浙江大学
ZHEJIANG UNIVERSITY

DATA VISUALIZATION SERIES

Geographical Visualization

Yingcai Wu
Professor
State Key Lab of CAD&CG
Email: ycwu@zju.edu.cn

OUTLINE

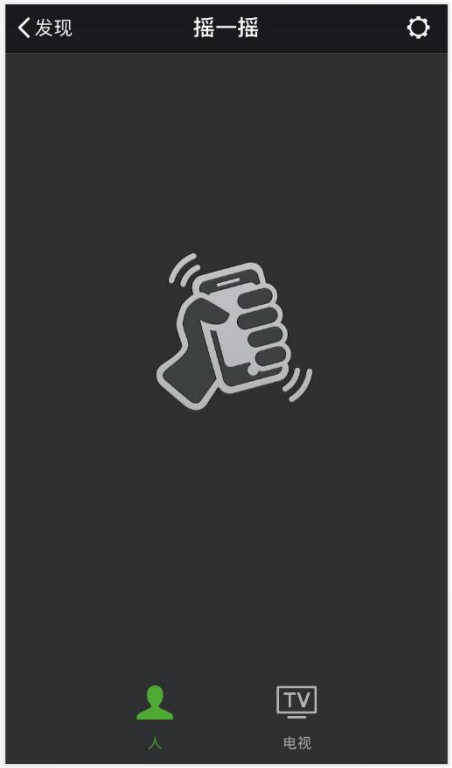
1. Geographic Data
2. Map Projections
3. Point Data Visualization
4. Line Data Visualization
5. Region Data Visualization
6. Geographic Datasets
7. Applications in Urban Problems

Geographic Data

Geographic Data

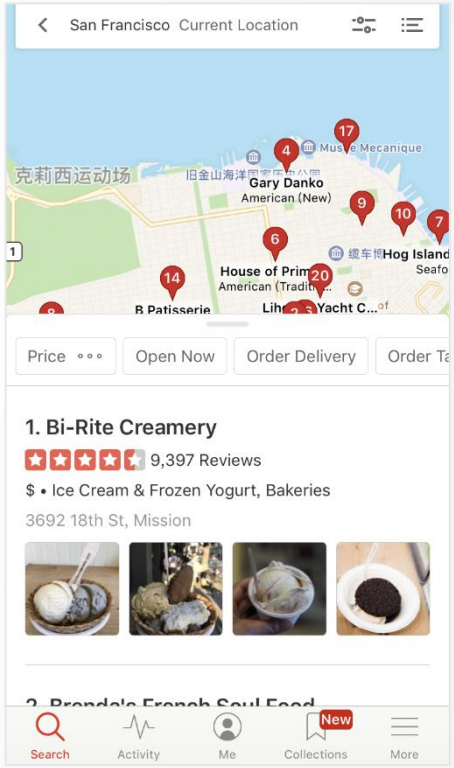
- Geographic data, or location-based data describe **the locations of objects**
- Geographic space is the space where human lives, which makes the information carrier and mapping very special and valuable
- Generated by mobile devices and sensors everyday

Location-Based Services



WeChat

Google Maps

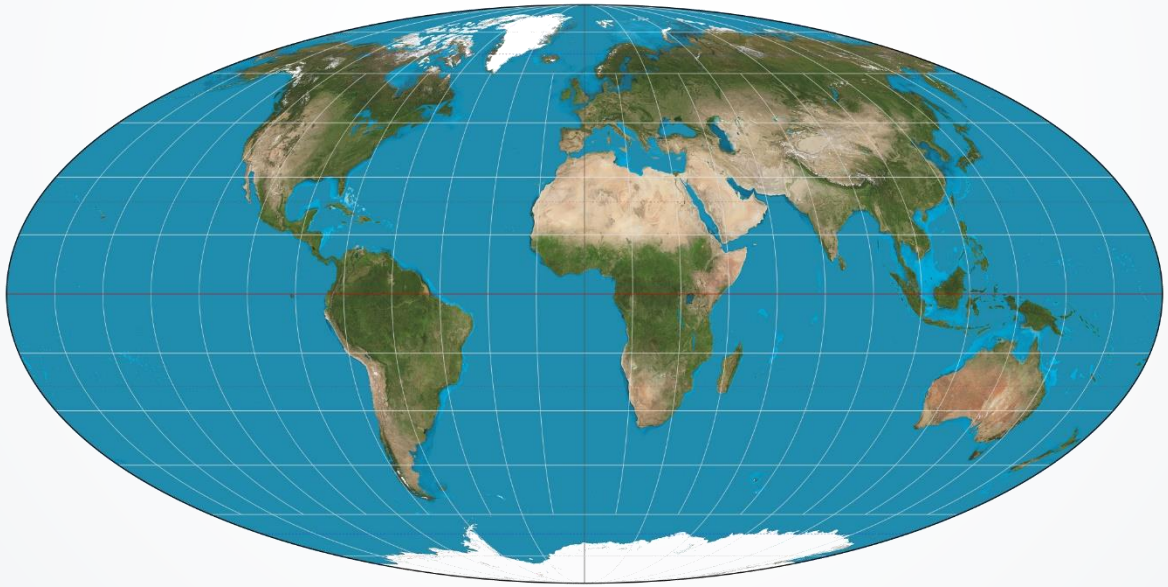


Yelp

Map Projections

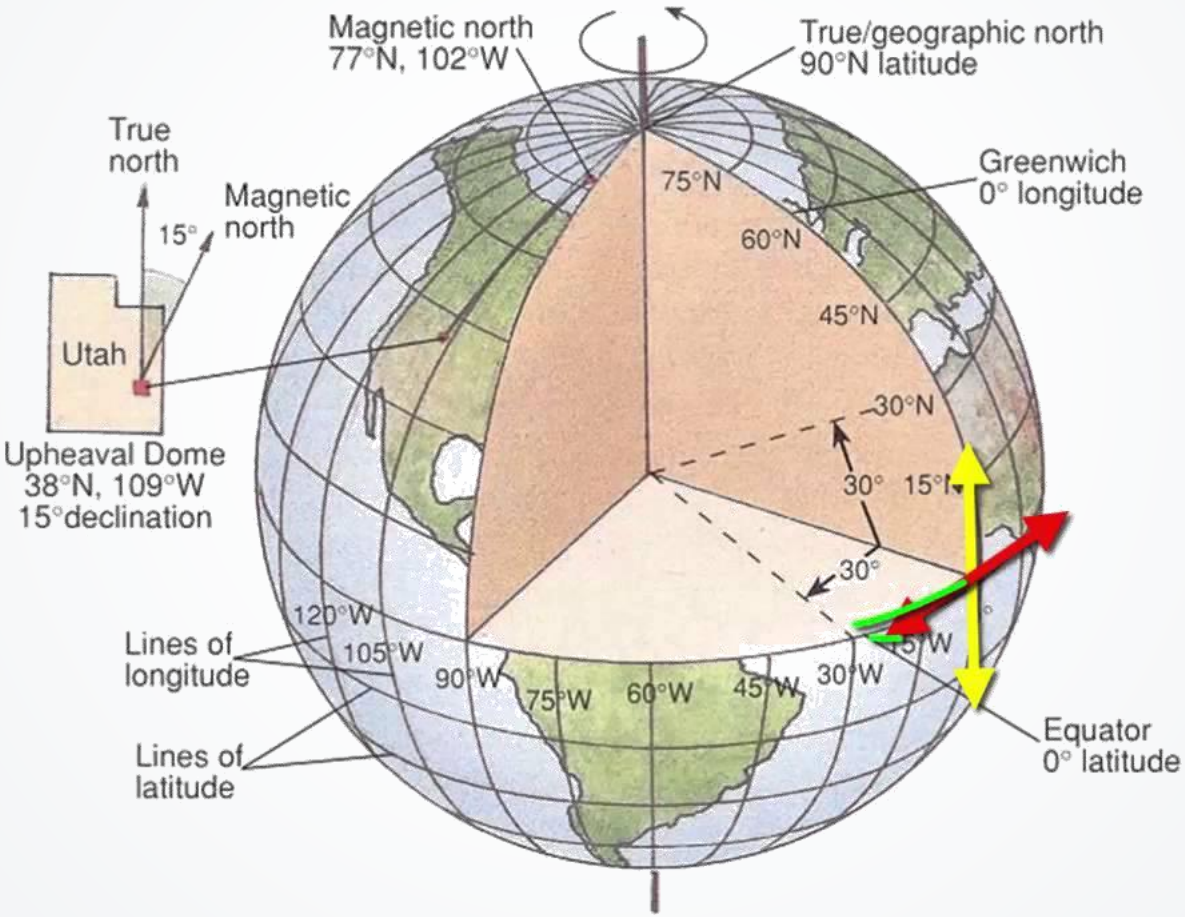
Map Projections

- Represent the **surface** of a sphere or other 3D body on a plane
- Necessary for creating maps



Wikipedia, Map projection.
https://en.wikipedia.org/wiki/Map_projection

Latitude-Longitude



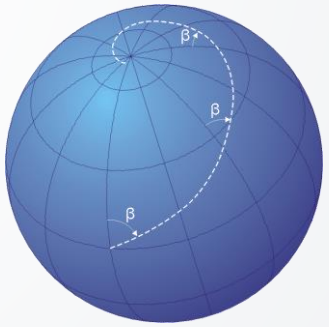
Katryn Wiese, Latitude & Longitude.
https://www.youtube.com/watch?v=2PllX2YOAHo

Map Projection Classification

- By preservation of a metric property…
  - **Conformal**: preserving angles locally.
  - **Equal-Area**: preserving area measure.
  - **Equidistant**: preserving distances from one (or two) points.
  - **Compromise**: balancing between distortions.
  - Gnomonic: keeping all great circles as straight lines.
  - Retroazimuthal: preserving the direction to a point.

Conformal Projections

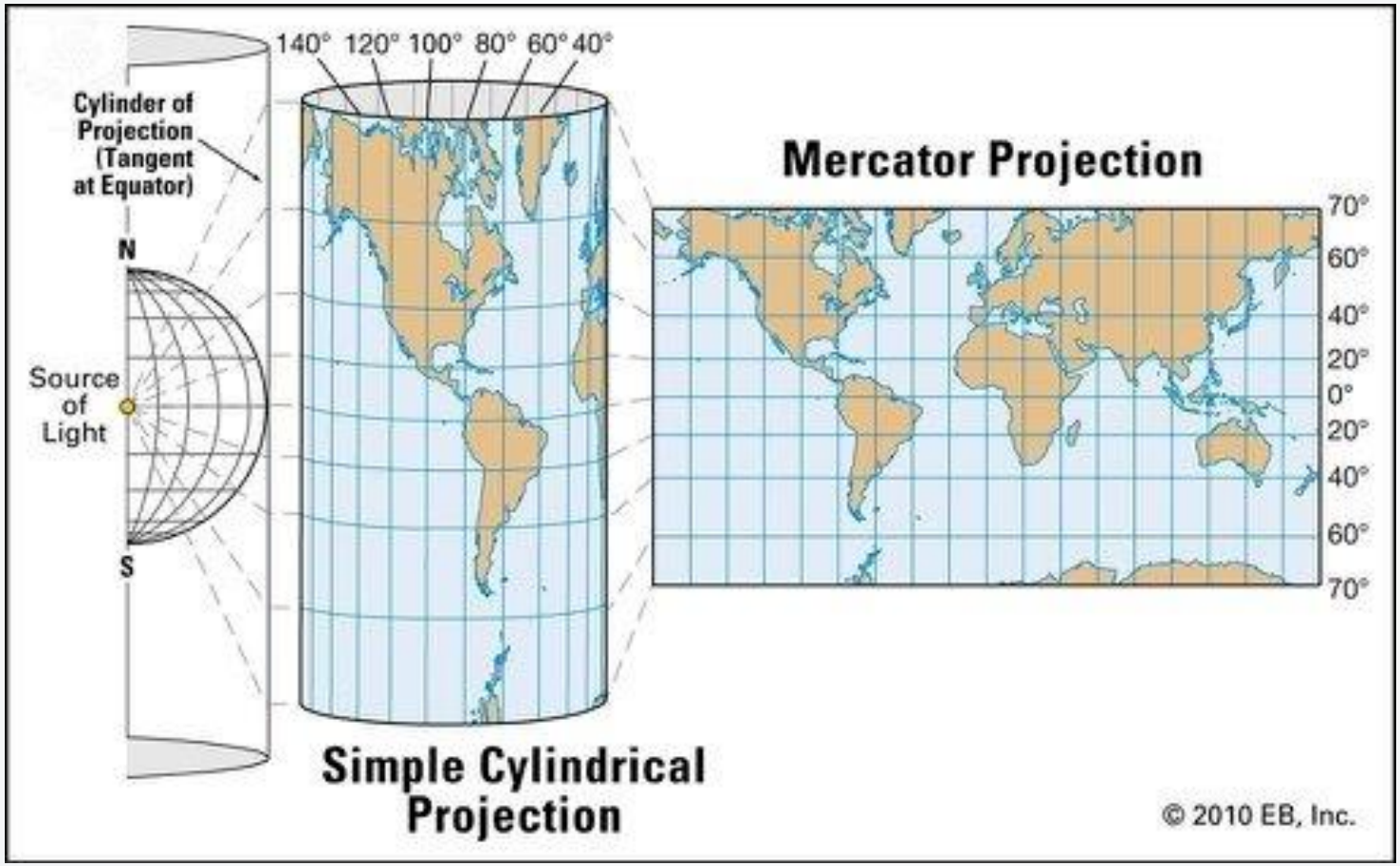
- Map infinitesimal **circles** of constant size anywhere on the Earth to infinitesimal **circles** of varying sizes.
  - Relative angles at each point of the map are correct.
  - The local scale in every direction around a point is constant.
- Example:
  - Mercator: Rhumb lines are straight.
  - Transverse Mercator.
  - Stereographic.
  - …



Rhumb Line

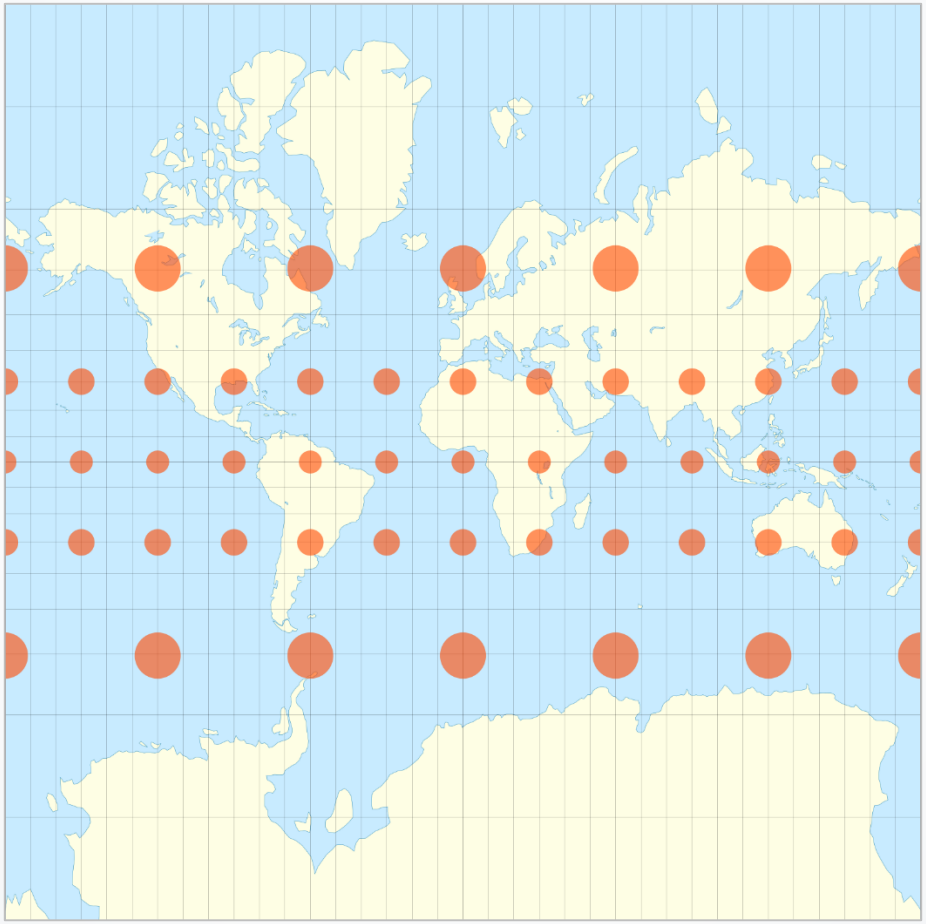
Wikipedia, Rhumb line. https://en.wikipedia.org/wiki/Rhumb_line

Mercator Projection



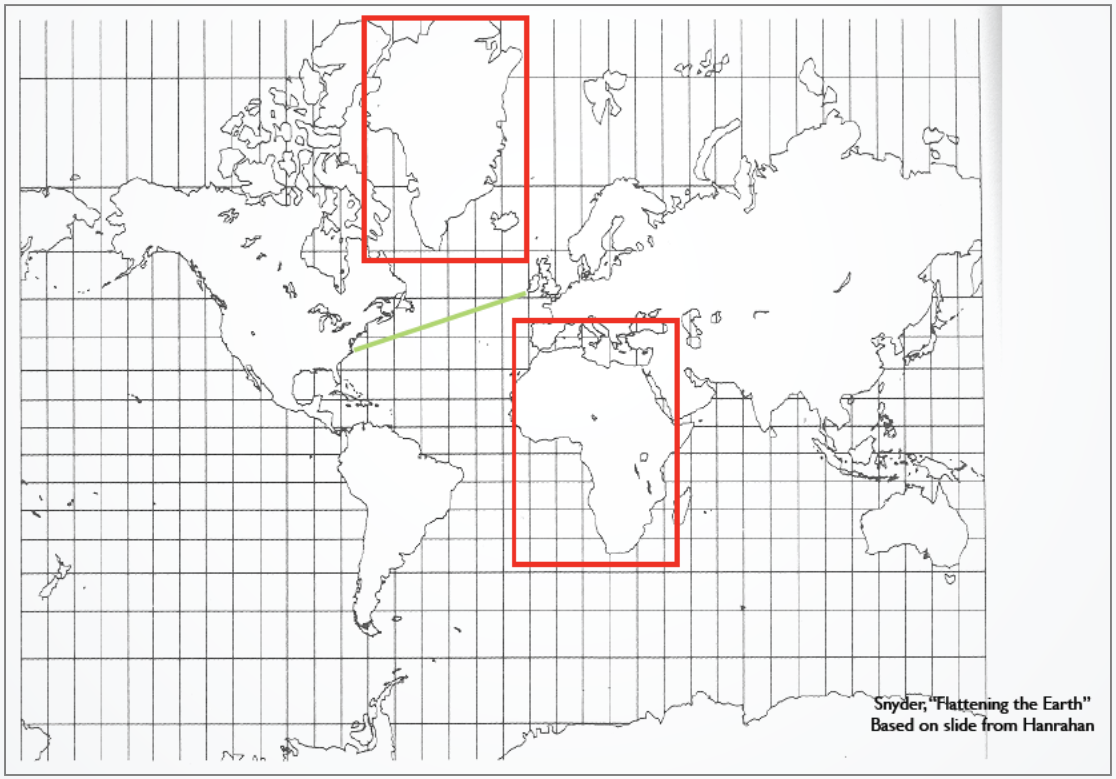
Cylindrical map projection

2D Projections Generated



Wikipedia, Mercator projection.
https://en.wikipedia.org/wiki/Mercator_projection

Distorted Area Size



The **True Size** of **Africa**

A small contribution in the fight against rampant *Immappancy*, by **Kai Krause**

Graphic layout for visualization only (some countries are cut and rotated)
But the conclusions are very accurate: refer to table below for exact data

COUNTRY	AREA x 1000 km²
China	9.597
USA	9.629
India	3.287
Mexico	1.964
Peru	1.285
France	633
Spain	506
Papua New Guinea	462
Sweden	441
Japan	378
Germany	357
Norway	324
Italy	301
New Zealand	270
United Kingdom	243
Nepal	147
Bangladesh	144
Greece	132
TOTAL	**30.102**
AFRICA	**30.221**

In addition to the well known social issues of *illiteracy* and *innumeracy*, there also should be such a concept as "*immappancy*", meaning *insufficient geographical knowledge*.

