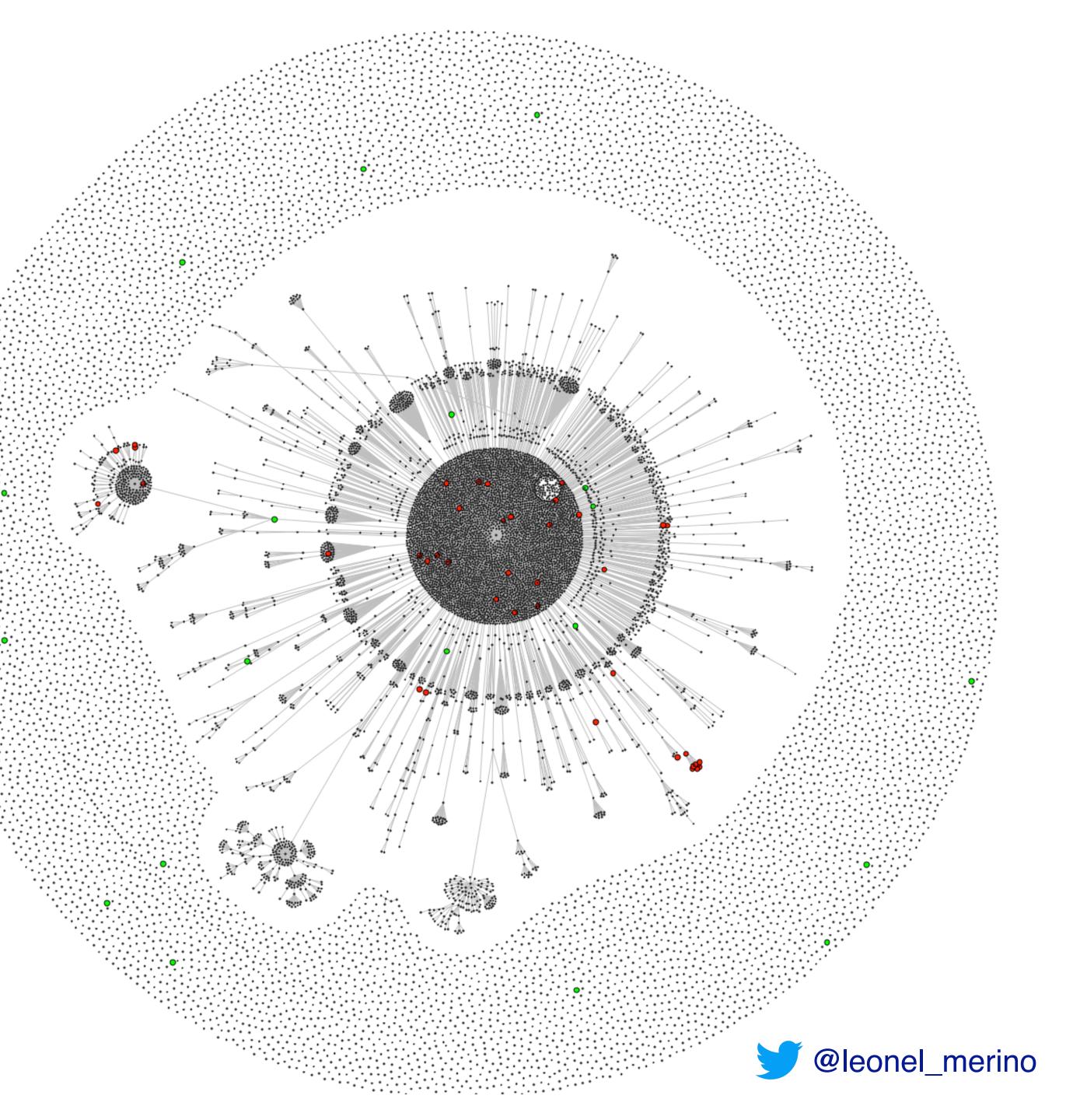
# **Software Visualization**

### Leonel Merino

Visualization Research Center (VISUS) University of Stuttgart

leonel.merino@visus.uni-stuttgart.de



# Roadmap

> Motivation
> Visual Perception
> Information Visualization
> Software Visualization



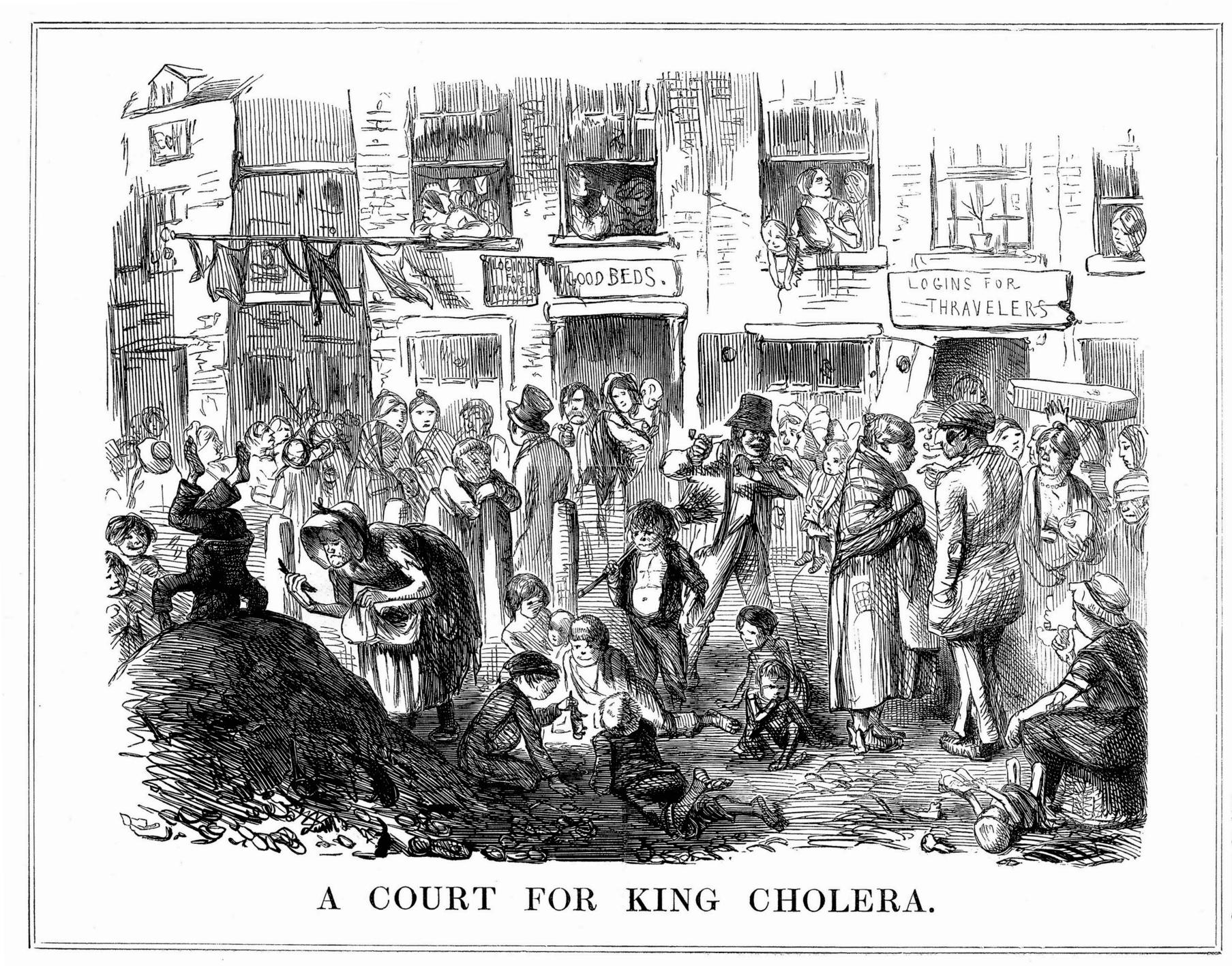


# Roadmap

> Motivation
> Visual Perception
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> Software Visualization

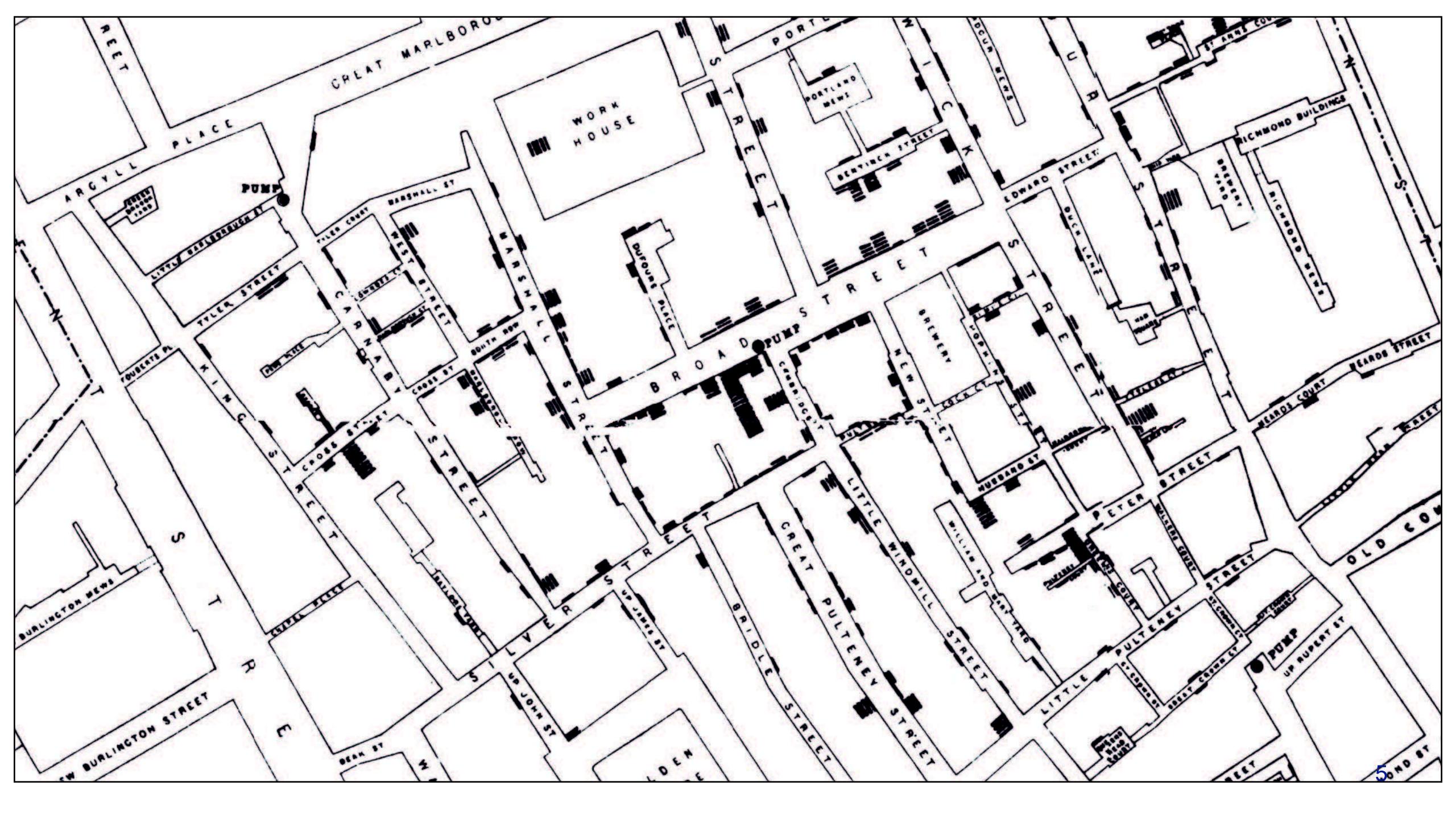




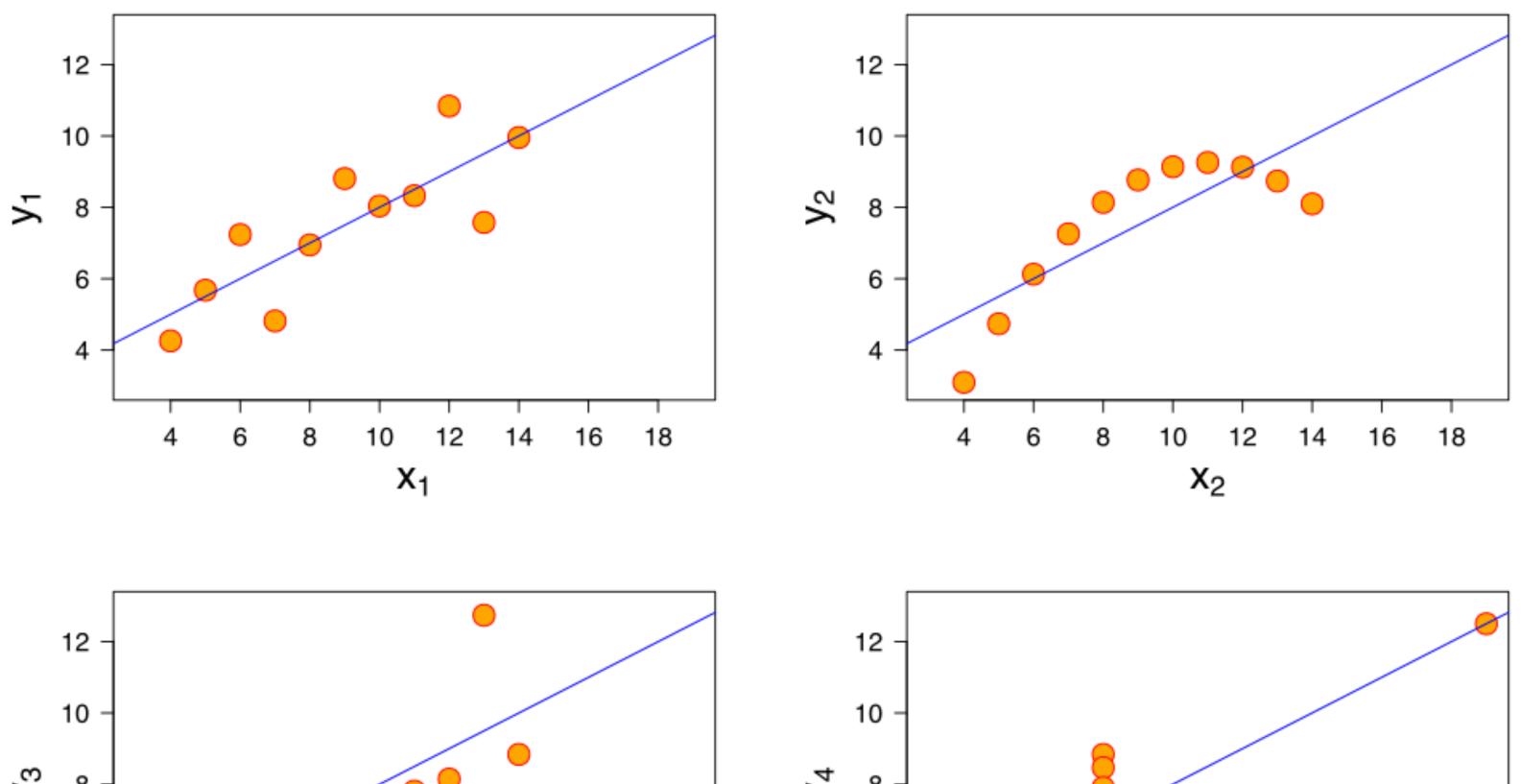


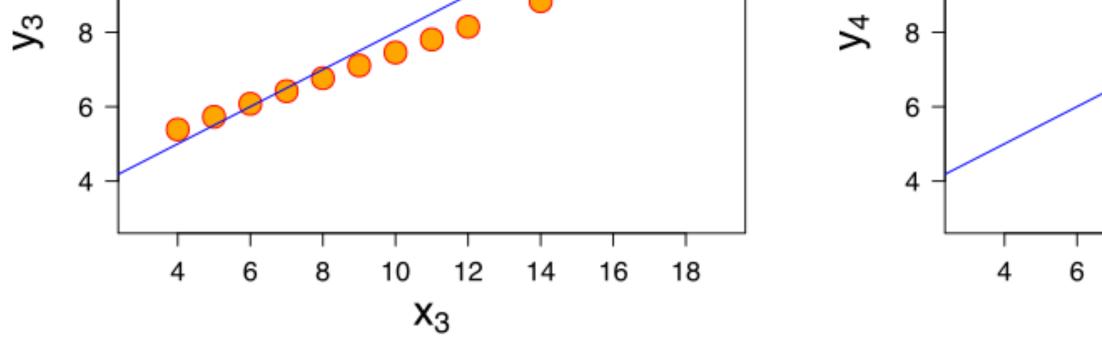
SEPTEMBER 25, 1852

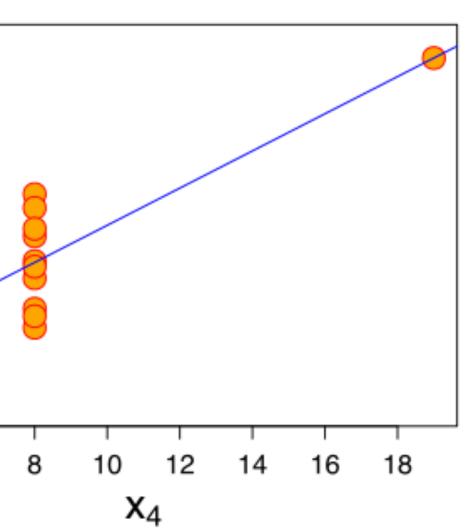




**Anscombe's Quartet** 







Number of observations (n) = 11Mean of the x's  $(\bar{x}) = 9.0$ Mean of the y's  $(\bar{y}) = 7.5$ Regression coefficient  $(b_1)$  of y on x = 0.5Equation of regression line: y = 3 + 0.5 xSum of squares of  $x - \bar{x} = 110.0$ Regression sum of squares = 27.50 (1 d.f.)Residual sum of squares of y = 13.75 (9 d.f.)Estimated standard error of  $b_1 = 0.118$ 

F.J. Anscombe. Graphs in statistical analysis. *American Statistician*, 27(1):17–21, Feb. 1973



### Datasaurus data set



Matejka, J., & Fitzmaurice, G. (2017, May). Same stats, different graphs: generating datasets with varied appearance and identical statistics through simulated annealing. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (pp. 1290-1294). ACM.



# Roadmap

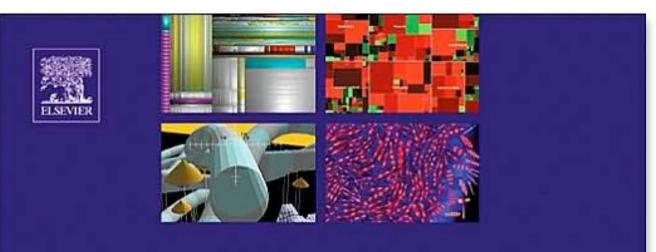
Motivation
Visual Perception
Information Visualization
Software Visualization







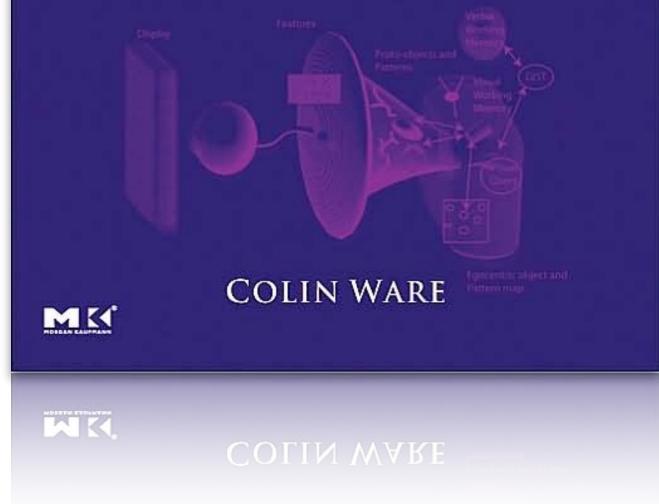
# We acquire **more** information through vision than all the other senses combined



SECOND EDITION

### INFORMATION VISUALIZATION

PERCEPTION FOR DESIGN





### **Pre-attentive Processing**

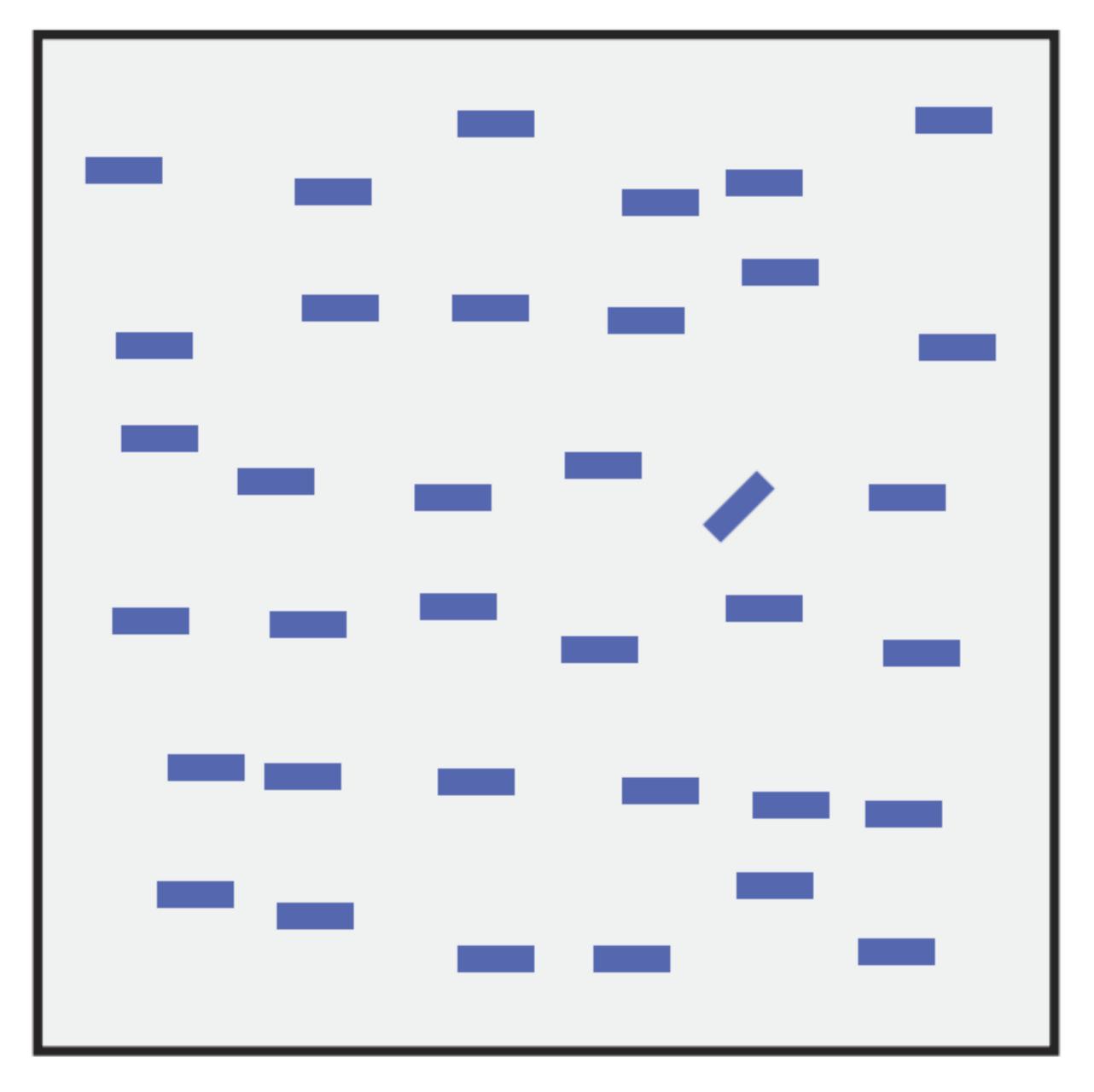
# milliseconds (msec) are considered pre-attentive."

