879: Stereogram (3D population pyramid)- Luigi Perozzo
1896: Area rectangles on a map to display two variables and their product- Jacques Bertillon
1884: Recursive multi-mosaic on a map- Emile Cheysson

1884: Recursive multi-mosaic on a map- Emile Cheysson

What makes an “Age”? What makes one “Golden”?

- Age:
  - Qualitatively distinct from before & after
- Golden age:
  - Recognizable period in a field where great tasks were accomplished
  - Years following some innovations
  - Artists apply skills to new areas
  - New ideas expressed, art forms flourish
  - Often ends with some turning point event(s)
Some Golden Ages

- Athens (Pericles): 448 BC—404 BC
- Islam: 750—1258 (sack of Baghdad)
- England: Elizabeth I (1558-1603)
- Piracy: 1690--1730
- Radio: 1920—1940
- Animation: 1928 (sound) – 1960s (TV)
- Senior citizens: 60+

Pietro Da Cortona, The Golden Age (Fresco, Sala della Stufa, Palazzo Pitti, Florence)

Preludes to the Golden Age

- Data: collection & dissemination
- Statistical theory: combining & summarizing quantitative information
- Technology: printing & reproduction of maps & diagrams
- Visual language: new graphic forms for maps and diagrams
  → a perfect storm for data graphics

Preludes: data

- Population: ~ 1660--
  - Bills of mortality: Graunt (1662)
  - Political arithmetic: Petty (1665)
  - Demography: Süssmilch (1741)
- Economic data: ~ 1770--
  - Revenue, expenditures, taxes
  - Imports, exports
  - Transport
- Social data: ~ 1820--
  - Literacy, education
  - Crime, suicides, illegitimate births, prostitution
  - Poverty, debtors, disease
  → An avalanche of data, waiting to be visualized!

“Data! Data! I can’t make bricks without clay.” – Sherlock Holmes, Copper Beeches

Preludes: technology

- Copperplate → Lithography (1800+) → color printing (1850+)
- Automatic recording: James Watt (1822)
- Calculation: Babbage (1822/33)
- Photography: Niépce (1827), Deguerre (1839), trichromatic process (1861)
- Motion: Muybridge (1872), Marey (1882)
Preludes: visual language

- Graphs & diagrams
  - Line, bar, pie charts – Playfair (1786, 1801)
  - Scatterplot – Herschel (1832)
  - Polar plots – Guerry (1829), Nightingale (1857)
  - Nomograms & graphical calculation – Lalanne (1846)

Exemplars of the Golden Age

- The graphic vision of C. J. Minard
- Galton’s graphic discoveries
- State statistical albums

The graphic vision of C. J. Minard

- Marey (1878): “defies the pen of the historian in its brutal eloquence”
- Tufte (1983): “the best statistical graphic ever produced”

Why Minard?

- Study breadth and depth of his work
  - How related to work in his time?
  - How related to modern statistical graphics?
  - How related to his personal history?

Civil Engineer for ENPC (1810-1842)

Visual Engineer for France (1843-1869)
Visual thinking, visual explanation

1840: Why did the bridge at Bourg-St. Andréol collapse?
Minard’s report consisted essentially of this self-explaining diagram.

Visual tools for state planning

• 1830—1860: emergence of modern French state, dawn of globalization
• Trade, commerce, transportation:
  ▪ Where to build railroads, canals?
  ▪ Visualizing changes over time, differences over space
  ▪ → Flow maps and other graphical innovations

Flow maps as visual tools

Transport of passengers on the principal railroads in Europe in 1862

Carte figurative: give precedence to the data over the map

Effect of US civil war on cotton trade

Before

After
The March Re-Visited (1869)

Hannibal’s retreat

Napoleon’s 1812 campaign

Galton’s discovery of weather patterns - Perhaps the most notable purely graphic discovery ever!

Data: recordings of barometric pressure, wind dir/speed, rain, temp., cloud: 3x/day, 50 weather stations in Europe.

Method: All weather stations across Europe asked to record data 3x/day for all of Dec., 1861

Graphic analysis: $3 \times 31 = 93$ maps, each with multivariate glyphs showing all variables

Visual ideas:
- Iconic symbols
- Multivariate glyphs (stamps!)

Visual abstraction → Patterns

How to see patterns of geographical variation over time?
- Iconic symbols on a geographical grid
- “Small multiples:” separate graphs laid out for direct comparison
Visual abstraction → Patterns

What varies with what, over time and space?