A survey with random American schoolkids let them guess the population and land area of their country. Not entirely unexpected, but still rather unsettling, the majority chose *"1-2 billion"* and *"largest in the world"*, respectively.

Even with Asian and European college students, geographical estimates were often off by factors of *2-3*. This is partly due to the highly distorted nature of the predominantly used mapping projections (such as *Mercator*).

A particularly extreme example is the worldwide misjudgement of the true size of *Africa*. This single image tries to embody the massive scale, which is larger than the *USA*, *China*, *India*, *Japan* and *all of Europe..... combined!*

Top 100 Countries

Area in square kilometers, Percentage of World Total
Sources: Britannica, Wikipedia, Almanac 2010

		AREA km²	%
1	Russia	17.098.242	11,50
2	Canada	9.984.670	6,70
3	China	9.596.961	6,40
4	United States	9.629.091	6,40
5	Brazil	8.514.877	5,70
6	Australia	7.692.024	5,20
7	India	3.287.263	2,30
8	Argentina	2.780.400	2,00
9	Kazakhstan	2.724.900	1,80
10	Sudan	2.505.813	1,70
11	Algeria	2.381.741	1,60
12	Congo	2.344.858	1,60
13	Greenland	2.166.086	1,50
14	Saudi Arabia	2.149.690	1,40
15	Mexico	1.964.375	1,30
16	Indonesia	1.860.360	1,30
17	Libya	1.759.540	1,20
18	Iran	1.628.750	1,10
19	Mongolia	1.564.100	1,10
20	Peru	1.285.216	0,86
21	Chad	1.284.000	0,86
22	Niger	1.267.000	0,85
23	Angola	1.246.700	0,85
24	Mali	1.240.192	0,83
25	South Africa	1.221.037	0,82
26	Colombia	1.141.748	0,76
27	Ethiopia	1.104.300	0,74
28	Bolivia	1.098.581	0,74
29	Mauritania	1.025.520	0,69
30	Egypt	1.002.000	0,67
31	Tanzania	945.087	0,63
32	Nigeria	923.768	0,62
33	Venezuela	912.050	0,61
34	Namibia	824.116	0,55
35	Mozambique	801.590	0,54
36	Pakistan	796.095	0,53
37	Turkey	783.562	0,53
38	Chile	756.102	0,51
39	Zambia	752.612	0,51
40	Myanmar	676.578	0,45
41	Afghanistan	652.090	0,44
42	Somalia	637.657	0,43
43	France	632.834	0,43
44	C. African Rep	622.984	0,42
45	Ukraine	603.500	0,41
46	Madagascar	587.041	0,39
47	Botswana	582.000	0,39
48	Kenya	580.367	0,39
49	Yemen	527.968	0,35
50	Thailand	513.120	0,34
51	Spain	505.992	0,34
52	Turkmenistan	488.100	0,33
53	Cameroon	475.442	0,32
54	Papua New Guinea	462.840	0,31
55	Uzbekistan	447.400	0,30
56	Morocco	446.550	0,30
57	Sweden	441.370	0,30
58	Iraq	438.317	0,29
59	Paraguay	406.752	0,27
60	Zimbabwe	390.757	0,26
61	Japan	377.930	0,25
62	Germany	357.114	0,24
63	Rep o.t. Congo	342.000	0,23
64	Finland	338.419	0,23
65	Vietnam	331.212	0,22
66	Malaysia	330.803	0,22
67	Norway	323.802	0,22
68	Côte d'Ivoire	322.463	0,22
69	Poland	312.685	0,21
70	Oman	309.500	0,21
71	Italy	301.336	0,20
72	Philippines	300.000	0,20
73	Burkina Faso	274.222	0,18
74	New Zealand	270.467	0,18
75	Gabon	267.668	0,18
76	Western Sahara	266.000	0,18
77	Ecuador	256.369	0,20
78	Guinea	245.857	0,17
79	United Kingdom	242.900	0,16
80	Uganda	241.038	0,16
81	Ghana	238.539	0,16
82	Romania	238.391	0,16
83	Laos	236.800	0,16
84	Guyana	214.969	0,14
85	Belarus	207.600	0,14
86	Kyrgyzstan	199.951	0,13
87	Senegal	196.722	0,13
88	Syria	185.180	0,12
89	Cambodia	181.035	0,12
90	Uruguay	176.215	0,12
91	Suriname	163.820	0,11
92	Tunisia	163.610	0,11
93	Nepal	147.181	0,10
94	Bangladesh	143.998	0,10
95	Tajikistan	143.100	0,10
96	Greece	131.957	0,09
97	Nicaragua	130.373	0,09
98	North Korea	120.538	0,08
99	Malawi	118.484	0,08
100	Eritrea	117.600	0,08
	TOP 100 TOTAL	132.632.524	89,34


United States

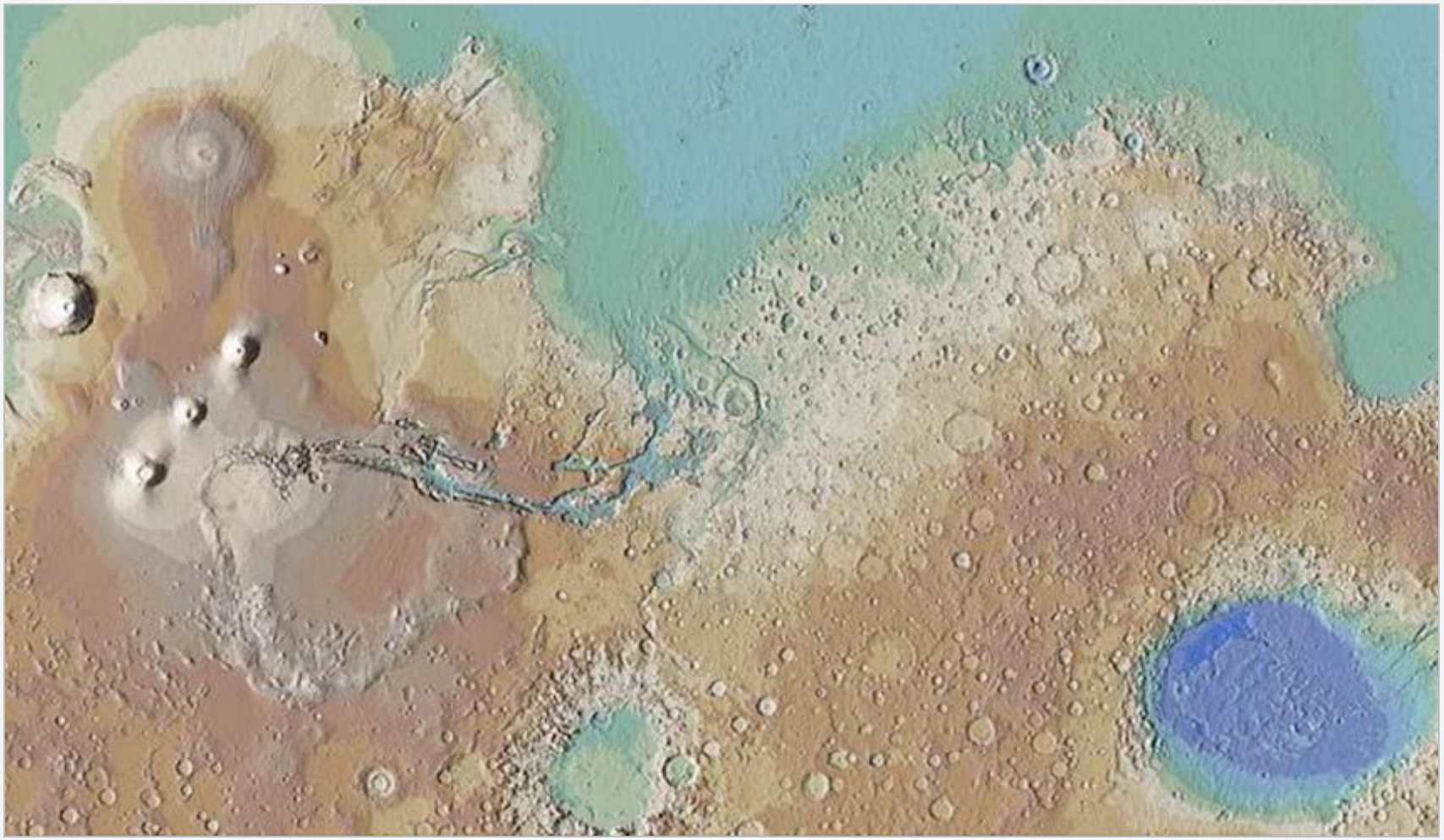

Europe


India


Japan


China

Mercator Projection of Mars



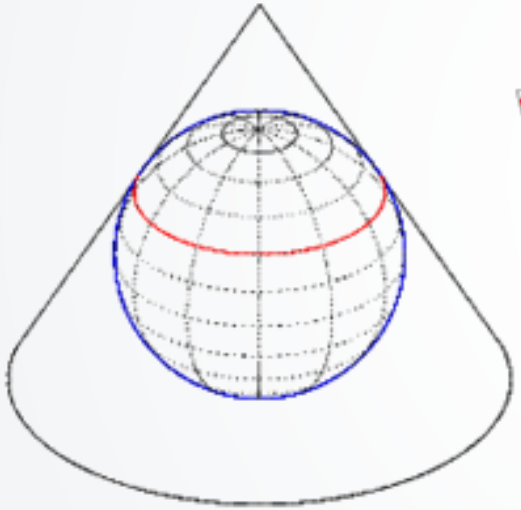
Circular craters map to circles
USGS, Planetary Index.
https://astrogeology.usgs.gov/search/planetary-index

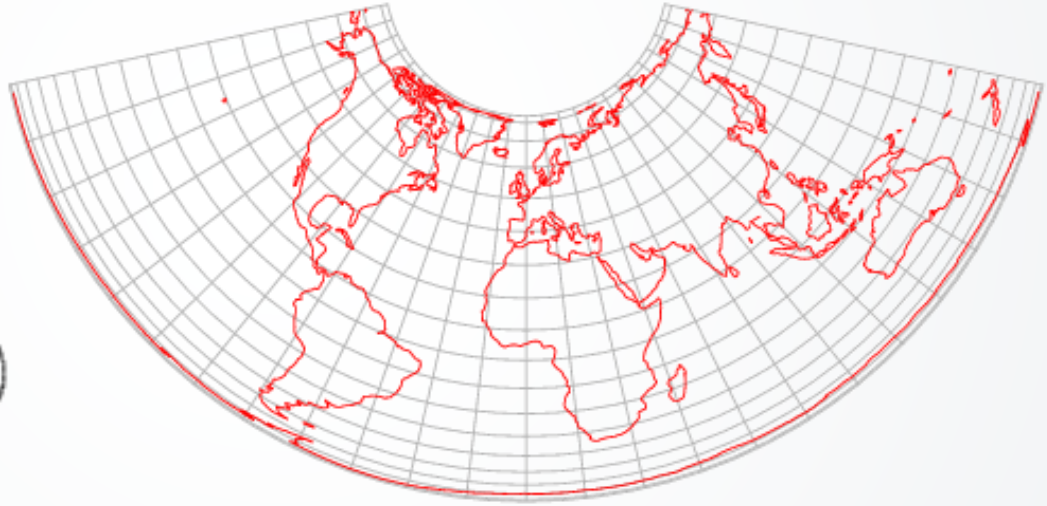
Equal-Area Projections

- Distort shapes to preserve area measure.
- Examples:
  - Albers conic
  - Sinusoidal
  - Cylindrical equal-area
  - Equal Earth
  - Werner
  - …

Albers Conic Projection

- A conic, equal area map projection that uses two standard parallels.

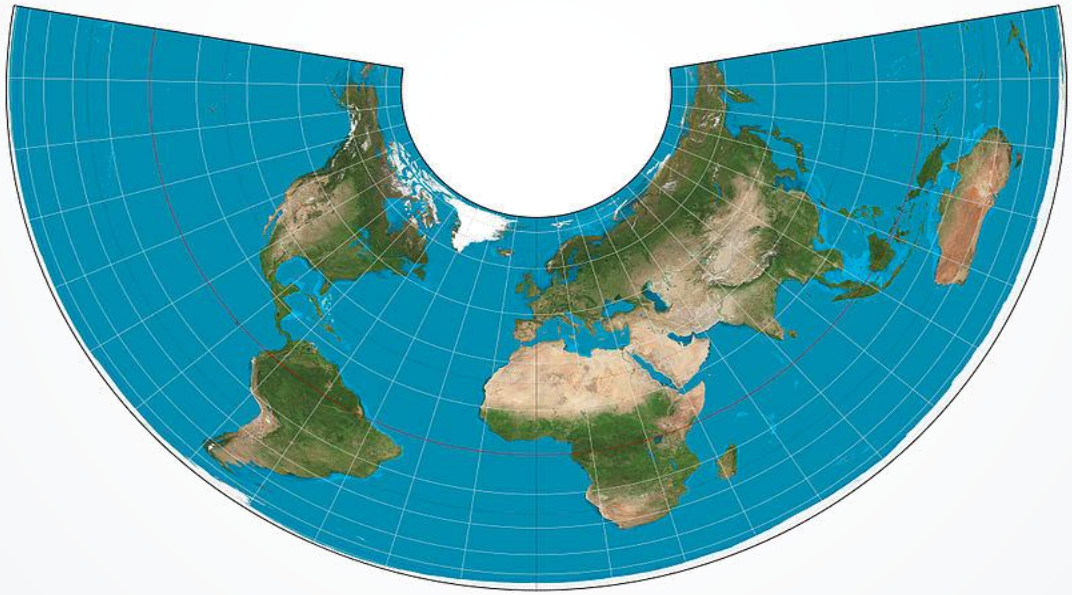




MathWorks, Manage distortions with map displays.
https://www.mathworks.com/discovery/map-projection.html

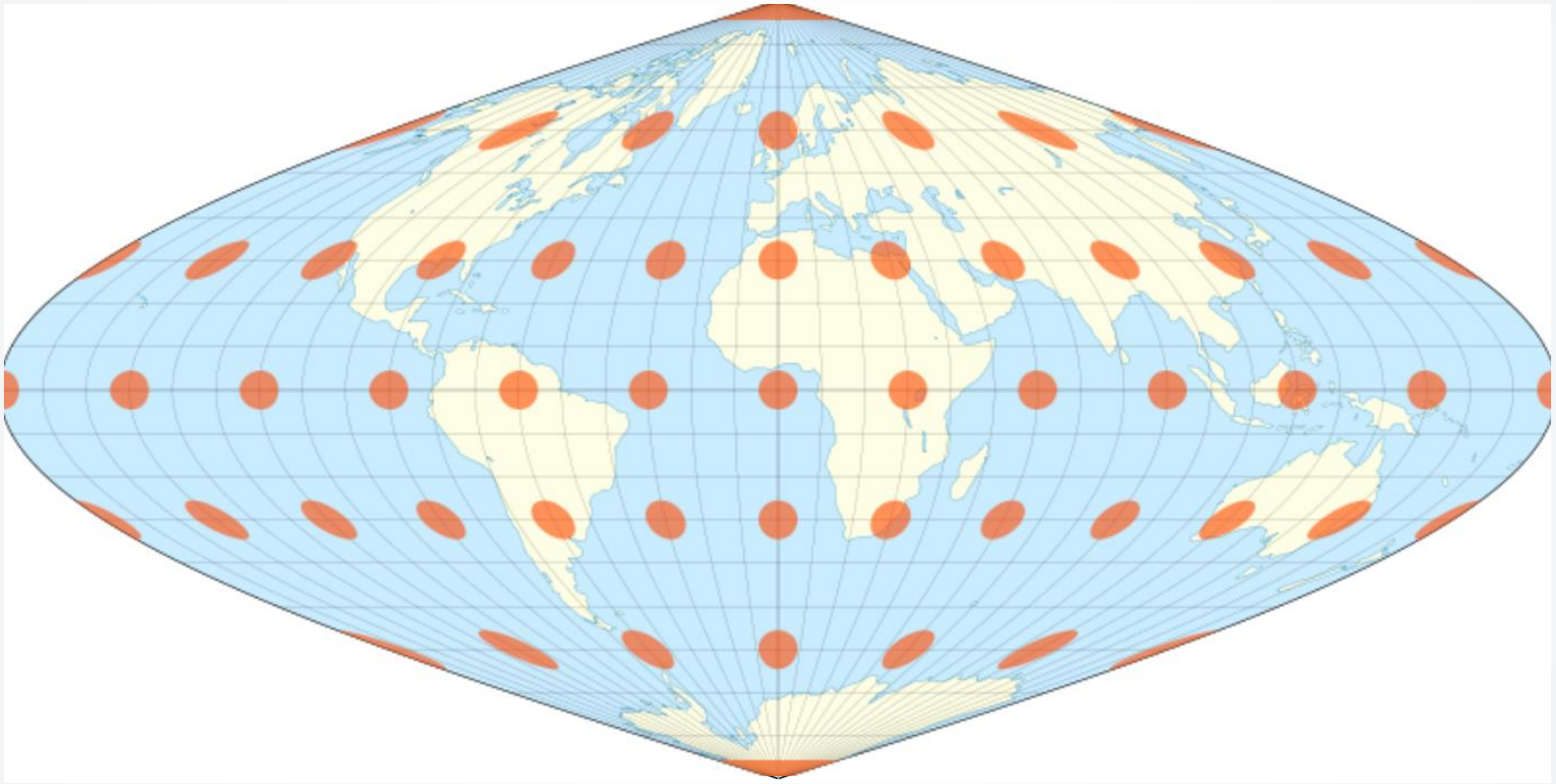
Albers Conic Projection

- The Albers projection is the standard projection for country or area map where area have to be preserved.



