Geog 126: Maps in Science and Society

Mapping Networks
Mapping Networks

- What are Networks
- Elements of Network Mapping
- Schematic Maps
- A brief history
- Networks as state expansion: railroads and highways
Networks, Defined

- What is a network?
  - An interconnected group or system
  - A system of intersecting lines or channels; "a railroad network"; "a network of canals"

- Networks are important in geography and mapping

- Abstraction allows analysis and better mapping
Elements of Networks

- Networks are a collection of:
  - Nodes
    - AKA: Vertices
  - Edges
    - AKA: Links
  - Directions
The Seven Bridges of Königsberg

“The Seven Bridges of Königsberg is a historically notable problem in mathematics. Its negative resolution by Leonhard Euler in 1735 laid the foundations of graph theory and prefigured the idea of topology.” Wikipedia

- Königsberg in Prussia (now Kaliningrad, Russia) was set on both sides of the Pregel River
- Two large islands, connected to each other and the mainland by seven bridges
- Is it possible to find a walk through the city that would cross each bridge once and only once?
- Islands can only be reached by the bridges
- Every bridge must have been crossed completely
- The walk need not start and end at the same spot
The Seven Bridges: 1651
The problem becomes simpler with abstraction....
So, what’s the solution?

- There is no solution! It is impossible.
- In 1736, Leonhard Euler proved it was impossible
- Invented “graph theory”
  - Eliminated all features except land masses and the bridges (nodes, edges)
- Work led on to topology
An Eulerian Path

- Problem concerned degrees of nodes
  - Degree of a node is the number of edges that touch it
  - Konisberg: 1 5-degree node, 3 3-degree nodes
- Euler proved that a “circuit” is only possible if there are exactly 0 or 2 nodes of an odd degree
  - This type of walk is called a Eulerian Path
Roads near Center, Pennsylvania
A modern equivalent

- Travel by car to each of the 48 contiguous U.S. States
- Visit each state in whatever order you chose, but start in Delaware
- Visit each state only once
- Do not go back into a state already visited
- What state do you finish up in?
Networks

• Roads
• Rivers
• Pipelines
• Air travel
• Infrastructure—the grid, sewers, cable, gas
• Communications links, e.g. post offices, transmission towers
• Social media
Rapid Transit New York 1908
Harry Beck

- Revised London Underground map, and revolutionized map design
- Drew an electrical schematic on which all the stations were more or less equally spaced, angles simplified
- First submitted his idea to Frank Pick of London Underground in 1931,
- Considered too radical
- Trial production of 500 copies of Beck's map in 1932
- Full publication in 1933 (700,000 copies)
- Positive reaction of the travelers proved it to be sound design
- Large reprint after only one month
Beck’s Original Design
Direct descendents
Octilinearity

- Every line on the map is drawn in one of 8 directions
  - Multiples of 45 degrees
  - Octilinearity
- Reduces geographic congruence, increases clarity
New Circular Underground Map
Dangers of the schematic style

- Results in warped mental maps of actual geography
  - Distance and direction are inaccurate
  - Walking station to station often much shorter/longer than believed
  - North-South and East-West errors
- Leads to longer trips than necessary
- Does this apply in vehicle navigation systems?
- Hierarchy effect
Picadilly Circus to Leicester Square: 39 seconds
Triptik maps

- Patented by AAA in 1932
- Offered personalized maps for trips
- Offered online since 2000
Google maps: Routing
Peutinger's table

- Tabula Peutingeriana: an itinerarium showing the cursus publicus the road network of the Roman Empire
- Original map was last revised in the fourth or early fifth century
- Covers Europe, parts of Asia (Persia, India) and North Africa
- Named for Konrad Peutinger, a German 15–16th-century humanist and antiquarian
- Original discovered in a library in Worms by Conrad Celtes, who bequeathed the map in 1508 to Peutinger
- Now in the Österreichische Nationalbibliothek, Vienna
Piri Reis Map

- Pre-modern world map compiled in 1513 from military intelligence by the Ottoman admiral and cartographer Piri Reis
- Half of the map that survives accurately shows the western coasts of Europe and North Africa and the coast of Brazil
- Emphasizes sailing routes via Portolan compass roses, a network!
- Azores and Canary Islands are depicted, as is the mythical island of Antillia and possibly Japan
- Used 10 Arabian sources, 4 Indian maps sourced from Portuguese and one map of Columbus
The Vinland Map

- Claimed to be a 15th century mappa mundi with unique information about Norse exploration of America
- Publicity campaign when presented as a "genuine" pre-Columbian map in 1965
- Africa, Asia and Europe, but also depicts a landmass southwest of Greenland in the Atlantic labeled as Vinland
- Claims Vinland as having been visited by Europeans in the 11th century
- Accompanying scholarly book written by British Museum and Yale University librarians
- Suspected a fake as soon as photographs of it became available
- Chemical analysis have shown one of the major ink ingredients is a 20th century artificial pigment
- Individual pieces of evidence disputed most recently at a 2009 conference
Vinland
1643 Matthew Simons in *A Direction for the English Traviller* publ. Thomas Jenner (distance tables by John Norden)
English Cities Strip Maps: 1715
Lewis and Clark 1800-1803
Santa Fe Trail