"Tasks that can be performed on large multi-element displays in less than 200-250

[Healy and Enns '12]



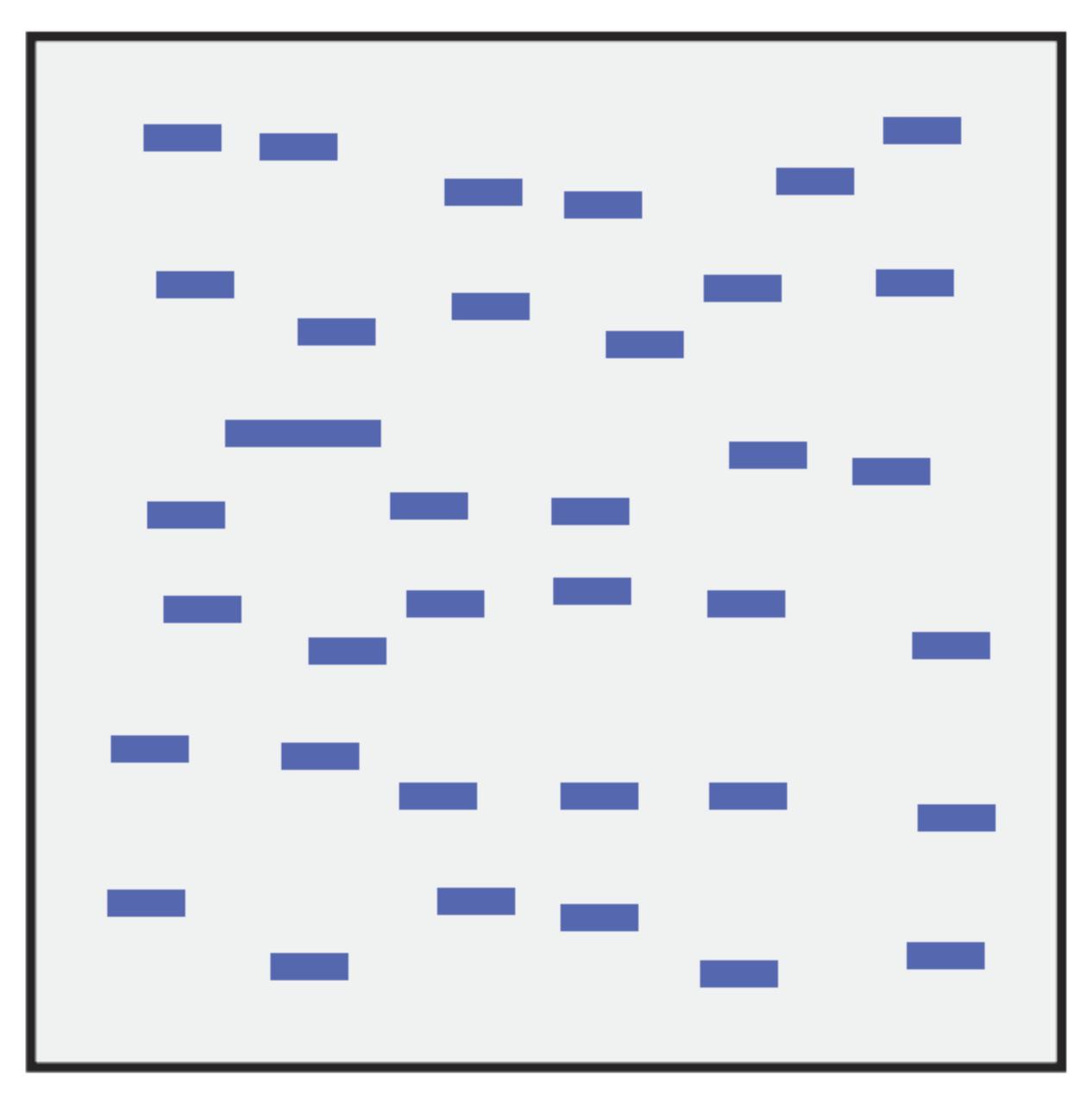




# orientation



11



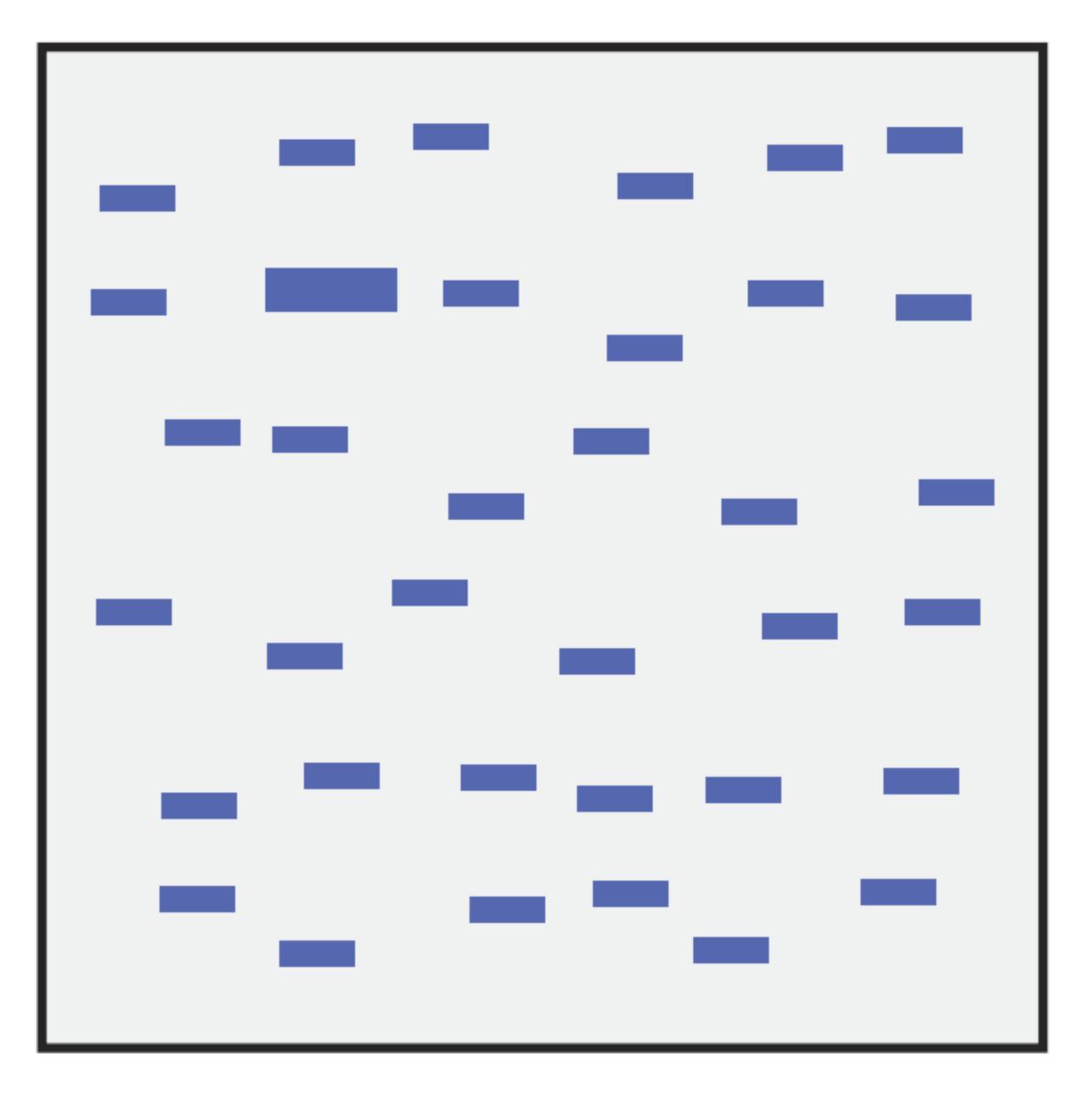
# length



# 

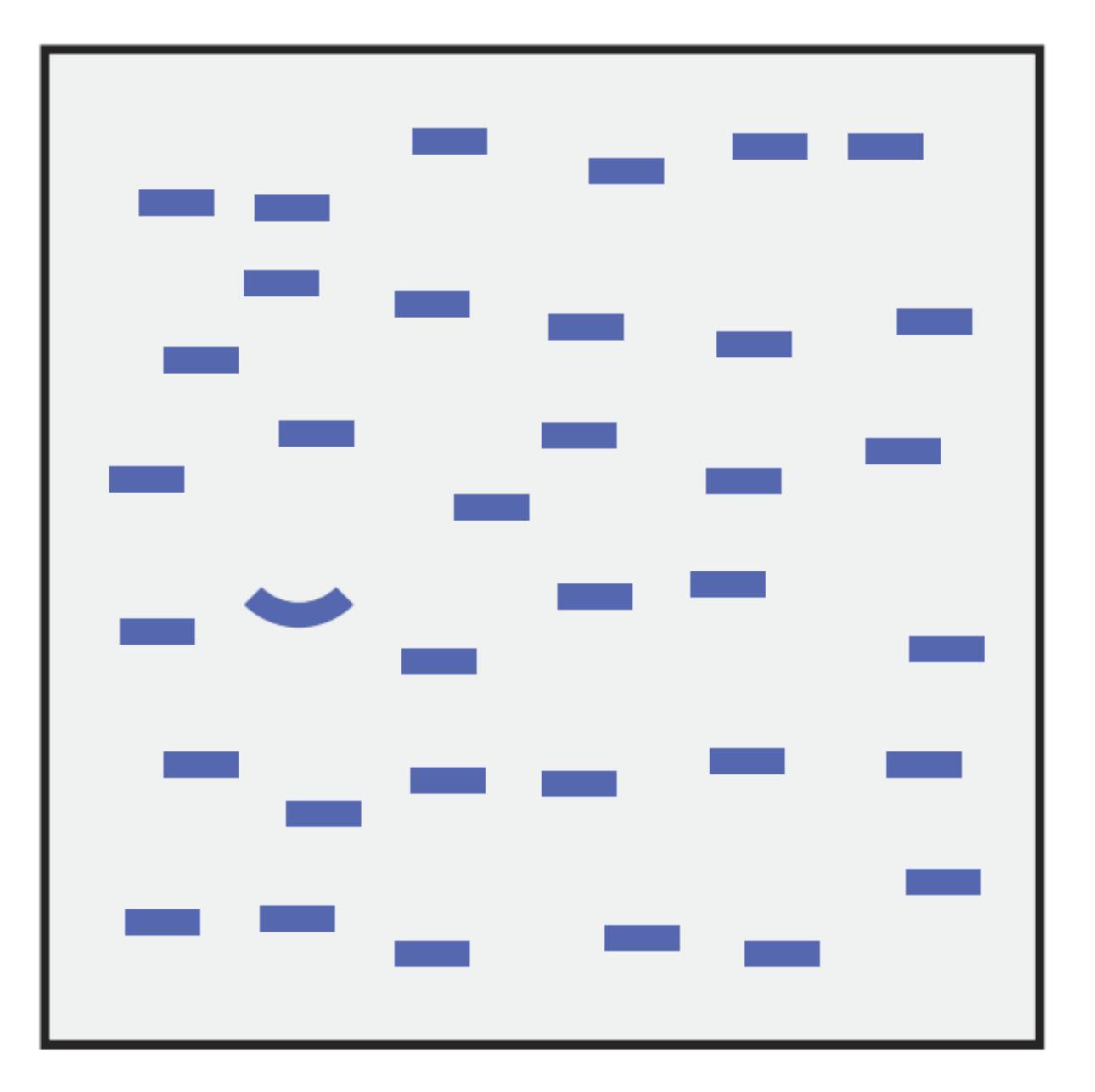
# closure





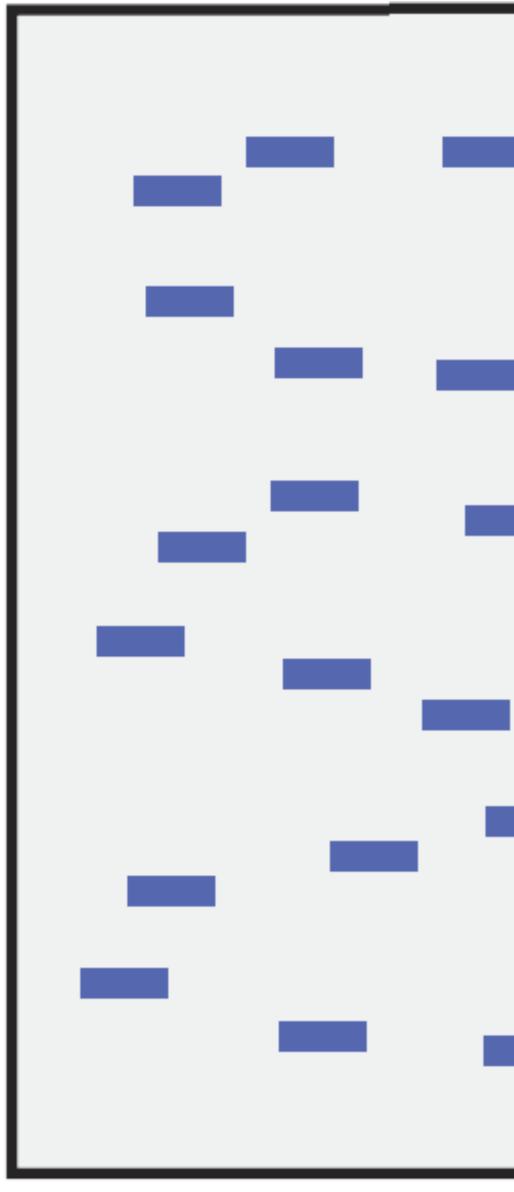
# size





# curvature

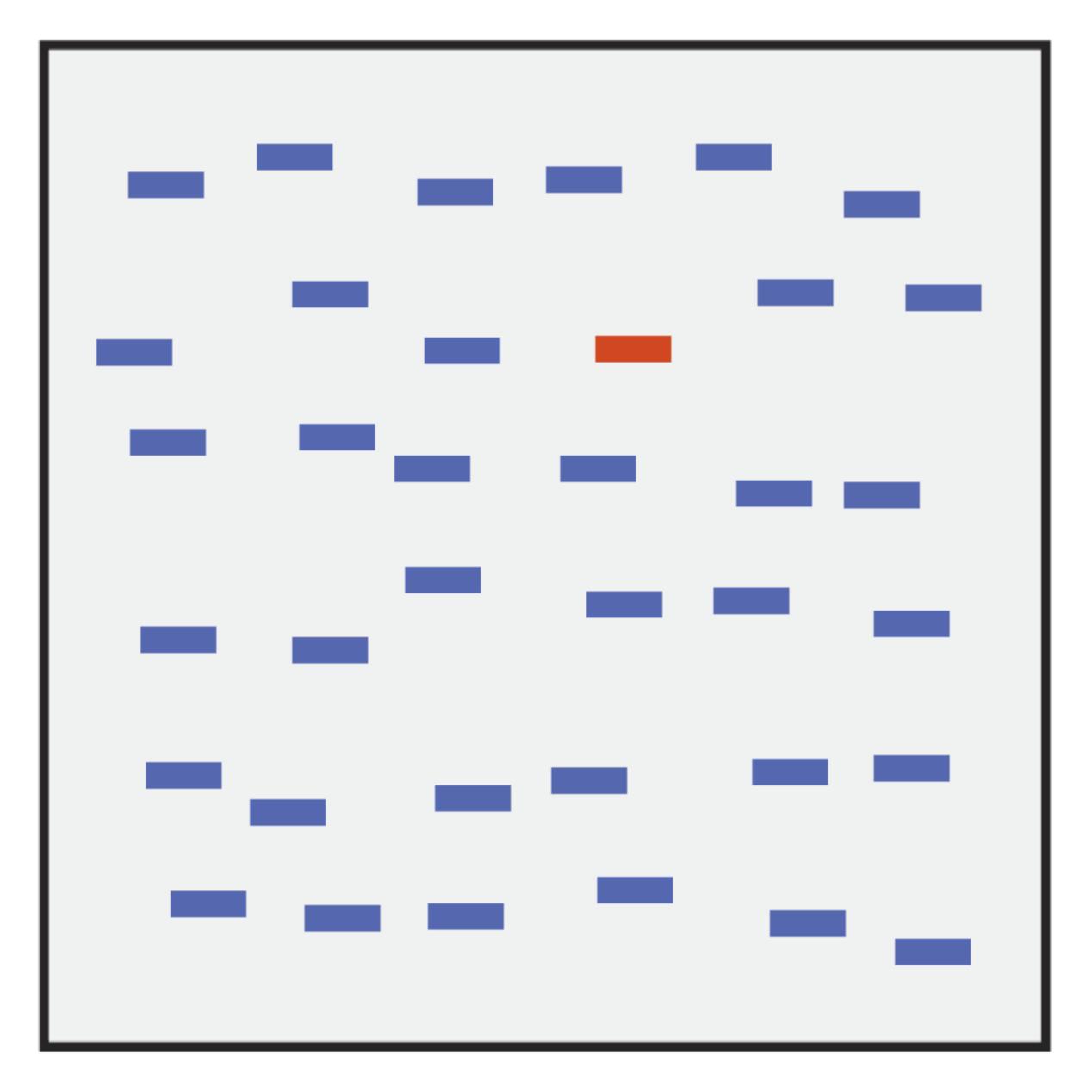




•		

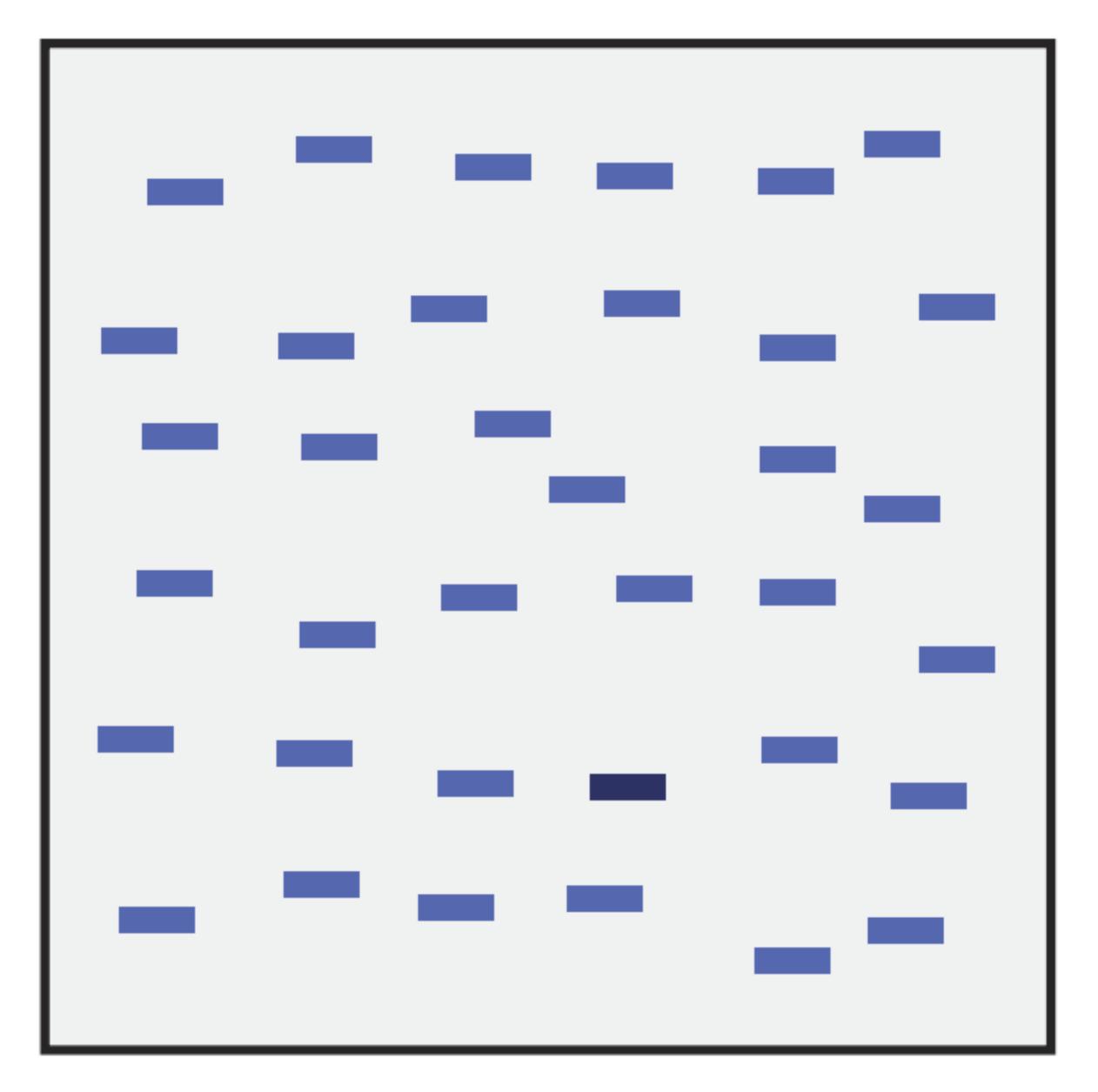
# density





# hue

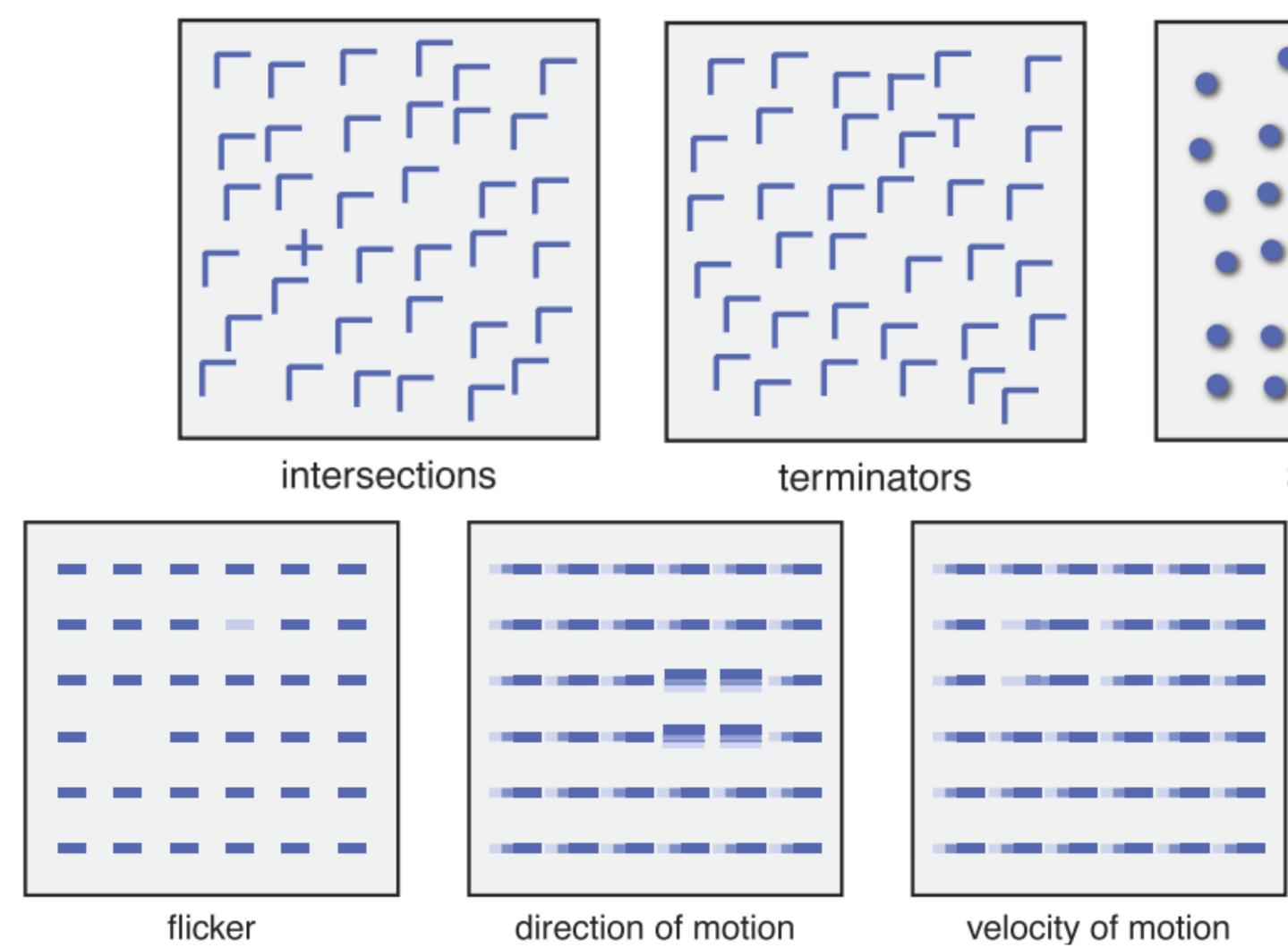


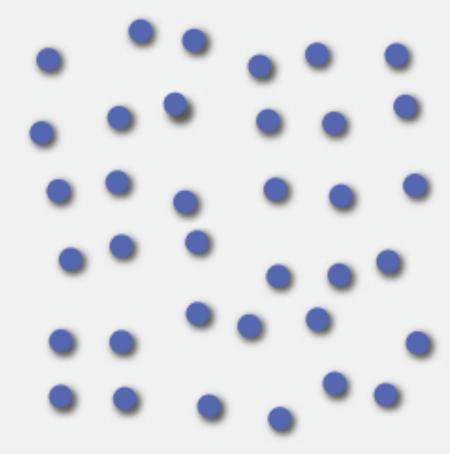


# luminance

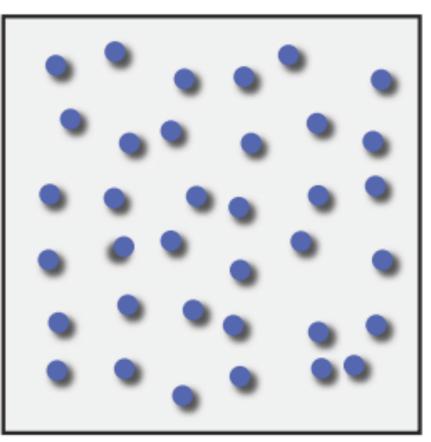


### **Preattentive Processing**





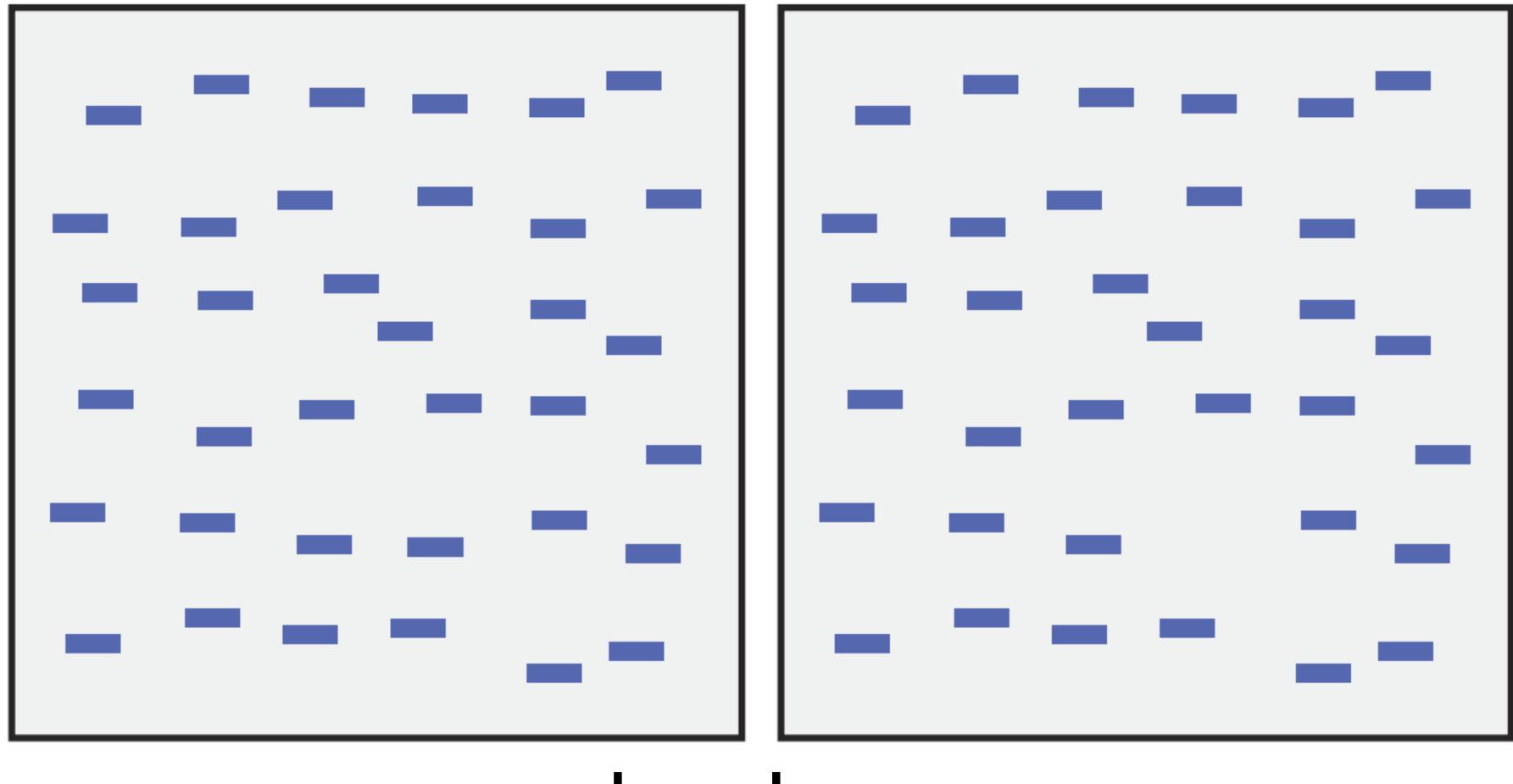
3D depth



lighting direction



### **Preattentive Processing**



Krekhov, Andrey, and Jens Krüger. "Deadeye: A Novel Preattentive Visualization Technique Based on Dichoptic Presentation." IEEE transactions on visualization and computer graphics (2018).