Wikipedia, Albers projection.
https://en.wikipedia.org/wiki/Albers_projection

Sinusoidal Equal-Area Projection



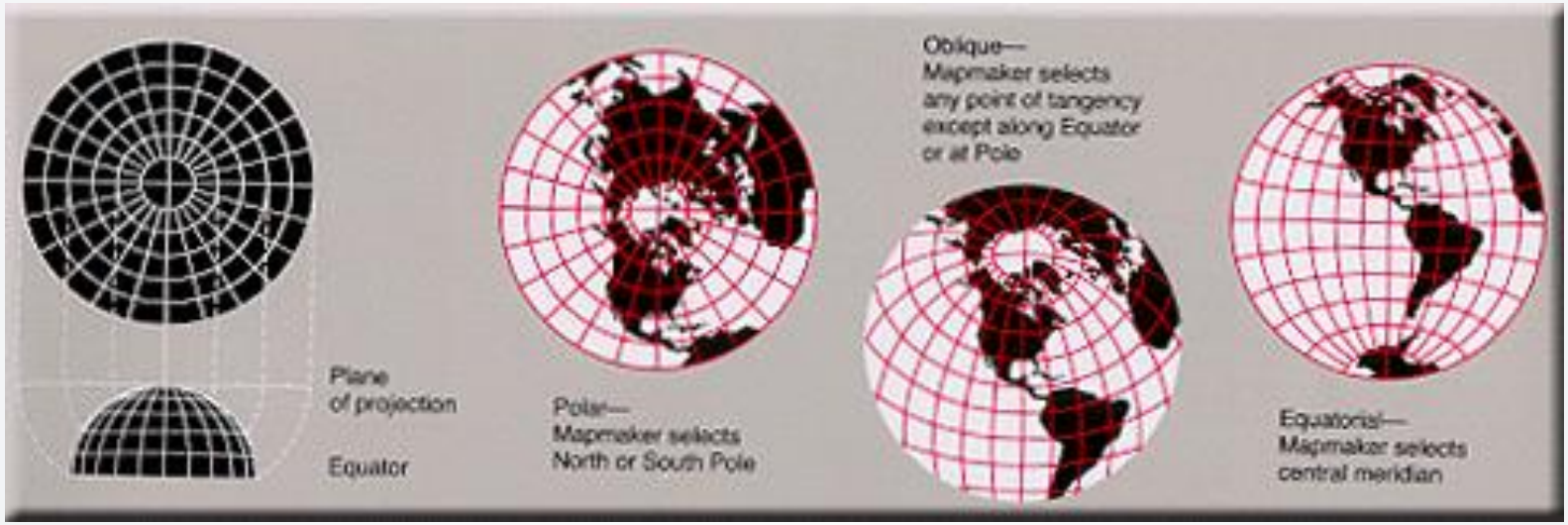
https://en.wikipedia.org/wiki/Sinusoidal_projection

Equidistant Projections

- Preserve distance from some standard point or line.
- Examples:
  - Azimuthal equidistant – conserves distances along great circles
  - Equirectangular – conserves distances along meridians
  - Sinusoidal – conserves distances along parallels
  - Two-point equidistant
  - …

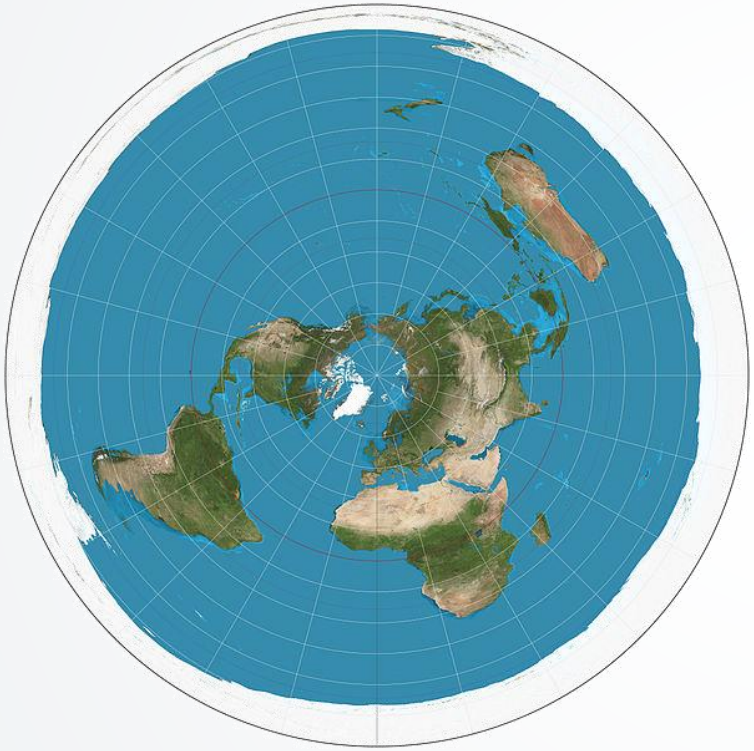
Azimuthal Projections

- Directions from a central point are preserved.
- Great circles through the central point are represented by straight lines on the map.

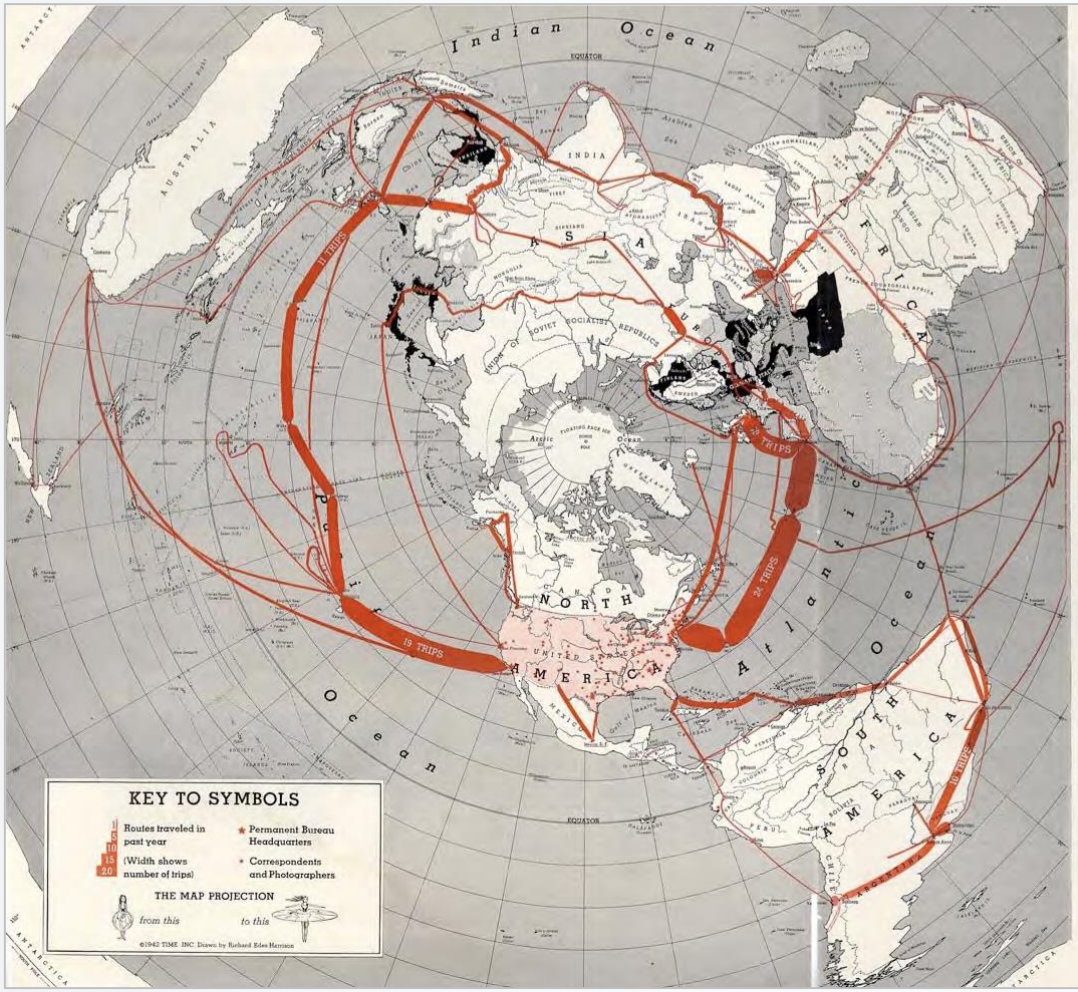


Wikipedia, Map projection.
https://en.wikipedia.org/wiki/Map_projection

Azimuthal Equidistant Projection



Wikipedia, Azimuthal equidistant projection. https://en.wikipedia.org/wiki/Azimuthal_equidistant_projection



ON ASSIGNMENT

In Reykjavik and Rio, New Delhi and Khartoum, Calcutta, Capetown, Sydney and Suva, as you read this—in every troubled news-corner of the globe—are one or more of the 300 special correspondents who work for TIME, LIFE and FORTUNE. In the past twelve months alone, their assignments carried them the 1,505,000 miles you see plotted on this map.

Some of these people are reporters, some photographers, some researchers. Two were on an American cruiser off Hawaii when the Japs blasted Pearl Harbor. Two more were in Manila on December 7, now are interned by the Japanese in ancient Santo Tomas University. Still another managed to make Corregidor from the mainland, filed almost daily dispatches all through January and February, last reported that he had finally reached Australia in safety, joined three other TIME — LIFE — FORTUNE correspondents there. Two of these men had made the trip to Australia in a troop ship with an AEF convoy; the third had arrived on a grimy freighter, he its only passenger, high explosives its only cargo.

But this is not a map of adventure. Rather it is an attempt to visualize a hard-working, world-wide research organization—the News and Picture Bureaus of TIME, LIFE and FORTUNE.

The real significance of the map grows out of the hundreds of fact-finding assignments it represents—the millions of words filed—the stories documented with photos, the weeks and months of observation and analysis it plots.

Eighty thousand of the 1,505,000 miles of travel plotted on the map, for example, were covered by Correspondent Allan Michie. The dispatches he filed from Cairo, Tehran, Simla, Singapore, Batavia and Manila were the basis of news stories in the columns of TIME. Documented with pictures taken by a Picture Bureau photographer in the Middle East, several of his pieces ran in LIFE. Back in New York, he assembled the threads of his experiences and first-hand knowledge on the broad pattern of world strategy into the story of *The Coming Battle for Asia* that appeared in FORTUNE for March.

This same mechanism functions similarly as Walter Graebner, head of the London office, returns to New York to report on the European situation for TIME and LIFE and write the story of *British Politics and the War* for the April FORTUNE—as Sherry Mangan heads back from Buenos Aires via Santiago, Lima and Panama — as correspondents file their dispatches from Ireland, Alaska, India and Bataan . . .

These and three hundred other men like them are a part of the world-wide news and picture organization which is constantly serving your editors, with spot news, with background information, with well-documented research.

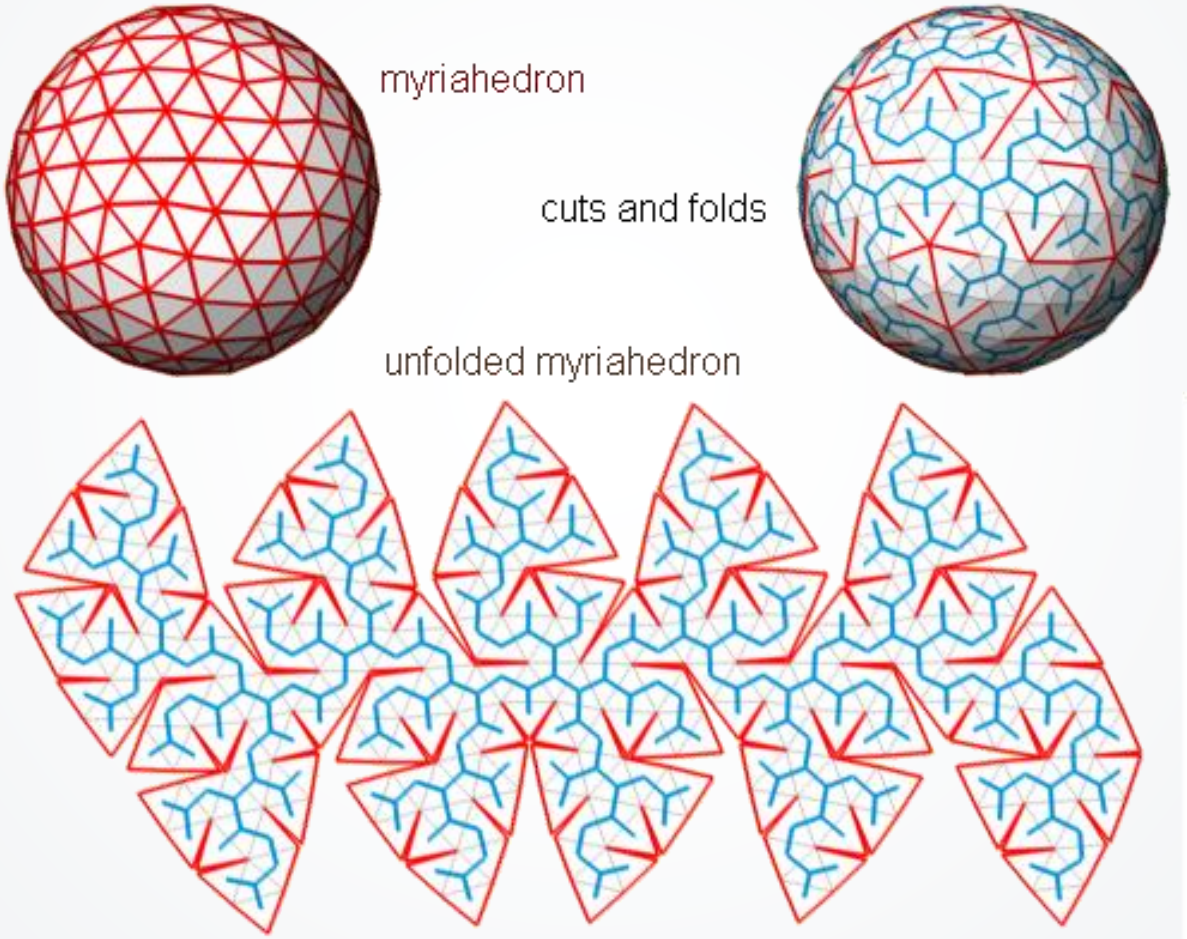
TIME—LIFE—FORTUNE

Richard Edes Harrison, Fortune magazine, 1942.
https://www.fulltable.com/vts/f/fortune/reh/mn.htm

Compromise Projections

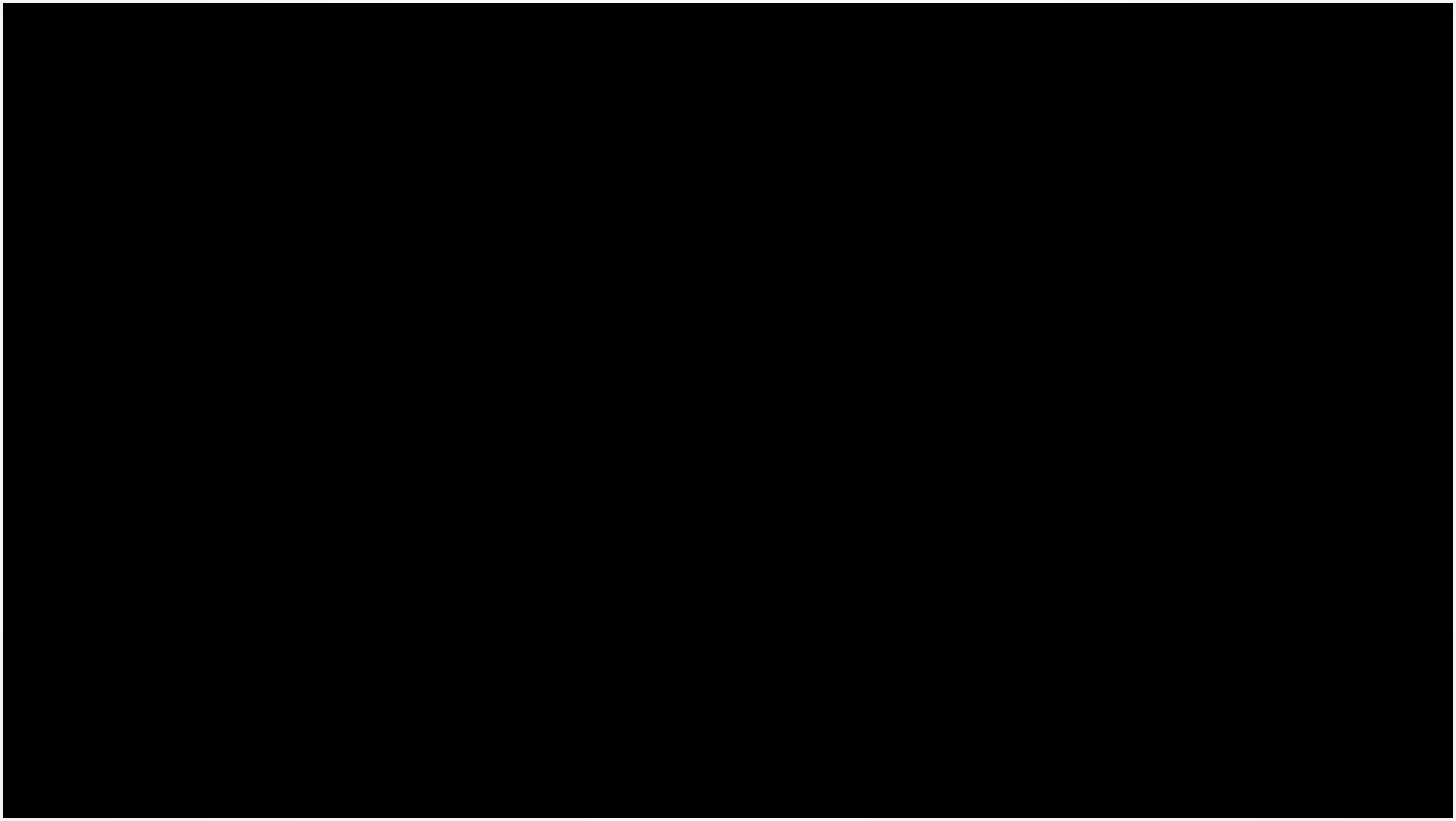
- Seek to strike a **balance** between distortions, or to simply make things "look right”.
- Example:
  - Myriahedral Projection (Jack van Wijk, 2008)
  - Robinson
  - van der Grinten
  - Miller cylindrical
  - Winkel Tripel
  - …

