



NYU | TANDON

Information/Data Visualization

Lecture 5 –

2D Visualization – Temporal Data

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Where We Are

- Basic mathematical tools
- Color: definition, space, map, and design
- 2D visualization: data ->  spatial, temporal, network
- Human perception and geometries of 3D
- 3D visualization: projection and interaction
- Application case studies

P A R T 0 1

Temporal Data

What is temporal data?

Data in which **values depends on time** and
time is explicitly recorded.

Example



	A	Date	Max.Temper	Mean.Temper	Min.Temper	Max.Dew.Po	MeanDew.Po	Min.Dewpoir
1		1/1/48	55	50	46	53	48	42
2	1	1/2/48	57	55	53	56	53	51
3	2	1/3/48	57	54	50	54	51	50
4	3	1/4/48	59	57	55	55	54	54
5	4	1/5/48	59	55	51	55	52	50
6	5	1/6/48	62	57	52	55	53	50
7	6	1/7/48	61	57	53	57	54	50
8	7	1/8/48	55	50	44	49	46	40
9	8	1/9/48	57	50	43	47	45	42
10	9							

Example



	A	B	C	D	E	F	G	H
1	VendorID	Ipep_pickup_datetime	Ipep_dropoff_datetime	store_and_fwd_flag	RatecodeID	PULocationID	DOLocationID	passenger_count
2	2	1/1/21 0:15	1/1/21 0:19	N	1	43	151	1
3	2	1/1/21 0:25	1/1/21 0:34	N	1	166	239	1
4	2	1/1/21 0:45	1/1/21 0:51	N	1	41	42	1
5	2	12/31/20 23:57	1/1/21 0:04	N	1	168	75	1
6	2	1/1/21 0:16	1/1/21 0:16	N	2	265	265	3
7	2	1/1/21 0:16	1/1/21 0:16	N	2	265	265	3
8	2	1/1/21 0:19	1/1/21 0:19	N	5	265	265	1
9	2	1/1/21 0:26	1/1/21 0:28	N	1	75	75	6
10	2	1/1/21 0:57	1/1/21 0:57	N	1	225	225	1

Two Types of Temporal Data

Measurement data

This is the value at time T. (Time + Measurement)

Examples:

- Temperature.
- Revenue.
- Stock value.

Event data

Something happened at time T. (Time + Object)

Examples:

- Tweet.
- Taxi pick up or drop off.
- Alarm.

Time Structure

ISO 8061 Format

Date

Year

Month

Day

2022-02-28T11:59:59-0500

Time

Hour

Min.

Sec.

Time Zone

Other forms:

Feb. 28, 2022

02/28/2022

28/02/2022

2022.16 (decimal date)

Week 9

Monday (week day)

Day 59 (year day)

Other forms:

11:59:59 am

11:59:59.283

11:59:59.283+00:00

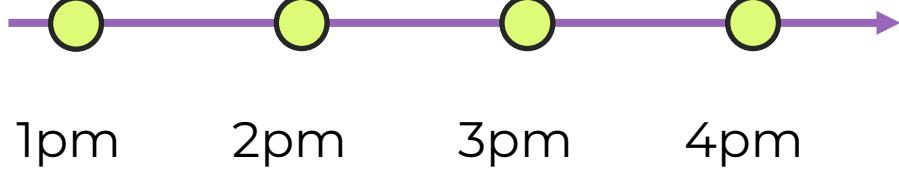
Packages:

R: lubridate

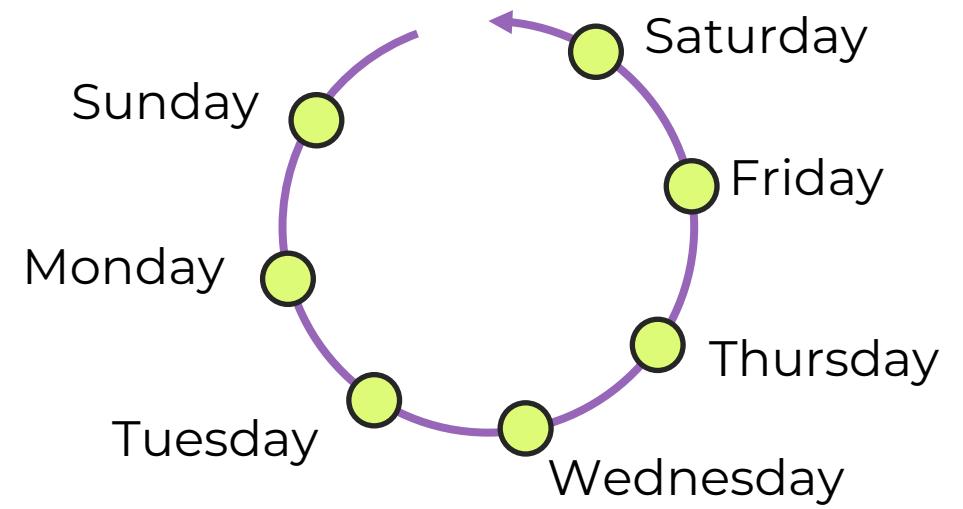
Python: datetime

JavaScript: Date class

Sequential

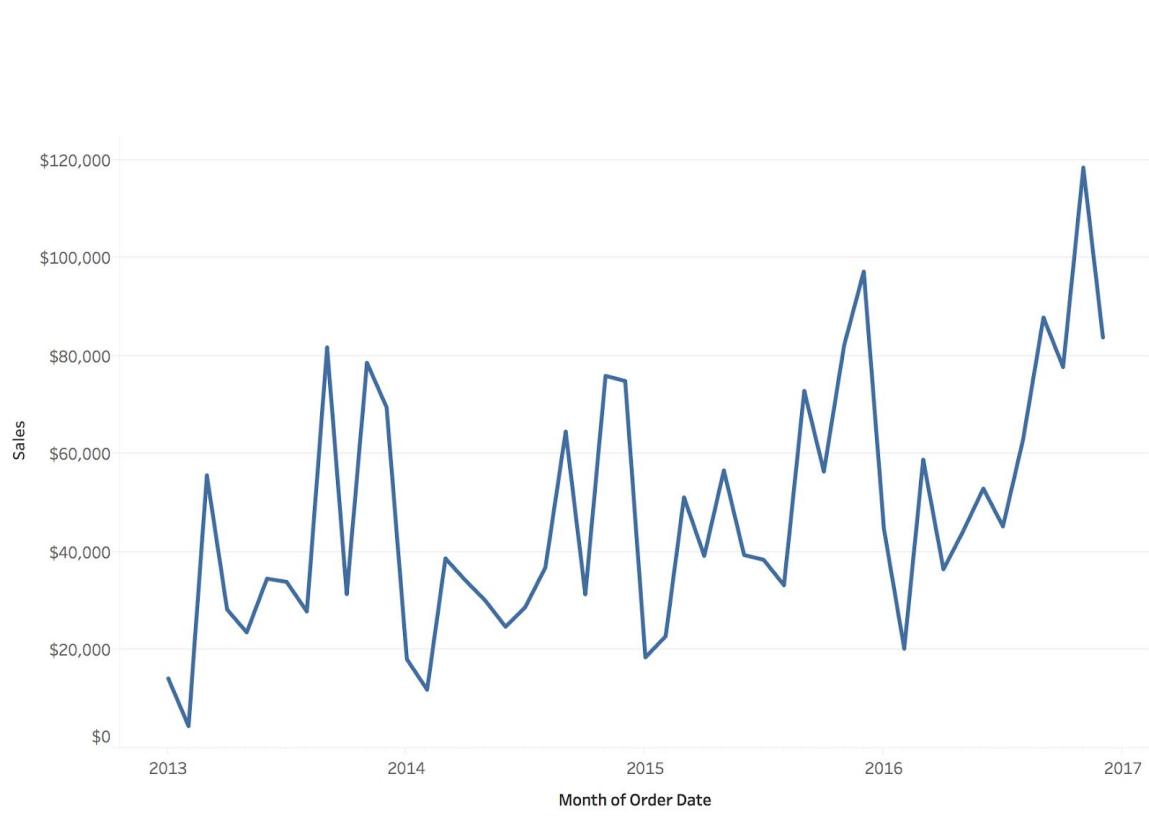


Cyclic

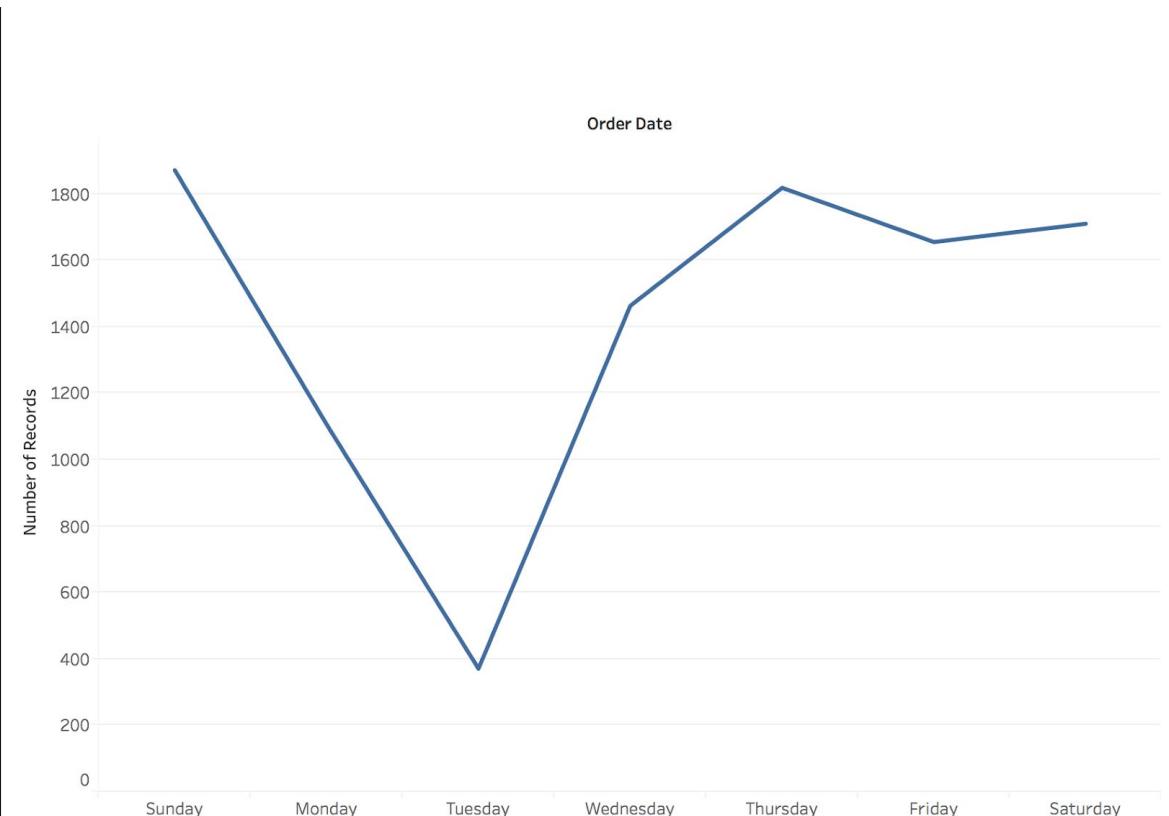


PART 01

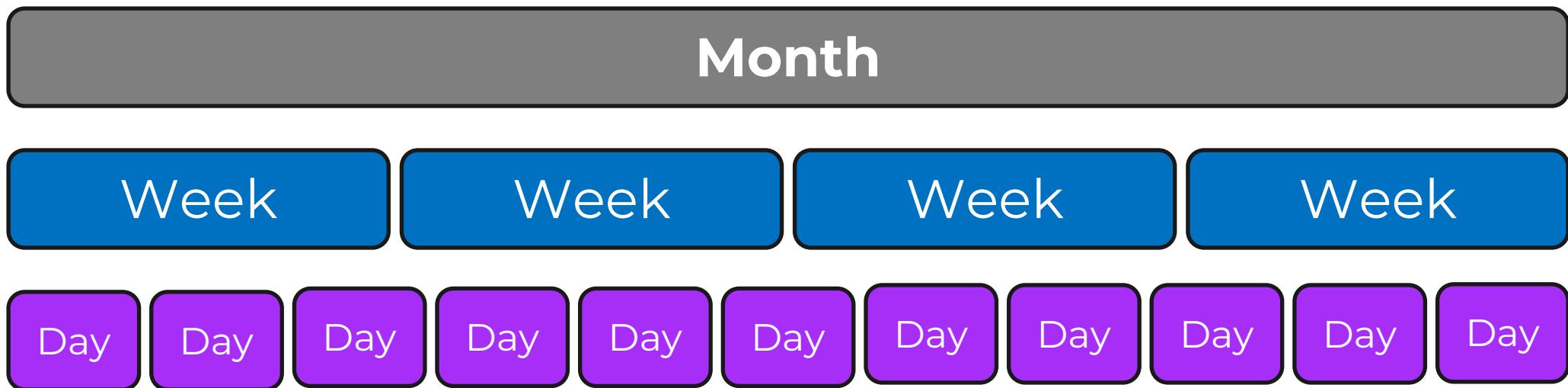
How did sale change over years?



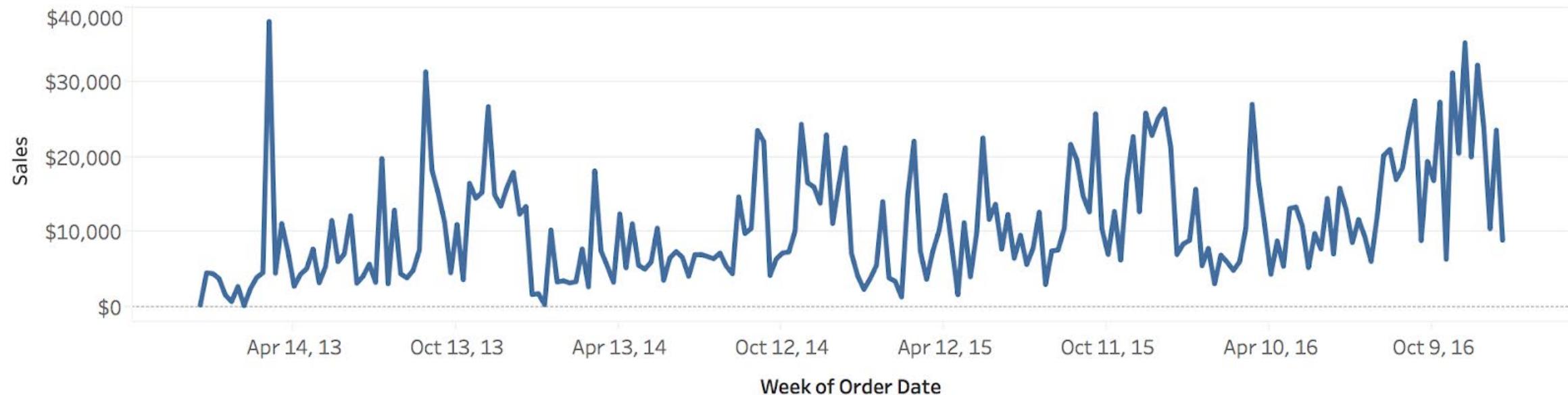
How does the number of orders change by day of the week?



Time is hierarchical/multi-resolution



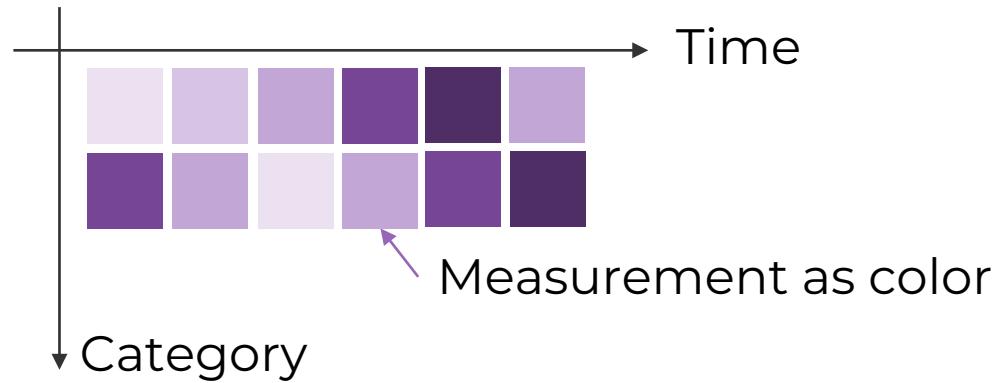
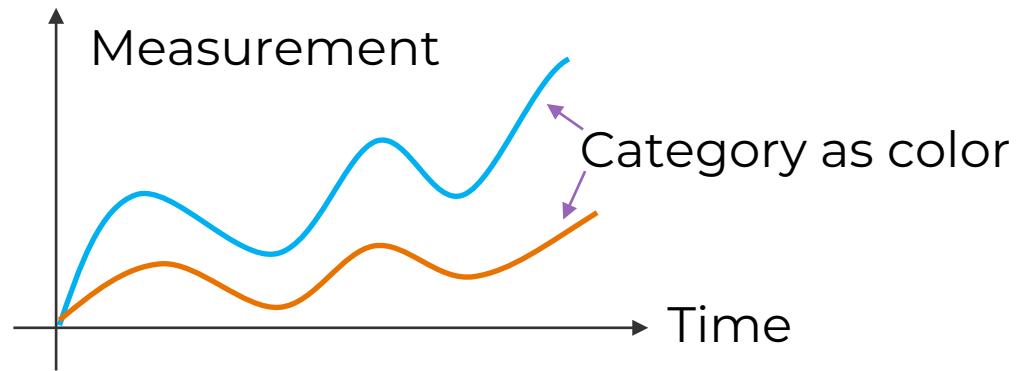
PART 01



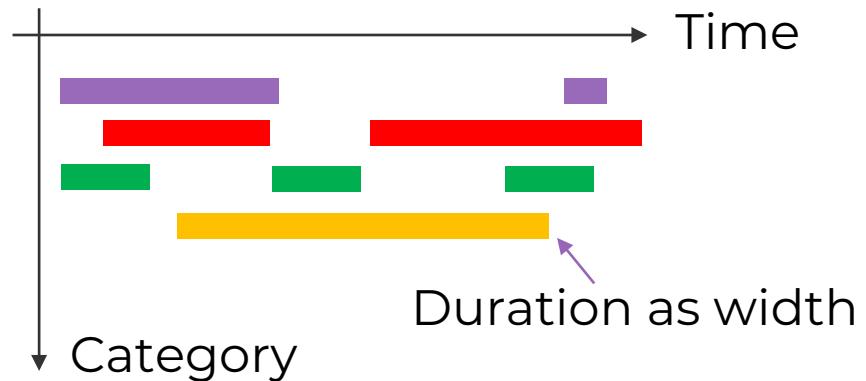
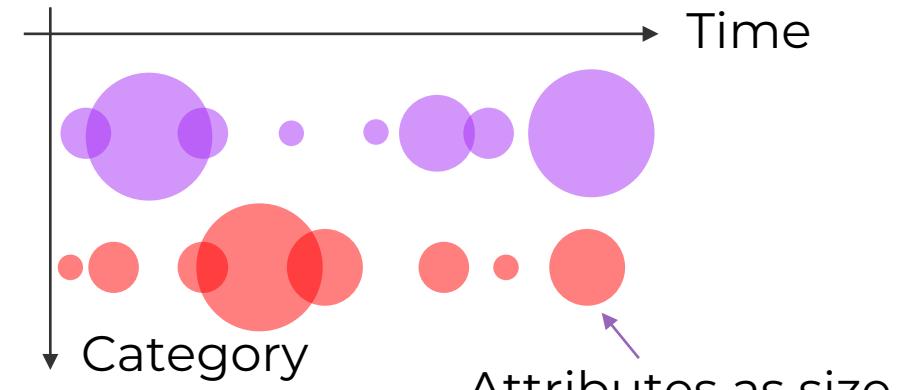
PART 02

Visualization Techniques

Measurement Data



Event Data



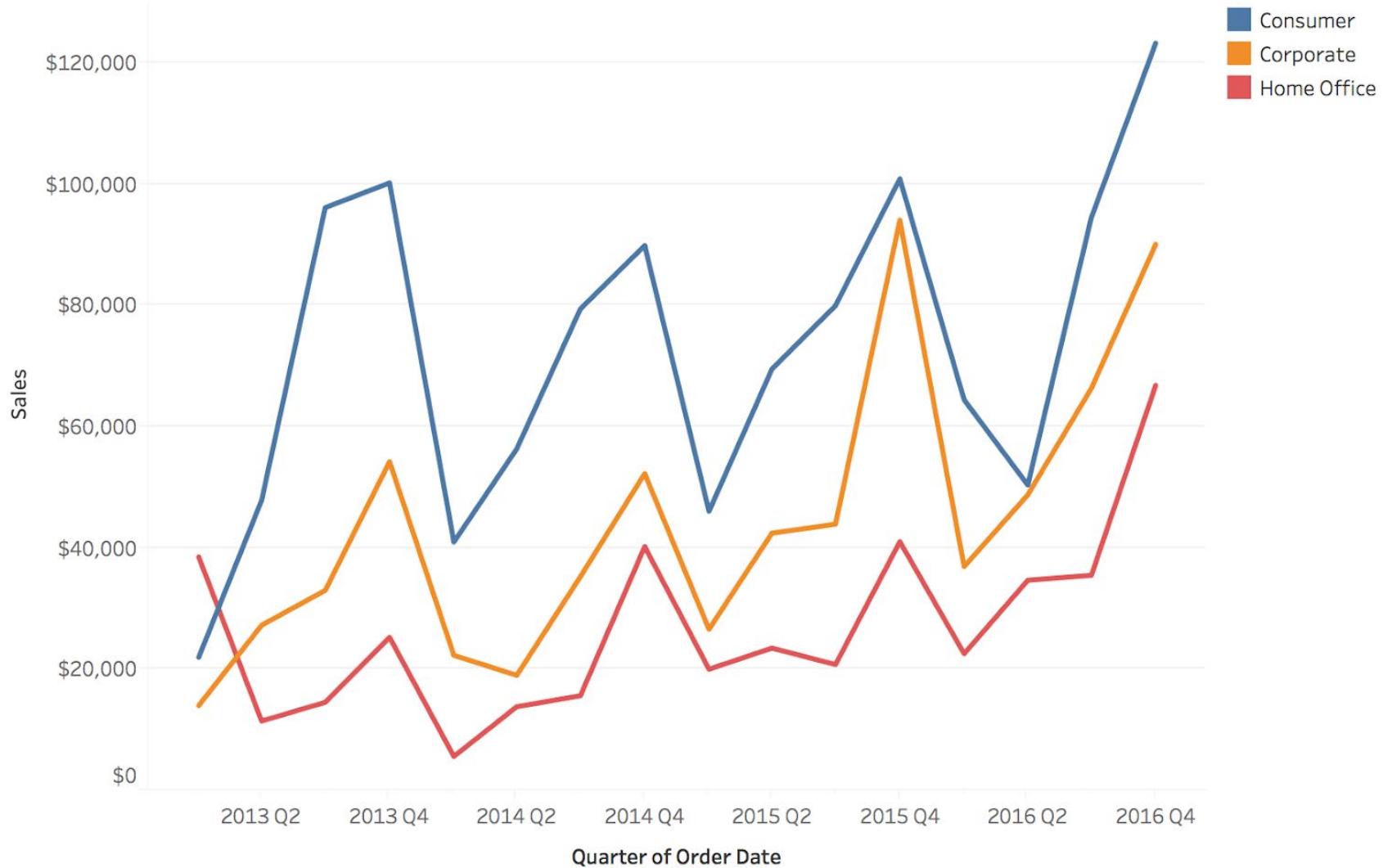
Line Chart

Time + Quantity

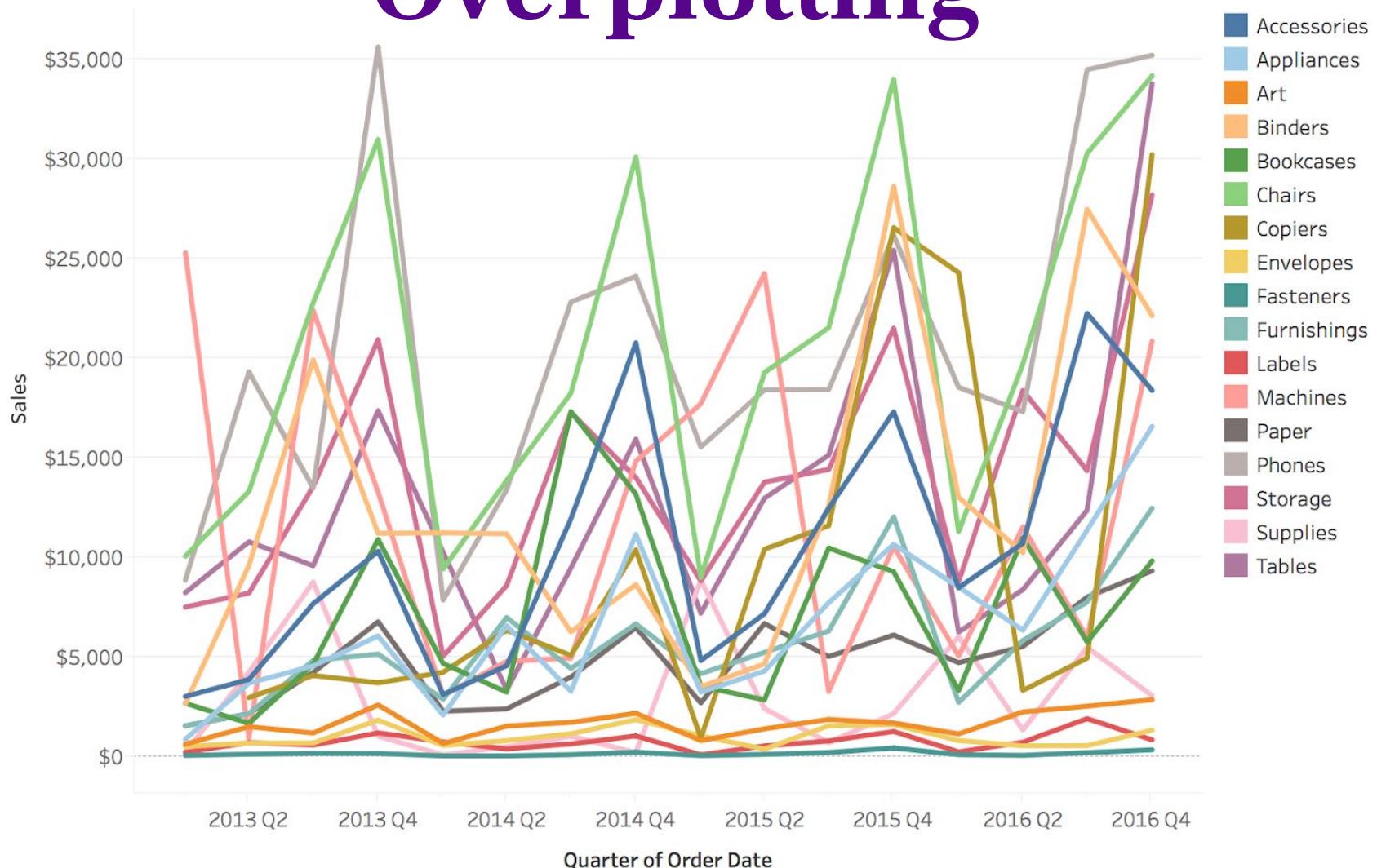
PART 0



PART 02



Overplotting



To Avoid Overplotting

Grouping

Combine data so there are fewer categories.

