

Lesson 6: It's About Time

Visualising and Analysing Time-Oriented Data

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What will you learn from this lesson?

- Characteristics of time-series data
- Classic ways of graphing time
- Time-series patterns
- Time-series data visualization
- Interactive techniques for time-series data visualisation

Characteristics of time-series data

A typical time-series data table

Month/Year	Country	Air	Sea	Land
01/2015	World	948689	154708	149211
02/2015	World	900198	151618	137002
03/2015	World	940077	133632	127939
04/2015	World	939370	118120	151134
05/2015	World	945080	123136	154620
06/2015	World	930642	115631	138474
07/2015	World	1184753	139088	195392
08/2015	World	1136524	117490	191048
09/2015	World	925233	95408	111335
10/2015	World	991913	119491	135543
11/2015	World	930209	138730	135053
12/2015	World	1058414	195431	171133
01/2016	World	1073904	175961	162257
02/2016	World	1015346	160700	158983
03/2016	World	1072456	148638	183044
04/2016	World	1074475	131579	187293
05/2016	World	1029812	131450	194292
06/2016	World	989191	114080	166275
07/2016	World	1258176	145088	218392

Characteristics of time-series data

Not so friendly time-series data

Monthly and Annually Inflation Rate History Singapore from 1993 to 2016

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Average Rate
2016	-0.60%	-0.80%	-1.00%	-0.40%	-1.60%	-0.80%	-0.70%	-	-	-	-	-	-
2015	-0.40%	-0.30%	-0.40%	-0.50%	-0.40%	-0.30%	-0.40%	-0.80%	-0.60%	-0.80%	-0.70%	-0.60%	-0.43%
2014	1.39%	0.34%	1.21%	2.54%	2.71%	1.83%	1.22%	0.86%	0.60%	0.03%	-0.34%	-0.17%	1.02%
2013	3.60%	4.90%	3.50%	1.50%	1.60%	1.80%	1.90%	2.00%	1.60%	2.00%	2.60%	1.48%	2.37%
2012	4.80%	4.60%	5.20%	5.40%	5.00%	5.30%	4.00%	3.90%	4.70%	4.00%	3.60%	4.30%	4.55%
2011	5.50%	5.00%	5.00%	4.50%	4.50%	5.20%	5.40%	5.70%	5.50%	5.40%	5.70%	5.50%	5.24%
2010	0.20%	1.00%	1.60%	3.20%	3.20%	2.70%	3.10%	3.30%	3.70%	3.50%	3.80%	4.60%	2.80%
2009	4.30%	3.30%	2.60%	0.30%	0.20%	0.00%	-0.30%	-0.30%	-0.50%	-0.90%	-0.80%	-0.50%	0.62%
2008	6.60%	6.50%	6.70%	7.50%	7.50%	7.50%	6.50%	6.40%	6.70%	6.40%	5.50%	5.50%	6.60%
2007	-0.60%	-0.10%	0.20%	0.40%	1.30%	1.70%	3.00%	3.50%	3.00%	4.10%	4.90%	3.70%	2.20%
2006	1.70%	1.20%	1.20%	1.10%	1.10%	1.40%	1.10%	0.70%	0.40%	0.40%	0.50%	0.80%	0.95%

Characteristics of time-series data

Not so friendly time-series data

Visitor Arrivals Statistics

Updated 10 Feb 2011

Country of Residence	ALL MODE OF ARRIVAL (AIR / SEA / LAND)												Jan_Deo 2010	Year-On-Year % Change
	Jan 2010	Feb 2010	Mar 2010	Apr 2010	May 2010	Jun 2010	Jul 2010	Aug 2010	Sep 2010	Oct 2010	Nov 2010	Dec 2010		
TOTAL	808,480	867,287	828,720	838,604	846,473	860,868	1,084,862	896,811	847,281	878,731	863,868	1,127,020	11,838,883	20.2
AMERICAS	44,800	38,868	46,835	43,006	40,114	48,310	60,466	44,116	34,748	46,981	43,866	44,763	624,831	12.2
Canada	6,860	6,424	7,048	6,733	5,456	4,969	6,645	6,397	4,336	6,161	6,485	7,623	75,137	7.3
USA	36,514	31,166	37,102	33,454	32,108	39,016	41,162	34,194	27,932	36,697	34,311	34,334	416,390	12.5
Other Countries in Americas	2,526	2,078	2,485	2,819	2,550	2,325	2,648	3,524	2,481	3,103	3,169	2,796	32,504	20.5
ASIA	627,002	627,581	661,040	697,441	736,393	731,922	831,322	743,847	720,118	726,367	712,178	860,934	8,676,135	25.8
Southeast Asia	331,914	300,137	360,062	390,263	403,076	433,791	466,056	361,037	447,643	410,299	391,352	633,440	4,619,761	30.0
Brunei Darussalam	5,245	4,139	5,692	3,943	4,796	5,953	5,578	4,244	4,628	3,750	4,673	9,513	62,154	10.0
Indonesia	173,639	143,917	165,942	162,800	185,757	214,392	232,528	165,483	243,763	178,903	175,969	262,056	2,305,149	32.1
Malaysia	67,941	68,663	81,745	77,441	81,867	93,070	82,592	75,867	95,455	82,745	99,333	129,599	1,036,918	35.7
Myanmar	5,512	4,492	7,000	9,591	6,655	6,232	6,877	5,838	5,376	6,482	5,953	8,276	78,184	11.3
Philippines	32,703	32,510	43,955	54,448	56,307	44,484	43,440	39,244	40,662	52,007	50,092	55,492	544,344	26.0
Thailand	34,635	23,153	31,813	50,655	38,921	30,710	37,256	34,790	30,709	57,950	30,192	39,238	430,022	36.3
Vietnam	19,109	20,477	21,236	26,680	26,152	35,586	43,869	32,843	24,331	24,691	21,246	26,543	322,863	21.6
Other Countries in Southeast Asia	3,130	2,786	2,599	4,705	3,723	3,364	3,785	3,528	2,719	3,771	3,324	2,723	40,127	21.5
North Asia	212,272	267,600	212,002	203,699	191,367	183,040	266,763	293,017	166,646	213,442	217,010	220,603	2,663,640	23.1
Hong Kong SAR	19,415	24,904	26,245	35,860	32,046	32,190	46,726	46,895	29,467	32,833	29,847	32,625	387,852	31.6
Japan	37,747	40,666	51,834	36,160	36,819	36,447	41,646	56,644	44,999	43,493	51,527	48,835	628,817	7.9
P.R. China	98,918	143,050	88,031	91,701	71,628	69,080	117,775	130,566	74,434	92,600	93,998	99,556	1,171,337	26.0
South Korea	39,437	29,589	30,113	34,781	32,199	30,032	32,668	34,169	25,653	29,008	27,814	25,290	360,673	32.6
Taiwan	15,510	17,737	15,219	14,508	17,111	13,542	23,933	20,959	13,486	13,851	13,131	12,186	191,173	22.0
Other Countries in North Asia	1,245	1,554	1,360	1,889	1,595	2,649	3,005	3,984	1,506	1,657	1,493	2,151	24,088	74.6
South Asia	74,021	69,674	70,799	94,410	133,267	102,683	66,526	76,337	71,160	92,950	89,479	96,052	1,046,200	12.6
Bangladesh	7,762	5,726	7,747	7,528	7,703	8,534	9,373	7,144	7,942	7,543	7,438	7,879	92,309	6.6
India	57,404	46,061	53,965	73,214	115,955	83,467	64,905	57,107	54,825	75,567	72,918	73,515	828,903	14.2
Nepal	1,619	1,011	1,286	1,222	1,188	1,004	1,242	1,196	912	1,372	1,005	1,246	14,303	-5.8
Pakistan	1,585	1,292	1,662	1,707	1,565	2,926	3,907	1,510	1,125	1,469	1,776	21,925	-1.6	
Sri Lanka	4,770	4,734	5,373	9,960	6,043	5,750	6,206	7,816	5,759	6,295	5,785	10,476	78,967	12.8
Other Countries in South Asia	881	750	766	779	813	892	895	564	617	734	932	1,170	9,793	6.8
West Asia	6,795	10,370	17,367	9,169	8,691	11,625	20,166	13,660	12,780	9,646	13,607	10,619	146,644	26.2
Iran	1,779	4,042	10,024	1,184	1,448	2,118	2,032	2,727	4,180	2,215	2,512	2,669	36,930	54.4
Israel	1,277	997	1,175	956	1,029	1,174	918	1,198	785	1,109	1,310	903	12,831	17.9
Kuwait	443	587	468	305	451	806	2,548	719	535	380	723	403	8,368	45.5
Saudi Arabia	512	714	689	1,038	771	941	2,400	972	1,345	902	1,554	793	12,631	16.8
United Arab Emirates	3,686	3,036	3,841	4,301	3,764	4,620	8,870	6,132	4,299	3,683	5,729	4,513	56,474	14.0
Other Countries in West Asia	1,098	994	1,160	1,385	1,228	1,969	3,388	1,908	1,606	1,357	1,679	1,538	19,310	19.8

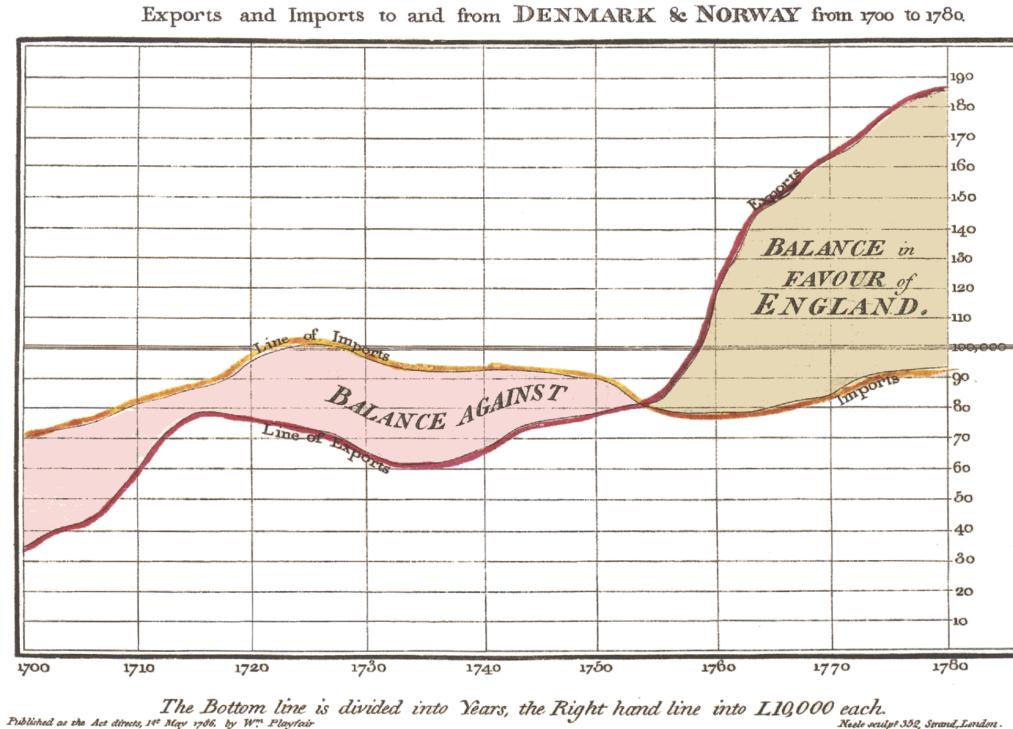
Characteristics of time-series data

Not so friendly time-series data

END OF PERIOD		S\$ PER UNIT OF EURO	S\$ PER UNIT OF POUND STERLING	S\$ PER UNIT OF US DOLLAR	S\$ PER 100 UNITS OF AUSTRALIAN DOLLAR	
2015	Jan	02	1.5994	2.0633	1.3264	107.84
		05	1.5953	2.0415	1.3352	107.70
		06	1.5940	2.0366	1.3347	108.47
		07	1.5861	2.0226	1.3353	107.91
		08	1.5823	2.0194	1.3375	108.51
		09	1.5780	2.0175	1.3366	108.80
		12	1.5790	2.0201	1.3318	109.82
		13	1.5806	2.0247	1.3337	109.22
		14	1.5731	2.0244	1.3360	108.06
		15	1.5716	2.0323	1.3340	109.24
		16	1.5418	2.0119	1.3246	109.16
		19	1.5354	2.0106	1.3280	109.03
		20	1.5494	2.0163	1.3379	109.28

A short visual history of time-series graphs

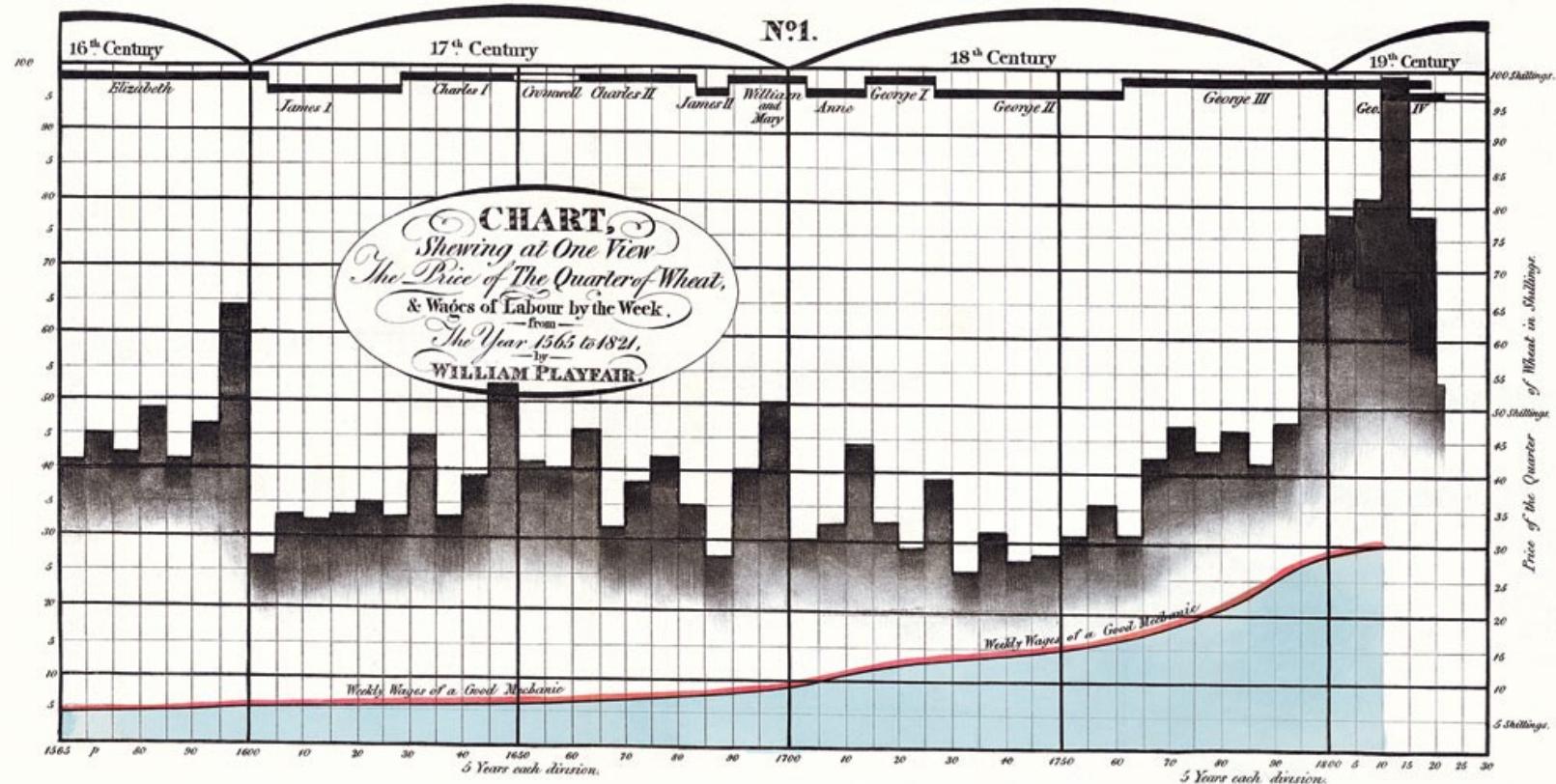
Playfair's Commercial and Political Atlas (1786)