- mini, abstract maps: vars x TOD
- iso-contours, shading to show equivalence
- arrows to show wind direction

The large picture → Insight

Pattern:
Low pressure (black) in early Dec. → CCW wind
High pressure (red) in late Dec. → CW wind

Graphic: 3x3x31 grid, mapping (pressure, wind/rain, temperature) x {AM, 12, PM} x day {1:31}

Visual insight → Theory

Visual insight from 93 (3x31) high-D graphs:
- Changes in wind dir w/ pressure over time
  - Winds revolve inwardly (CCW) in low pressure areas— as in a cyclone;
  - revolve outwardly (CW) in high pressure areas— “anti-cyclone”

Theory:
- Explained by Dove’s ‘Law of Gyration’
- Prediction: reversed pattern (CW/CCW) in southern hemisphere – confirmed!

Theory → Practice

The first modern weather map, London Times, Apr. 1, 1875

Galton did for weathermen what Kepler did for Tycho Brahe. This is no small accomplishment. (Wainer 2005)
Statistical atlases: Data → practice, national identity & graphical excellence

- Collection of gov't statistics on pop., trade, moral & political issues widespread in Europe & US, starting ~ 1820
- Statistical albums ~ 1870—1910
  - France: *Album de Statistique Graphique*: 1879-1899
  - USA: Census atlases: 1870/80/90
  - Gemany: local albums (Berlin, Frankfurt, etc.)
  - Switzerland: *Atlas graphique de la Suisse*: 1897, 1914
  - Others: Latvia, Romania, Bulgaria, etc.

*Album de statistique graphique*

- Published by the Statistical Graphics Bureau, Ministry of Public Works, Emile Cheysson, director
- 18 volumes: 1879-1899, 12—34 plates each, ~ 11”x15” pages
- Graphic forms:
  - Flow maps (simple, double, multi)
  - Pie maps, star, radial, polar time-series, proportional circles
  - Mosaic maps, anamorphic maps, planetary diagrams
  - Choropleth, bi-polar scales
  - Charts: line, bar, time-series
- Formats: 1x1, 2x1, 2x2, 3x2, 5x3!
- Themes:
  - Recurrent: railroads, navigation, transport--- B&B
  - Occasional: agriculture, Paris, expositions, …
- Pinnacle of the Golden Age: exquisite sampler of all known graphic forms!

Recursive multi-mosaic map

Distribution of passengers and goods from the Paris railways to the rest of France [Album, 1884, pl. 11]

Spiral time-series on a map

Changes in the population of France from 1801—1881, by department [Album, 1881, plate 25]
Anamorphic map

Shrinking France to show change in travel time over 200 years [Album, 1888, plate 8]

Two-way table of star/radar diagrams

Attendance at the universal expositions in 1867, 1878, 1889 (rows), by month (cols) and days (rays). [Album, 1889, plate 21]

Planetary diagrams

Movement of principal merchandise by region. Spiral ~ distance; circles ~ tonnage [Album, 1895, plate 9]

Classed choropleth maps, bipolar color scale

Circulation on the national roads in 'colliers réduits' Left: 1894; Right: % change, 88-94 [Album, 1895, plate 21]
Golden Age → Modern Dark Ages

- Albums: discontinued (cost), became routinized
- Statistics: enthusiasm for graphics replaced by rise of quantification
  - Statistical models (regression, correlation)
  - Estimates ± standard errors: precise!
- Few innovations, but popularization
  - College courses, text books
- Some significant graphical discoveries
  - E.W. Maunder (1904): “butterfly diagram” of sunspots
  - Hertzsprung-Russell (1911) diagram: stellar physics
  - Henry Moseley (1913): atomic number

Conclusions

- Data visualization has deep roots:
  - Cartography
  - Statistics
  - Data collection
  - Visual thinking
  - Technology
- The Golden Age
  - Qualitatively distinct, deserves recognition
  - Works of unparalleled beauty & scope
  - Thematic maps & diagrams often aided each other

Golden Lessons

- What are the lessons for the future?
- Phenomena, not numbers
  - Playfair, Guerry, Minard, Galton, etc. all developed new graphic forms to show the phenomena:
    - balance of trade, rates of crime, patterns in weather data, …
- 1st lesson: data visualization today should have a similar focus

Golden Lessons

- Impact = Interocularity, Immediacy, Inescapability
  - Playfair, Guerry: data should “speak to the eyes”
  - Minard, Lalanne: allow “calculation by the eyes”
  - Nightingale: graphs should speak to the heart and mind, influence public policy & practice
- Graphical impact (Tukey, 1990)
  - Interocularity: the message hits you between the eyes
  - Immediacy: it hits you fast
  - Inescapability: it is hard to avoid the message
- 2nd lesson: strive for visual impact in graphs and tables
Golden Lessons

• Hand-made graphics were often beautiful, but entailed much sweat and hard work.
• Today: software— ease of use vs. expressive power
• Theories of graphics → graphic “languages”
  ▪ Bertin: *Semiology of graphics*
  ▪ Wilkinson: *Grammar of Graphics*
    • Wickham: *ggplot2* R package
  ▪ In all: the devil is in the details!
• 3rd lesson: continue to reduce the distance between a graphic idea and appearance on screen or paper.