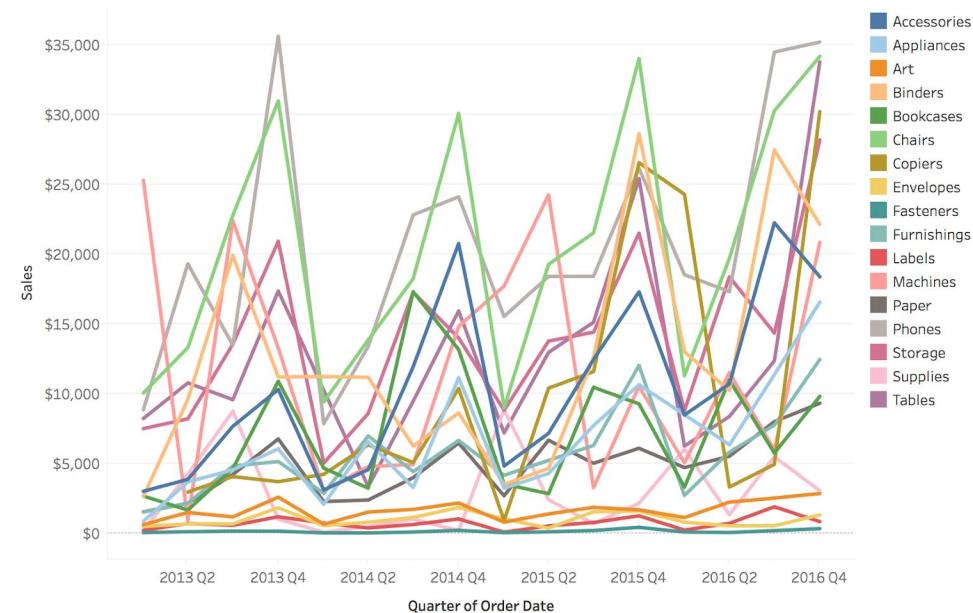
Filtering/Focusing

Only show a few categories of interest.

Highlighting

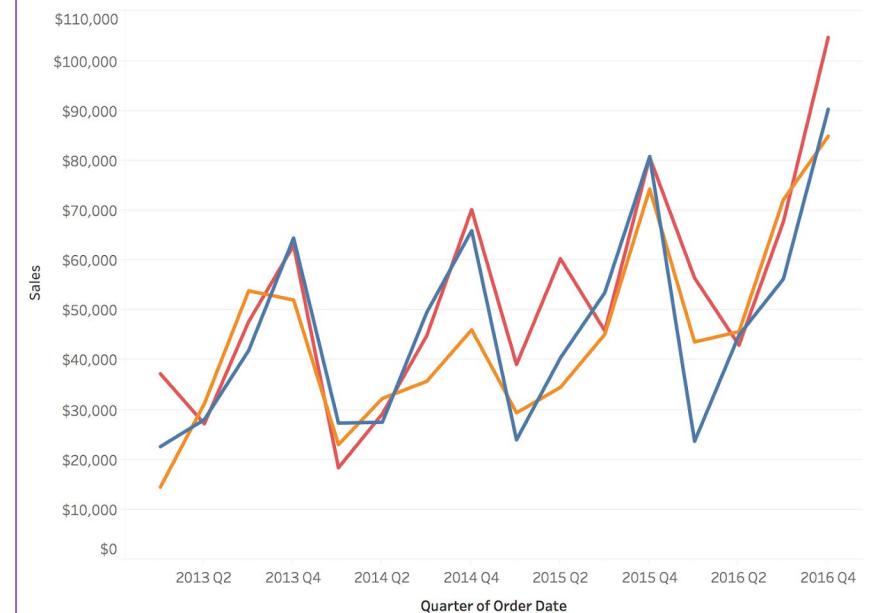
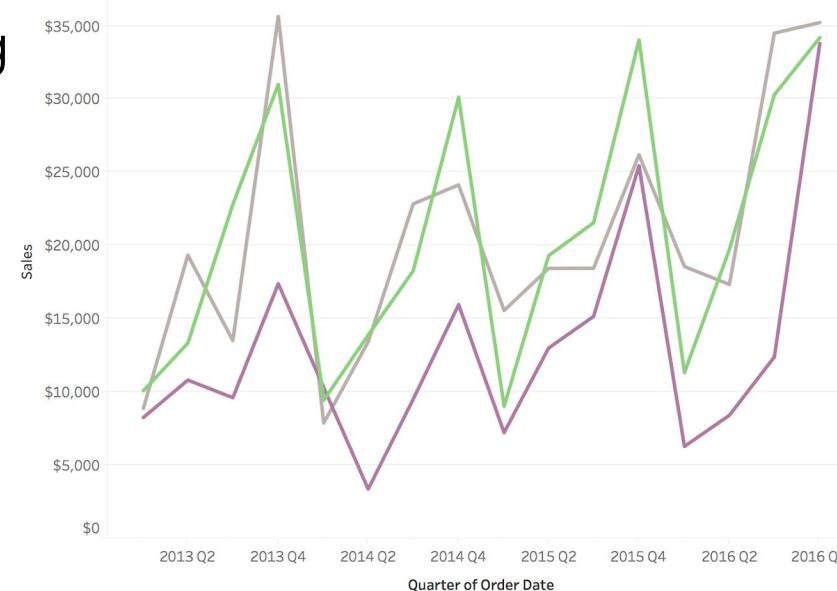
Gray out un-interesting categories and highlight the categories of interest with bright color and larger line width.

Original



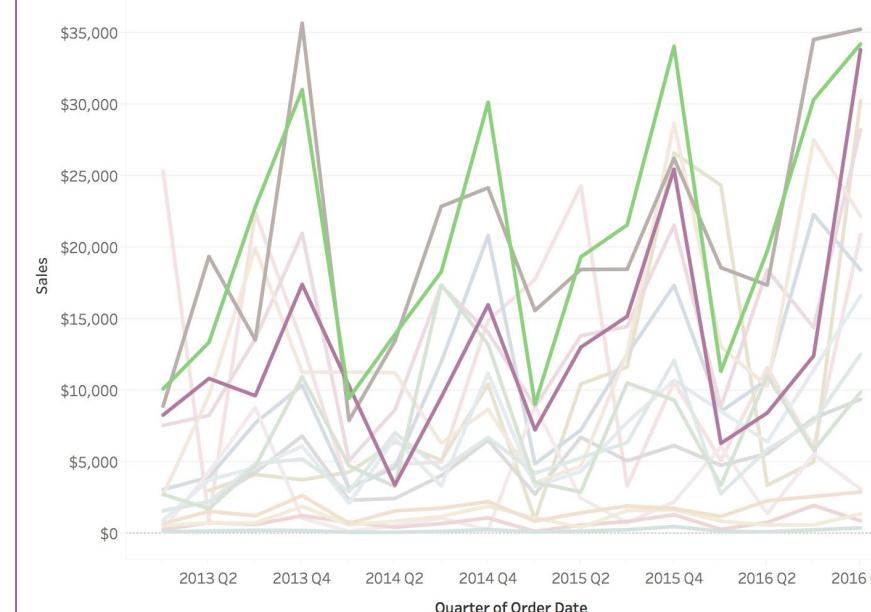
Accessories
Appliances
Art
Binders
Bookcases
Chairs
Copiers
Envelopes
Fasteners
Furnishings
Labels
Machines
Paper
Phones
Storage
Supplies
Tables

Filtering



Furniture
Office Supplies
Technology

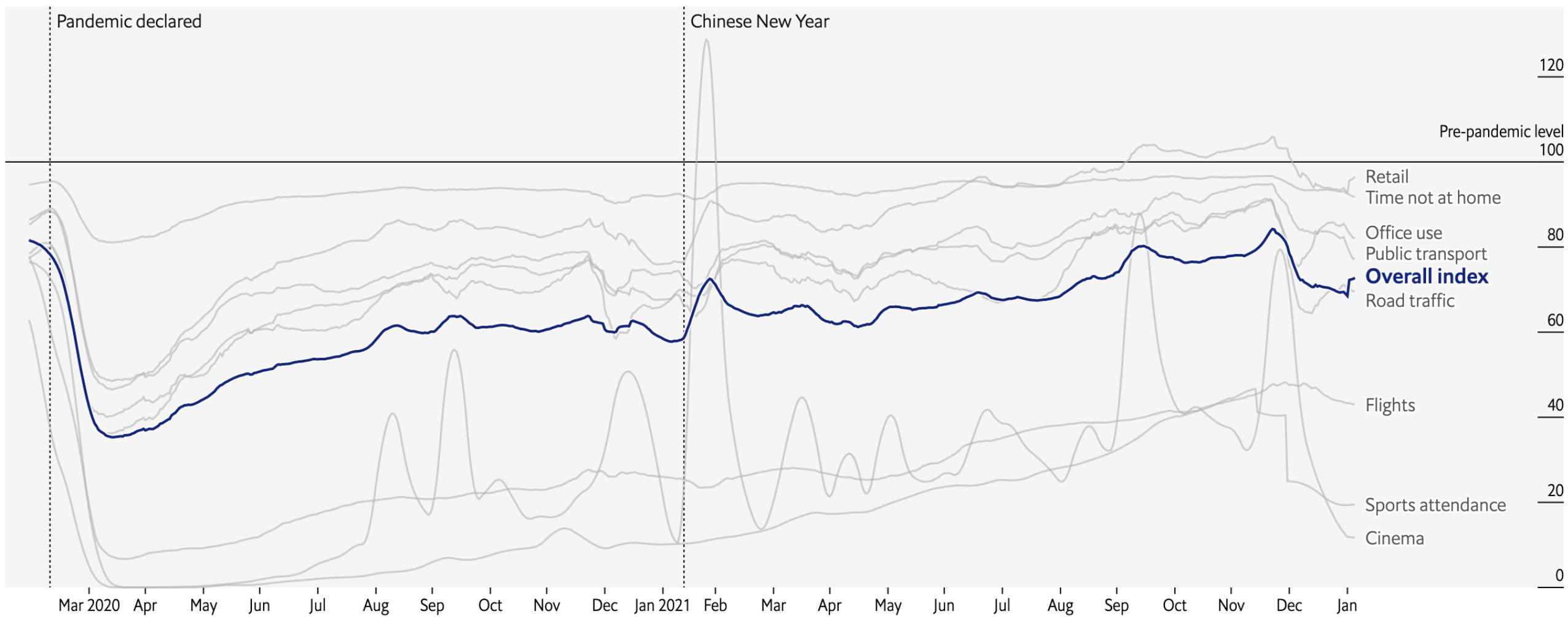
Grouping



Highlighting

Source: [Erico Bertini](#)

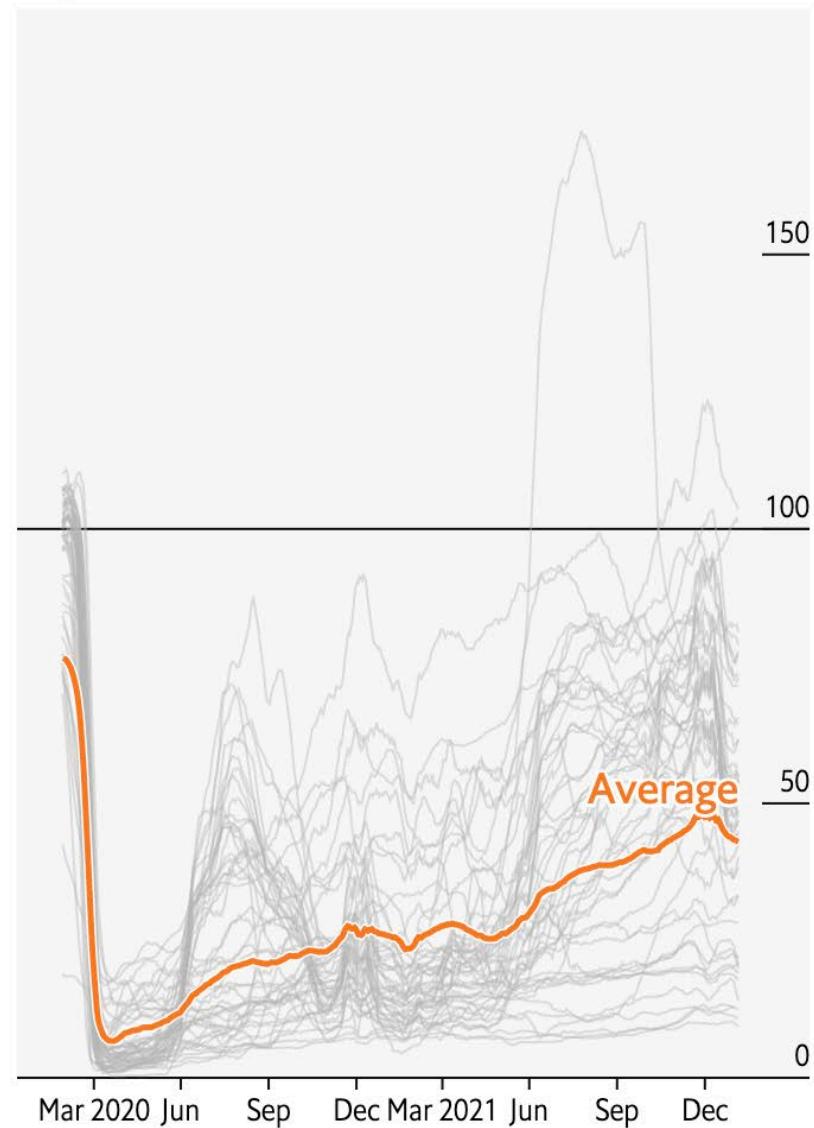
Case Study: Global Normalcy Index from The Economist



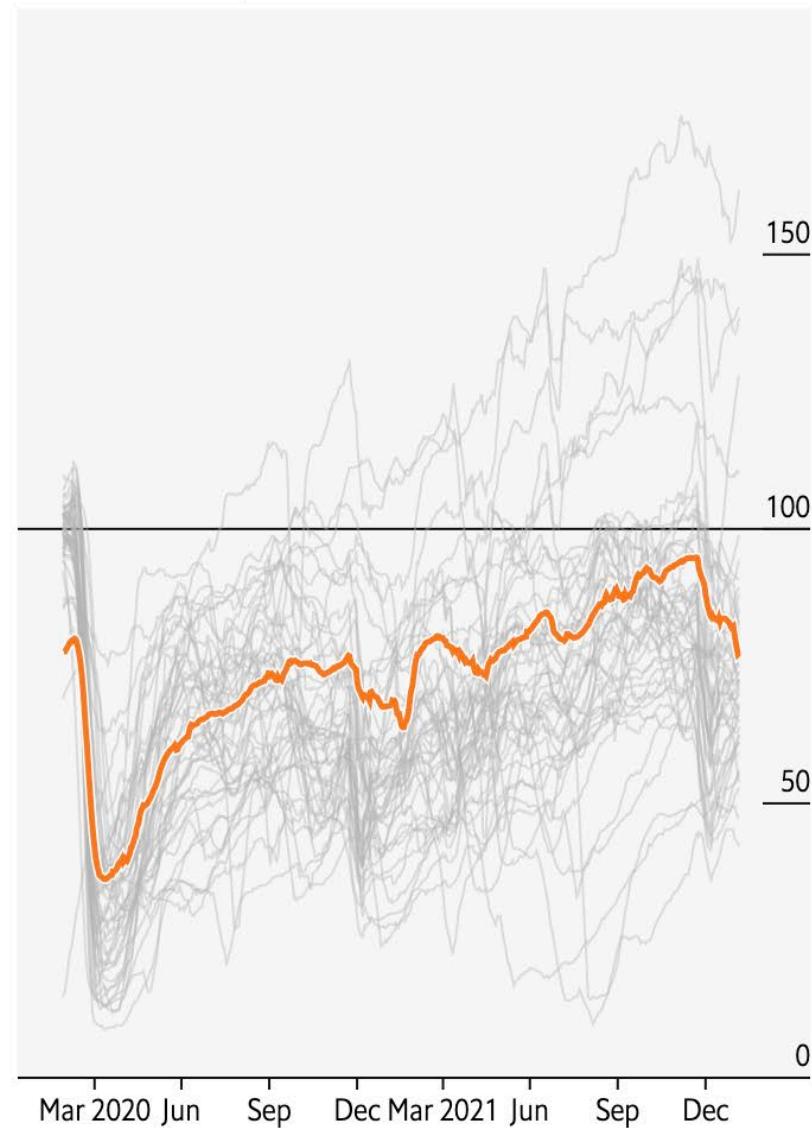
Source: <https://www.economist.com/graphic-detail/tracking-the-return-to-normalcy-after-covid-19>

Case Study: Global Normalcy Index from The Economist

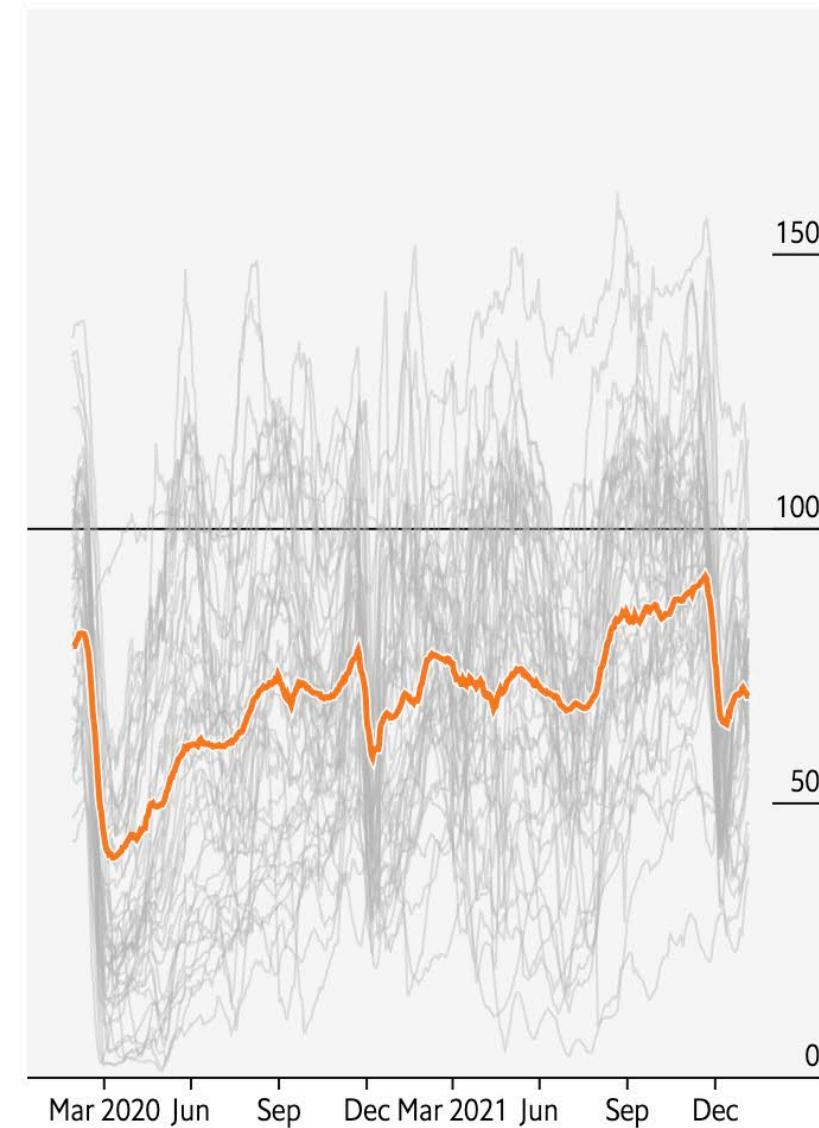
Flights



Public transport

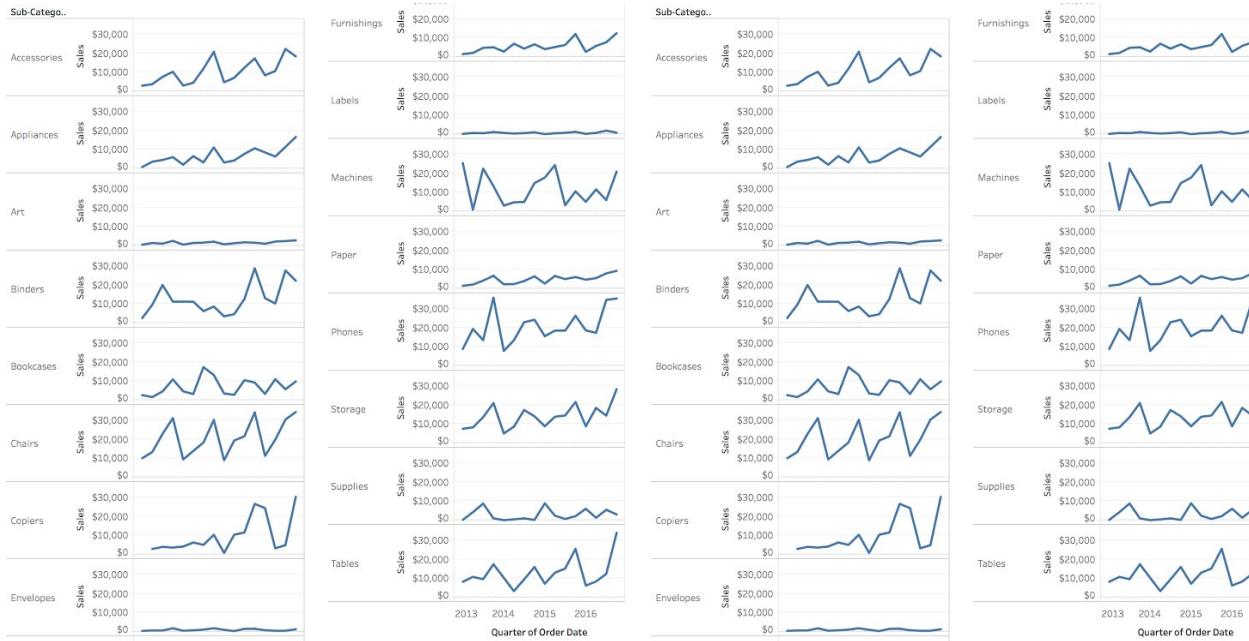


Road traffic



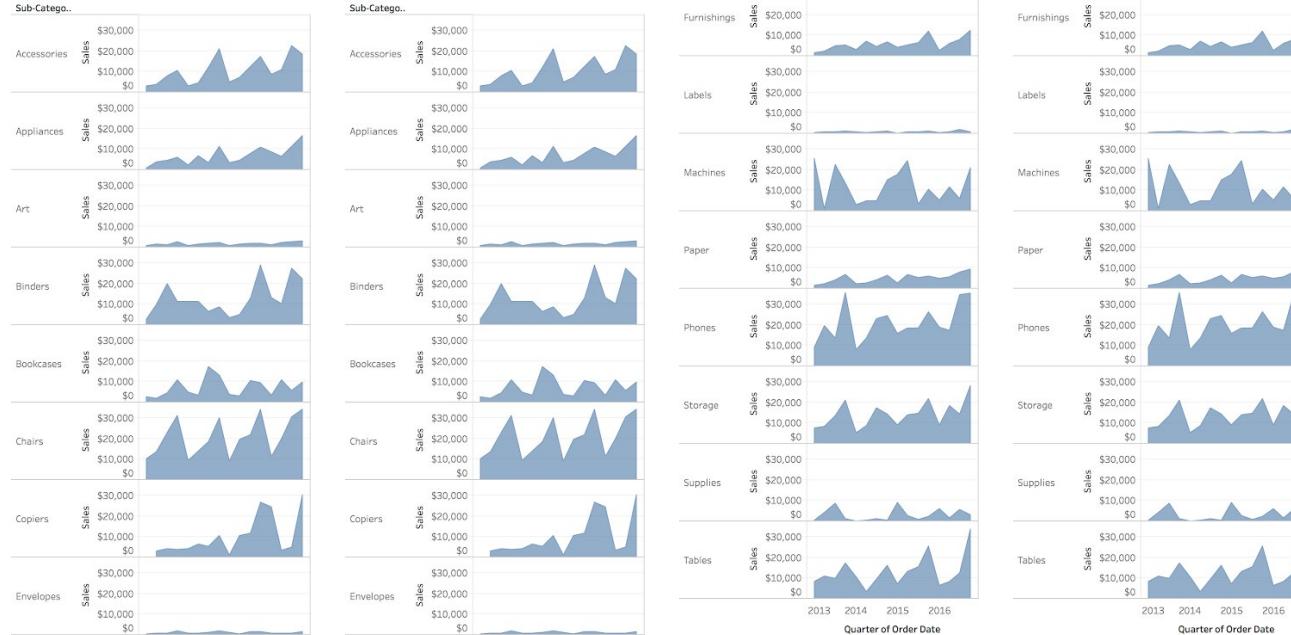
Source: <https://www.economist.com/graphic-detail/tracking-the-return-to-normalcy-after-covid-19>

