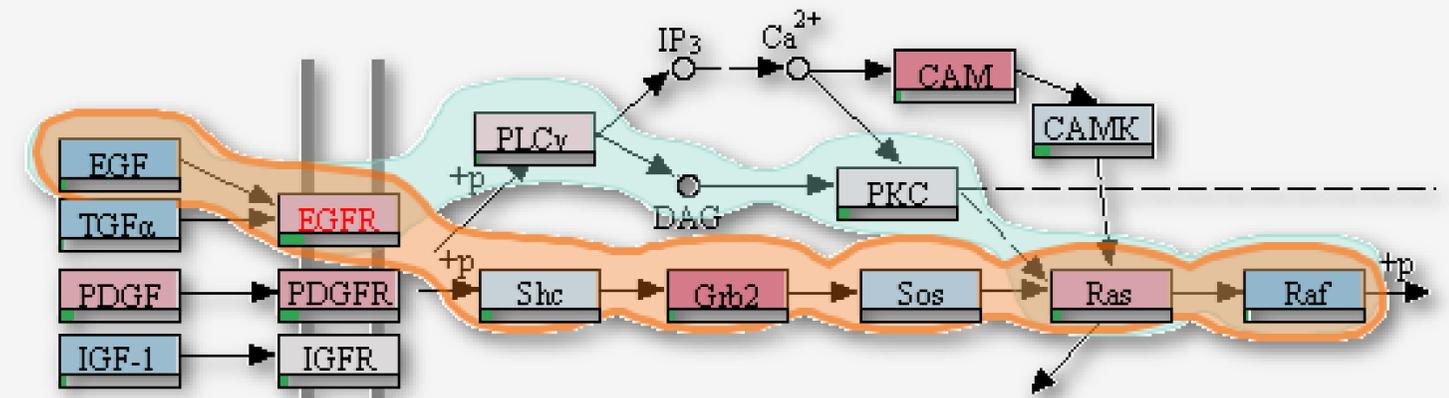


# A Very Short Visualization Introduction

## Visualizing Multi-Attribute Rankings

Alexander Lex



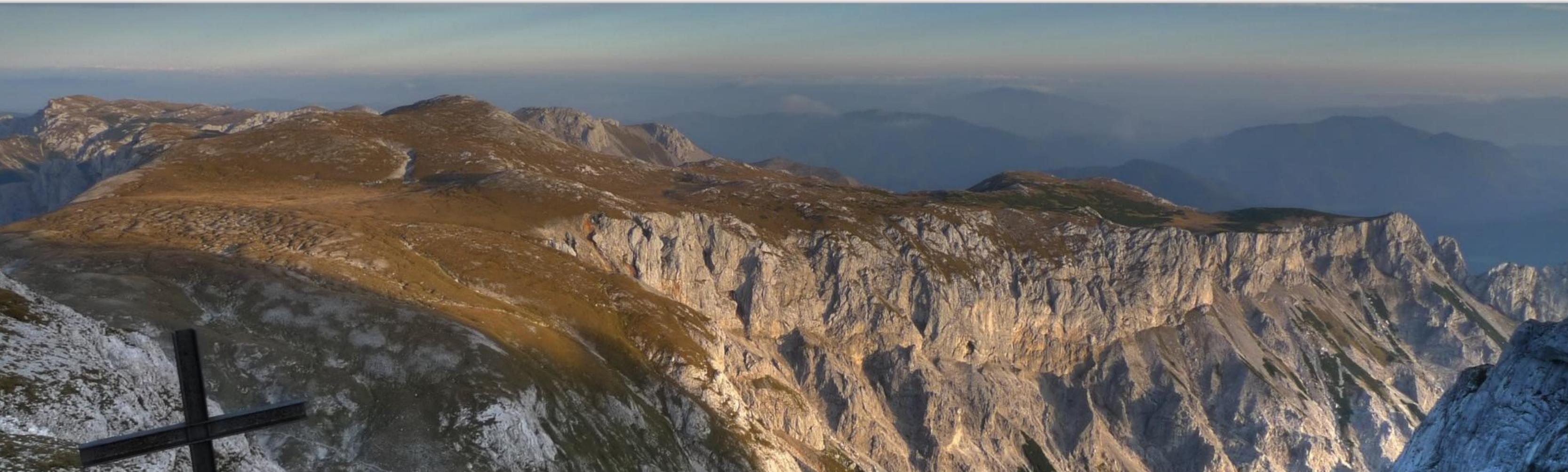
Strategic Data Project  
Harvard Graduate School of Education  
March 07, 2014



HARVARD  
School of Engineering  
and Applied Sciences

**Who am I?**  
**alexander-lex.com**

**PostDoc @ Harvard,**  
**Hanspeter Pfister's Group**  
**PhD from TU Graz, Austria**  
**Co-leader of**  
***Caleydo Project***



# Core Collaborators

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*Johannes Kepler University Linz, AT*

**Christian Partl**

*Graz University of Technology, AT*

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*Johannes Kepler University Linz, AT*

**Nils Gehlenborg**

*Harvard Medical School, Boston, USA*

**Dieter Schmalstieg**

*Graz University of Technology, AT*

**Hanspeter Pfister**

*Harvard University, Cambridge, USA*



# **Historical Quotes**

***Imagination or visualization, and in particular the use of diagrams, has a crucial part to play in scientific investigation.***

**- René Descartes, 1637**

***The purpose of computing is insight, not numbers.***

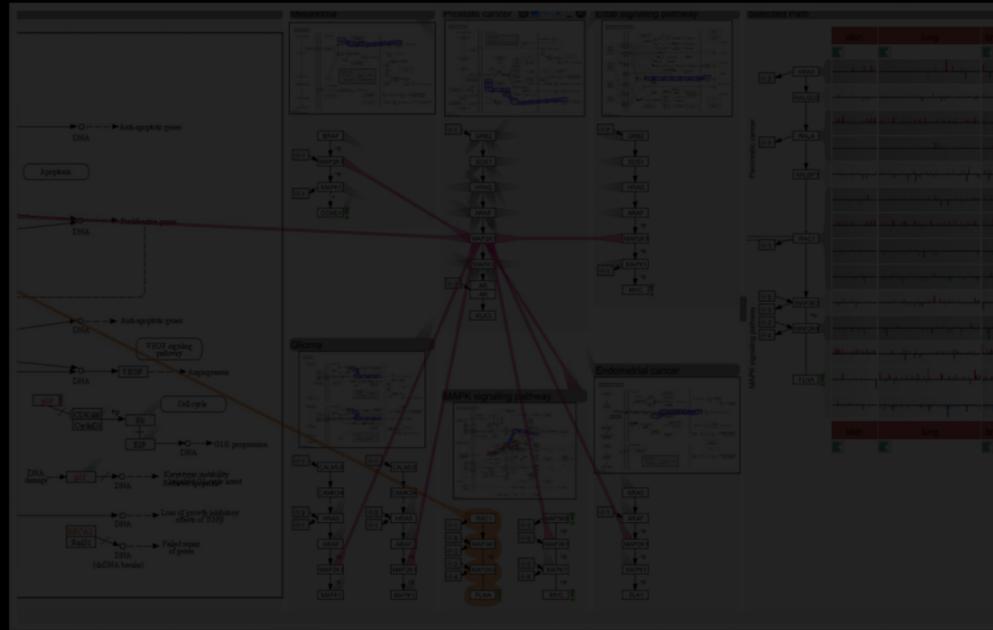
**- Richard Wesley Hamming(Founder of the ACM), 1962**

***Graphics is the visual means of resolving logical problems.***

**- Jacques Bertin, 1977**



**Heterogeneous Datasets**



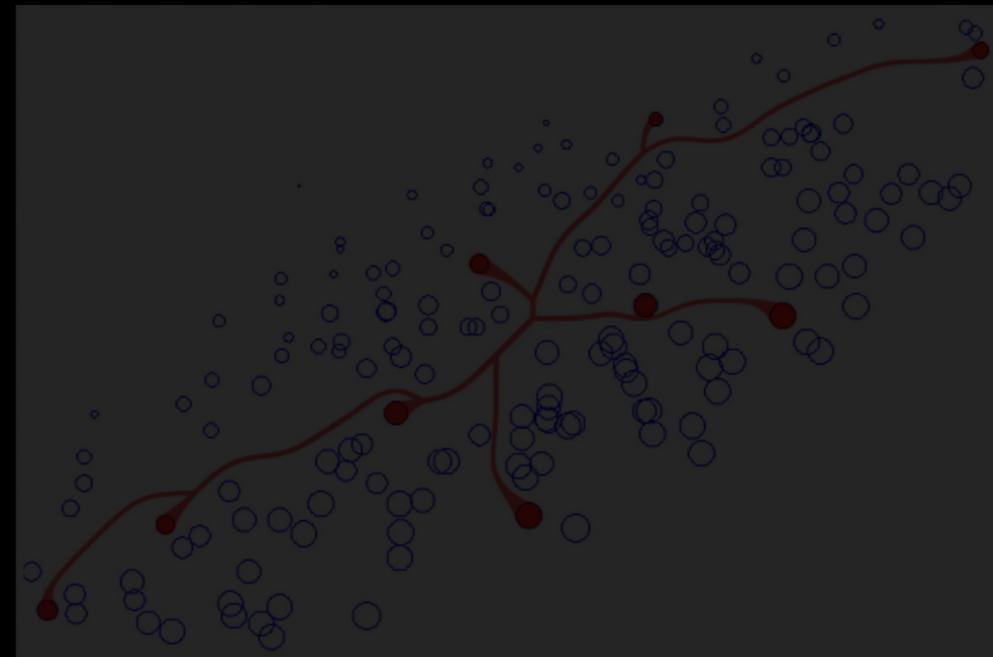
**Multi-variate Graphs**

Rank	School Name	Country	World University Ranking					Separator	Rank	Academic reputati
			Acade	Employer repu	Faculty/	Citation	I I			
1.	Massachusetts Insti	United States	17.99%	32.94%	19.63%	19.63%	4. 4.		1.	40.00%
2.	Harvard University	United States						2.		
3.	University of Camb	United Kingdom						3.		
4.	Imperial College L	United Kingdom						4.		
5.	University of Oxfor	United Kingdom						5.		
6.	UCL (University Col	United Kingdom						6.		
7.	Stanford University	United States						7.		
8.	Yale University	United States						8.		
9.	Princeton Universi	United States						9.		
10.	University of Chica	United States						10.		
11.	ETH Zurich (Swiss F	Switzerland						11.		
12.	Columbia Universi	United States						12.		
13.	University of Penns	United States						13.		
14.	Cornell University	United States						14.		
15.	University of Edinb	United Kingdom						15.		
16.	Ecole Polytechniqu	Switzerland						16.		
17.	King's College Lond	United Kingdom		93.7 (0.94)				17.		
18.	University of Toron	Canada						18.		
19.	McGill University	Canada						19.	94.6 (0.95)	
20.	National University	Singapore						20.		
21.	University of Michi	United States						21.		
22.	University of Califo	United States						22.		
23.	California Institute	United States						23.		
24.	University of Bristol	United Kingdom						24.		
25.	Duke University	United States						25.		

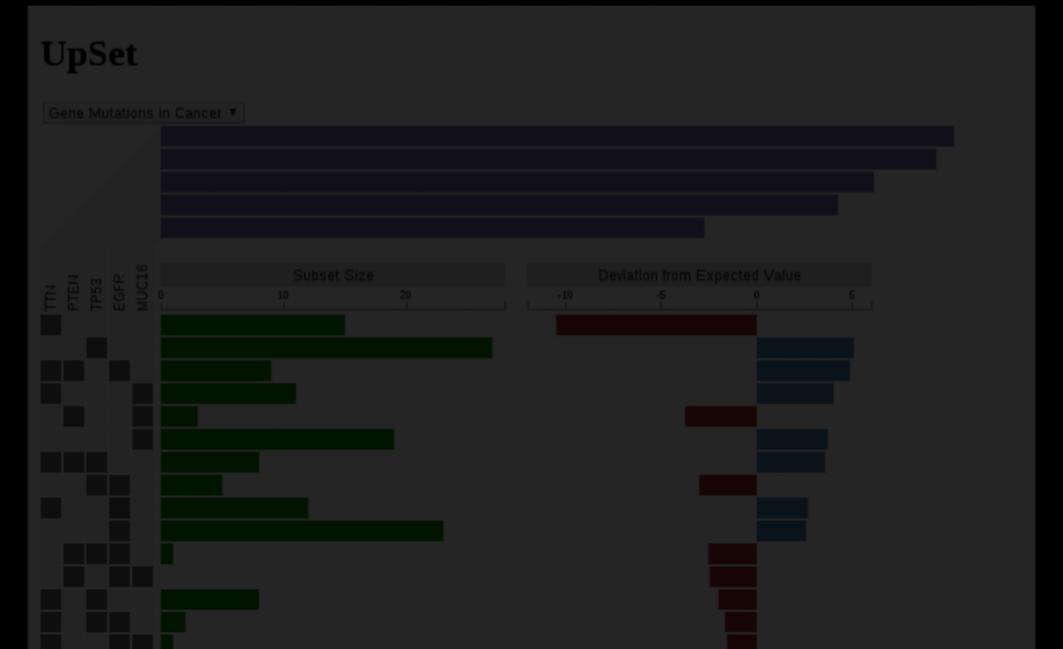
**Multi-attribute Rankings**



**Multi-dim. Datasets**



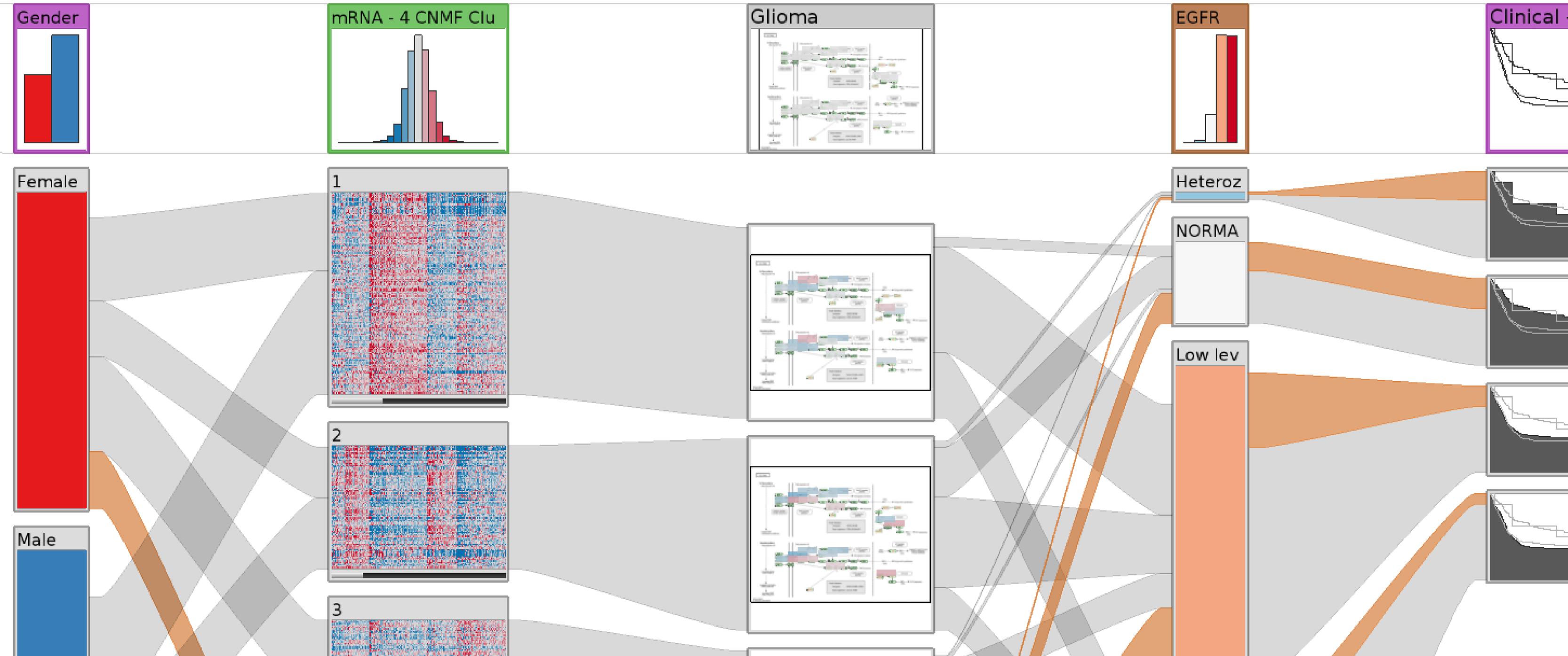
**Visual Linking**

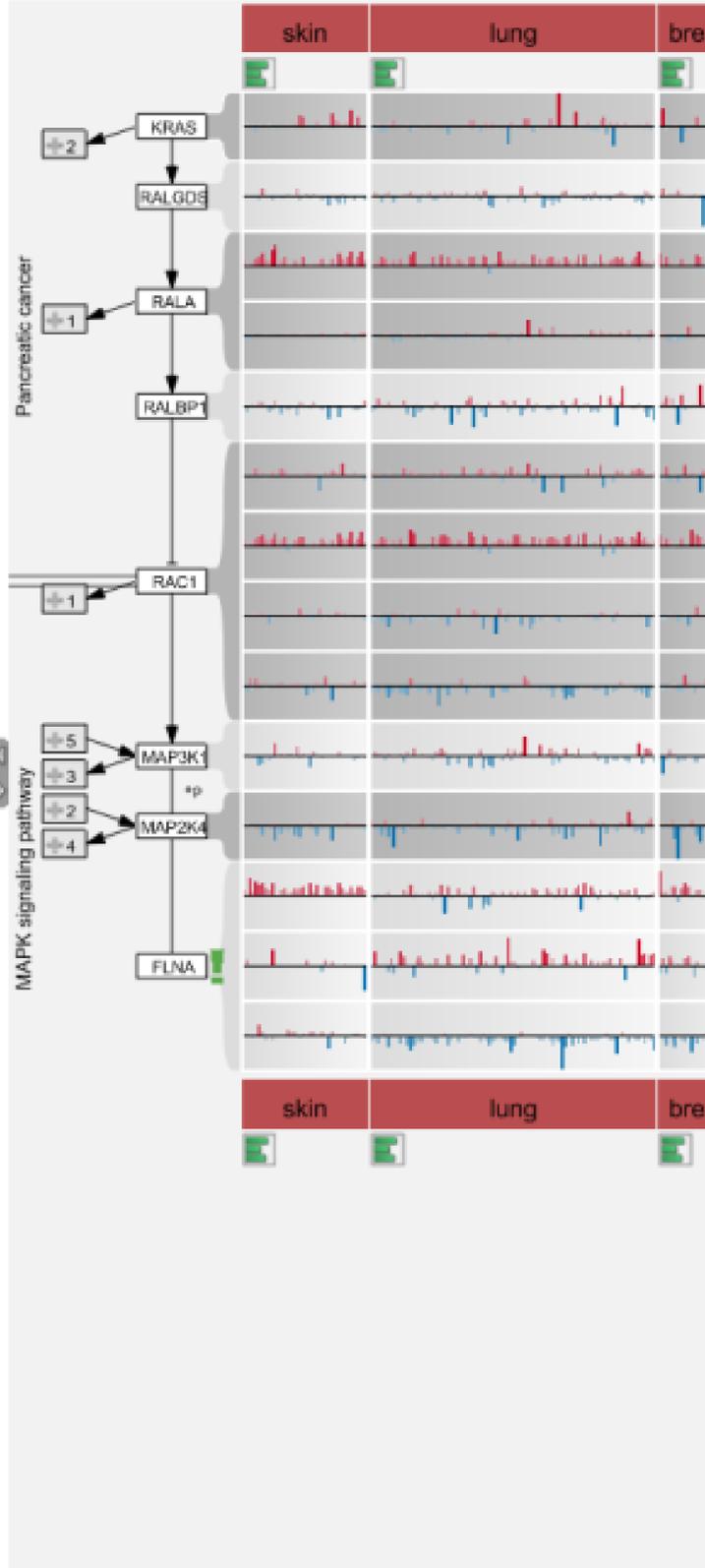
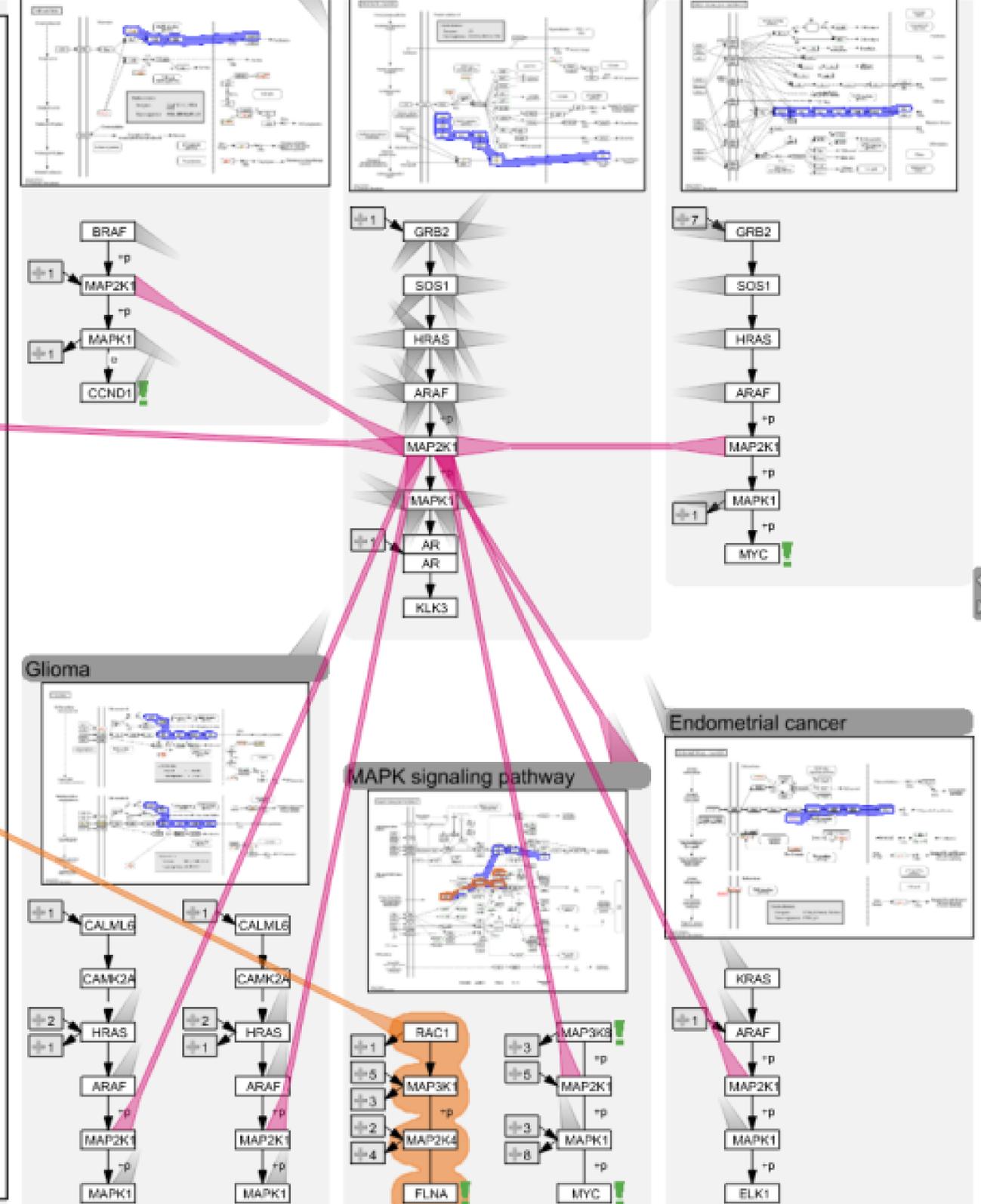
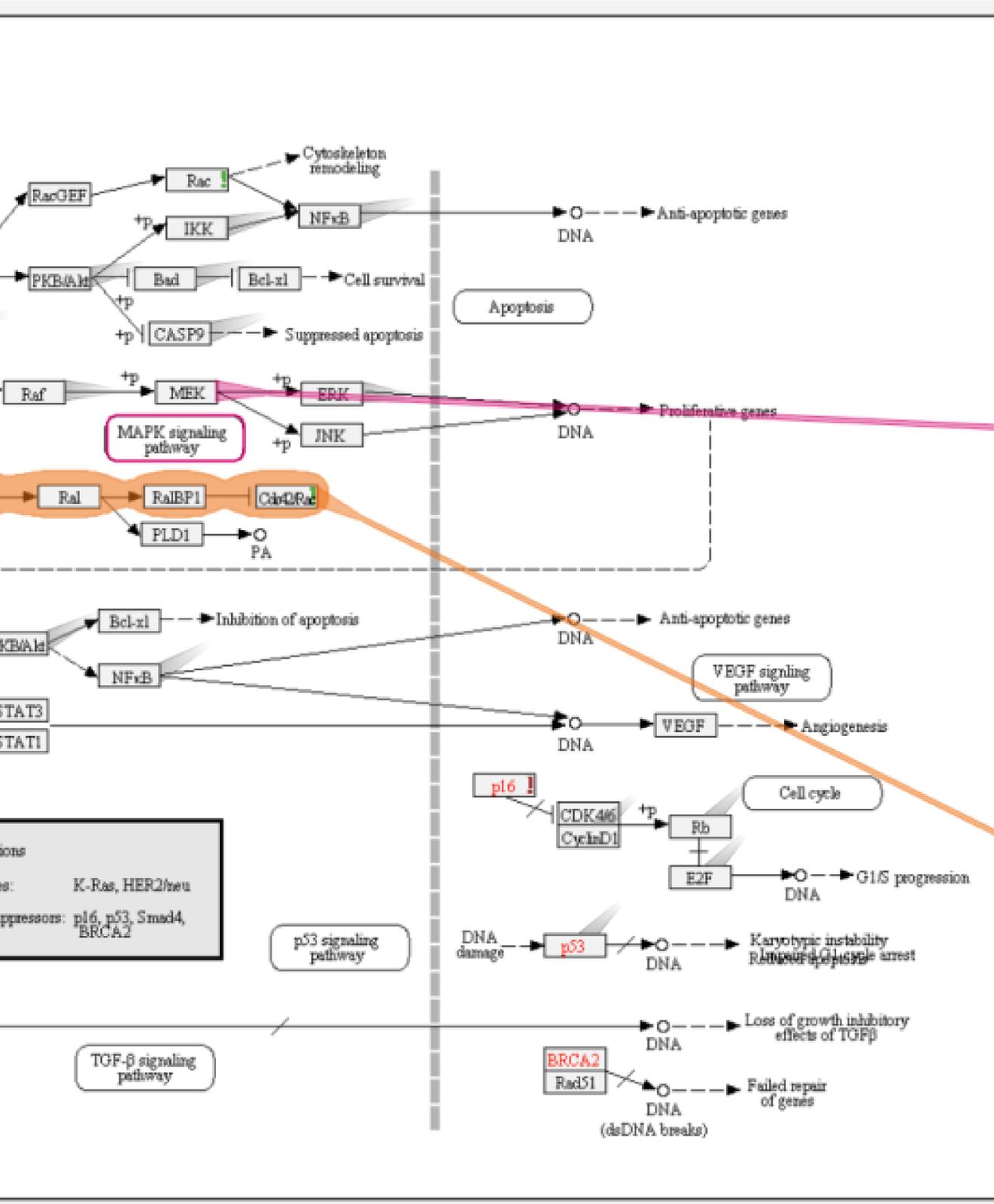