# deadeye



### **Pre-attentive Processing: Color**

### 878936408237640312876453298473298473209487329084538 9274-0329874-32874-231984750983409834098324098320498 23-0984903281453209481-0839393947896587436598





### **Pre-attentive Processing: Color**

### 878936408237640312876453298473298473209487329084538 9274-0329874-32874-231984750983409834098324098320498 23-0984903281453209481-0839393947896587436598





### **Gestalt Psychology**

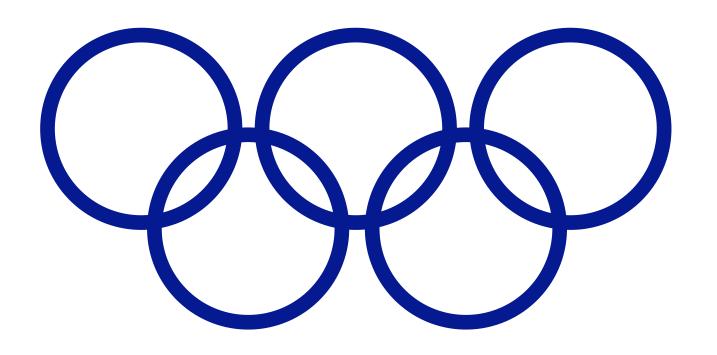
### > The Gestalt Laws

- 1. Simplicity
- 2. Closure
- 3. Similarity
- 4. Proximity
- 5. Continuity



### 1. Law of Simplicity

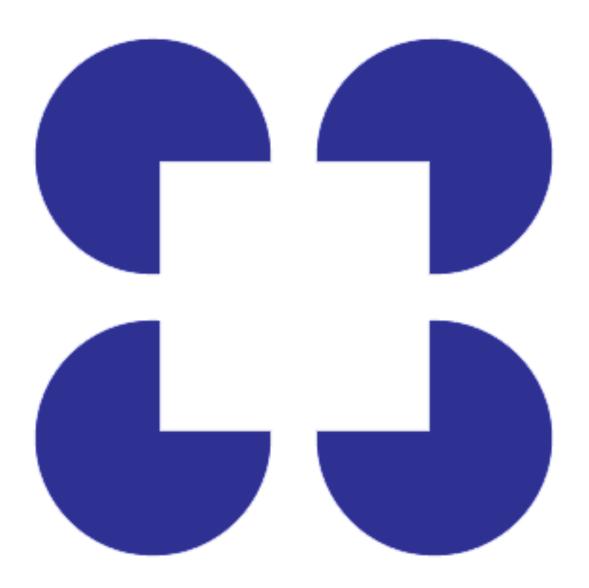
> Reality is organized and reduced to the simplest form possible





### 1. Law of Closure

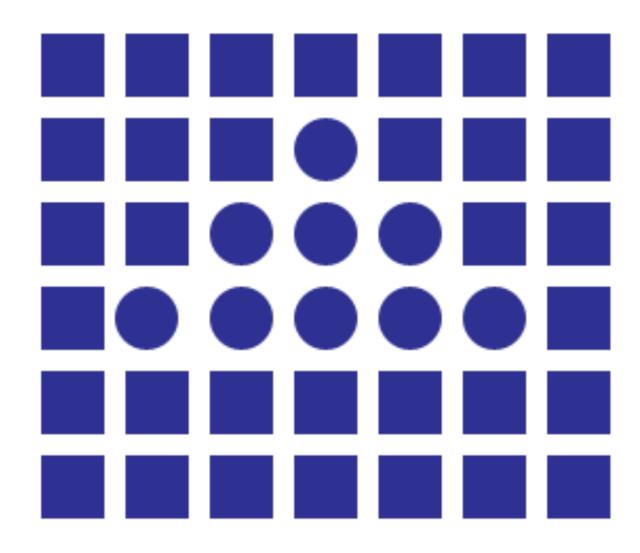
> The mind completes missing parts so it can see a simple image





### 2. Law of Similarity

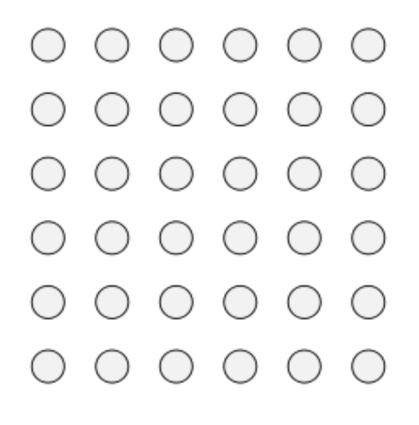
> The mind groups similar elements together

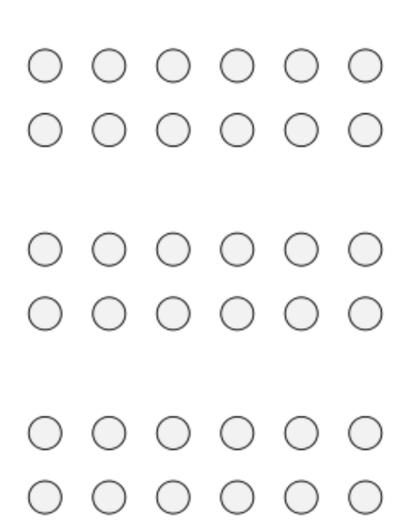




### 3. Law of Proximity

> Spatial (or temporal) proximity induces the mind to see a totality

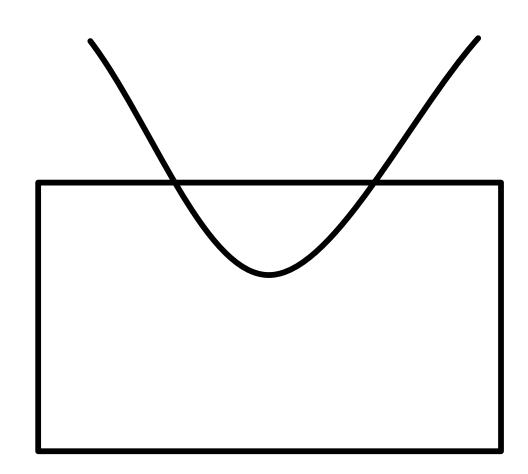






### 4. Law of Continuity

> Lines follow the smoothest and simplest path.





# Roadmap

> Motivation >Visual Perception >Information Visualization Software Visualization



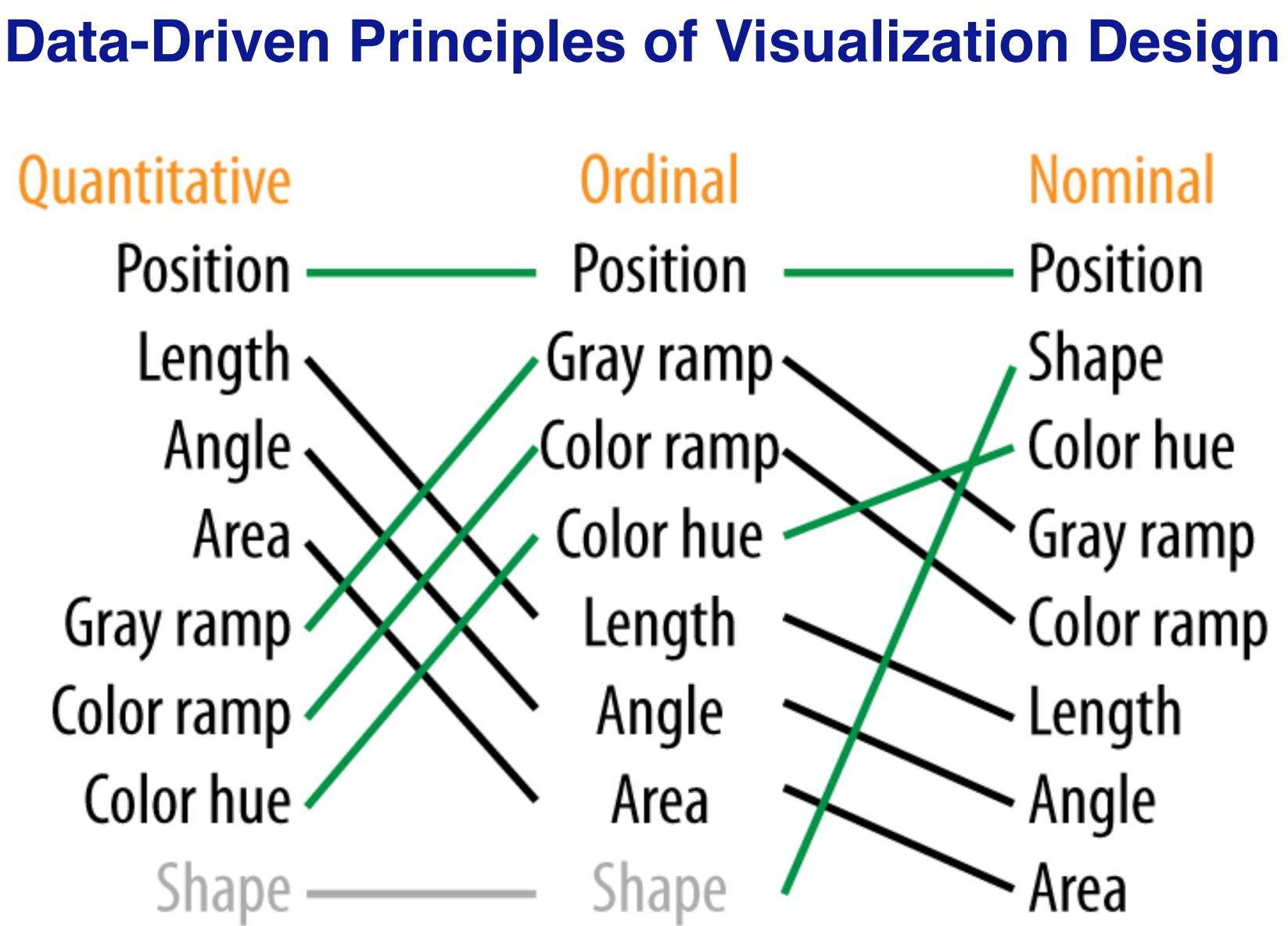


"The use of computer-supported inter data to amplify cognition."

### "The use of computer-supported interactive, visual representations of abstract

[Card et al., 1999]



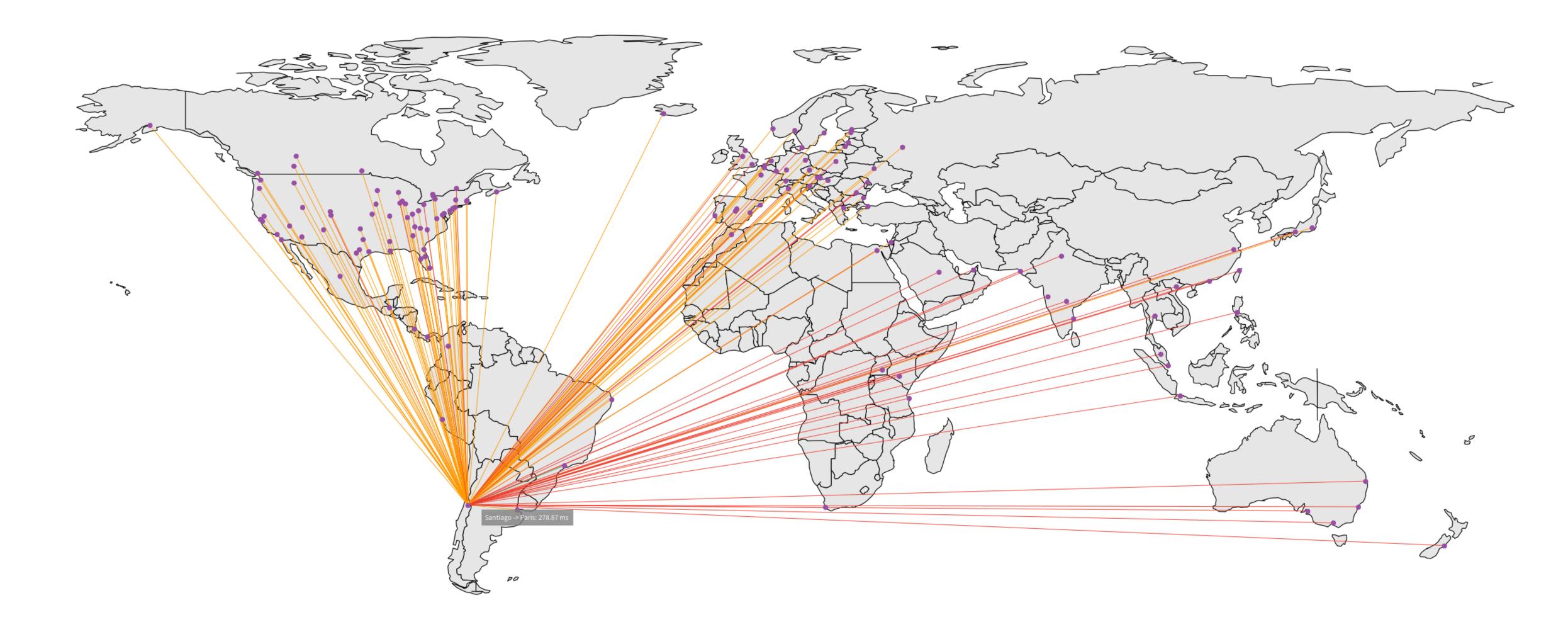


# Nominal Position Shape Color hue Gray ramp Color ramp Length Angle Area

[Mackinlay, 1986]

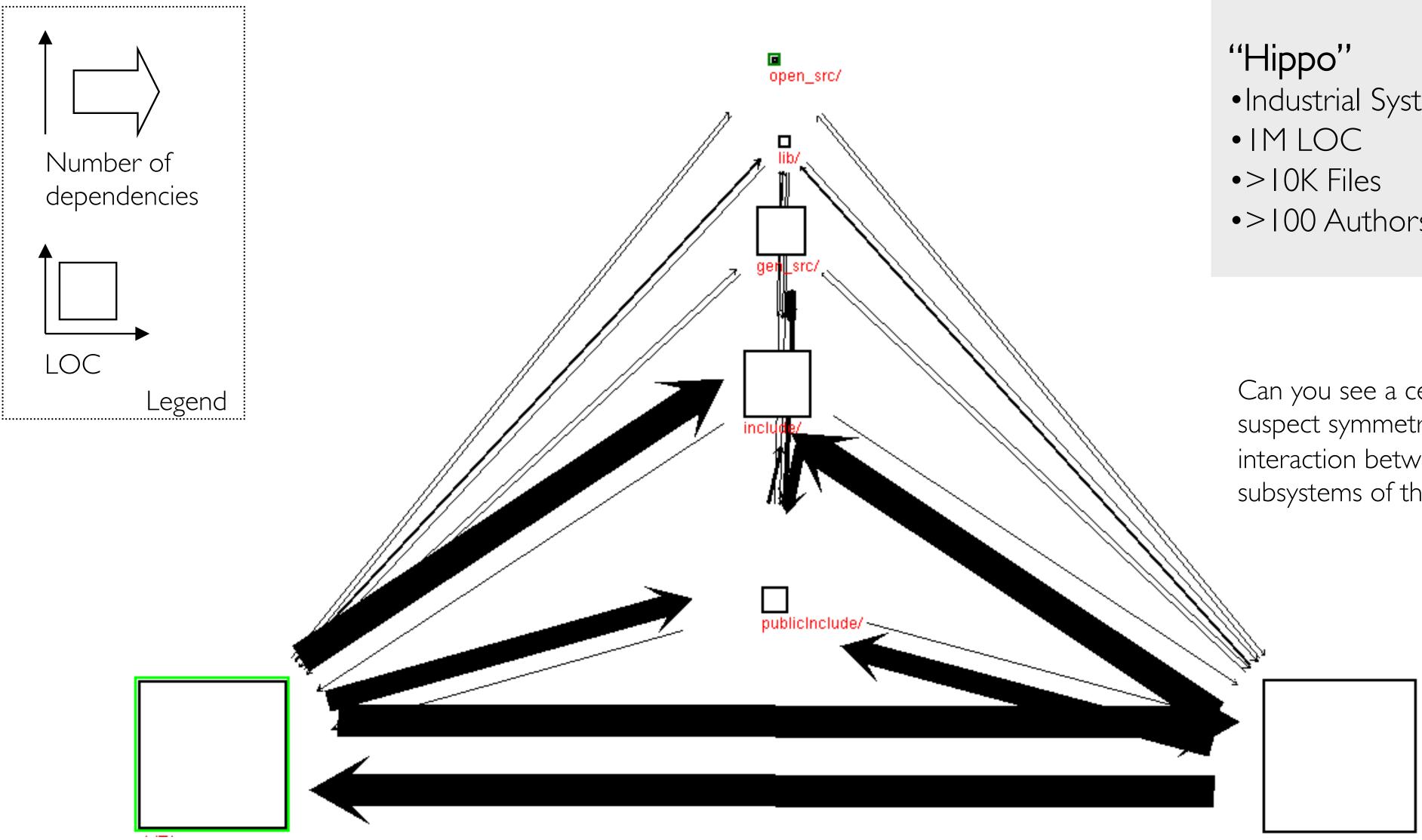


### **Uncovers emergent properties and outliers**





### **Exposes problems with the dataset**

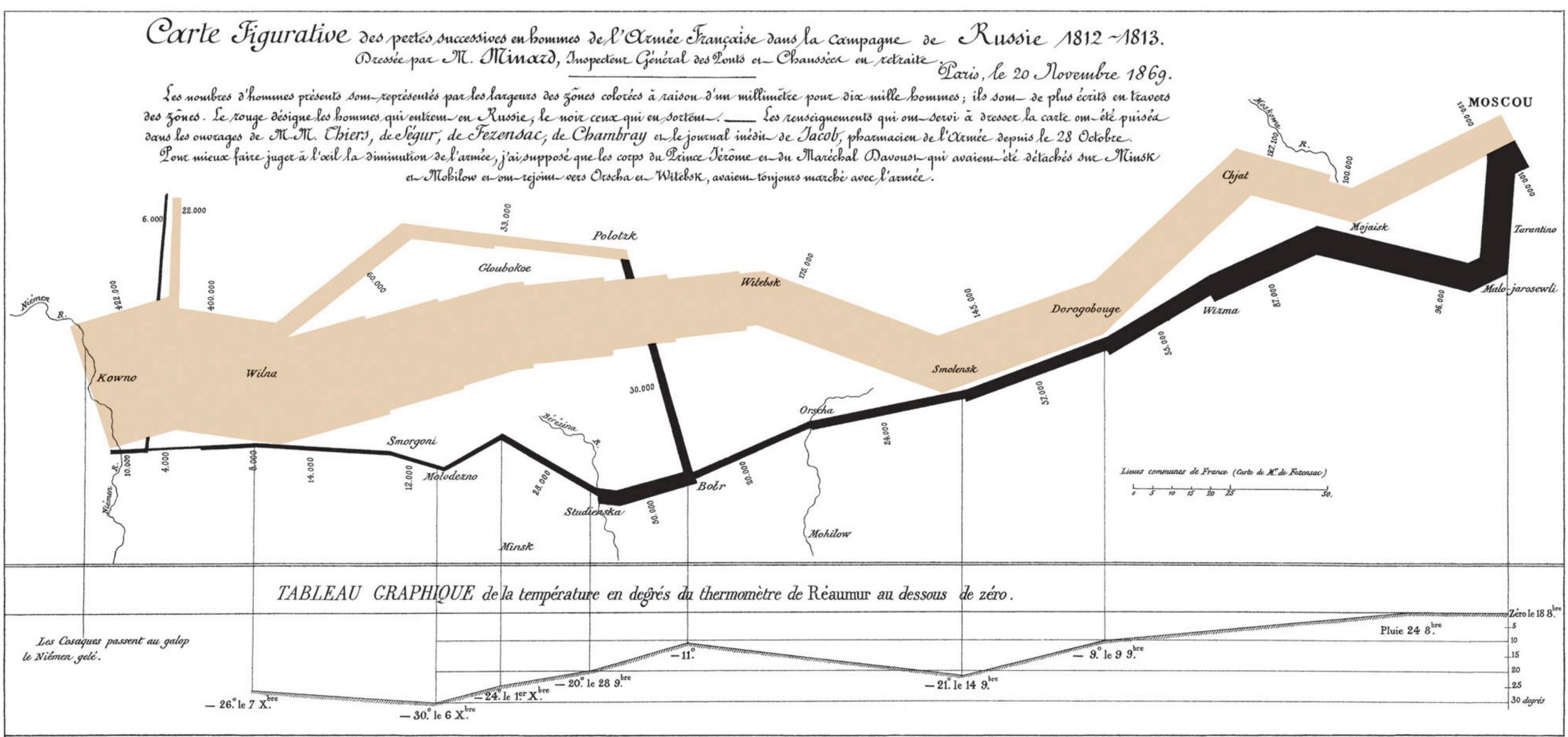


- Industrial System
- •>100 Authors

Can you see a certain suspect symmetry in the interaction between the subsystems of this project?



### **Enhances communication**



Autog. par Regnier, 8. Pas. Ste Marie St Gain à Paris.

Imp. Lith. Regnier et Dourdet .