Other forms



Faceting/Small multiple

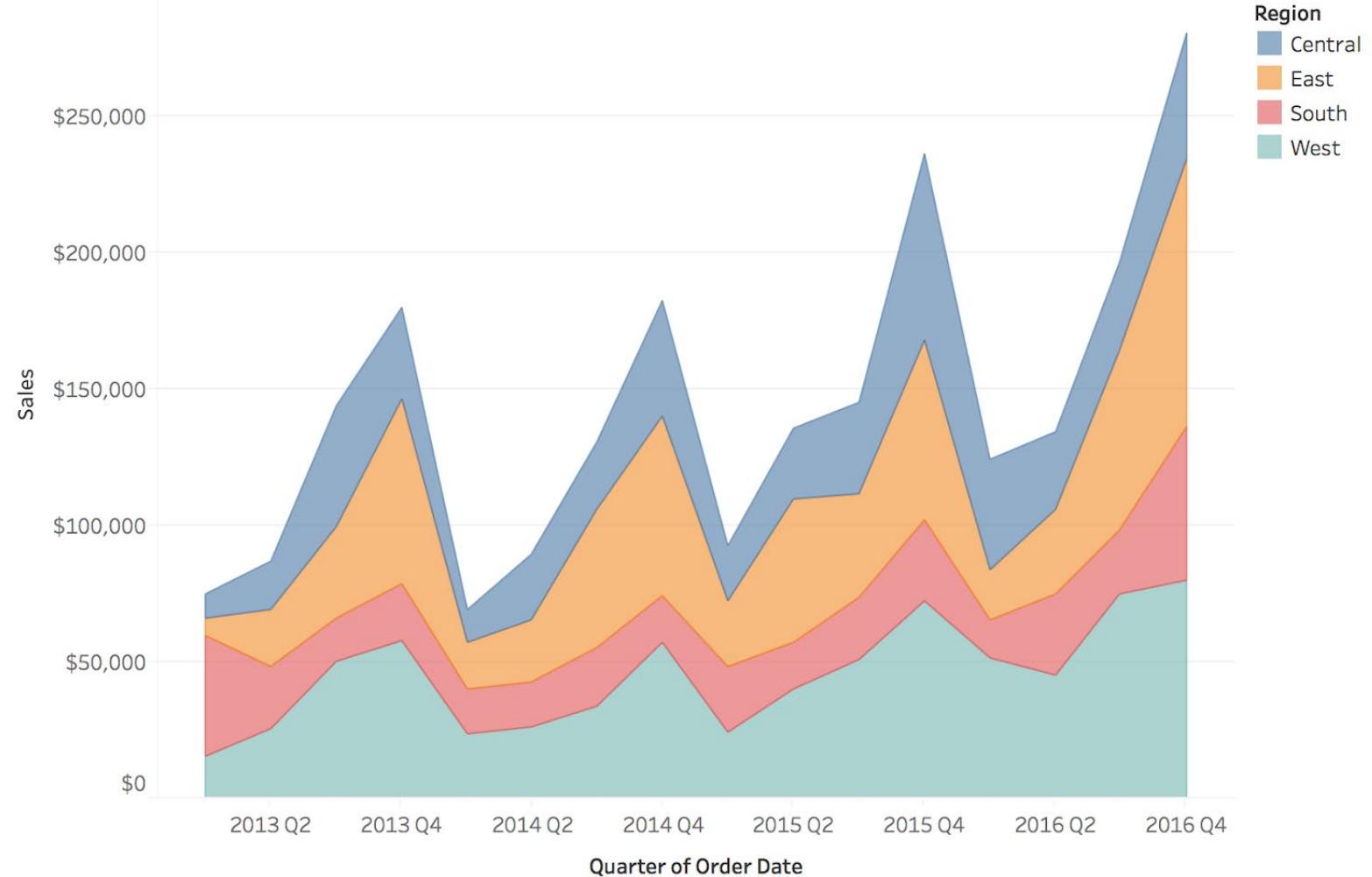
Other forms



Faceting/Small multiple
Area plot

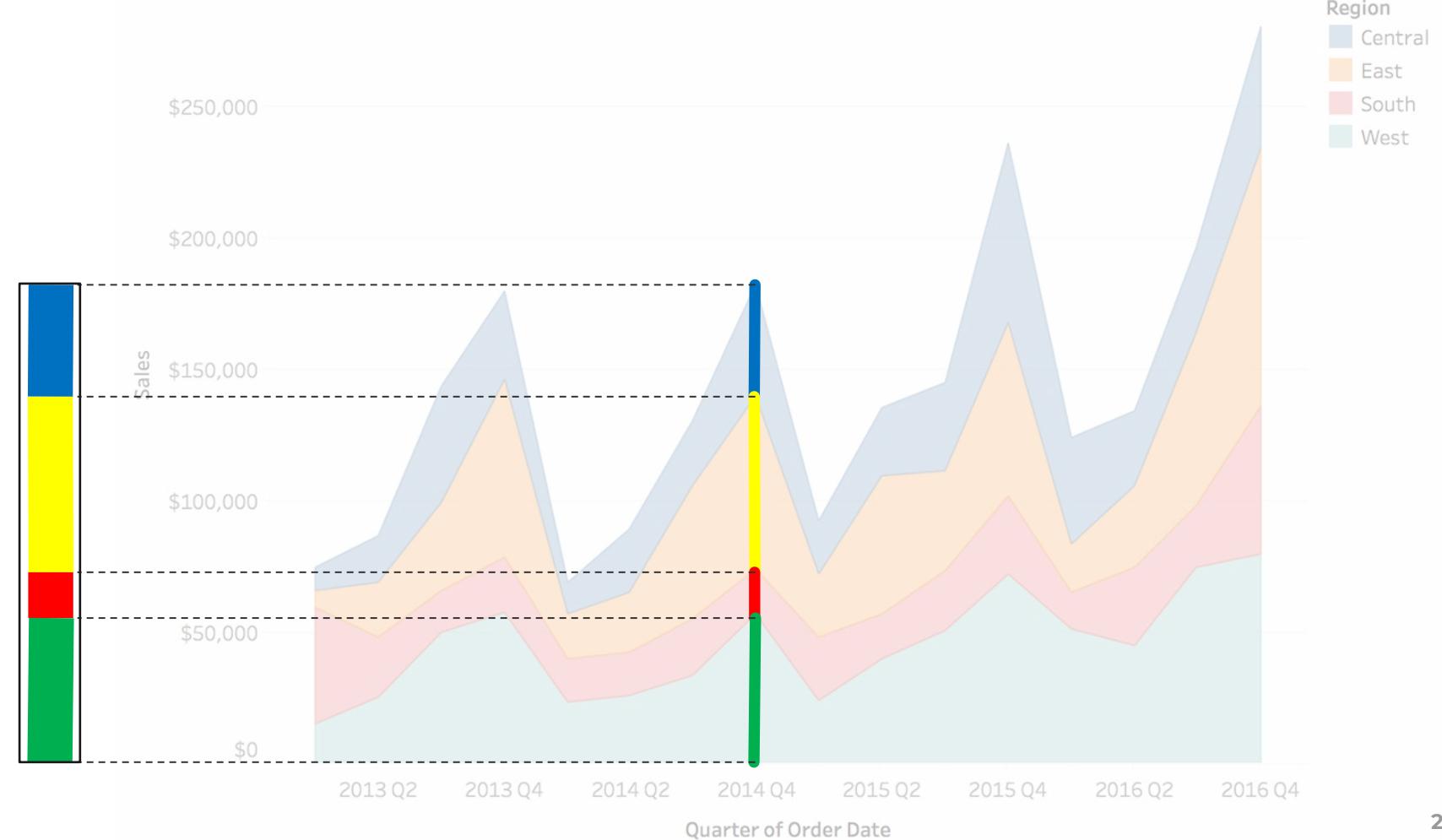
Stacked Area Chart

- Useful to depict proportion change over time.



Stacked Area Chart

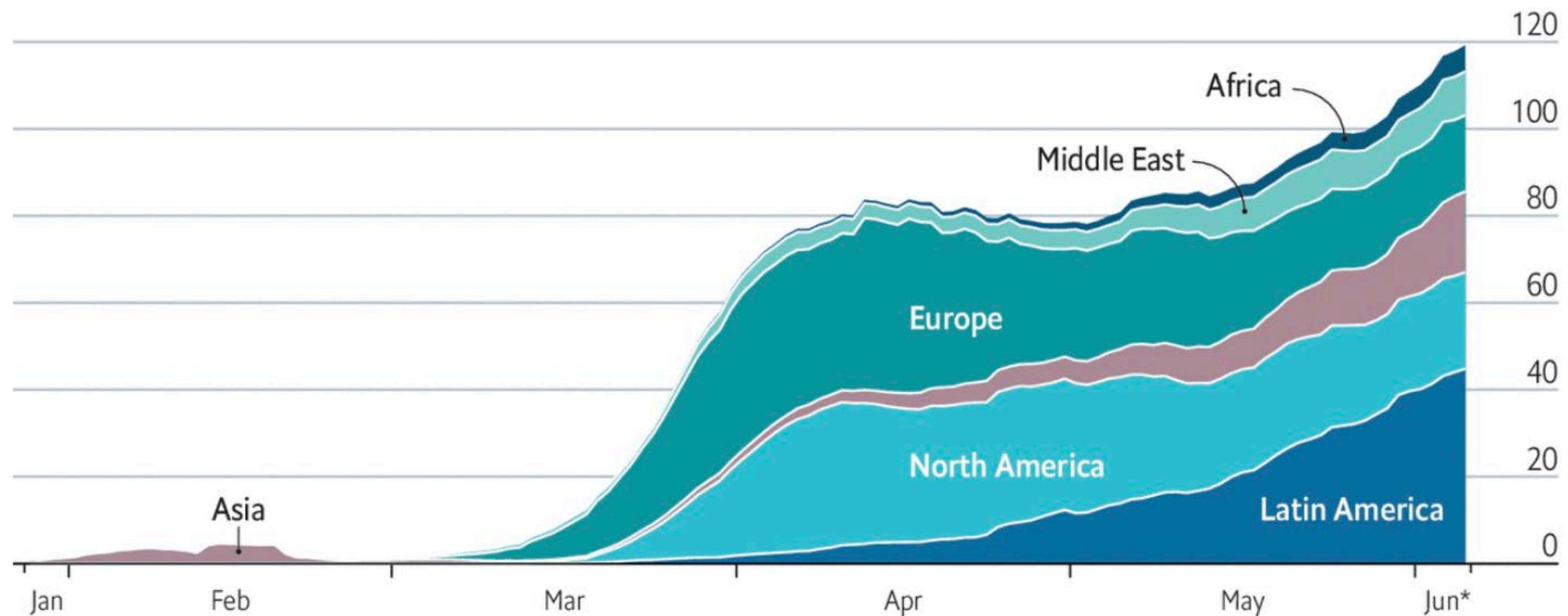
Data corresponds
to the same time
point is stacked.



Going south

New confirmed cases of covid-19 by region, '000

2020, seven-day moving average



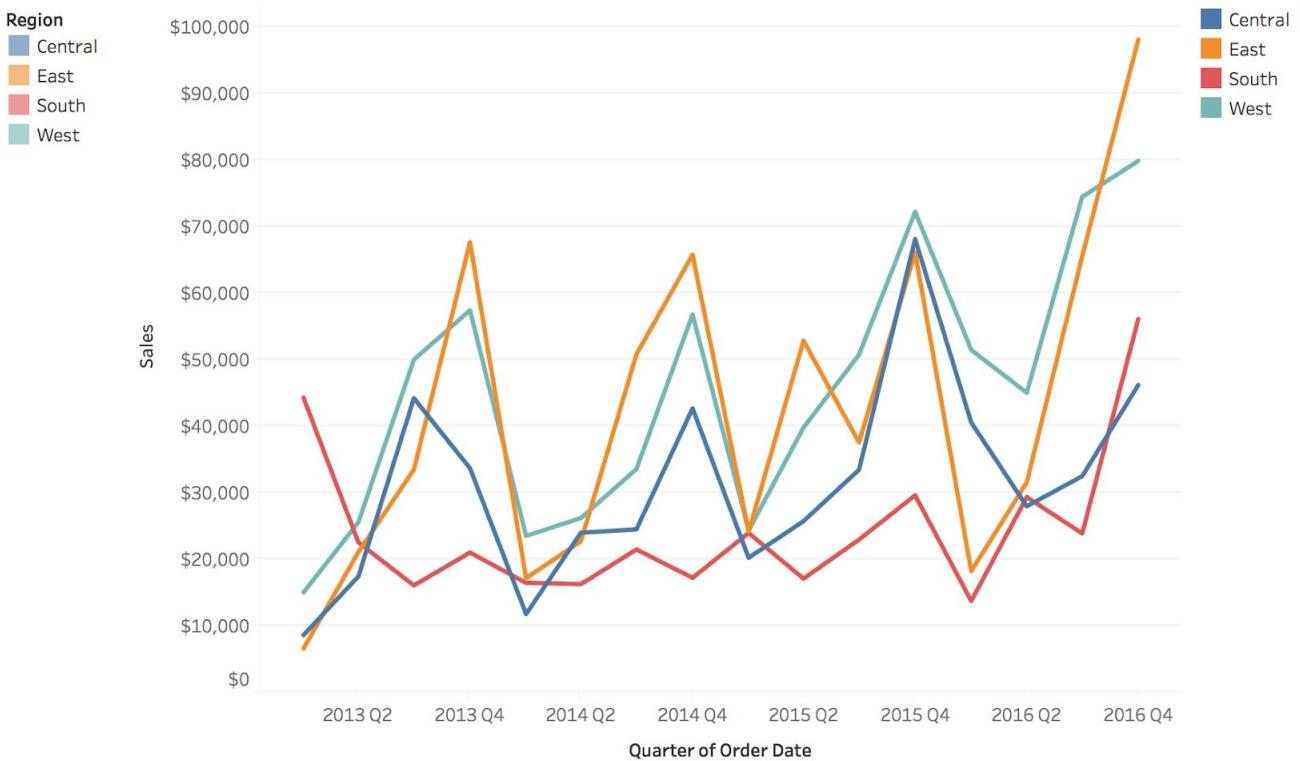
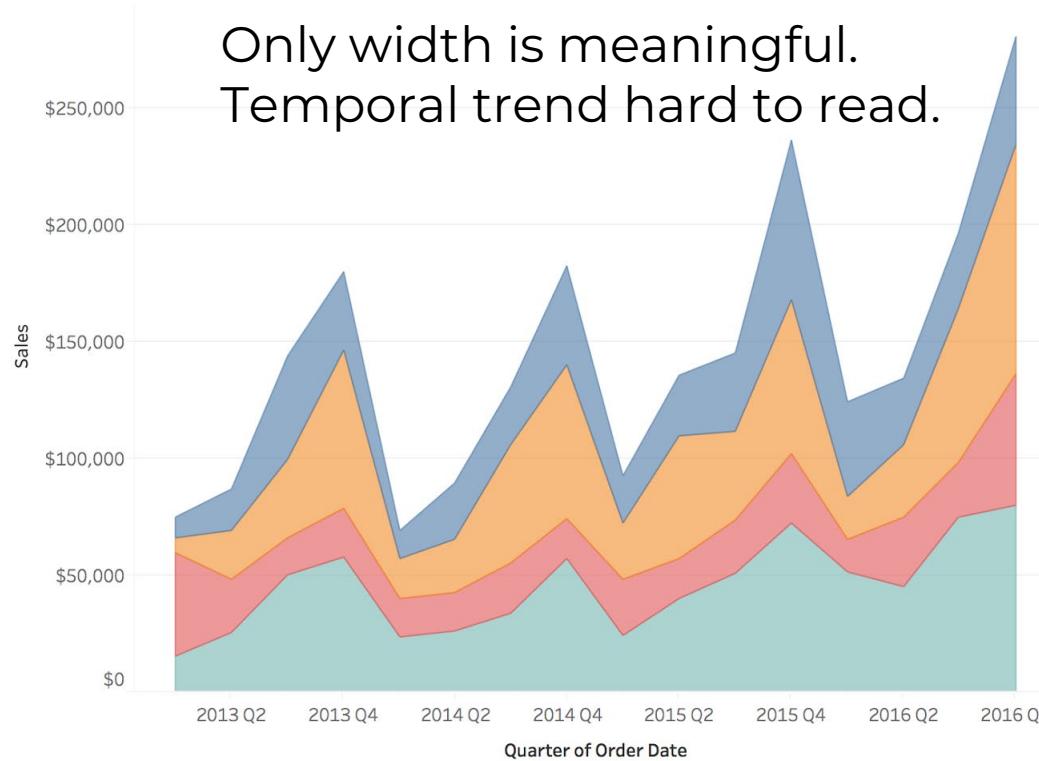
Source: Johns Hopkins University CSSE

*To June 5th

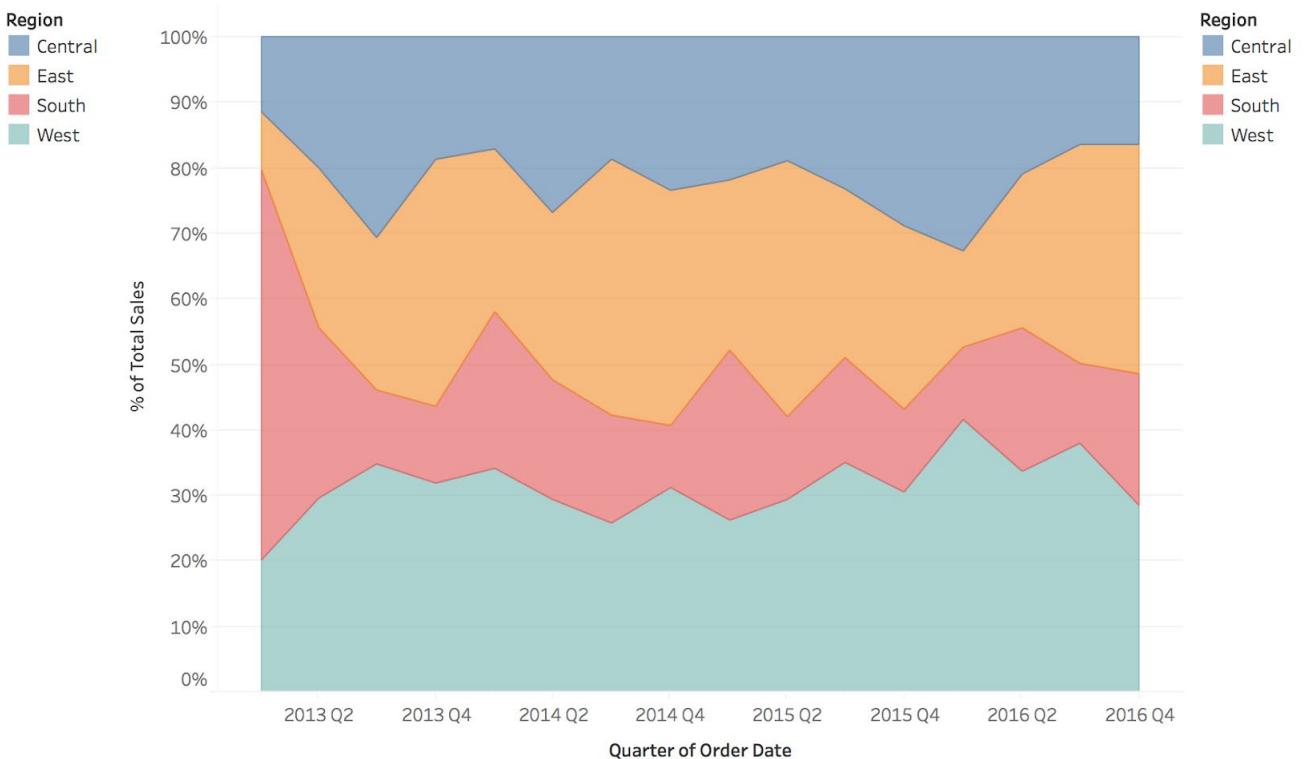
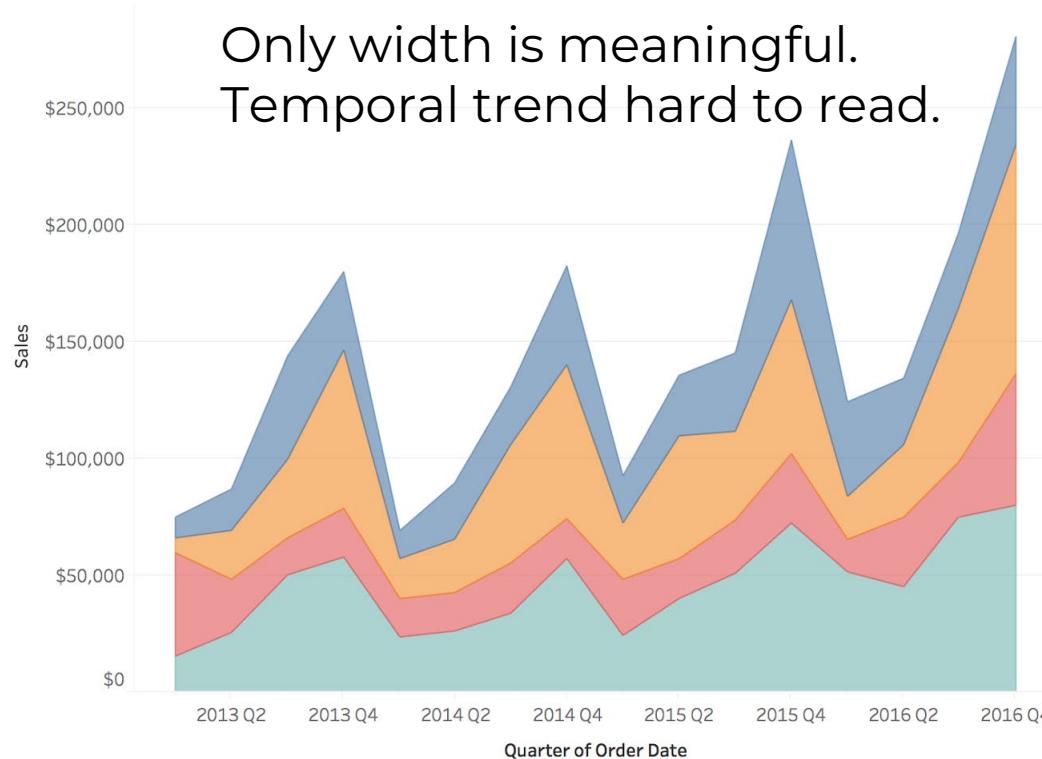
The Economist

Source: <https://www.economist.com/graphic-detail/2020/06/10/coronavirus-cases-are-surgeing-in-latin-america>

Stacked Area Chart

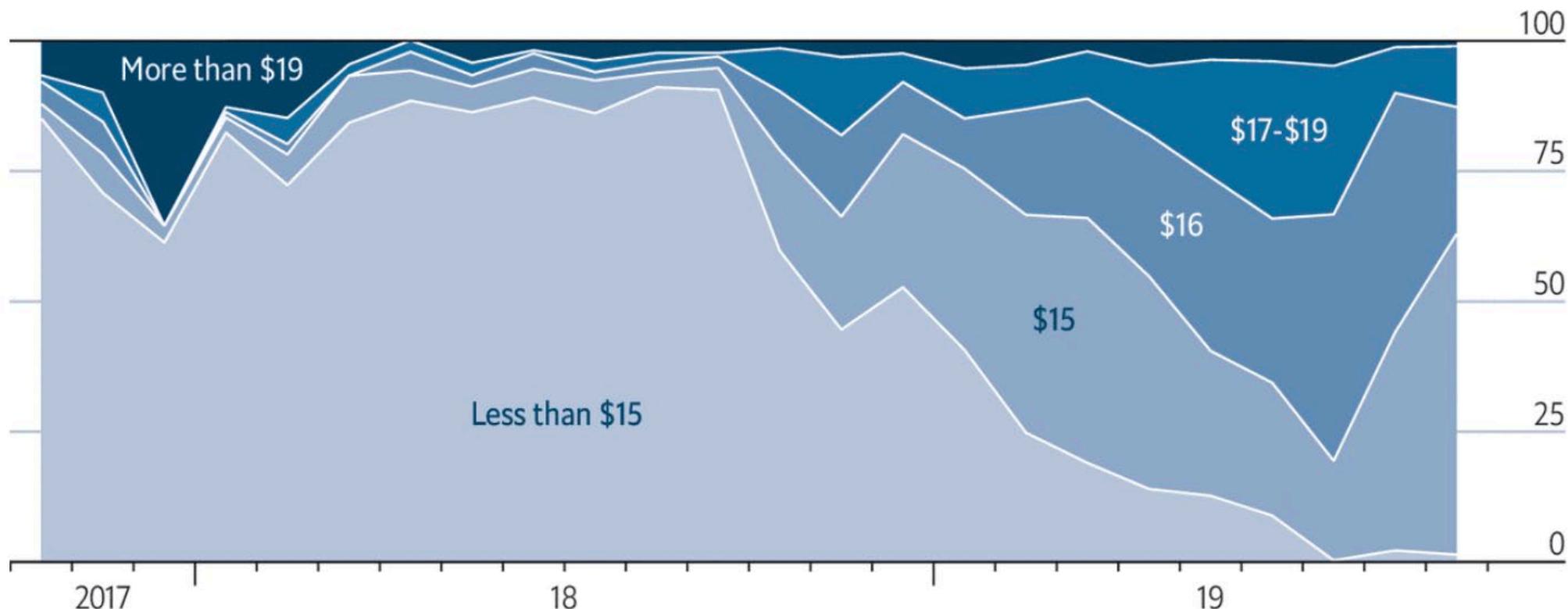


Percent Area Chart



The buck starts here

United States, Amazon job adverts by hourly wage*, %

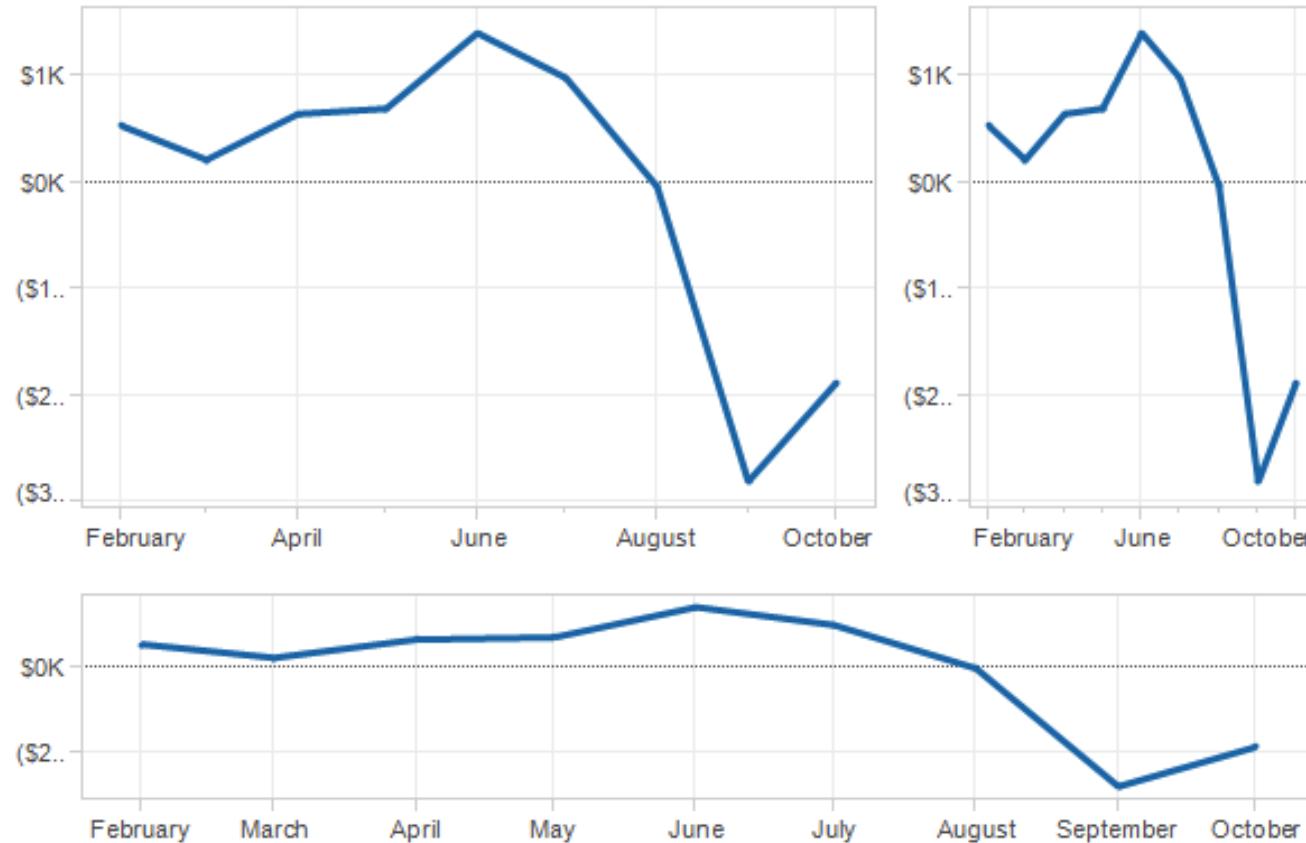


Source: "Spillover effects from voluntary employer minimum wages",
by Ellora Derenoncourt, Clemens Noelke and David Weil, 2021