Reference: https://en.wikipedia.org/wiki/William_Playfair

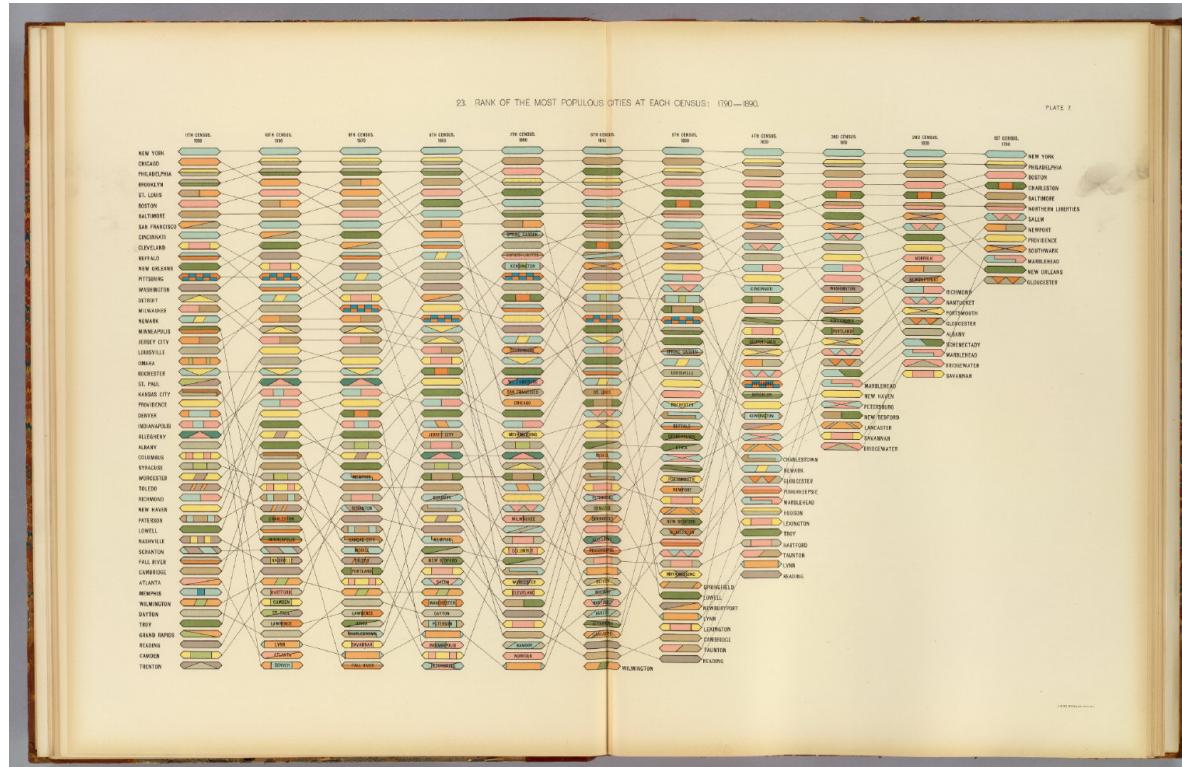
A short visual history of time-series graphs

Playfair's Chewing at One View Chart (1821)



A short visual history of time-series graphs

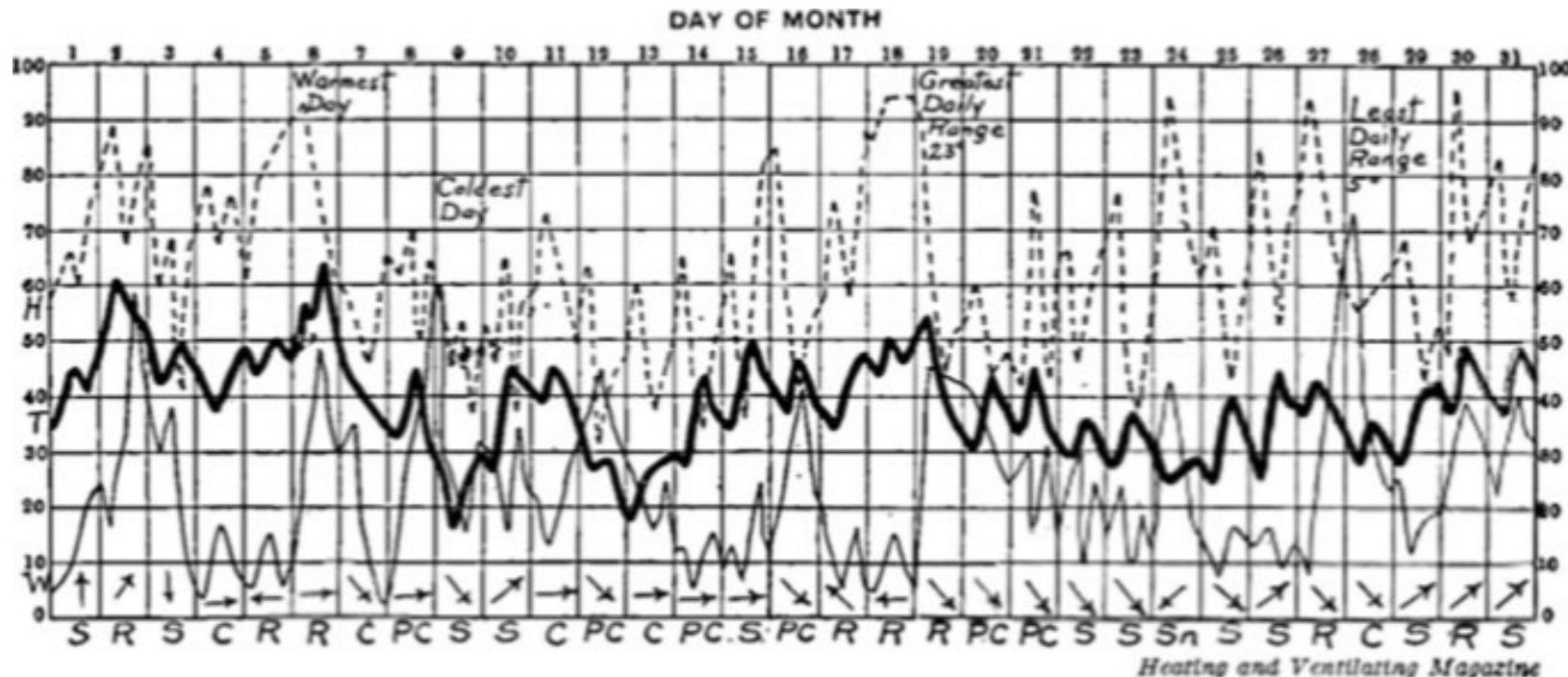
Bump Chart shows rank of the most populous cities at each census:
1790-1890



An interactive version here http://vallandingham.me/census_bump/

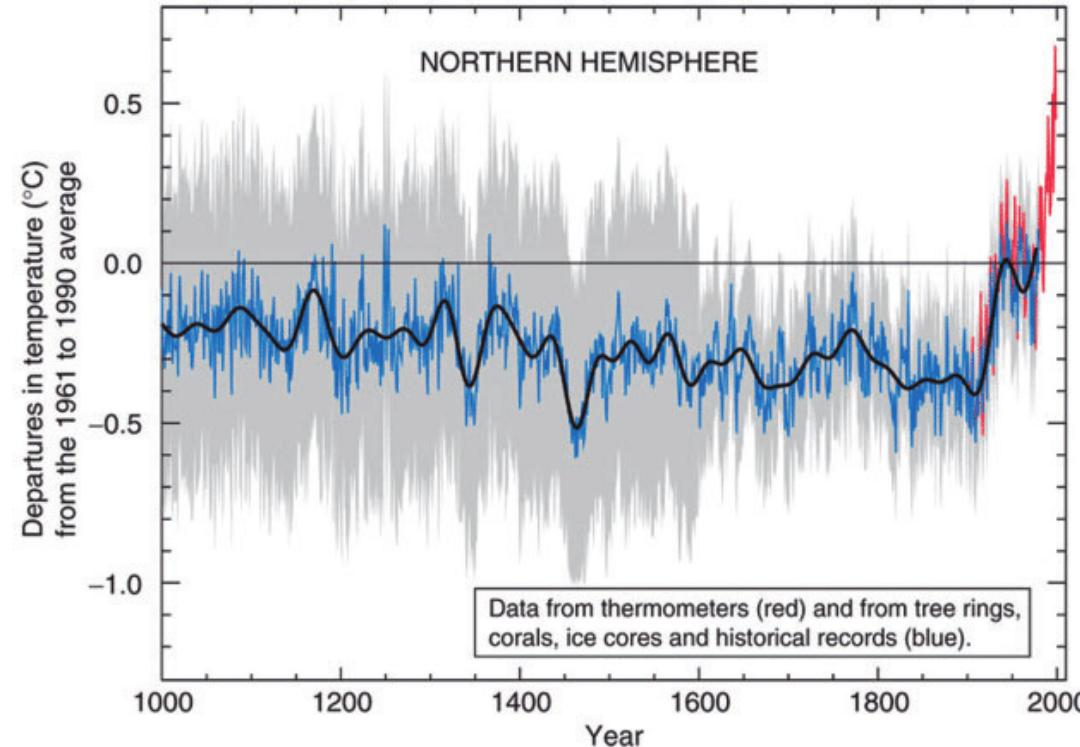
A short visual history of time-series graphs

Multiple charts showing records of the Weather in New York City for December, 1912.



Time-series graph that change public understanding

The Hockey Stick Chart



Reference: Michael E. Mann, Raymond S. Bradley, Malcolm K. Hughes (1999) "[Northern hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations](#)". *Geophysical Research Letters*, Vol. 26, No. pp. 759-762.

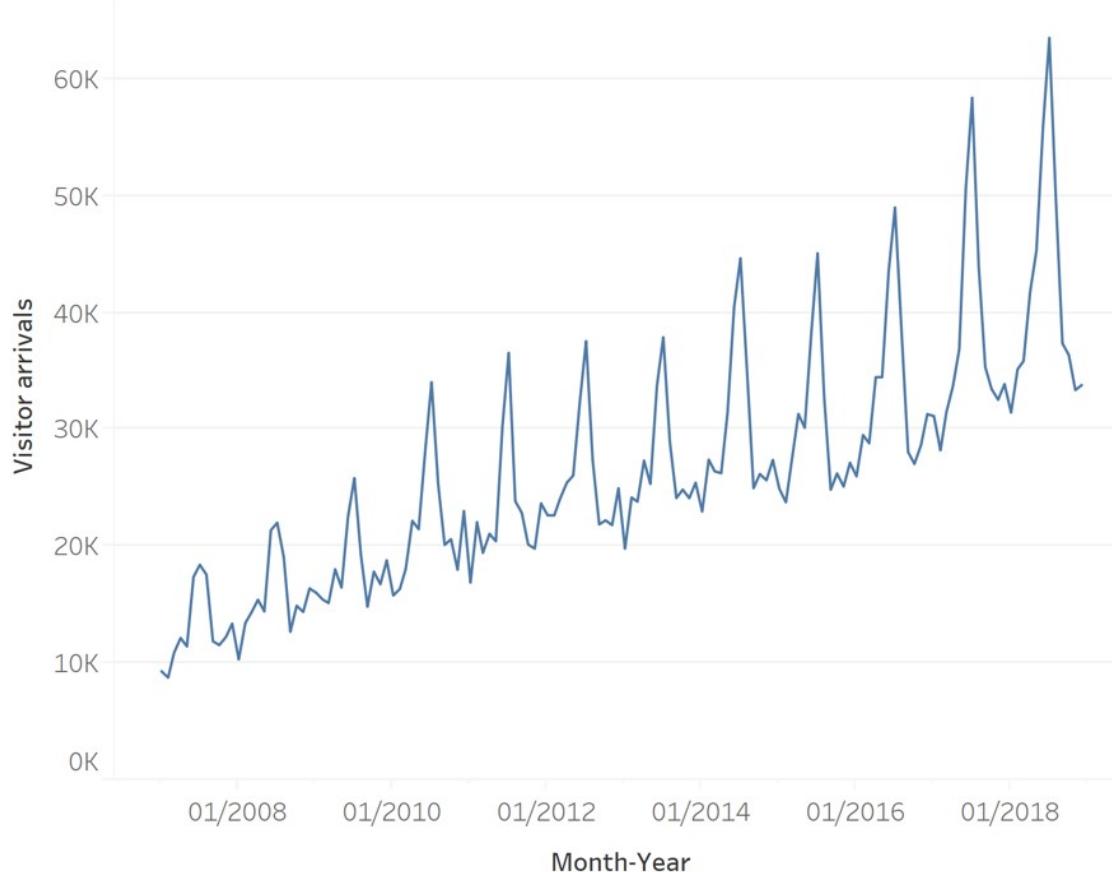
Time-series data patterns

- Trend
- Variability
- Rate of change
- Co-variation
- Cycles
- Exceptions

Time-series Patterns: Trend

- The overall or general direction of change in a series of time-series values is called the trend.

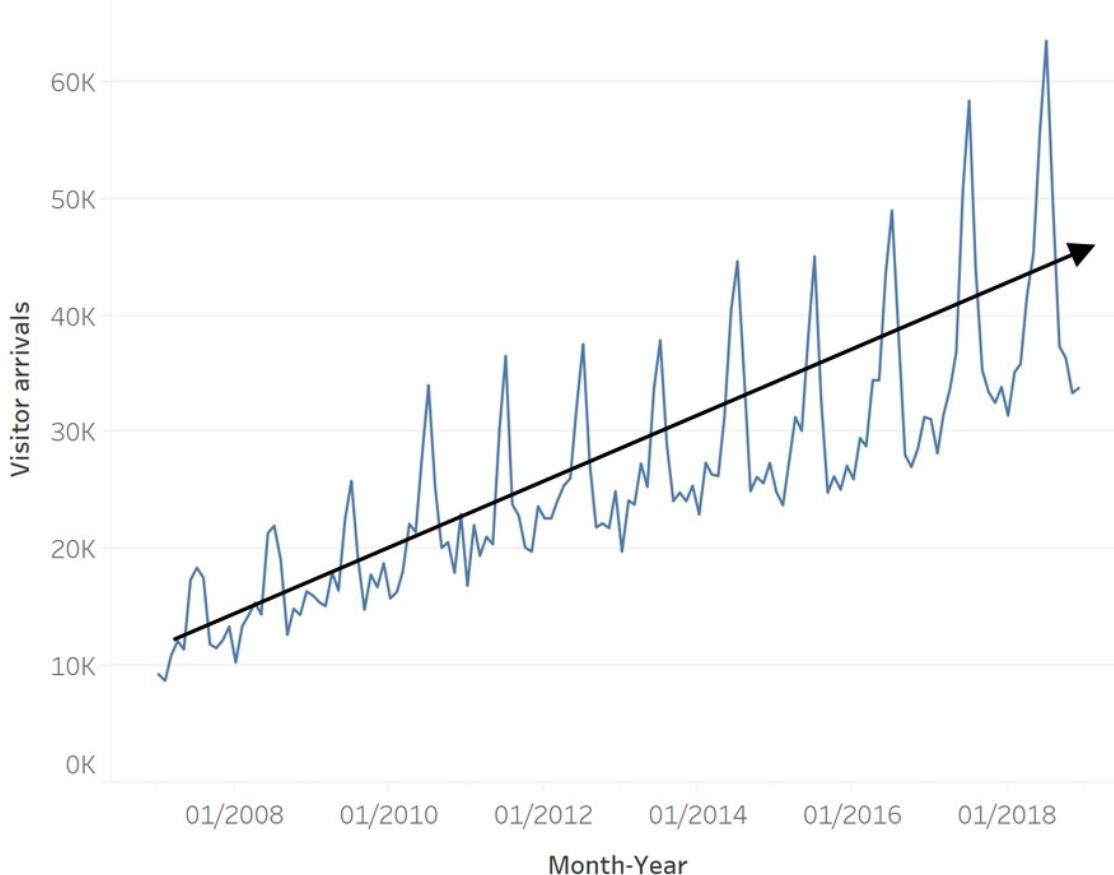
Monthly visitor arrivals from **Vietnam**, 2007-2018



Time-series Patterns: Trend

- An upward trend.

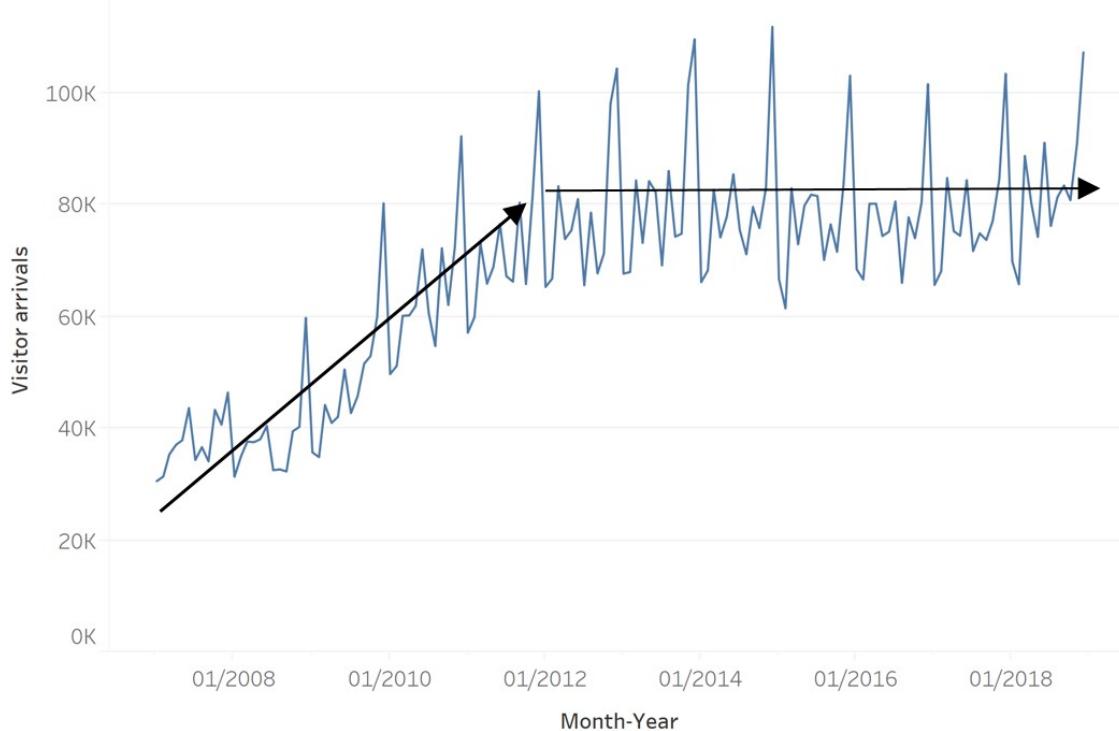
Monthly visitor arrivals from **Vietnam**, 2007-2018



Time-series Patterns: Trend

- A mixed trends.