Myriahedral Projection



Jack van Wijk, Unfolding the Earth: Myriahedral Projections.
https://www.win.tue.nl/~vanwijk/myriahedral/

Map Projections

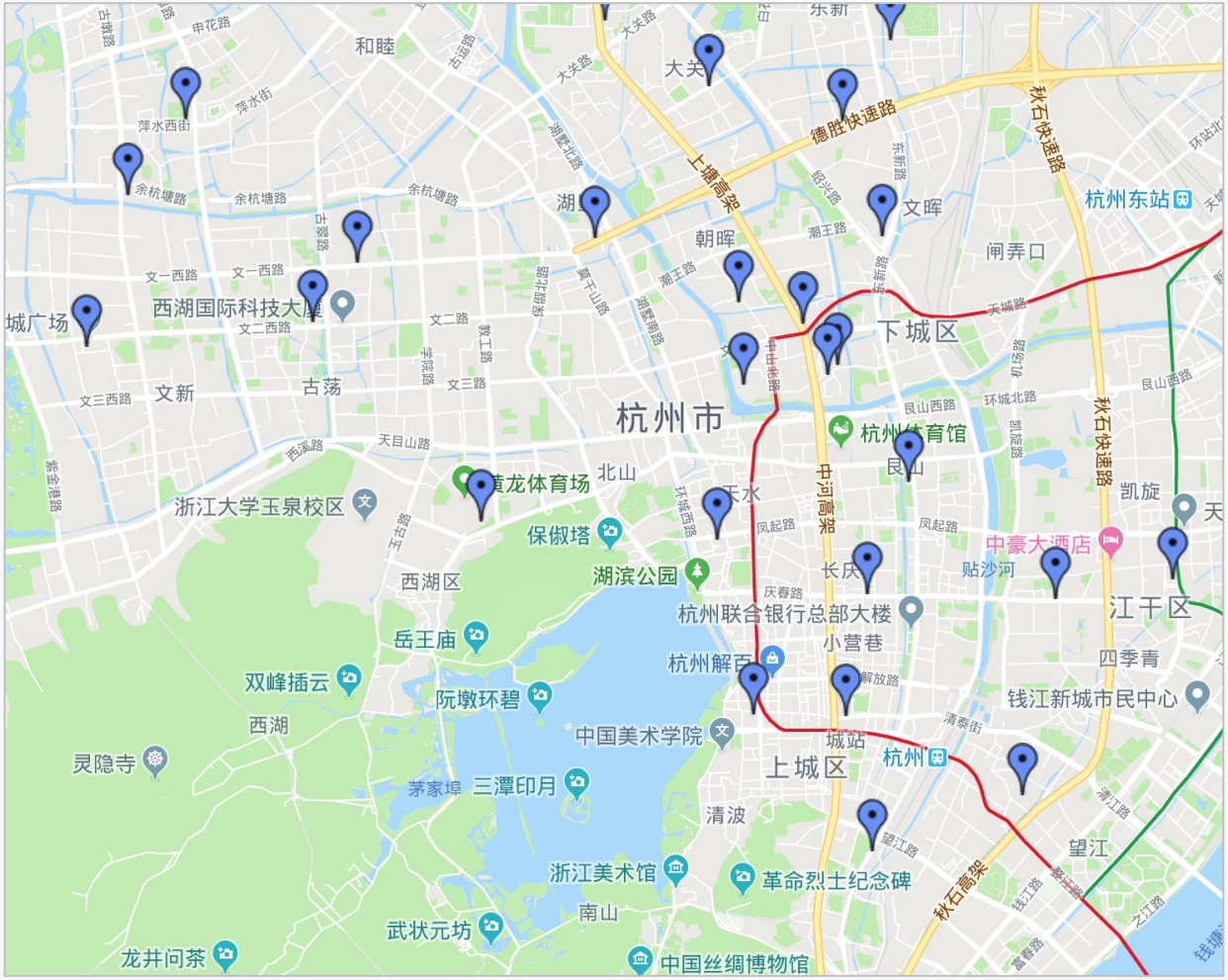


Point Data Visualization

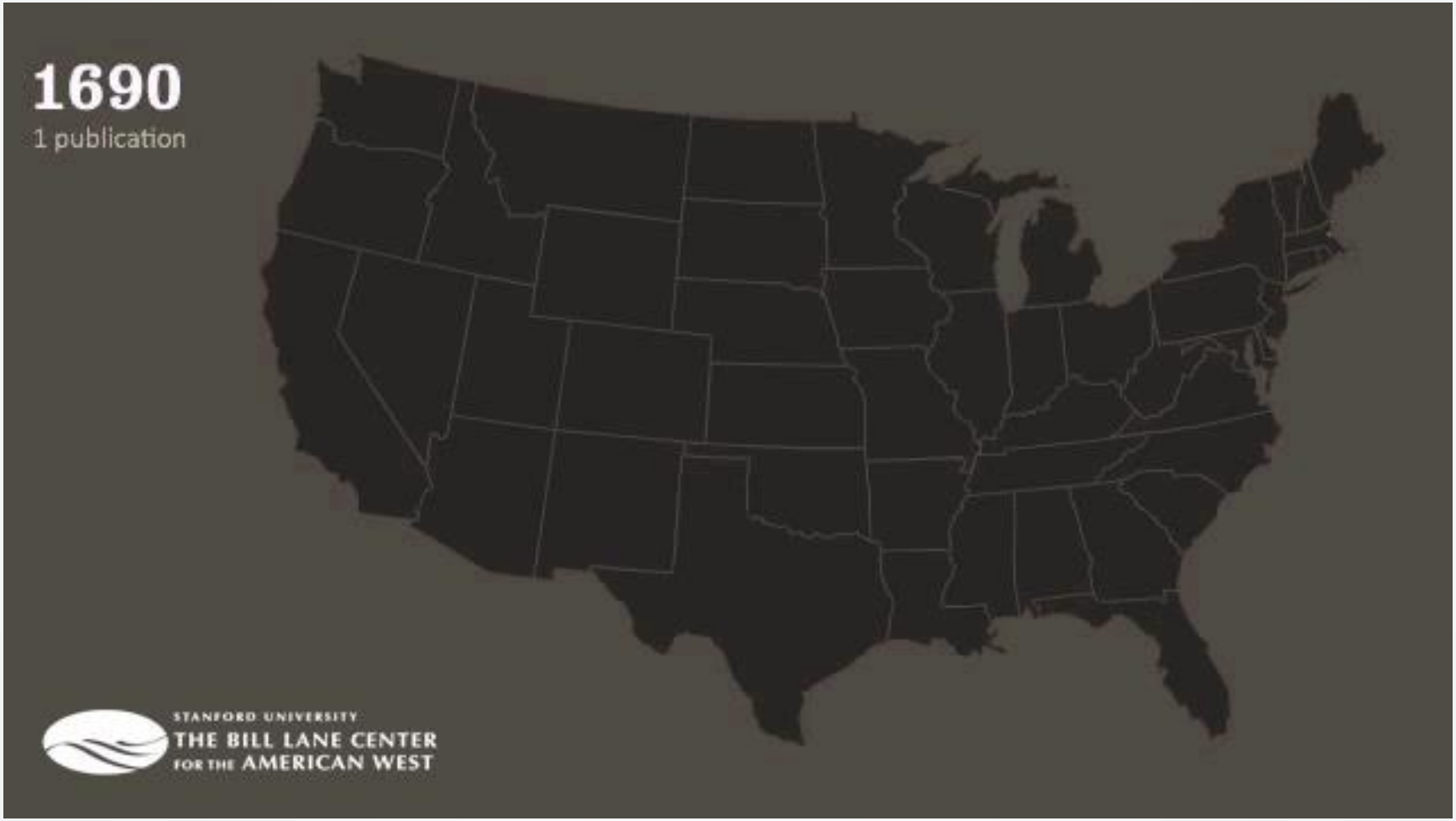
Point Data

- Points scattered in the geographical space, with longitude and latitude information, optionally with weights.
  - Landmarks on the map
  - Restaurants of your neighborhood
- Marking the data on the map would be the most direct and simplest way to visualize point data.
- Point-based visualizations are widely used.

Supermarkets in Hangzhou

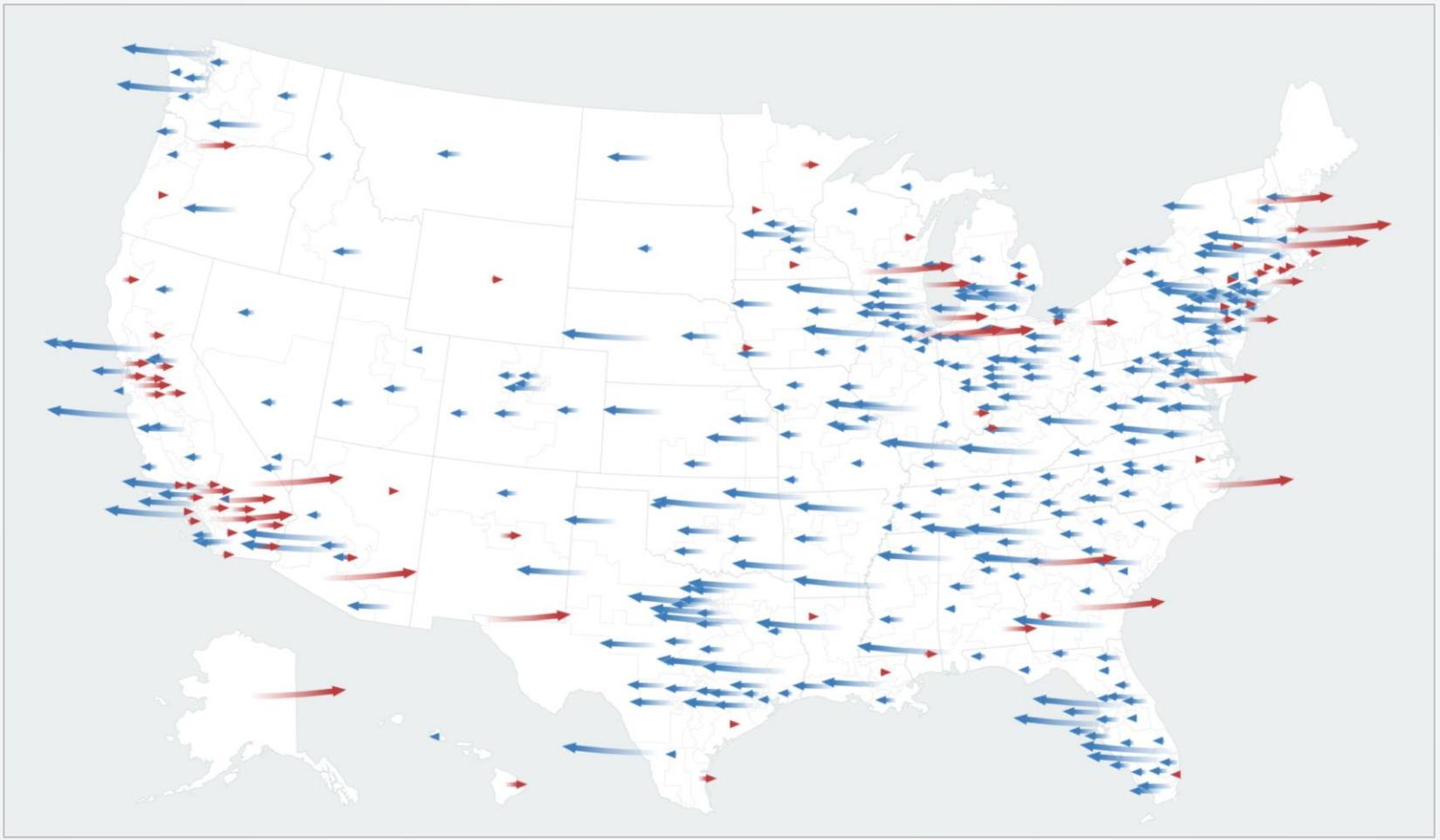


Temporal Point Data



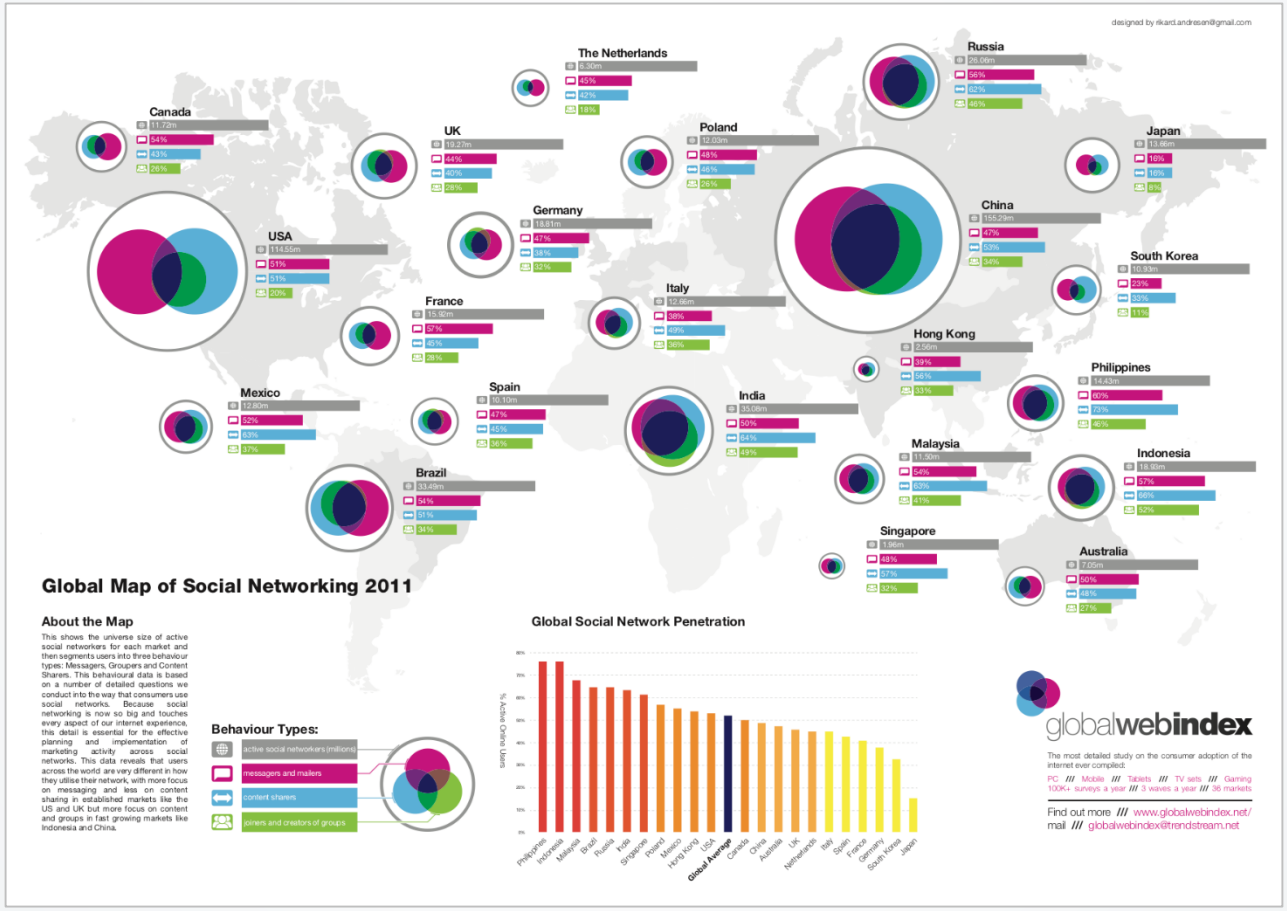
Rural West Initiative, Mapping Journalism's Voyage West.
https://web.stanford.edu/group/ruralwest/cgi-bin/drupal/visualizations/us_newspapers

Vector Point Data



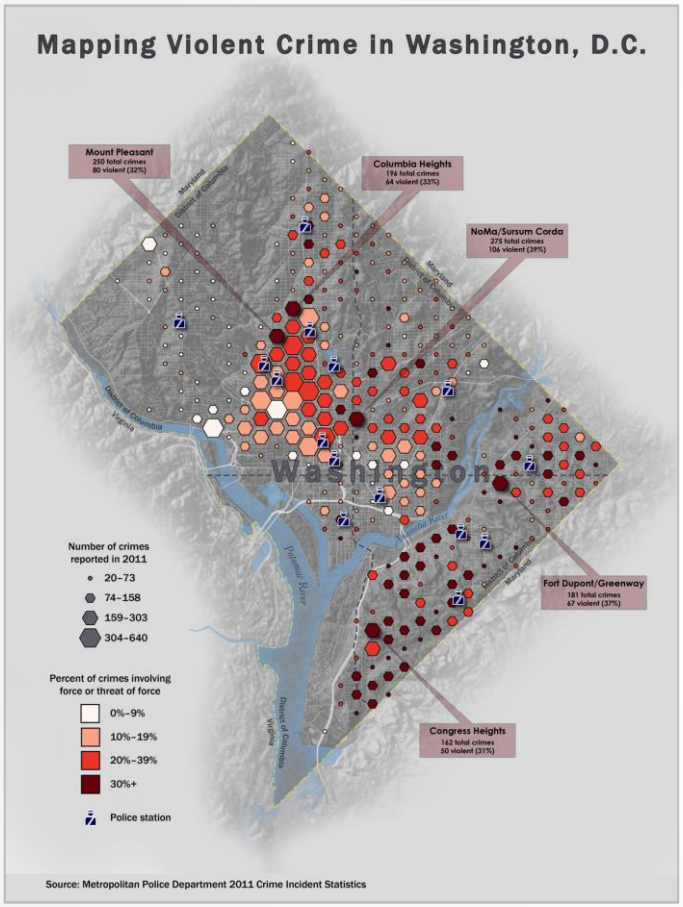
The New York Times, How Democrats Took the House. https://www.nytimes.com/interactive/2018/11/07/us/politics/how-democrats-took-the-house.html