### **Uses of Information Visualization**

### > Supports analysis

- Uncovers emergent properties and outliers
- Exposes problems with the data set
- > Enhances communication





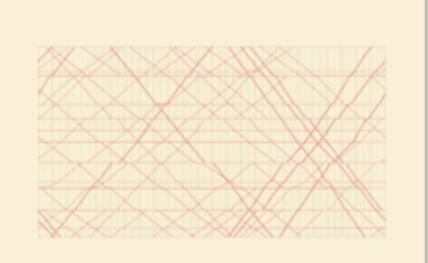
# Roadmap

> Motivation >Visual Perception >Information Visualization -Guidelines Software Visualization





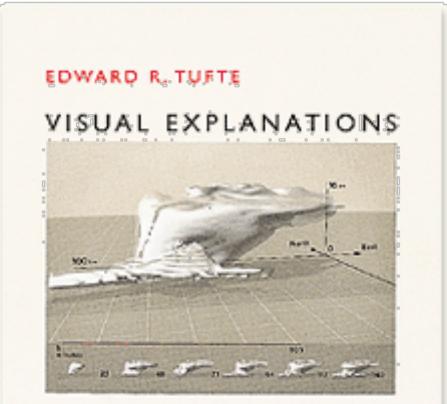
# Guidelines of valuable information visualization can consider style, integrity, and design



### SECOND EDITION

The Visual Display of Quantitative Information

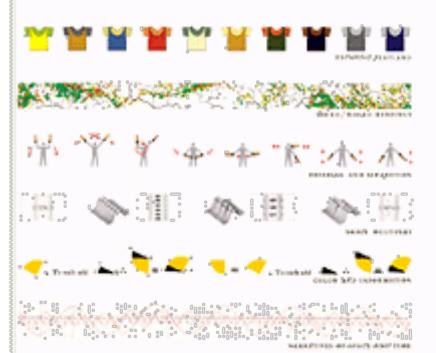
EDWARD R. TUFTE



IMAGES AND QUANTITIES. EVIDENCE AND NARRATIVE

Edward R. Tigle

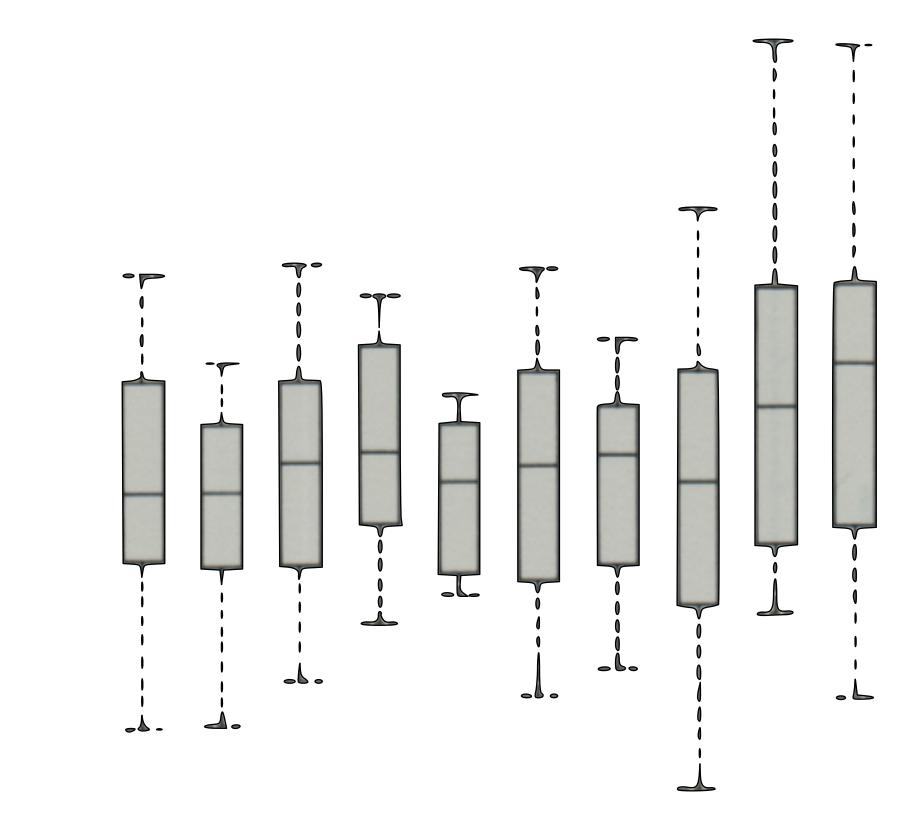
Envisioning Information



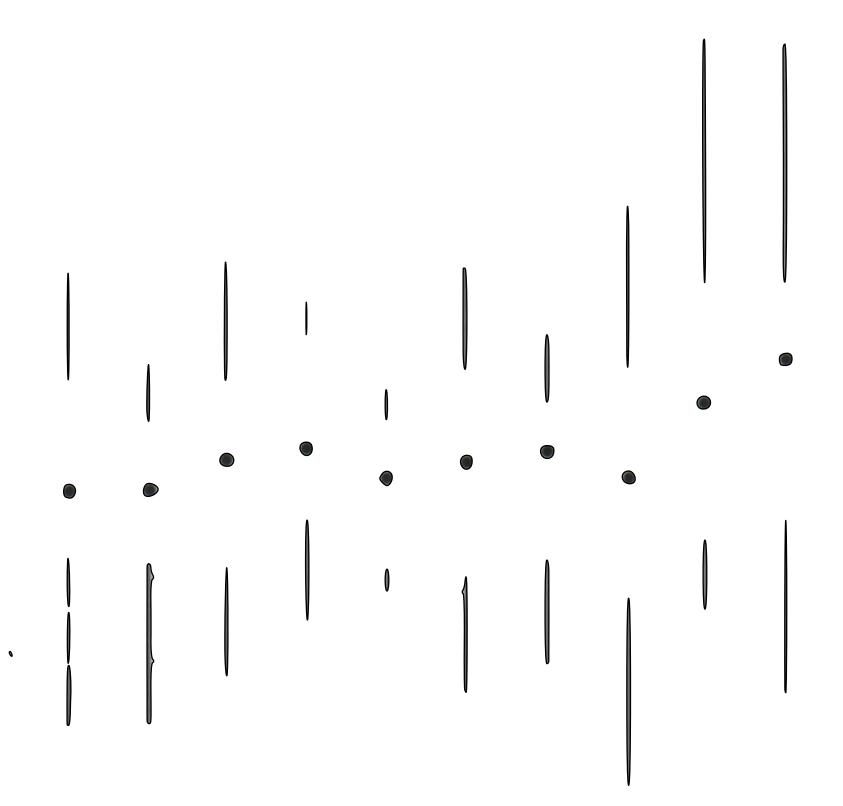
A DEPARTMENT OF DEPARTMENT



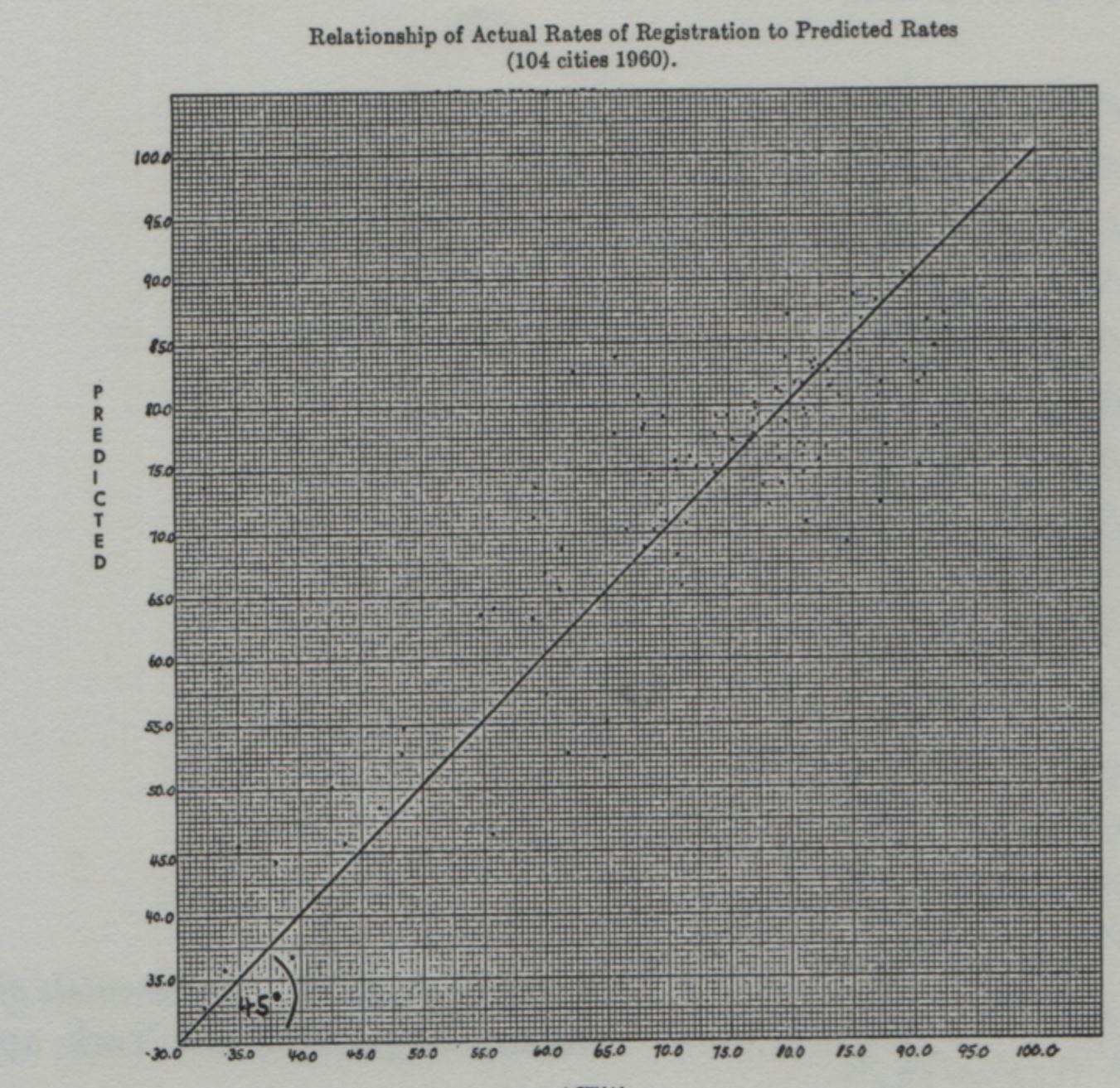
### **Style: Minimize Non-Data Ink**

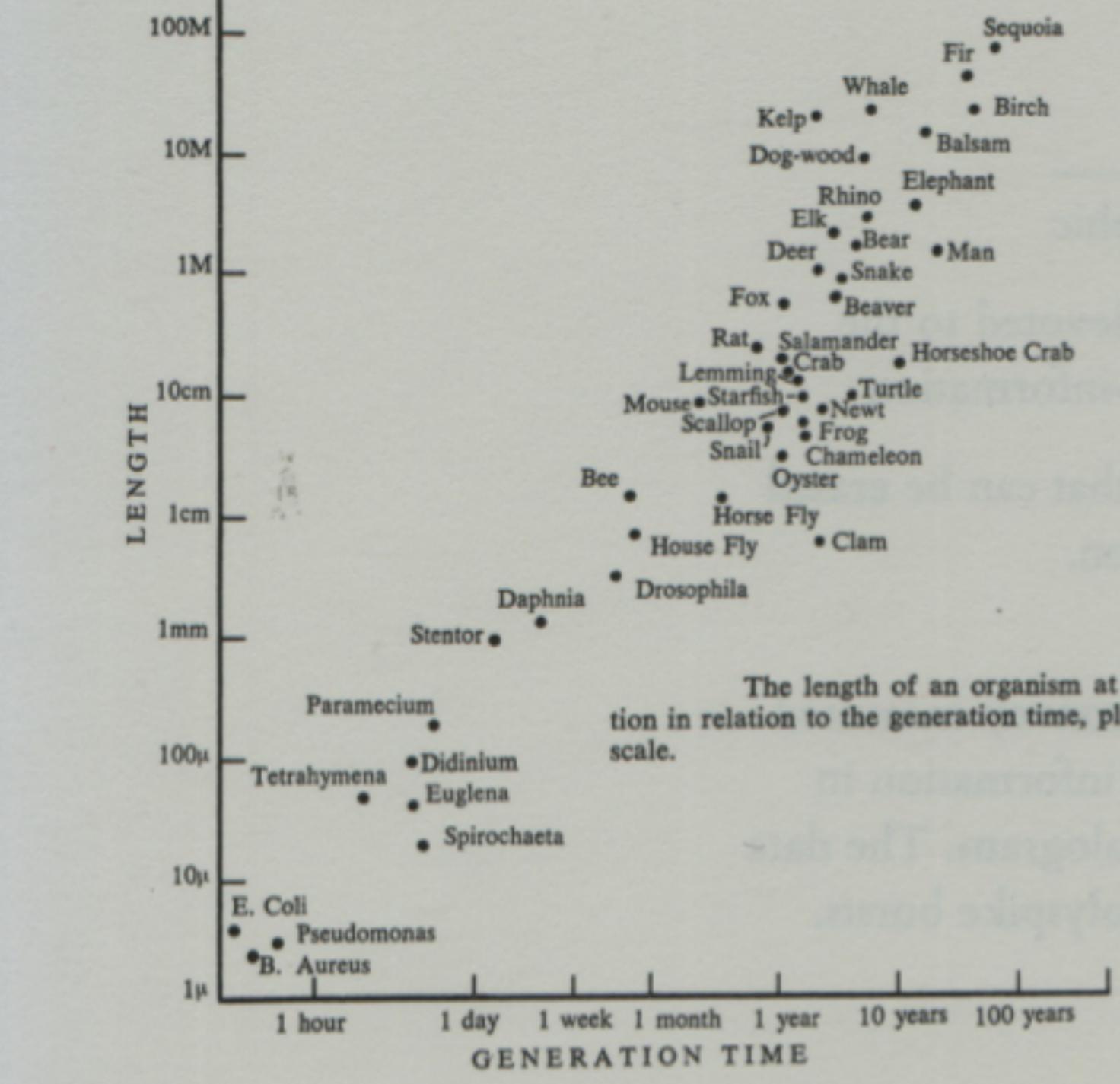


Removing ink from your graph should remove meaning from it.







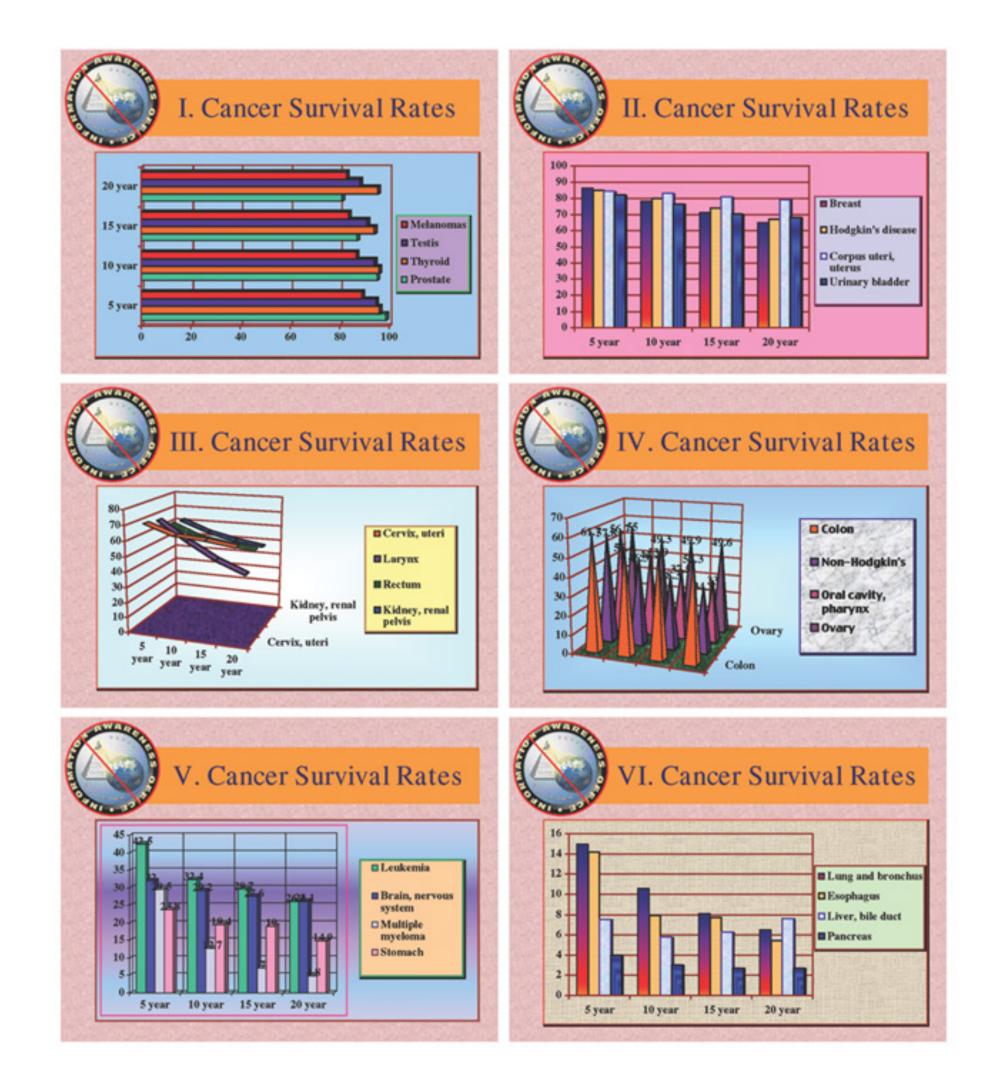


The length of an organism at the time of reproduction in relation to the generation time, plotted on a logarithmic

### **Design: Choose the appropriate representation**

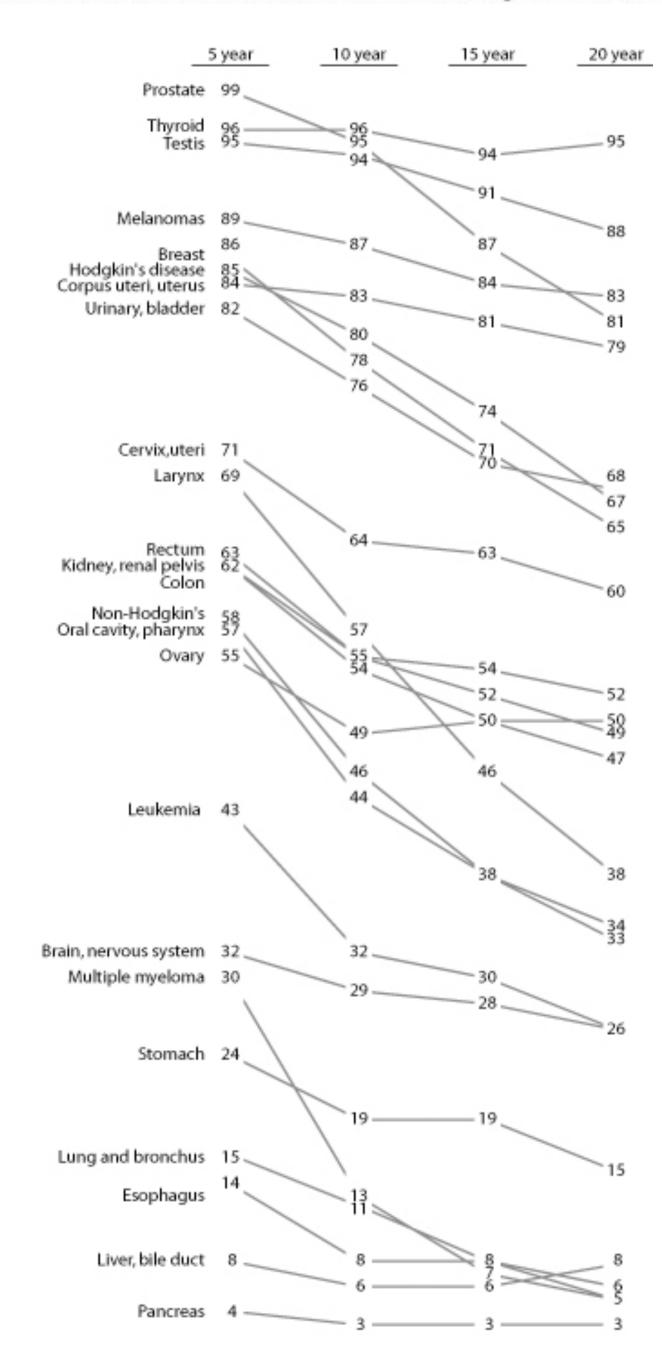
### Estimates of relative survival rates, by cancer site

	% s	urvi	val rat	tes a	nd sta	ndar	d erro	rs
	5 yea	r	10 ye	ar	15 ye	ar	20 ye	ar
Prostate	98.8	0.4	95.2	0.9	87.1	1.7	81.1	3.0
Thyroid	96.0	0.8	95.8	1.2	94.0	1.6	95.4	2.1
Testis	94.7	1.1	94.0	1.3	91.1	1.8	88.2	2.3
Melanomas	89.0	0.8	86.7	1.1	83.5	1.5	82.8	1.9
Breast	86.4	0.4	78.3	0.6	71.3	0.7	65.0	1.0
Hodgkin's disease	85.1	1.7	79.8	2.0	73.8	2.4	67.1	2.8
Corpus uteri, uterus	84.3	1.0	83.2	1.3	80.8	1.7	79.2	2.0
Urinary, bladder	82.1	1.0	76.2	1.4	70.3	1.9	67.9	2.4
Cervix, uteri	70.5	1.6	64.1	1.8	62.8	2.1	60.0	2.4
Larynx	68.8	2.1	56.7	2.5	45.8	2.8	37.8	3.1
Rectum	62.6	1.2	55.2	1.4	51.8	1.8	49.2	2.3
Kidney, renal pelvis	61.8	1.3	54.4	1.6	49.8	2.0	47.3	2.6
Colon	61.7	0.8	55.4	1.0	53.9	1.2	52.3	1.6
Non-Hodgkin's	57.8	1.0	46.3	1.2	38.3	1.4	34.3	1.7
Oral cavity, pharynx	56.7	1.3	44.2	1.4	37.5	1.6	33.0	1.8
Ovary	55.0	1.3	49.3	1.6	49.9	1.9	49.6	2.4
Leukemia	42.5	1.2	32.4	1.3	29.7	1.5	26.2	1.7
Brain, nervous system	32.0	1.4	29.2	1.5	27.6	1.6	26.1	1.9
Multiple myeloma	29.5	1.6	12.7	1.5	7.0	1.3	4.8	1.5
Stomach	23.8	1.3	19.4	1.4	19.0	1.7	14.9	1.9
Lung and bronchus	15.0	0.4	10.6	0.4	8.1	0.4	6.5	0.4
Esophagus	14.2	1.4	7.9	1.3	7.7	1.6	5.4	2.0
Liver, bile duct	7.5	1.1	5.8	1.2	6.3	1.5	7.6	2.0
Pancreas	4.0	0.5	3.0	1.5	2.7	0.6	2.7	0.8





### Estimates of relative survival rates, by cancer site



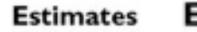
### Estimates of relative survival rates, by cancer site

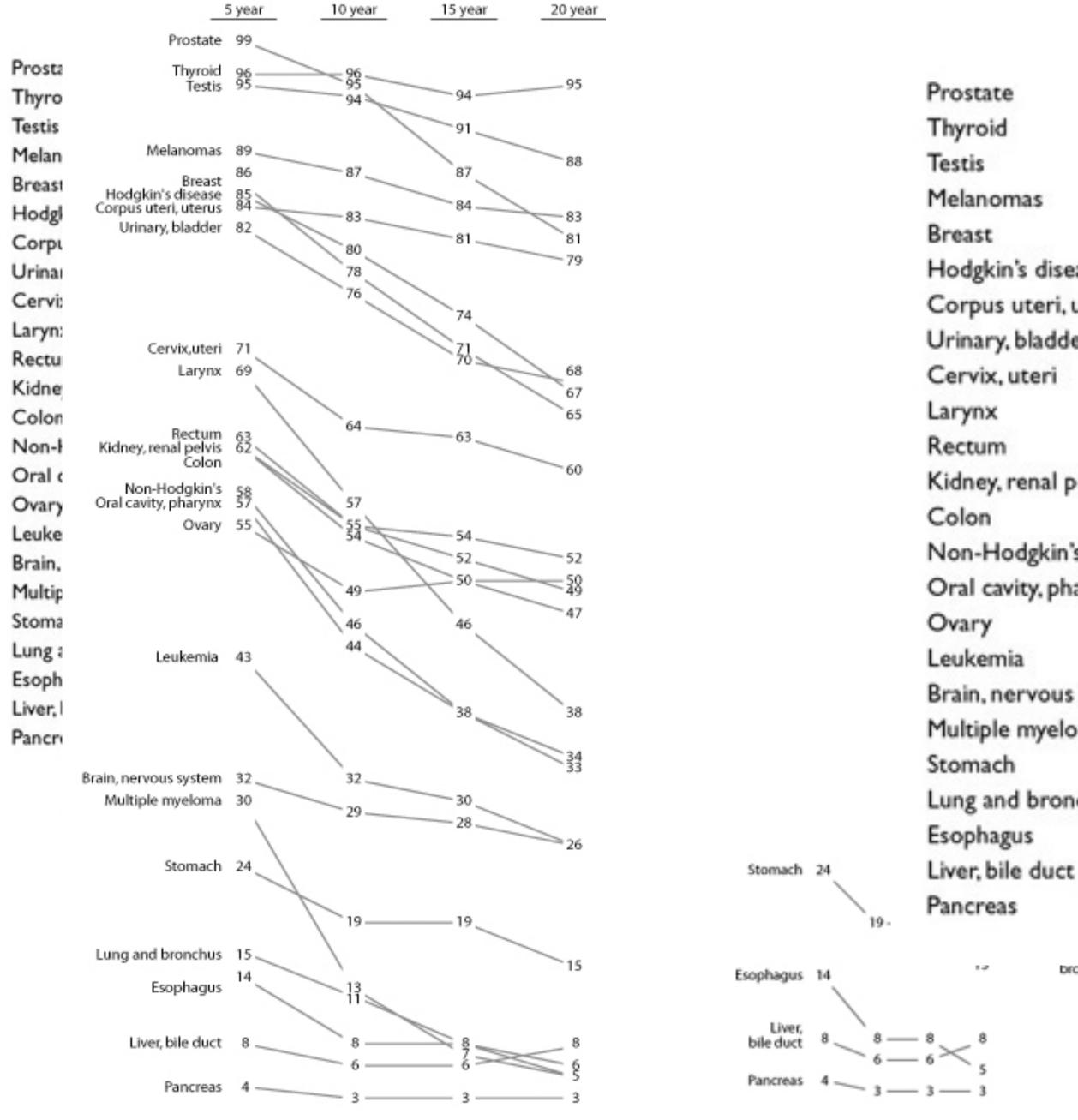
% survival rates and	standard	errors
----------------------	----------	--------