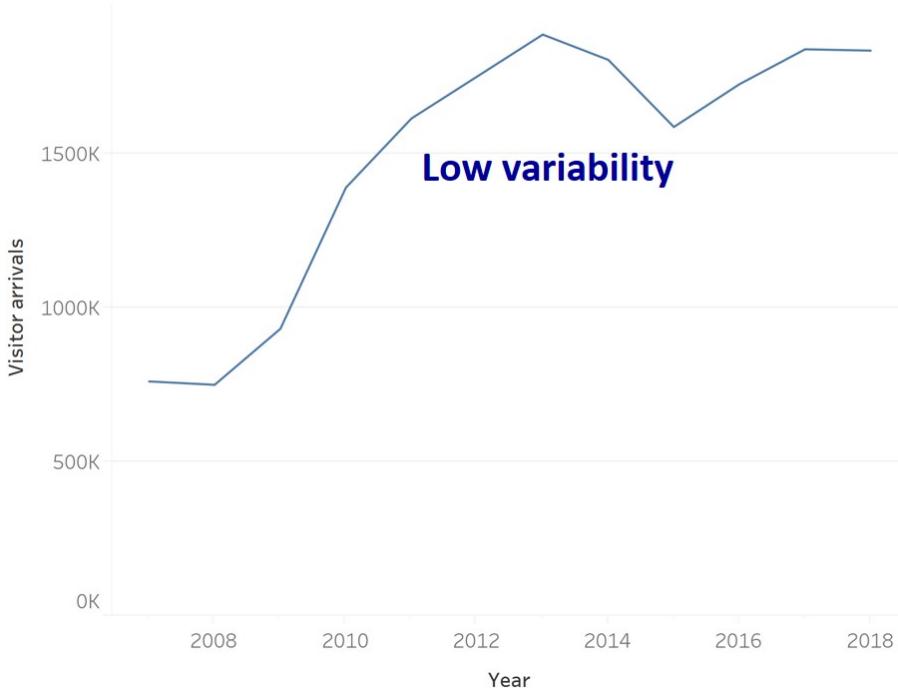
Monthly visitor arrivals from **Malaysia**, 2007-2018



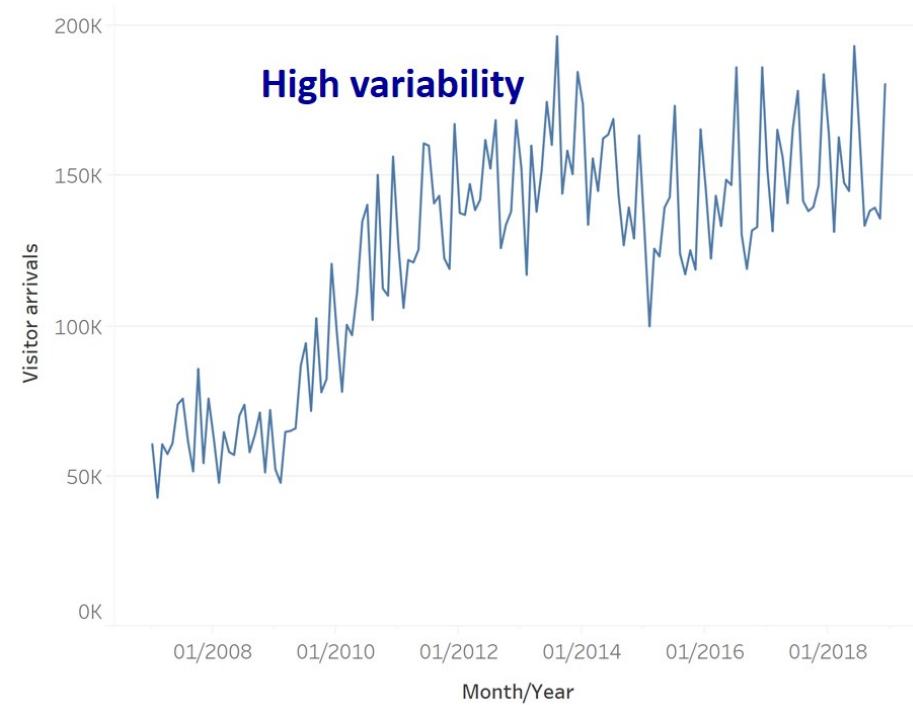
Time-series Patterns: Variability

- The average degree of change from one point of time to the next throughout a particular span of time.

Monthly visitor arrivals from Indonesia, 2007-2018



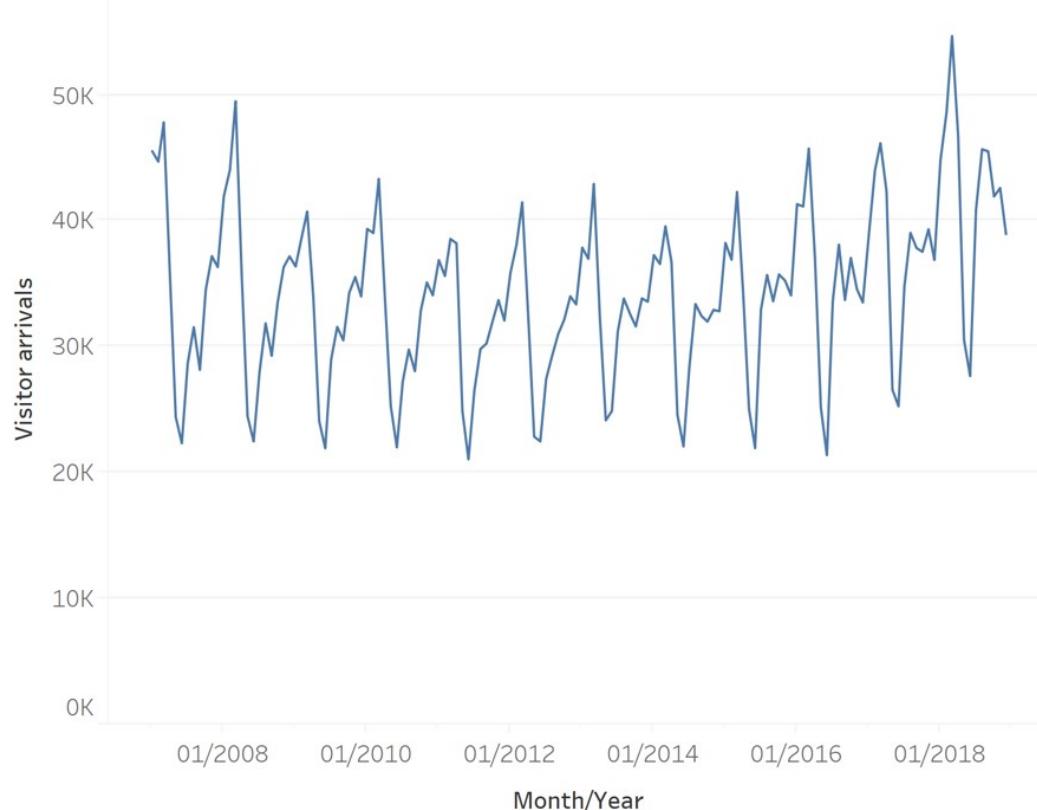
Monthly visitor arrivals from Indonesia, 2007-2018



Time-series Patterns: Cycles

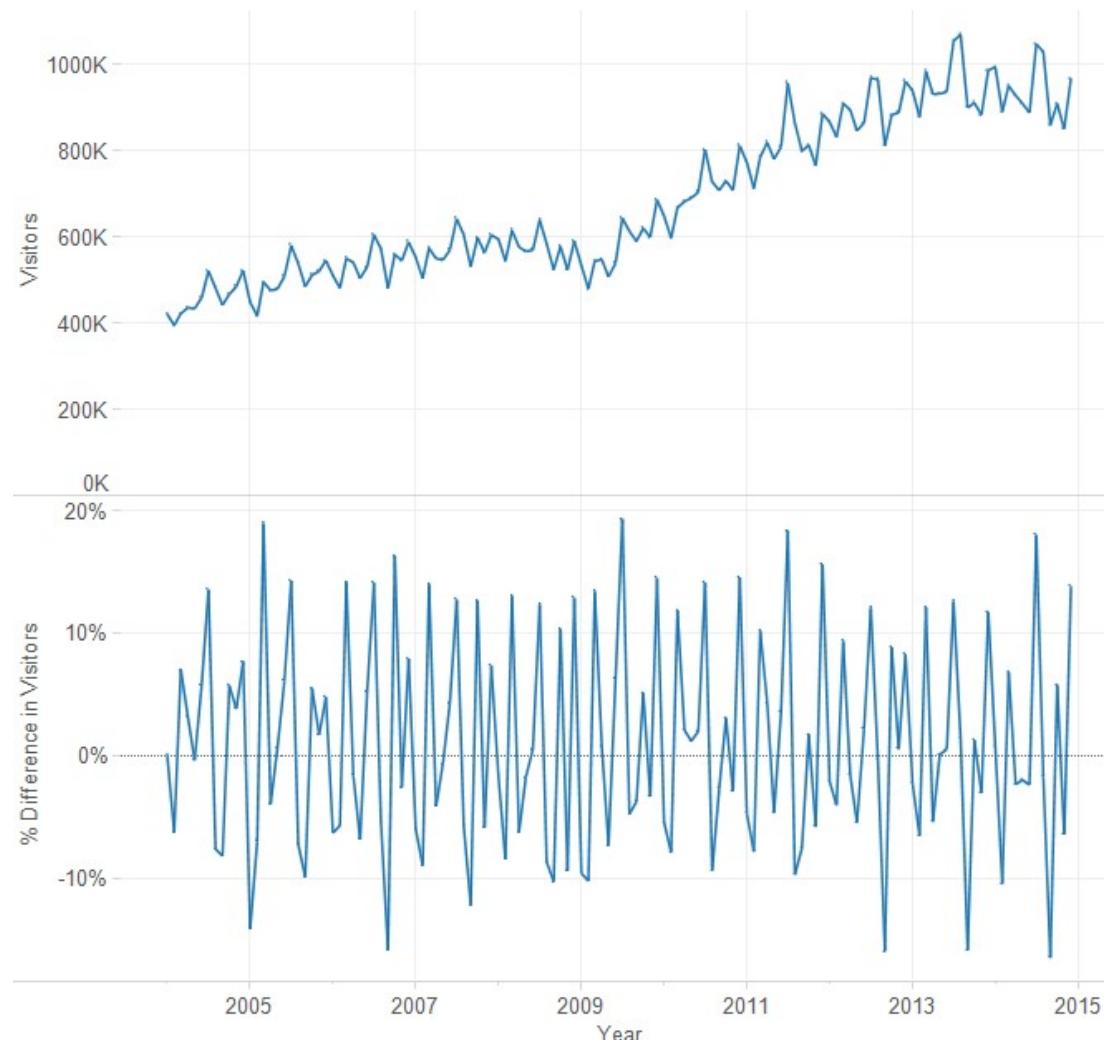
- Cycles are patterns that repeat at regular intervals.

Monthly visitor arrivals from **United Kingdom**,
2007-2018



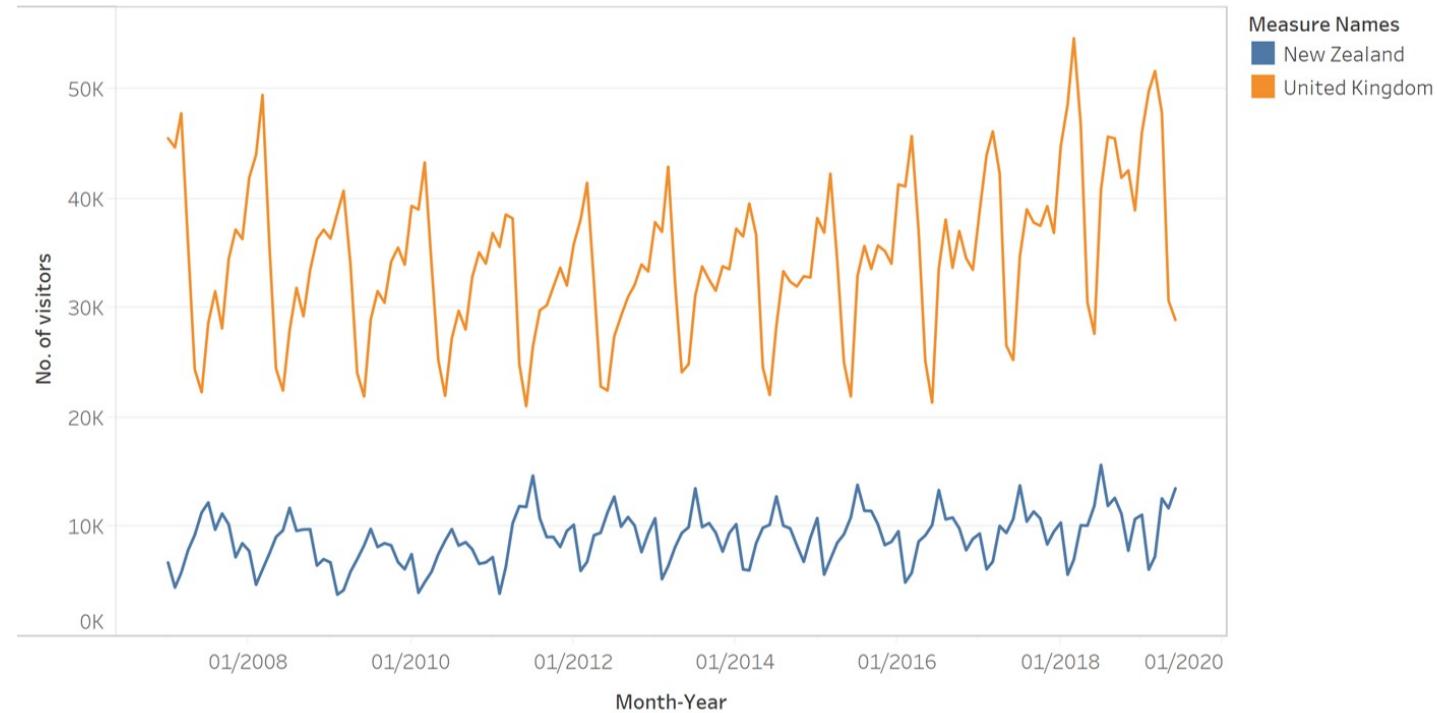
Time-series Patterns: Rate of change

- The percentage difference between one value to the next value.



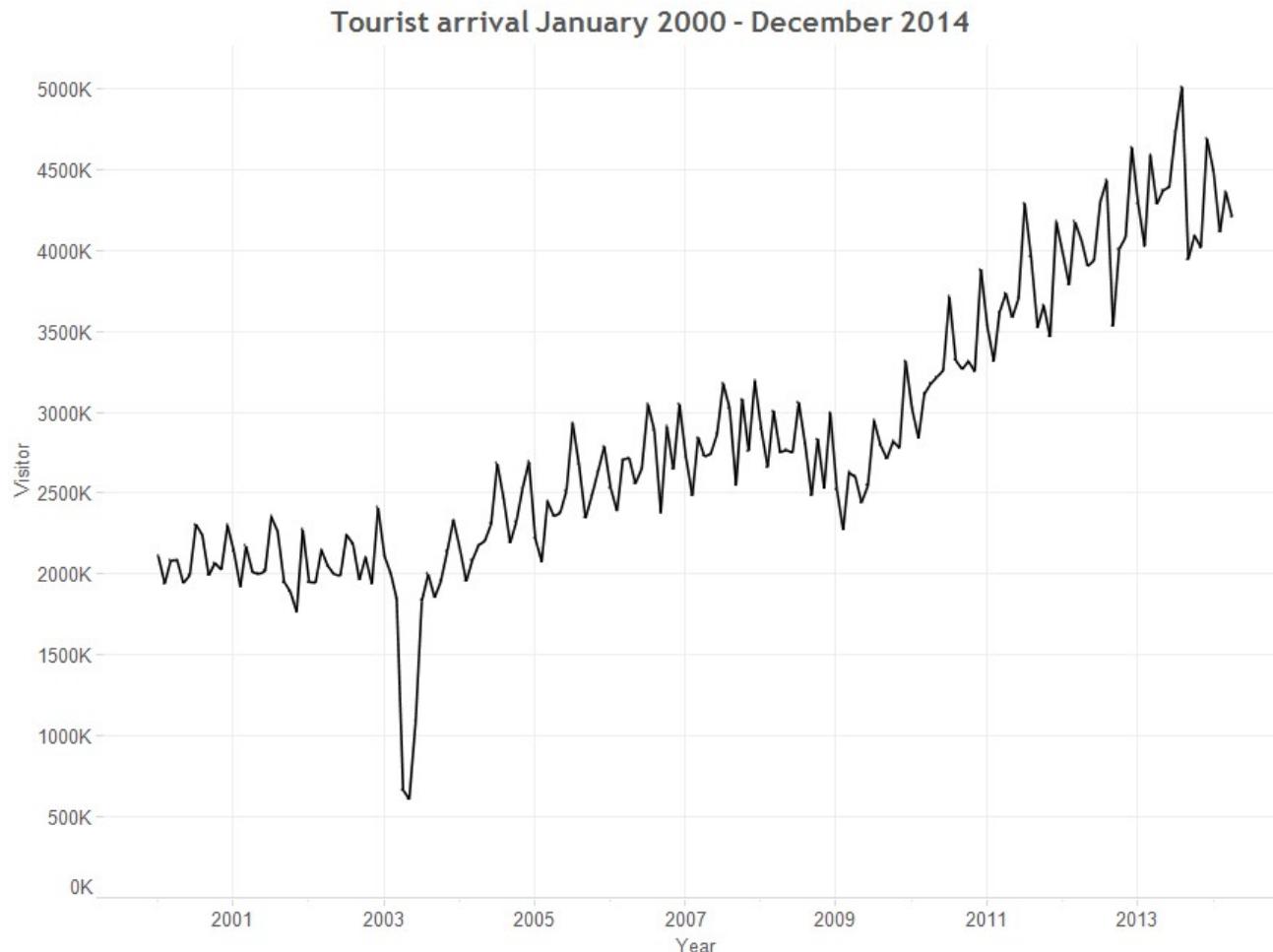
Time-series Patterns: Co-variation

- When two time series relate to one another so that changes in one are reflected as changes in the other, either immediately or later.