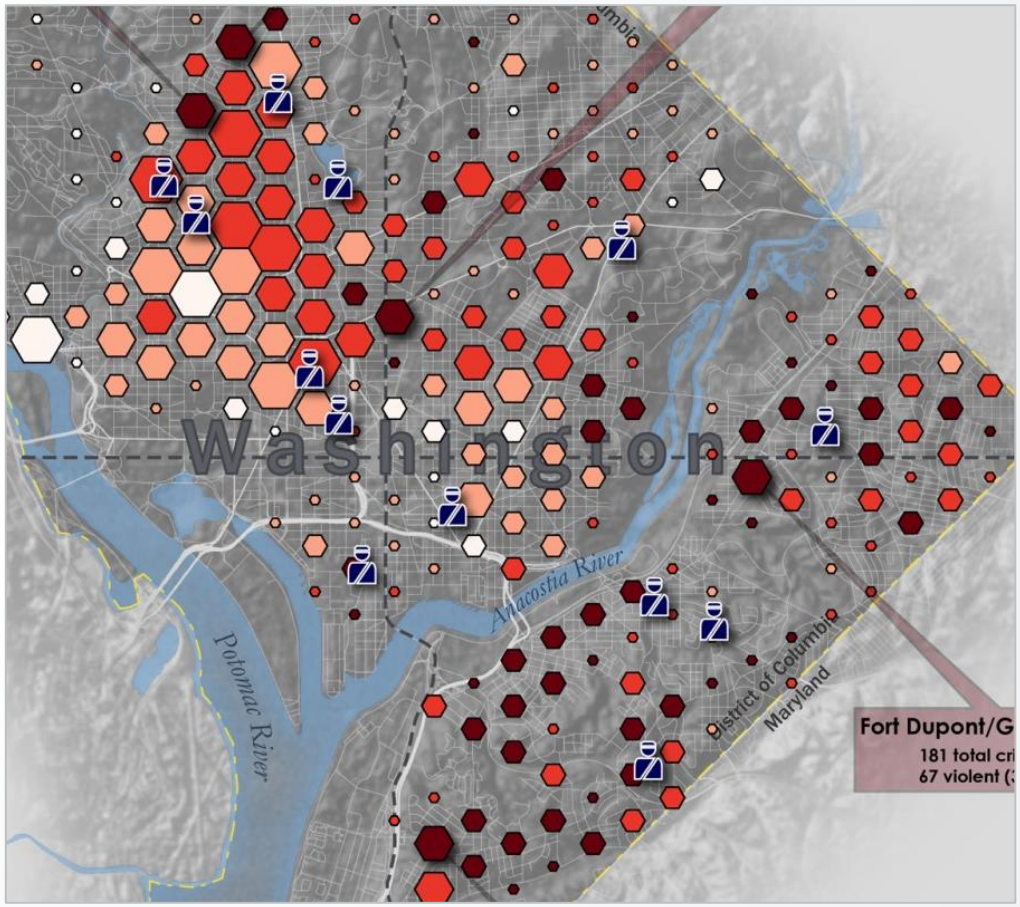
Global Map of Social Networking in 2011



Global Web Index, Global Map of Social Networking.
https://blog.globalwebindex.com/chart-of-the-day/new-globalwebindex-infographic/

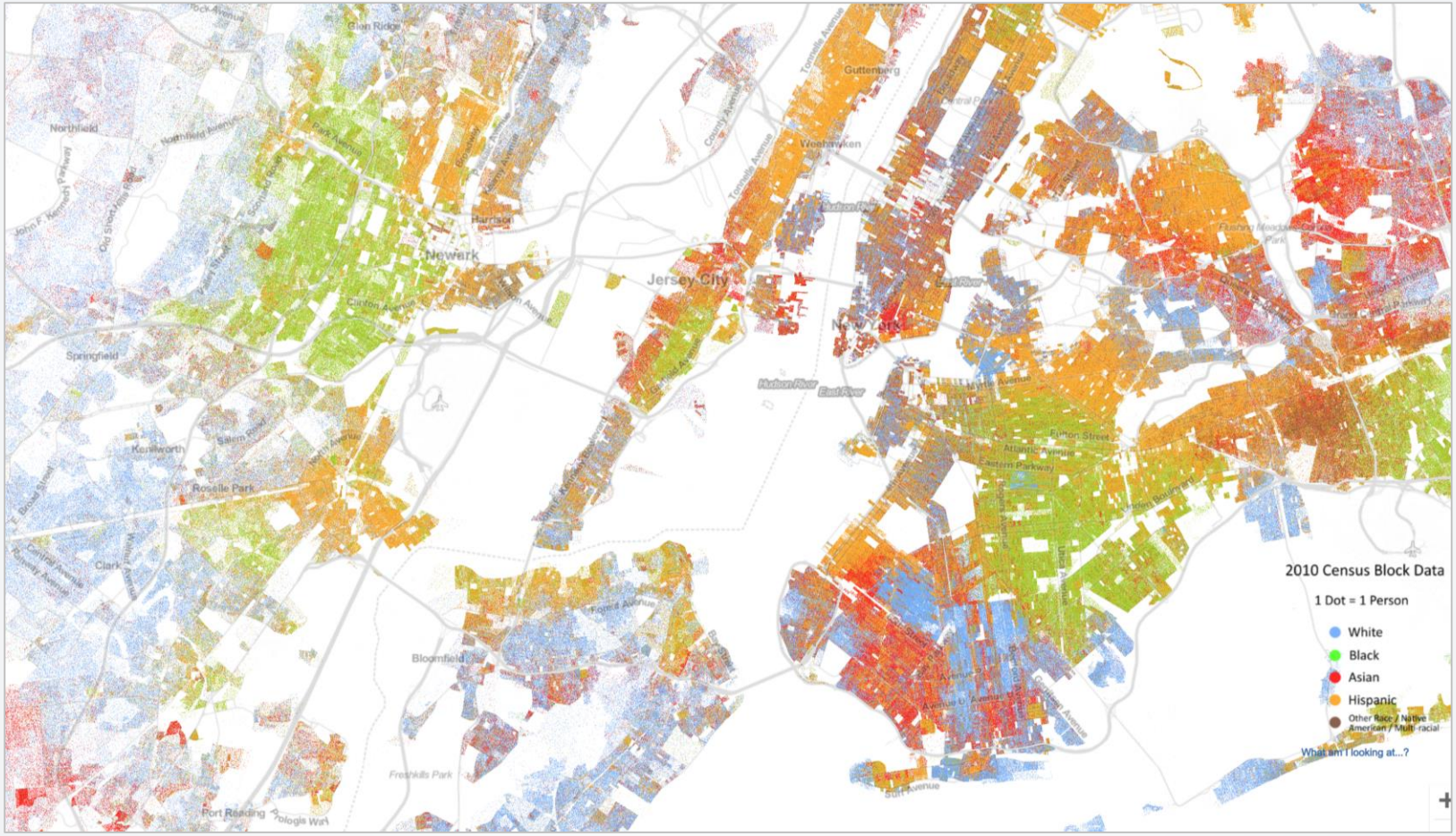
Violent Crime in Washington, D.C.





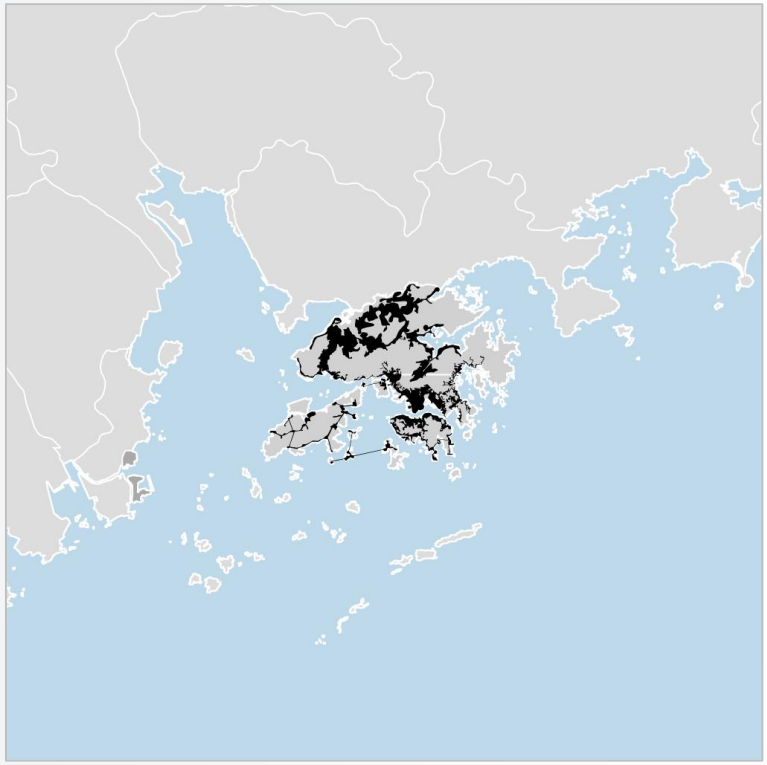
Cooper Thomas, Violent Crime in Washington, D.C.
https://visual.ly/community/infographic/geography/violent-crime-washington-dc

Races via Point Visualization

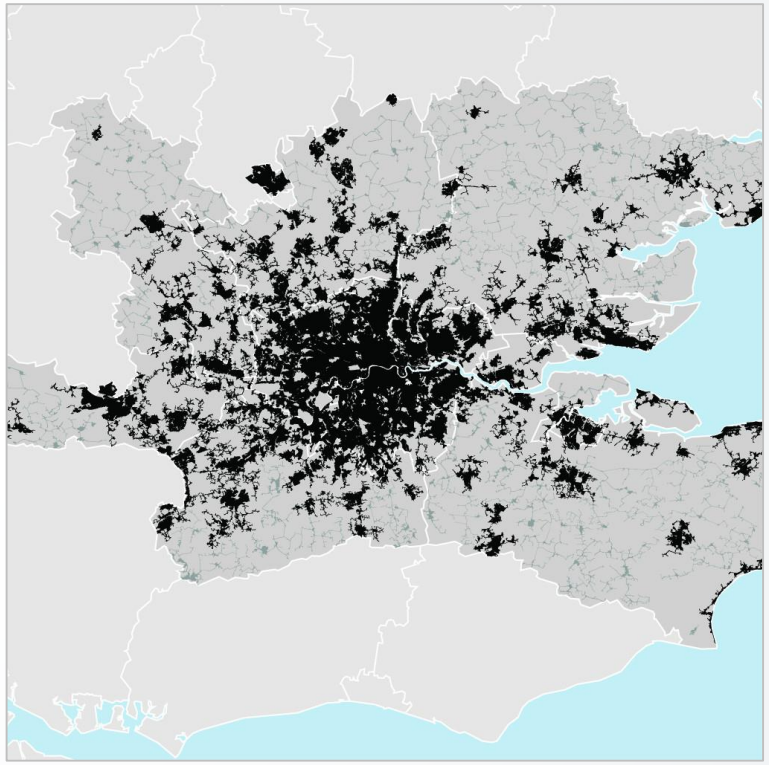


Demographics Research Group, The Racial Dot Map.
https://demographics.coopercenter.org/racial-dot-map

Measuring the Human Urban Footprint



Hong Kong

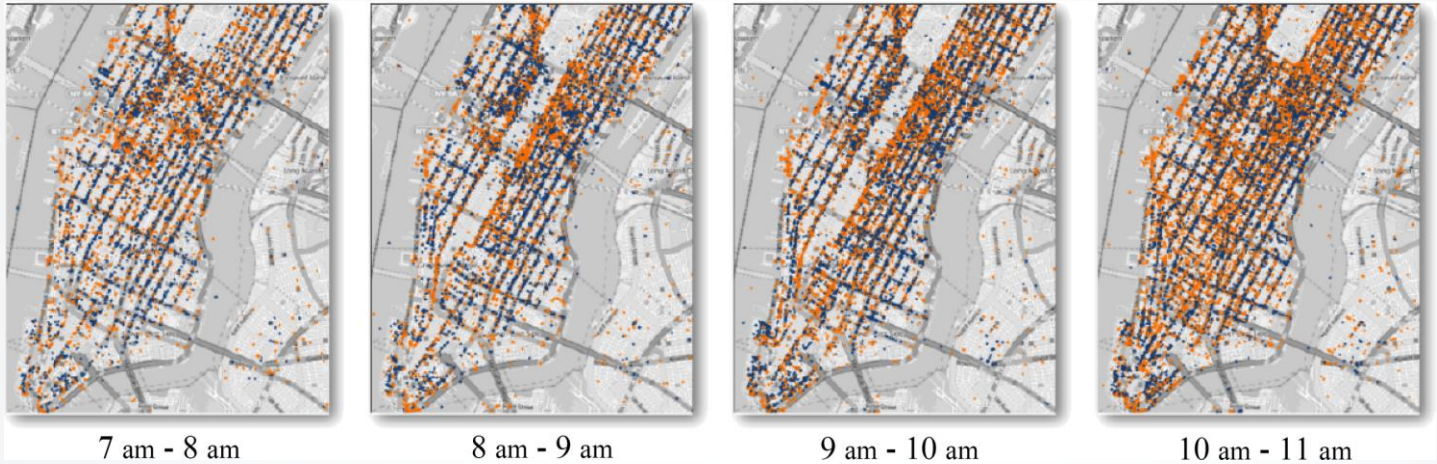


London

LSE Cities, Measuring the Human Urban Footprint.
https://lsecities.net/media/objects/articles/measuring-the-human-urban-footprint/en-gb/

基于点的空间数据可视化

将每个坐标点直接放置在空间上下文中



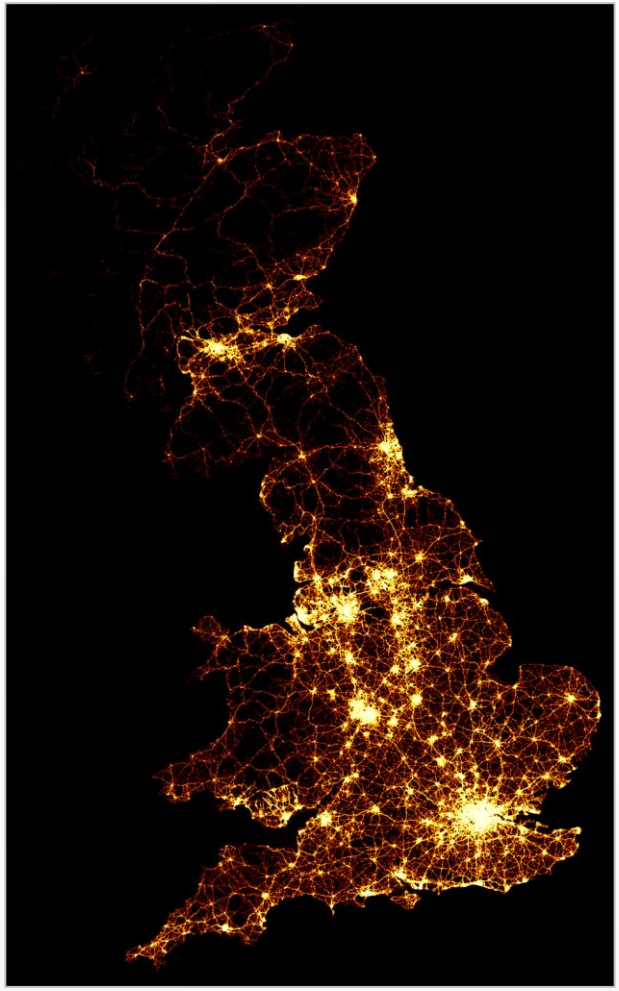
分时段可视化纽约市曼哈顿区的出租车上下客记录。 *N. Ferreira, et. al, 2013*

利用热力图避免视觉混淆

带核密度估计的热力图通过聚合位置相近的对象可以良好的解决由大量放置在地图上的坐标点带来的视觉混淆。

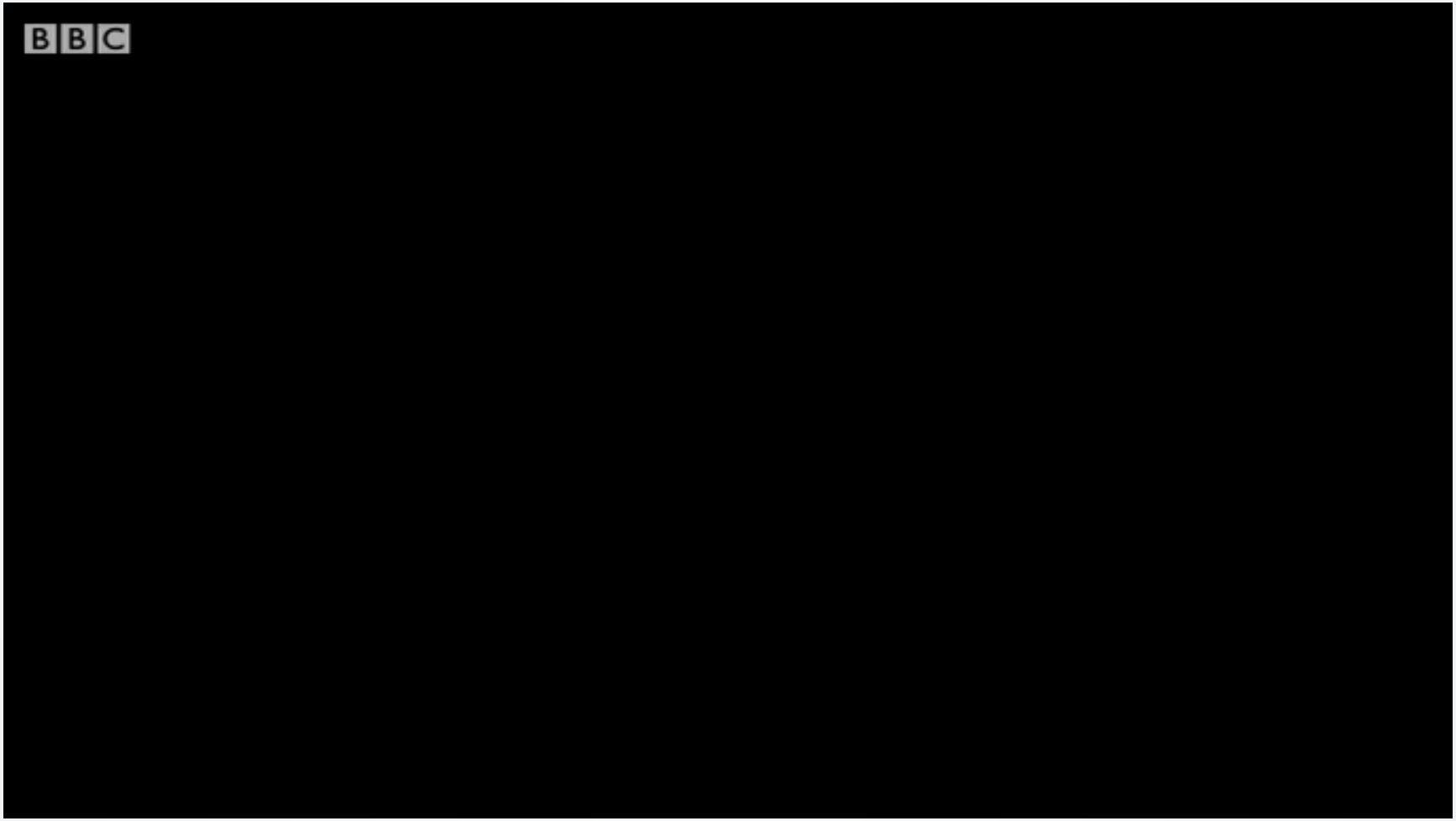
H. Liu, et. al, 2011

Every death on every road in Great Britain



BBC, Every death on every road in Great Britain 1999-2010.
https://www.bbc.co.uk/news/uk-15975724

Every death on every road in Great Britain

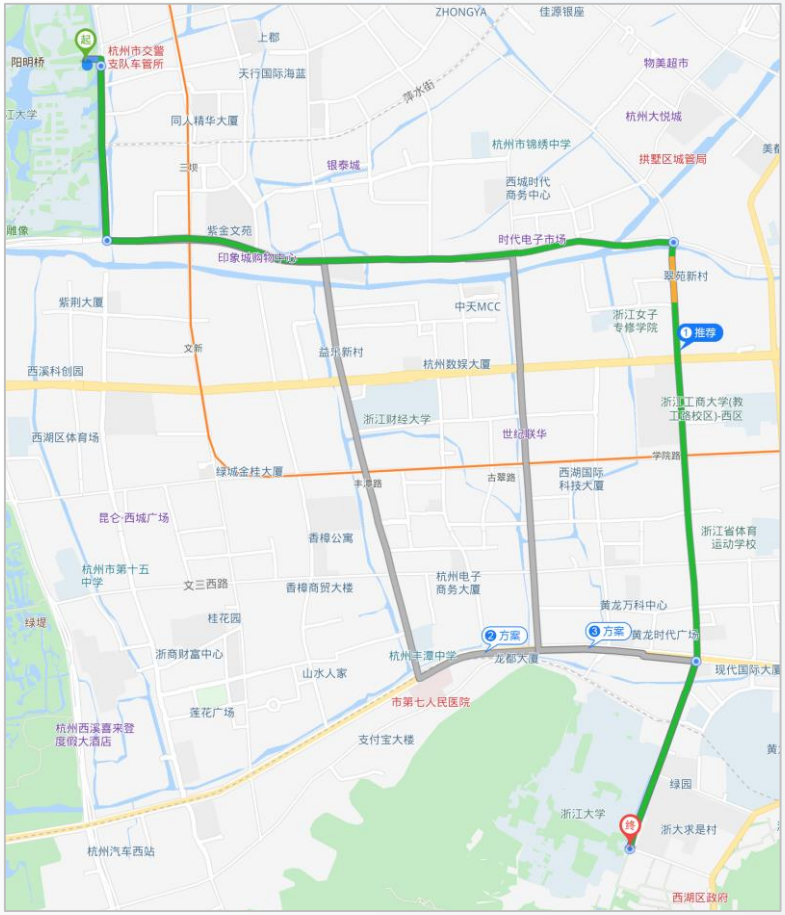


BBC, Every death on every road in Great Britain 1999-2010.
https://www.bbc.co.uk/news/uk-15975724

Line Data Visualization

Line Data

- Line data comprise locations and the paths between them.
- Each line has a length property, namely the distance between two locations.