**Set Visualization**

[Lex, EuroVis '12]  
3<sup>rd</sup> Best Paper Award

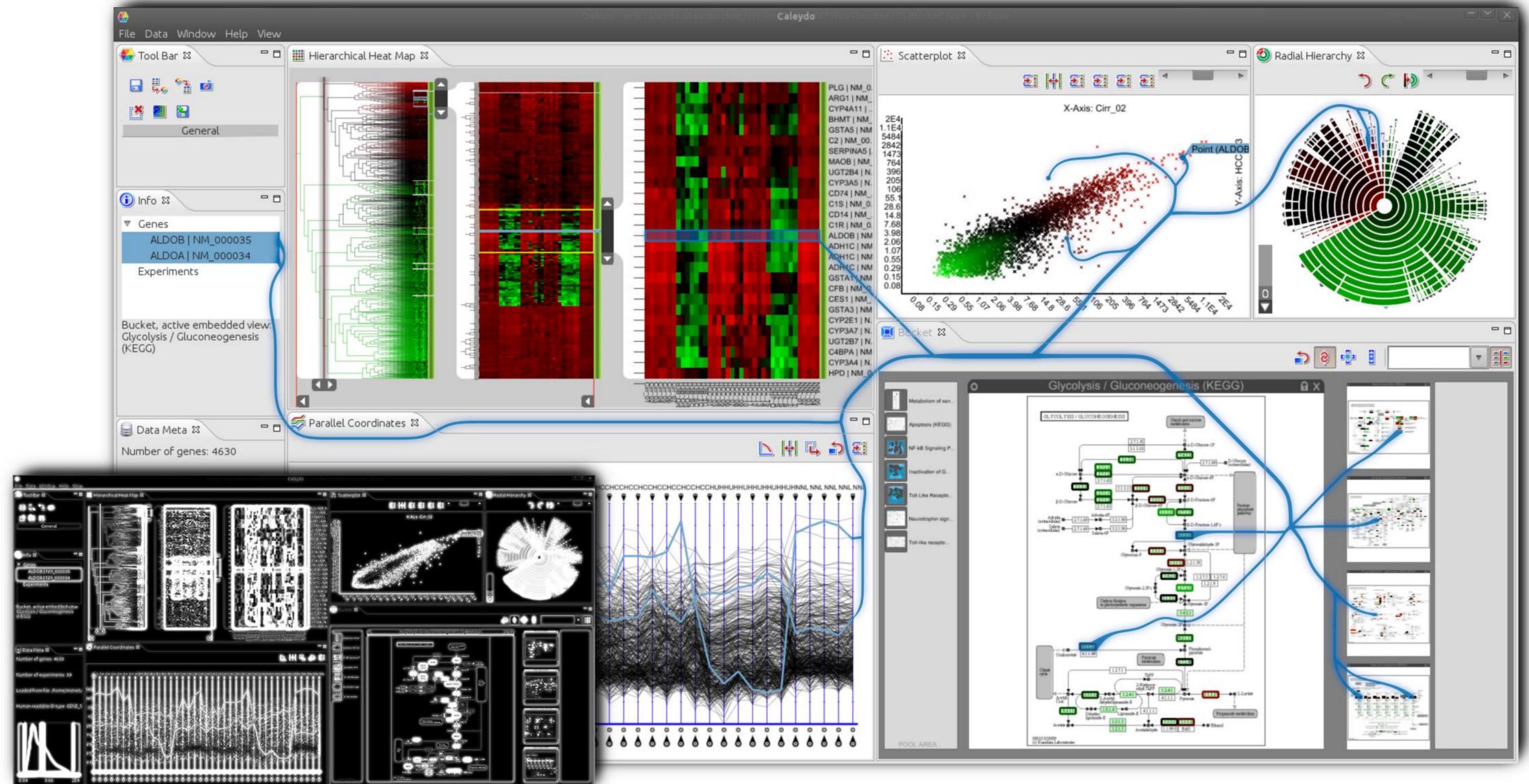
# Heterogeneous Data Cancer Subtypes





[Steinberger InfoVis'11]  
Best Paper Award

# Visual Links



[Steinberger InfoVis'11]  
Best Paper Award

[Geymayer CHI'14]  
Honorable Mention Award

# Visualizing Hidden Content

streamliner program with an  
for 50 aircraft in 2004.

## Design phase [edit source | edit beta]

The 787 was assembled with one-piece composite barrel sections instead of the multiple aluminum sheets and 50,000 fasteners used on existing aircraft. Boeing selected two new engine types to power the 787, the General Electric GEnx and Rolls-Royce Trent 1000. Boeing stated the 787 would be approximately 20 percent lighter than the 777, with approximately 40 percent of the efficiency gain from the engine improvements, increased use of lighter-weight composite materials, and additional aerodynamic improvements. Boeing initially priced the 787-8 variant at approximately US\$146-151.5 million for the 787-9, and US\$19-200 million for the 787-9.

During the design phase, the 787 underwent extensive wind tunnel testing at Boeing's 8-foot diameter wind tunnel at Farnborough, UK, and NASA Ames Research Center's wind tunnel at the dynamics research agency, ONERA. The final styling of the aircraft was more conventional, and cockpit windows changed to a more conventional form. By the end of 2003, Boeing had ordered 237 aircraft for the 787-8 variant. Boeing initially priced the 787-8 variant at approximately US\$146-151.5 million for the 787-9, and US\$19-200 million for the 787-9.

Due to stiff competition, Boeing announced on December 16, 2003, that the 787 would be built in Everett, Washington. Instead of building the complete aircraft from the ground up in the traditional manner, Boeing contracted 800 to 1,200 people to join completed subassemblies and to integrate systems. Boeing contracted 800 to 1,200 people to join completed subassemblies and to integrate systems. Boeing contracted 800 to 1,200 people to join completed subassemblies and to integrate systems.

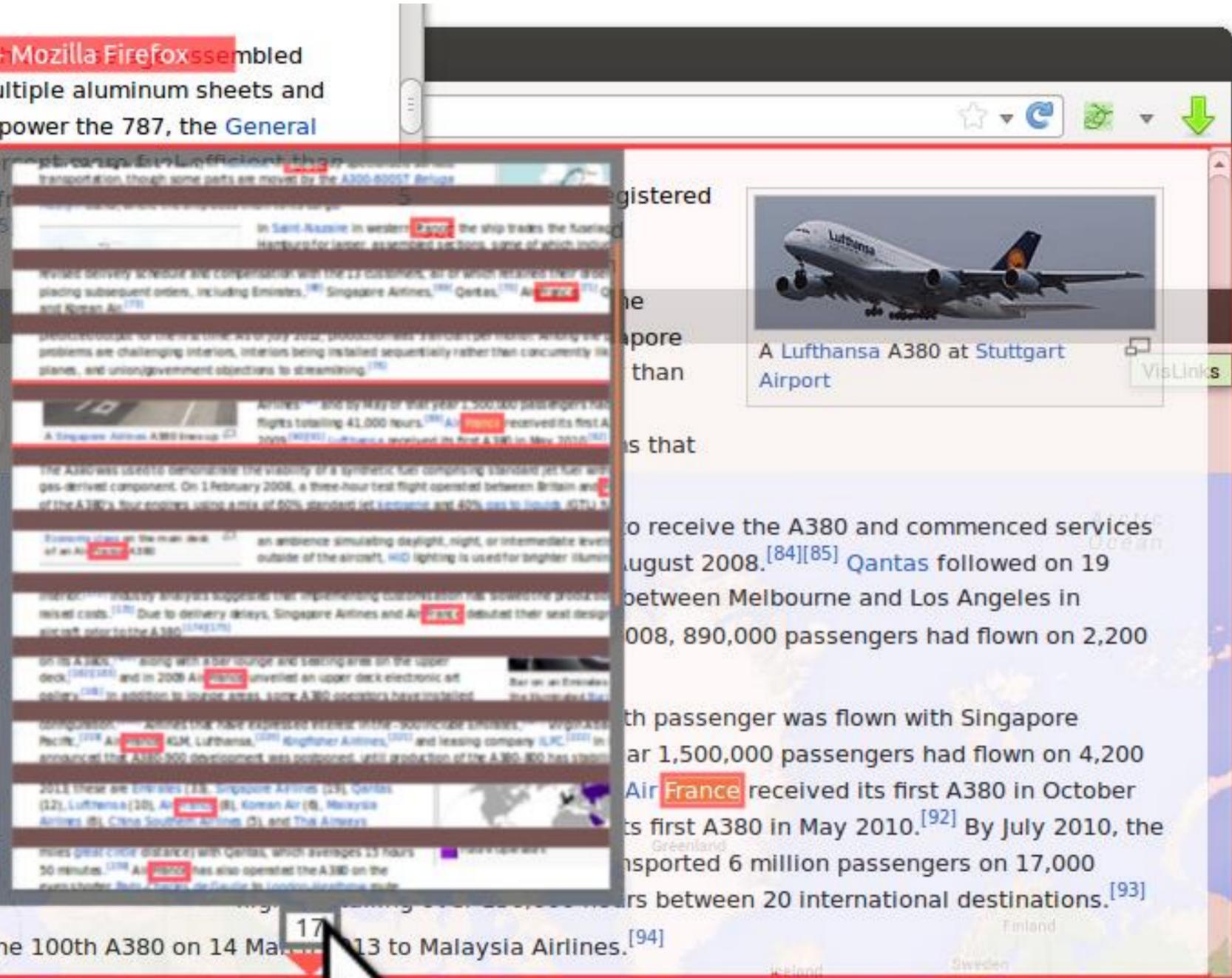
## Manufacturing and suppliers [edit source | edit beta]

Due to stiff competition, Boeing announced on December 16, 2003, that the 787 would be built in Everett, Washington. Instead of building the complete aircraft from the ground up in the traditional manner, Boeing contracted 800 to 1,200 people to join completed subassemblies and to integrate systems. Boeing contracted 800 to 1,200 people to join completed subassemblies and to integrate systems. Boeing contracted 800 to 1,200 people to join completed subassemblies and to integrate systems.

Dubbed the Super 787, the aircraft was designed to be more efficient than the 777. The aircraft was designed to be more efficient than the 777. The aircraft was designed to be more efficient than the 777.



A Singapore Airlines A380-800 aircraft on the tarmac at Zurich Airport.



The screenshot shows a Wikipedia article about the Airbus A380. A red box highlights a paragraph of text. A browser window is overlaid on the article, showing search results for "Airbus A380". The browser window shows a search bar with "Airbus A380" entered, and a list of search results. The first result is "Airbus A380 - Wikipedia, the free encyclopedia". The browser window also shows a map of the world with a red dot over France. A mouse cursor is pointing at the number "17" in the text "Airbus delivered the 100th A380 on 14 March 2013 to Malaysia Airlines."



A Lufthansa A380 at Stuttgart Airport.



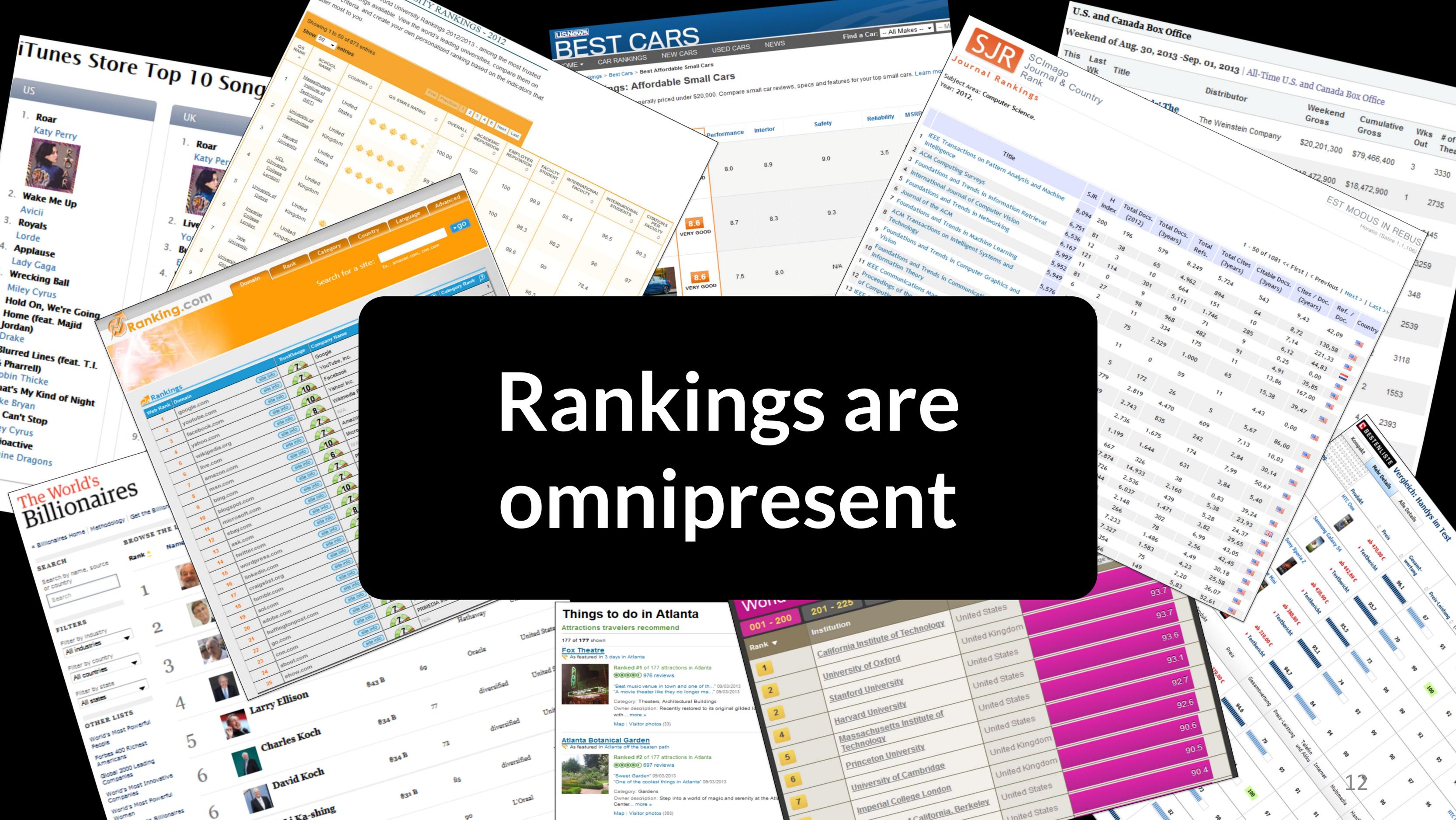
Airbus delivered the 100th A380 on 14 March 2013 to Malaysia Airlines.





# Rankings





Rankings are omnipresent

### iTunes Store Top 10 Song

Rank	Artist	Song
1	Katy Perry	Roar
2	Avicii	Wake Me Up
3	Lorde	Royals
4	Lady Gaga	Applause
5	Miley Cyrus	Wrecking Ball
6	Drake	Hold On, We're Going Home (feat. Majid Jordan)
7	T.I. (feat. Pharrell)	Blurred Lines
8	Robin Thicke (feat. Pharrell)	Blurred Lines
9	Ke\$ha (feat. Ryan Murphy)	My Kind of Night
10	Miley Cyrus	Can't Stop

### QS World University Rankings - 2012

Rank	School Name	Country	QS Stars Rating	Overall	Academic Reputation	Employer Reputation	Faculty Student	International Faculty	International Students	Citations per Faculty
1	Massachusetts Institute of Technology (MIT)	United States	5	100.00	100	100	100	100	100	99.3
2	University of Cambridge	United Kingdom	5	99.7	99.7	99.9	99.9	98.4	98.5	99.3
3	Harvard University	United States	5	99.7	99.7	99.9	99.9	98.4	98.5	99.3
4	UCL (University College London)	United Kingdom	5	99.7	99.7	99.9	99.9	98.4	98.5	99.3
5	University of Oxford	United Kingdom	5	99.7	99.7	99.9	99.9	98.4	98.5	99.3

### US News Best Cars

#### Best Affordable Small Cars

Rank	Model	Performance	Interior	Safety	Reliability	MSRP
1	Toyota Yaris	8.0	8.9	9.0	3.5	10,000
2	Honda Fit	8.0	8.3	9.3	3.5	10,000
3	Ford Fiesta	8.7	8.3	9.3	3.5	10,000
4	Hyundai Accent	8.7	8.3	9.3	3.5	10,000
5	Vauxhall Corsa	8.7	8.3	9.3	3.5	10,000

### SJR Journal Rankings

Rank	Title	SJR	H Index	Total Docs. (2012)	Total Docs. (3years)	Total Refs.	Total Cites (3years)	Citable Docs. (3years)	Cites / Doc. (2years)	Ref. / Doc.	Country
1	IEEE Transactions on Pattern Analysis and Machine Intelligence	8,094	200	196	579	8,249	5,724	894	64	9.43	42,09
2	ACM Computing Surveys	6,536	12	38	10	4,962	894	151	10	7.14	130,58
3	Foundations and Trends in Information Retrieval	6,167	121	3	65	1,746	285	6,12	0.25	44,83	0,00
4	International Journal of Computer Vision	5,997	11	114	9	5,111	151	64	9.43	42,09	0,00
5	Foundations and Trends in Networking	5,952	81	27	11	1,746	285	6,12	0.25	44,83	0,00
6	ACM Transactions on Intelligent Systems and Technology	5,949	6	27	11	1,746	285	6,12	0.25	44,83	0,00
7	Foundations and Trends in Computer Graphics and Vision	5,576	2	2	2	1,000	65	13,86	35,85	167,00	0,00
8	Foundations and Trends in Information Theory	5,576	2	2	2	1,000	65	13,86	35,85	167,00	0,00
9	Proceedings of the IEEE	5,576	2	2	2	1,000	65	13,86	35,85	167,00	0,00
10	IEEE Transactions on Communications	5,576	2	2	2	1,000	65	13,86	35,85	167,00	0,00

### U.S. and Canada Box Office

Rank	Title	Distributor	Weekend Gross	Cumulative Gross	Wks Out	# of Theaters
1	EST MODUS IN REBUS	The Weinstein Company	\$20,201,300	\$79,466,400	3	3330
2	...	...	...	...	...	...