Zebulon Pike
Map of the "Santa Fe Trail"
St. Louis: ca. 1806
Manuscript map
National Archives, Washington, D.C.
The First Modern Networks: Railroads

First edition of G.K. Warren's "hurried compilation," indicating the routes of the Pacific railroad surveys. The map was appended to the U.S. War Department's official report to Congress. (1857)
Right Half of James Hayward's 1828 plan of a survey for the proposed Boston and Providence Railway. (horse drawn trains)
Cross country travel

- US Civil War Apr 12, 1861 – Apr 9, 1865
- Central Pacific Railroad authorized by Congress in 1862
- Financed and built through "The Big Four" Leland Stanford, Collis Huntington, Charles Crocker, and Mark Hopkins
- Starting in 1863 12,000 Chinese laborers employed by the Central Pacific Railroad representing 90 percent of the entire work force
- "Golden spike", connecting the western railroad to the Union Pacific Railroad at Promontory, Utah, May 10, 1869
- Coast-to-coast train travel in eight days became possible, replacing months-long sea voyages and lengthy, hazardous travel by wagon trains
The End Game

• In 1885 the Central Pacific Railroad was leased by the Southern Pacific Company.

• The original right-of-way is now controlled by the Union Pacific, which purchased Southern Pacific in 1996.

• The Union Pacific-Central Pacific (Southern Pacific) mainline followed the historic Overland Route from Omaha, Nebraska to San Francisco Bay.
Promontary Point UT
US Time Zones Nov 18, 1883

1891
Congress provided land grants. The land grant railroads, received millions of acres of public land, sold the land to make money, built their railroads, and contributed to a more rapid settlement of the West. Four out of the five transcontinental railroads were built with help from the federal government.
Northeastern portion of a map of Iowa by Frank H. Galbraith. 1897
International Meridian Conference 1884

Held in October 1884 in Washington, D.C. At the old State Dept. Building

Declaration 4: That the Conference proposes the adoption of a universal day for all purposes for which it may be found convenient, and which shall not interfere with the use of local or standard time where desirable.

Declaration 5: That this universal day is to be a mean solar day; is to begin for all the world at the moment of mean midnight of the initial meridian, coinciding with the beginning of the civil day and date of that meridian; and is to be counted from zero up to twenty-four hours.

Declaration 6: That the Conference expresses the hope that as soon as may be practicable the astronomical and nautical days will be arranged everywhere to begin at midnight.
European railways

Railways network in Europe (1870)

Railways network in Europe (2000)
European Expansion
Trans-Siberian Railway
Trans Siberian

- Opened March 1891, by the future Tsar Nicholas II at Vladivostok
- Made notes in his diary about his anticipation of traveling in the comfort of "The Tsar's Train" across the unspoiled wilderness of Siberia
- The main route originates in Moscow at Yaroslavsky Vokzal, runs through Yaroslavl, Omsk, Novosibirsk, Irkutsk, to Vladivostok via southern Siberia
- Built 1891-1916 under the government ministers appointed by Tsar Alexander III and by his son, Tsar Nicholas II.
- Chinese Eastern Railway connected Russia with China and provided a shorter route to Vladivostok
- Moscow–Pyongyang (10,267 km, 6,380 mi)
- Kiev–Vladivostok (11,085 km, 6,888 mi)
- Main Russian segment 9,259 km (5,753 miles), spans seven time zones and takes eight days
Dwight D. Eisenhower National System of Interstate and Defense Highways

- Commonly known as the Interstate Highway System
- Network of limited-access roads including freeways, highways, and expressways forming part of the National Highway System
- Named for President Dwight D. Eisenhower, who championed its formation
- Serves nearly all major U.S. Cities
- Construction authorized by the Federal-Aid Highway Act of 1956, original portion was completed 35 years later
- As of 2016, about one-quarter of all vehicle miles driven in the country used the Interstate Highway System, which had a total length of 48,191 miles (77,556 km)
- Cost of construction was $425 billion (in 2006 dollars), making it the largest public works project in history.
Interstate Numbering

East-west highways assigned even numbers
North-south highways are assigned odd numbers
Odd route numbers increase from west to east
Even-numbered routes increase from south to north
Numbers divisible by five are major arteries on primary routes
Completing the System 1991...
First map of the Arpanet: 1967
Internet Maps
Historical Map of the World Wide Web
Our distorted web maps

Share of the population using the Internet, 2015
All individuals who have used the Internet in the last 3 months are counted as Internet users. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.

Source: World Bank

The Digital Divide

Polarized cloud
Conclusion

- Graph theory useful when route maps are abstracted
- Route maps have history back to Romans
- Walk, Horse, Sail, Railroad, Car, Internet
- Network cartography expanding!