Time-series Patterns: Exceptions

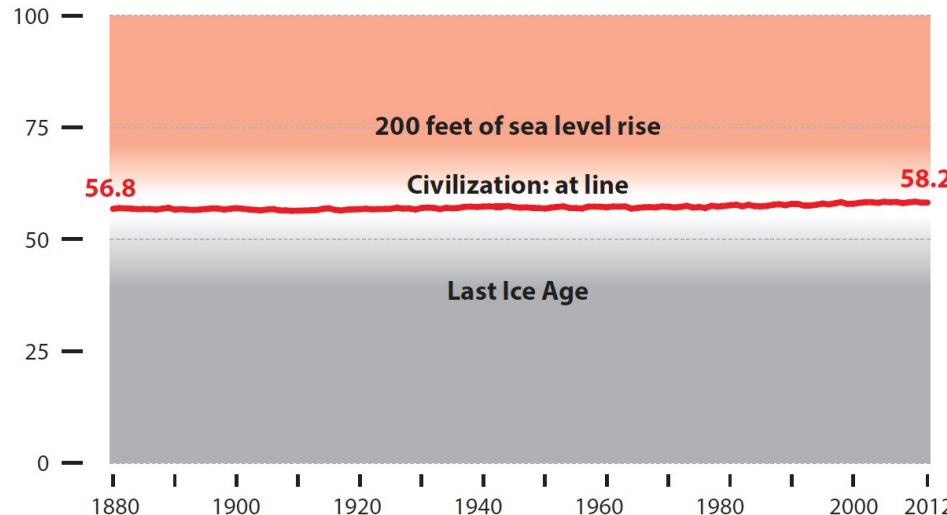
- Values that fall outside the norm.



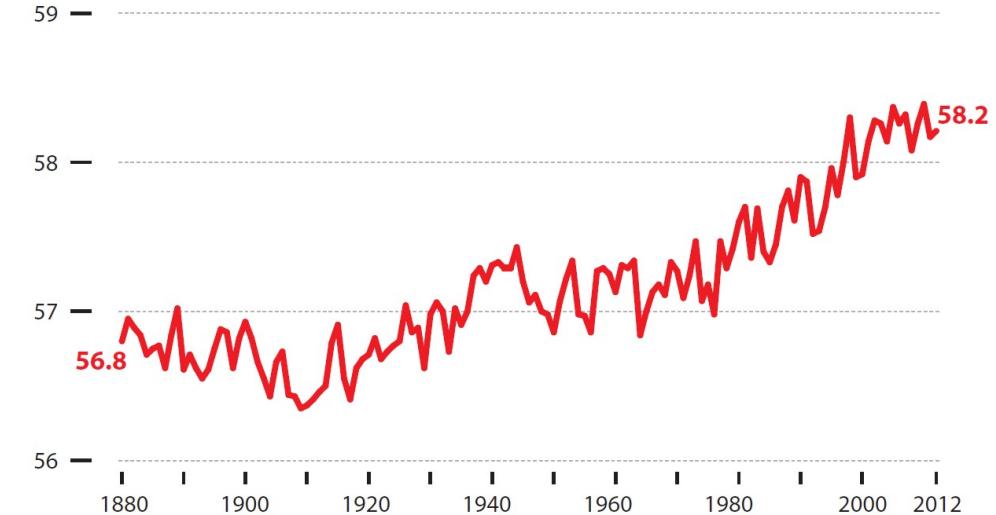
Line graph design tips

Not all line graphs should start at zero!

Average annual global temperature in degrees Fahrenheit



Average annual global temperature in degrees Fahrenheit

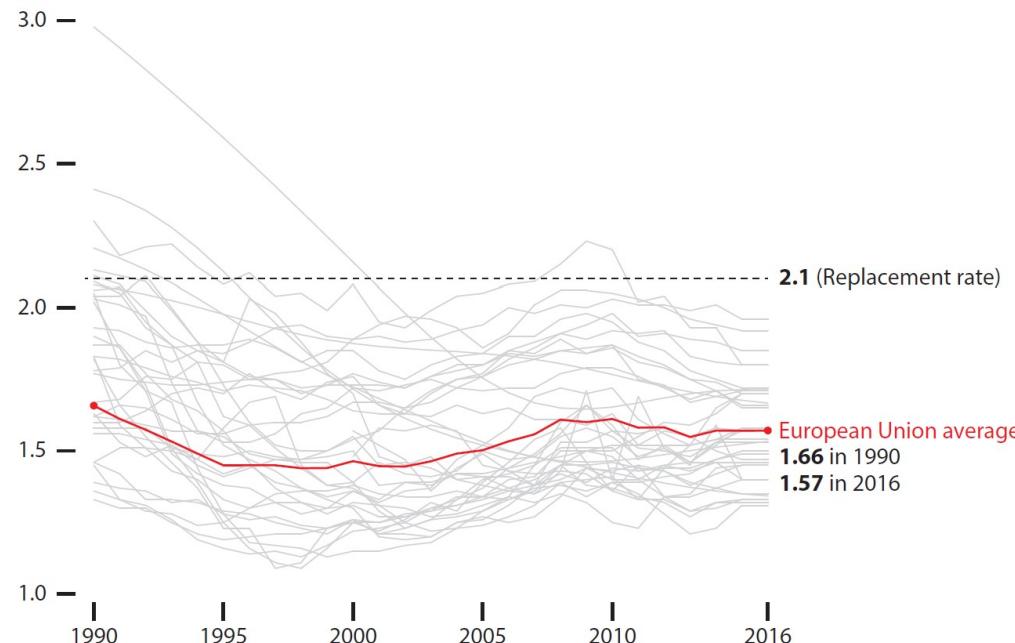


Line graph design tips

Multiple lines in a single graph is less effective than trellis line graph

Fertility rate in European countries

Children per woman. Each grey line is a country.



Fertility rate in European countries, 1990–2016

Compared to the replacement rate: 2.1 children per woman

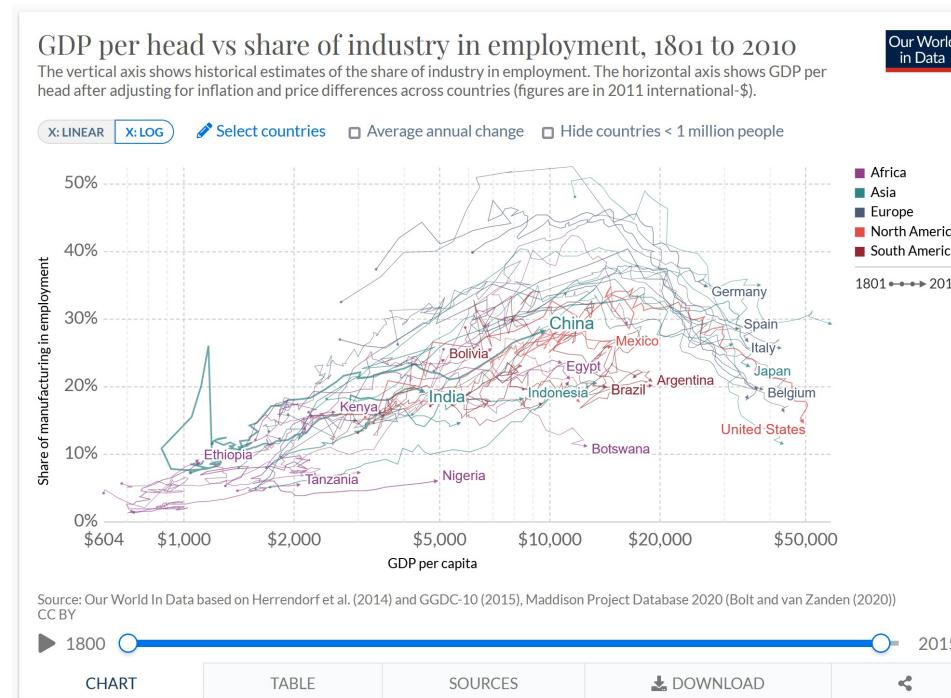
Note: not all these countries belong to the European Union



Line graph design tips

Not all time-series graphs have time on the x-axis

The **connected scatter plot** below reveals changes over time by joining each time event points on the scatter plot. The historical trail can be an effective alternative to animation.

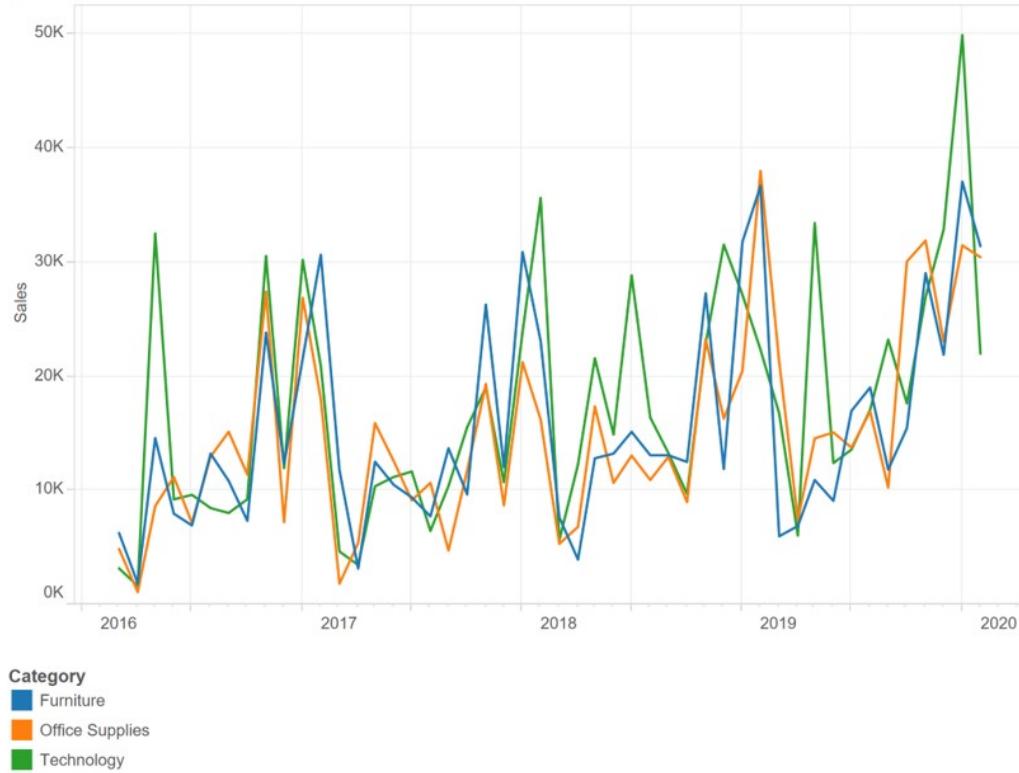


Source: <https://ourworldindata.org/growth-and-structural-transformation-are-emerging-economies-industrializing-too-quickly>