### The World's Billionaires

Rank	Name	Net Worth	Industry
1	Larry Ellison	\$43 B	69 diversified
2	Charles Koch	\$34 B	77 diversified
3	David Koch	\$34 B	73 diversified
4	...	...	...
5	...	...	...
6	Li Ka-shing	\$31 B	85 diversified

### Things to do in Atlanta

Rank	Attraction	Reviews
1	Fox Theatre	976 reviews
2	Atlanta Botanical Garden	697 reviews

### World's Best Universities

Rank	Institution	Country	Score
1	California Institute of Technology	United States	93.7
2	University of Oxford	United Kingdom	93.6
3	Stanford University	United States	93.1
4	Harvard University	United States	92.7
5	Massachusetts Institute of Technology	United States	92.6
6	Princeton University	United States	90.6
7	University of Cambridge	United Kingdom	90.5
8	Imperial College London	United Kingdom	90.4

### Bestenliste Vergleich: Handys im Test

Rank	Produkt	Preis	Leistungs	Preis-Leistung
1	HTC One	ab 470,00 €	95.1	67
2	Samsung Galaxy S4	ab 442,00 €	95.7	70
3	Sony Xperia Z	ab 439,00 €	95.5	73
4	...	...	...	...

Goal

Intuitive

Interactive

Multi-Attribute

Ranking Visualization

To Create

Refine

Explore

# 10 Requirements

## University

MIT, USA

Harvard, USA

Princeton, USA

Cambridge, UK

Oxford, UK

10 Requirements

Encode Rank

# 10 Requirements

1. Encode Rank

## Encode Rank

Rank	University
------	------------

1. MIT, USA
2. Harvard, USA
3. Princeton, USA
4. Cambridge, UK
5. Oxford, UK

# 10 Requirements

## 1. Encode Rank

# Encode Cause of Rank

# 10 Requirements

1. Encode Rank
2. Encode Cause of Rank

Encode Cause of Rank

Rank	University	Score
------	------------	-------

1. MIT, USA 
2. Harvard, U 
3. Princeton, 
4. Cambridge 
5. Oxford, UK  4.0

# 10 Requirements

1. Encode Rank
2. Encode Cause of Rank

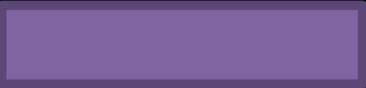
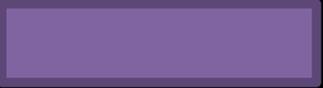
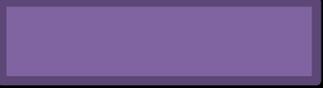
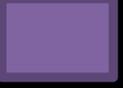
**Support Multiple Attributes**

# 10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes

**Support Multiple Attributes**

$$\text{Score} = f(A, B, C)$$

Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA		 	
3.	Princeton, US		 	
4.	Cambridge, U		 	
5.	Oxford, UK			

# Combiner functions: $f(A,B,C)$

(Weighted) sum

$$\text{Score} = w_a A + w_b B + w_c C$$

→ Serial

Maximum

$$\text{Score} = \max(A, B, C)$$

→ Parallel

Product

Nesting

...

→ Complex  
Combiners

# Serial Combiner (as Stacked Bar)



Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Princeton, USA			
4.	Cambridge, UK			
5.	Oxford, UK			

# Serial Combiner (as Stacked Bar)



Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Princeton, USA			
4.	Cambridge, UK			
5.	Oxford, UK			

# Serial Combiner (as Stacked Bar)



Rank	University	A	B	C
1.	MIT, USA	Large red segment	Medium green segment	Medium purple segment
2.	Harvard, USA	Large red segment	Medium green segment	Medium purple segment
3.	Princeton, USA	Medium red segment	Medium green segment	Medium purple segment
4.	Cambridge, UK	Large red segment	Small green segment	Small purple segment
5.	Oxford, UK	Large red segment	Very small green segment	Small purple segment

# 10 Requirements

1. Encode Rank

2. Encode Cause of Rank

3. Support Multiple Attributes

## Interactive Refinement and Visual Feedback

# 10 Requirements

1. Encode Rank

2. Encode Cause of Rank

3. Support Multiple Attributes

4. Interactive Refinement  
and Visual Feedback

## Interactive Refinement and Visual Feedback

Rank	School Name	Country	Faculty/student ratio	Employer reputation	Citations per faculty
	Filter: <None>	Filter: 2 out of 72			
1.	American University	United States			
2.	Arizona State University	United States			
3.	Aston University	United Kingdom			
4.	Birkbeck College, University of L	United Kingdom			
5.	Boston College	United States			
6.	Boston University	United States			
7.	Brandeis University	United States			
8.	Brown University	United States			
9.	Brunel University	United Kingdom			
10.	California Institute of Technology	United States			
11.	Cardiff University	United Kingdom			
12.	Case Western Reserve University	United States			
13.	City University London	United Kingdom			
14.	College of William & Mary	United States			
15.	Colorado State University	United States			
16.	Columbia University	United States			
17.	Cornell University	United States			
18.	Cranfield University	United Kingdom			
19.	Dartmouth College	United States			
20.	Drexel University	United States			
21.	Duke University	United States			
22.	Durham University	United Kingdom			

# 10 Requirements

1. Encode Rank

2. Encode Cause of Rank

3. Support Multiple Attributes

4. Interactive Requirement

and Visual Feedback

## Flexible Mapping of Attributes to Scores

# 10 Requirements

1. Encode Rank

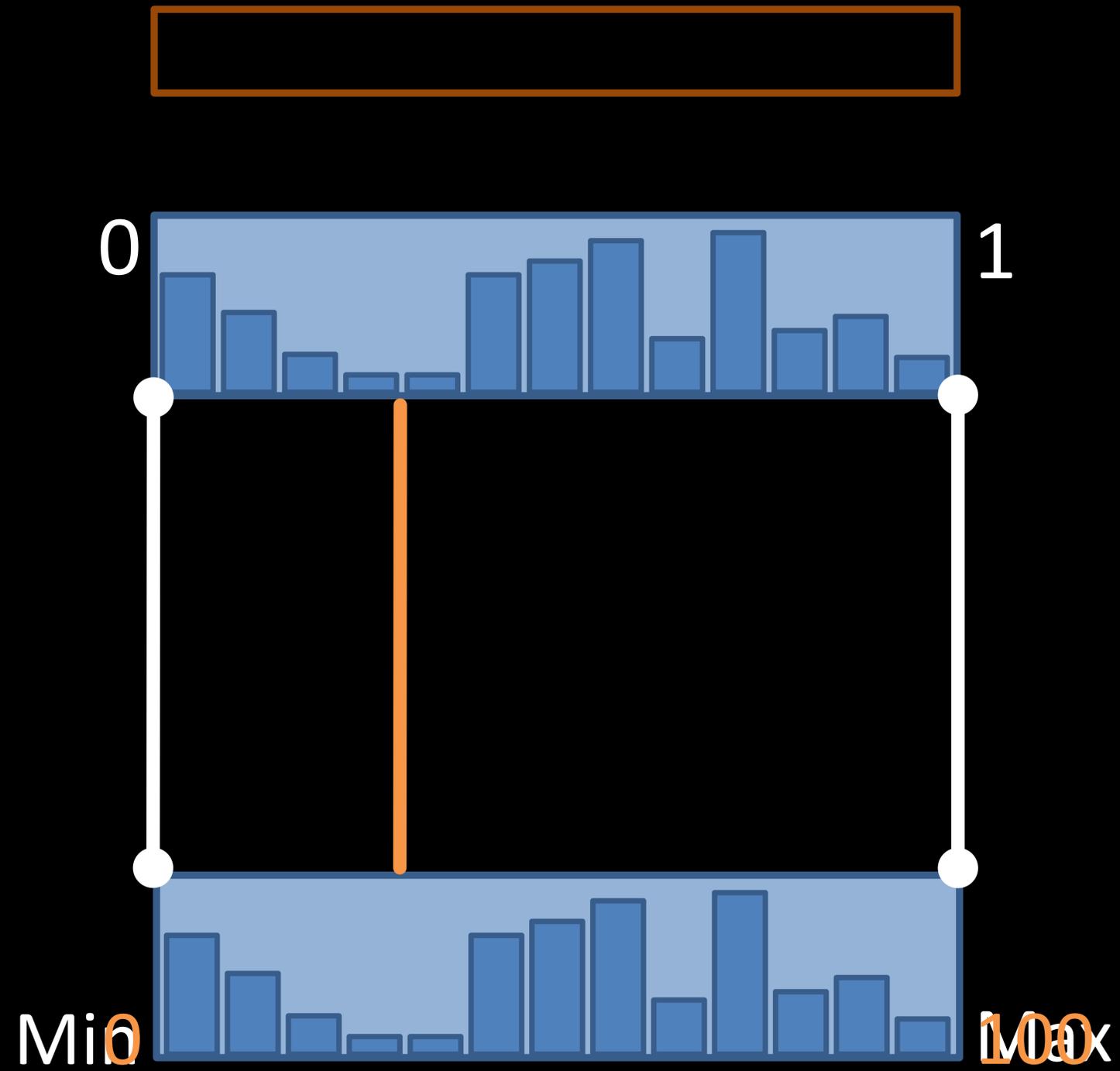
2. Encode Cause of Rank

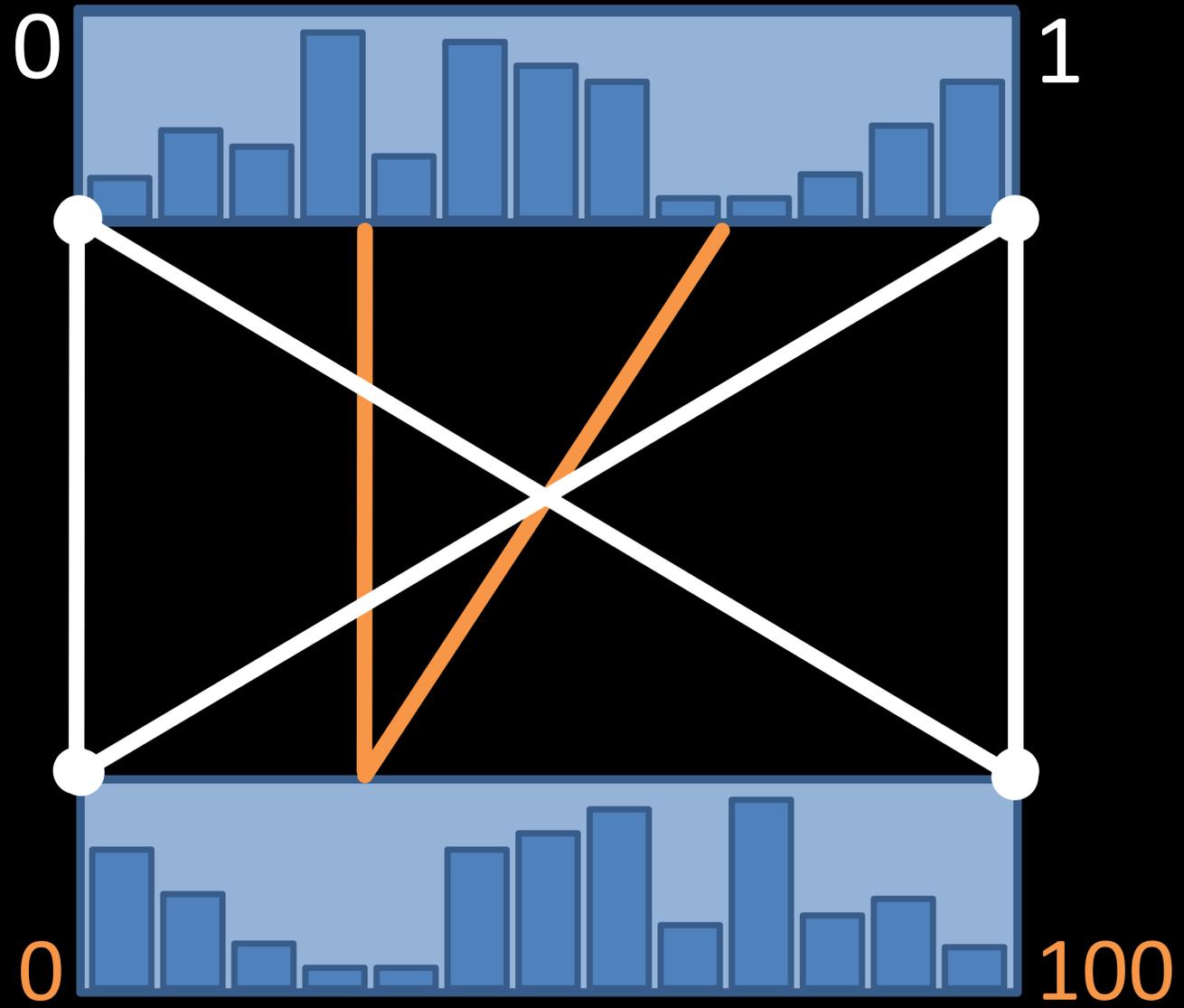
3. Support Multiple Attributes

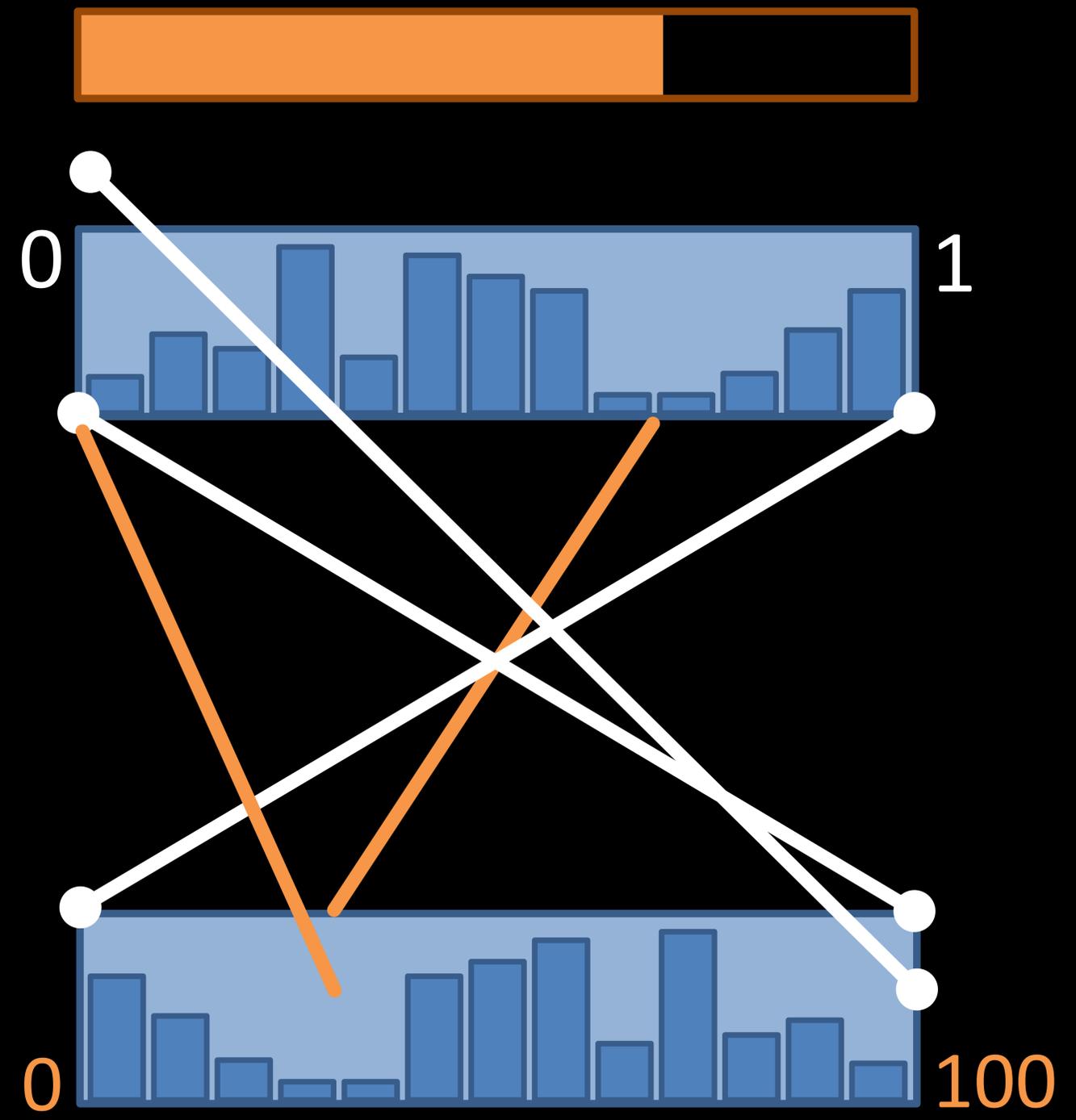
4. Interactive Requirement  
and Visual Feedback

5. Flexible Mapping of  
Attributes to Scores

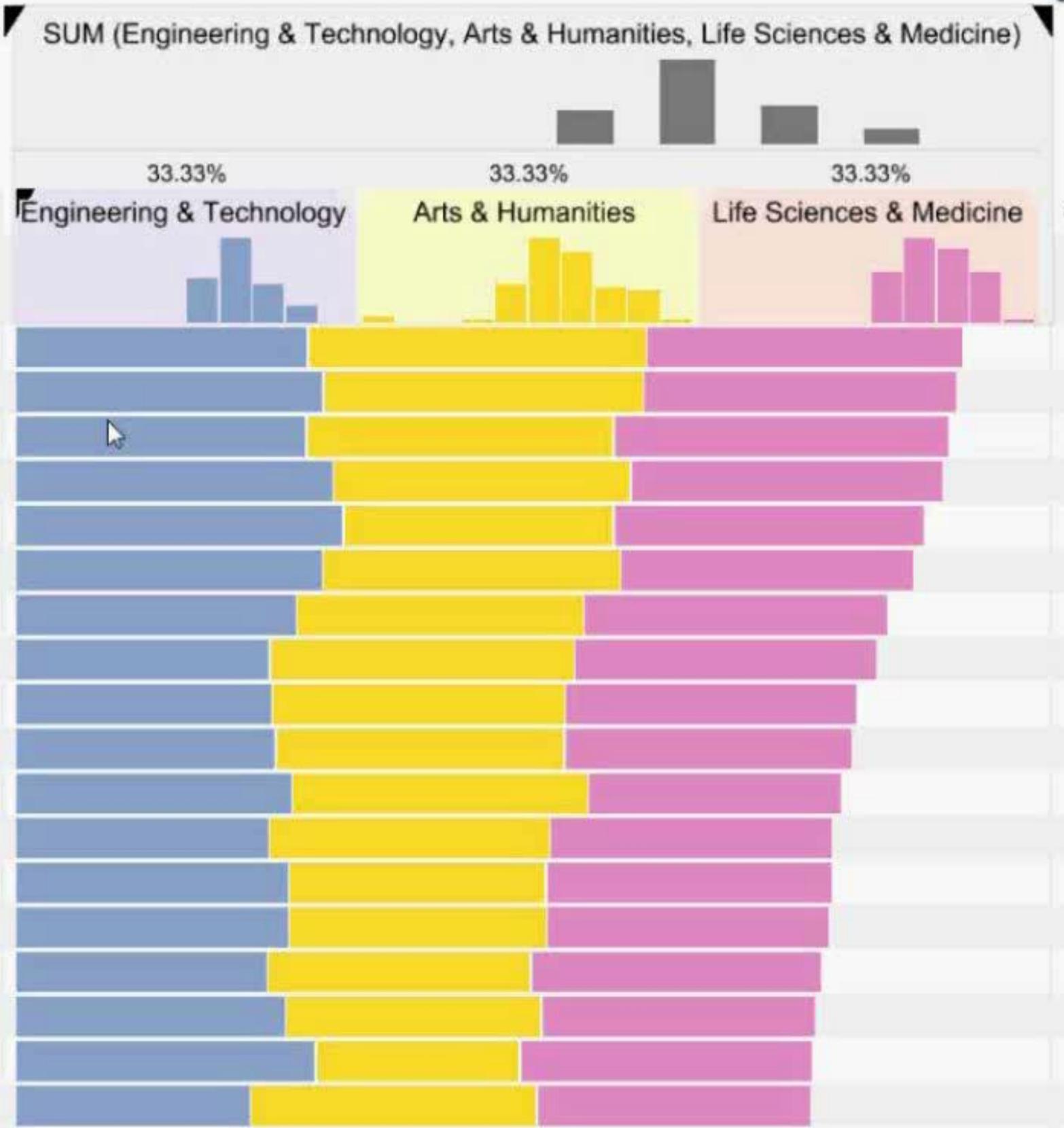
## Flexible Mapping of Attributes to Scores







Ran	School Name	Country
	Filter: <None>	Filter: 2 out of 43
1.	University of Oxford	United Kingdom
2.	University of Cambridge	United Kingdom
3.	Harvard University	United States
4.	Stanford University	United States
5.	Massachusetts Institute of Technology (MIT)	United States
6.	University of California, Berkeley (UCB)	United States
7.	University of California, Los Angeles (UCL)	United States
8.	Yale University	United States
9.	UCL (University College London)	United Kingdom
10.	Columbia University	United States
11.	Princeton University	United States
12.	University of Edinburgh	United Kingdom
13.	University of Michigan	United States
14.	Cornell University	United States
15.	University of Pennsylvania	United States
16.	The University of Manchester	United Kingdom
17.	Imperial College London	United Kingdom
18.	University of Chicago	United States