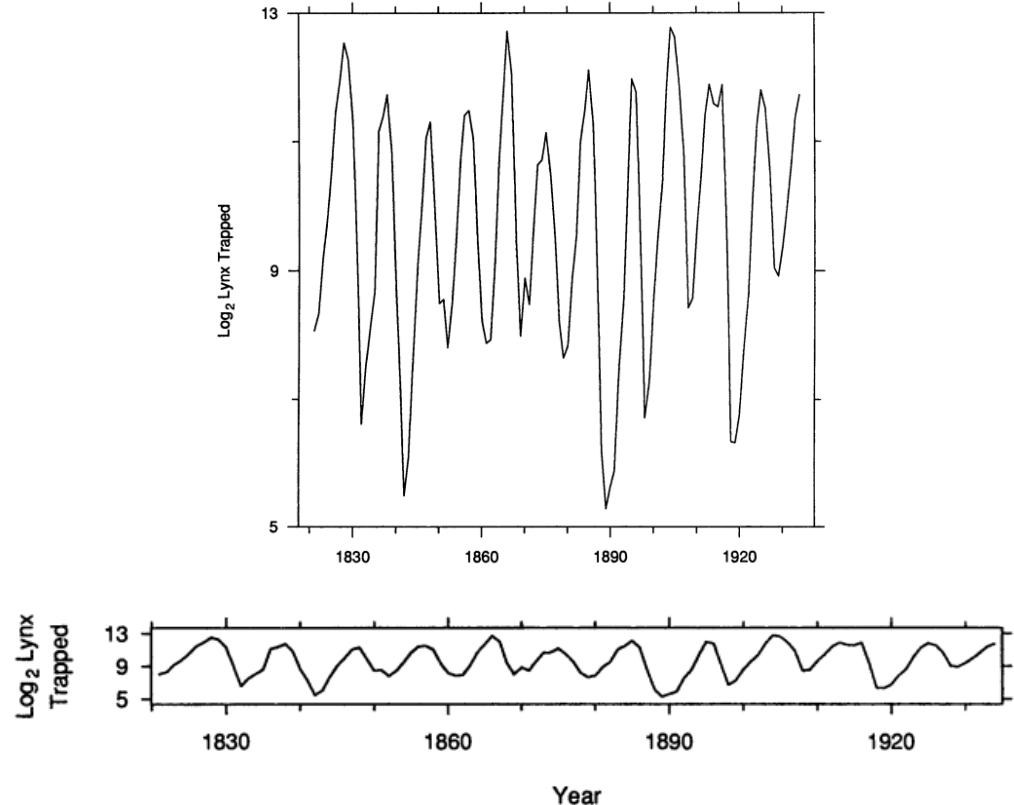
*Among ads that include job title, location and pay

The Economist

Aspect Ratio Matters



Banking to 45°



The Shape Parameter of a Two-Variable Graph

WILLIAM S. CLEVELAND, MARYLYN E. MCGILL, and ROBERT MCGILL*

The shape parameter of a two-variable graph is the ratio of the horizontal and vertical distances spanned by the data. For at least 70 years this parameter has received much attention in writings on data display, because it is a critical factor on two-variable graphs that show how one variable depends on the other. But despite the attention, there has been little systematic study. In this article the shape parameter and its effect on the visual decoding of slope information are studied through historical, empirical, theoretical, and experimental investigations. These investigations lead to a method for choosing the shape that maximizes the accuracy of slope judgments.

KEY WORDS: Statistical graphics; Aspect ratio; Graphical perception; Visual perception.

1. INTRODUCTION

Figure 1 gives data on the amount of solar radiation penetrating sea water at different depths: the filled circles are actual measurements and the open circles are estimates (Littler, Littler, Blair, and Norris 1985). The dashed rectangle, which is the *data rectangle*, shows the maximum and minimum values of the data along both the vertical scale and the horizontal scale. Suppose the height of the data rectangle of a graph is h centimeters (cm) and the width is w cm. The *shape parameter*, or *shape*, of the graph is h/w . In Figure 1 the shape is .85.

Shape is a critical factor for two-variable graphs that show the dependence of y on x . Figures 2 and 3 show the Canadian lynx data (Elton and Nicholson 1942), a time series of substantial historical interest because of the many analyses it has inspired (Campbell and Walker 1977). In Figure 2 the shape parameter is 1, and in Figure 3—the shape is .074. In Figure 2 it is impossible to see a critical property of the data that can be seen in Figure 3—the number of lynx trappings rises more slowly than it declines. As we shall explain, this phenomenon of graphical perception—the better perception of the lynx rise and fall in Figure 3—is a result of the effect that the change in shape has on our judgments of slopes.

It is hard to find a statistical-graphics topic more universally discussed than shape. But despite the importance of this parameter and the ubiquity of comments on it, there has been almost no systematic study. In this article we study shape in several ways. Section 2 defines objects critical to the study. In Section 3, comments and recommendations from a sample of twentieth-century writings on graphical data display are reviewed. In Section 4, measurements of the shapes of 481 graphs are analyzed. In Section 5, observations are made about our processing of slope information on a graph; the discussion is critical to the subsequent study of shape and slope, because it determines in a fundamental way how the problem is ap-

proached. Section 6 contains theory; we hypothesize that the accuracy of slope judgments depends on what is called *orientation resolution*. The dependence of orientation resolution on other quantities is then investigated. Section 7 describes an experiment that probes the hypothesis of Section 6. In Section 8, the results of the theory and experimentation are used to develop an algorithm for choosing the value of the shape parameter that maximizes both the resolution and accuracy of slope judgments. Section 9 concludes the article with a discussion of the general applicability of our methods, including the significance (for the analysis of the lynx data) of the phenomenon observed in Figure 3.

2. DEFINITIONS

Suppose we have a two-variable graph showing how y depends on x . In such a case, the decoding of quantitative information encoded by the slopes of line segments is a fundamental visual task that we perform. The reason, of course, is that the slopes encode the rate of change of y as a function of x , and decoding the rate of change is important for understanding the dependence of y on x .

2.1 Actual Line Segments and Virtual Line Segments

The line segments on a graph that encode slope information might be *actual line segments* drawn on the graph. For example, the lynx numbers in Figures 2 and 3 are graphed by connecting successive yearly values by line segments. We visually decode the slopes of these segments to infer the local rate of change of the lynx numbers through time. The line segments can also be superimposed on the graph by our visual system. For example, in Figure 1 we can visually superimpose segments connecting successive points on the graph to judge the local rate of change of log of radiation as a function of depth. We will follow Marr (1982) and Stevens (1978) and refer to these superimposed segments as *virtual line segments*.

2.2 Coordinate Systems

Consider a point (x, y) inside the data rectangle of a graph. Now, x and y can have the units shown on the two

* William S. Cleveland and Robert McGill are statisticians, AT&T Bell Laboratories, Murray Hill, NJ 07974. Marilyn E. McGill is President, MEM Research, Inc., Murray Hill, NJ 07974. John Chambers, Colin Mallows, and Daryl Pregibon made helpful comments on an earlier draft of this article. We are indebted to the referees, whose comments led to a substantial improvement in the exposition. Joseph Follett convinced us, from his comments on our earlier experiments in graphical perception, that showing stimuli for short time intervals is an important noise-reduction technique.

© 1988 American Statistical Association
Journal of the American Statistical Association
June 1988, Vol. 83, No. 402, Applications and Case Studies

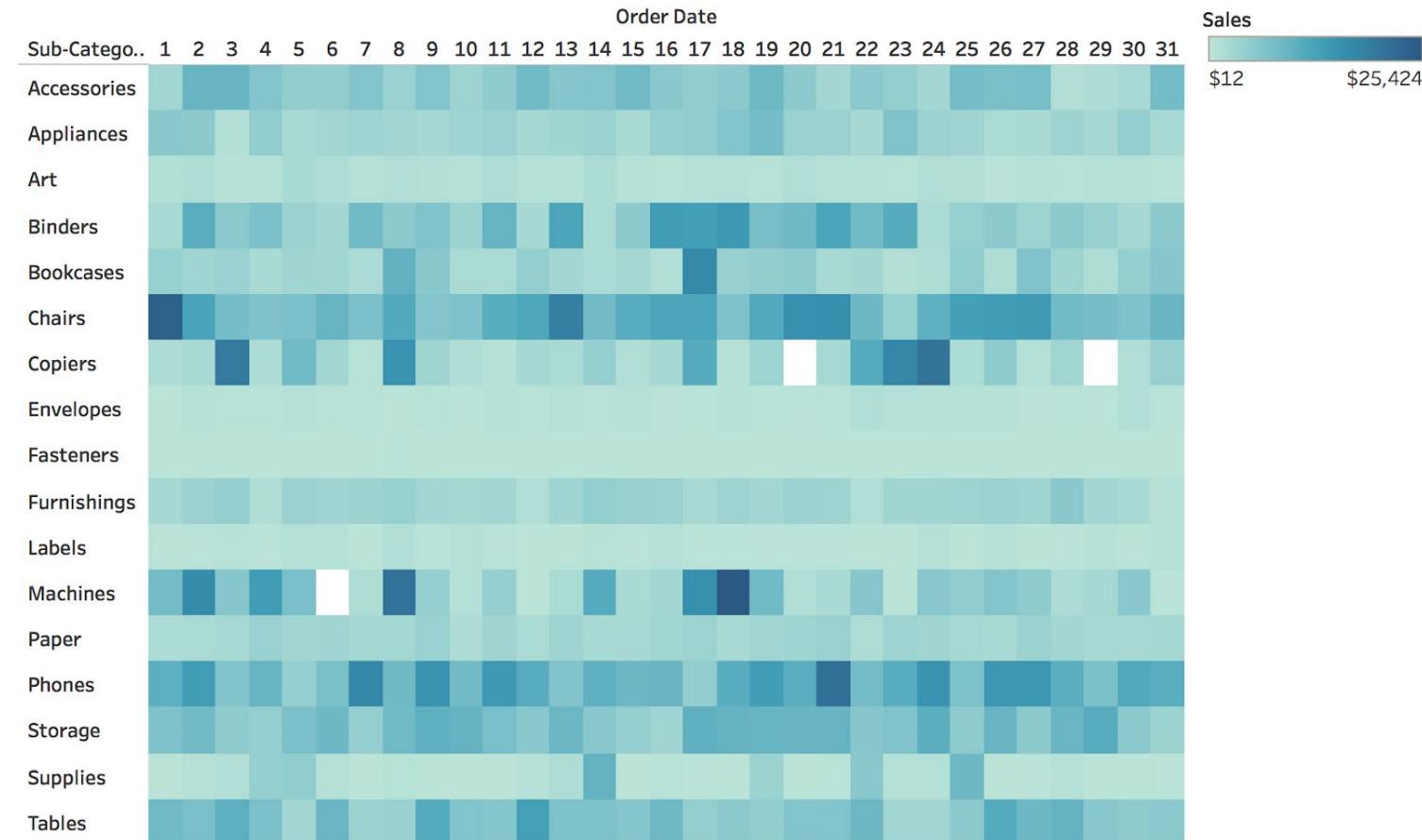
Cleveland, William S., et al.
“The Shape Parameter of a
Two-Variable
Graph.” *Journal of the
American Statistical
Association*, vol. 83, no.
402, [American Statistical
Association, Taylor &
Francis, Ltd.], 1988, pp. 289–
300,
<https://doi.org/10.2307/228843>.

Rule of Thumb:

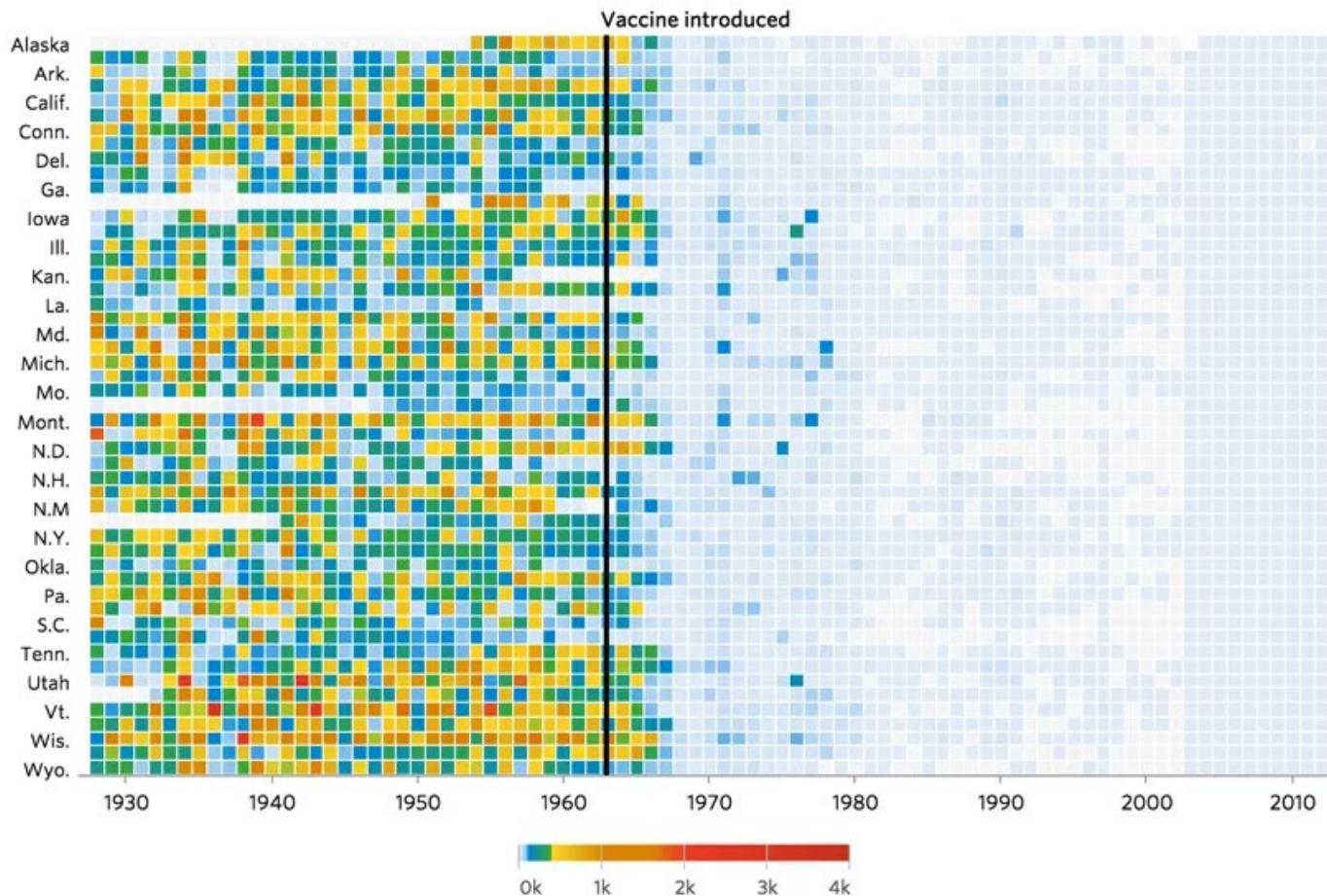
Always test different aspect ratios and see which one convey your message better.

Beyond Line Chart

Heat Maps (Matrix)

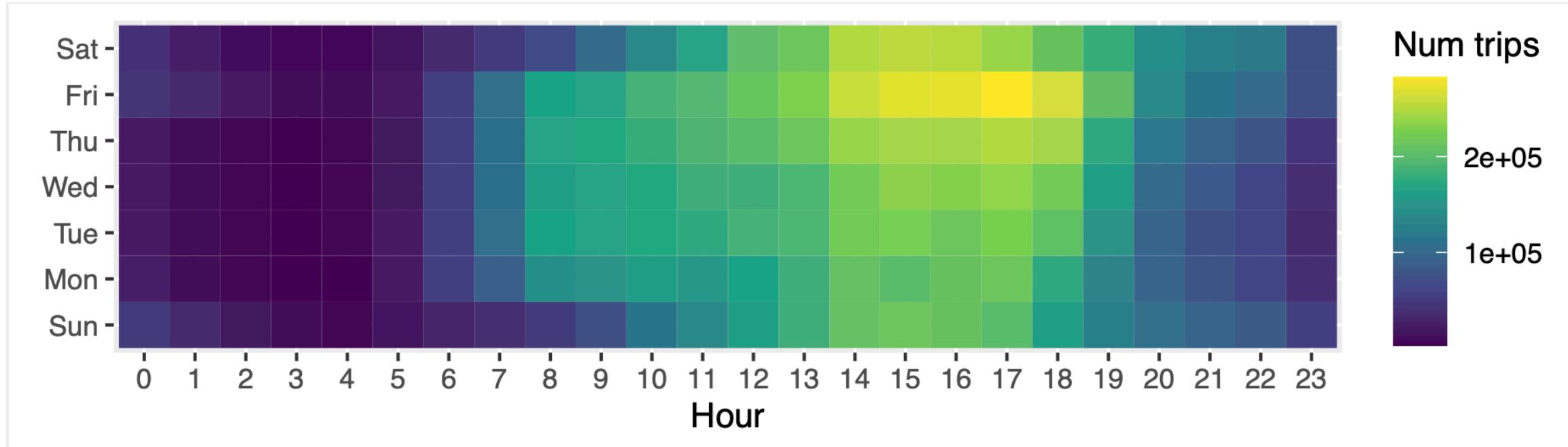


Measles

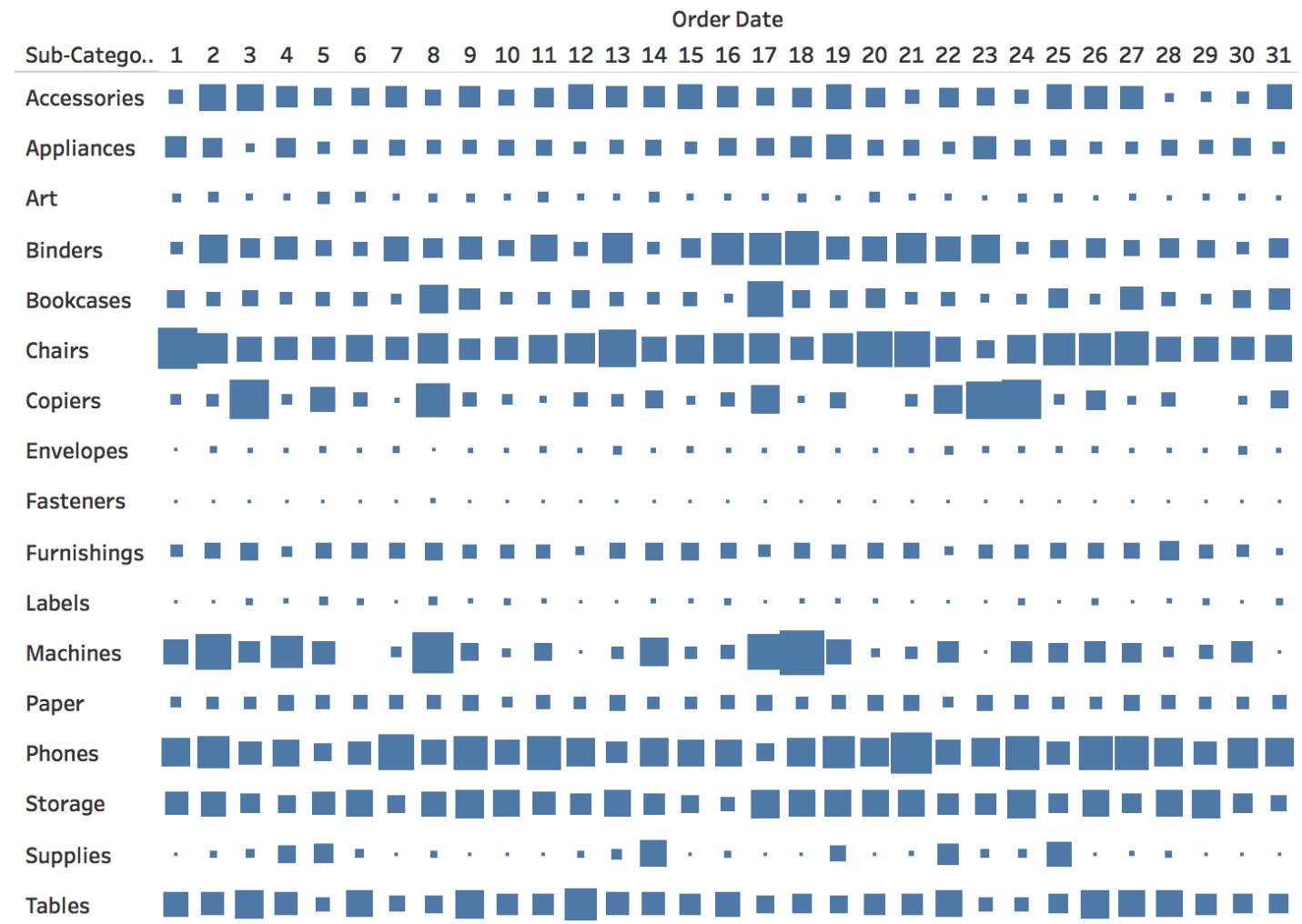


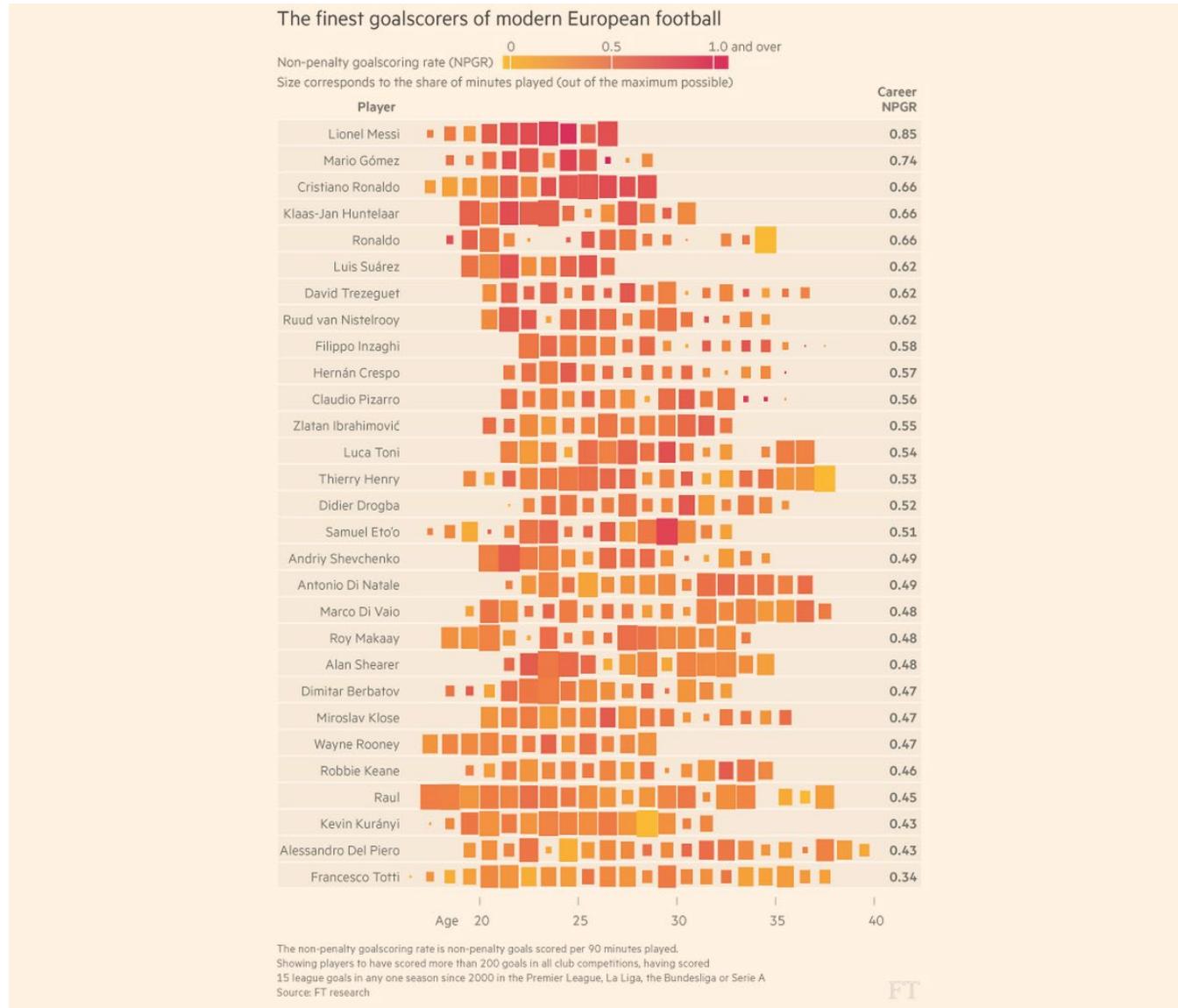
Wall Street Journal: "Battling Infectious Diseases in the 20th Century: The Impact of Vaccines"