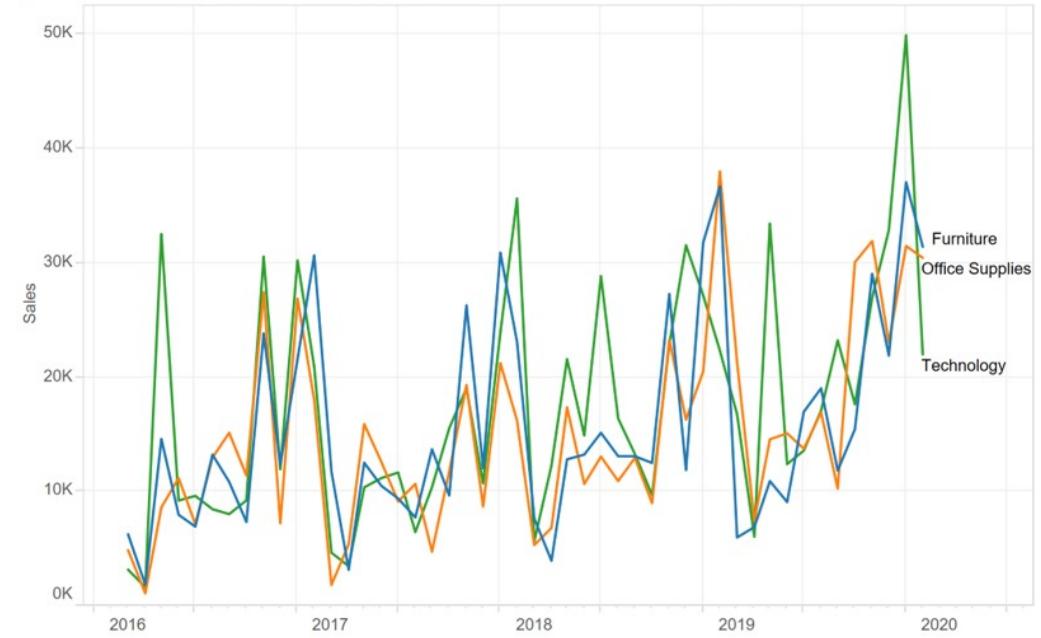
Line graph design tips

Label line graph instead of using legend

Monthly sales by product category, January 2016-December 2019

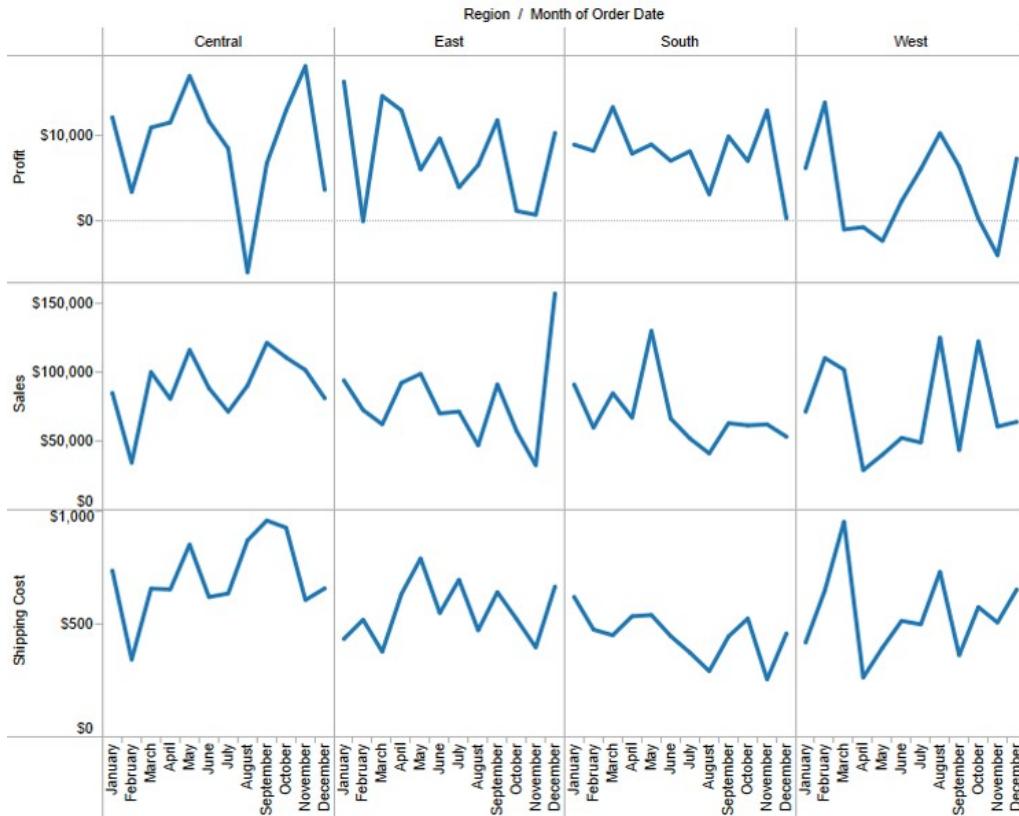


Monthly sales by product category, January 2016-December 2019

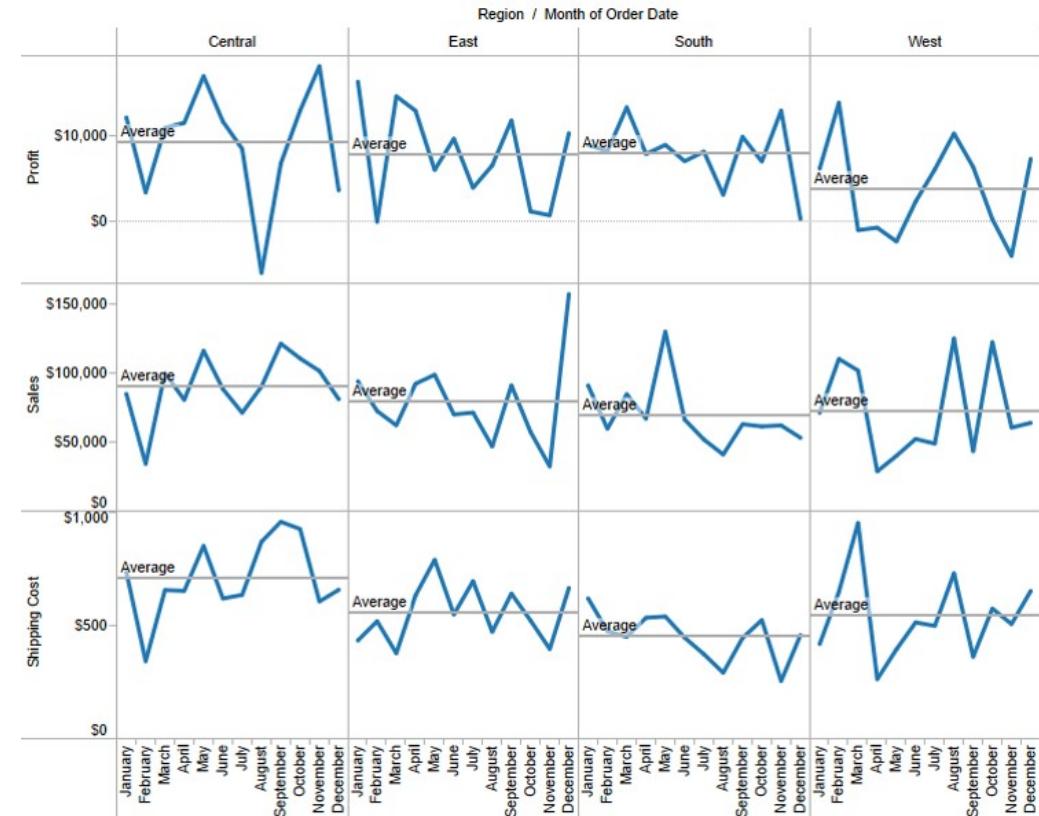


Line graph design tips

Line chart without reference line

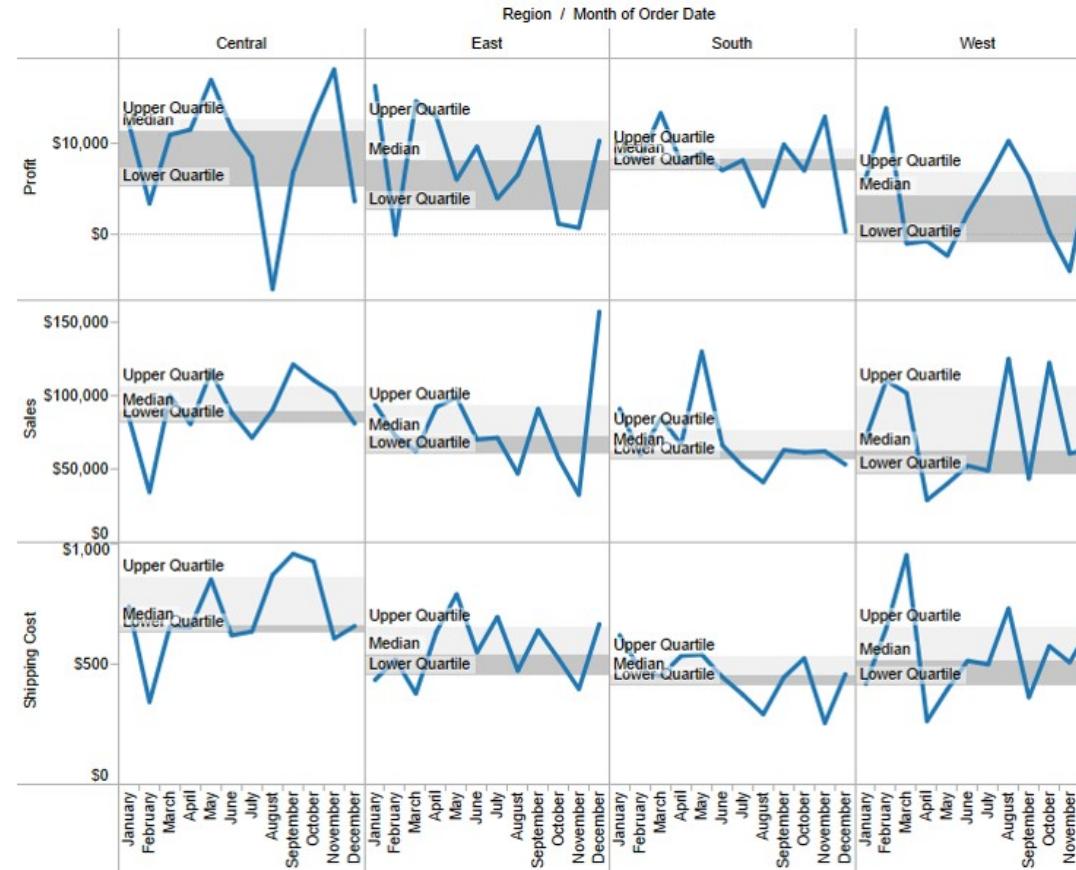


Line chart with reference line



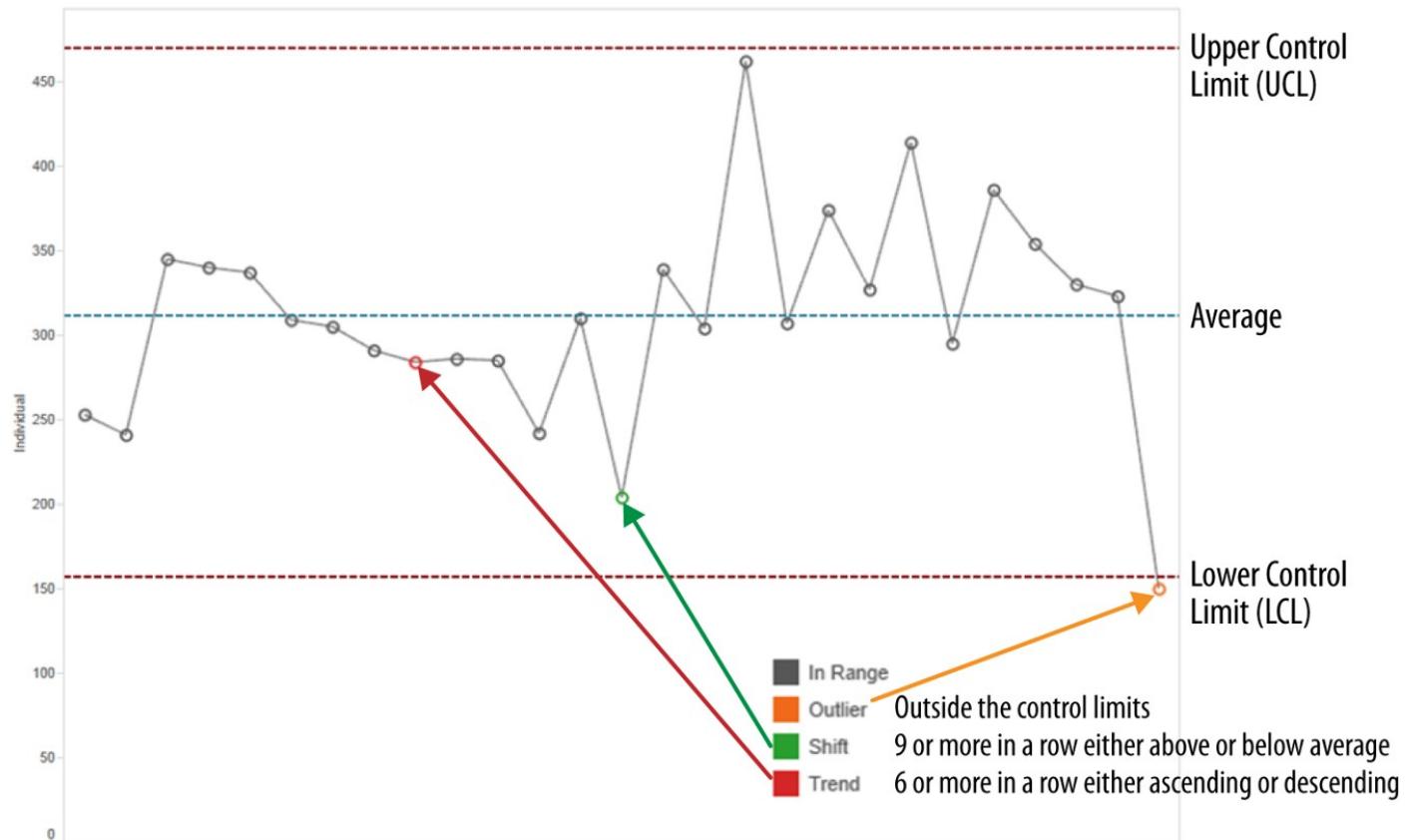
Line graph design tips

Line chart with reference band



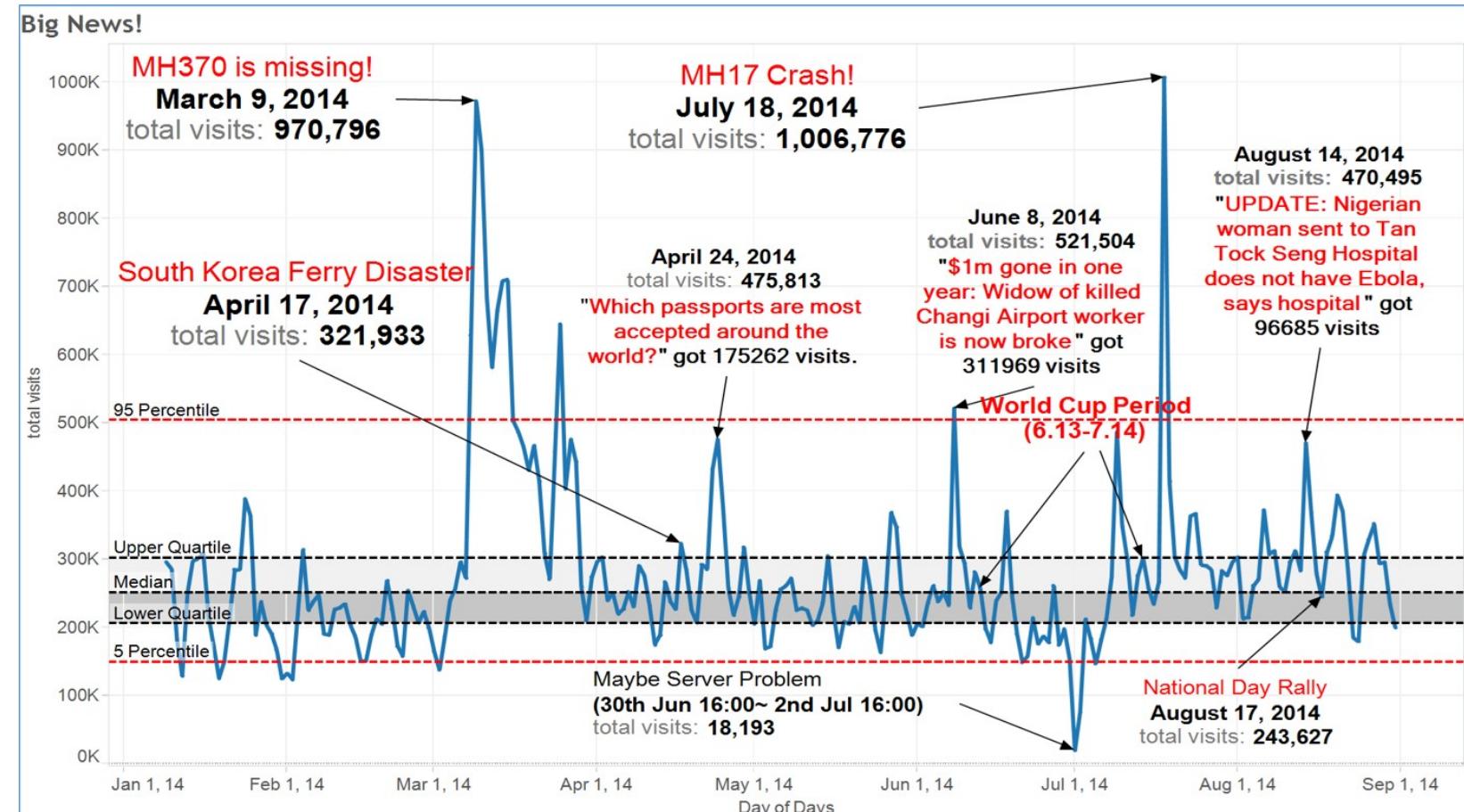
Beyond Line Graph

Control Chart: An analytical line chart



Control chart in real world

In this use-case, control chart was used to display numbers of views of a digital news platform.



Beyond Line Graph

Candlestick chart

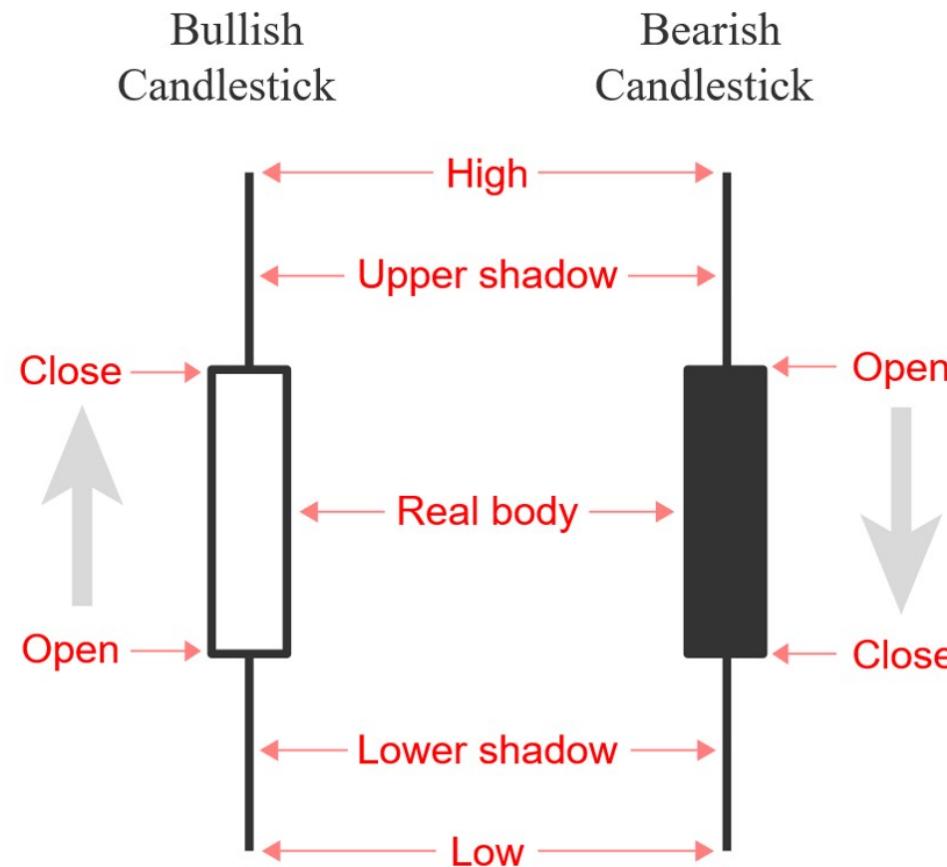
Candlestick Charts display multiple bits of price information such as the open price, close price, highest price and lowest price through the use of candlestick-like symbols.