	5 year		10 year		15 year		20 year	
rostate	98.8	0.4	95.2	0.9	87.1	1.7	81.1	3.0
hyroid	96.0	0.8	95.8	1.2	94.0	1.6	95.4	2.1
estis	94.7	1.1	94.0	1.3	91.1	1.8	88.2	2.3
1elanomas	89.0	0.8	86.7	1.1	83.5	1.5	82.8	1.9
Breast	86.4	0.4	78.3	0.6	71.3	0.7	65.0	1.0
lodgkin's disease	85.1	1.7	79.8	2.0	73.8	2.4	67.1	2.8
Corpus uteri, uterus	84.3	1.0	83.2	1.3	80.8	1.7	79.2	2.0
Jrinary, bladder	82.1	1.0	76.2	1.4	70.3	1.9	67.9	2.4
Cervix, uteri	70.5	1.6	64.1	1.8	62.8	2.1	60.0	2.4
arynx	68.8	2.1	56.7	2.5	45.8	2.8	37.8	3.1
lectum	62.6	1.2	55.2	1.4	51.8	1.8	49.2	2.3
Cidney, renal pelvis	61.8	1.3	54.4	1.6	49.8	2.0	47.3	2.6
Colon	61.7	0.8	55.4	1.0	53.9	1.2	52.3	1.6
Non-Hodgkin's	57.8	1.0	46.3	1.2	38.3	1.4	34.3	1.7
Dral cavity, pharynx	56.7	1.3	44.2	1.4	37.5	1.6	33.0	1.8
Dvary	55.0	1.3	49.3	1.6	49.9	1.9	49.6	2.4
eukemia	42.5	1.2	32.4	1.3	29.7	1.5	26.2	1.7
Brain, nervous system	32.0	1.4	29.2	1.5	27.6	1.6	26.1	1.9
1ultiple myeloma	29.5	1.6	12.7	1.5	7.0	1.3	4.8	1.5
tomach	23.8	1.3	19.4	1.4	19.0	1.7	14.9	1.9
ung and bronchus	15.0	0.4	10.6	0.4	8.1	0.4	6.5	0.4
sophagus	14.2	1.4	7.9	1.3	7.7	1.6	5.4	2.0
iver, bile duct	7.5	1.1	5.8	1.2	6.3	1.5	7.6	2.0
ancreas	4.0	0.5	3.0	1.5	2.7	0.6	2.7	0.8



### Estimates of relative survival rates, by cancer site





### Estimates of relative survival rates, by cancer site

	% s	urvi	val rat	tes a	nd sta	ndar	d erro	rs
	5 yea	r	10 ye	ar	15 ye	ar	20 ye	ar
tate	98.8	0.4	95.2	0.9	87.1	1.7	81.1	3.0
bio	96.0	0.8	95.8	1.2	94.0	1.6	95.4	2.1
s	94.7	1.1	94.0	1.3	91.1	1.8	88.2	2.3
nomas	89.0	0.8	86.7	1.1	83.5	1.5	82.8	1.9
st	86.4	0.4	78.3	0.6	71.3	0.7	65.0	1.0
gkin's disease	85.1	1.7	79.8	2.0	73.8	2.4	67.1	2.8
ous uteri, uterus	84.3	1.0	83.2	1.3	80.8	1.7	79.2	2.0
ary, bladder	82.1	1.0	76.2	1.4	70.3	1.9	67.9	2.4
ix, uteri	70.5	1.6	64.1	1.8	62.8	2.1	60.0	2.4
x	68.8	2.1	56.7	2.5	45.8	2.8	37.8	3.1
um	62.6	1.2	55.2	1.4	51.8	1.8	49.2	2.3
ey, renal pelvis	61.8	1.3	54.4	1.6	49.8	2.0	47.3	2.6
n	61.7	0.8	55.4	1.0	53.9	1.2	52.3	1.6
Hodgkin's	57.8	1.0	46.3	1.2	38.3	1.4	34.3	1.7
cavity, pharynx	56.7	1.3	44.2	1.4	37.5	1.6	33.0	1.8
У	55.0	1.3	49.3	1.6	49.9	1.9	49.6	2.4
emia	42.5	1.2	32.4	1.3	29.7	1.5	26.2	1.7
, nervous system	32.0	1.4	29.2	1.5	27.6	1.6	26.1	1.9
ple myeloma	29.5	1.6	12.7	1.5	7.0	1.3	4.8	1.5
ach	23.8	1.3	19.4	1.4	19.0	1.7	14.9	1.9
and bronchus	15.0	0.4	10.6	0.4	8.1	0.4	6.5	0.4
hagus	14.2	1.4	7.9	1.3	7.7	1.6	5.4	2.0

Pancreas

1.2

bronchus

7.5 1.1

4.0 0.5

5.8 1.2

3.0 1.5

6.3 1.5

2.7 0.6

7.6 2.0

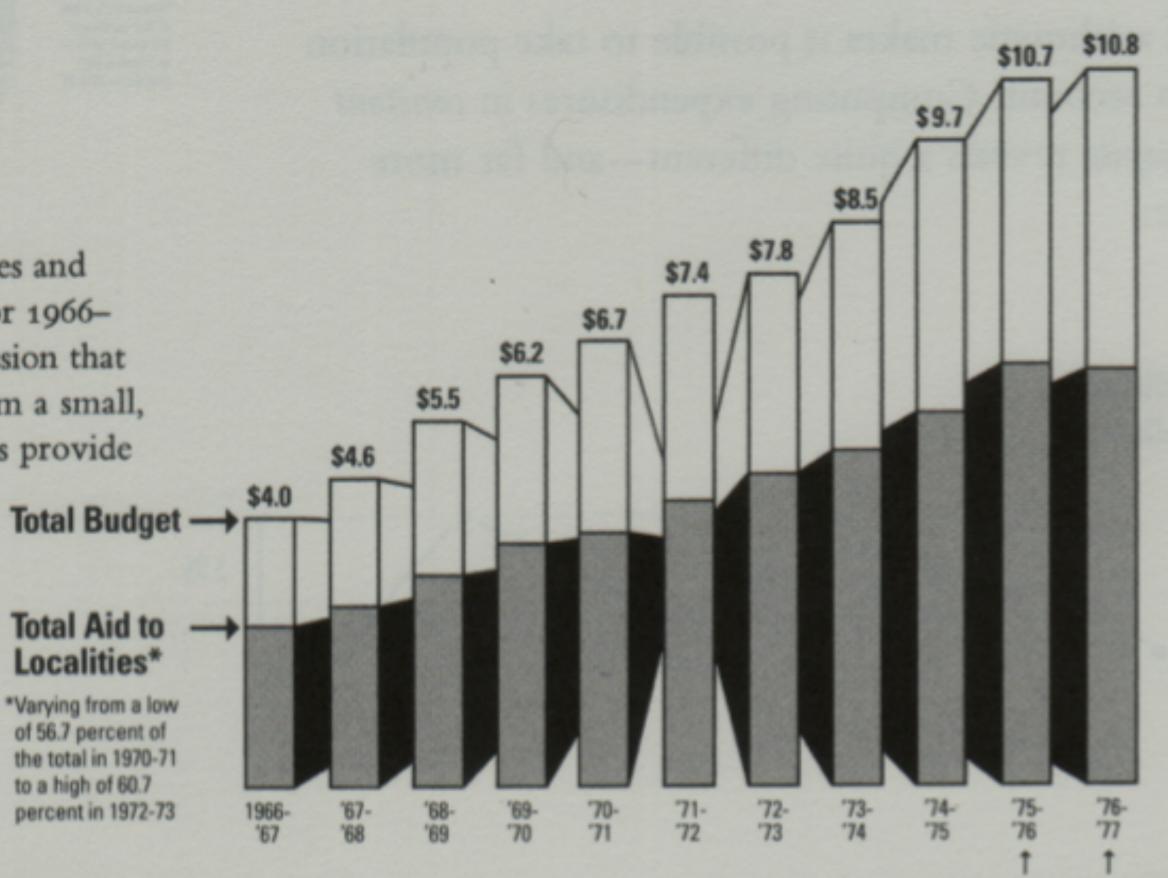
2.7 0.8

13



### **Integrity: Present only the data**

This cluster of type emphasizes and stretches out the low value for 1966-1967, encouraging the impression that recent years have shot up from a small, stable base. Horizontal arrows provide similar emphasis.



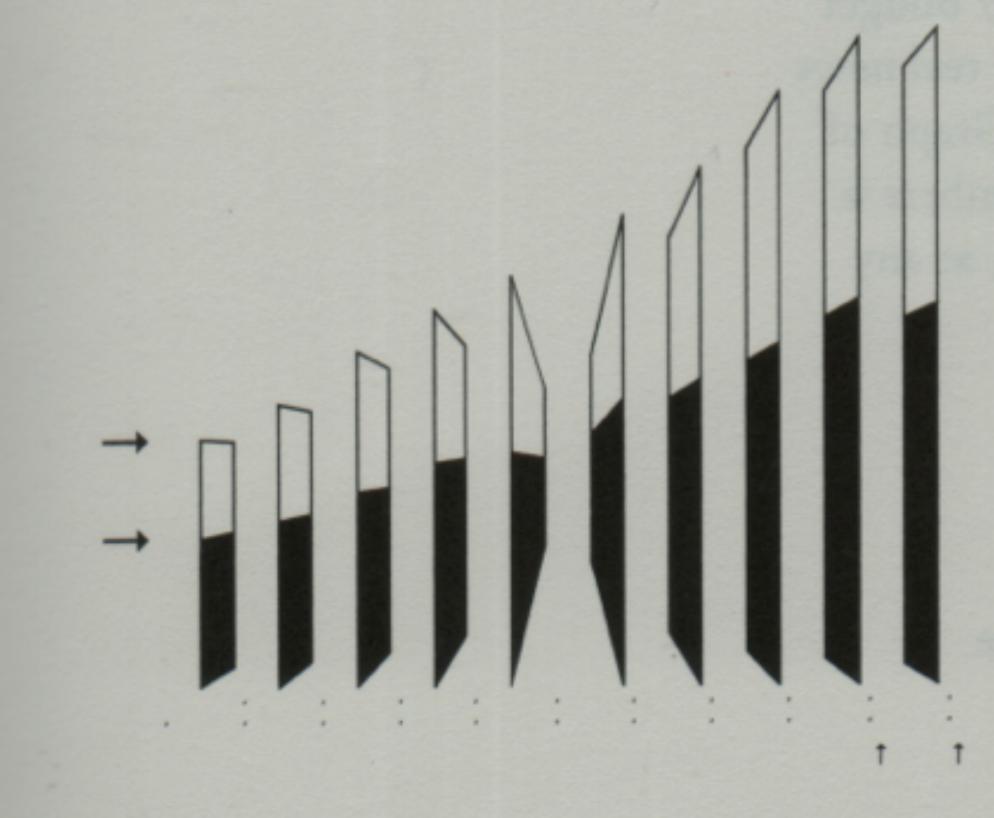
This squeezed-down block of type contributes to an image of small, squeezed-down budgets back in the good old days.

Estimated Recommended Arrows pointing straight up emphasize recent growth. Compare with horizontal arrows at left.



### Improvement 1: Eliminate Chart Junk

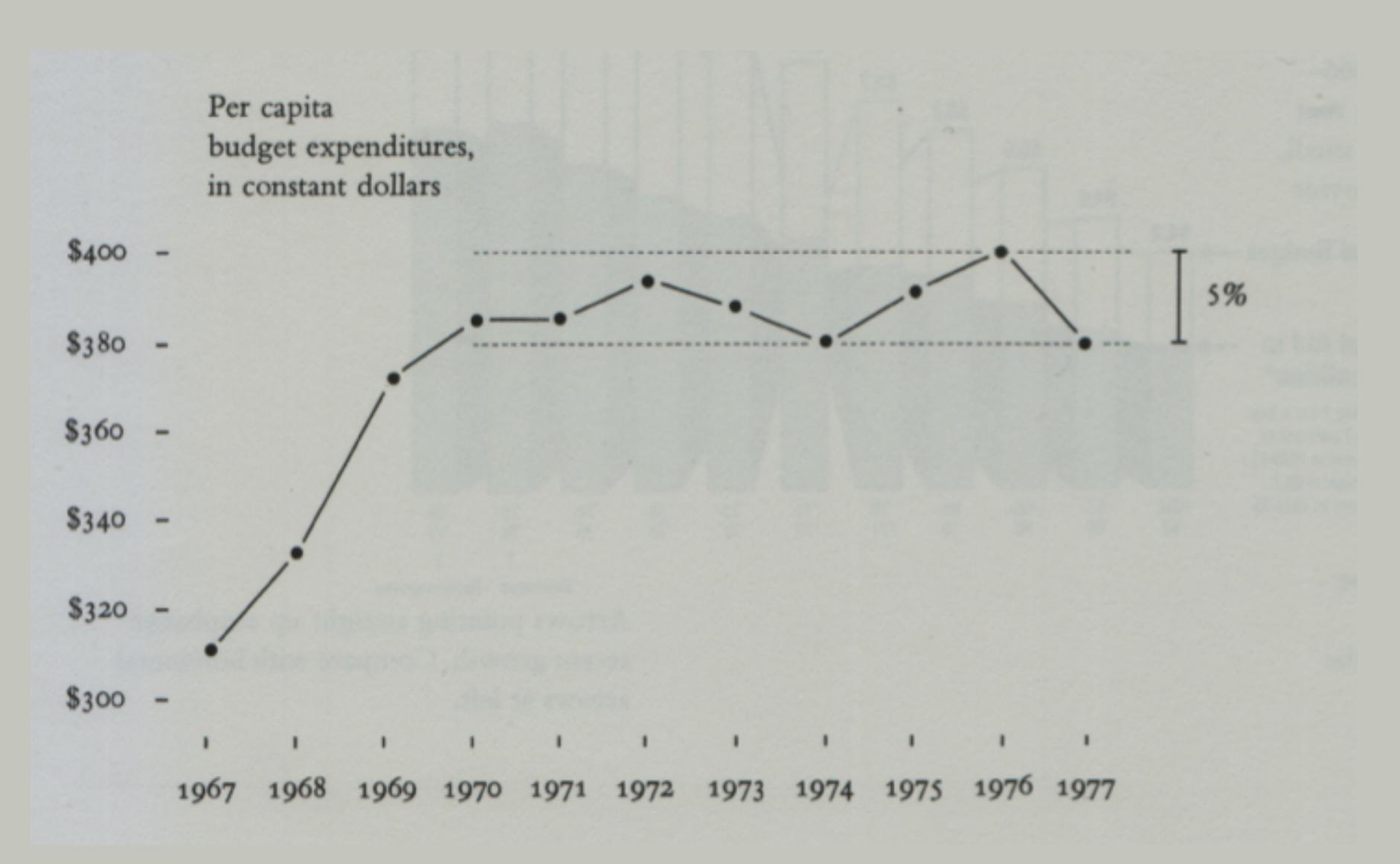
Leaving behind the distortion in the chartjunk heap at the left yields a calmer view:







## Improvement 2: Adjust the underlying information...





# Roadmap

Motivation
Visual Perception
Information Visualization
Software Visualization





"SV is the use of interactive computer graphics to enhance the interface between users and their programs."

[Price, 1992]



# Roadmap

> Motivation >Visual Perception >Information Visualization >Software Visualization -Structure -Evolution -Behavior



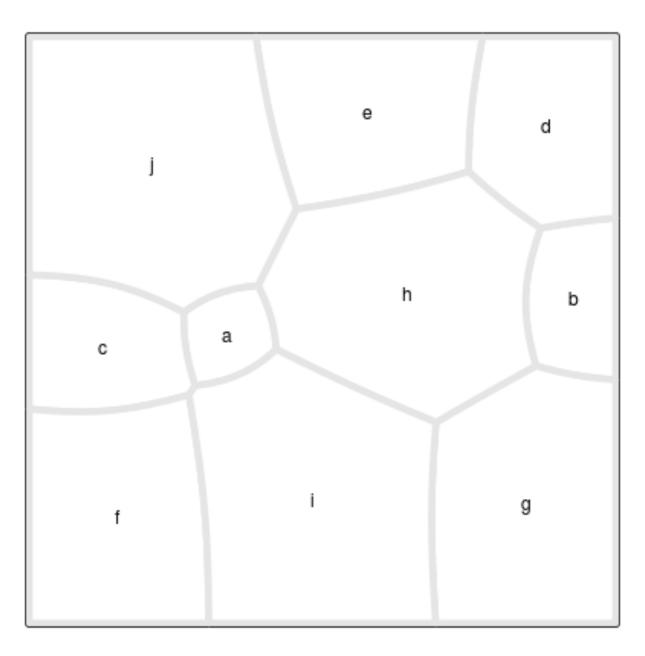




### **Space Filling Techniques**

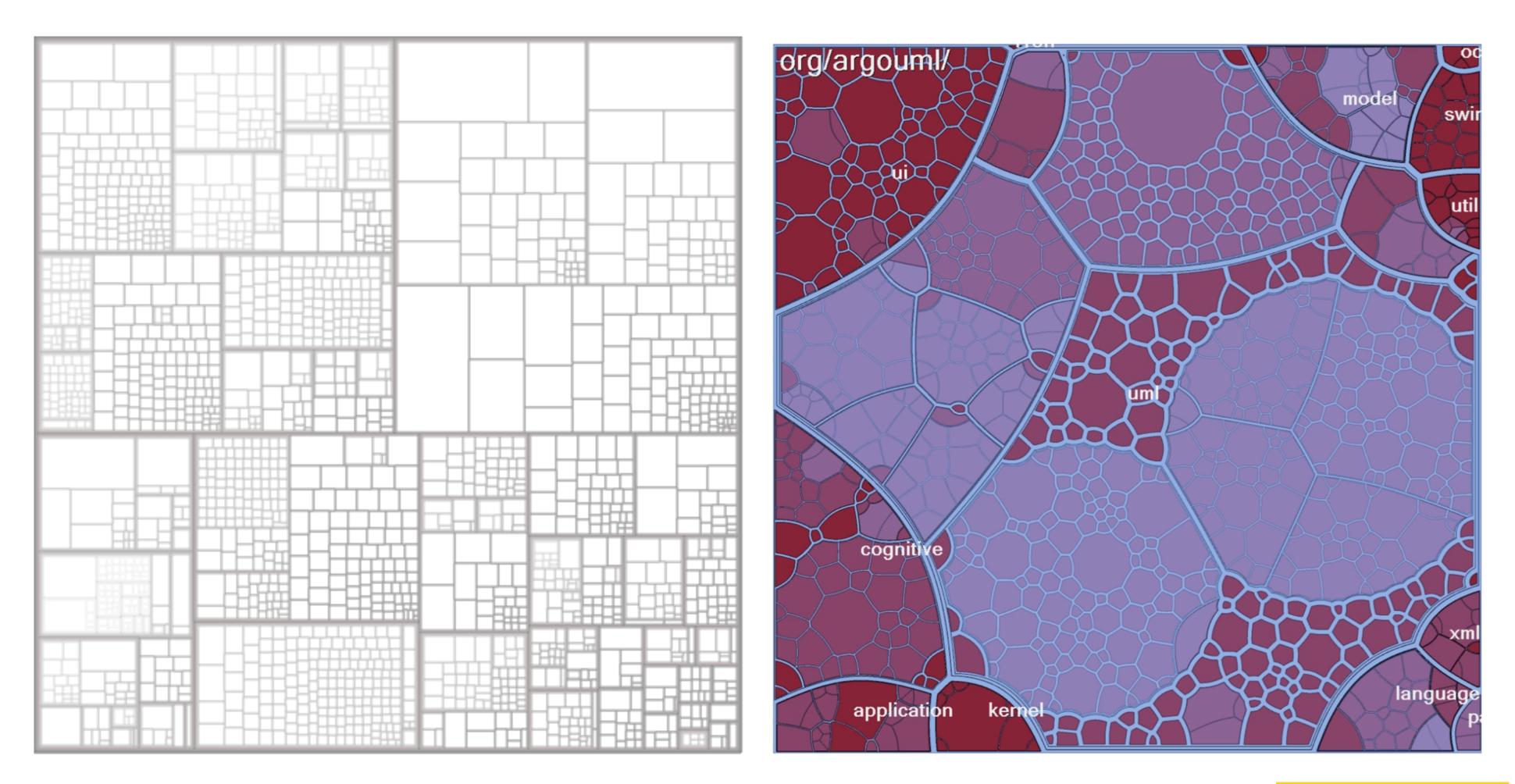
- > Use of pre-attentive processing features of
  - Locality
  - -Size
- > Techniques
  - Treemaps
  - Voronoi diagrams

Texas		Oregon		
	Nevada		Colorado	
	New Mex	ico	Arizona	
Alaska	California		Montana	