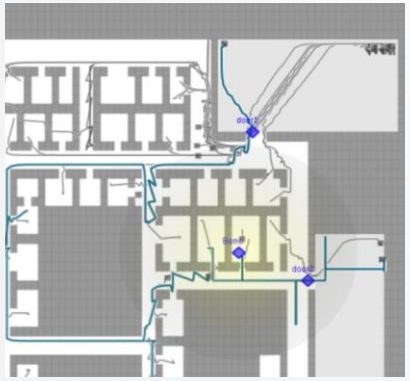
基于线段的空间数据可视化

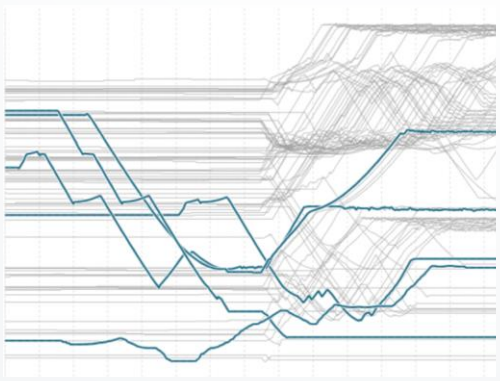
道路网络上的位置可以应用基于线段的可视化方法

基于北京道路网络可视化交通流量特征。带颜色的线条展示了不同道路的状况。

Z. Wang, et. al, 2013

从离散的坐标点构造**轨迹**，并利用基于线段的可视化方法加以呈现





可视化在一场应急演习中人们从办公楼撤离的路线。

T. Crnovrsanin, et. al, 2009

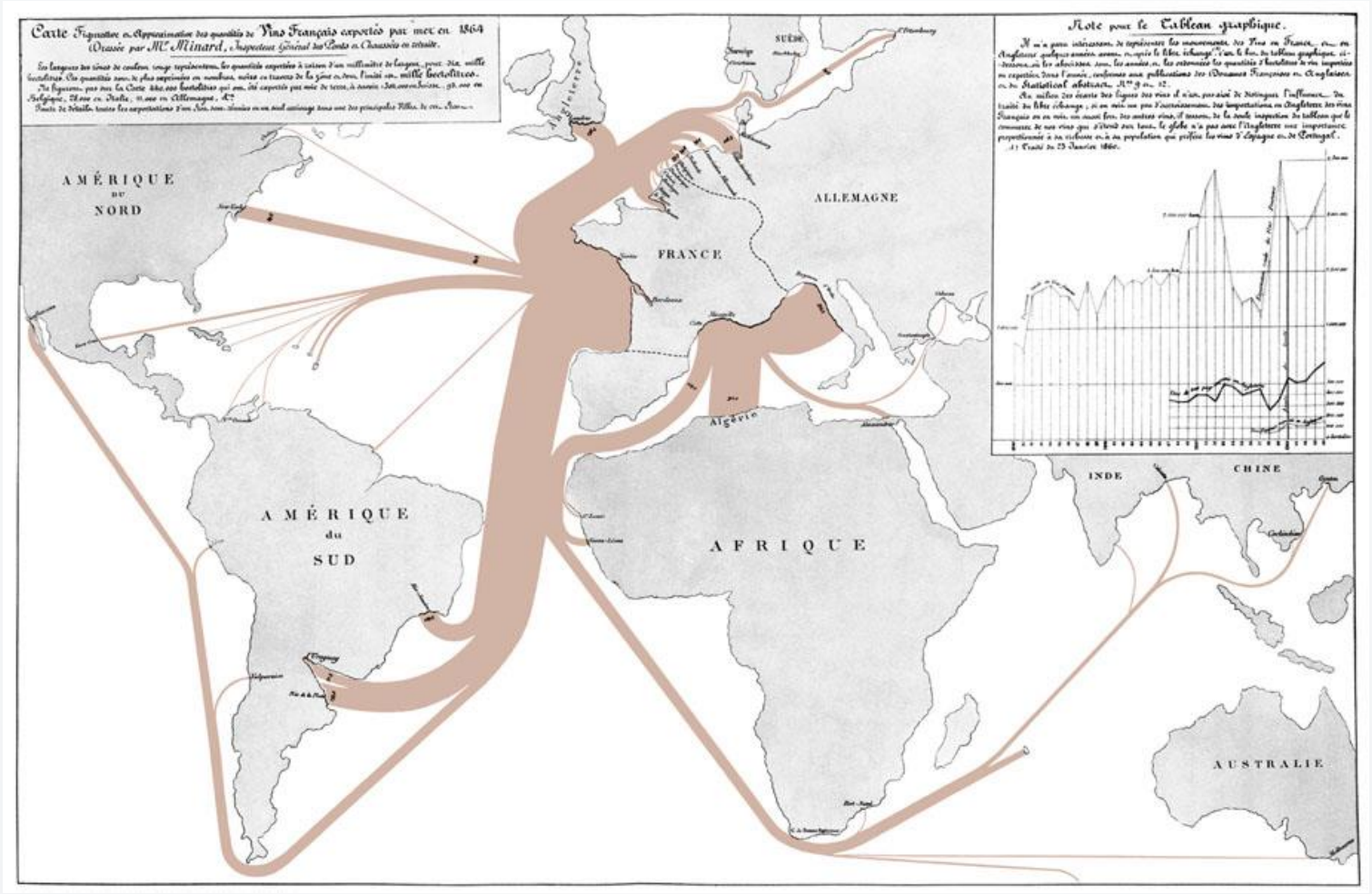
Air Traffic Network

Martin Grandjean, Connected World: Untangling the Air Traffic Network.
http://www.martingrandjean.ch/connected-world-air-traffic-network/

Facebook Friend Relationship

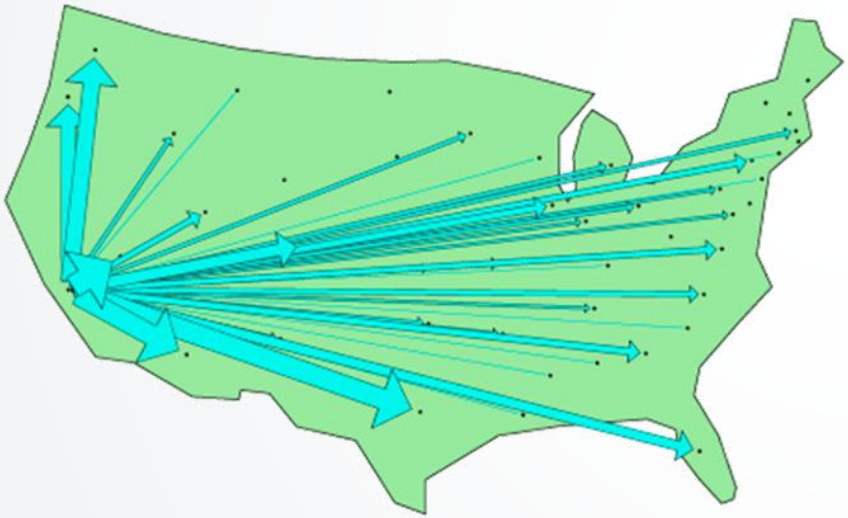
Facebook, 2013.
https://bit.ly/2P7WZep

Bundling Lines



Charles Joseph Minard, French wine exports,1864.
https://en.wikipedia.org/wiki/Flow_map

Flow Map



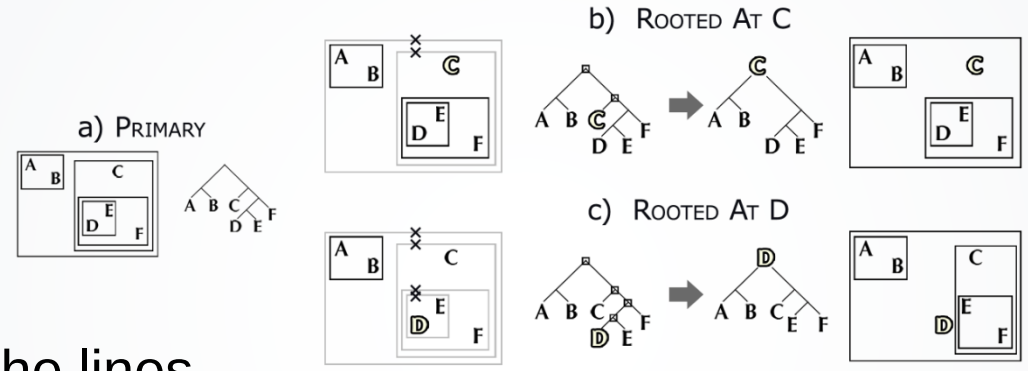
Linking the immigrations from California to other states with arrows

Visualized with Flow Map

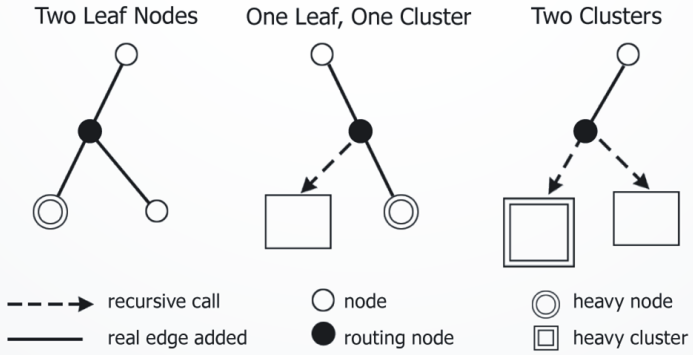
Buchin, Kevin, Bettina Speckmann, and Kevin Verbeek. "Flow map layout via spiral trees."
IEEE transactions on visualization and computer graphics 17.12 (2011): 2536-2544.

Flow Map Procedures

- Computing the bundles.



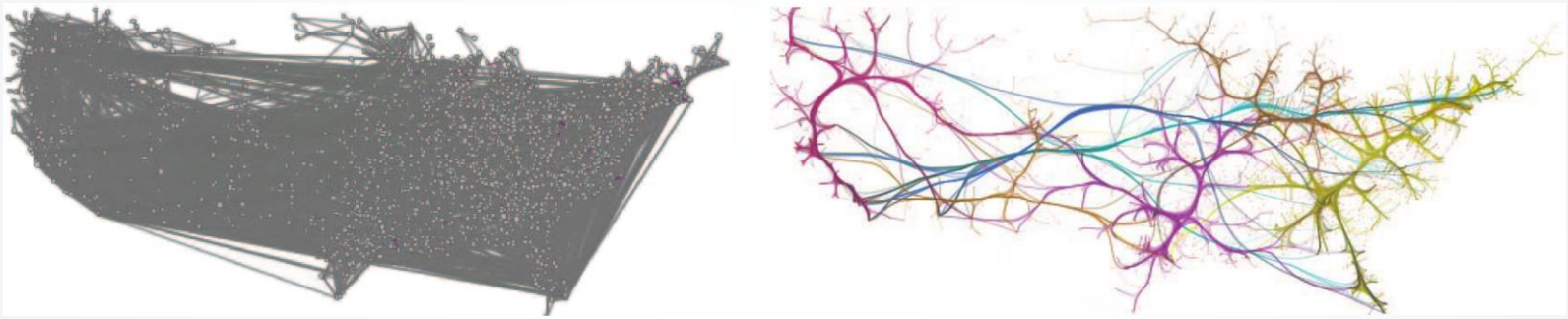
- Layout of the lines.



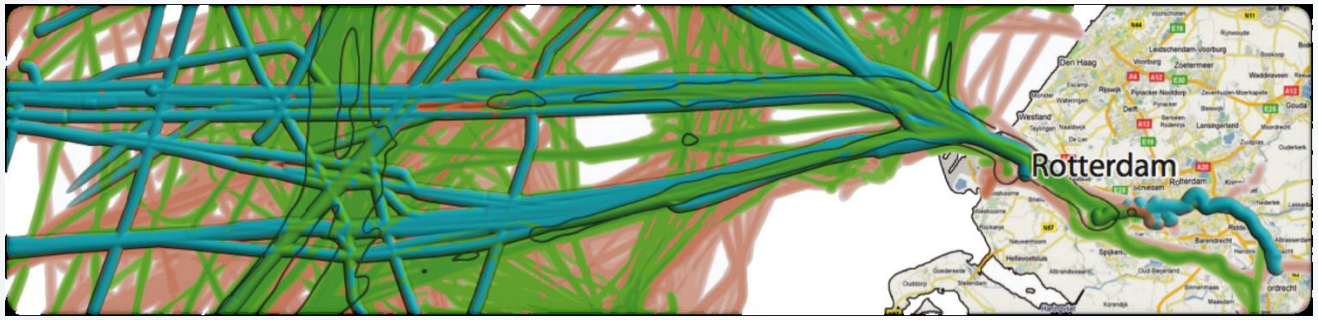
Buchin, Kevin, Bettina Speckmann, and Kevin Verbeek. "Flow map layout via spiral trees."
IEEE transactions on visualization and computer graphics 17.12 (2011): 2536-2544.

基于线段的空间数据可视化

对于大规模的轨迹数据，边捆绑技术和核密度估计可以很好地解决视觉混淆的问题



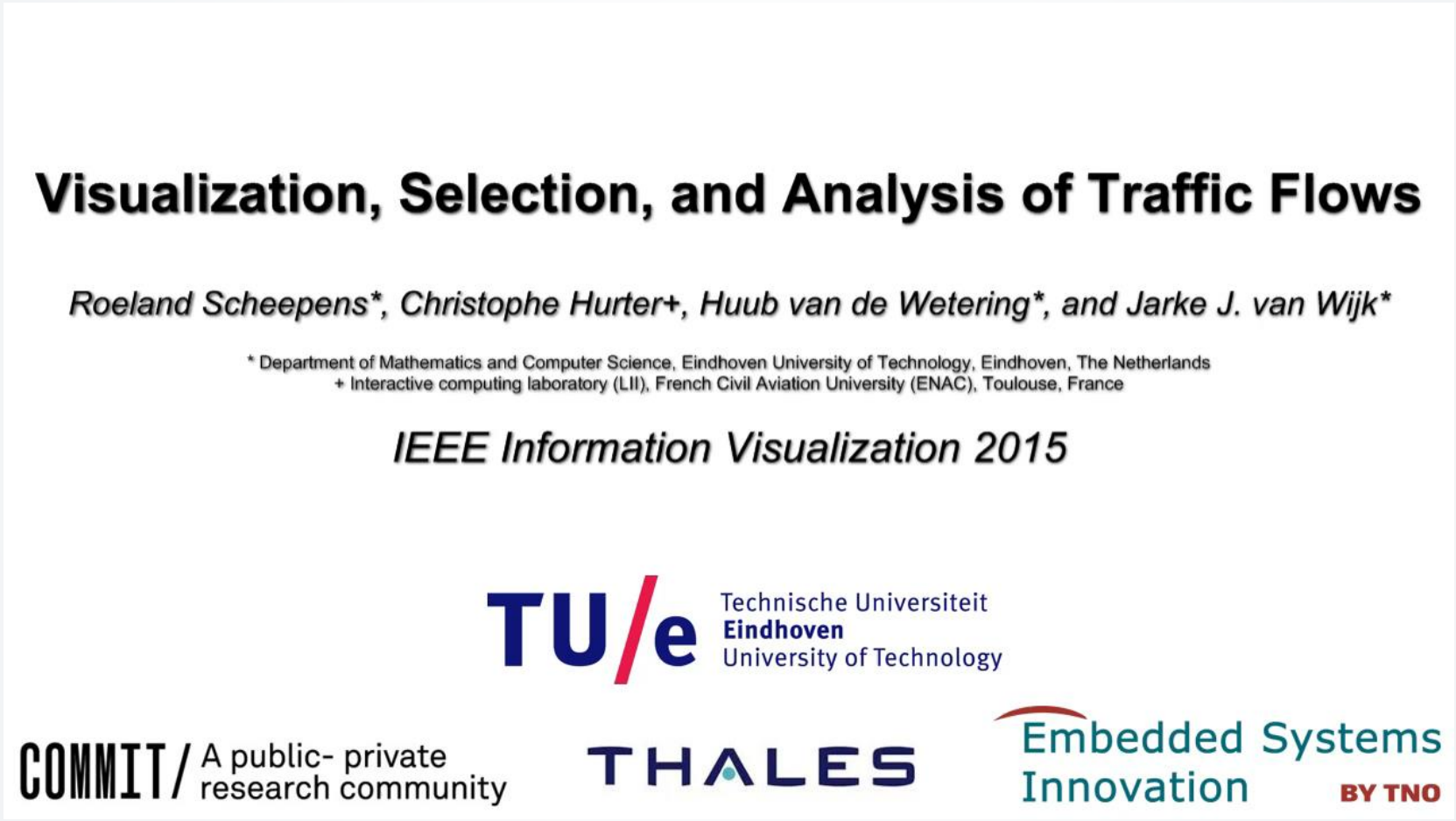
边捆绑技术应用之前和之后的效果对比。*H. Zhou, et. al, 2013*



利用颜色编码轨迹的密度。*R. Scheepens, et. al, 2011*

空间数据可视化 – 边捆绑

空间数据可视化 - 核密度估计



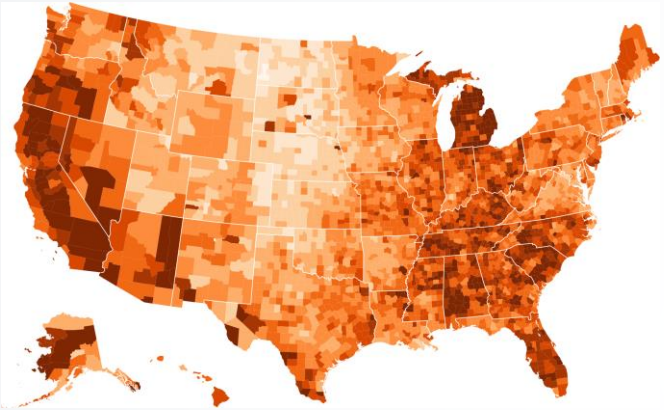
Region Data Visualization

Choropleth Map

- A thematic map in which areas are shaded or patterned in proportion to the measurement of the statistical variable being displayed on the map.
- Assumes that the data is evenly distributed in the area.
- Represents the scales of data with color.