Yellow Taxi Trips in NYC



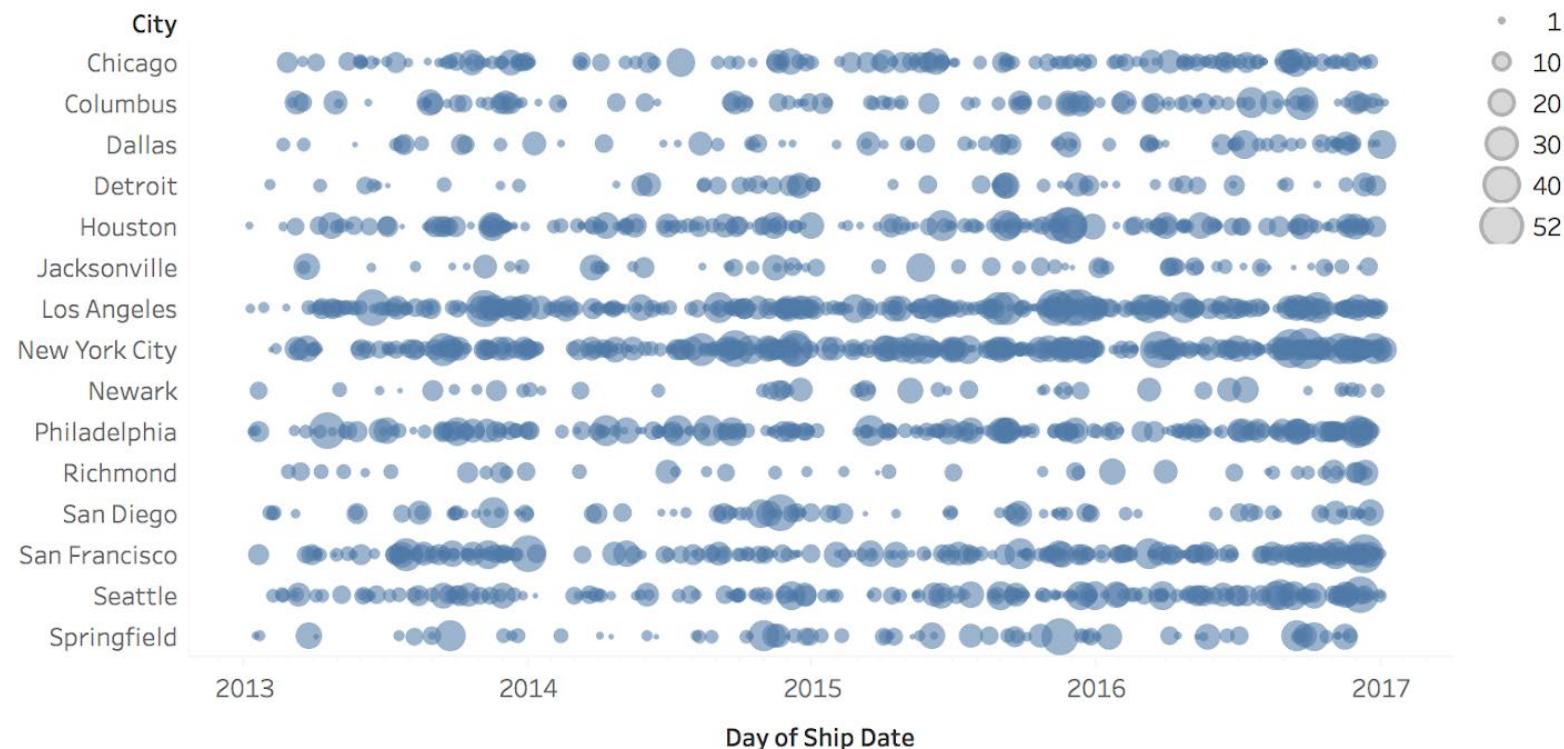
PART 02



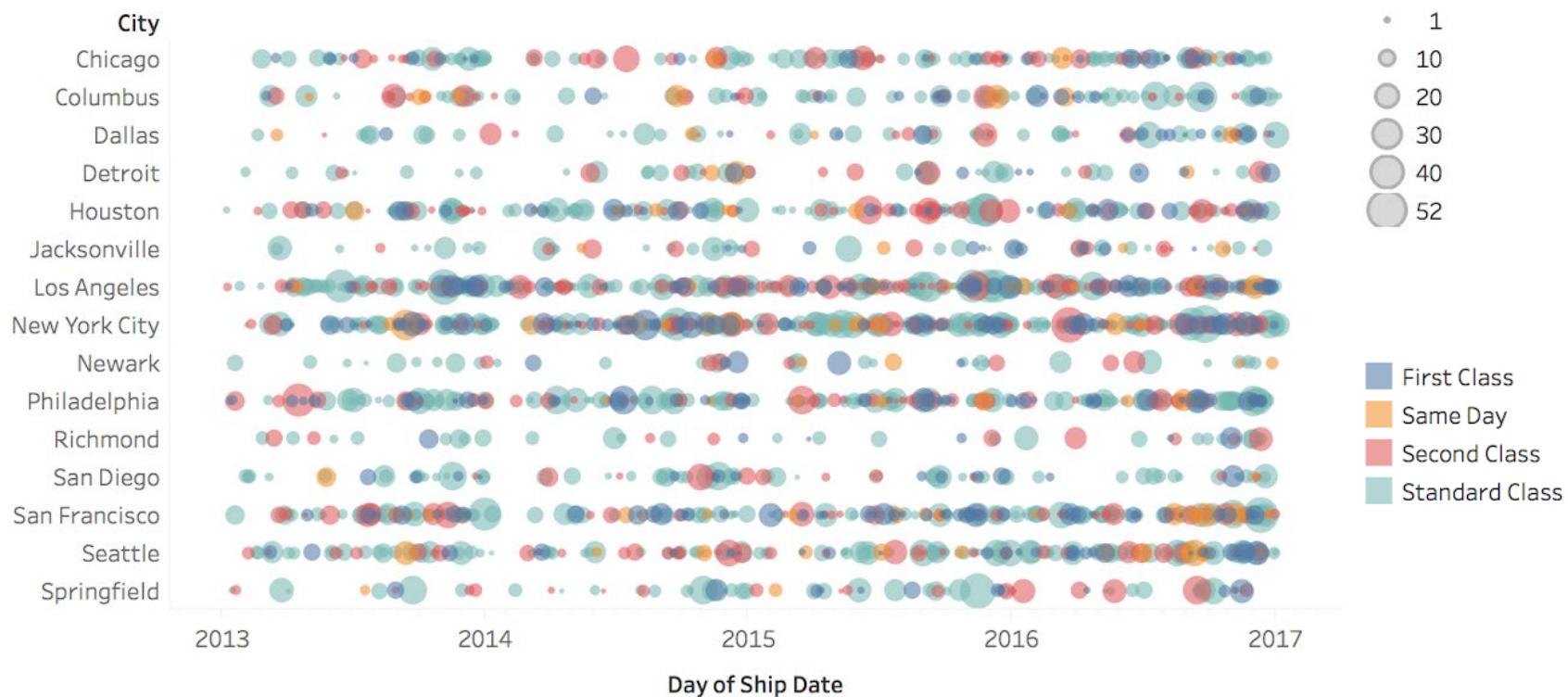


Visualize Event Data

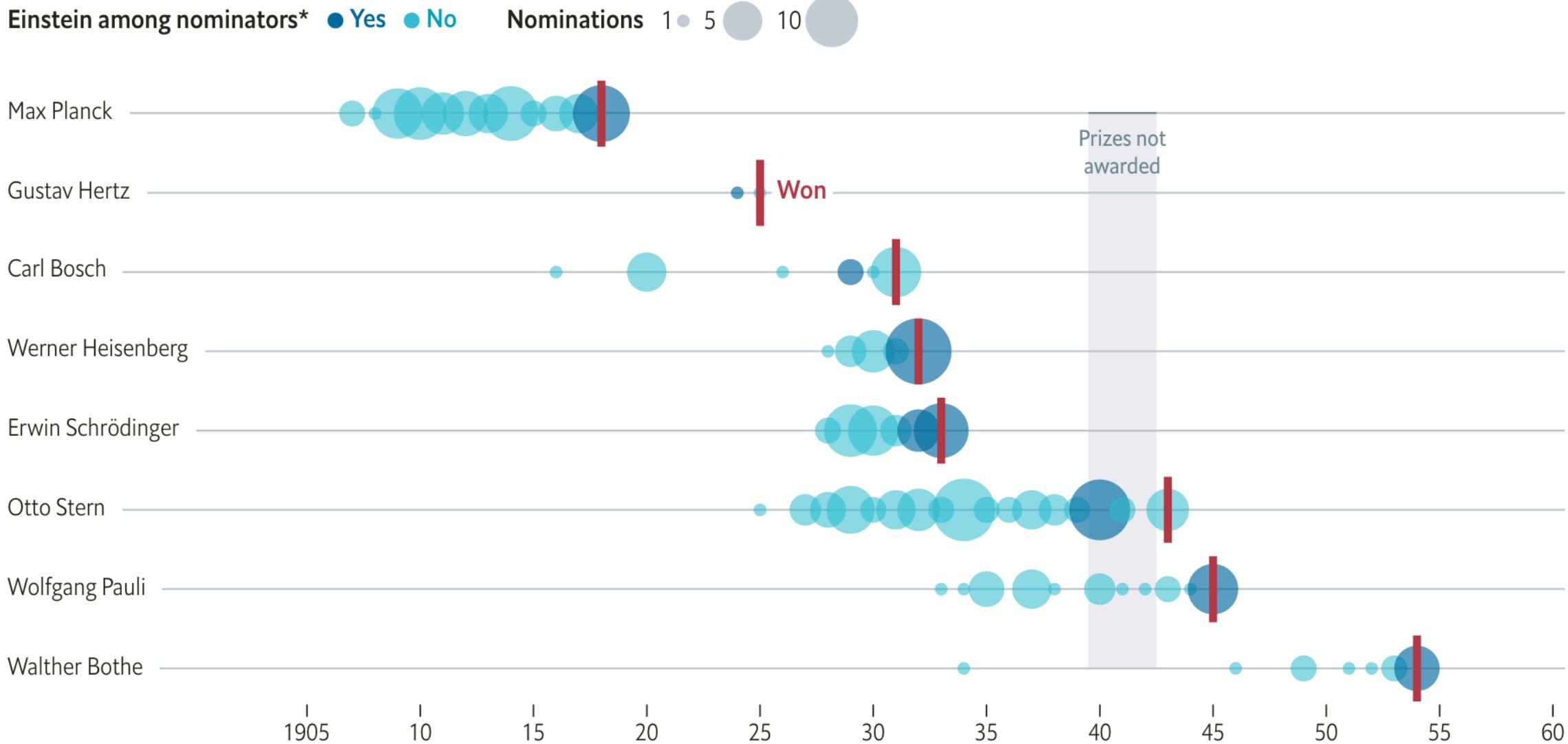
Bubble Plot (Punch Card)



Bubble Plot (Punch Card)



Candidates nominated by Albert Einstein usually won within a few years



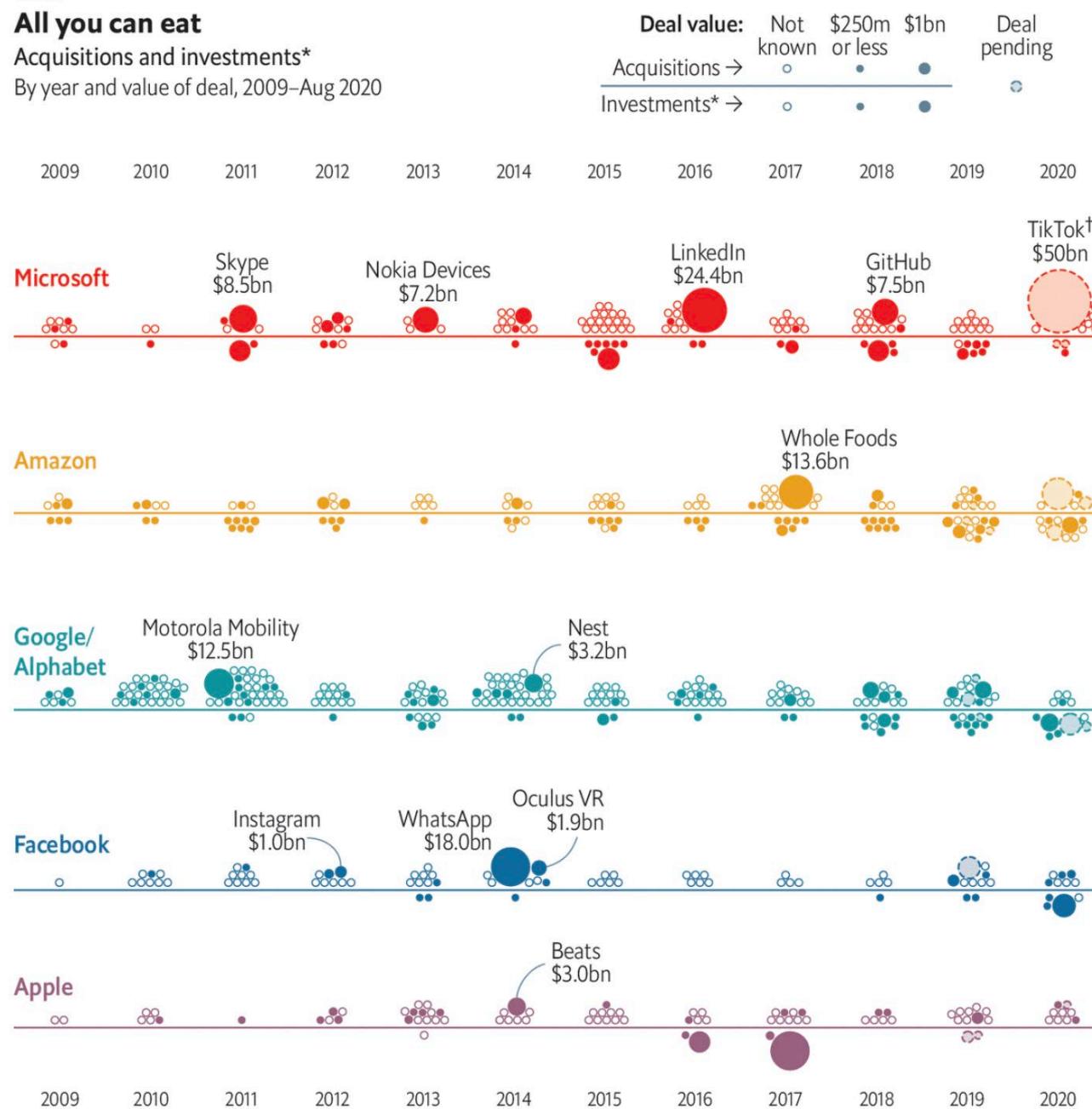
*For prizes that were given a year late, nominations are back-dated to the official year of the award. Three candidates not shown

Source: <https://www.economist.com/graphic-detail/2021/10/09/the-best-way-to-win-a-nobel-is-to-get-nominated-by-another-laureate>

All you can eat

Acquisitions and investments*

By year and value of deal, 2009–Aug 2020



Sources: Bloomberg; *The Economist*

The Economist

*Partial investment in a company, usually as part of a consortium; value shown is the total value of the acquisition, not the share owned by a particular company
†Estimated value

Case Study:

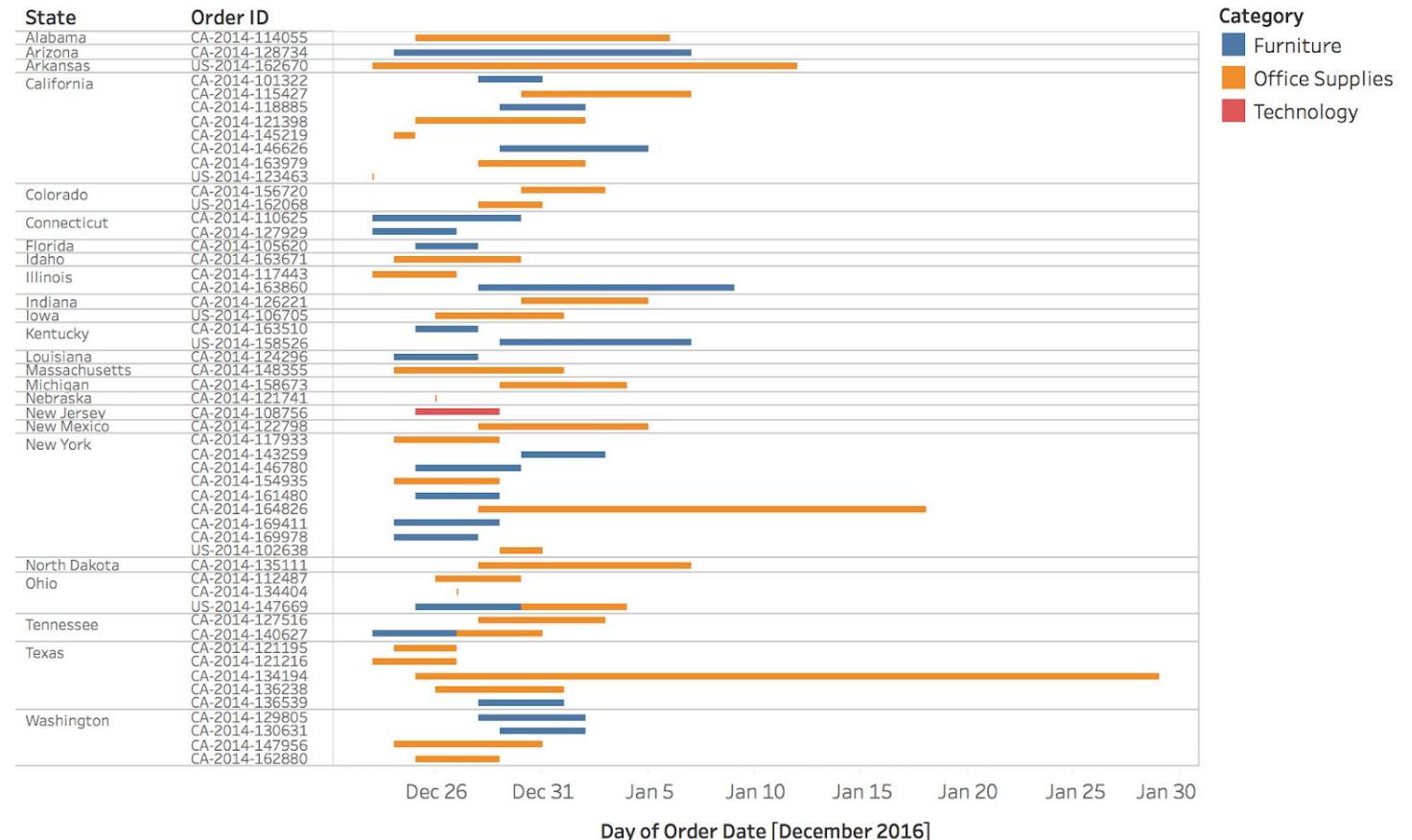
Microsoft's proposed purchase of TikTok would be its biggest yet

The Economist
Aug 4, 2020

Source: <https://www.economist.com/graphic-detail/2020/08/04/microsofts-proposed-purchase-of-tiktok-would-be-its-biggest-yet>

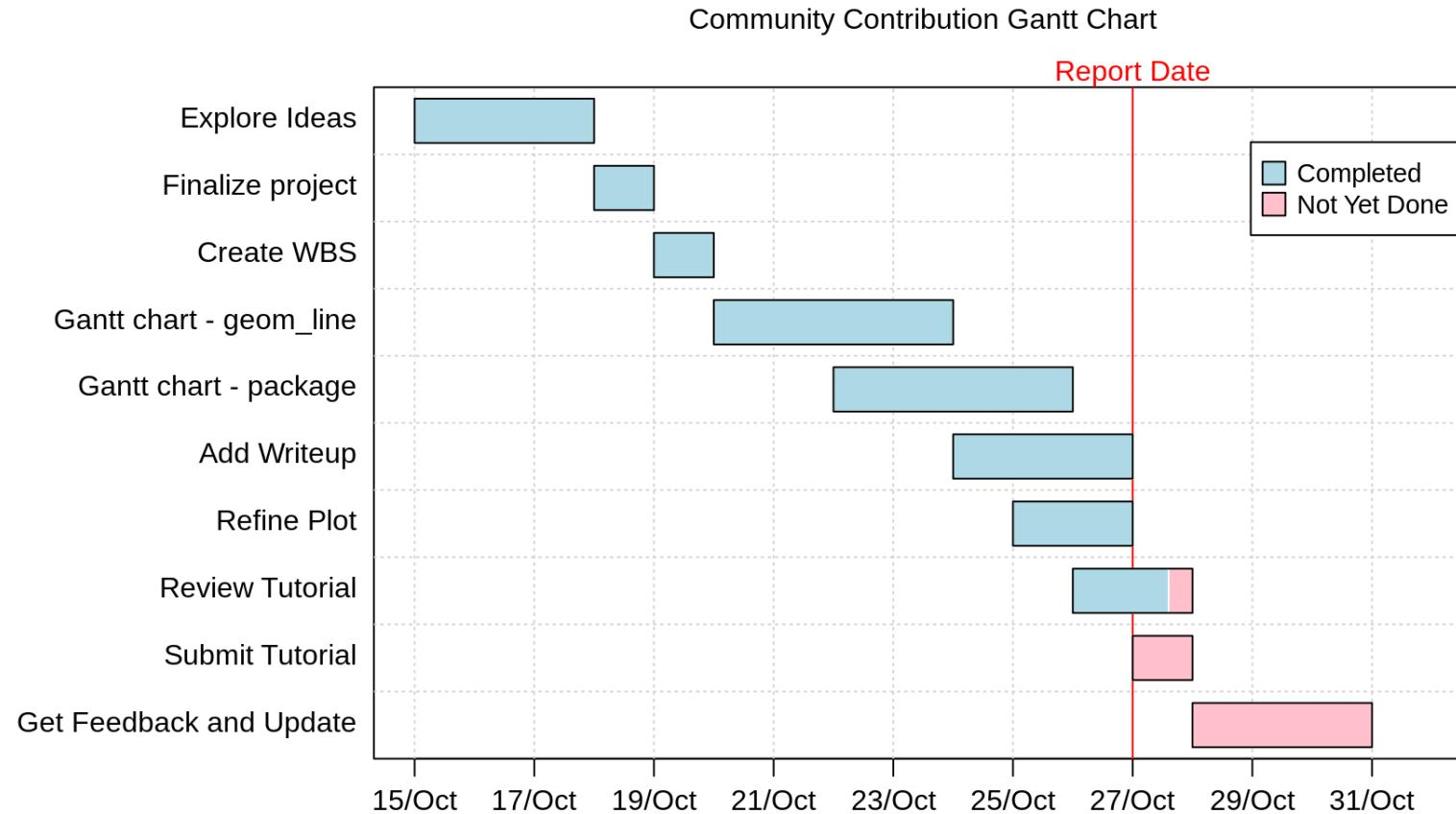
Visualize Event with Duration

Gantt Chart



Henry Gantt

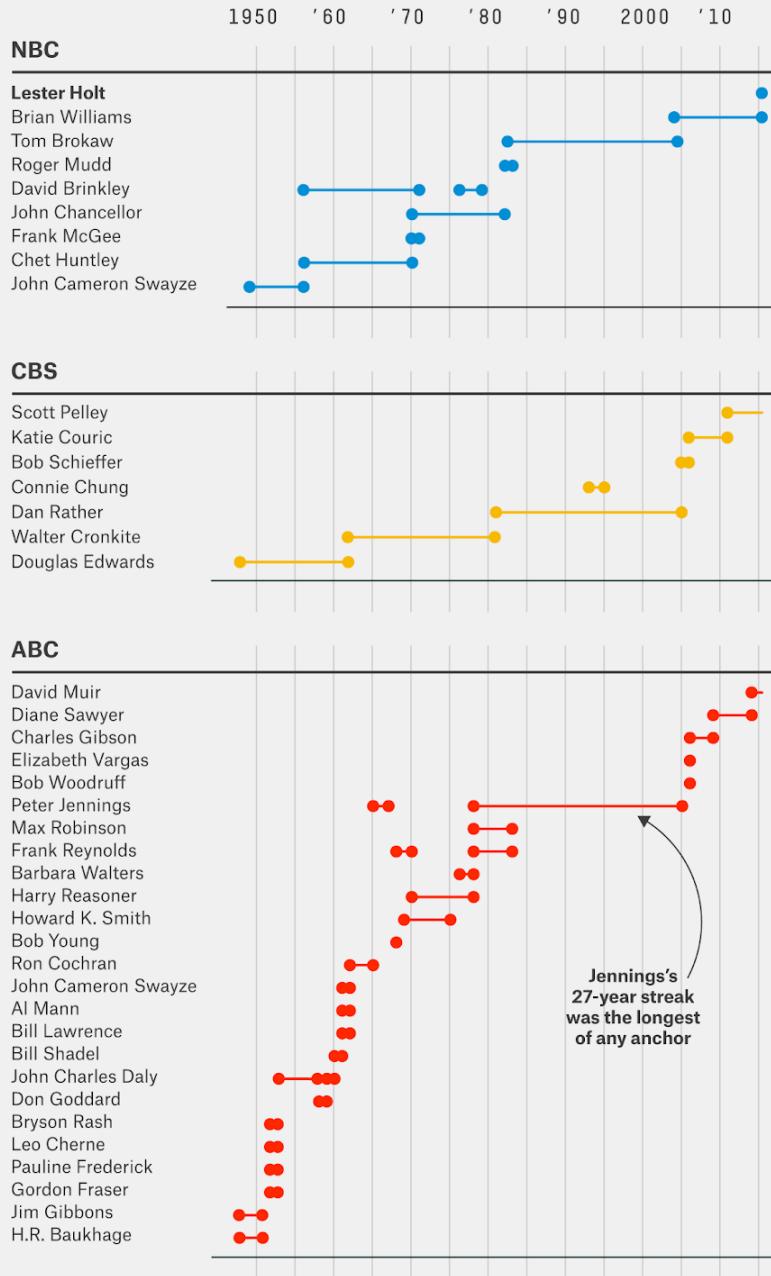
Gantt Chart



Ranged Dot Plot Lollipop Chart

Source: <https://fivethirtyeight.com/features/brian-williams-has lasted-longer-than-most-in-nbc-and-cbs-anchor-chair/>