# 10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement  
and Visual Feedback
5. Flexible Mapping of  
Attributes to Scores

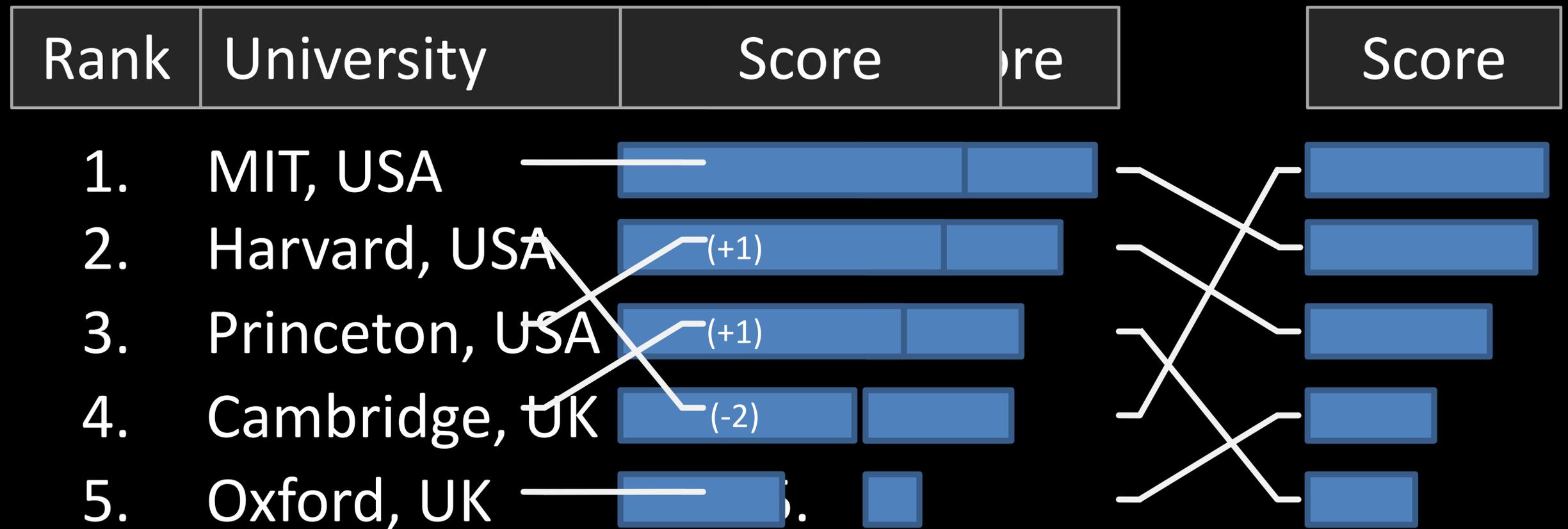
## Compare Rankings

# 10 Requirements

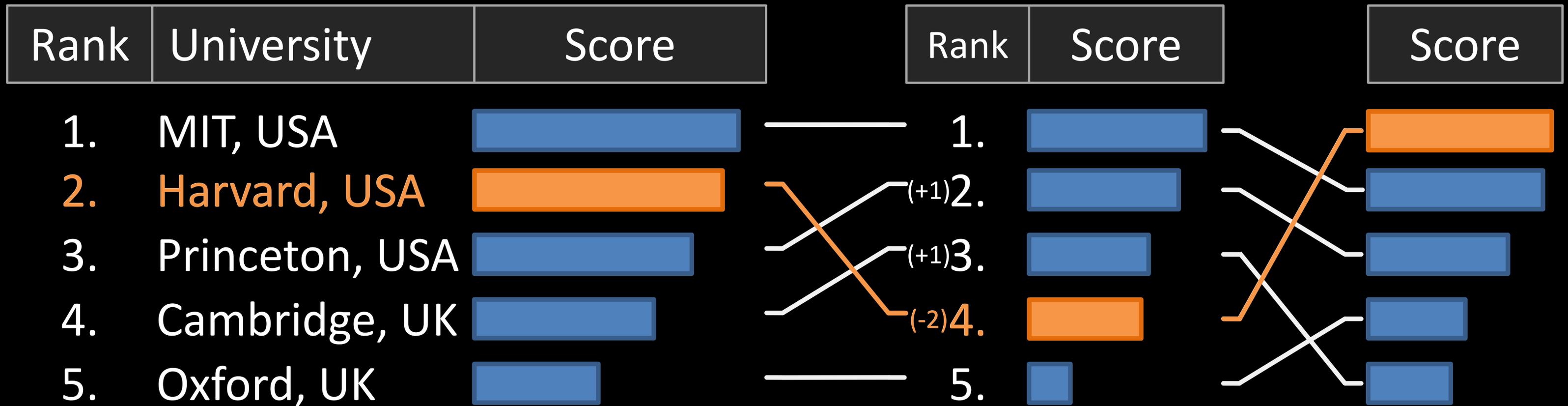
1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores
6. Compare Rankings

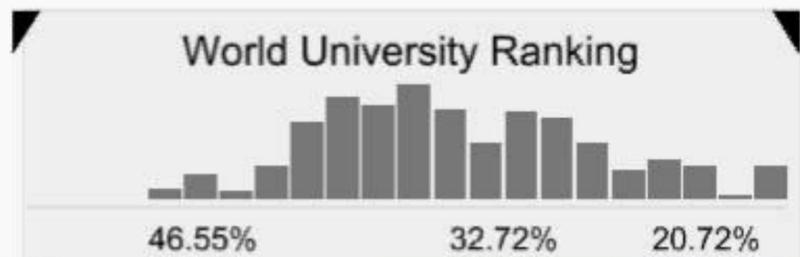
## Compare Rankings

# Bump Charts



# Bump Charts





Rank	School Name	MAX (Academic re	Faculty/stud	Citatio
	Filter: <None>			
1.	Massachusetts Institute of Te			
2.	California Institute of Technol			
3.	Harvard University			
4.	University of Cambridge			
5.	UCL (University College Lond			
6.	University of Oxford			
7.	Princeton University			
8.	Imperial College London			
9.	University of Chicago			
10.	Stanford University			
11.	Columbia University			
12.	Duke University			
13.	University of Pennsylvania			
14.	Johns Hopkins University			
15.	Yale University			
16.	University of Michigan			
17.	Ecole normale supérieure, Pa			
18.	Northwestern University			

# 10 Requirements

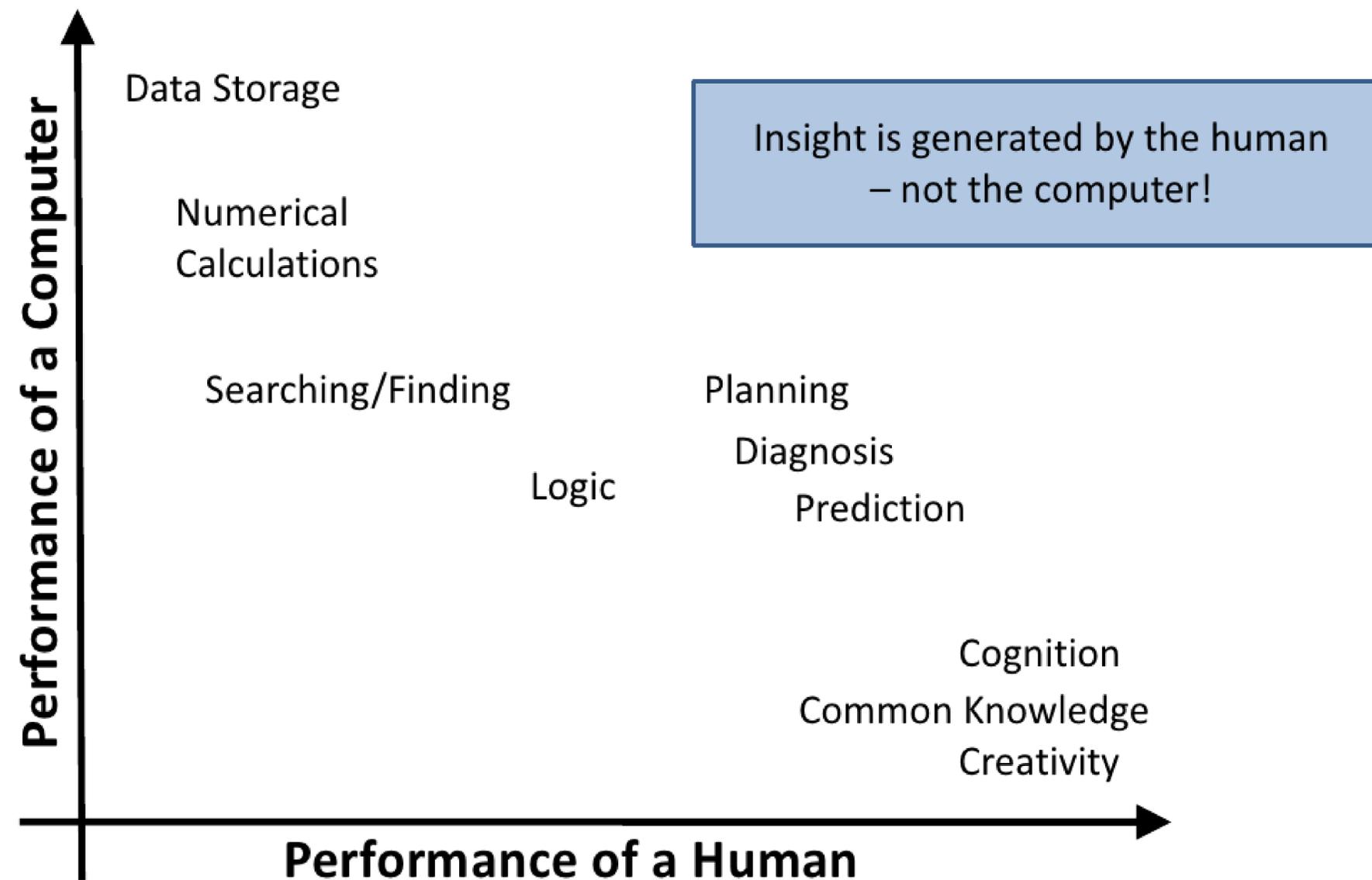
1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores
6. Compare Rankings
7. Scalability
8. Filtering
9. Handle Missing Values
10. Optimization

Demos, Videos & More:  
<http://lineup.caleydo.org>

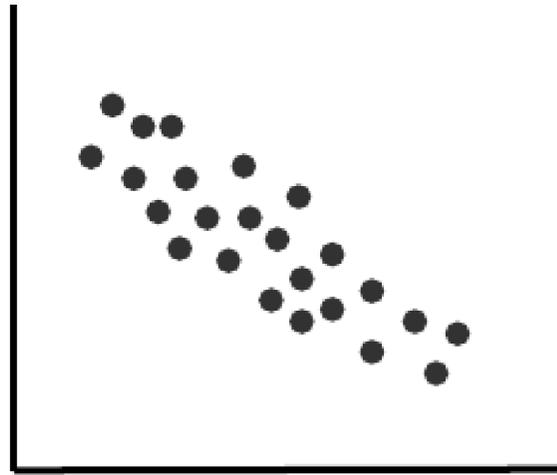


# **A VERY SHORT VISUALIZATION INTRODUCTION**

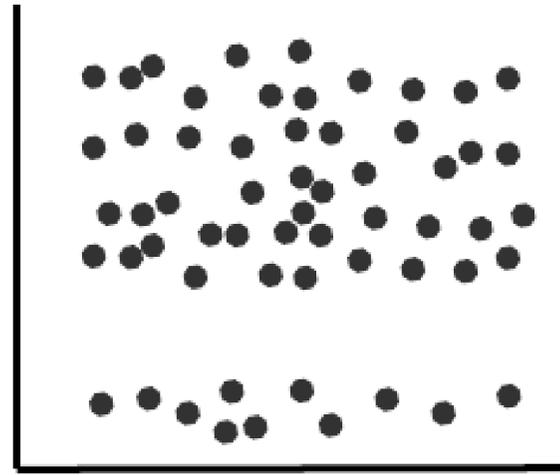
# The Ability Matrix



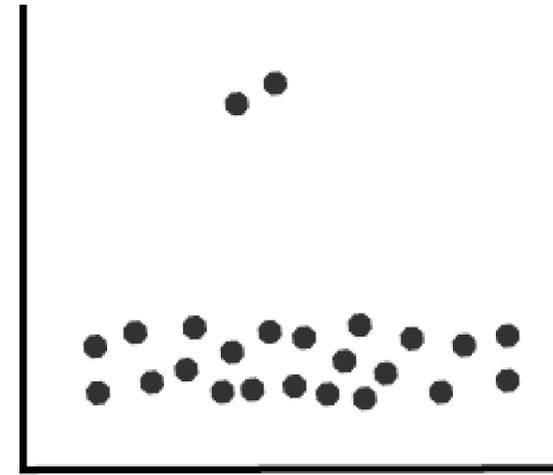
# Pattern Discovery



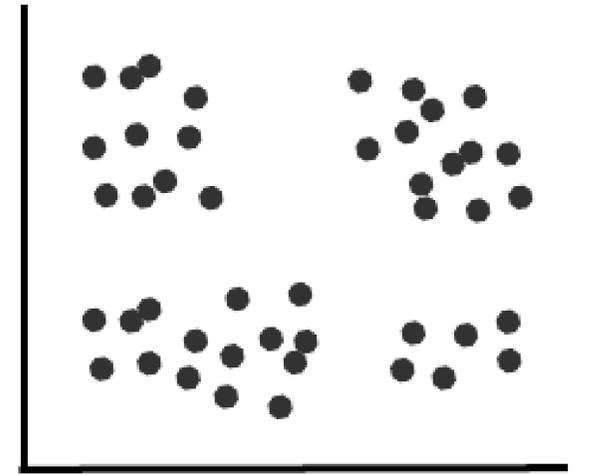
trends



gaps



outliers



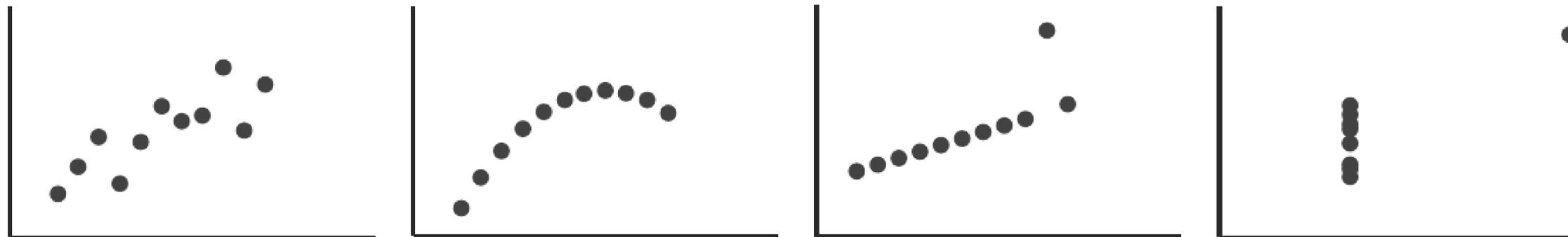
clusters

# Can We Always Trust Statistics?

I		II		III		IV	
x	y	x	y	x	y	x	y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.6					8	6.89

**Mean x: 9 y: 7.50**  
**Variance x: 11 y: 4.122**  
**Correlation x - y: 0.816**  
**Linear regression:  $y = 3.00 + 0.500x$**

# Anscombe's Quartett



**Mean x: 9 y: 7.50**

**Variance x: 11 y: 4.122**

**Correlation x - y: 0.816**

**Linear regression:  $y = 3.00 + 0.500x$**

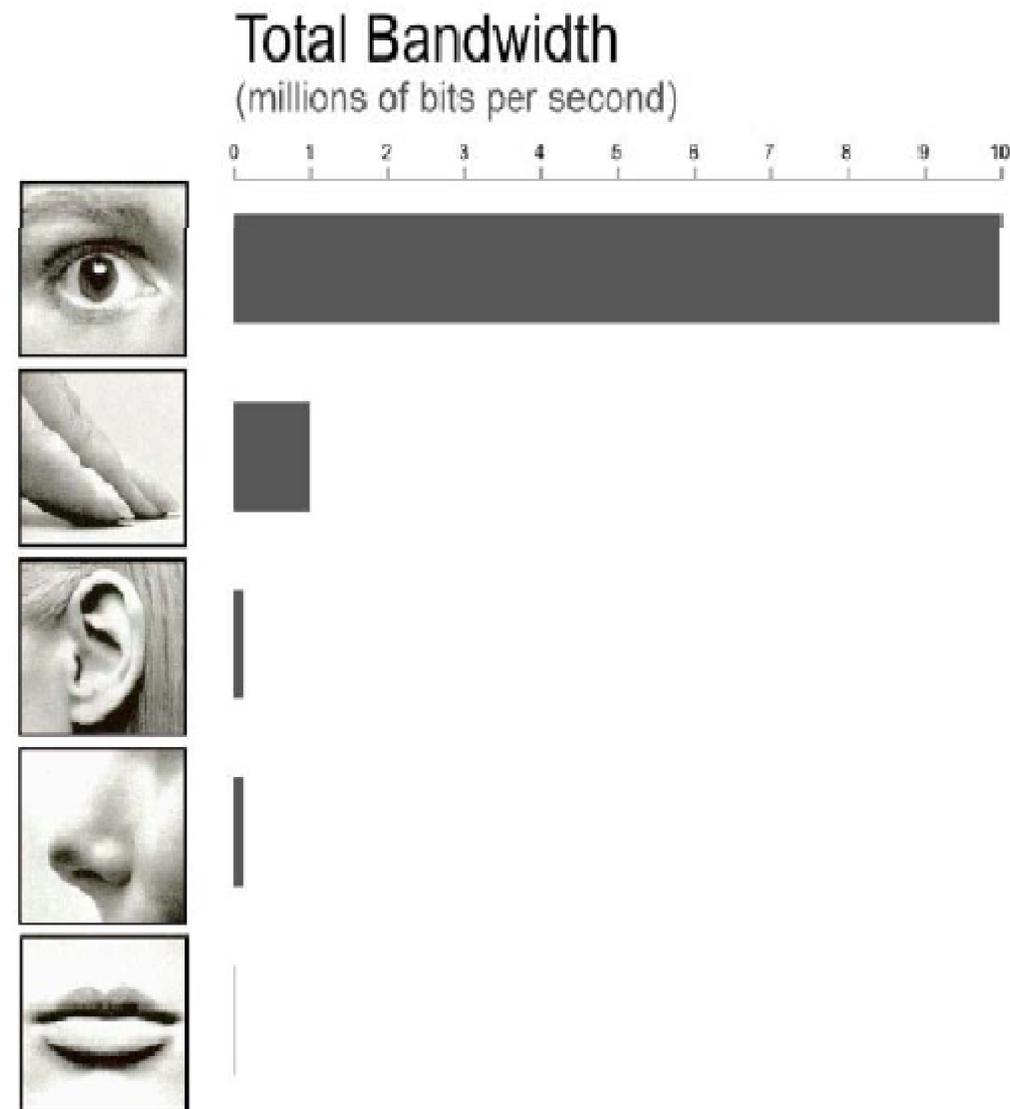
# Why Graphics?

Figures are **richer**; provide more information with less clutter and in less space.

Figures provide the *gestalt* effect: they give an overview; **make structure more visible**.

Figures are **more accessible**, easier to understand, **faster to grasp**, more comprehensible, **more memorable**, more fun, and less formal.