基于区域的空间数据可视化

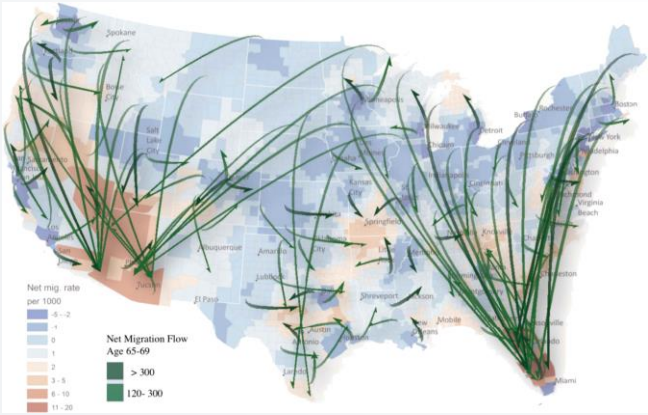
根据预定义的空间划分展示聚合的信息



可视化美国不同区域的失业率情况。

M. Bostock, 2012

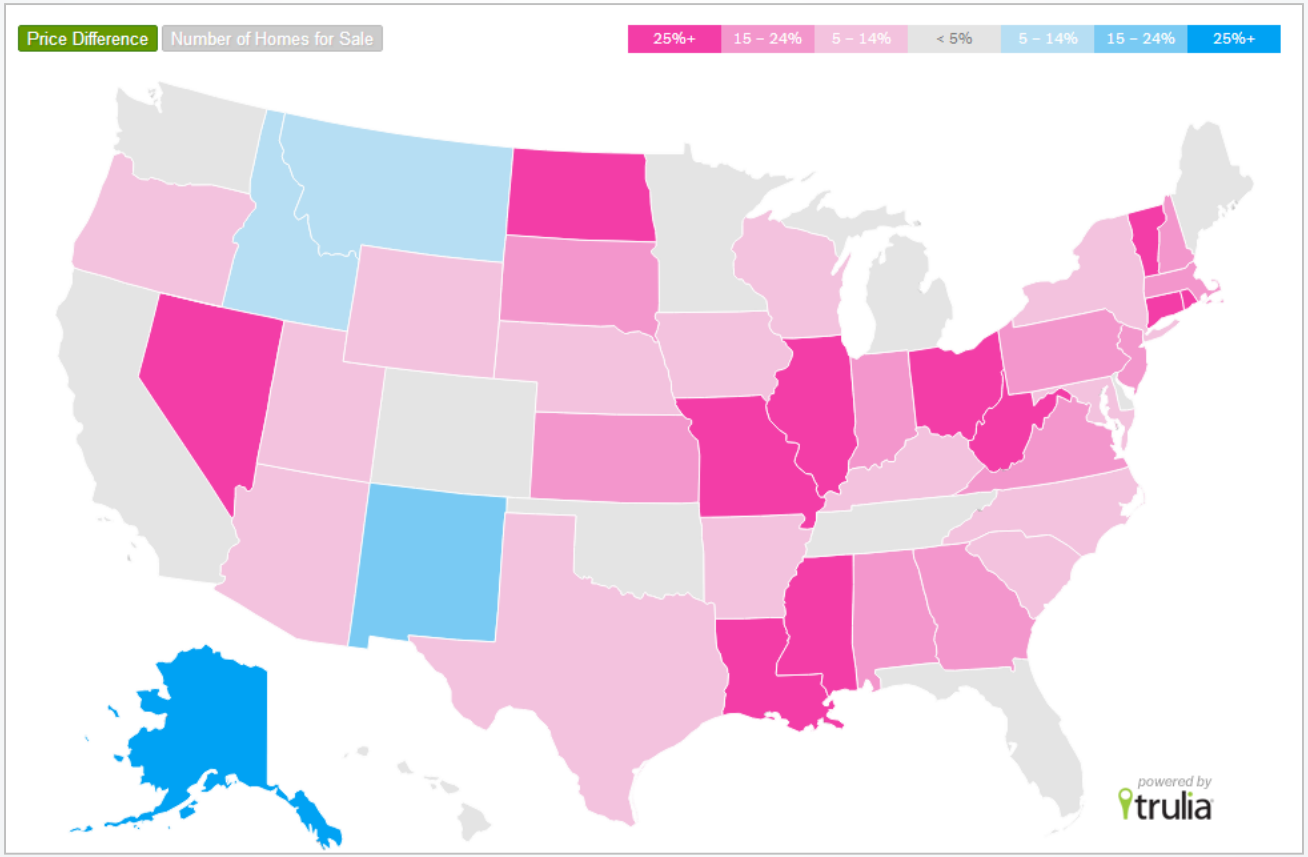
嵌入流图可视化不同区域之间的流动



可视化美国65-69周岁的居民在不同区域间的迁移状况。

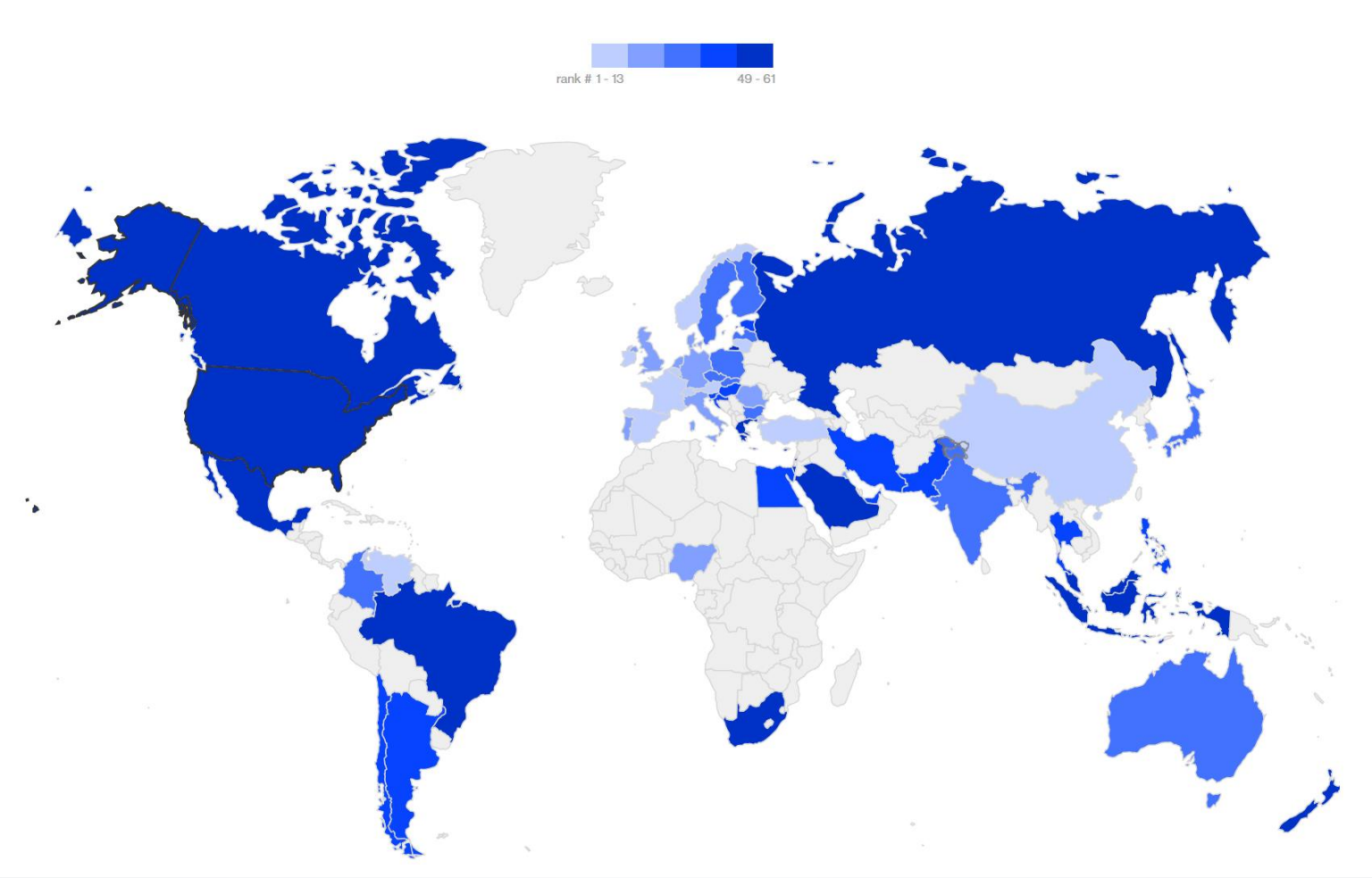
D. Guo, et. al, 2014

Selling Real Estate: Men vs. Women



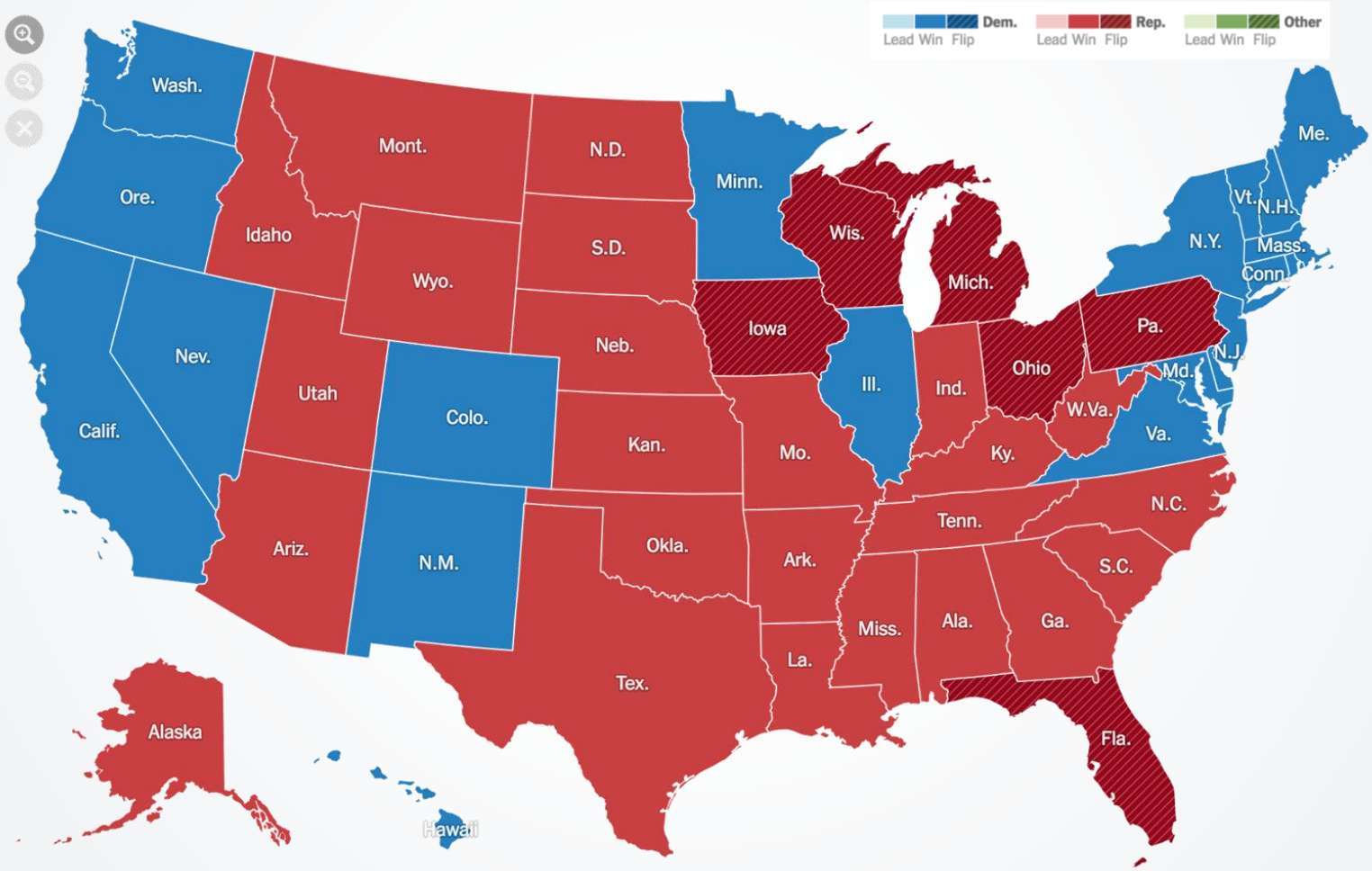
Trulia, Is real estate a man's or woman's world.
https://bit.ly/2KIh9LE

The World Gas Prices



Gasoline Prices Around the World
https://www.bloomberg.com/graphics/gas-prices/#20183:United-States:USD:g

Choropleth Map

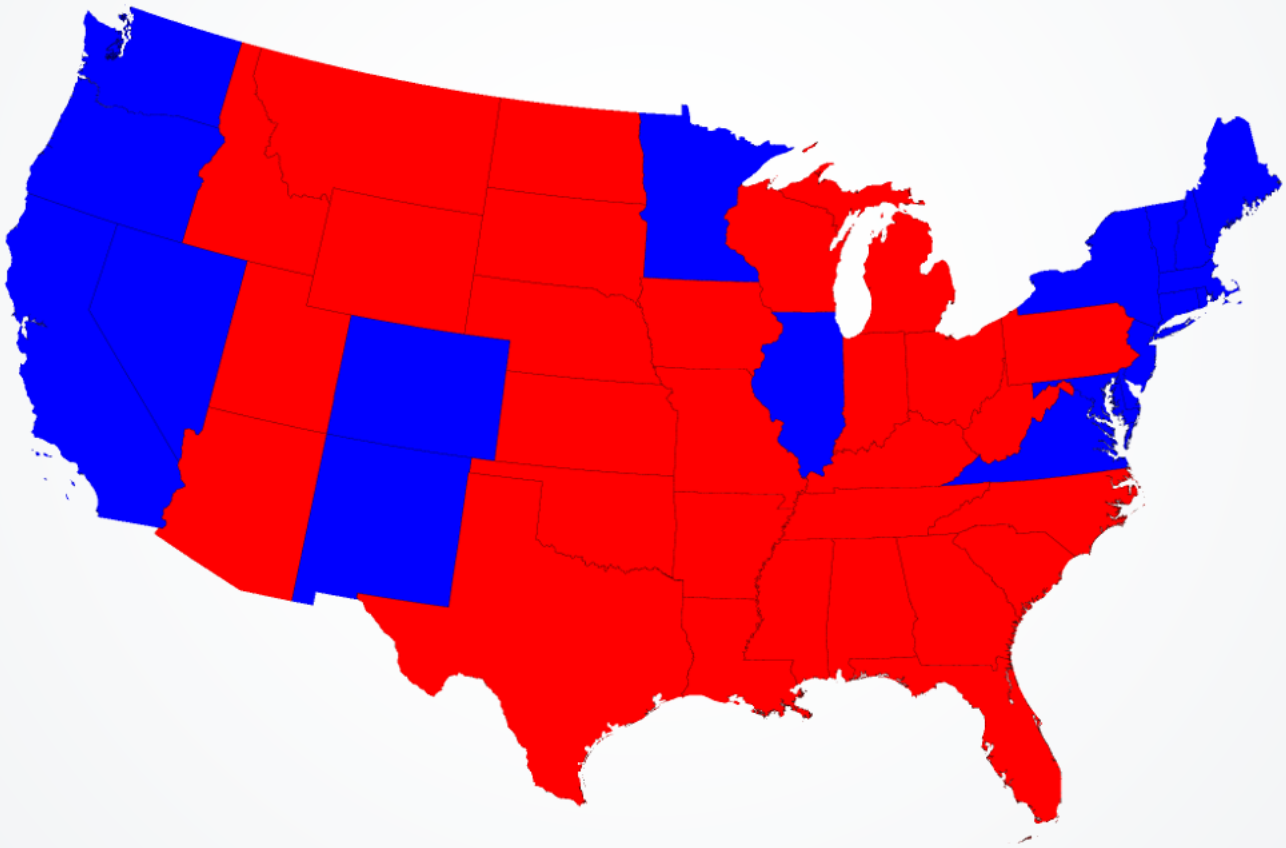


The New York Times, 2016 Presidential Election Results.
https://www.nytimes.com/elections/2016/results/president

Misleading of Choropleth Map

- The map fails to take account of **the population distribution.**
  - It fails to allow for the fact that the population of the red states is on average significantly lower than that of the blue ones. The blue may be small in area, but they represent a large number of voters, which is what matters in an election.
- When data is accumulated at the place where display space is less, there comes a mismatch, and vice versa.
- This mismatch would very possibly **mislead** the audience.