## Providing an overview of size distribution

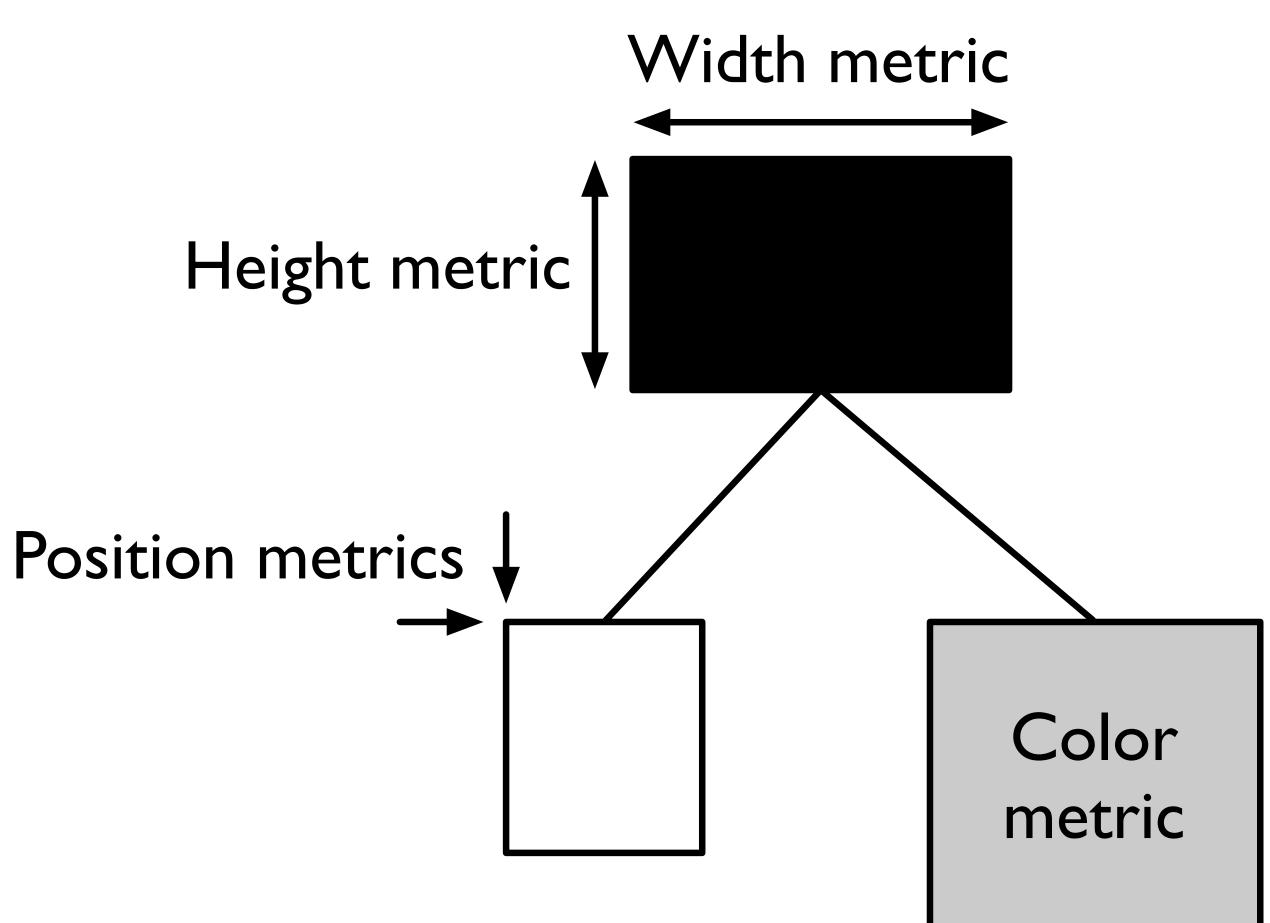


### ArgoUML

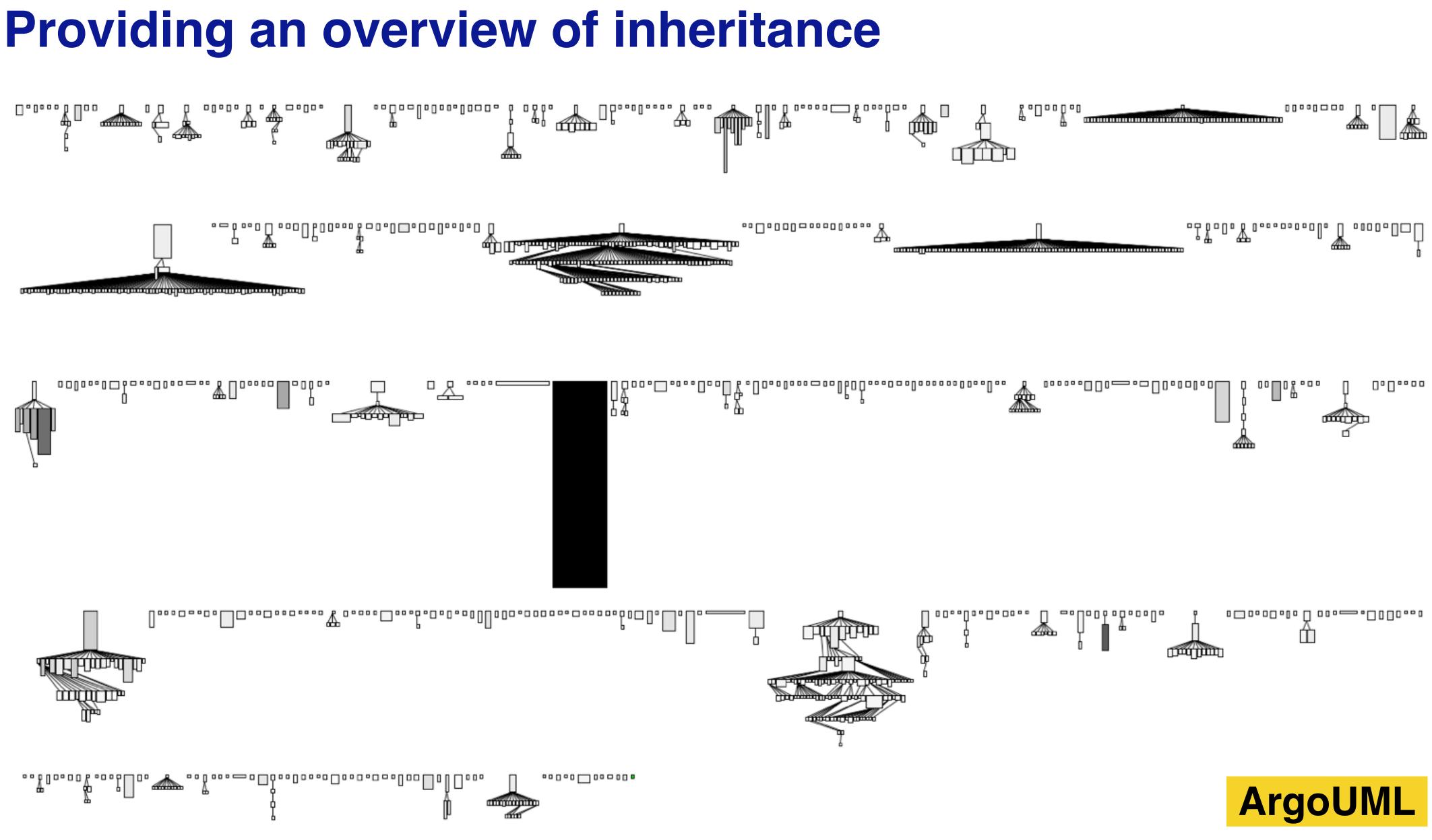


### **Polymetric Views**

- > Use of pre-attentive processing features
  - -Size
  - -Color
  - Connectedness
- > Available tools
  - Roassal, Mondrian, XRay





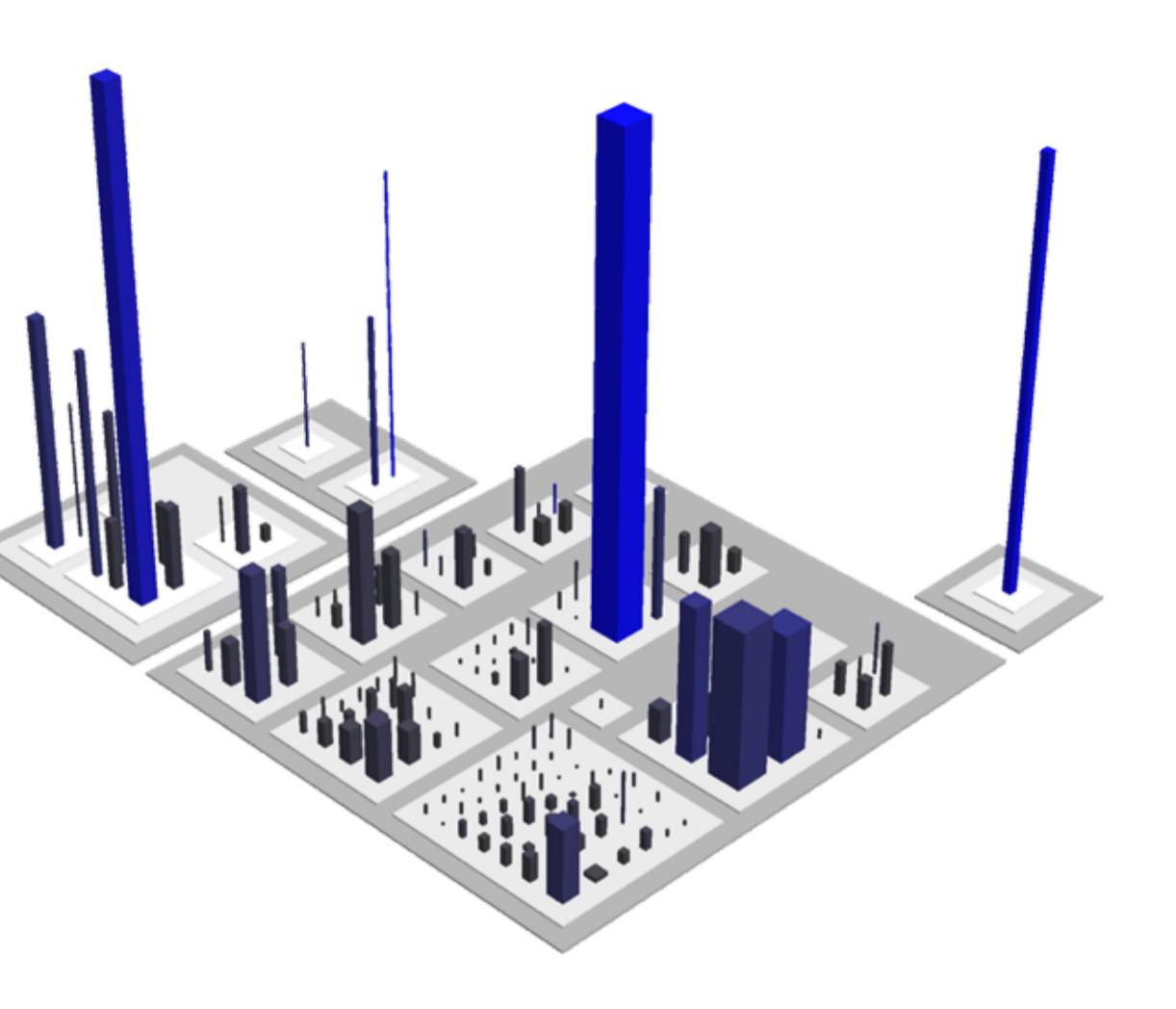






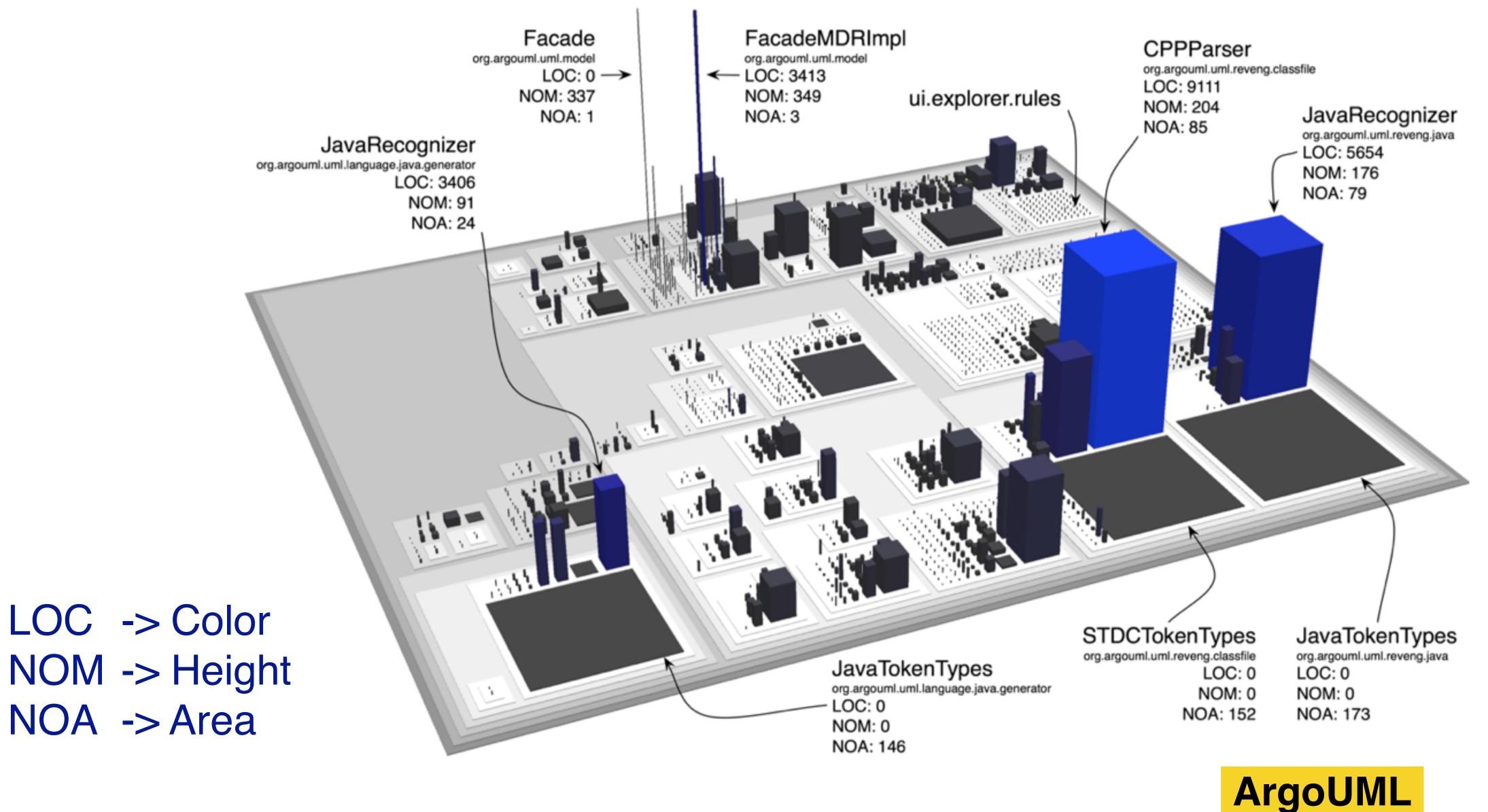
### **Metaphor: City**

 > Use of pre-attentive processing features of -- Size
 - Color
 - 3D spatial locality
 > Available tools
 - CodeCity
 - CityVR

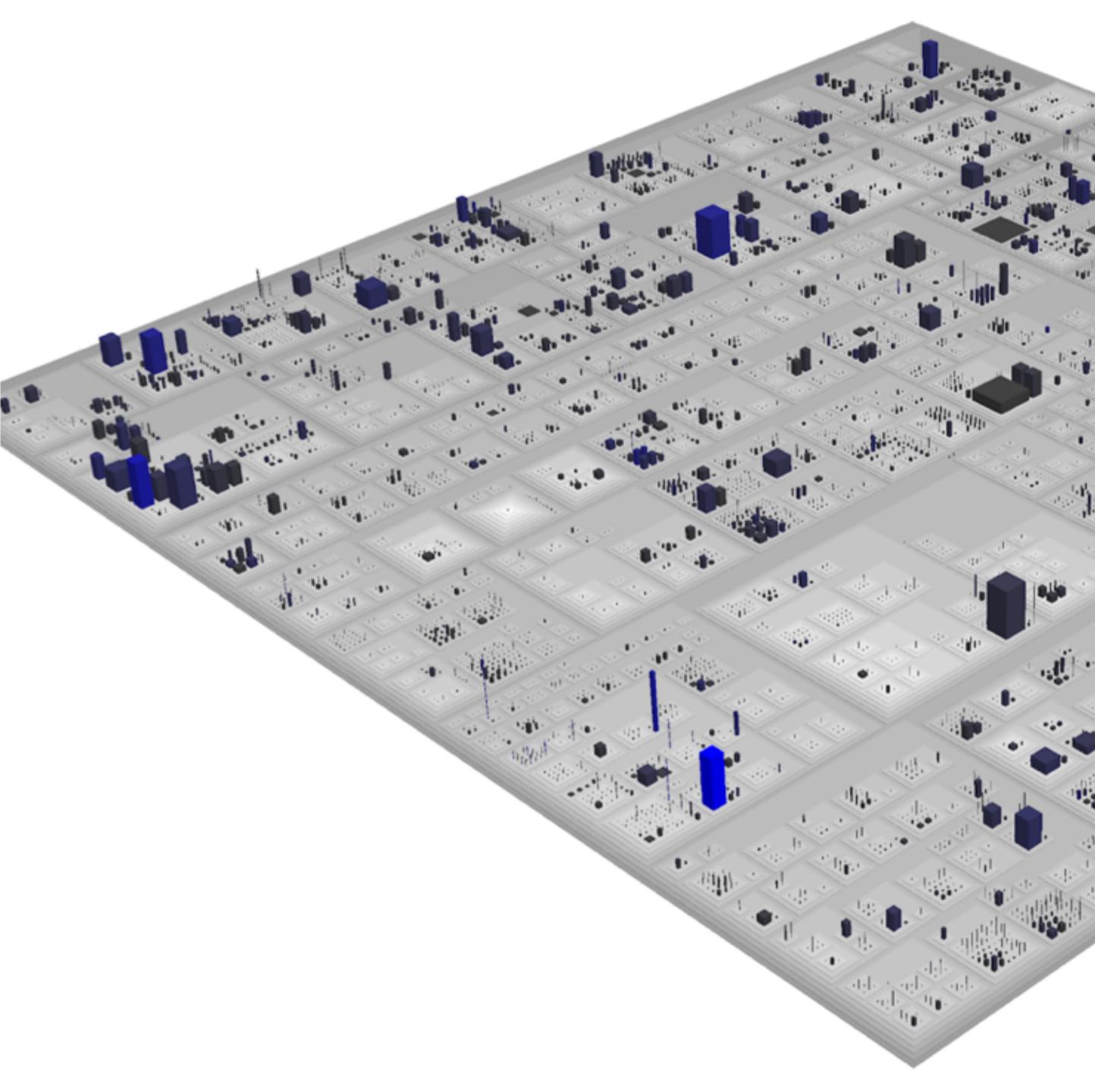




### **Detecting Outliers**







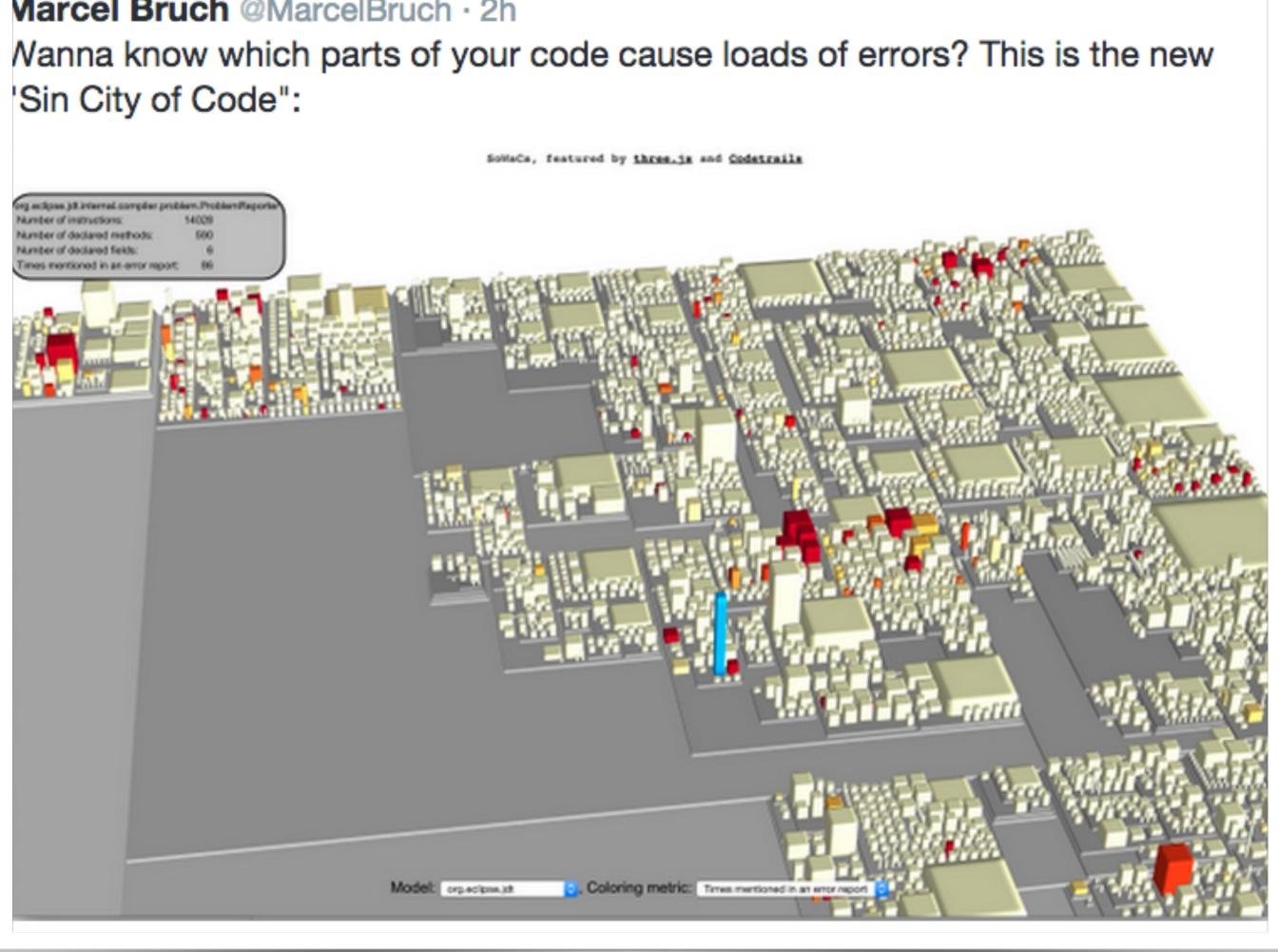
### **JBoss Application Server**





## **Communicating the locality of problems**

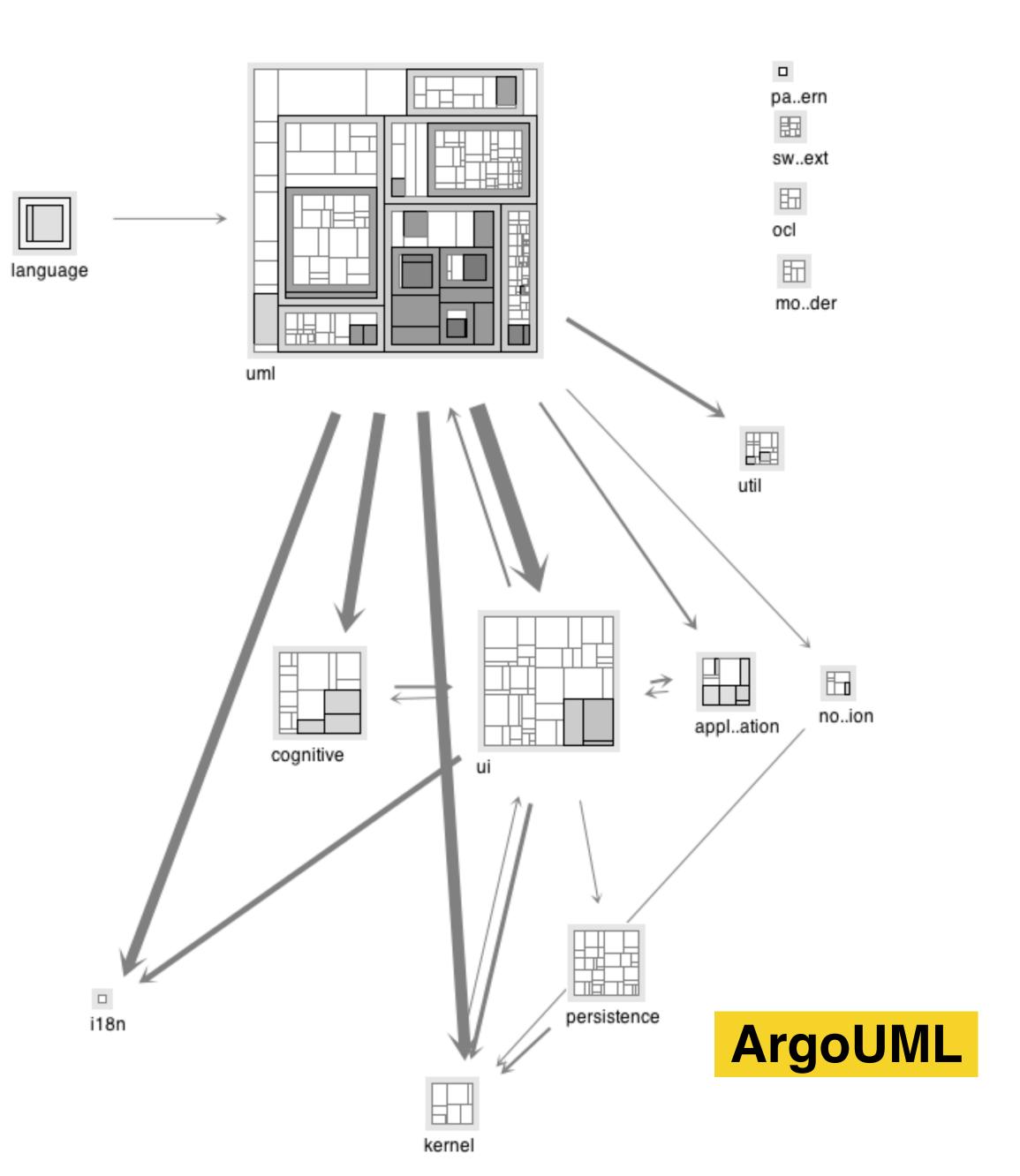
# Marcel Bruch @MarcelBruch · 2h





### **Hierarchical Visualization**

- > Use of pre-attentive processing features of
  - Size
  - Spatial locality
  - Connectedness
  - -Color
- > Available tools
  - Softwarenaut, Rigi, Shrimp, etc.