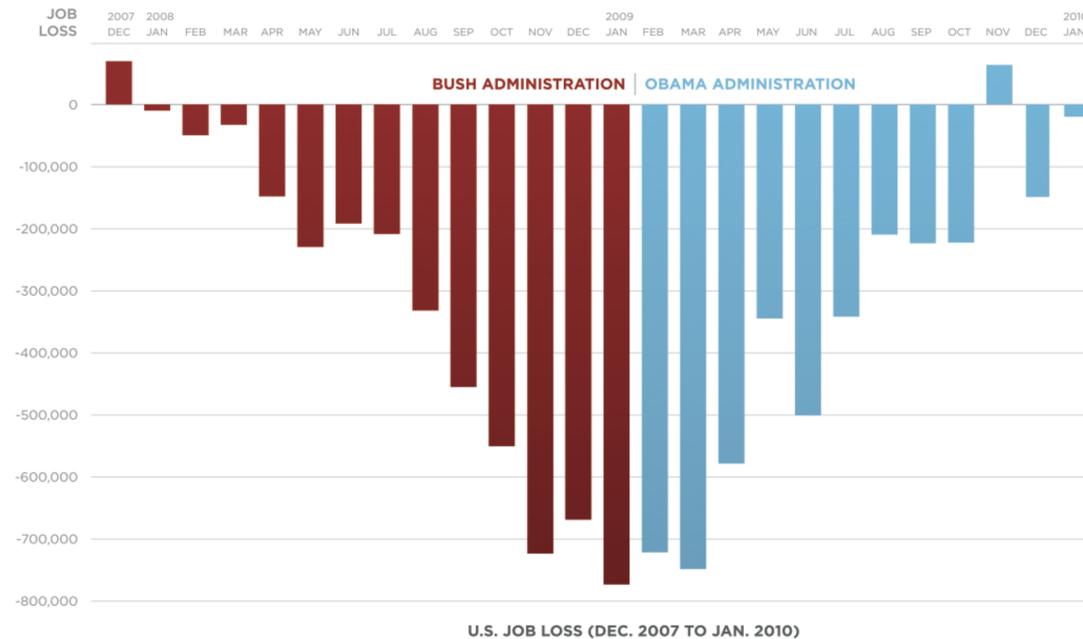
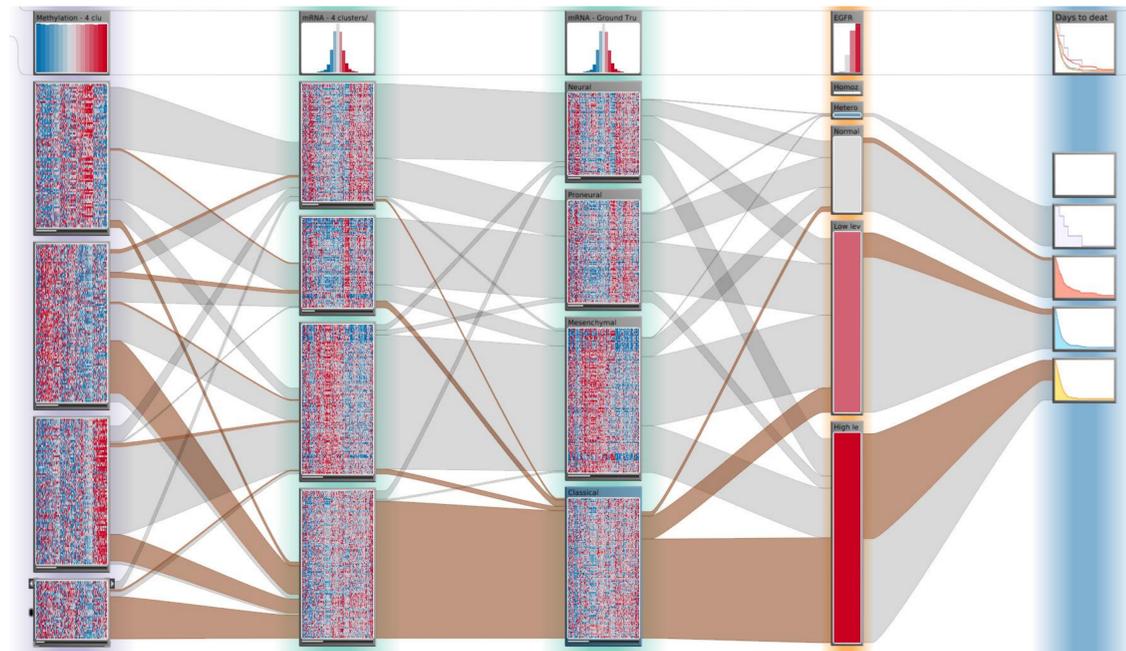
list adapted from: [Stasko et al. 1998]



# **Visualization Definition**

**Visualization is the process that transforms (abstract) data into interactive graphical representations for the purpose of exploration, confirmation, or presentation.**

# Applications of Visualization



←

## Open Exploration

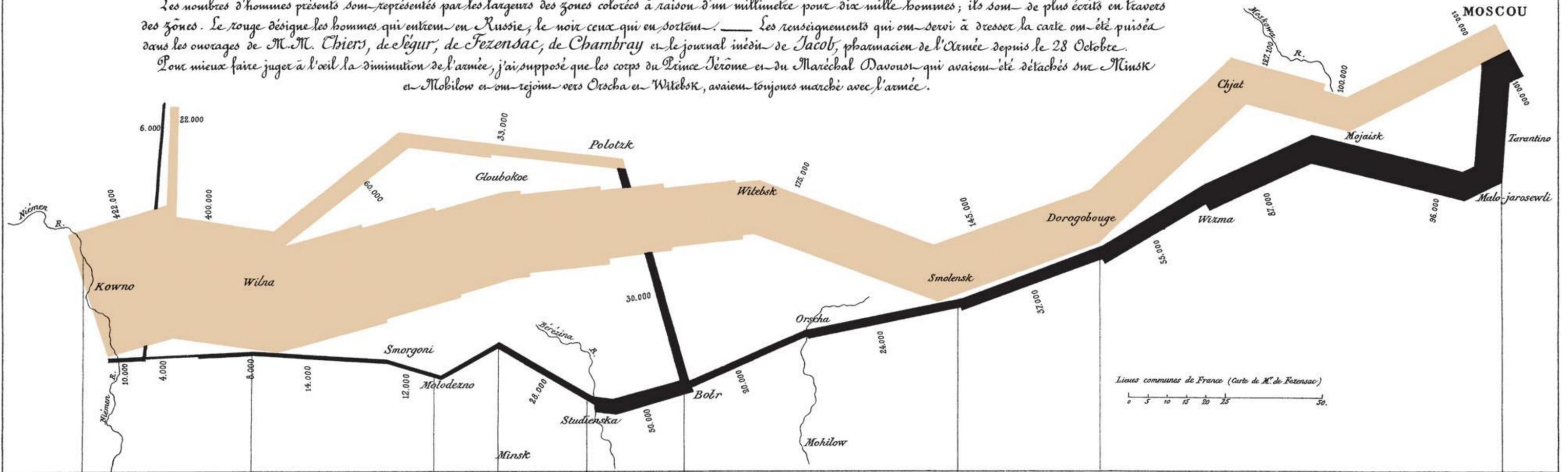
## Illustration

# Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. — Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

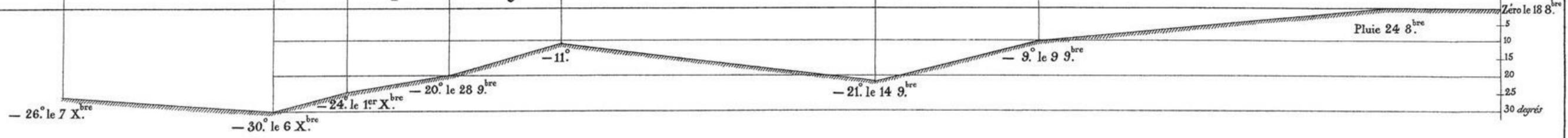
Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout qui avaient été détachés sur Minsk et Mohilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.



Lieux communs de France (Carte de M. de Fezensac)  
0 5 10 15 20 25 30

## TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Les Cosaques passent au galop le Niemen gelé.



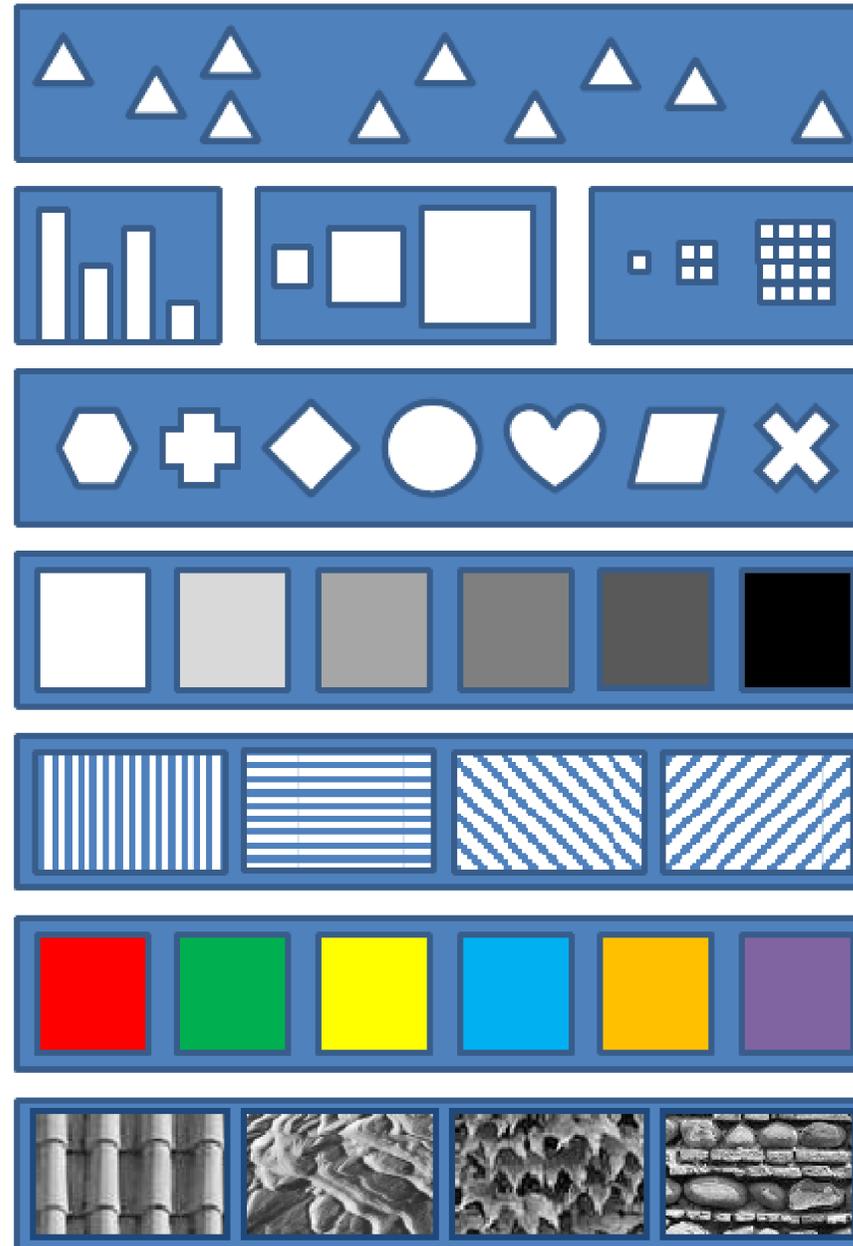
Autog. par Regnier, 8. Pas. S<sup>te</sup> Marie S<sup>te</sup> G<sup>ene</sup> à Paris.

Imp. Lith. Regnier et Dourdet.

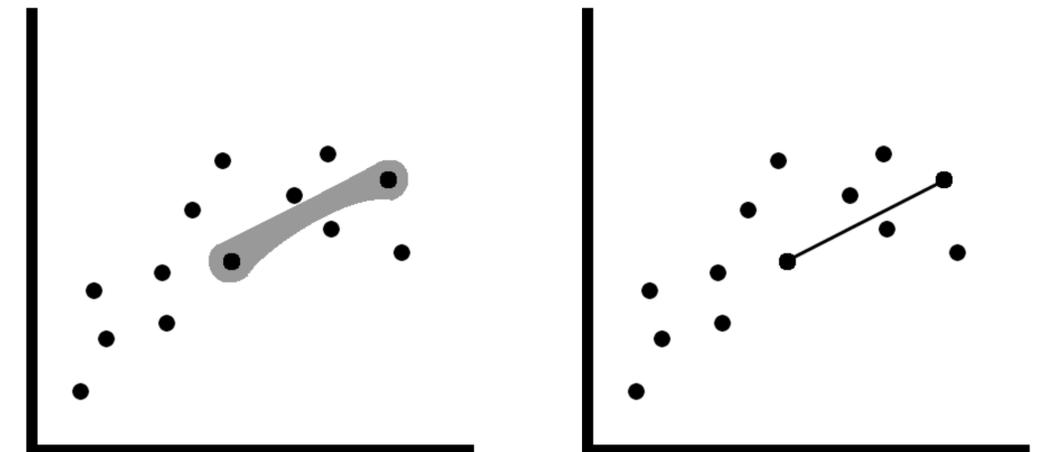
# Visual Variables

- **position**  
change in location
- **size**  
change in length, area, repetition
- **shape**  
change to the outer form
- **value**  
change from light to dark
- **orientation**  
change in alignment
- **color**  
change in hue at a given value
- **texture**  
change in pattern

(adapted from S.Carpendale)



**For Relationships:  
Containment  
Connection**



# Position

**Strongest visual variable**  
**Suitable for all data types**



# Size & Length

**Good visual variable**

**Easy to see whether one is bigger**

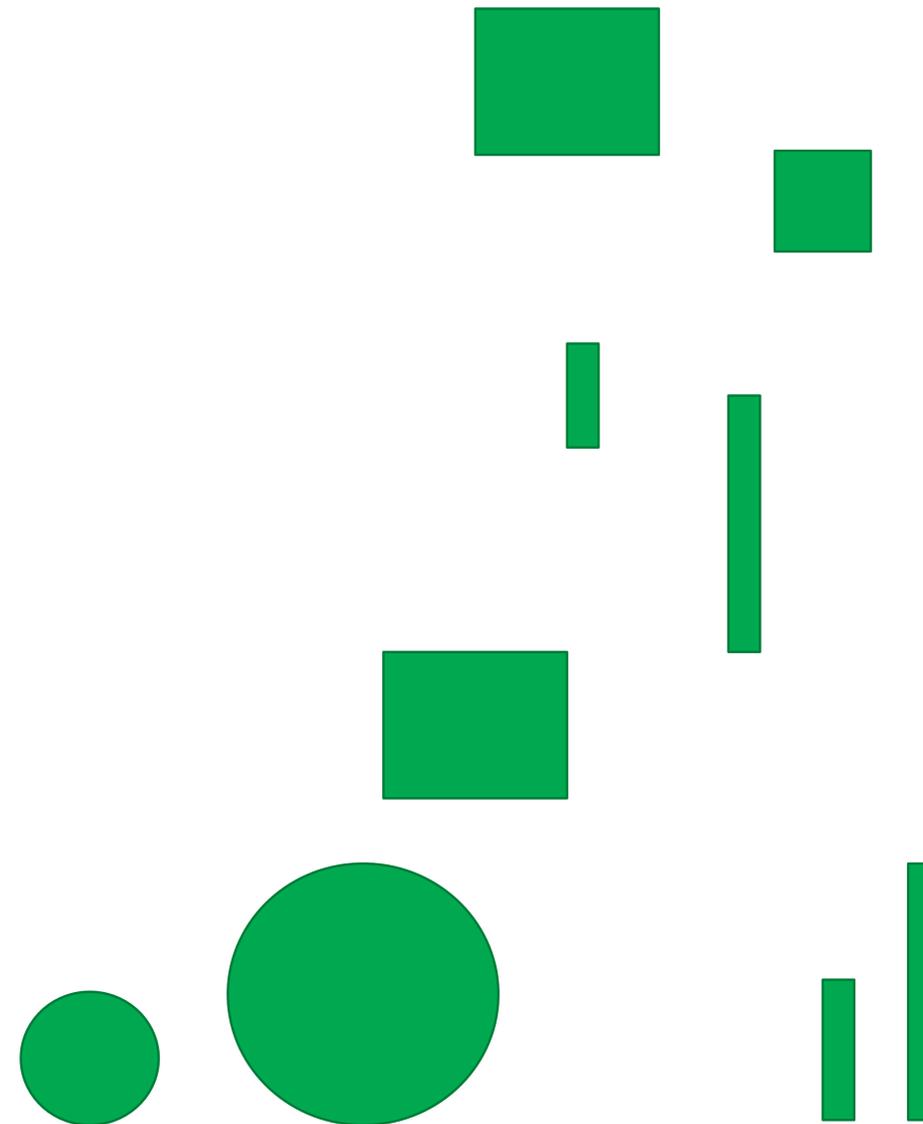
**Grouping works**

**Judging differences**

**Good for aligned bars (position)**

**OK for changes in length**

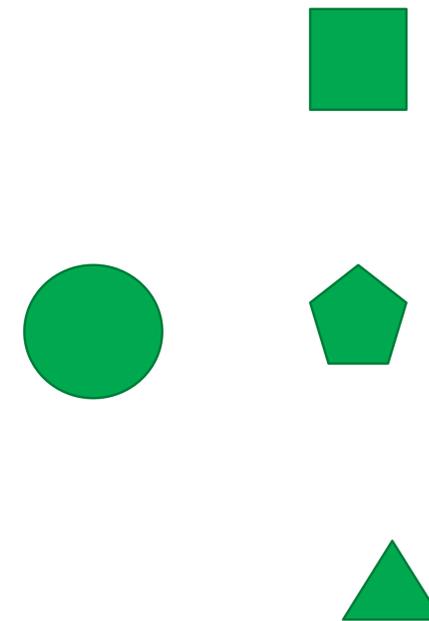
**Bad for changes in area**



# Shape

**Great to recognize many classes.**

**No grouping, ordering.**



# Value

**Good for quantitative data when length & size are used.**

**Not very many shades recognizable**

**Supports grouping**

**Is preattentive (stands out) if sufficiently different**



# Color

**Good for qualitative data**

**Limited number of classes!**

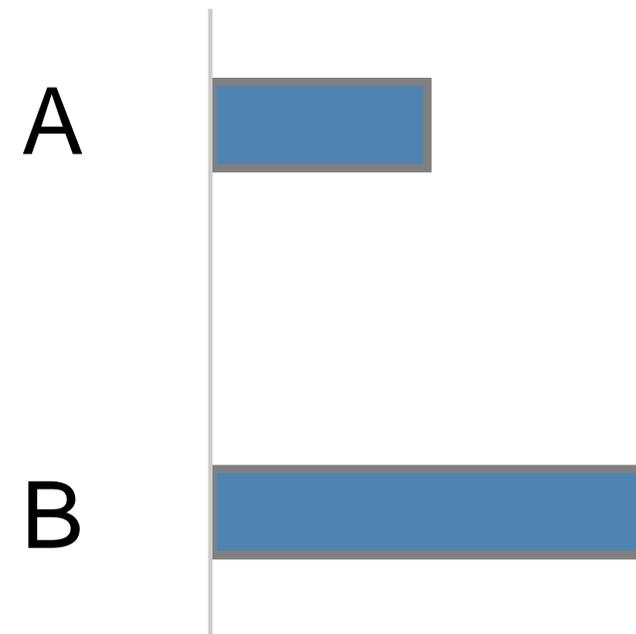
**Not good for quantitative data!**

**Is preattentive if sufficiently different.**

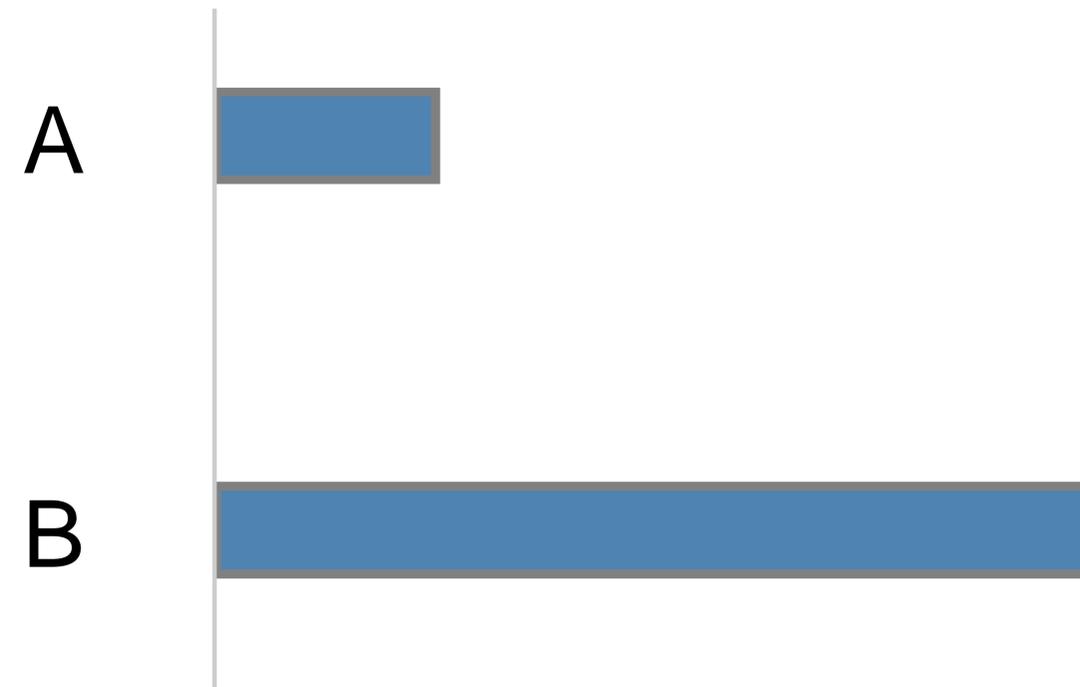
**Lots of pitfalls! Be careful!**



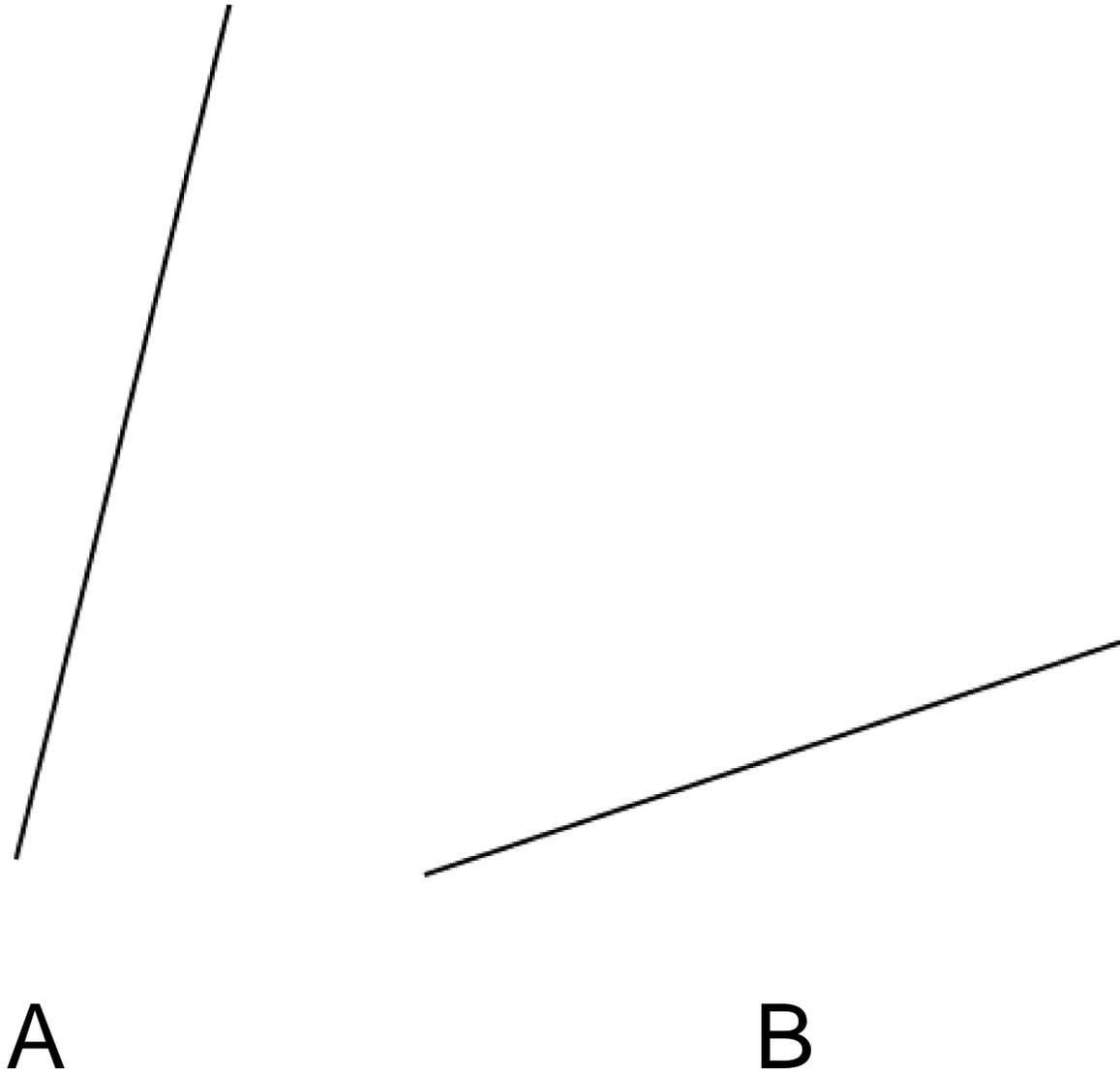
# How much longer?