The Lifespan Of An Evening News Anchor
News anchor tenures on NBC, CBS and ABC since 1948

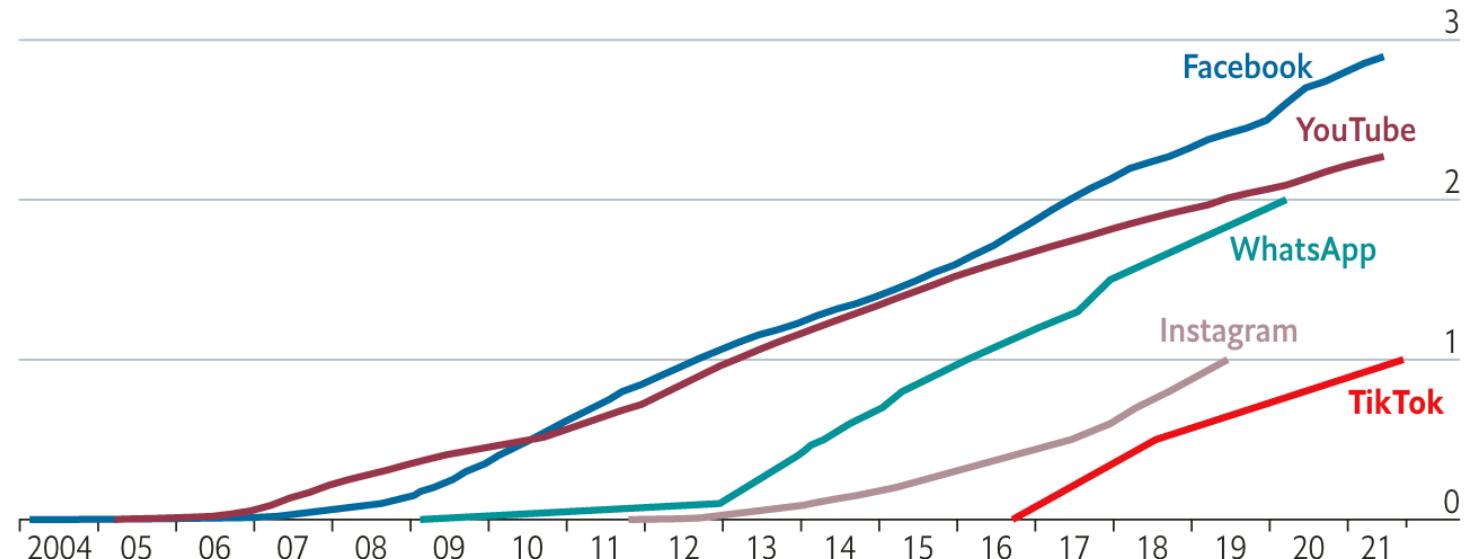


Case Study:

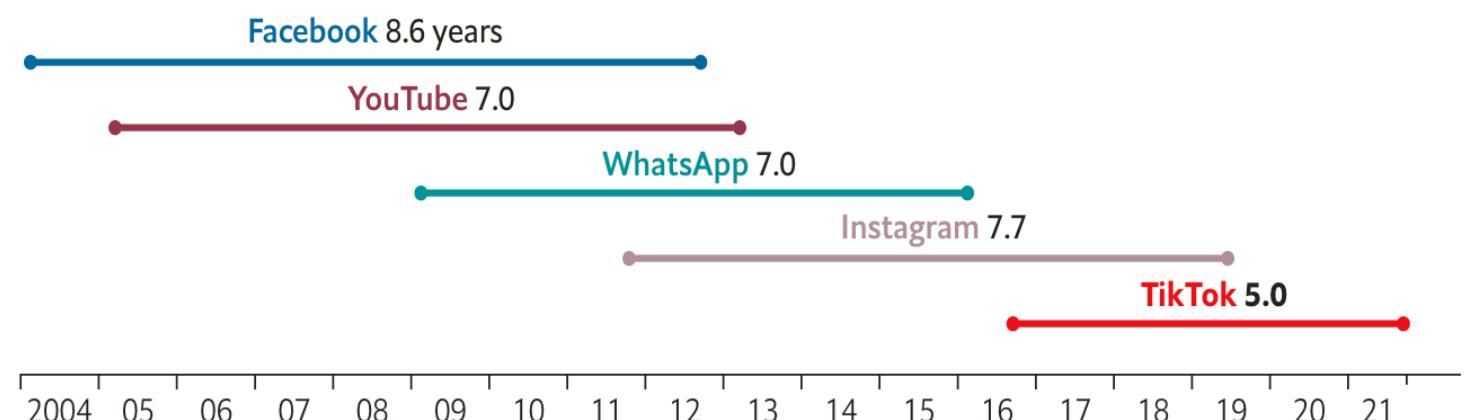
TikTok's rapid growth shows the potency of video

The Economist
Oct 7, 2021

Social media platforms, monthly active users, bn



Time from launch to 1bn users

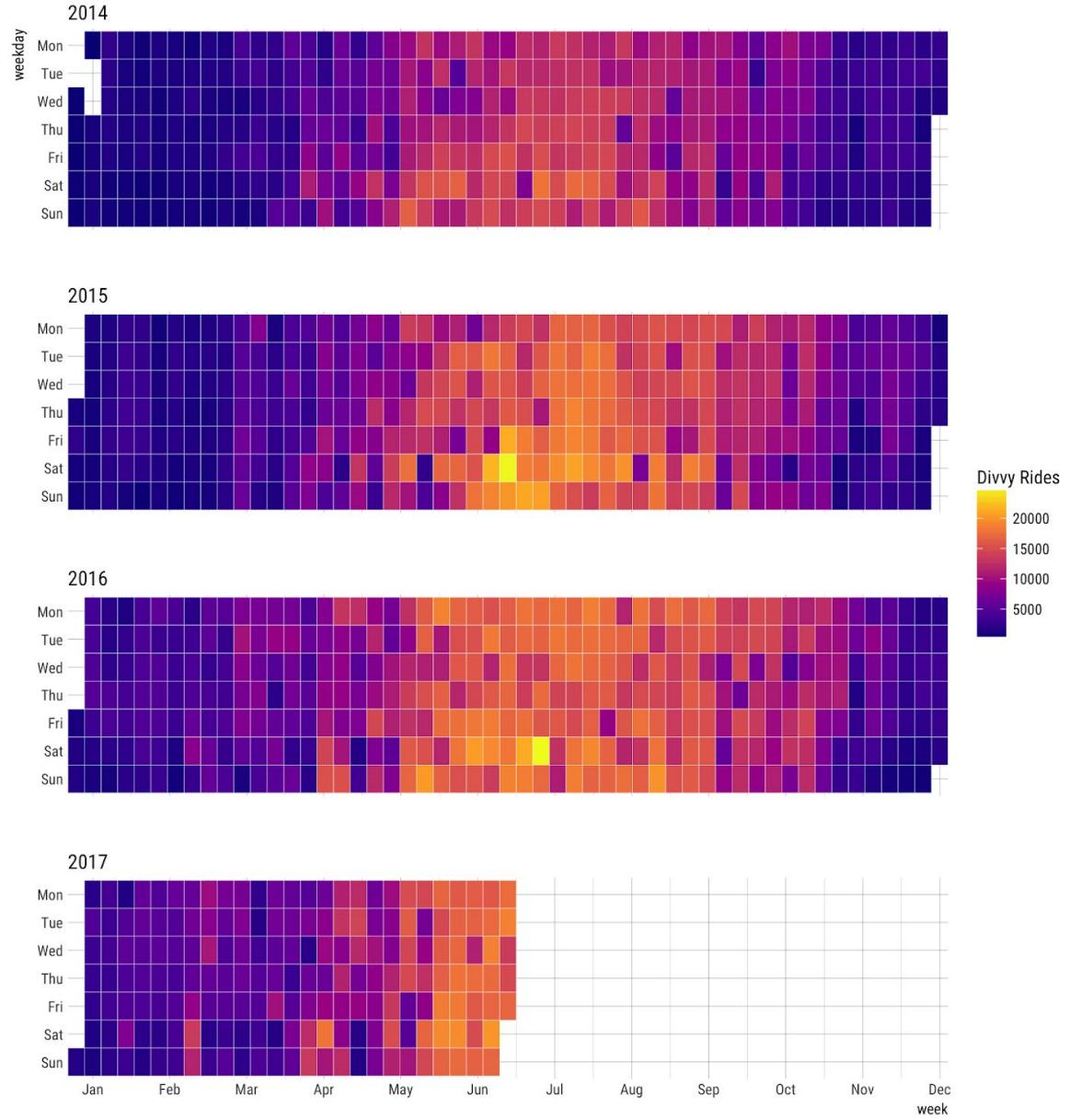


Sources: Statista; *The Economist*

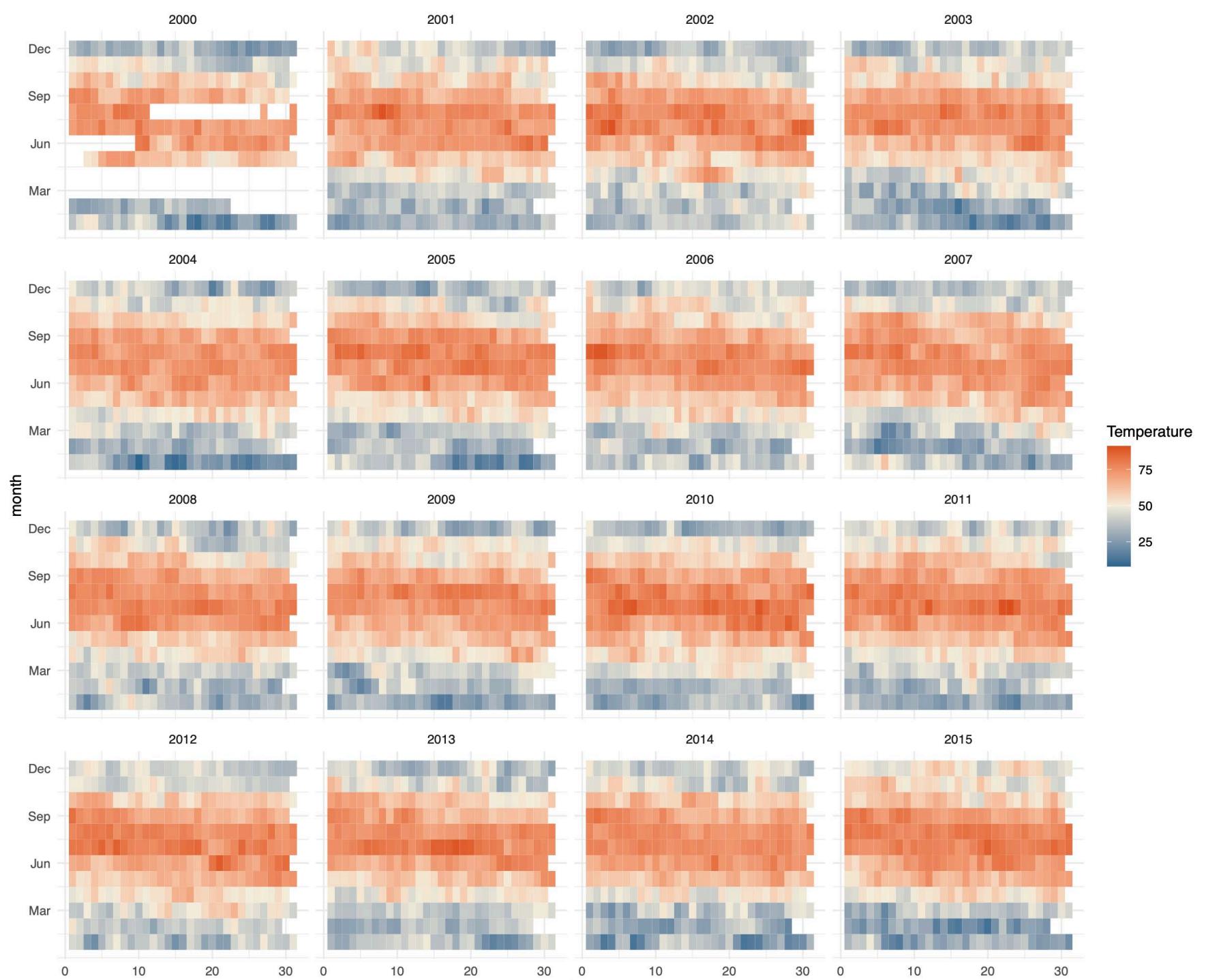
Visualize Periodic Data

PART 02

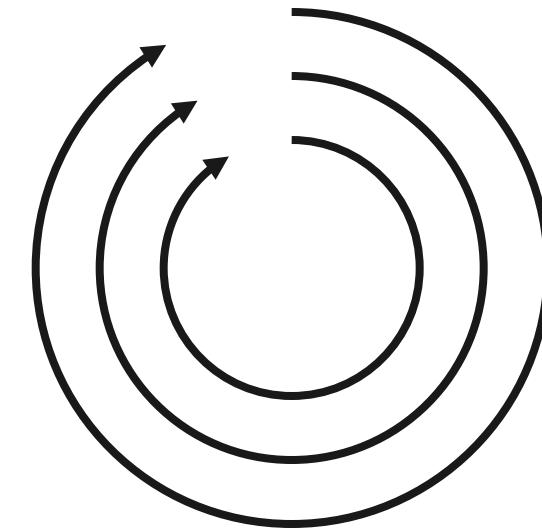
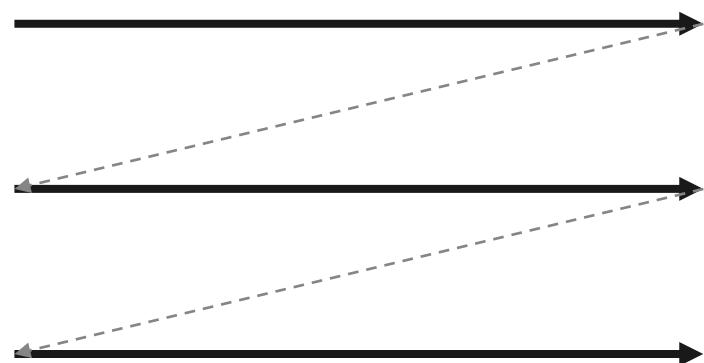
Calendar



Source: Erico Bertini

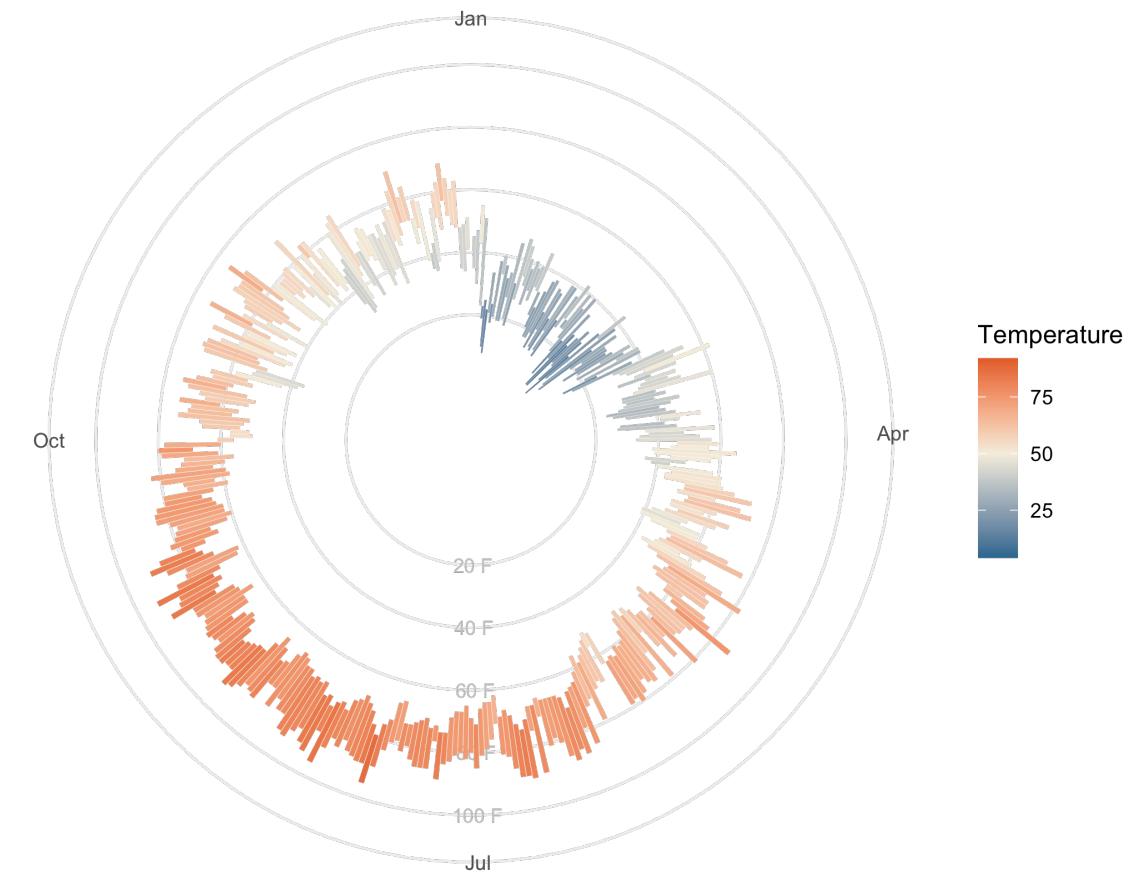
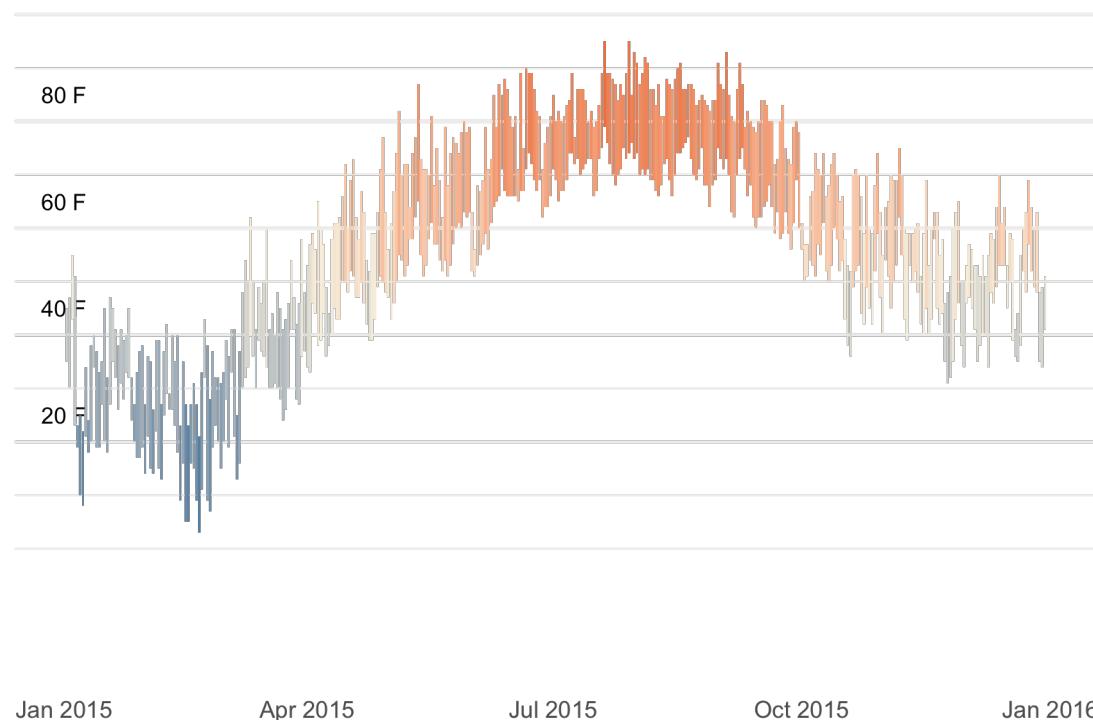