### Structure — Summary

### > Visualized software aspects

- Inheritance
- Containment
- Dependencies
- > Visualization techniques
  - Space filling techniques
  - Polymetric Views
  - Metaphors
  - Hierarchical Visualization



# Roadmap

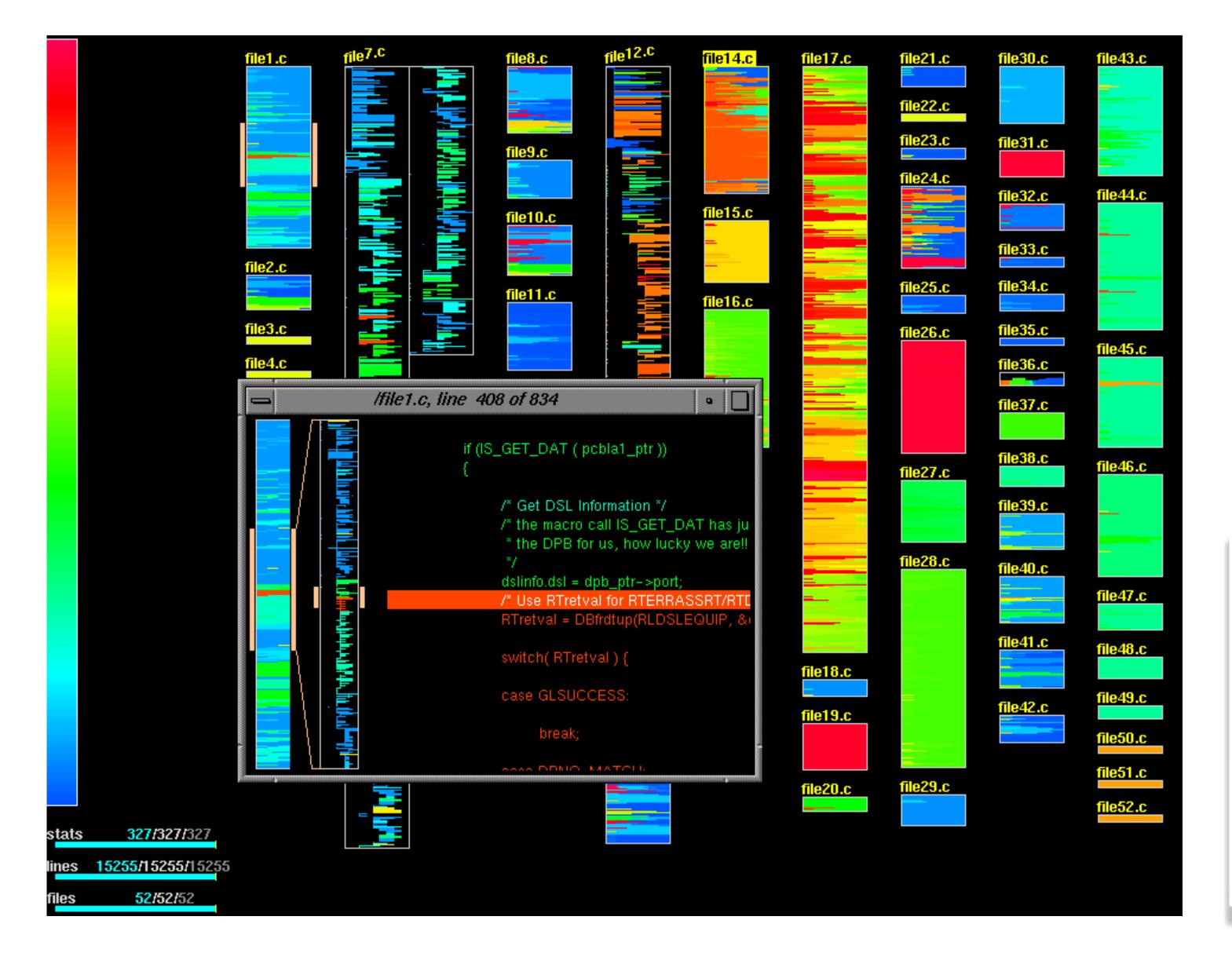
- > Visual Perception
- > Information Visualization
- Software Visualization
  - -Structure
  - -Evolution
  - -Behavior





## CODE\_SWARM

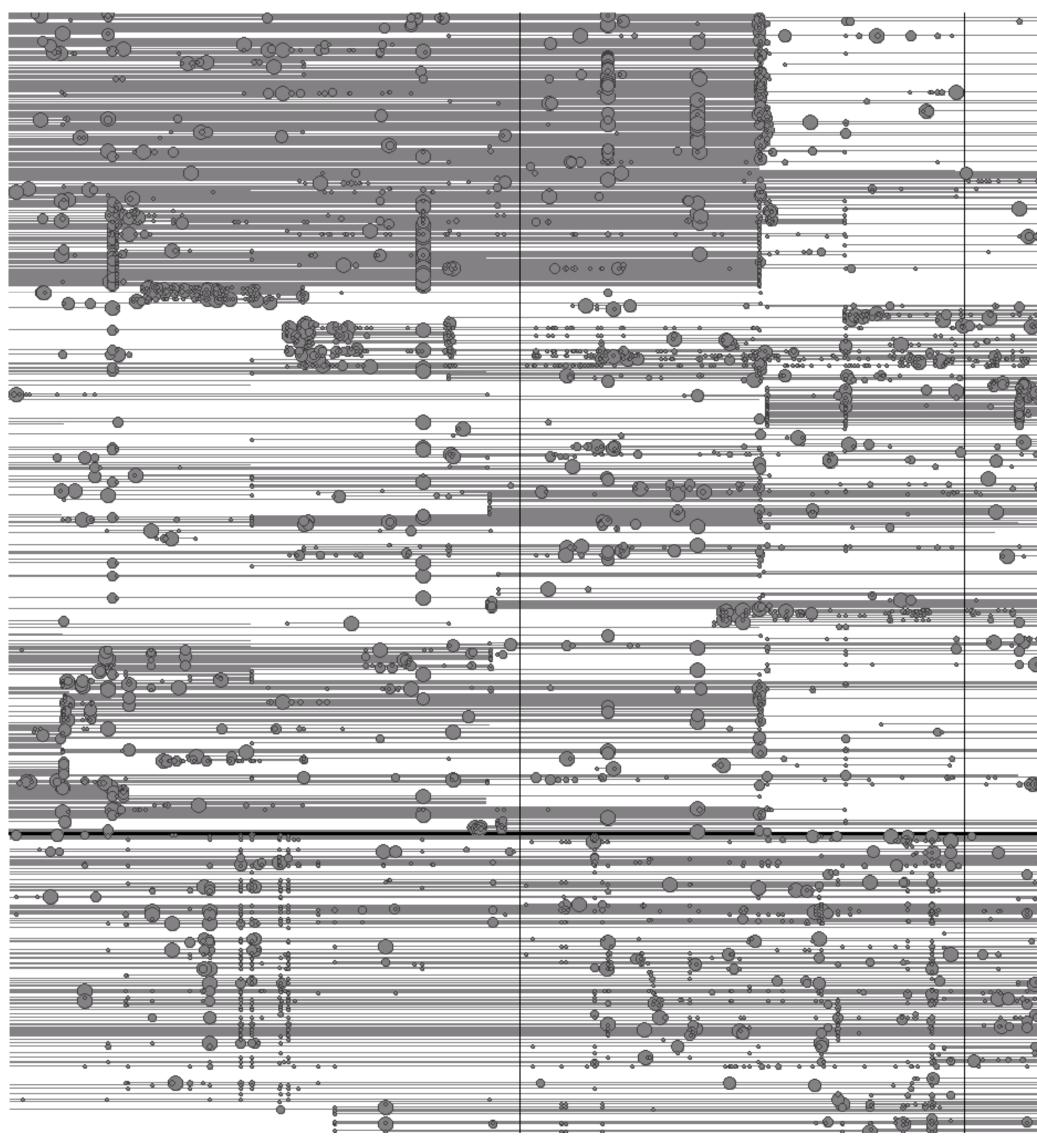
### SeeSoft mapped time on color to visualize churn



The Seesoft system maps each line of code into a thin row. The color of each row indicates a statistic of interest, e.g., red rows are those most recently changed, and blue are those least recently changed



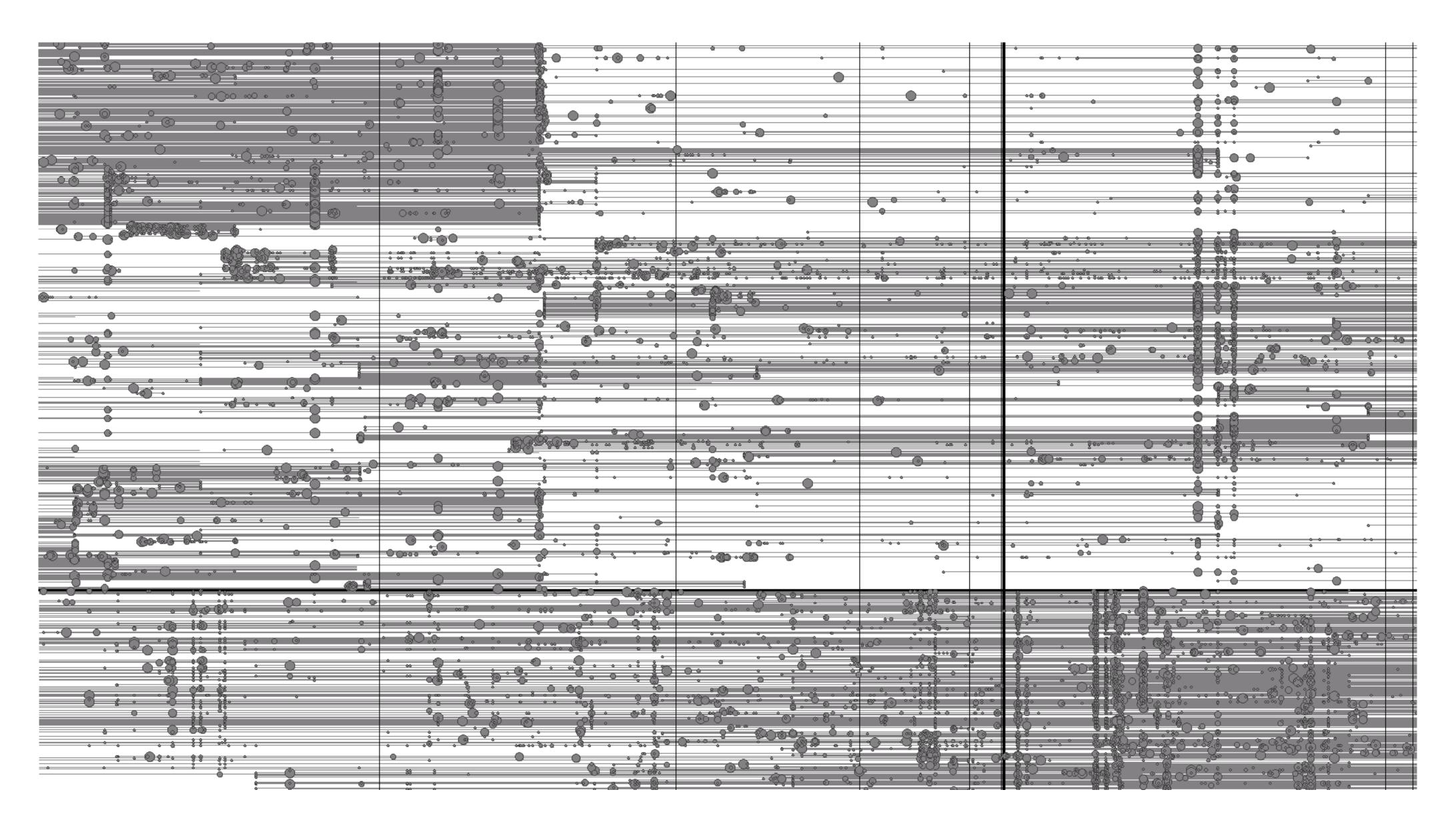
## Mapping evolution on space (the x-axis)



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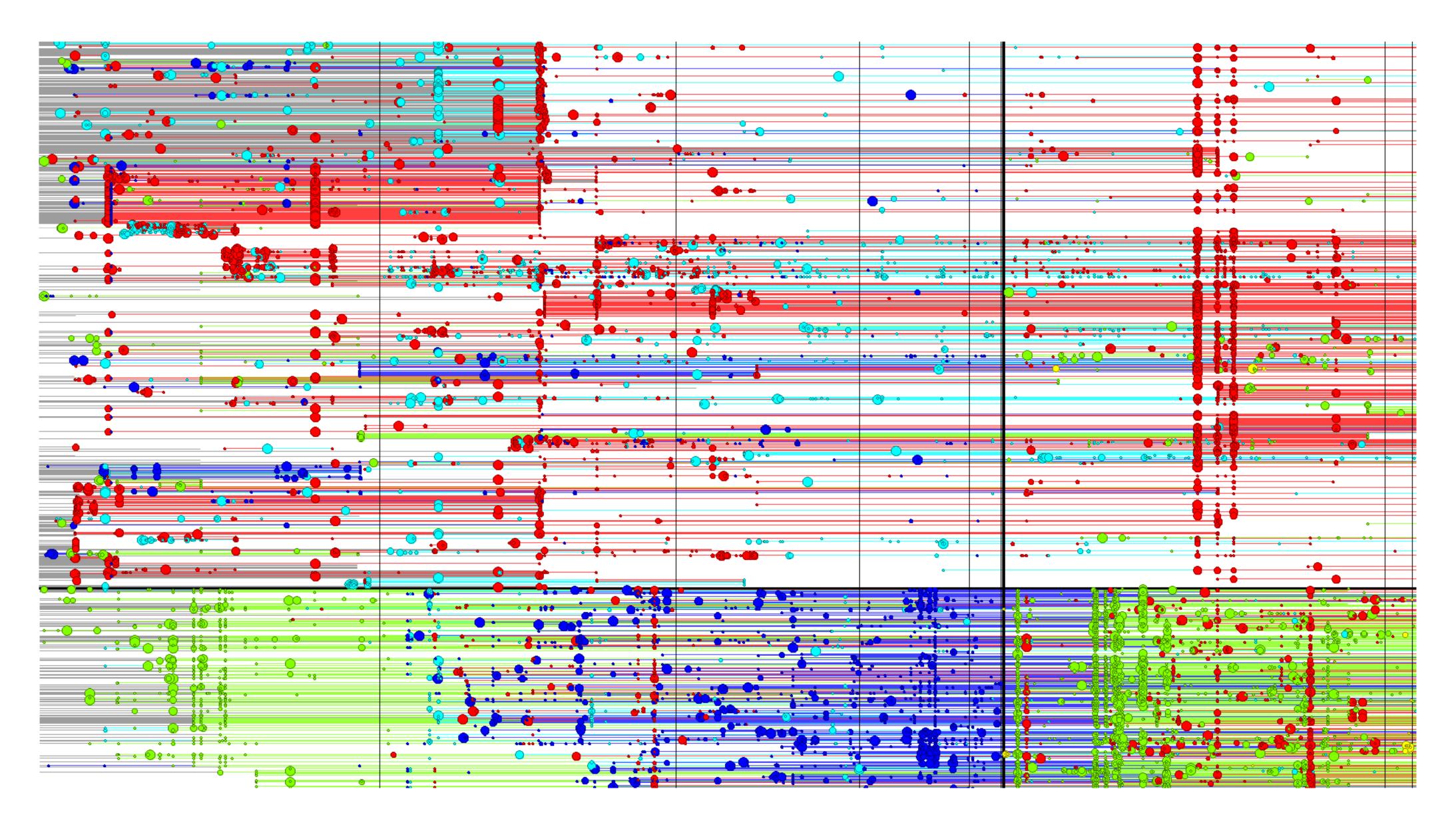


### Y-axis represents individual files sorted alphabetically



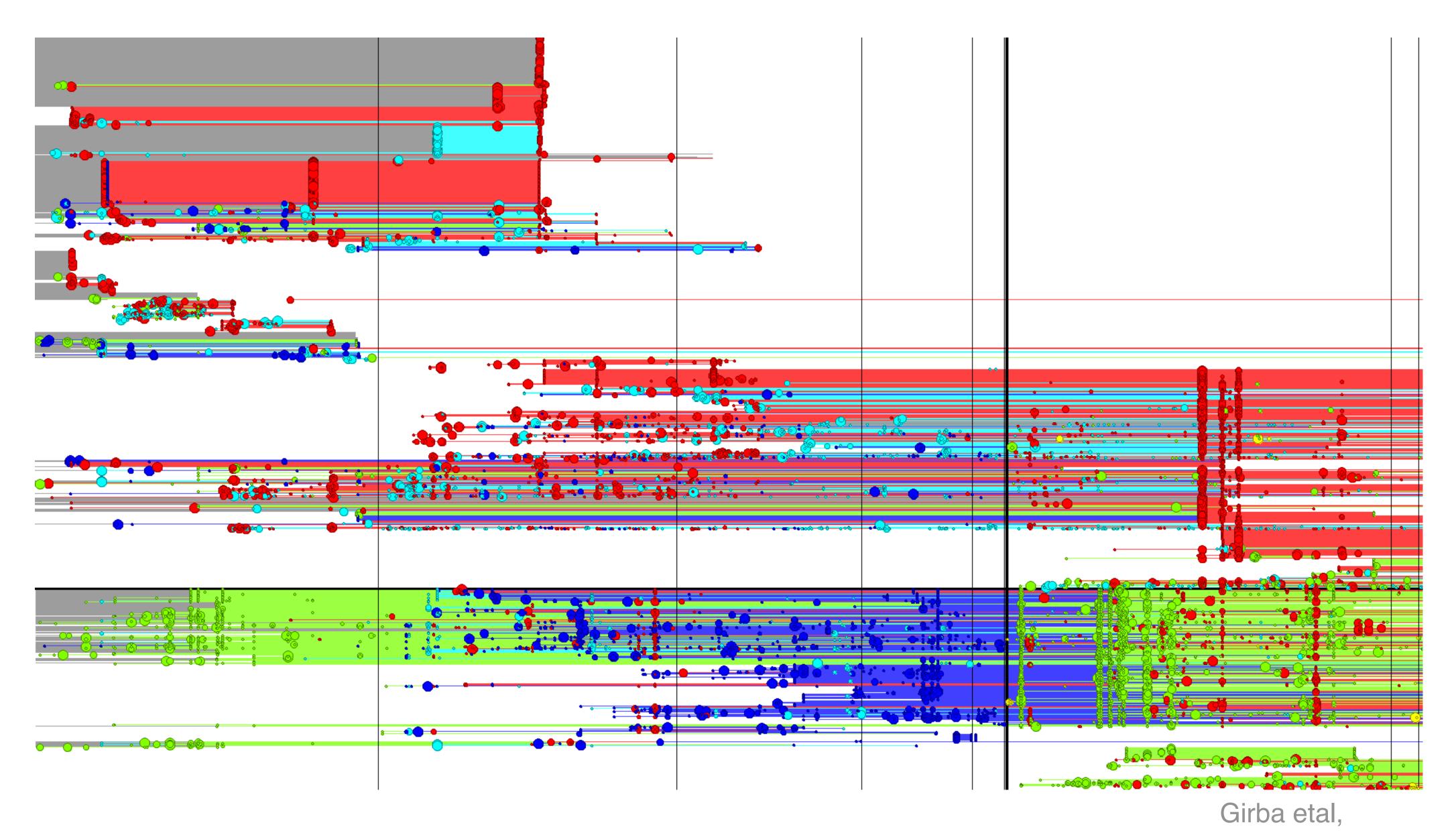


### Map authors on colors and kill alphabetical order



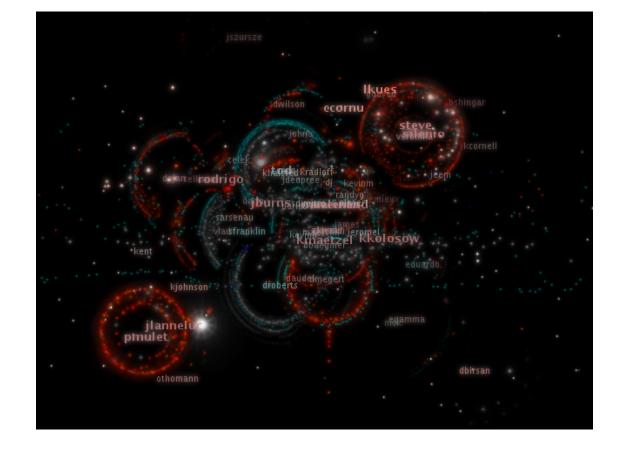


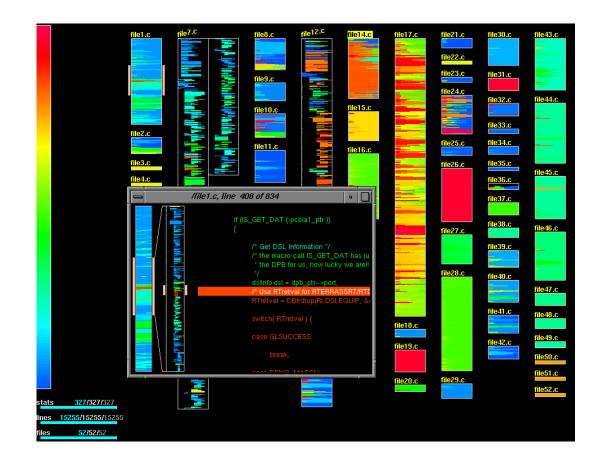
## Alphabetical order must die (J. Nielsen)



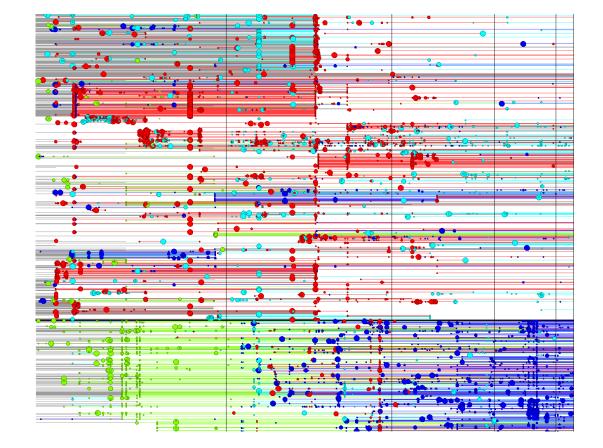


### System evolution can be mapped on









### color

### space



# Roadmap

- > Visual Perception > Information Visualization
- Software Visualization
  - -Structure
  - -Evolution
  - -Behavior