# How much longer?

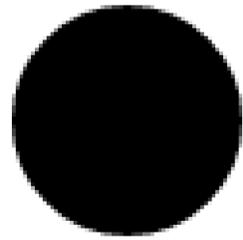


# How much steeper?

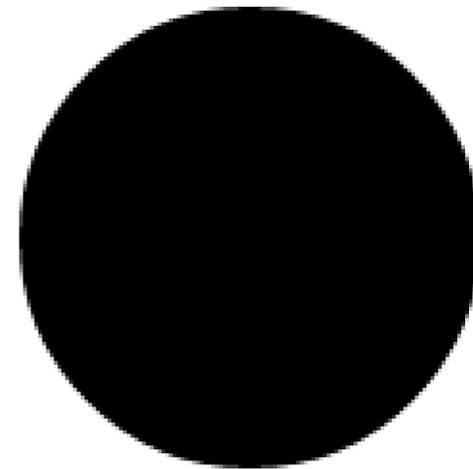


4x

# How much larger?



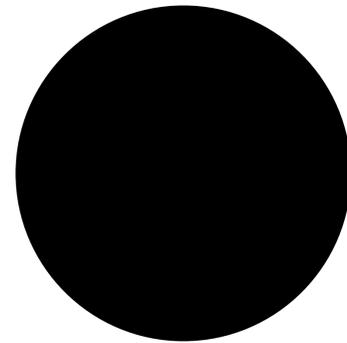
A



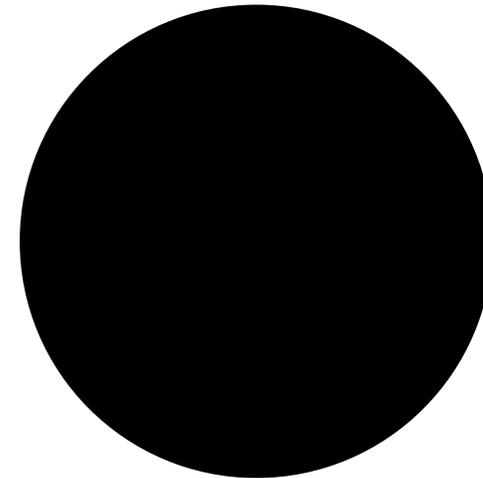
B

2x (diameter)

# How much larger?



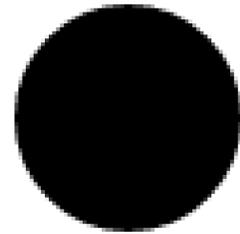
A



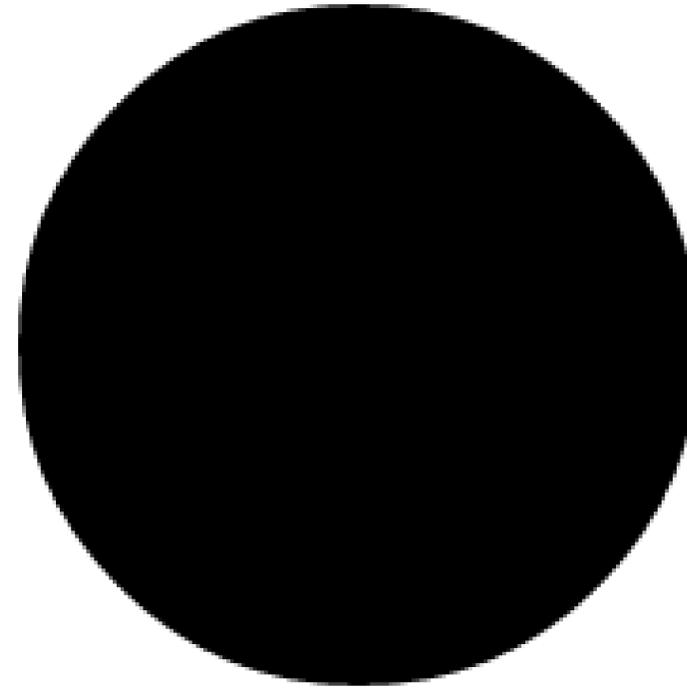
B

2x Area

# How much larger?



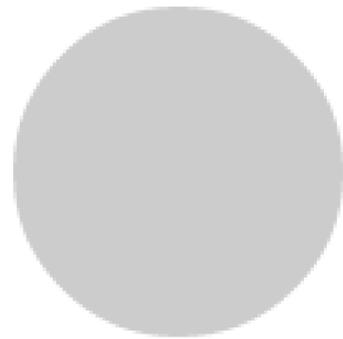
A



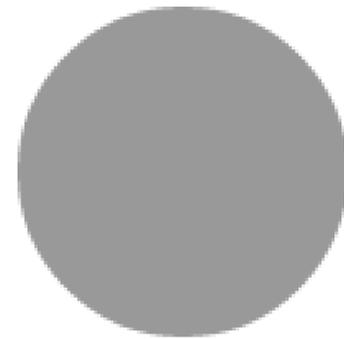
B

3x

# How much darker?



A

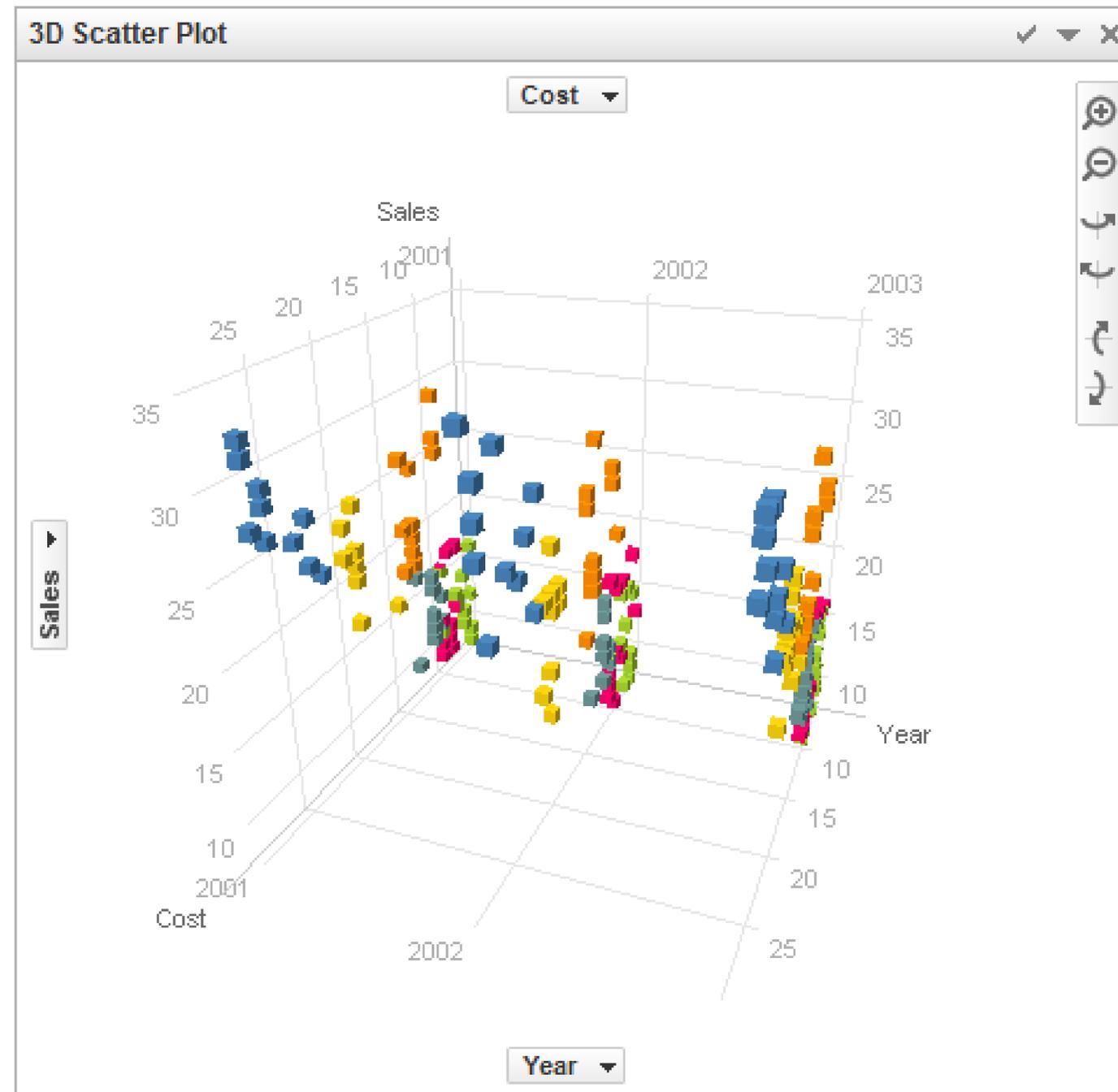


B

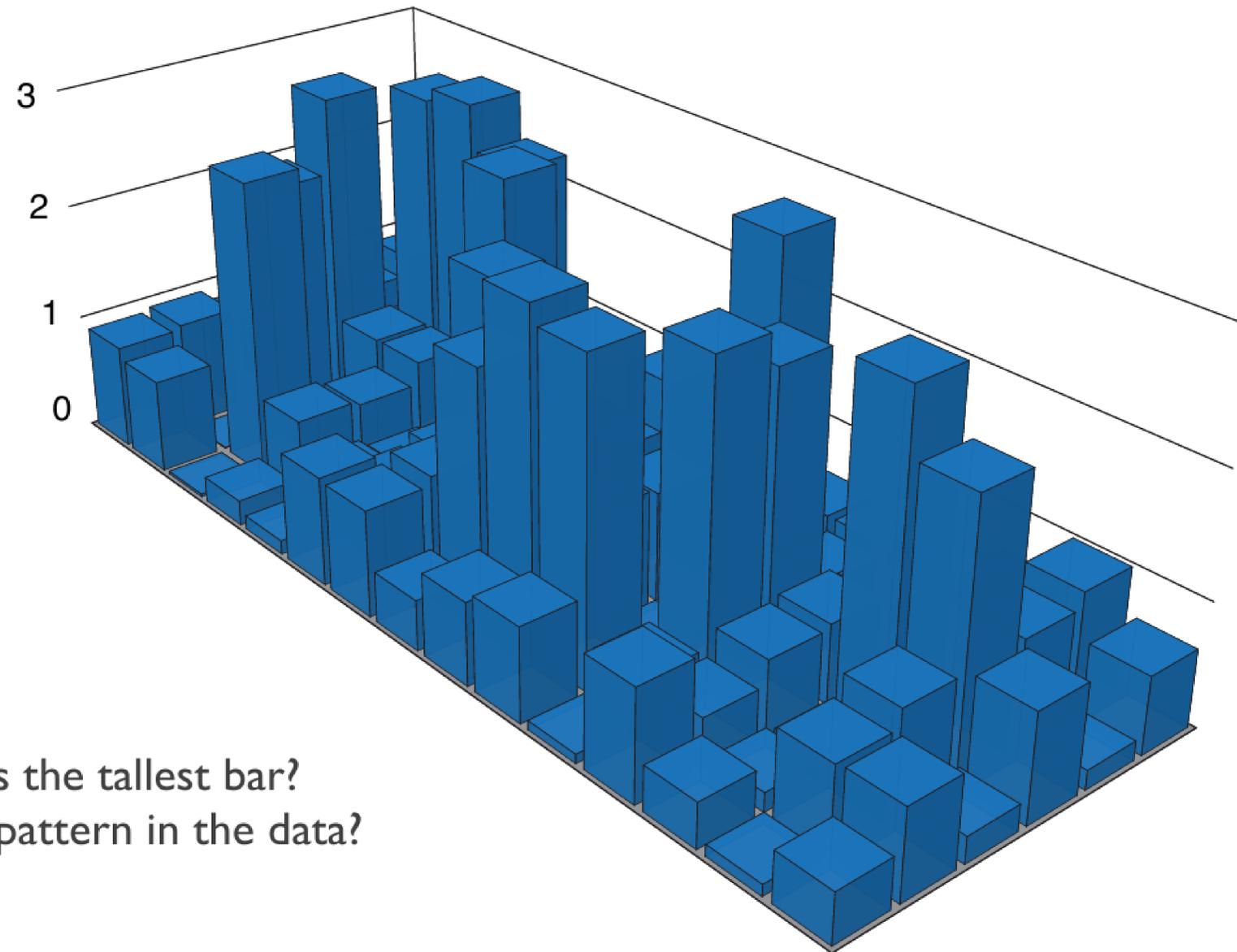
Opacity: A = 0.2 / B = 0.4 ->  
But: non-linearities of the human visual system

# **VISUALIZATION GUIDELINES & PITFALLS**

# 3D!

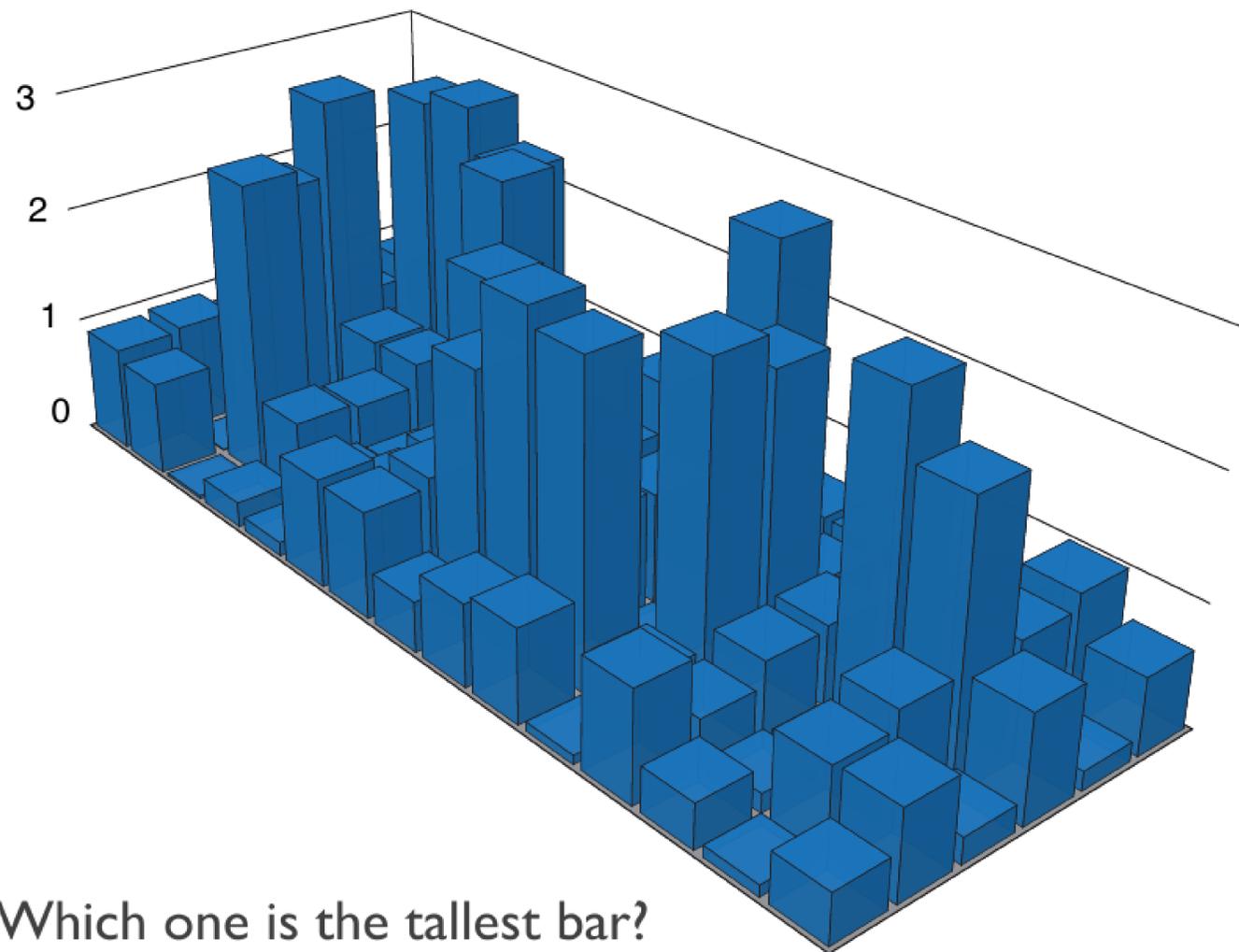


# 3D Pitfall: Occlusion & Perspective

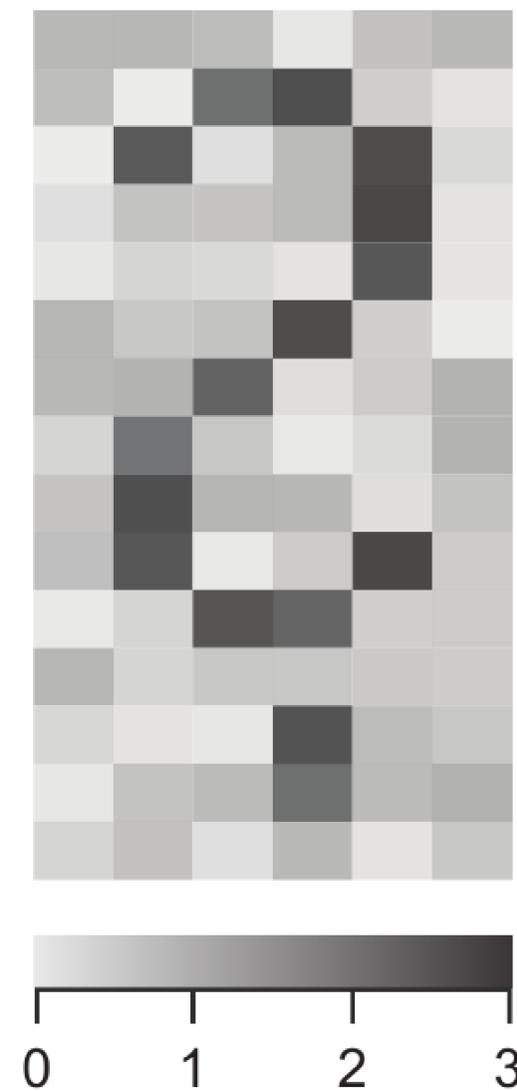


Which one is the tallest bar?  
What is the pattern in the data?

# 3D Pitfall: Occlusion & Perspective



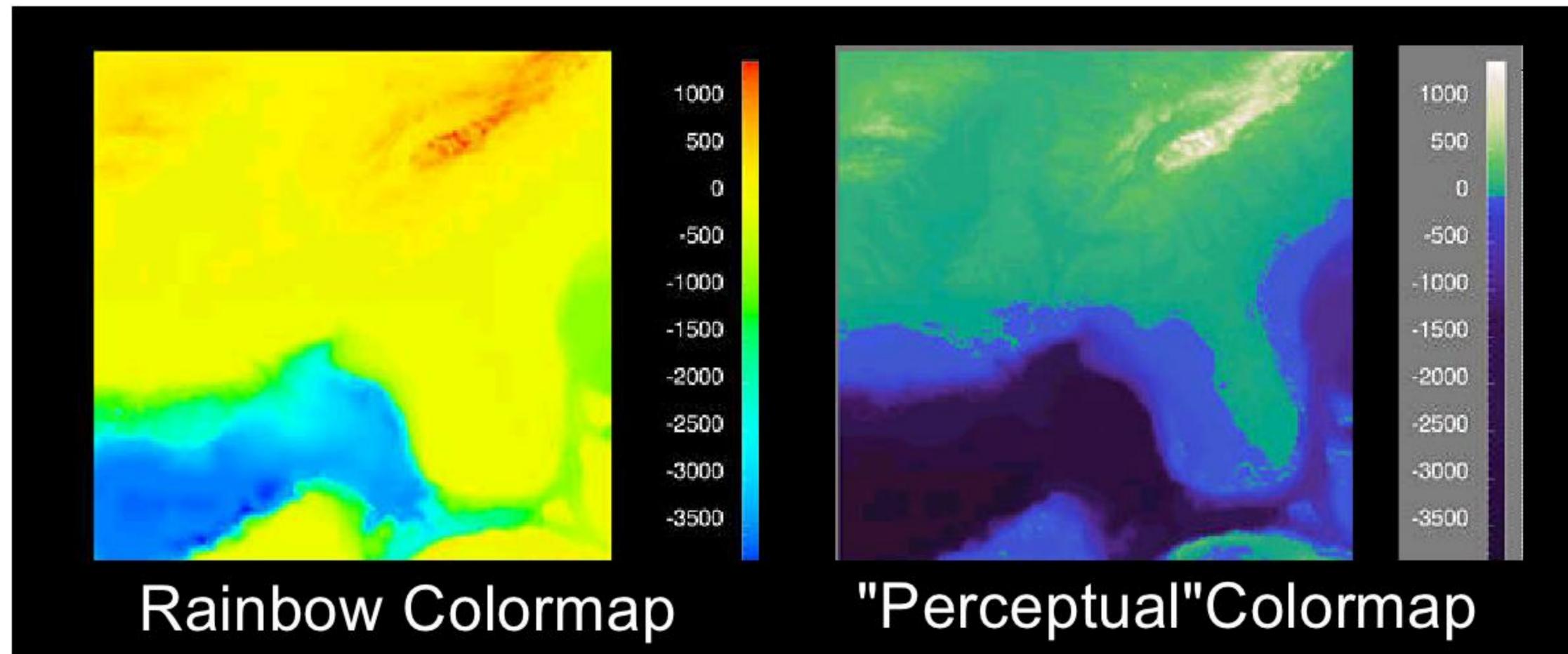
Which one is the tallest bar?  
What is the pattern in the data?