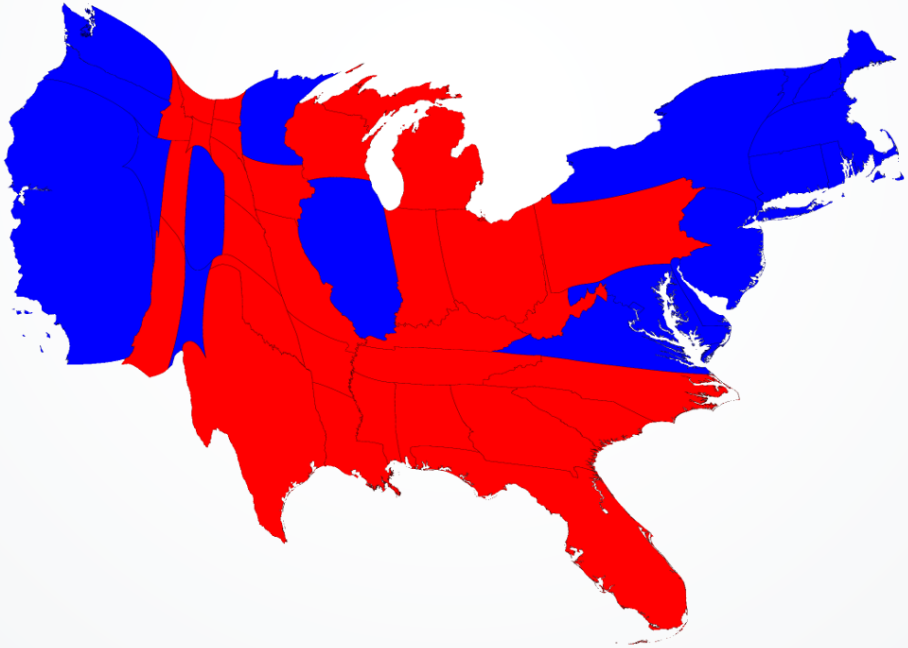
Misleading of Choropleth Map



Mark Newman, 2016 Maps of the 2016 US presidential election results.
http://www-personal.umich.edu/~mejn/election/2016/

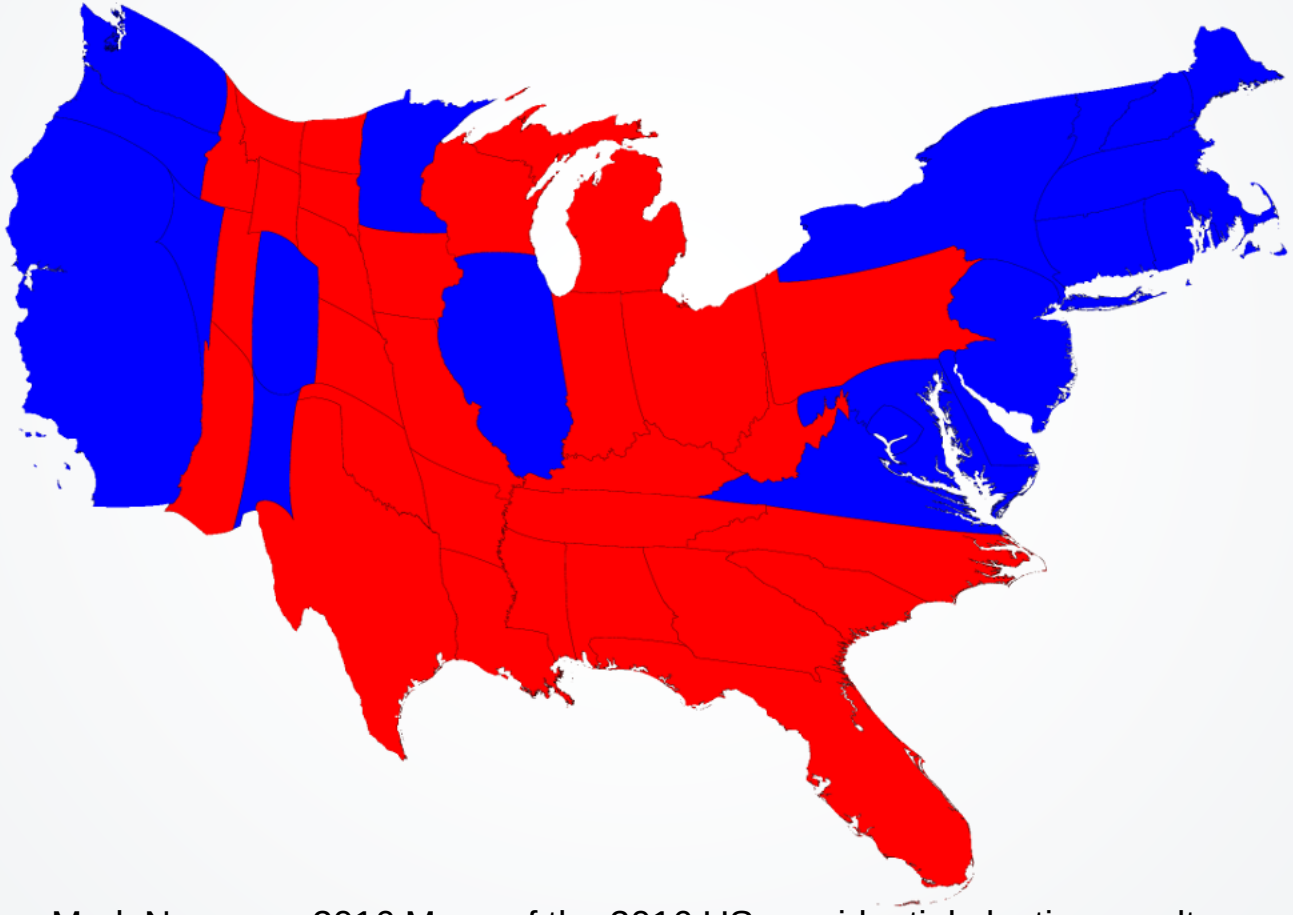
Cartogram Map

- A map in which some thematic mapping variable – **such as travel time, population, or Gross National Product** – is substituted for land area or distance.



Mark Newman, 2016 Maps of the 2016 US presidential election results.
http://www-personal.umich.edu/~mejn/election/2016/

Cartogram Map

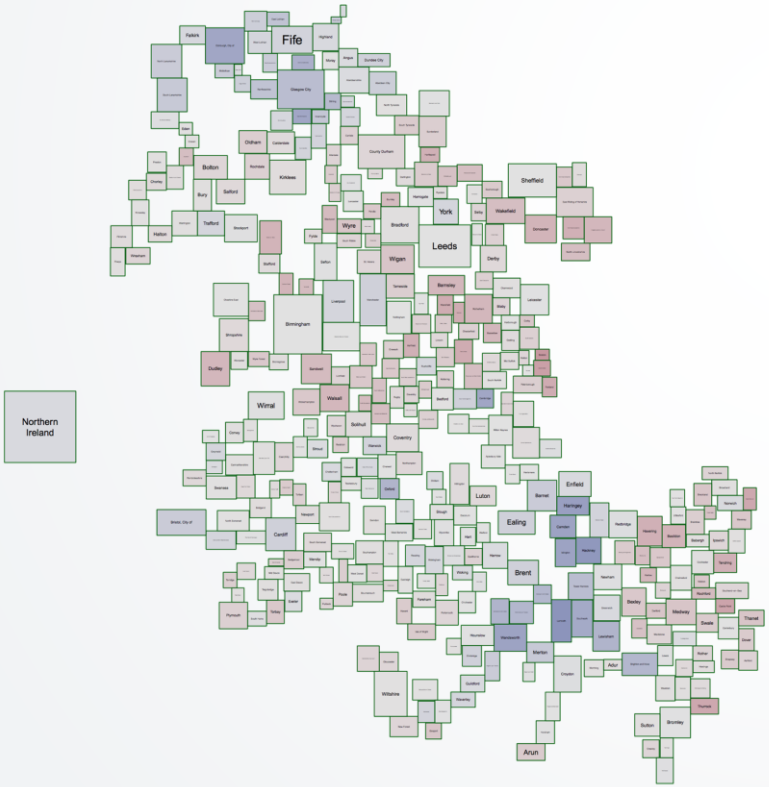


Mark Newman, 2016 Maps of the 2016 US presidential election results.
http://www-personal.umich.edu/~mejn/election/2016/

Other Maps

Regular Shape Map

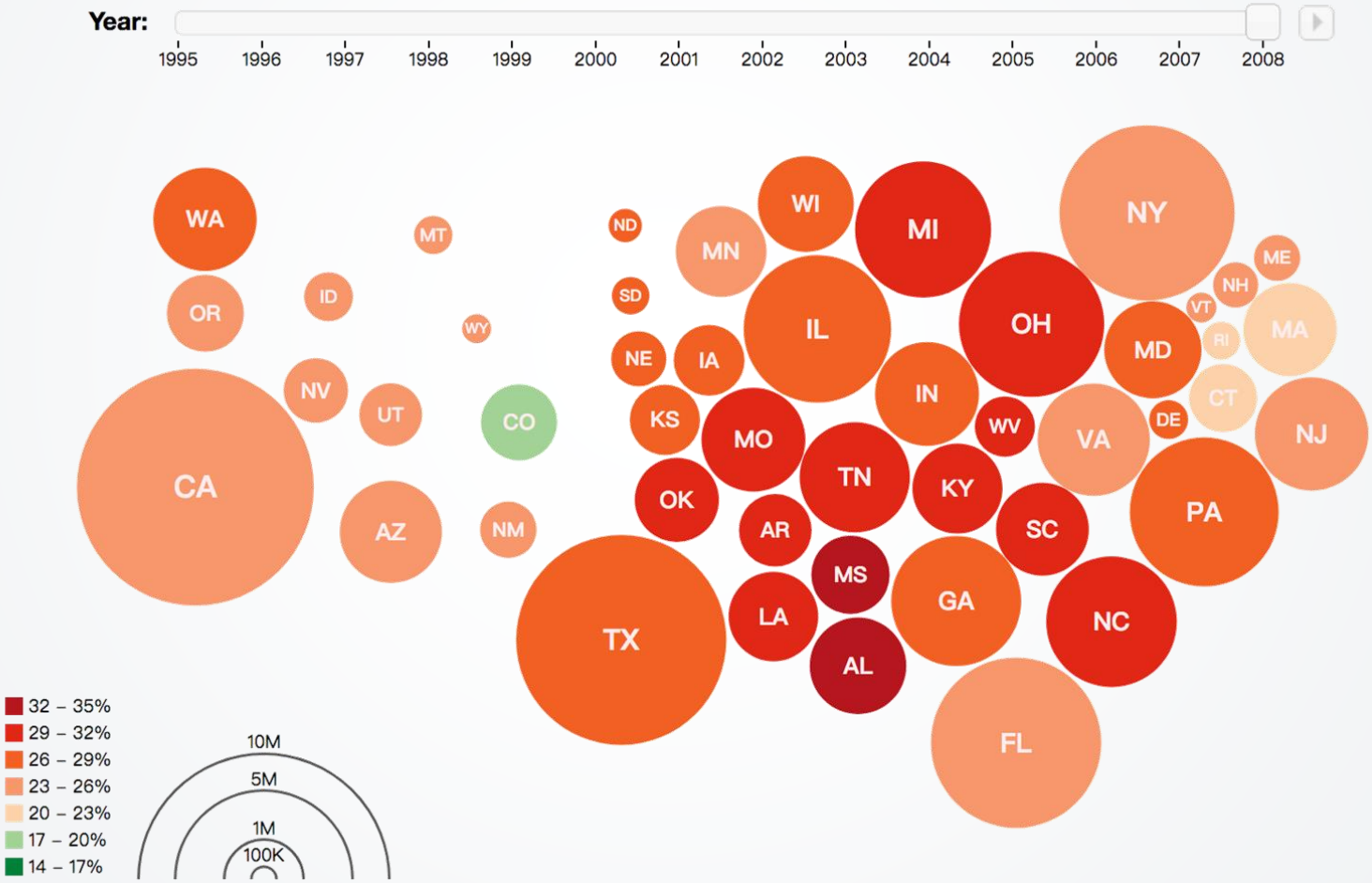
- Visualizing areas with simple shapes like rectangles or circles, so that users can compare the size of data easier.



- The outcome of the UK Brexit EU-referendum is displayed.
- The region areas represent the number of the electorates.
- The colors are indicating the outcome of the referendum (blue: remain/red: leave; the lower the color intensity the closer is the outcome to 50%:50%).

Christian Panse, Rectangular Statistical Cartograms in R: The recmap Package. Journal of Statistical Software

Dorling Cartogram

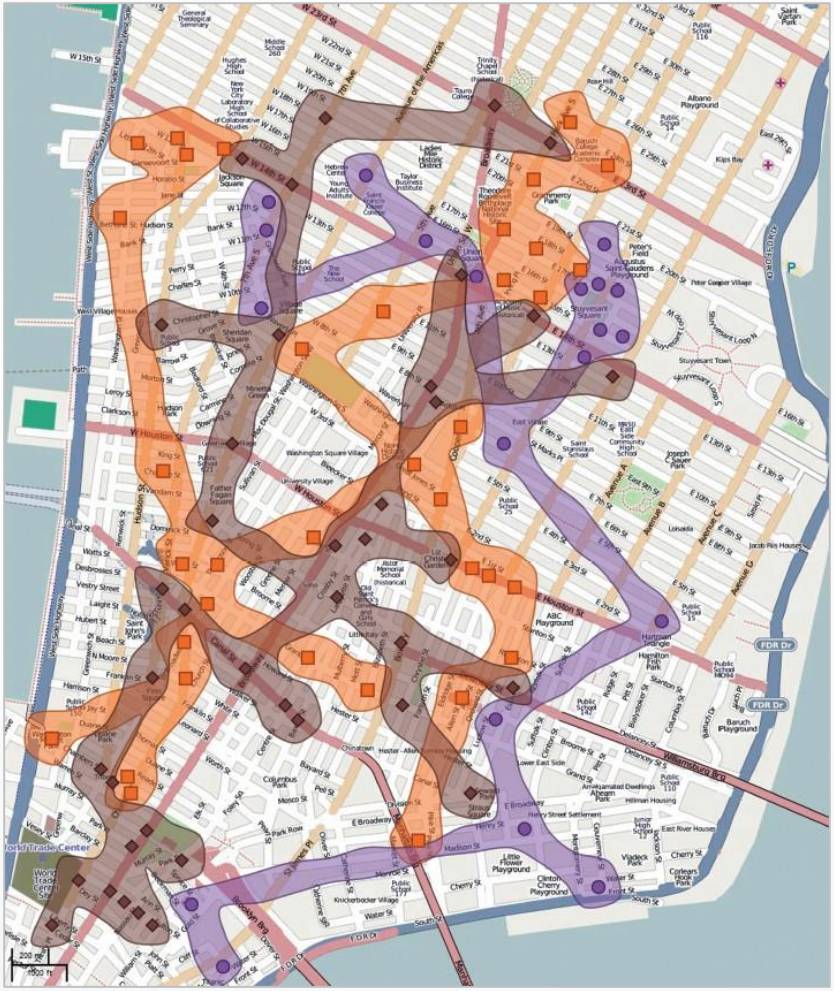


Mike Bostock , Obese People Per State.
http://mbostock.github.io/protovis/ex/cartogram.html

Multi-Set Map

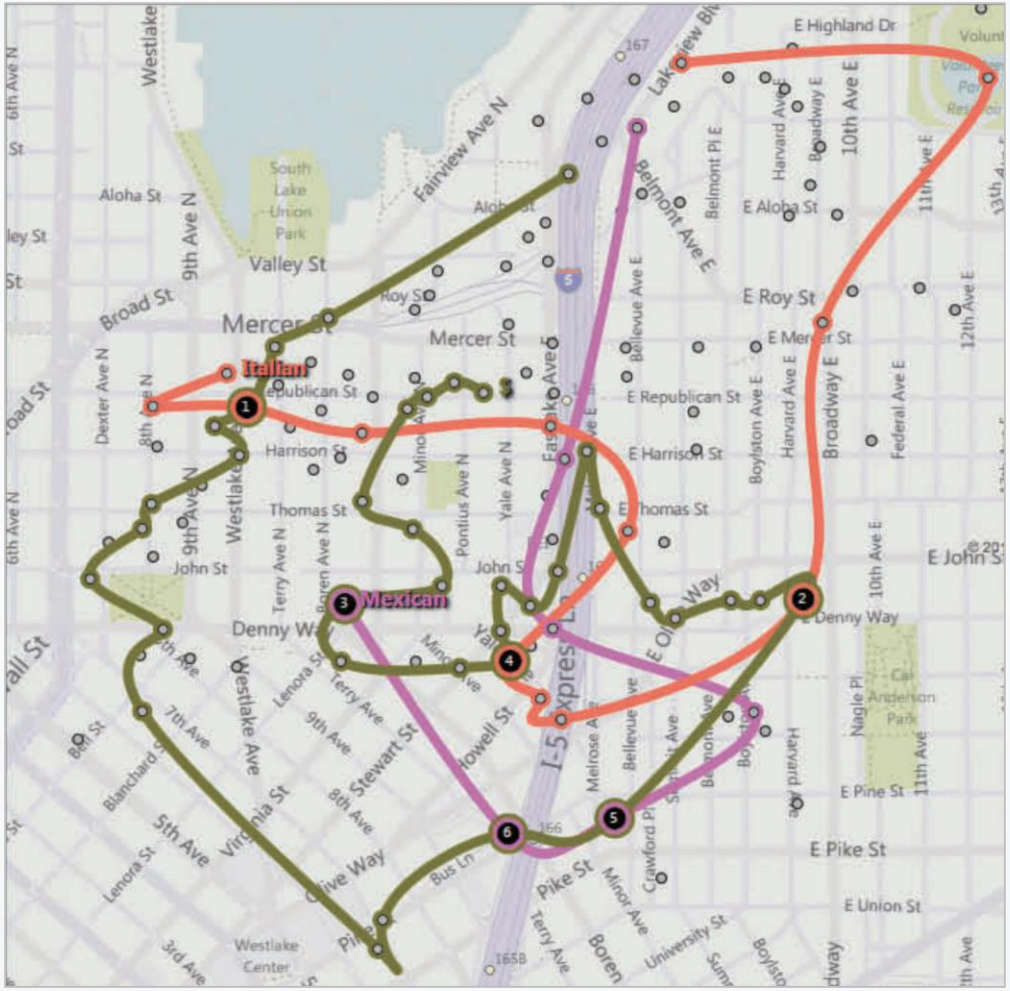
- To represent different attributes of the locations.
  - restaurants, gas stations…
- Multiple set representations are applied.
  - Bubble Sets
  - LineSets

Bubble Sets



Collins, Christopher, et al. Bubble sets: Revealing set relations with isocontours over existing visualizations.
IEEE Transactions on Visualization & Computer Graphics 6 (2009): 1009-1016.

LineSets



Alper, Basak, et al. Design study of linesets, a novel set visualization technique. IEEE Transactions on Visualization & Computer Graphics 12 (2011): 2259-2267.

Geographic Datasets

Geographic Datasets

OpenStreetMap
https://www.openstreetmap.org/

HK Government Datasets
https://data.gov.hk

Geographic Datasets

- Google/Baidu API
- OpenStreetMap (http://www.openstreetmap.org)
- HK government dataset (http://data.gov.hk)
- NYC Open Data (https://opendata.cityofnewyork.us)
- Data.gov (https://www.data.gov)

Applications in Urban Problems