Candlestick chart

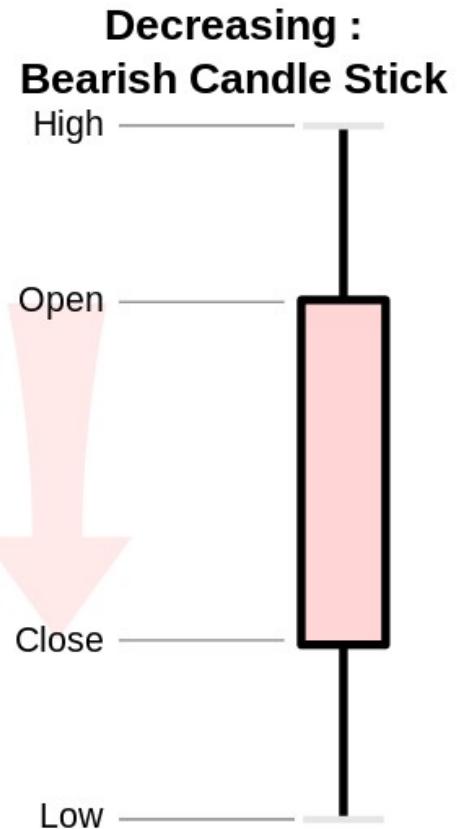
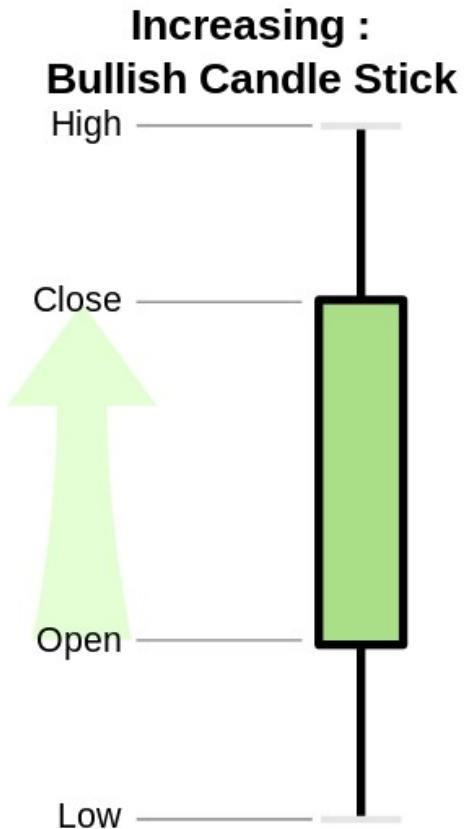
Interpreting candlestick chart

Candlesticks are usually composed of the body (black or white), and an upper and a lower shadow (wick): the area between the open and the close is called the real body, price excursions above and below the real body are called shadows.



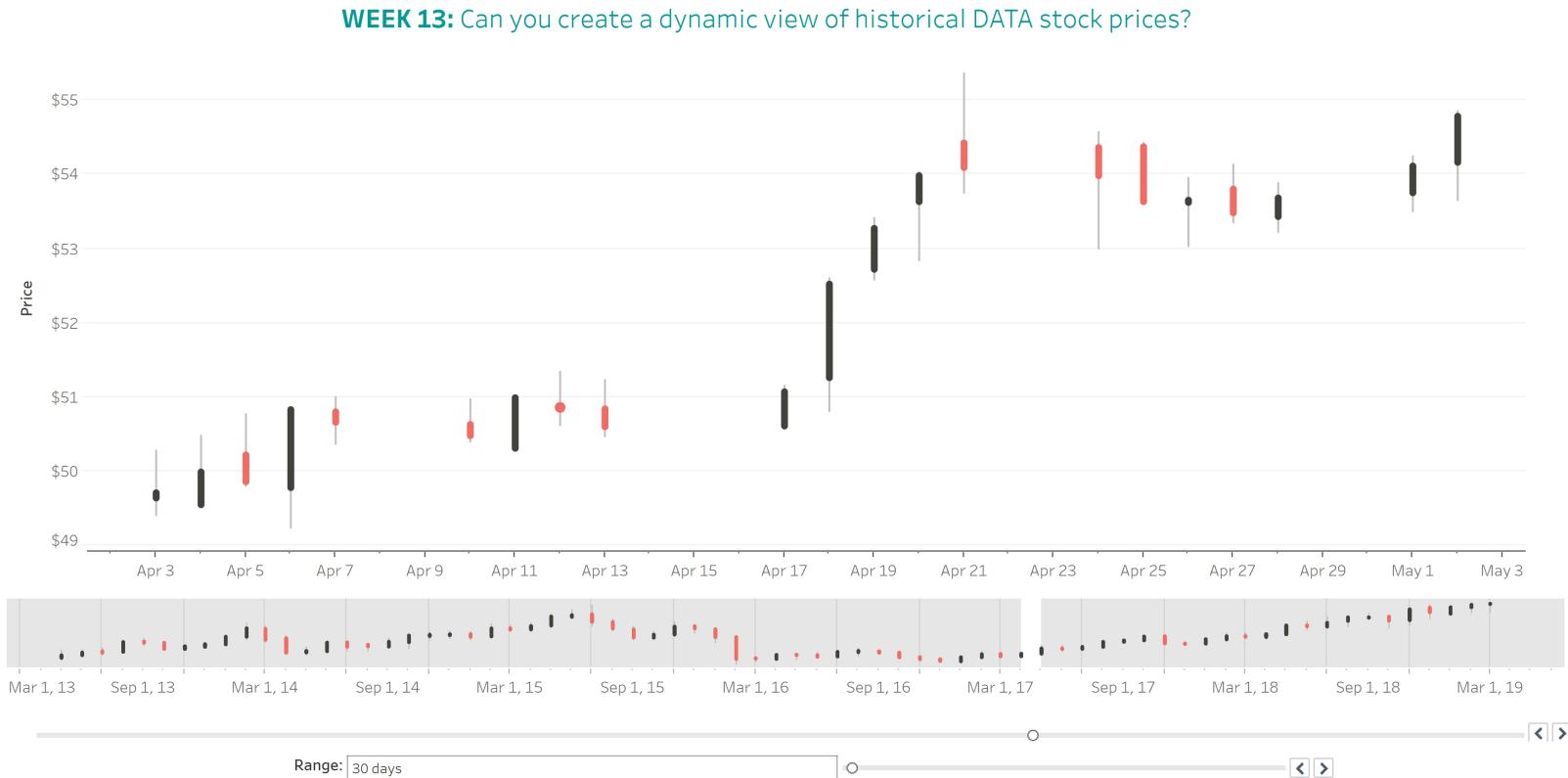
Candlestick chart

Interpreting candlestick chart



Learning from the Master

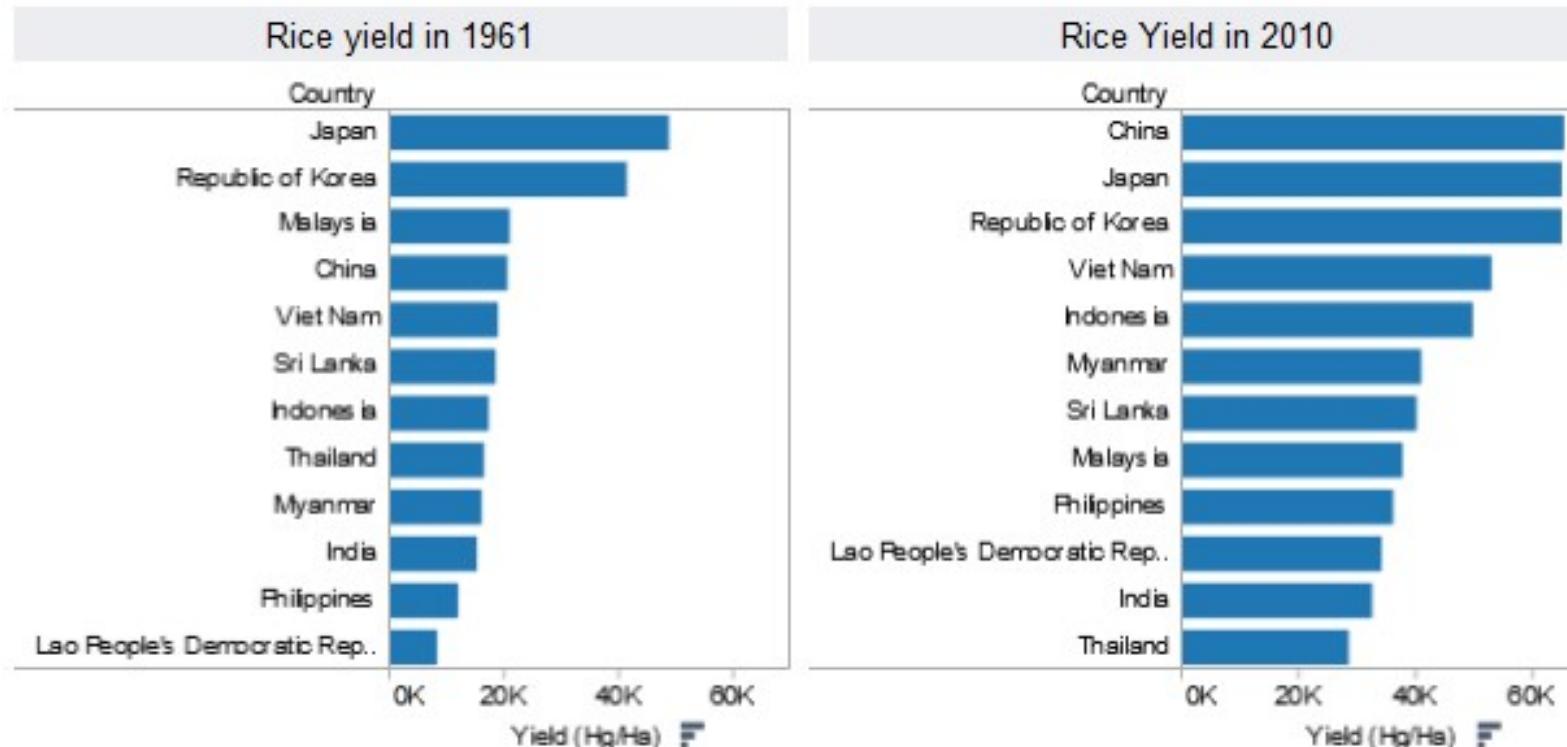
This link provides an example of [interactive candlestick](#).



Click on this [link](#) for more detail.

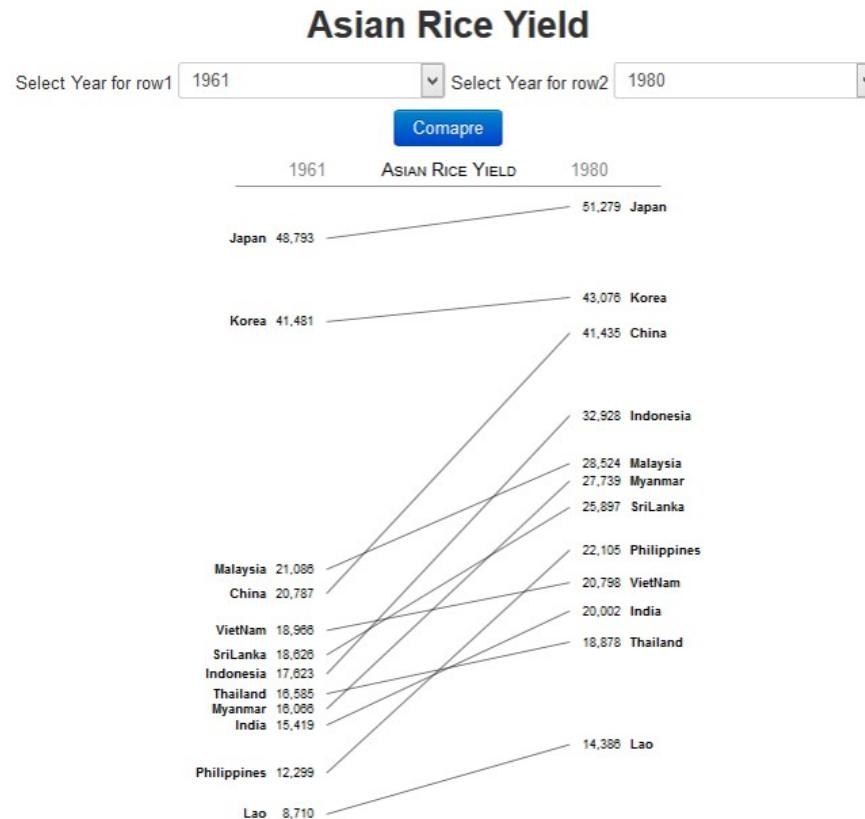
Challenge I: Visualising Change between Two Points in Time

Bar chart method



Slopegraphs come to rescue!

Slopegraphs
compare changes
usually over time
for a list of nouns
located on an
ordinal or interval
scale.