# Color Scales

**Don't! Ever! use multiple hues for (continuous) quantitative data**

**Use multiple hues for meaningful intervals**



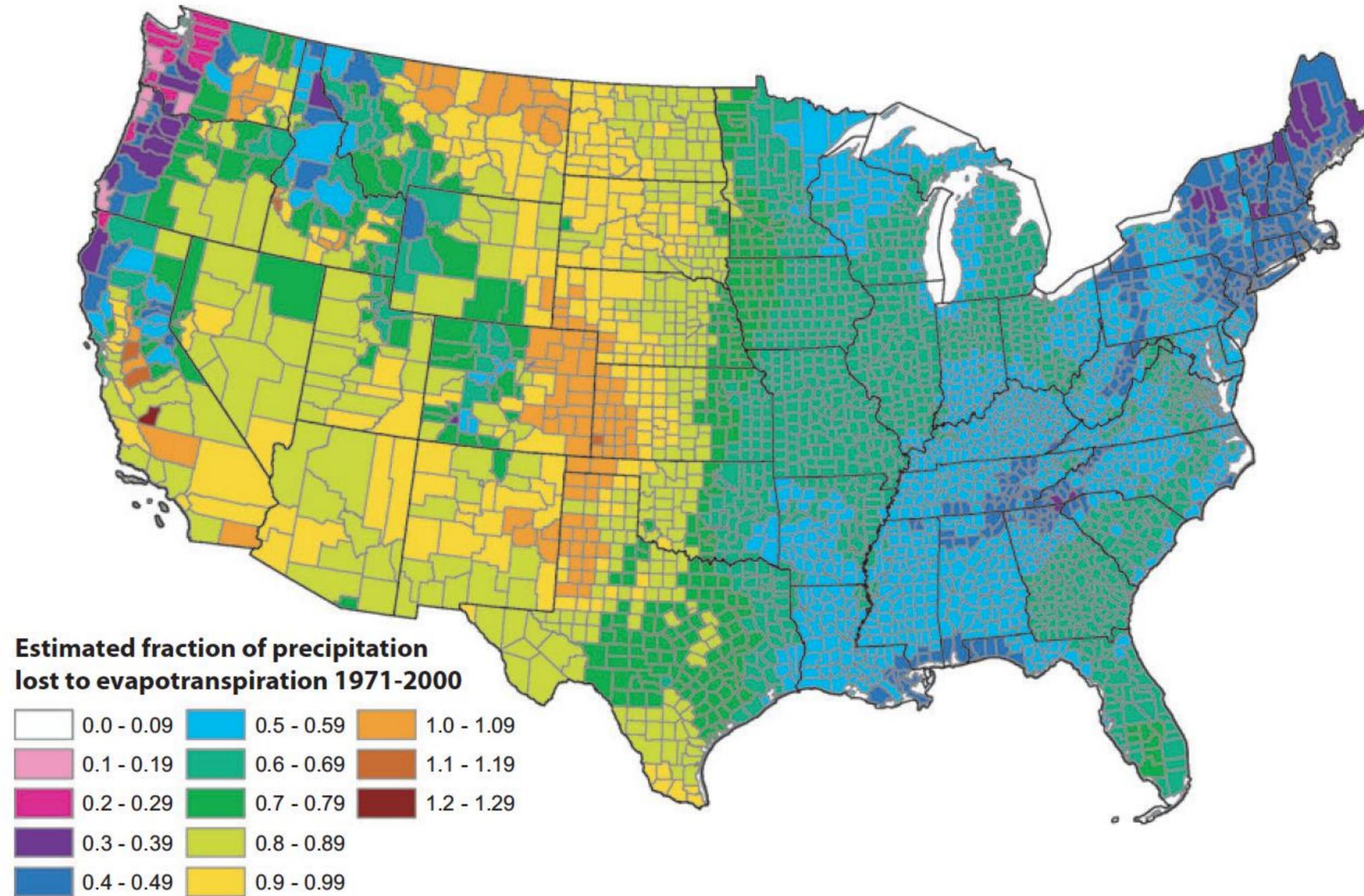
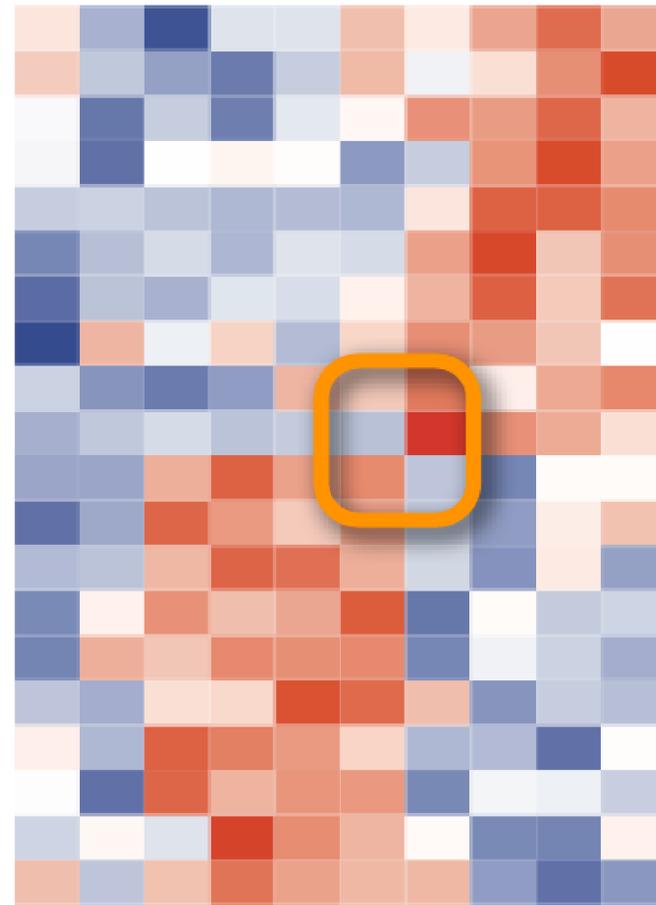


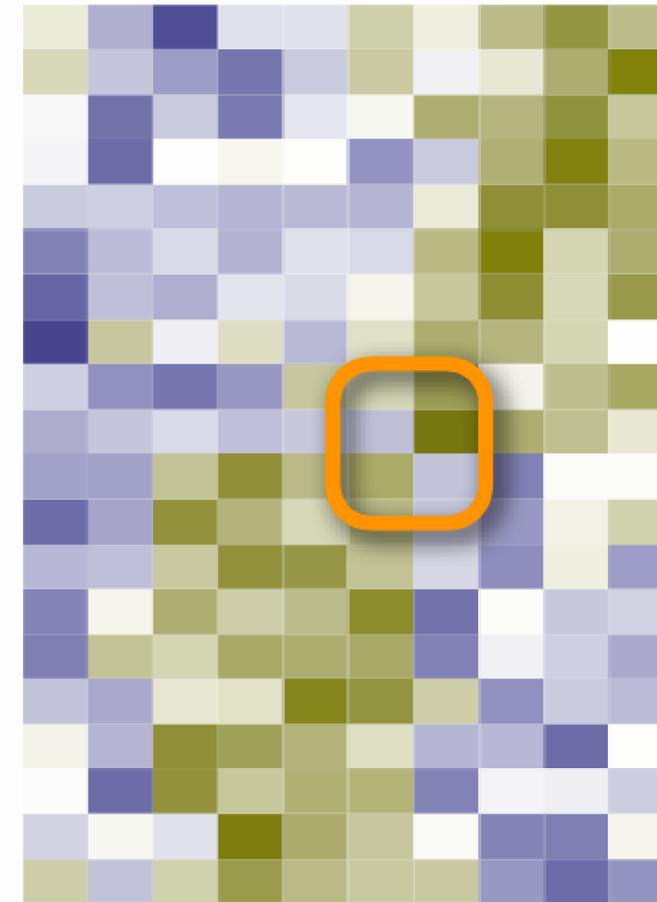
FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation ( $P$ ) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/ $P$  were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions  $>1$  are agricultural counties that either import surface water or mine deep groundwater.



# Good Color Mapping

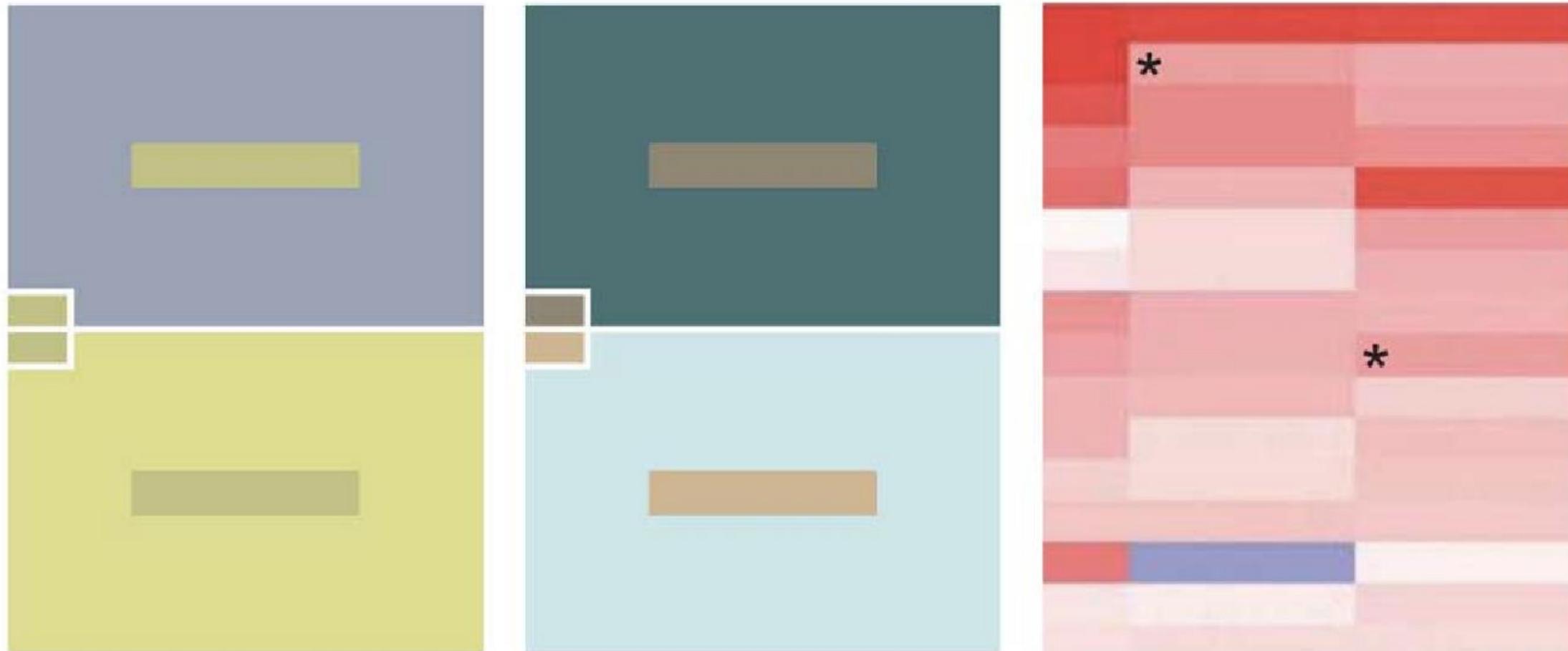


Normal Vision



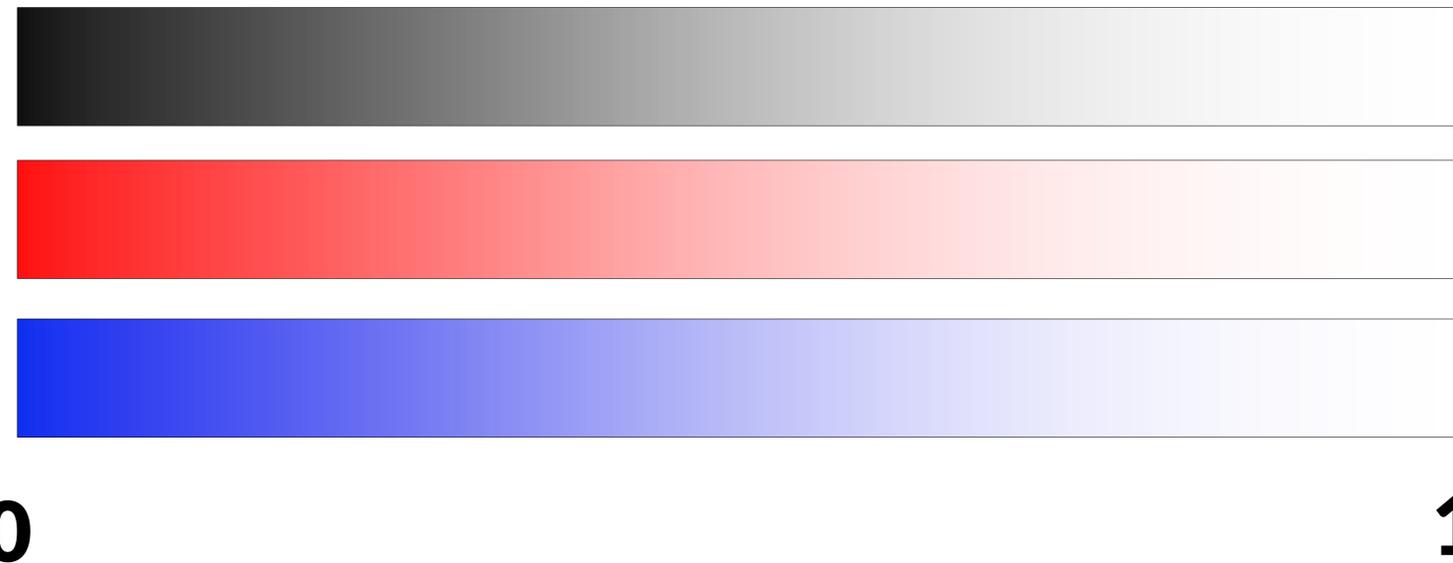
Deuteranope Vision  
("Red-Green Blindness")

# Color is relative!

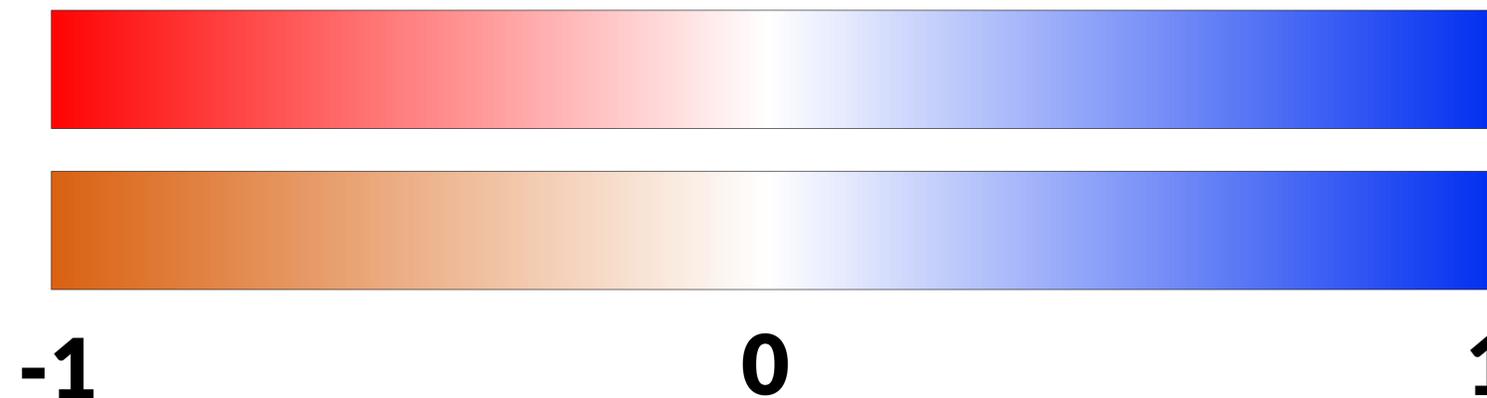


# Creating Color Scales

**Quantitative range: go for one color**

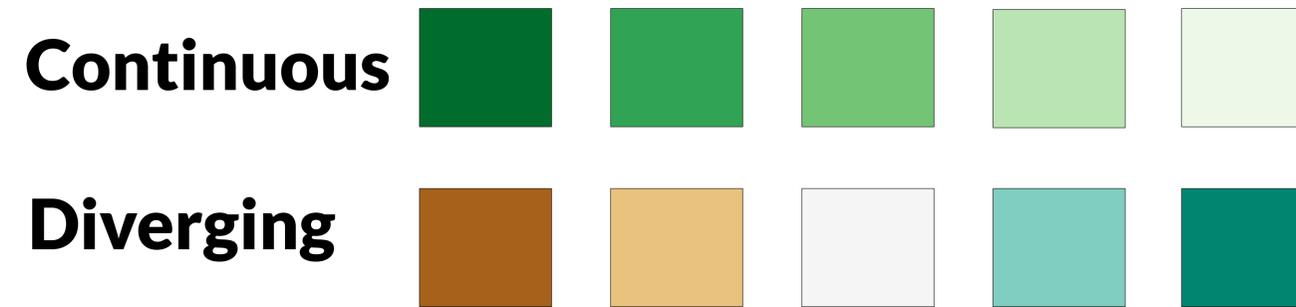


**Quantitative range with “neutral” value:  
use two colors (diverging)**



# Creating Color Scales

## For Ordinal Data: same principles

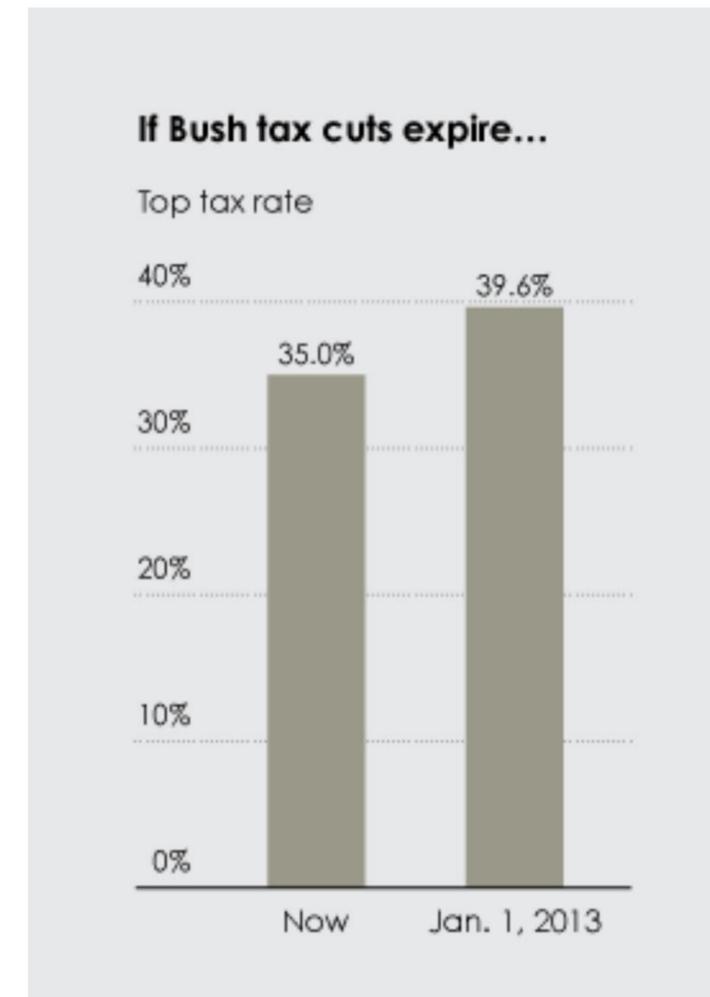
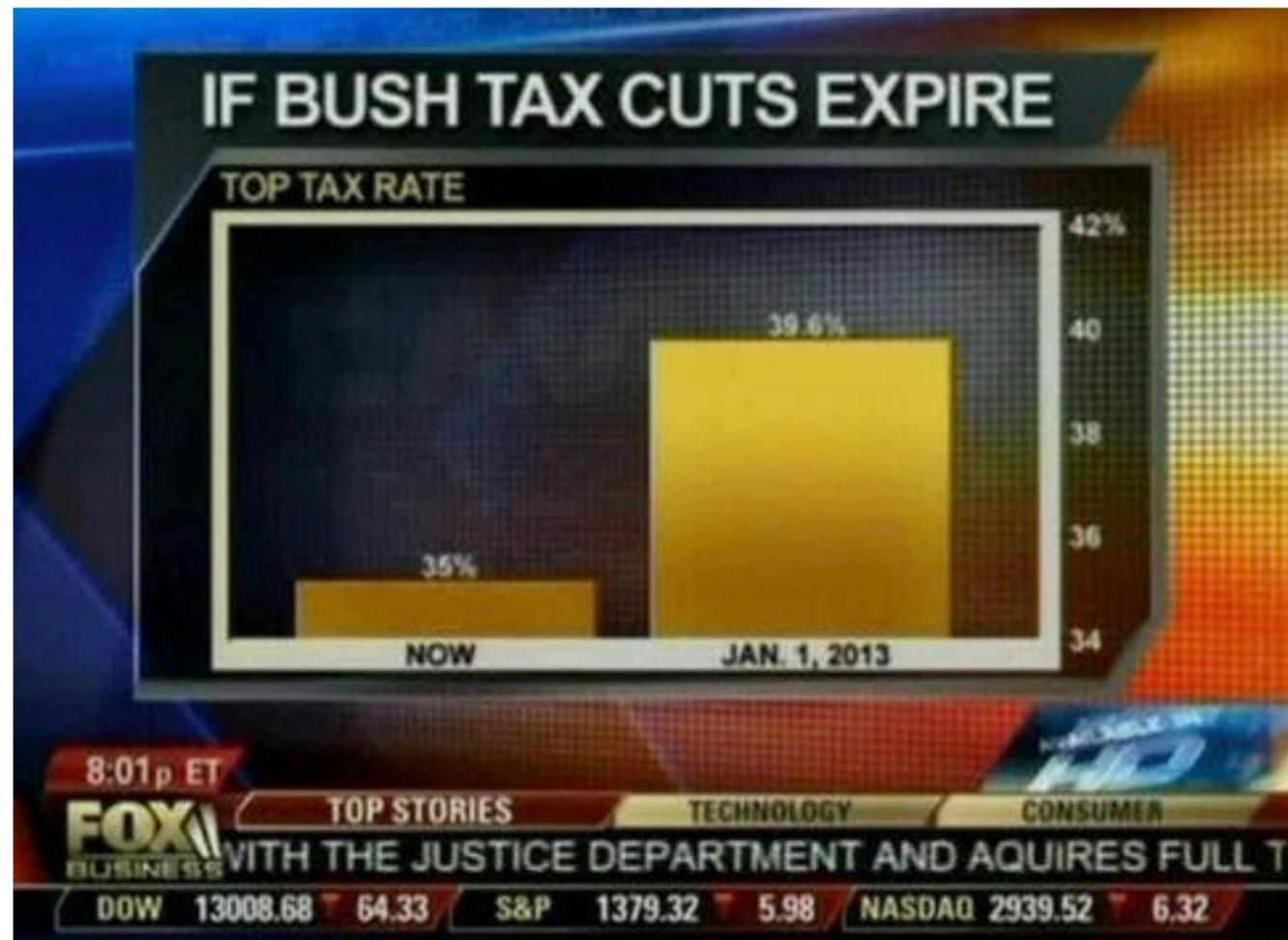