Radial Layout

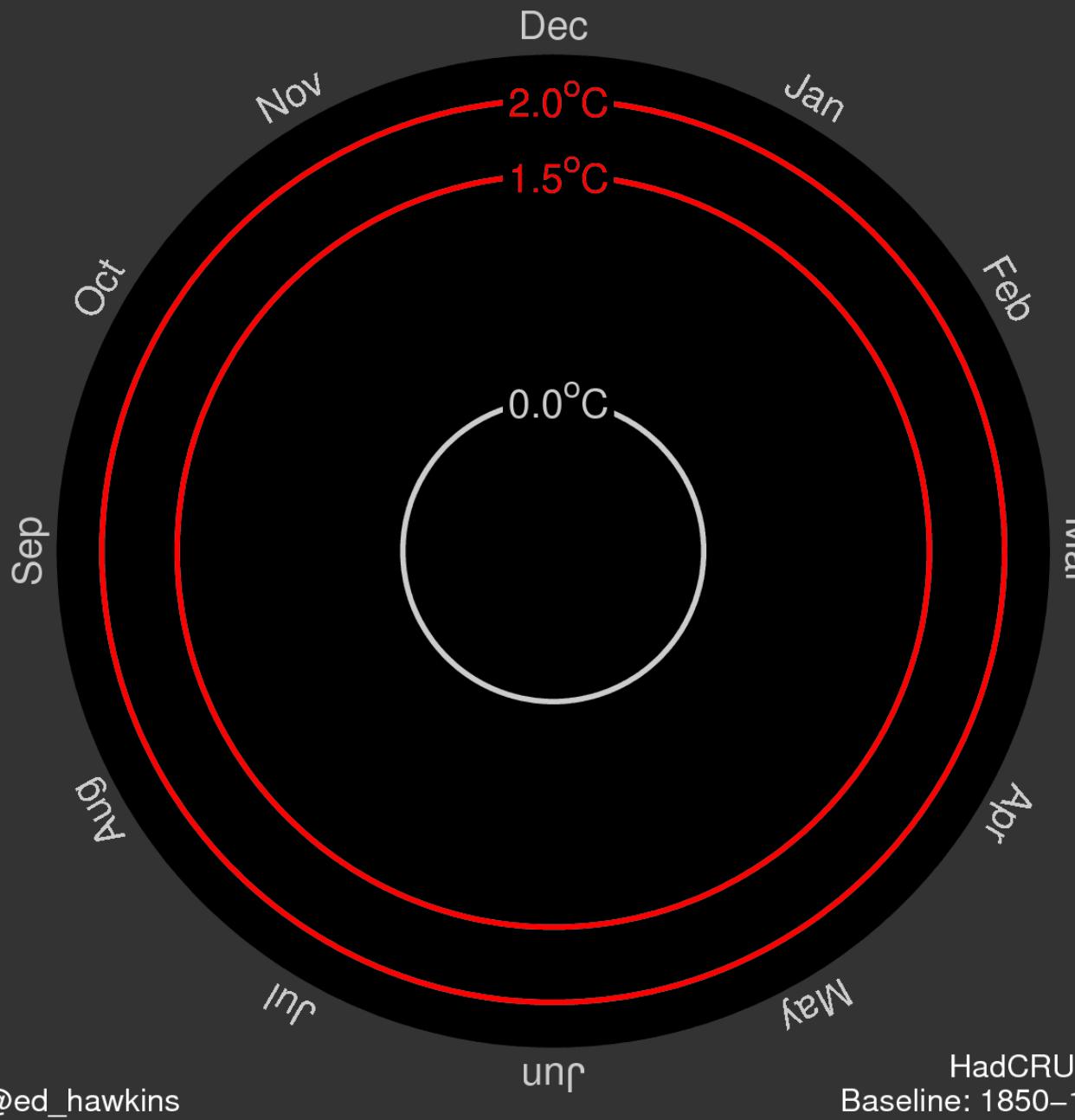


Avoids temporal discontinuity

Radial Layout

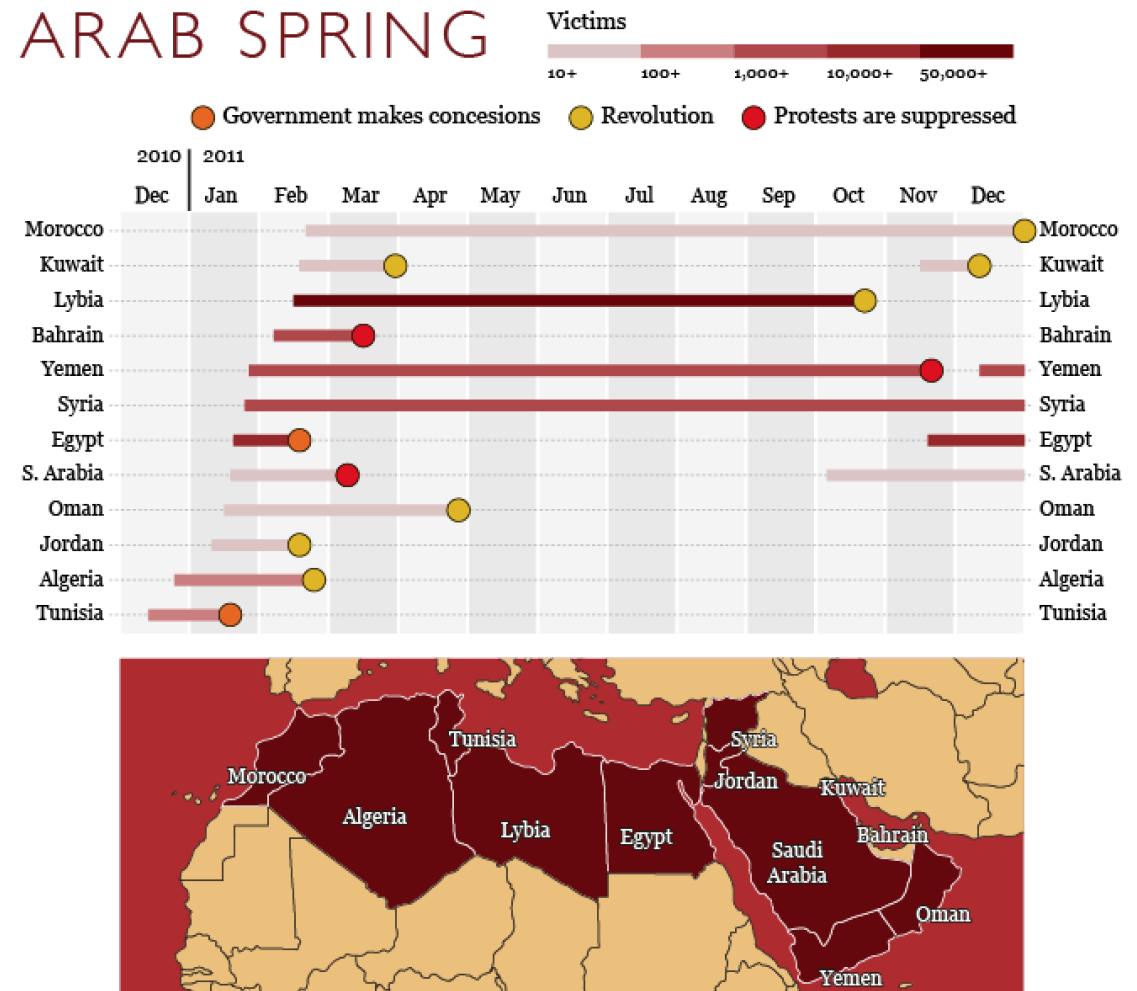
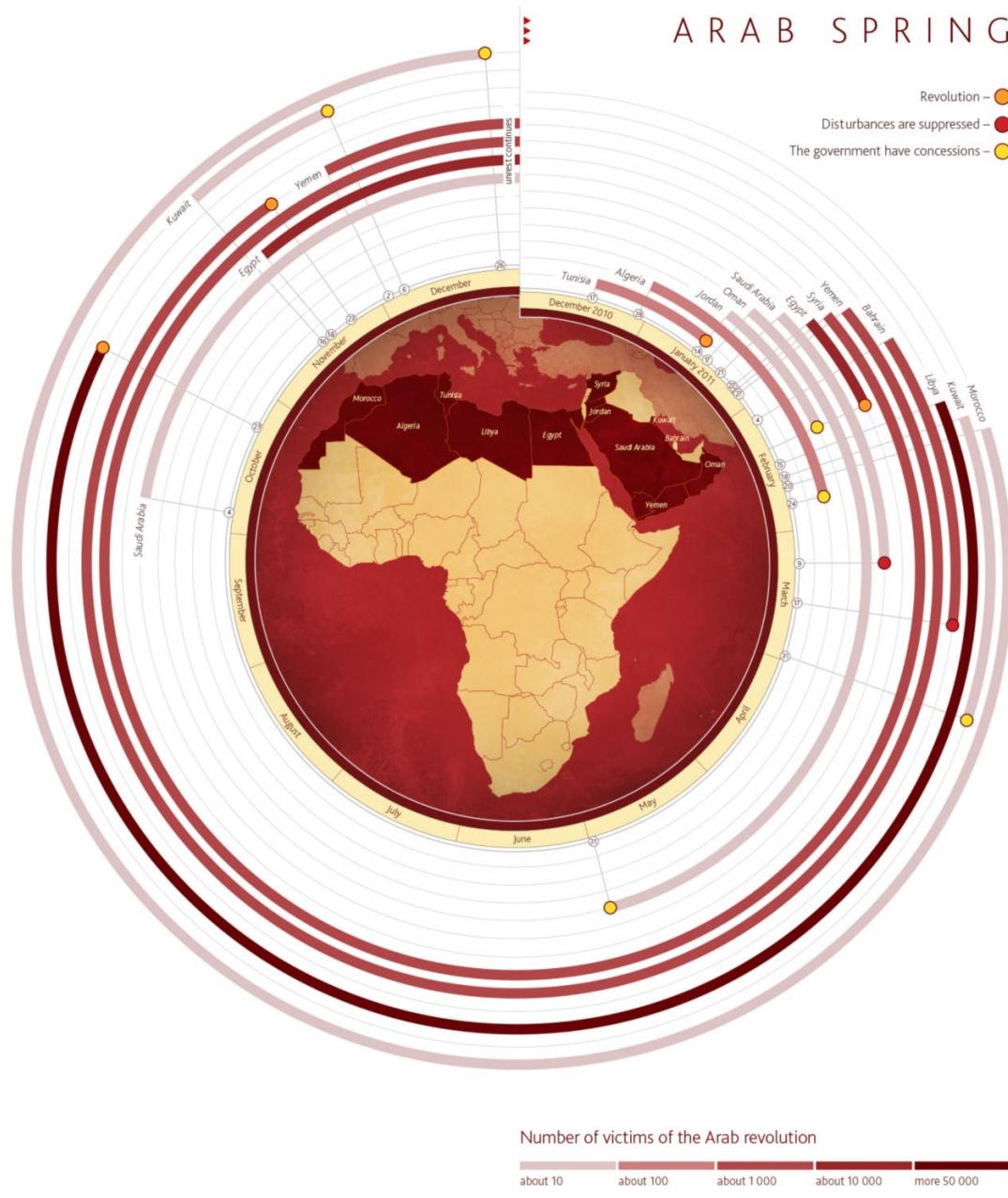


Global temperature change (1850–2017)



@ed_hawkins

Source: <http://www.climate-lab-book.ac.uk/2016/spiralling-global-temperatures/>

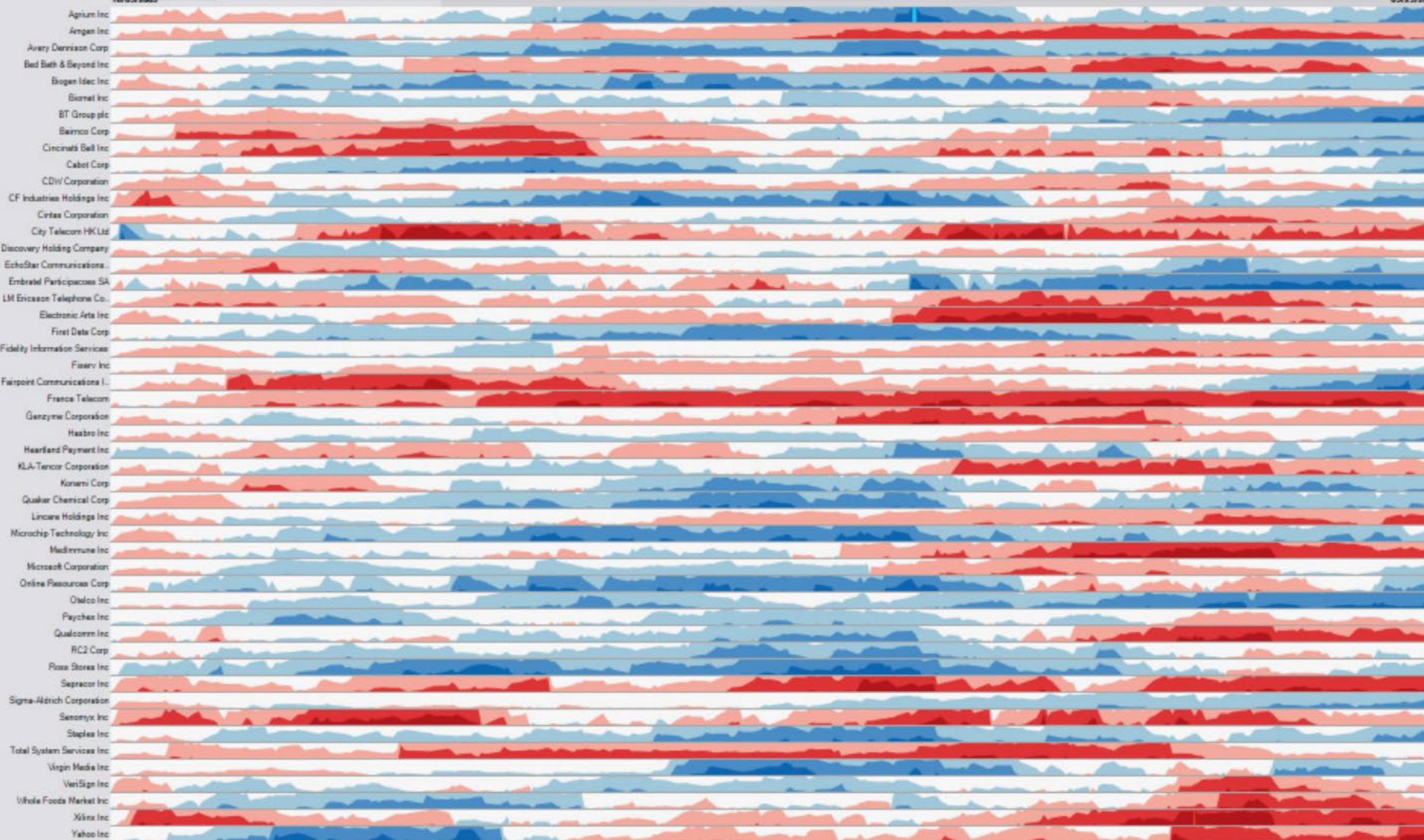


Increase Visual Scalability

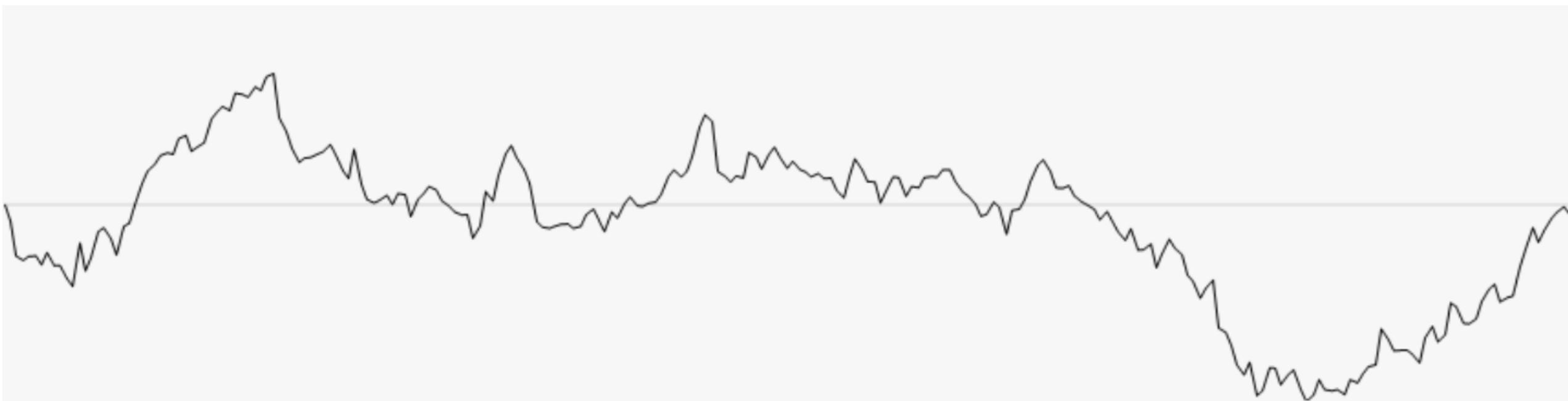
10/03/2005

09/29/2006

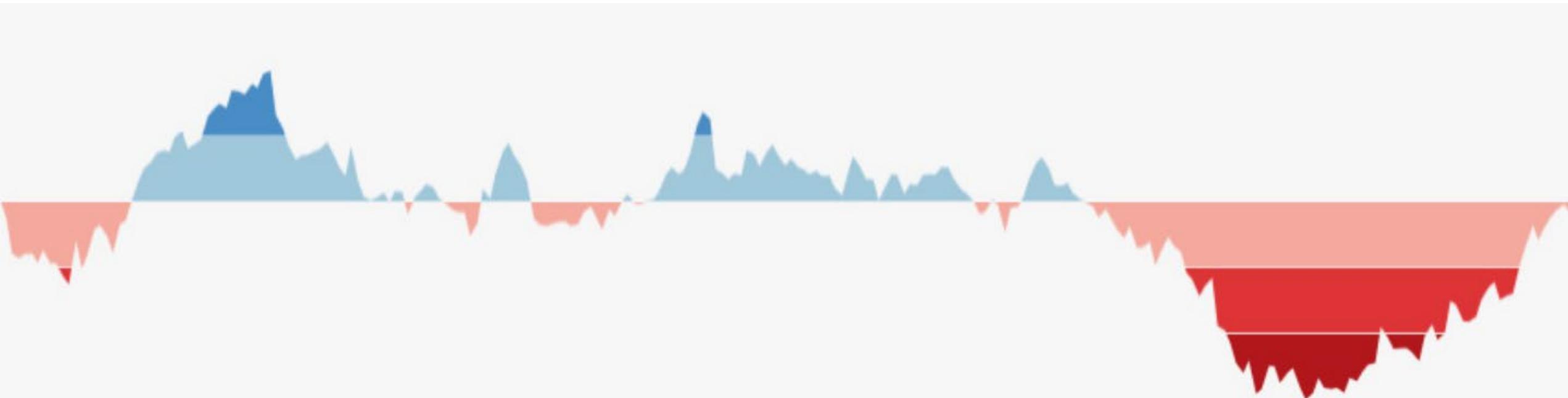
Agricor Inc
Amgen Inc
Avery Dennison Corp
Bainco Corp
Bed Bath & Beyond Inc
Biogen Idec Inc
Biomet Inc
BT Group plc
Cable Corp
CDIV Corporation
CF Industries Holdings Inc
Cincinnati Bell Inc
Cintas Corporation
City Telecom HK Ltd
Discovery Holding Company
EchoStar Communications
Electronic Arts Inc
Embratel Participacoes SA
Fairport Communications Inc
Fidelity Information Services
First Data Corp
Fiserv Inc
France Telecom
Genzyme Corporation
Hasbro Inc
Heartland Payment Inc
KLA-Tencor Corporation
Koram Corp
Lincare Holdings Inc
LM Ericsson Telephone Co.
MedImmune Inc
Microchip Technology Inc
Microsoft Corporation
Online Resources Corp
Otiseco Inc
Paychex Inc
Quaker Chemical Corp
Qualcomm Inc
RCI Corp
Ross Stores Inc
Sensormic Inc
Sepracor Inc
Sigma-Aldrich Corporation
Staples Inc
Total System Services Inc
VeriSign Inc
Virgin Media Inc
Whole Foods Market Inc
Xilinx Inc
Yahoo Inc



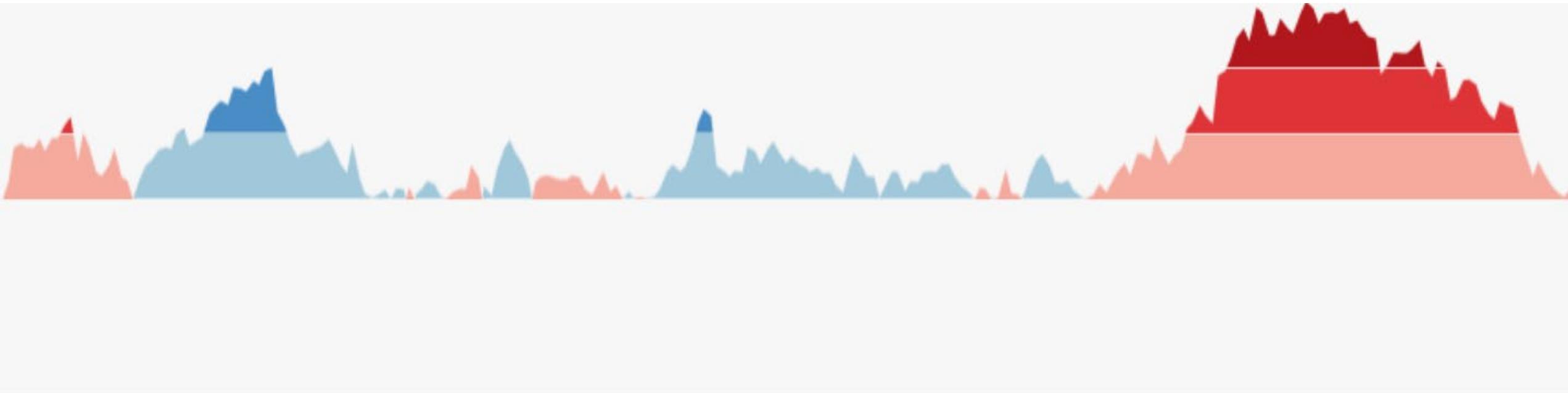
Horizon Chart



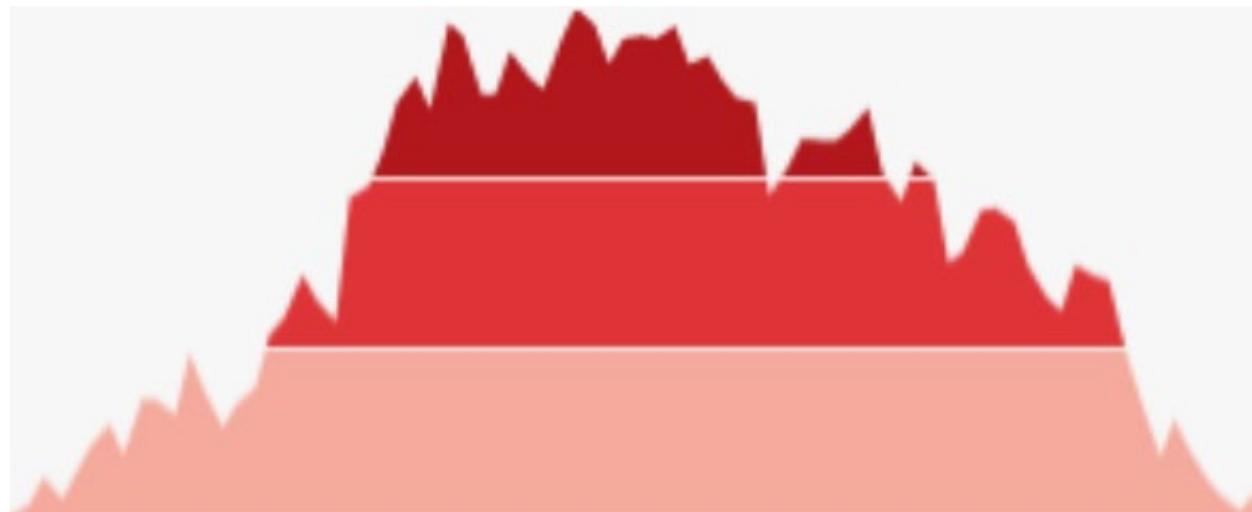
Horizon Chart

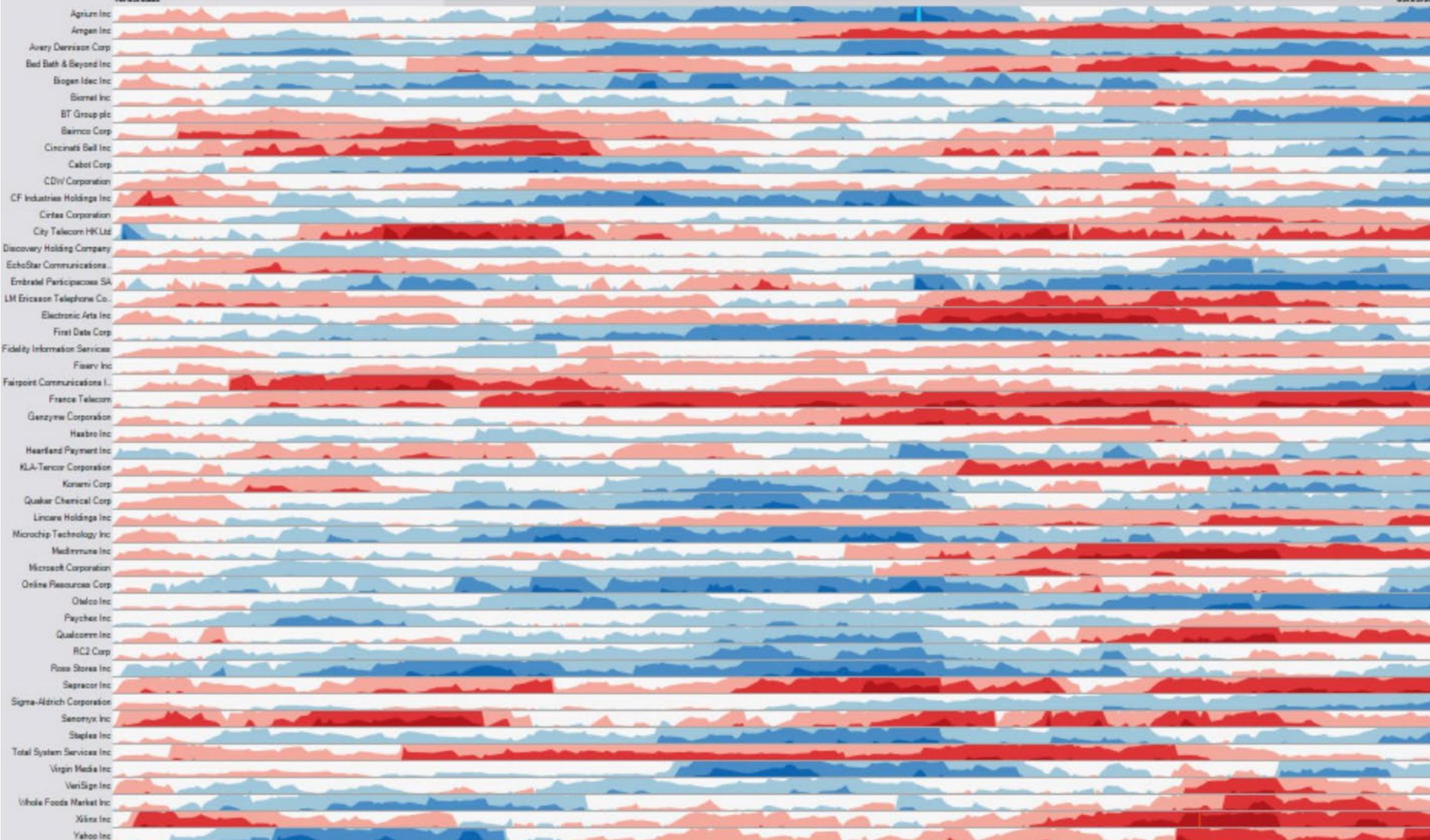


Horizon Chart



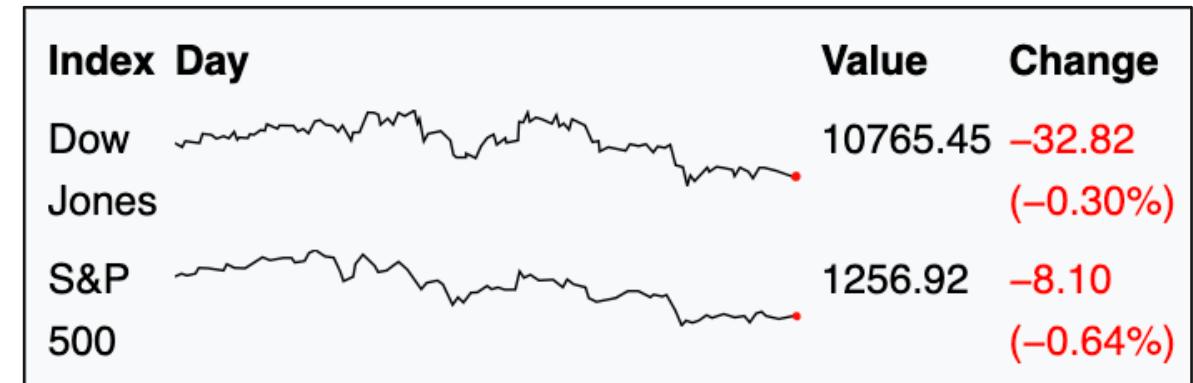
Horizon Chart





Sparklines

Sparklines are small, intense, word-sized graphics with typographic resolution. Sparklines can be placed anywhere that words or numbers or graphics can be placed: in sentences, maps, graphics, tables.



--Edward Tufte (History of Sparklines)

Sparklines

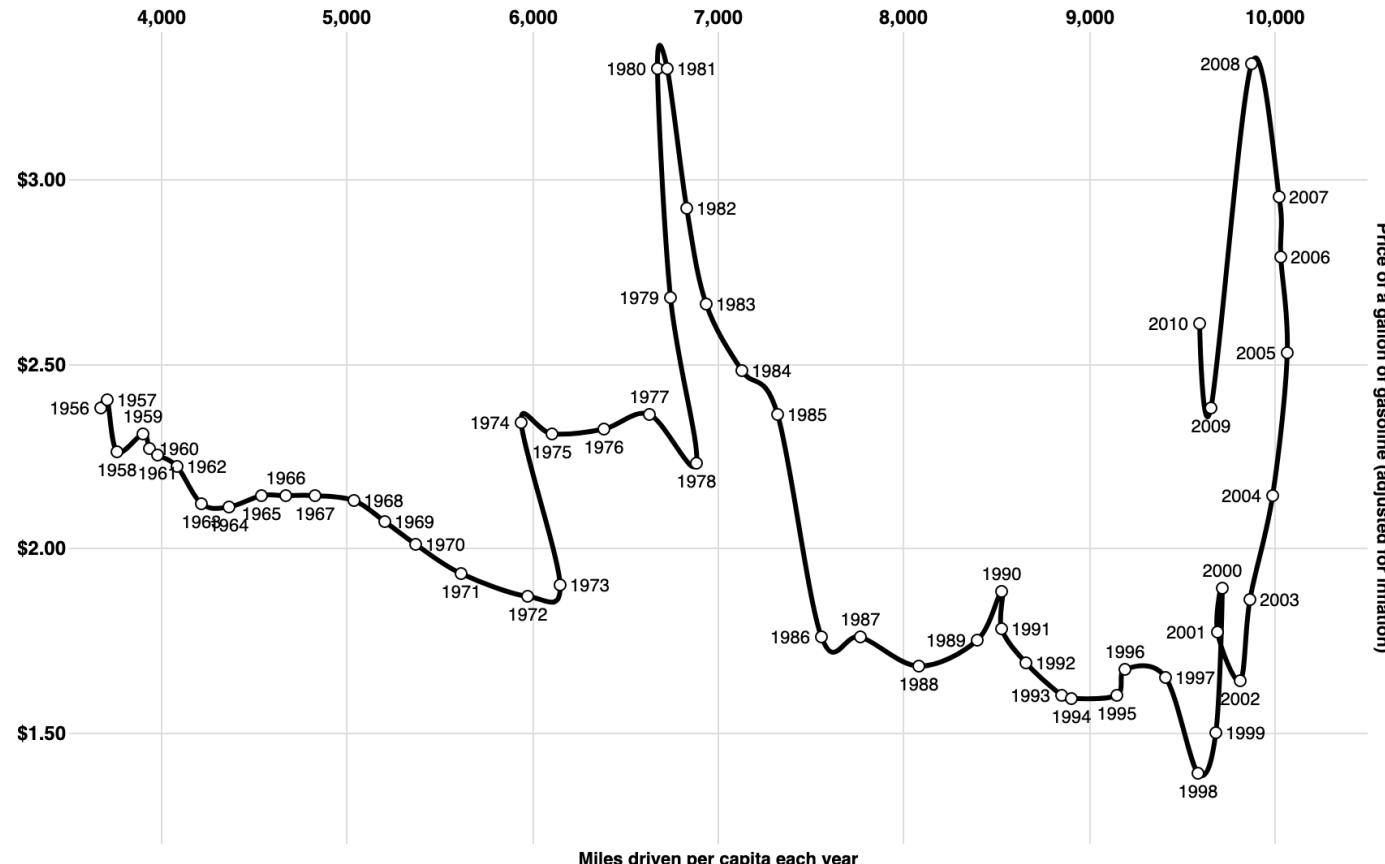
Sparklines are small, intense, word-sized graphics with typographic resolution. Sparklines can be placed anywhere that words or numbers or graphics can be placed: in sentences, maps, graphics, tables.