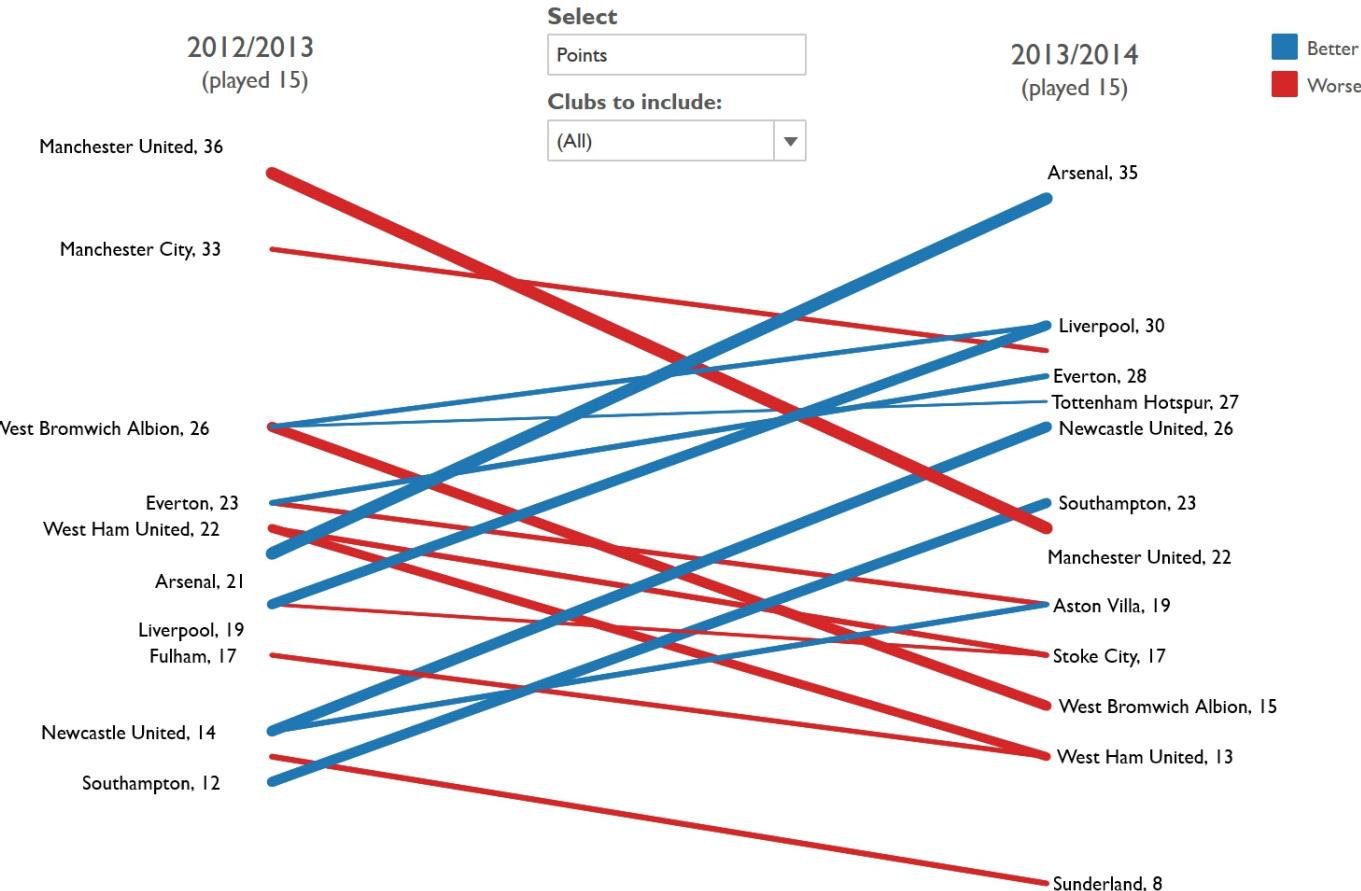


Reference: http://www.edwardtufte.com/bboard/q-and-a-fetch-msg?msg_id=0003nk

Learning from the Master

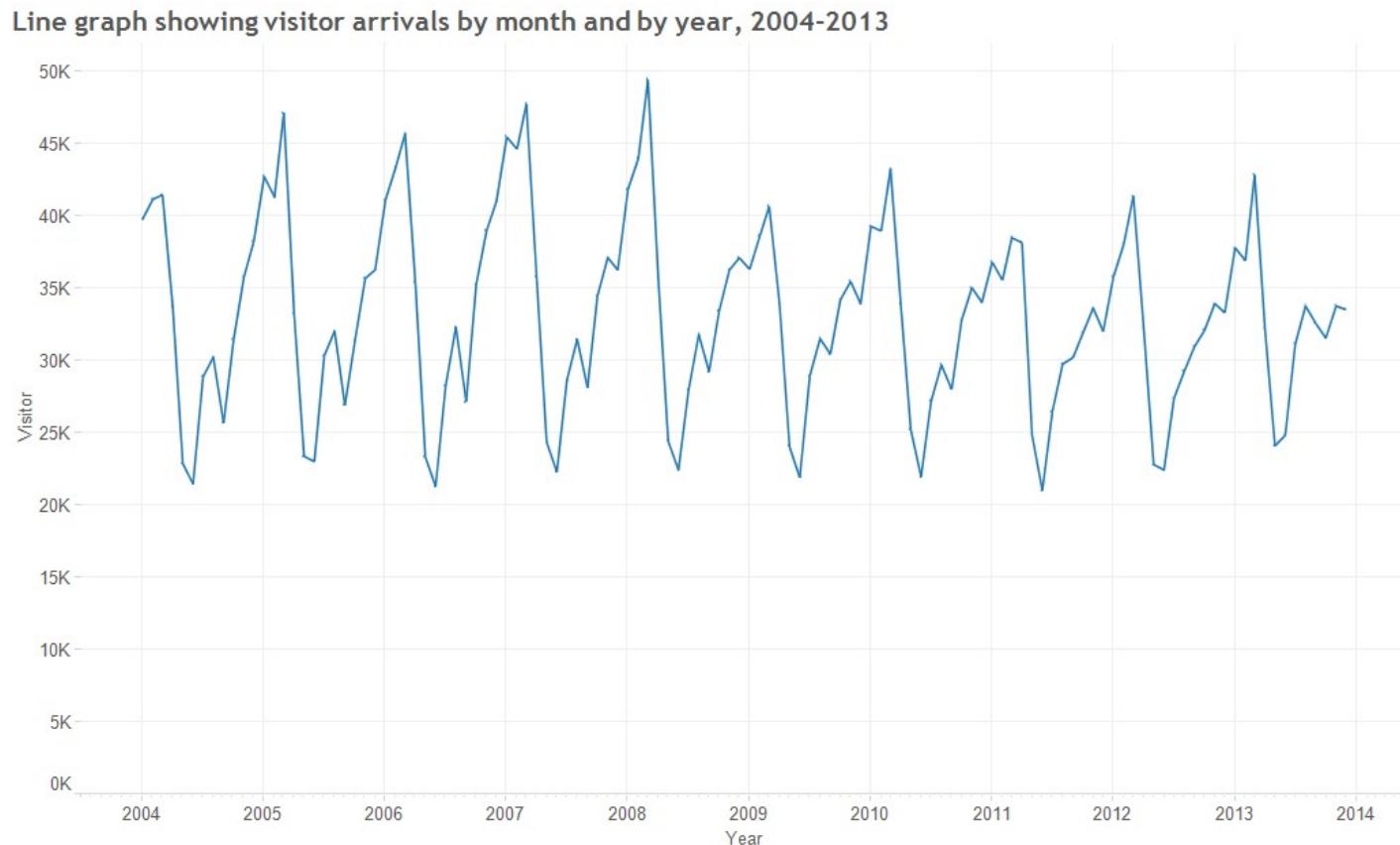
Visit [Tableau Public](#) to try out the interactive version and visit this [link](#) to learn more.

Barclay's Premier League Tables: Comparing 2012/2013 Starts to 2013/2014 Starts



Challenge II: Visualising cyclical patterns

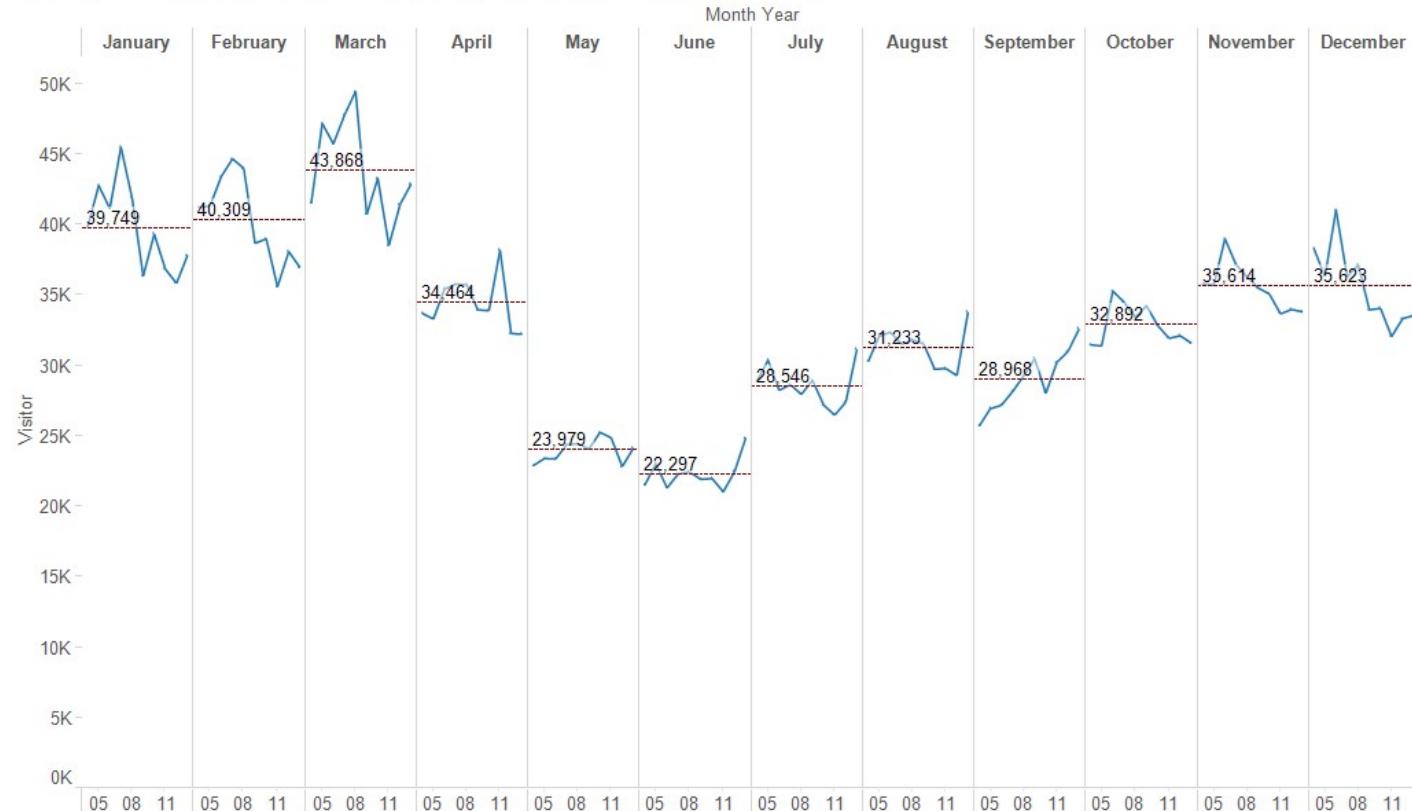
Classic line graph method



Challenge II: Visualising cyclical patterns

Solution: Cycle plot

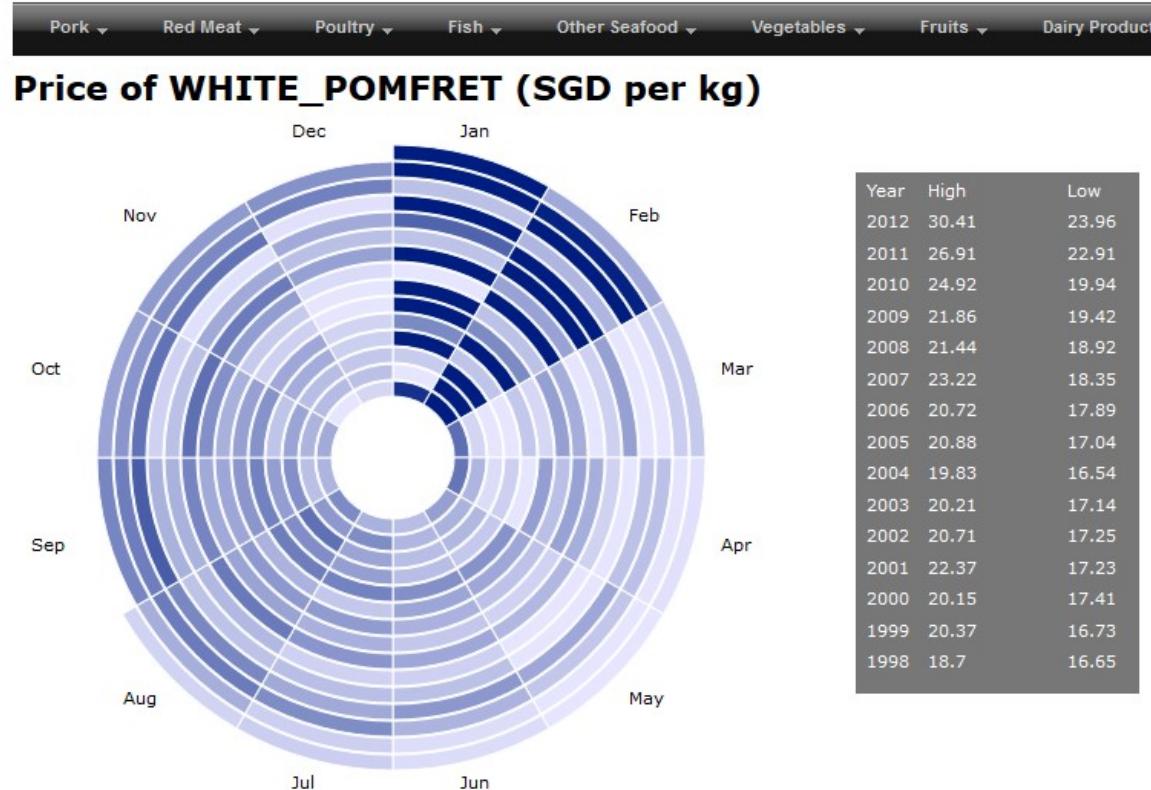
Cycle plot showing visitor arrivals by month and by year, 2004-2013



Reference: http://www.perceptualedge.com/articles/guests/intro_to_cycle_plots.pdf

Challenge II: Visualising cyclical patterns

Solution: Sunburst diagram method

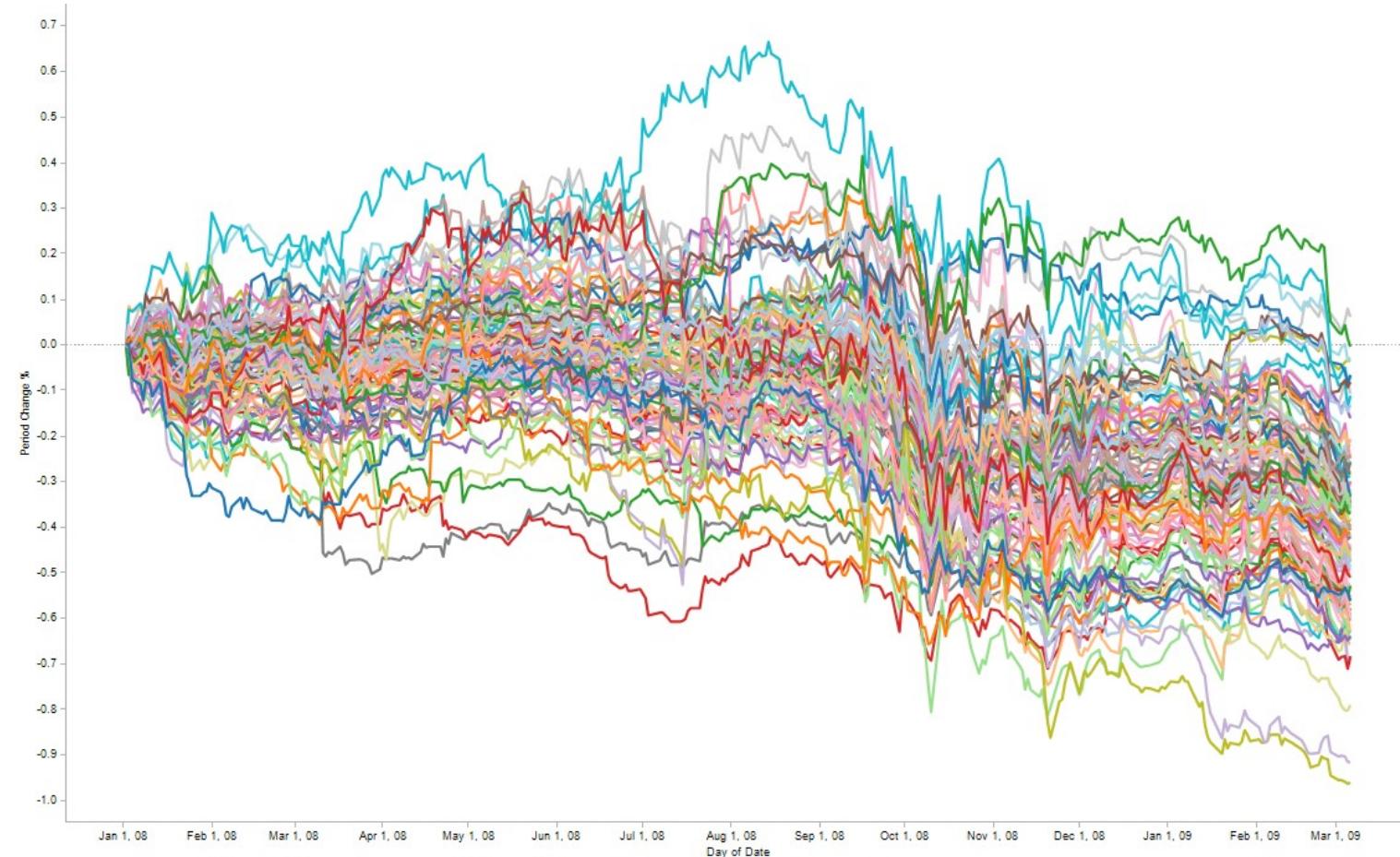


Each concentric ring represents a year, beginning from year 1998 for the innermost ring, to year 2012 for the outermost ring.
Click on any of the 12 sections of the circle to view the numerical prices of the food item.

Challenge III: Massive Time-series Data

Classic line graph method

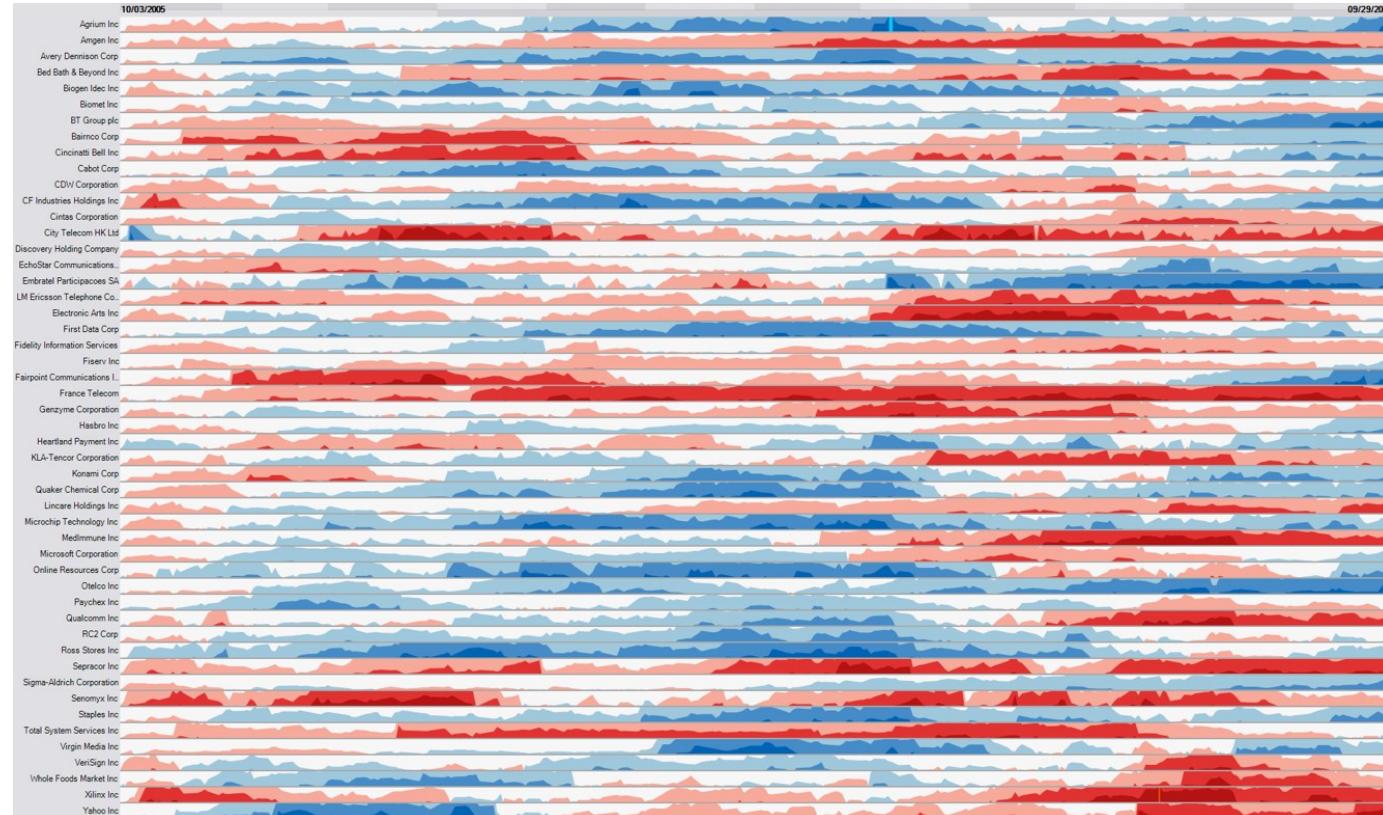
Line graph will not be effective to reveal high number of time series lines (for example 50)



Challenge III: Massive Time-series Data

Solution: Horizon graph

By dividing an area chart into consecutive layers, horizon graphs present time-series data in a compact space while preserving resolution.