## For Categorical (nominal) Data: use unique hue

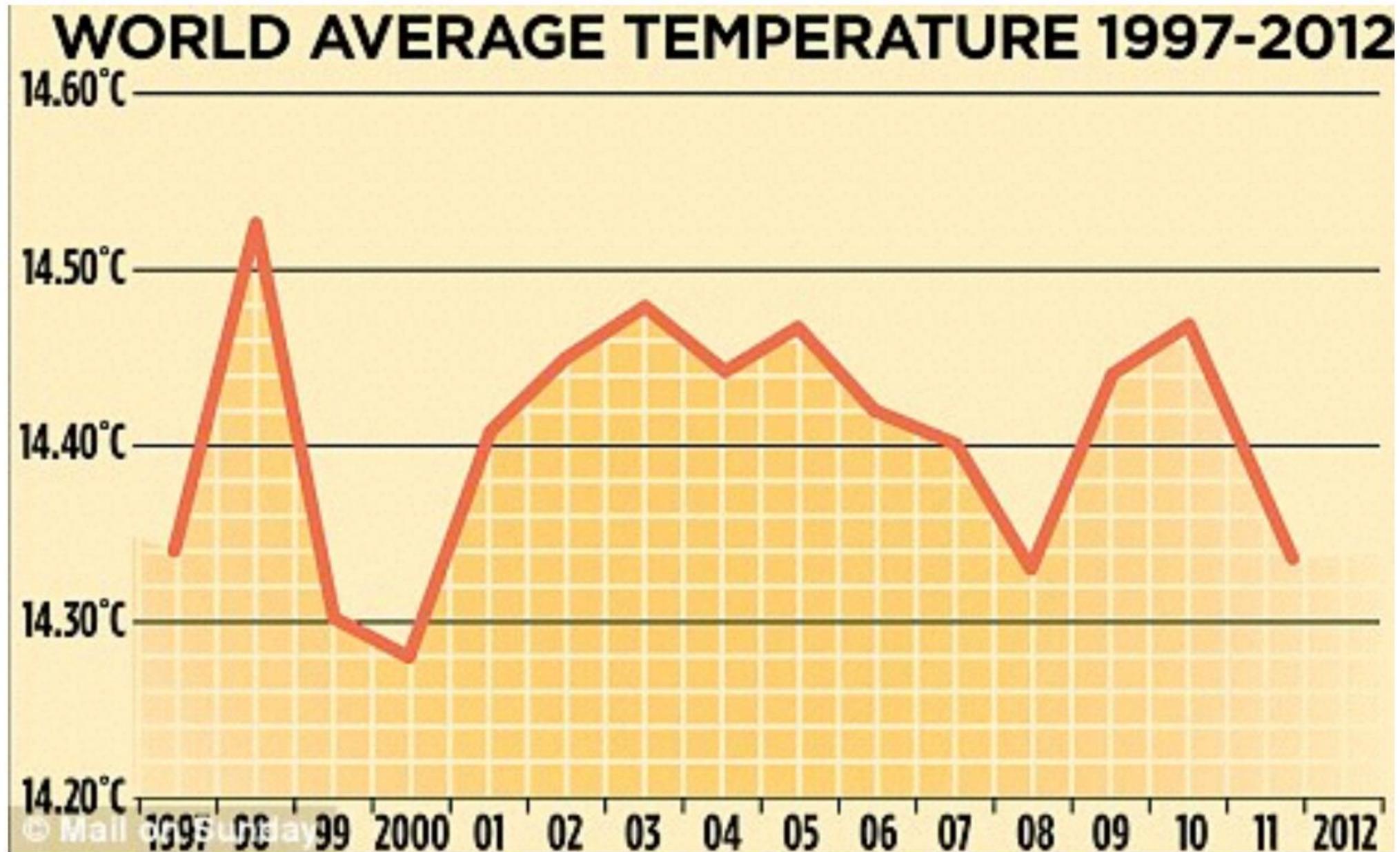


**Helpful Tool: <http://colorbrewer.org>**

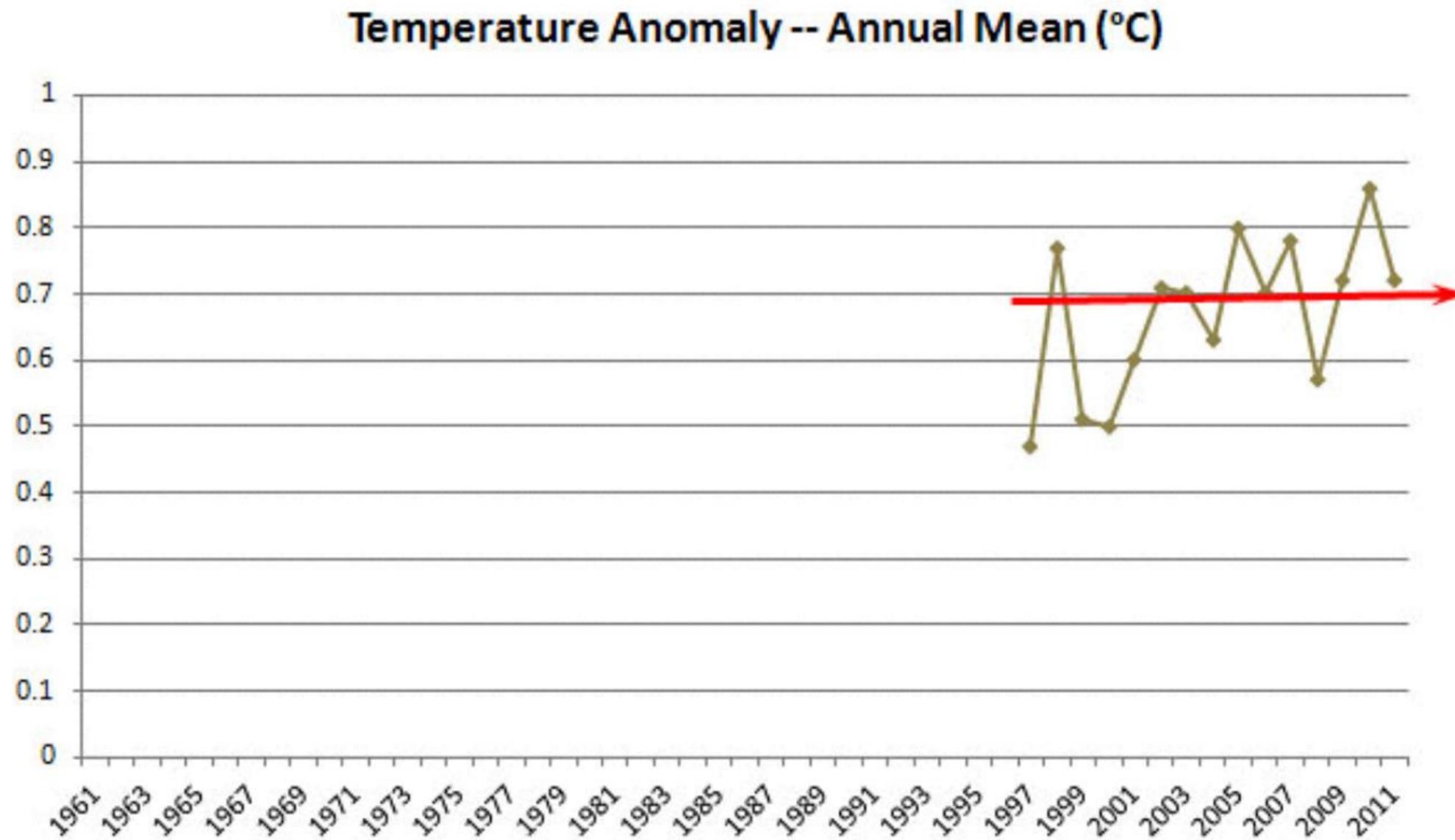
# Scales



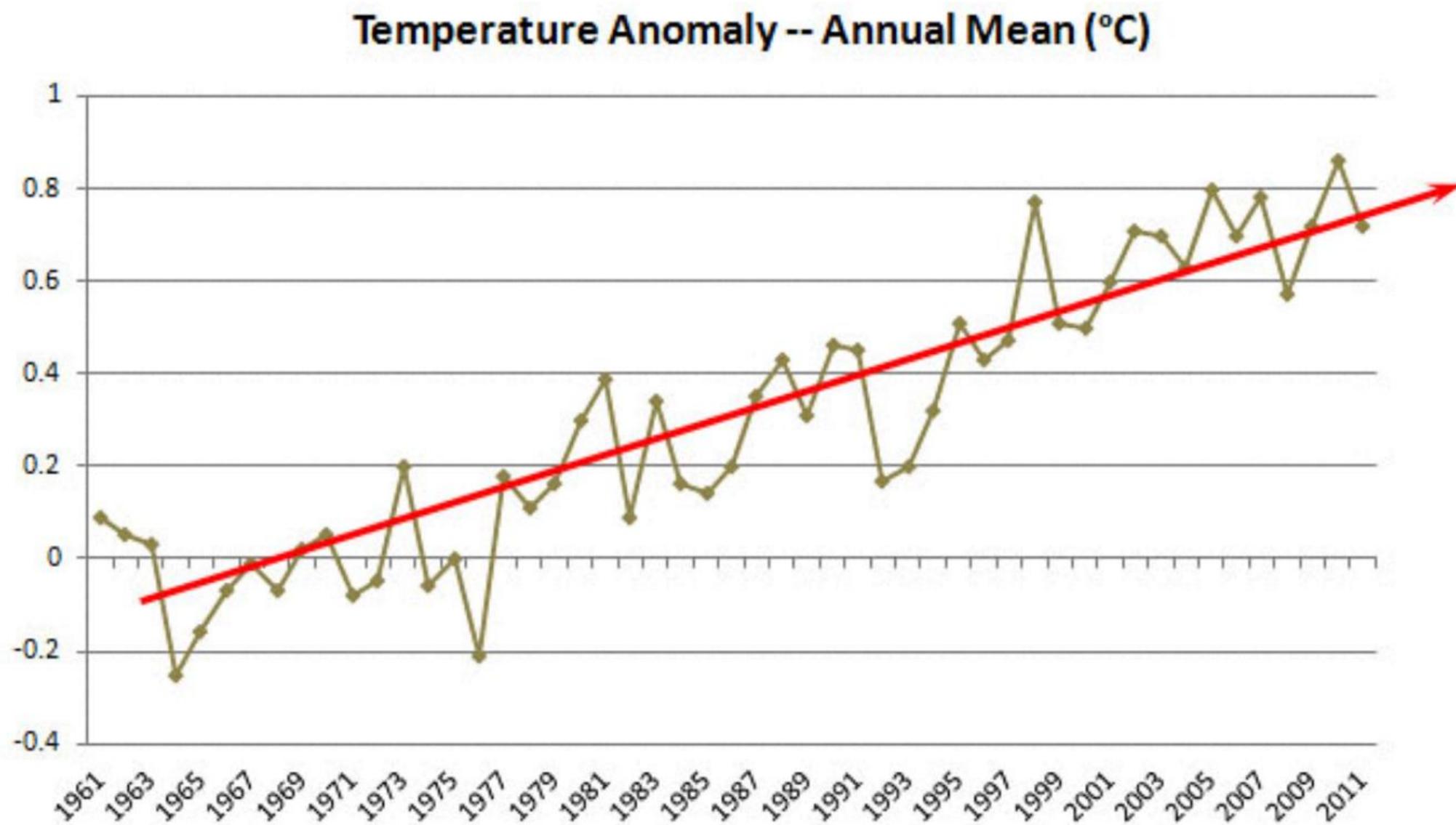
# Context



# Context



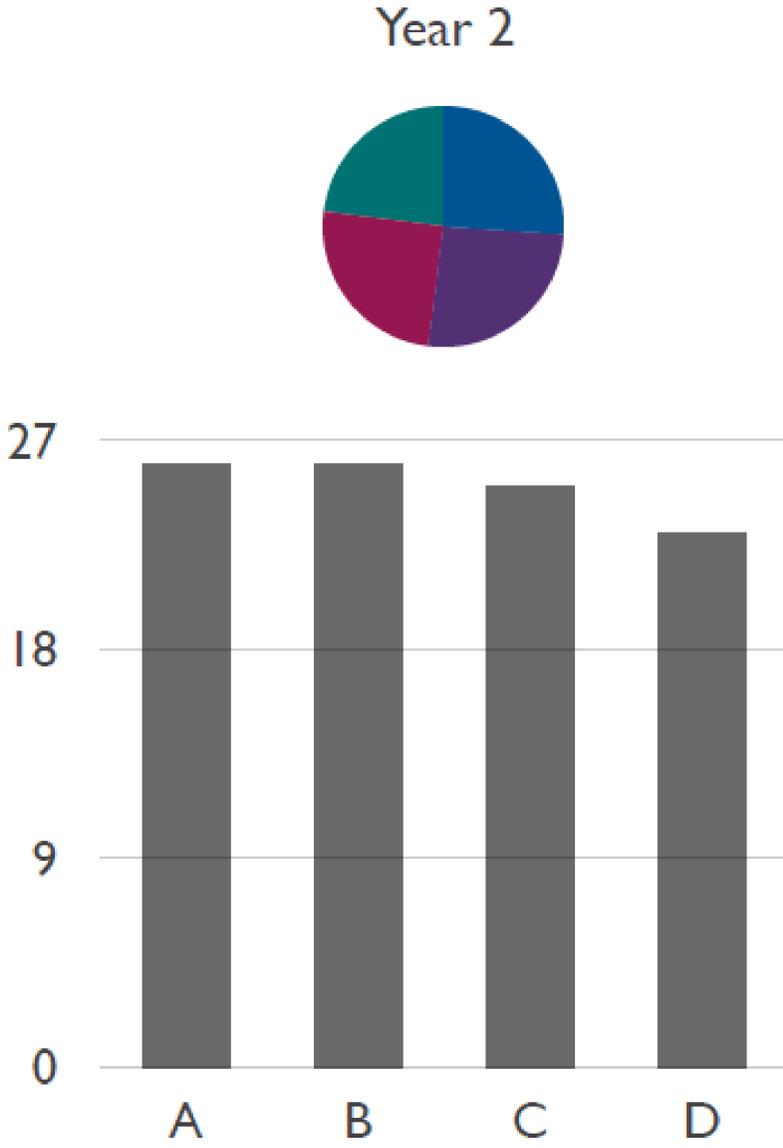
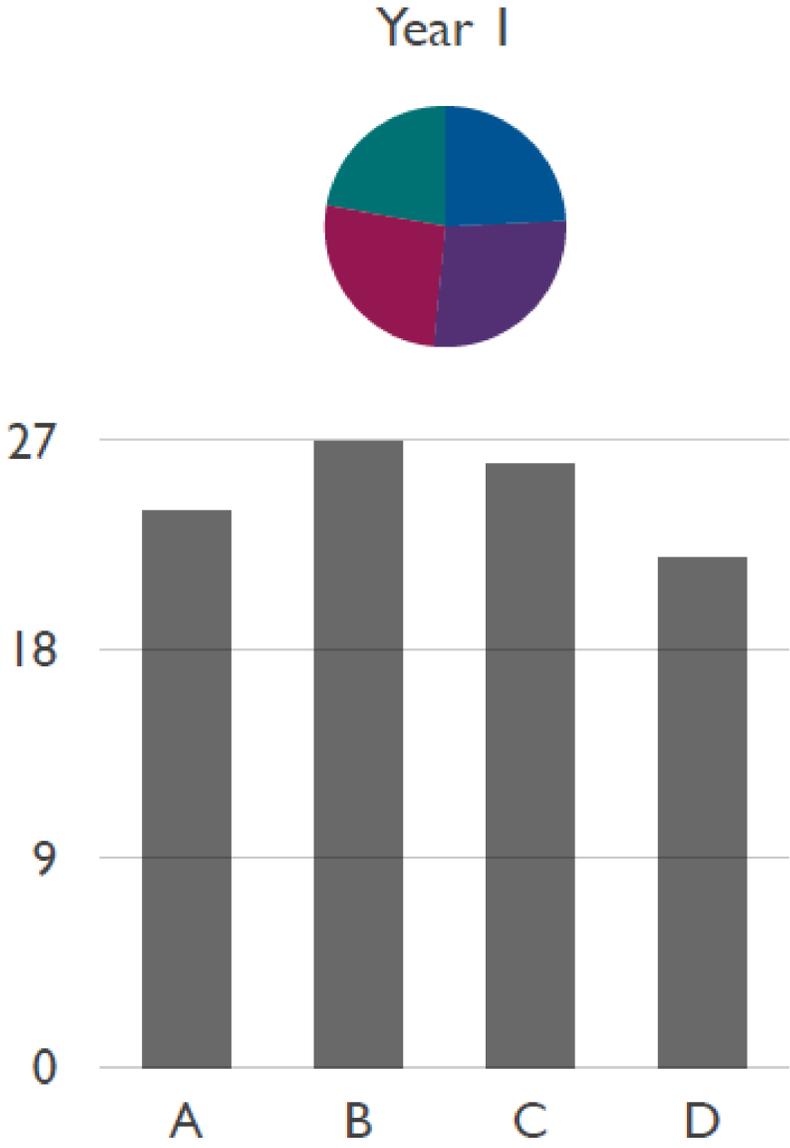
# Context



# Wrong Visual Encoding



# Wrong Visual Encoding



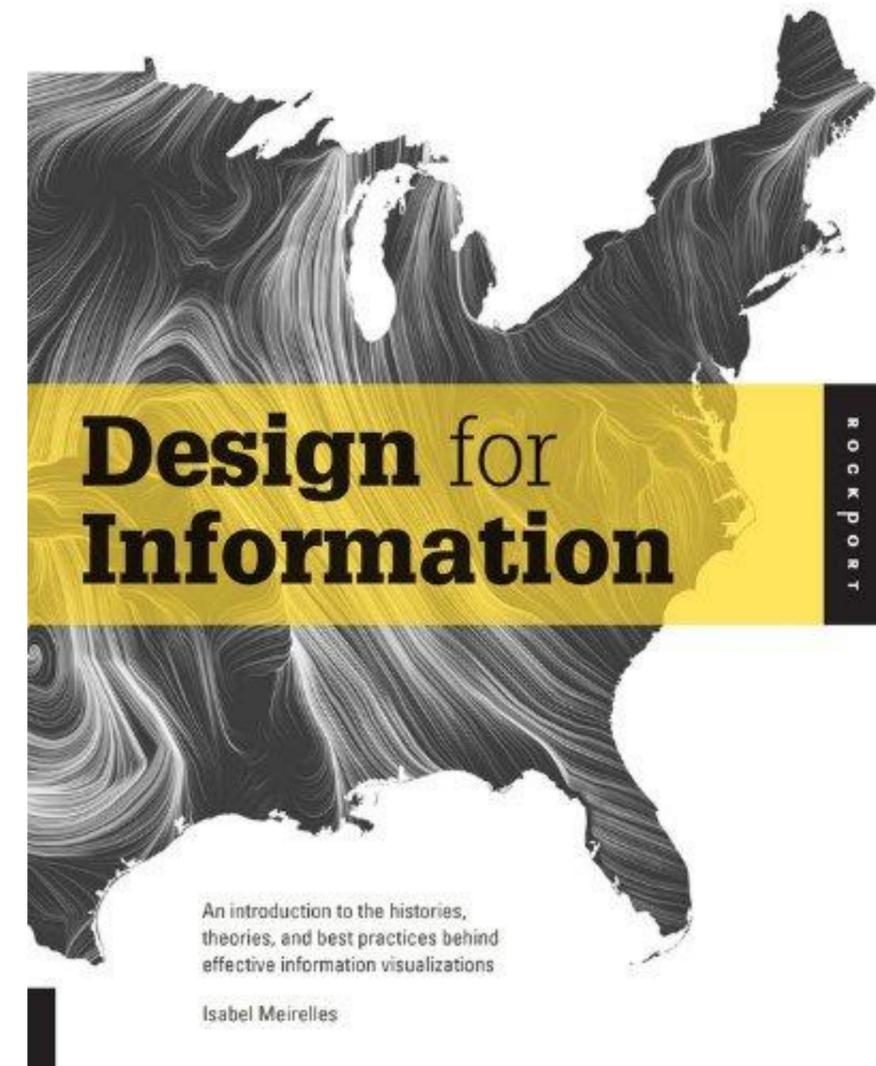
# Resources

## Hanspeter Pfister's Visualization Class

<http://www.cs171.org/>

## Visualization on the Web:

<http://d3js.org/>



**Isabel Meirelles**



# Visualizing Multi-Attribute Rankings

## A Very Short Visualization Introduction

Alexander Lex, Harvard University

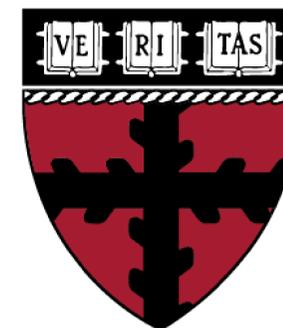
[alex@seas.harvard.edu](mailto:alex@seas.harvard.edu)

<http://alexander-lex.com>

@alexander\_lex

Credits:

Marc Streit, Nils Gehlenborg, Hanspeter Pfister, Anne  
Mai Wasserman, Mark Borowsky, Christian Partl, Denis  
Kalkofen, Samuel Gratzl, Dieter Schmalstieg



**HARVARD**  
School of Engineering  
and Applied Sciences