--Edward Tufte (History of Sparklines)



Other Techniques

Connected Scatter Plot



Time Curves

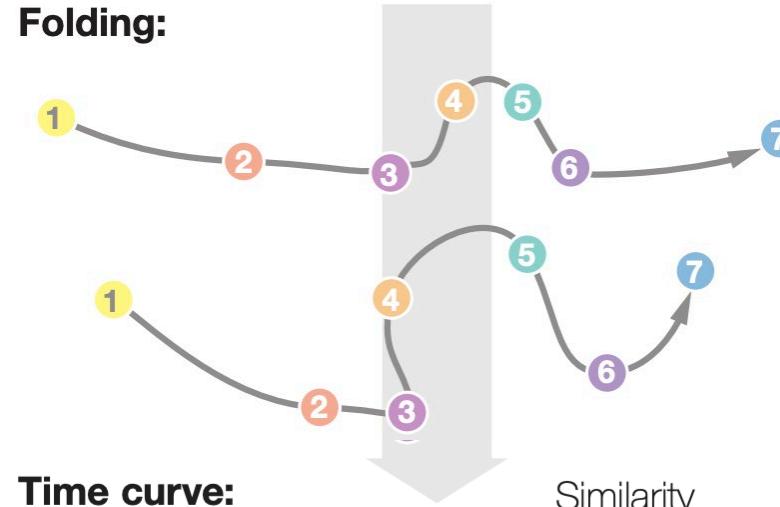
B. Bach, C. Shi, N. Heulot, T. Madhyastha, T. Grabowski and P. Dragicevic, "[Time Curves: Folding Time to Visualize Patterns of Temporal Evolution in Data](#)," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 22, no. 1, pp. 559-568, 31 Jan. 2016, doi: 10.1109/TVCG.2015.2467851.

Timeline:

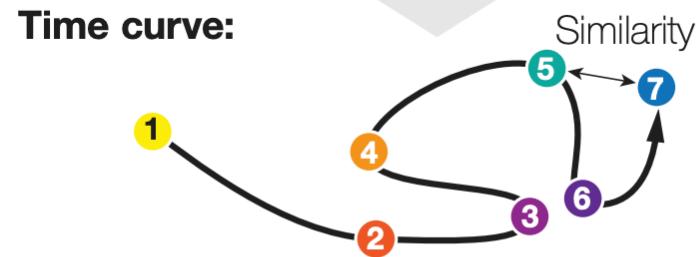


Circles are data cases with a time stamp.
Similar colors indicate similar data cases.

Folding:



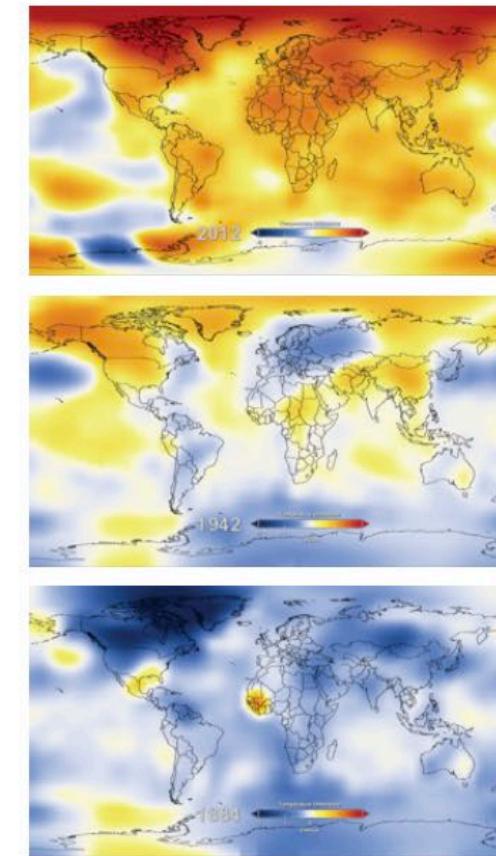
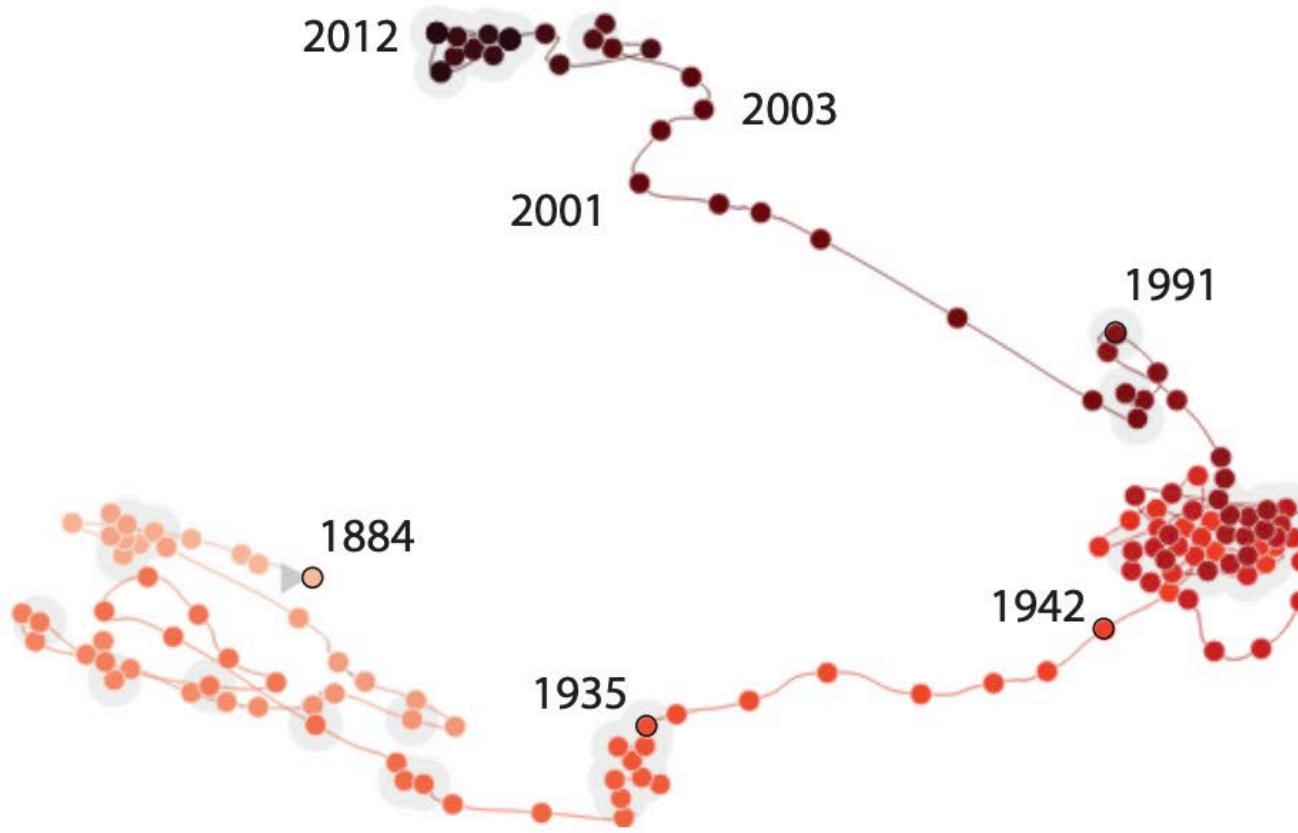
Time curve:



The temporal ordering of data cases is preserved.
Spatial proximity now indicates similarity.

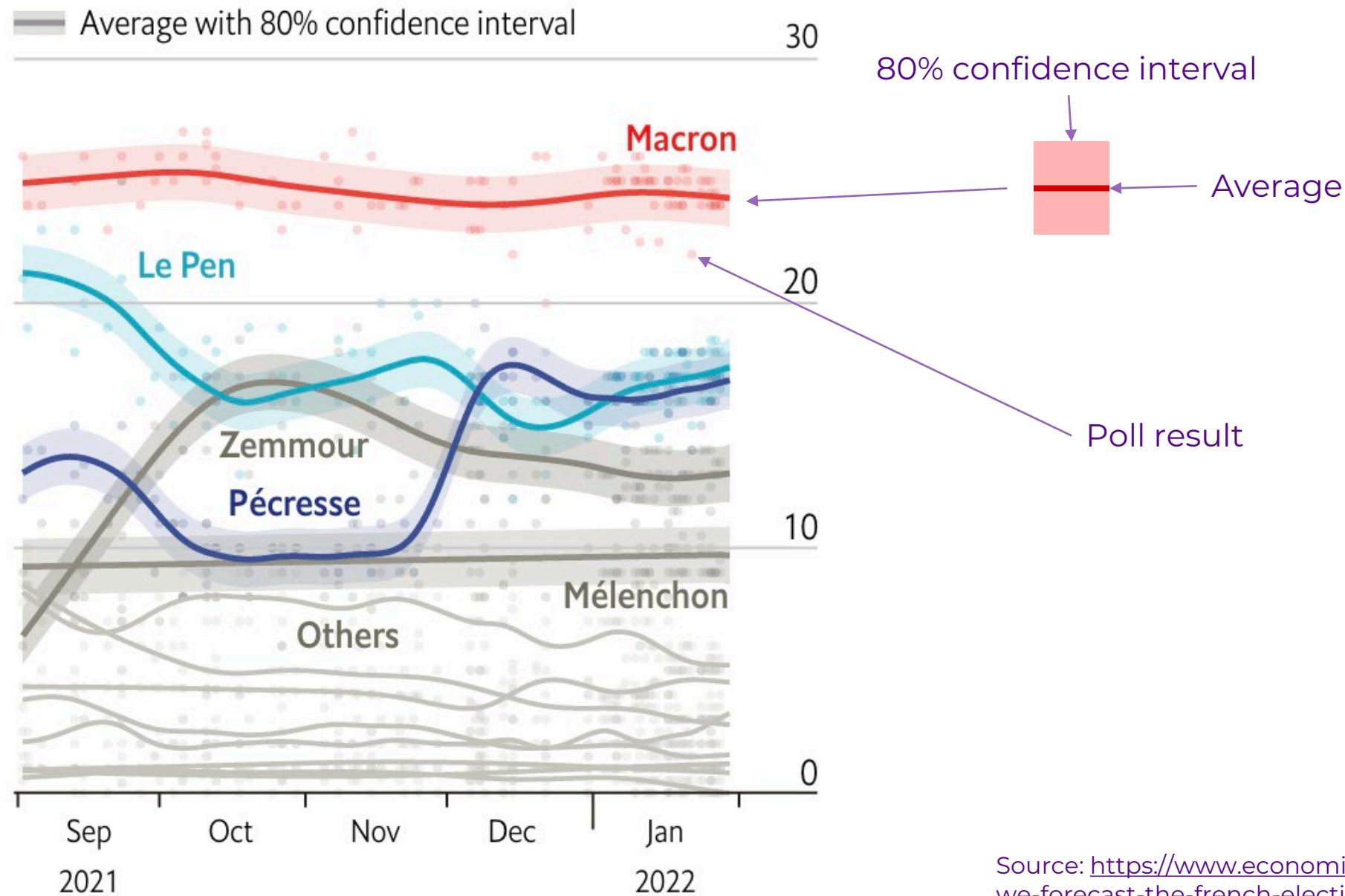
(a) **Folding time**

Time Curves

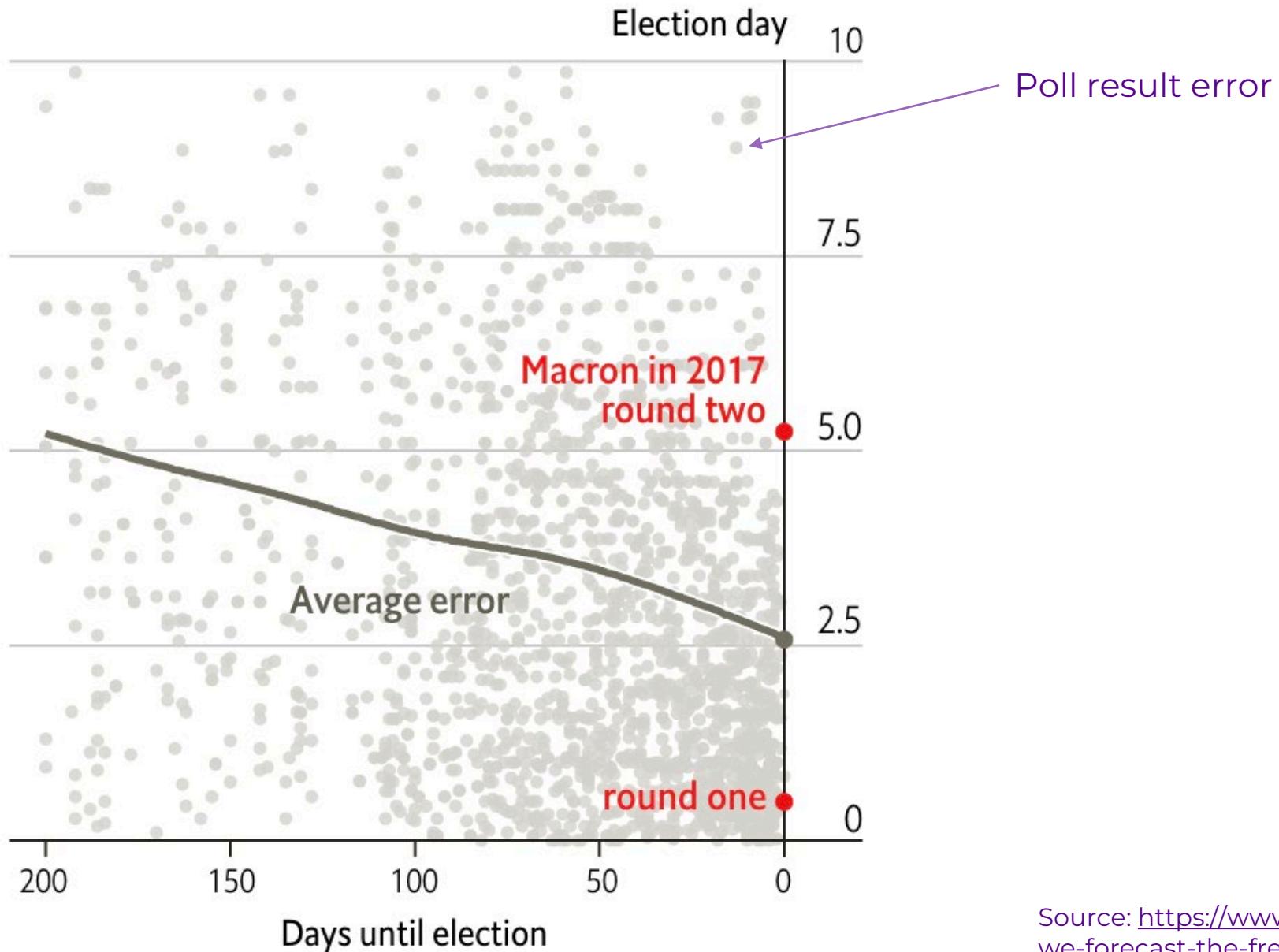


Uncertainties

Step 1: Aggregate polling results



Step 2: historical polling error analysis



Source: <https://www.economist.com/graphic-detail/how-we-forecast-the-french-election/21807484>

Step 3: Voting simulation

Macron

Median 24

Le Pen

17

Pécresse

17

Zemmour

13

Mélenchon

Greater chance ↑

0

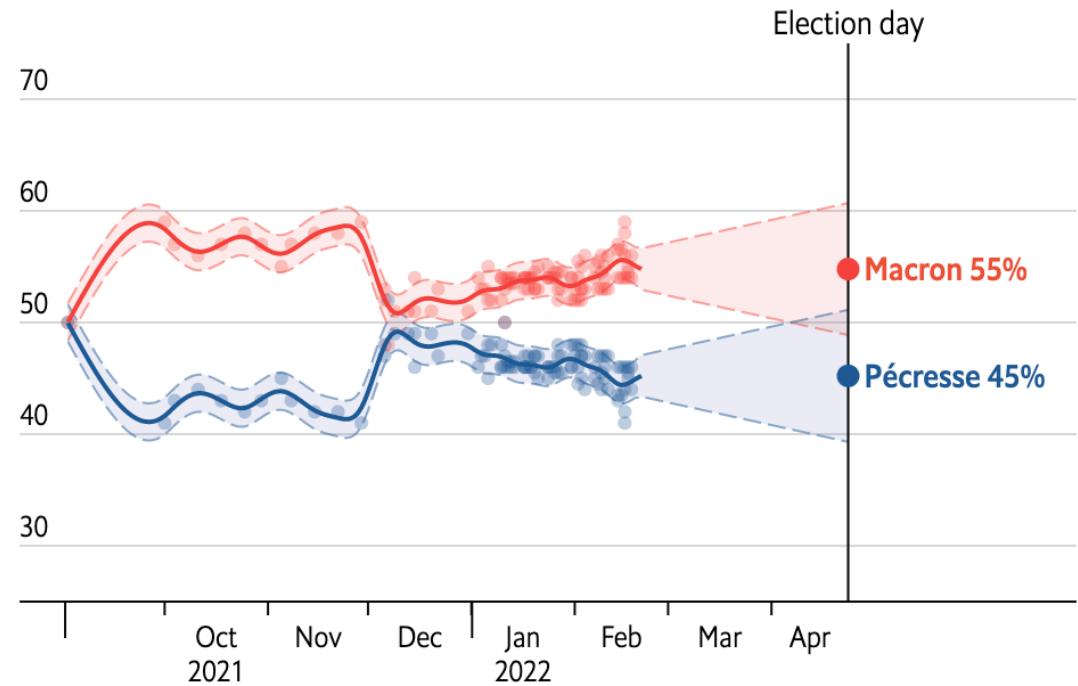
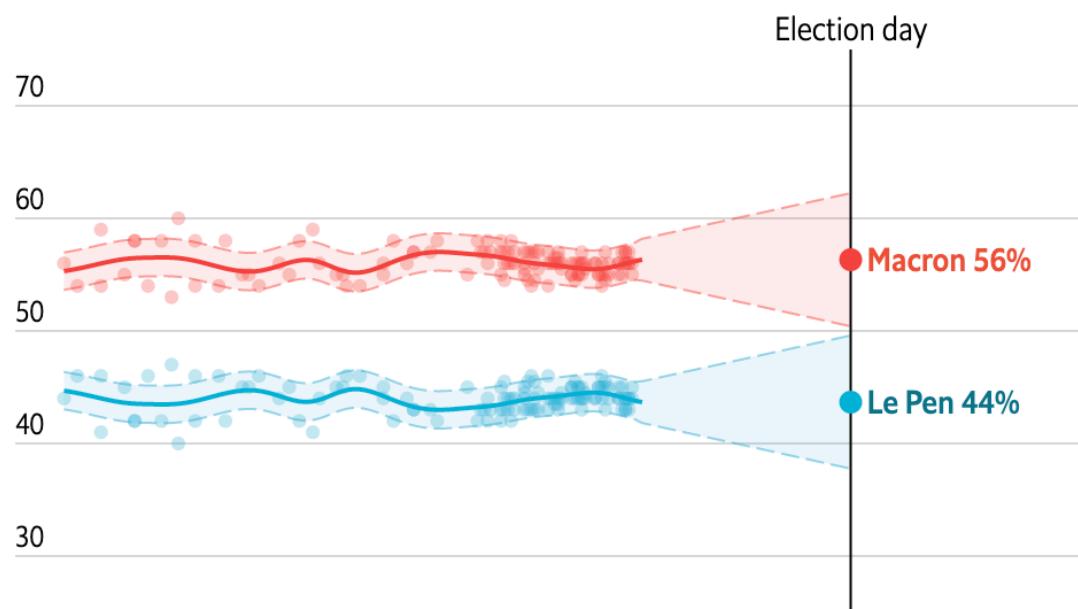
10

20

30

40

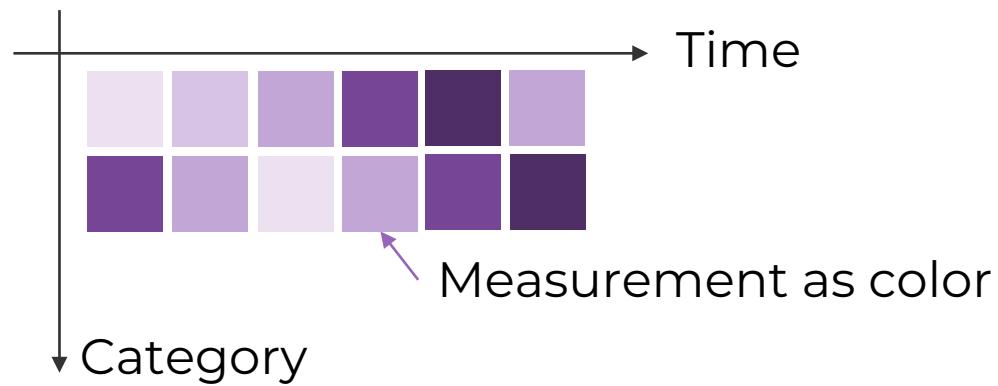
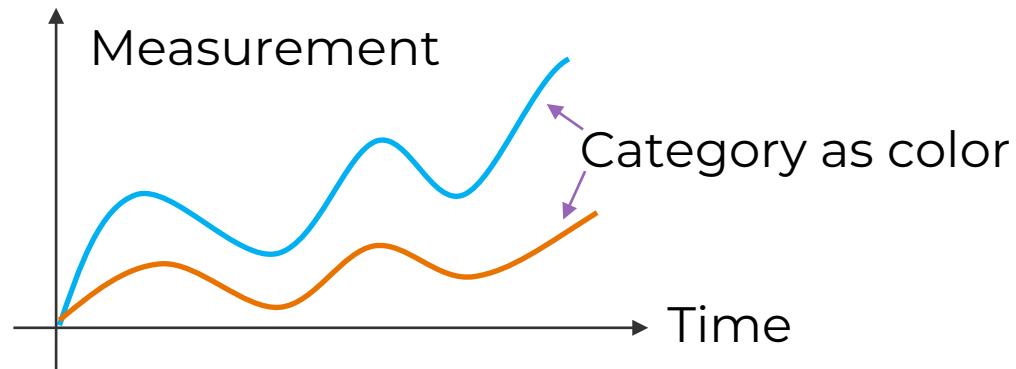
Vote share, %



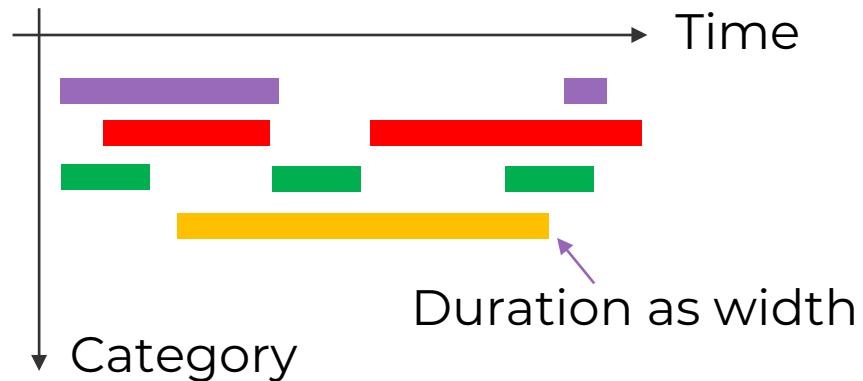
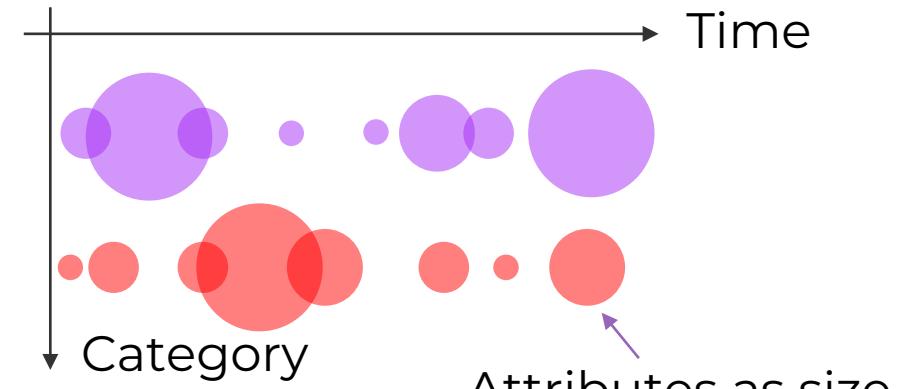
Source: <https://www.economist.com/graphic-detail/how-we-forecast-the-french-election/21807484>

Summary

Measurement Data



Event Data



The TimeViz Browser

A Visual Survey of Visualization Techniques for Time-Oriented Data
by Christian Tominski and Wolfgang Aigner

of Techniques: 115

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- Want:** Show me!
- Indifferent:** I don't care.
- Hide:** I'm not interested!

Data

Frame of Reference

Abstract
 Spatial

Number of Variables

Univariate
 Multivariate

Time

Arrangement

Linear
 Cyclic

Time Primitives

Instant
 Interval

Visualization

Mapping

Static
 Dynamic

Dimensionality

2D
 3D

Our book:





Source: <https://breathingearth.visualcinnamon.com/>