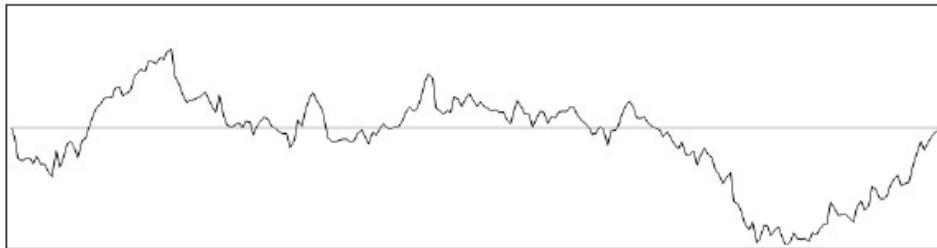
Reference: https://www.perceptualedge.com/articles/visual_business_intelligence/time_on_the_horizon.pdf

Solution: Horizon graph

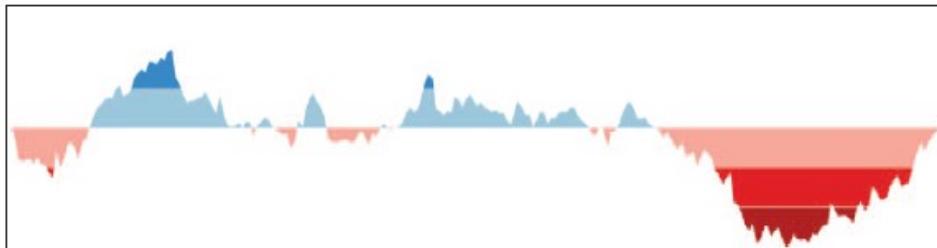
The basic construct of a horizon graph

Figure on the right shows the process of constructing an horizon graph.

Reference: [The Development of the Horizon Graph](#)



(a) Standard line graph centered around a baseline.



(b) Color (blue is positive, red is negative) and layering.



(c) Mirroring around the baseline.



(d) Wrapping bands into a single space.

Horizon graph in Tableau

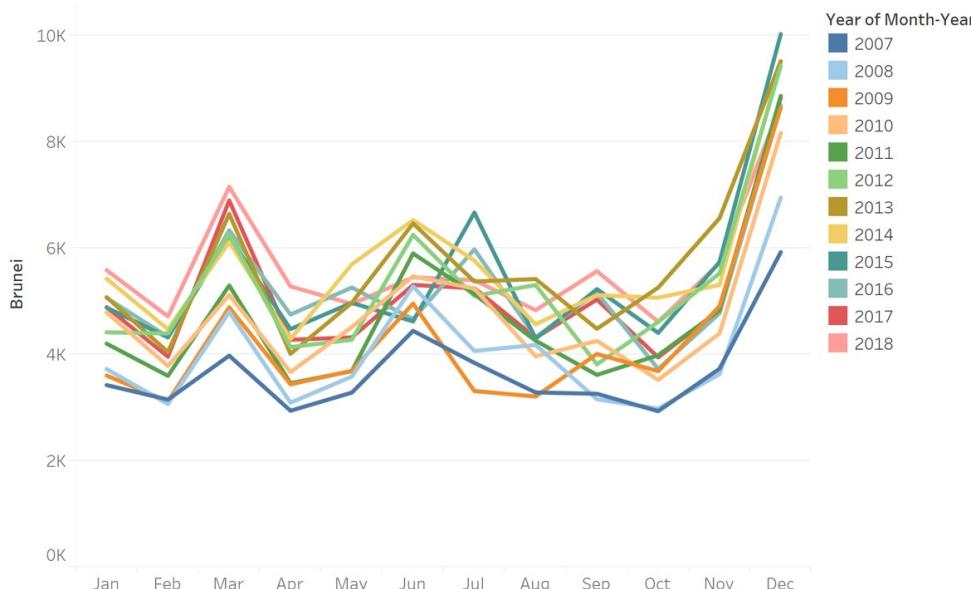


Source: <https://public.tableau.com/en-us/gallery/unemployment-horizon-chart>. This video <https://www.tableau.com/learn/tutorials/on-demand/horizon-charts> provides step-by-step explanation on how to create a horizon graph using Tableau.

Challenge IV: Distribution over time

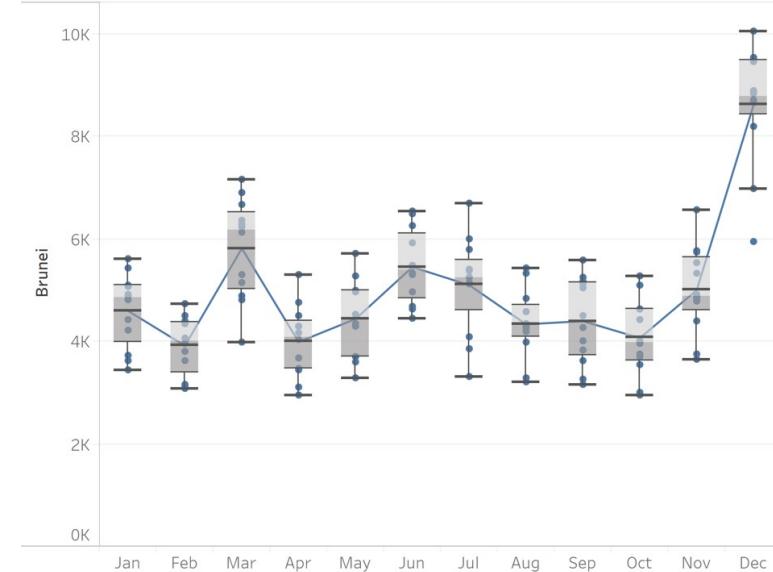
Line graph method

Distribution of monthly visitors by air from Brunei Darussalm, 2007-2018



Boxplot method

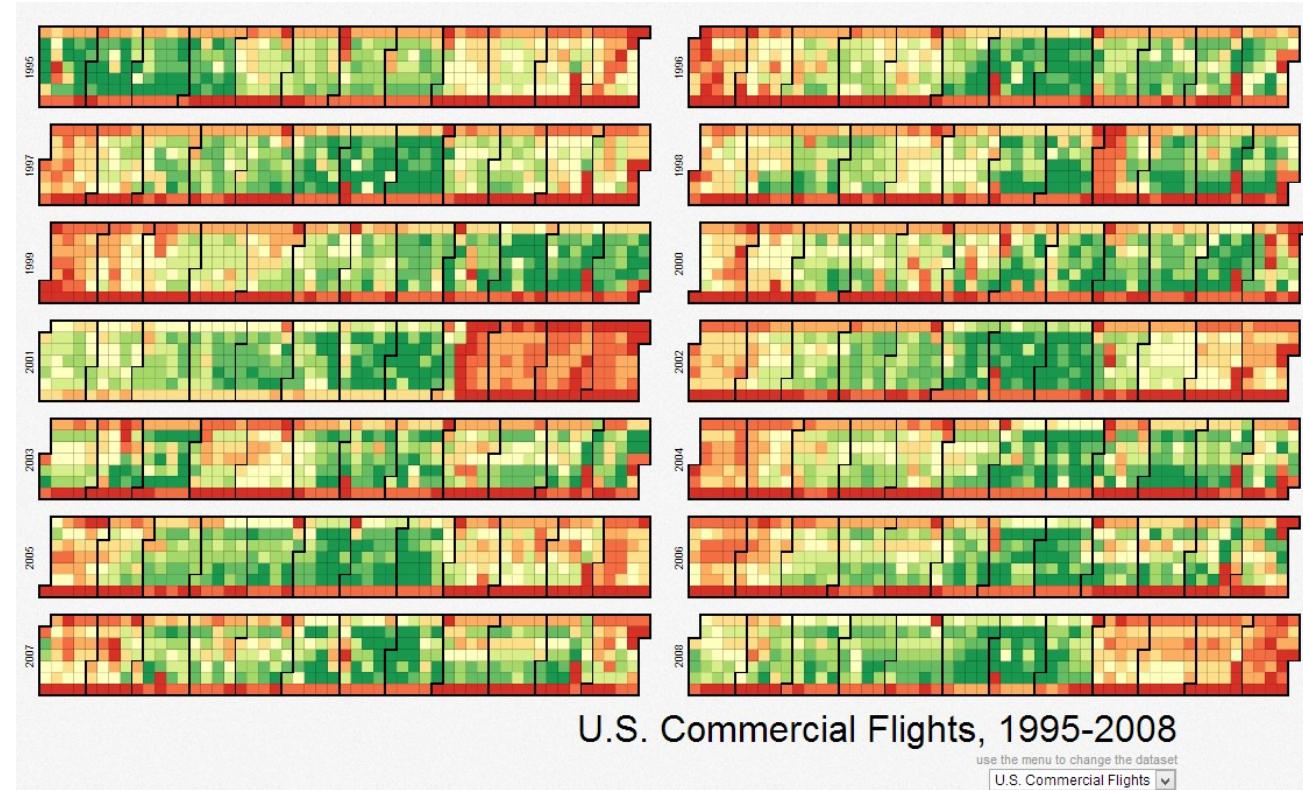
Distribution of monthly visitors by air from Brunei Darussalm, 2007-2018



Alternative Time-series Data Visualisation methods

Calendar Heatmap

It is a 2-dimensional calendar view that shows a value over time through color coding it, often with warmer colors indicating higher values (hence heatmap).

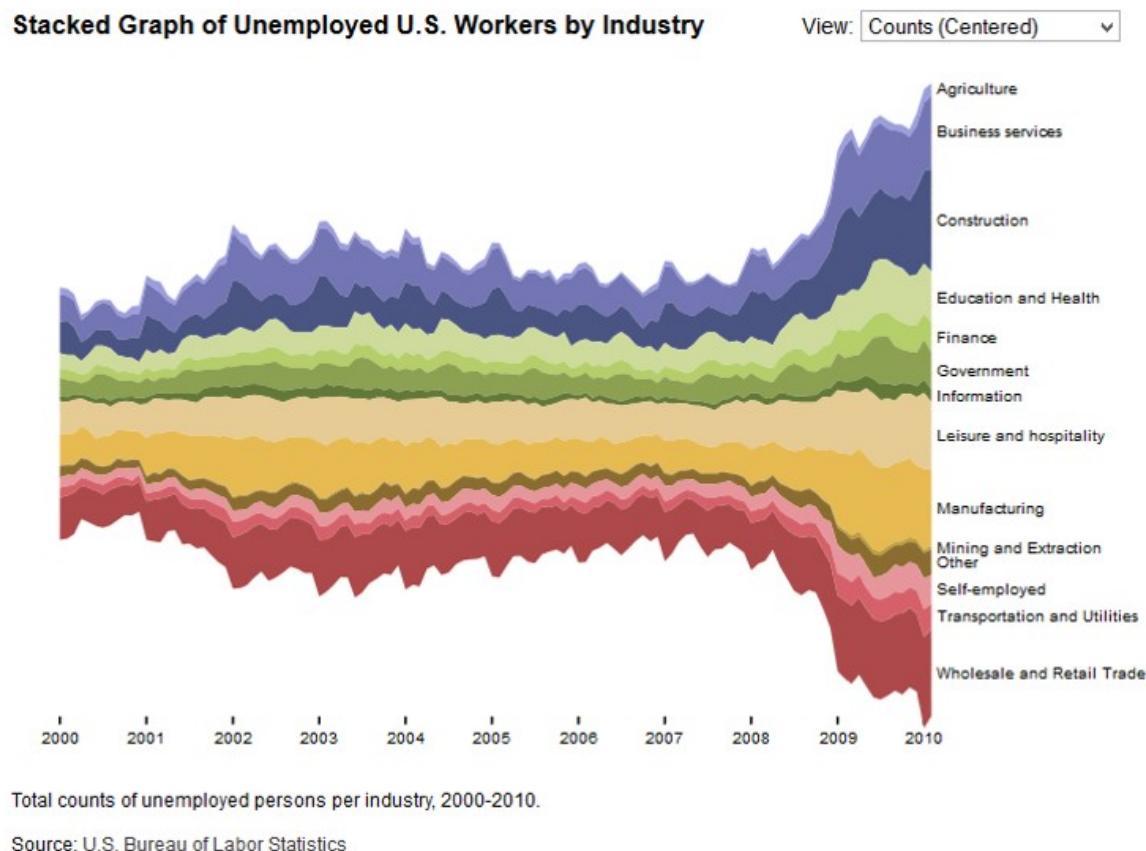


Source: <http://mbostock.github.io/d3/talk/20111018/calendar.html>

Alternative Time-series Data Visualisation methods

Stream Graph (also know as ThemeRiver)

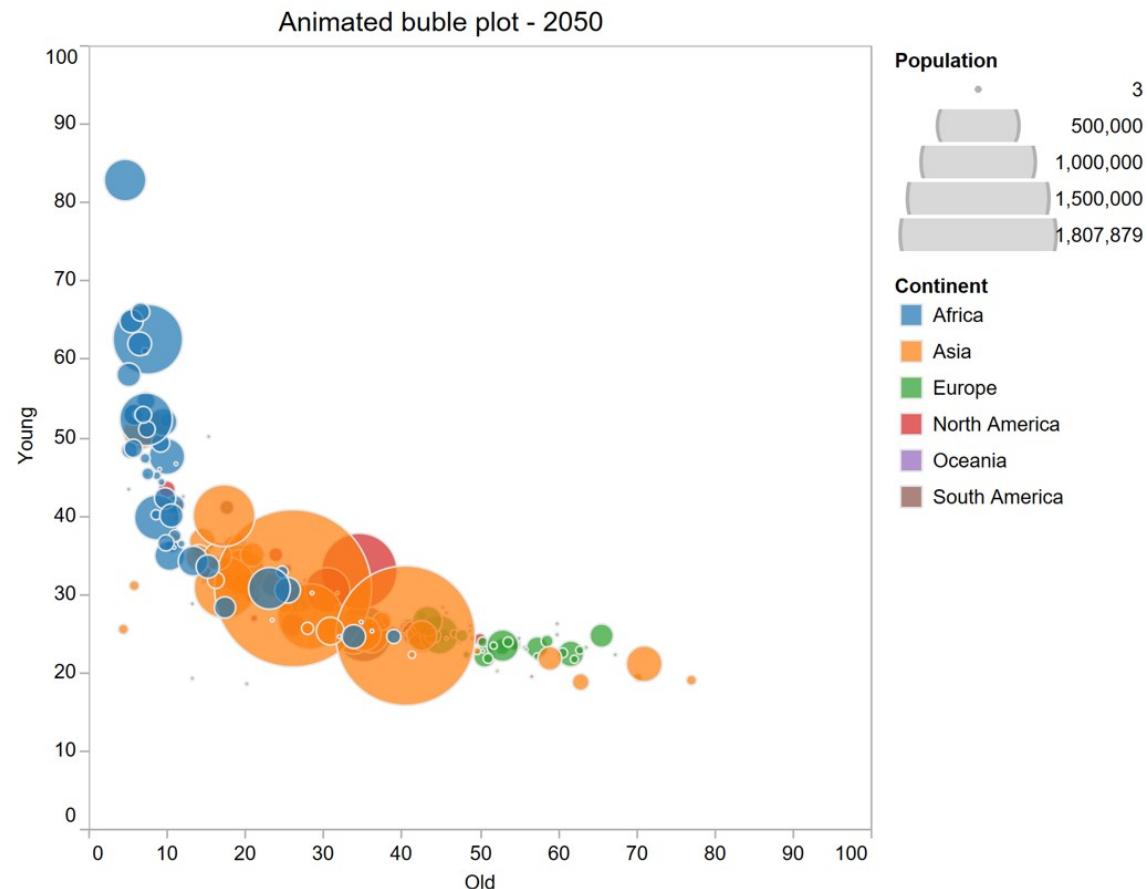
A streamgraph, or stream graph, is a type of stacked area graph which is displaced around a central axis, resulting in a flowing, organic shape.



Visualising Change Over Time

Animated bubble plot (or motion chart)

A motion chart displays changes over time by showing movement within the two-dimensional space and changes in the size and color of the bubbles.



References

Claus. O. Wilke (2019) **Fundamentals of Data Visualisation**, O'Reilly. USA. Chapter 13 Visualizing time series and other functions of an independent variable and Chapter 14 Visualizing trends

Introduction to Cycle Plots

Slopegraphs for comparing gradients: Slopegraph theory and practice

The Development of the Horizon Graph