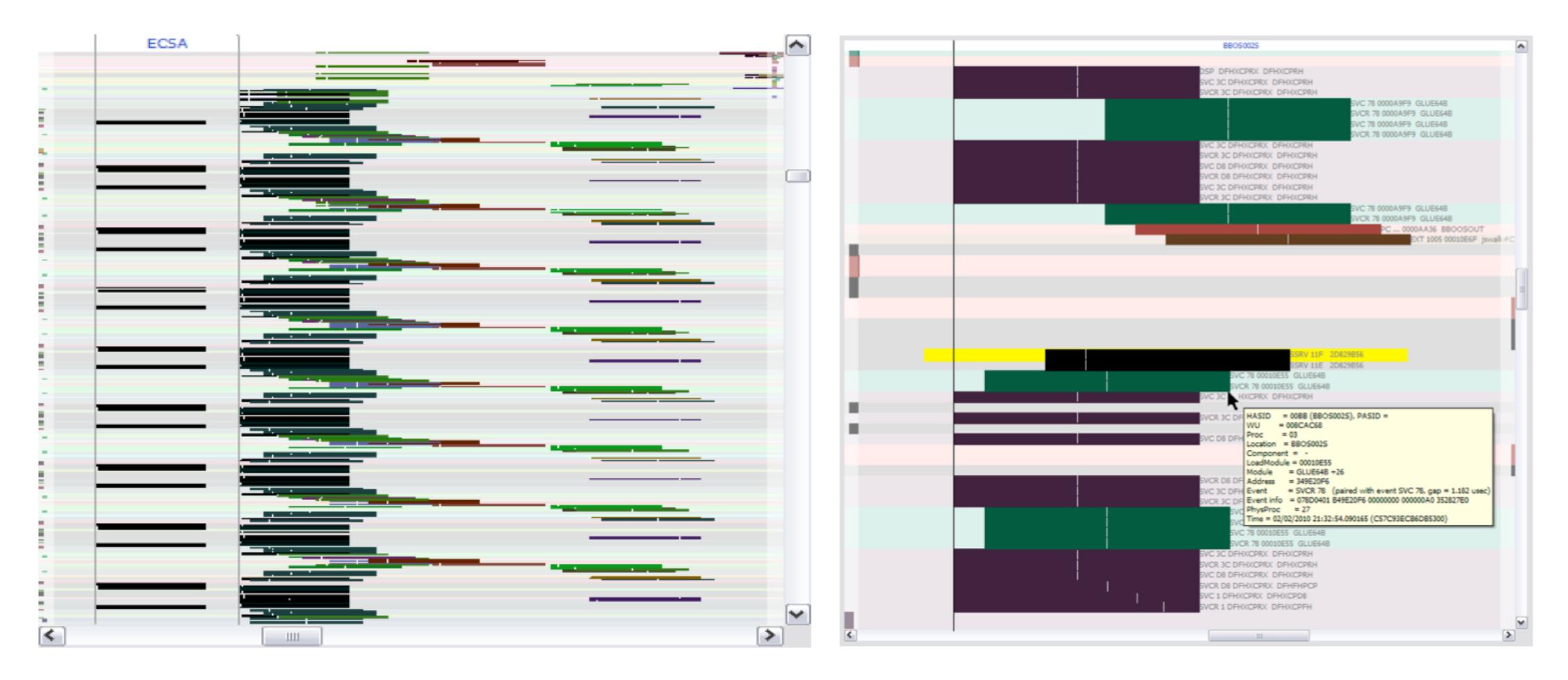




**Zinsight** is a visualization of large <u>event traces</u> using a *pixel based* representation



## Massively reliant on visual pattern recognition and interactivity

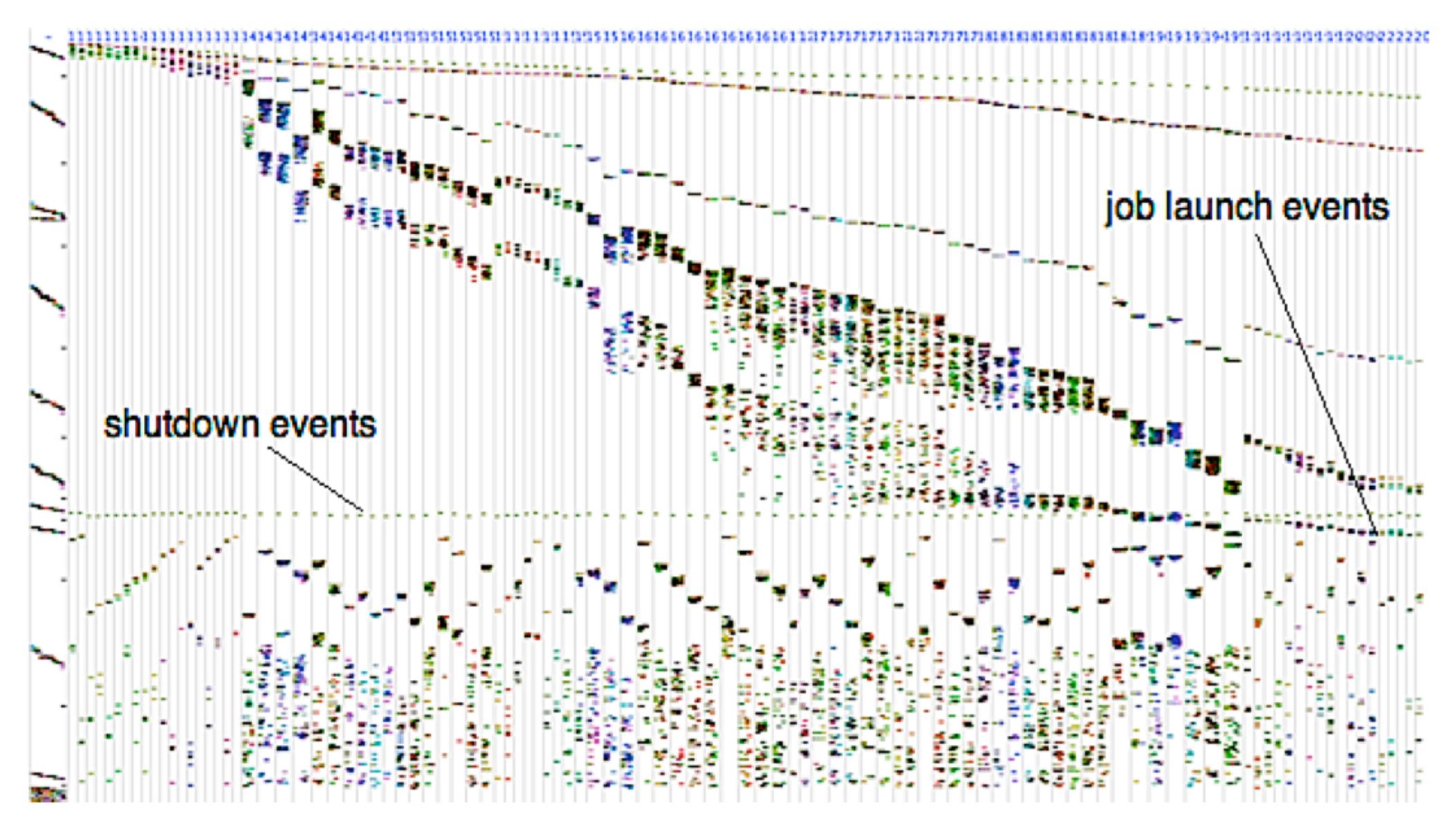


### Semantic Zooming





### Visual detection of bugs





### **Present and Future of Software Visualization**

> Novel interaction techniques





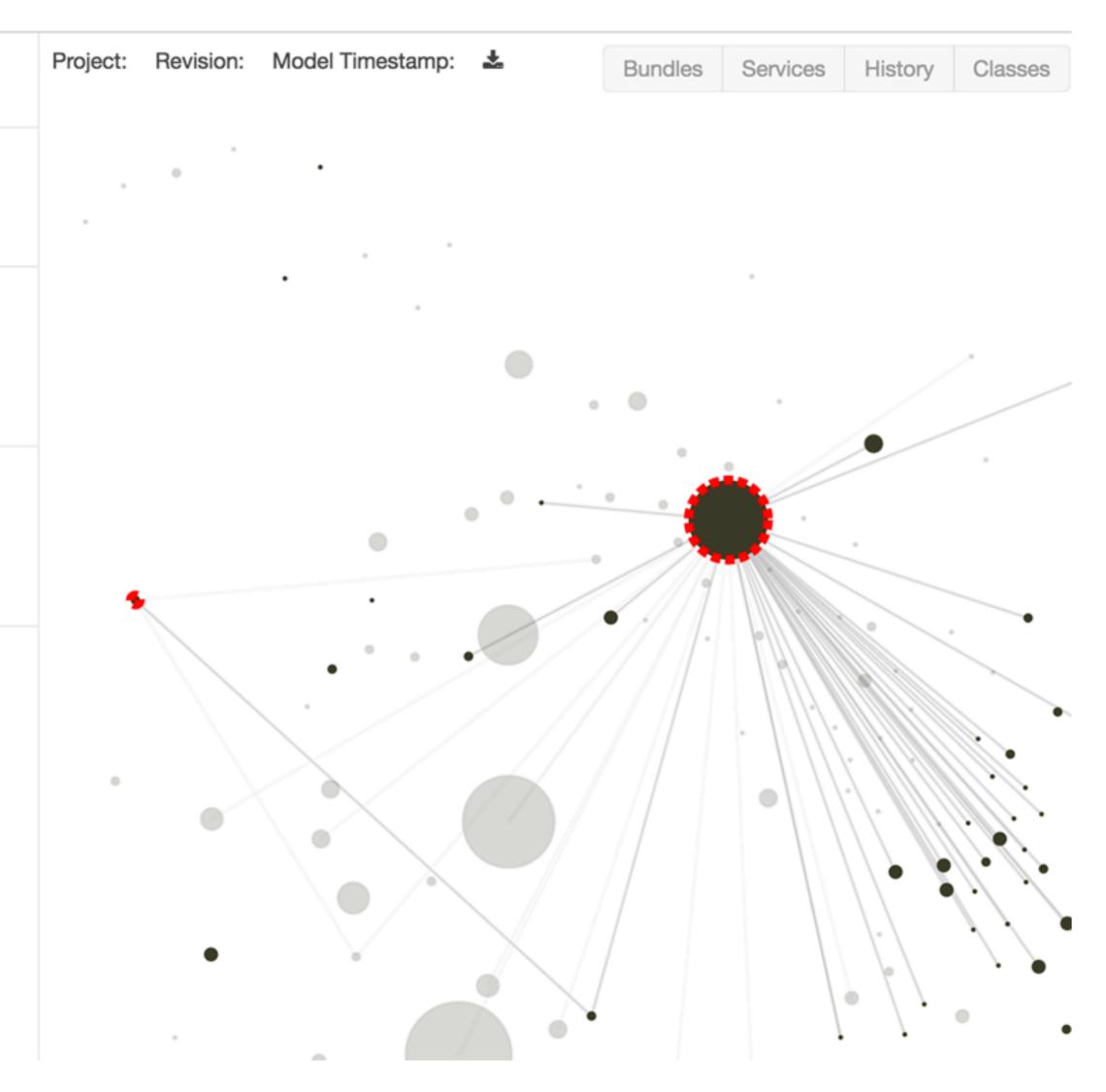


☆ <b>#</b> general	
Start of conversation	
February 15, 2017	
<b>Stefan</b> Admin 7:00 PM Has joined the channel.	
February 17, 2017	
SO Sofia 8:15 PM Has joined the channel.	
June 21, 2017	
BO Bob 10:06 AM Has joined the channel.	
stefan Admin 10:07 AM I've got a bug (see ticket) that relates to the login function. Did anybody know where I should start to locking for a potential solution?	
BO 10:08 AM Oh year you should look into the login bundle and maybe also into the gui bundle	



stefan Admin 10:09 AM

Okay thanks, I will look into the code 🙂

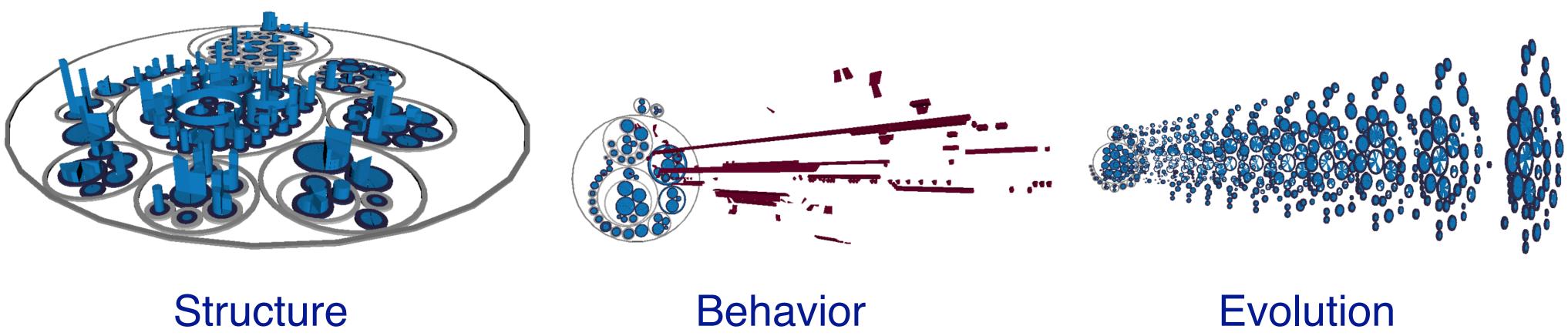




Novel interaction techniques
 3D Software Visualization



- > Novel interaction techniques
- > 3D Software Visualization



Baum, D., Schilbach, J., Kovacs, P., Eisenecker, U., & Müller, R. (2017, September). GETAVIZ: generating structural, behavioral, and evolutionary views of software systems for empirical evaluation. In Software Visualization (VISSOFT), 2017 IEEE Working Conference on (pp. 114-118). IEEE.



- > Novel interaction techniques
- > 3D Software Visualization
- > Multiple media to display visualizations
  - 2D: Wall displays, Tabletops, Mobile devices

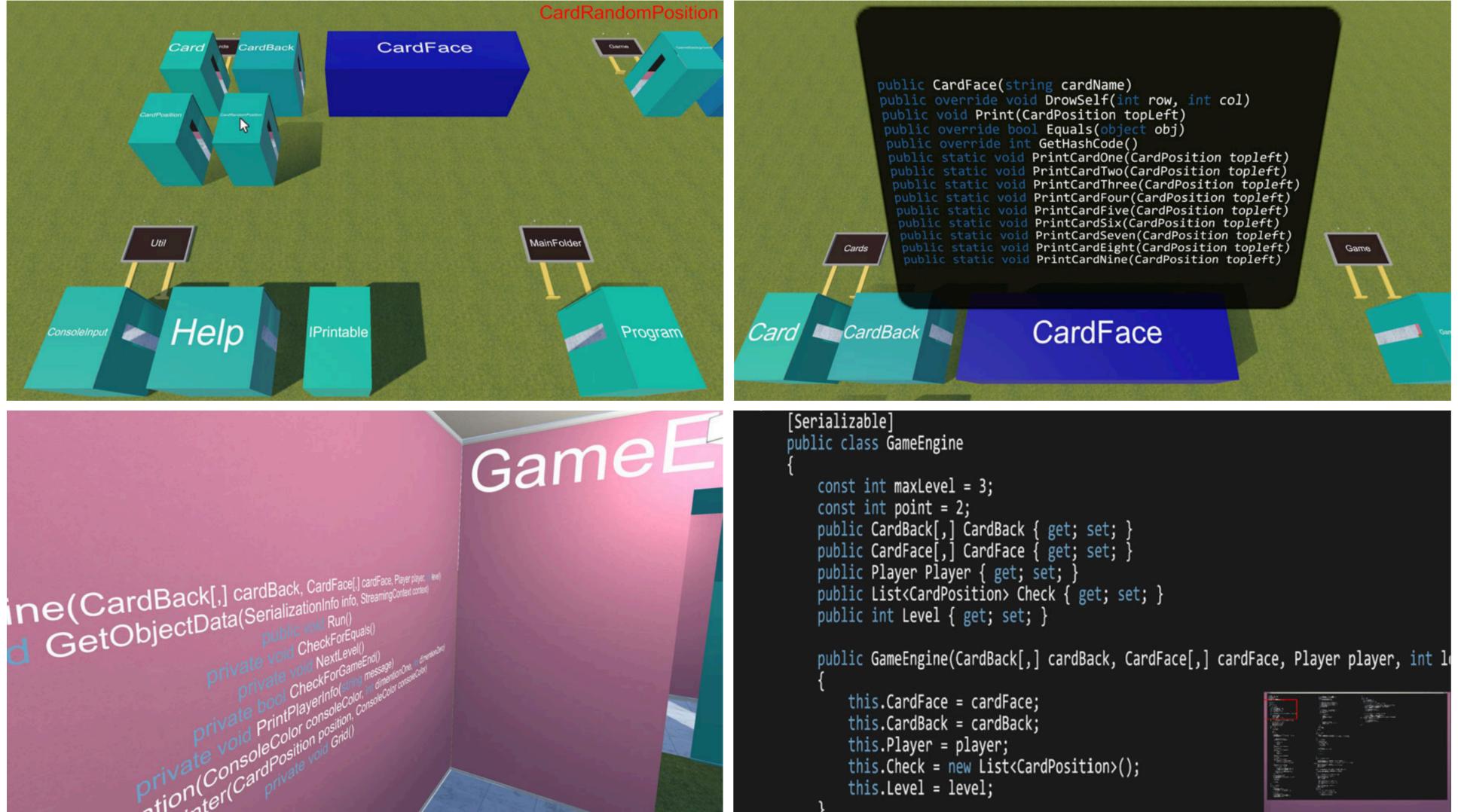






- > Novel interaction techniques
- > 3D Software Visualization
- > Multiple media to display visualizations
  - 2D: Wall displays, Tabletops, Mobile devices
  - 3D: AR, VR, CAVE, Stereo glasses, 3D prints

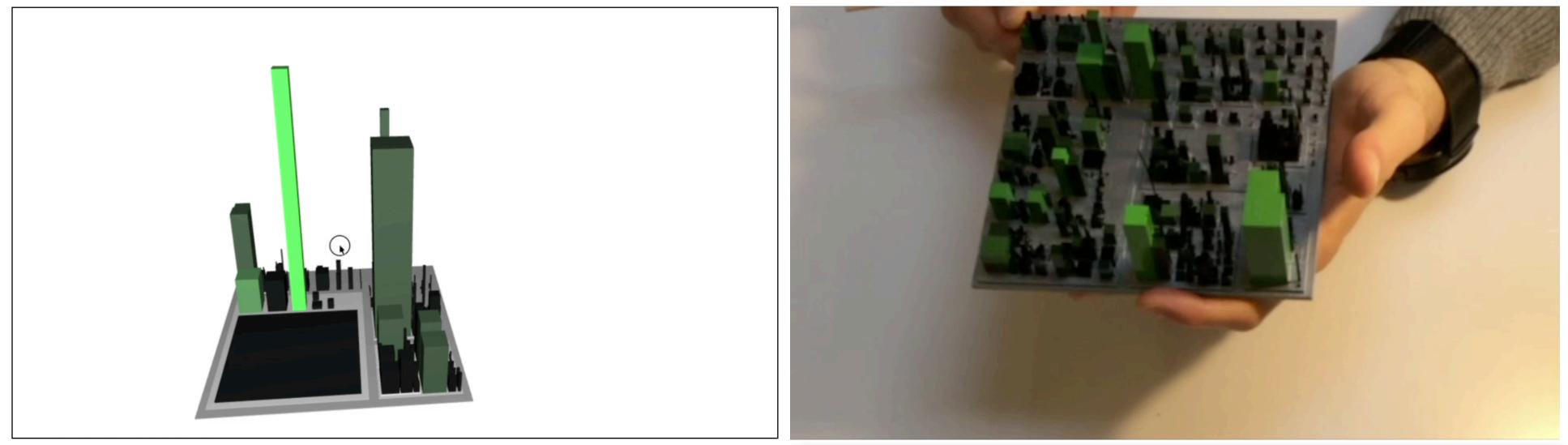


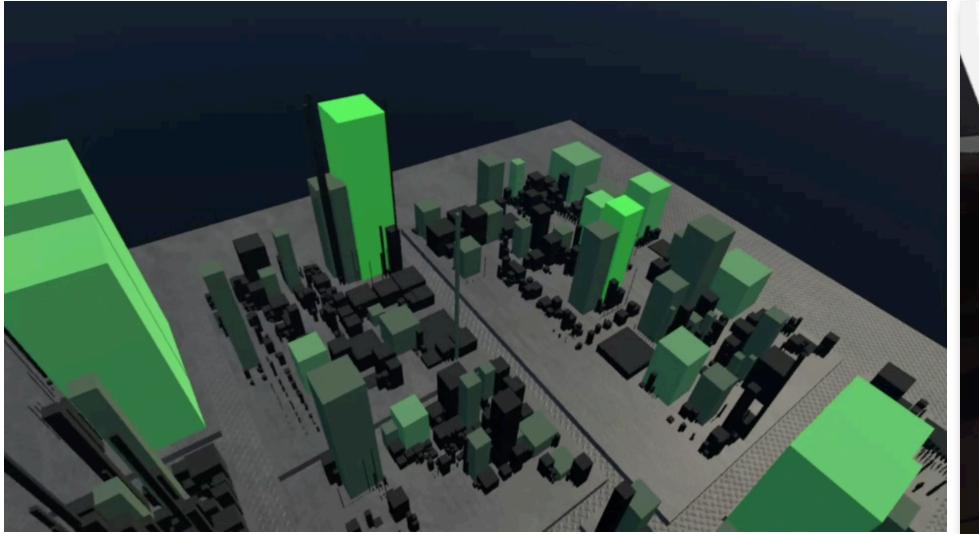


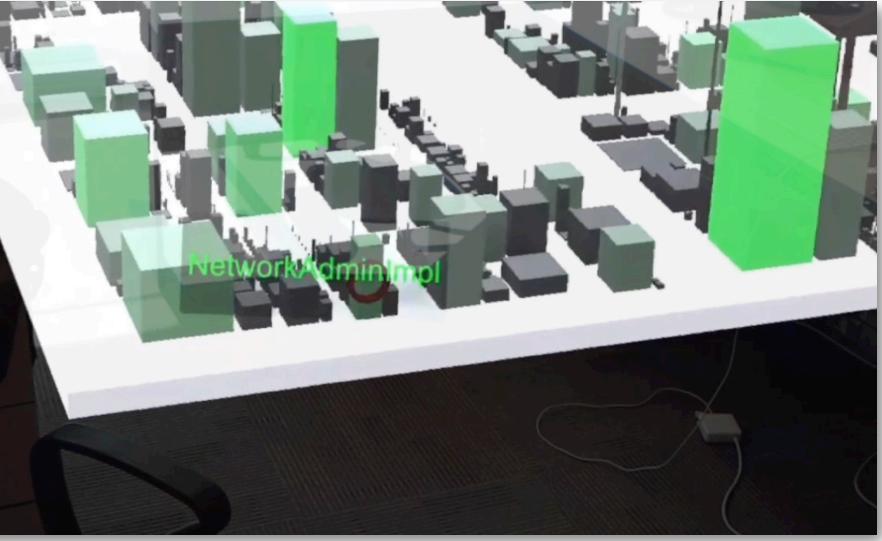


Khaloo, P., Maghoumi, M., Taranta, E., Bettner, D., & Laviola, J. (2017, September). Code Park: A New 3D Code Visualization Tool. In Software Visualization (VISSOFT), 2017 IEEE Working Conference on (pp. 43-53). IEEE.











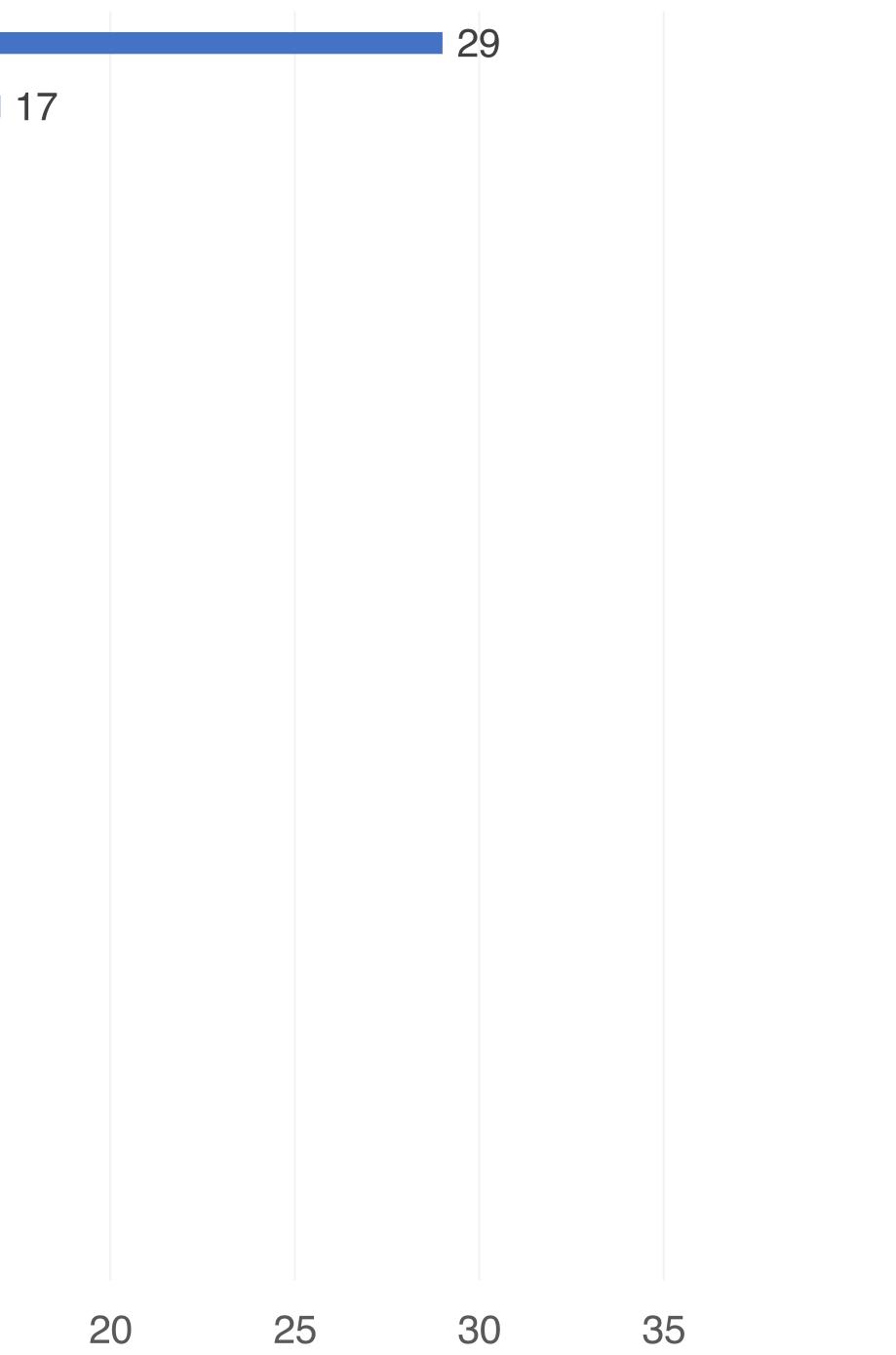
- > Novel interaction techniques
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- > Multiple media to display visualizations
  - 2D: Wall displays, Tabletops, Mobile devices
  - 3D: AR, VR, CAVE, Stereo glasses, 3D prints
- Focus on evaluation of software visualizations
   Beyond time & Correctness



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User Experience	U

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Effectiveness				
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Not Explicit	2			
Completion	2			
Recollection	2			
Efficiency	<b>1</b>			
Scalability	<b>1</b>			
Visual Effort	<b>1</b>			
Usability				14
Not Explicit	3			
Engagement	2			
Understandability	2			
Acceptability	<b>1</b>			
Difficulty	<b>1</b>			
Confidence	<b>1</b>			
Enjoyment	<b>1</b>			
Intuitiveness	<b>1</b>			
Learnability	<b>1</b>			
Satisfaction	<b>1</b>			
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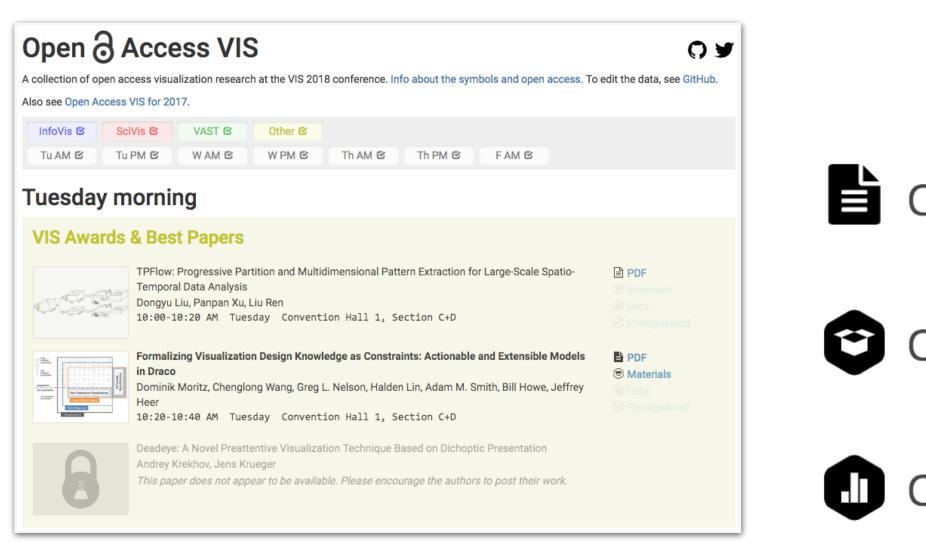


- > Novel interaction techniques
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- > Focus on evaluation of software visualizations
  - > Beyond time & Correctness
  - > Replicability & Reproducibility





### http://evaluate.inf.usi.ch/artifacts https://www.artifact-eval.org/



### http://oavis.steveharoz.com/



https://www.acm.org/publications/ policies/artifact-review-badging

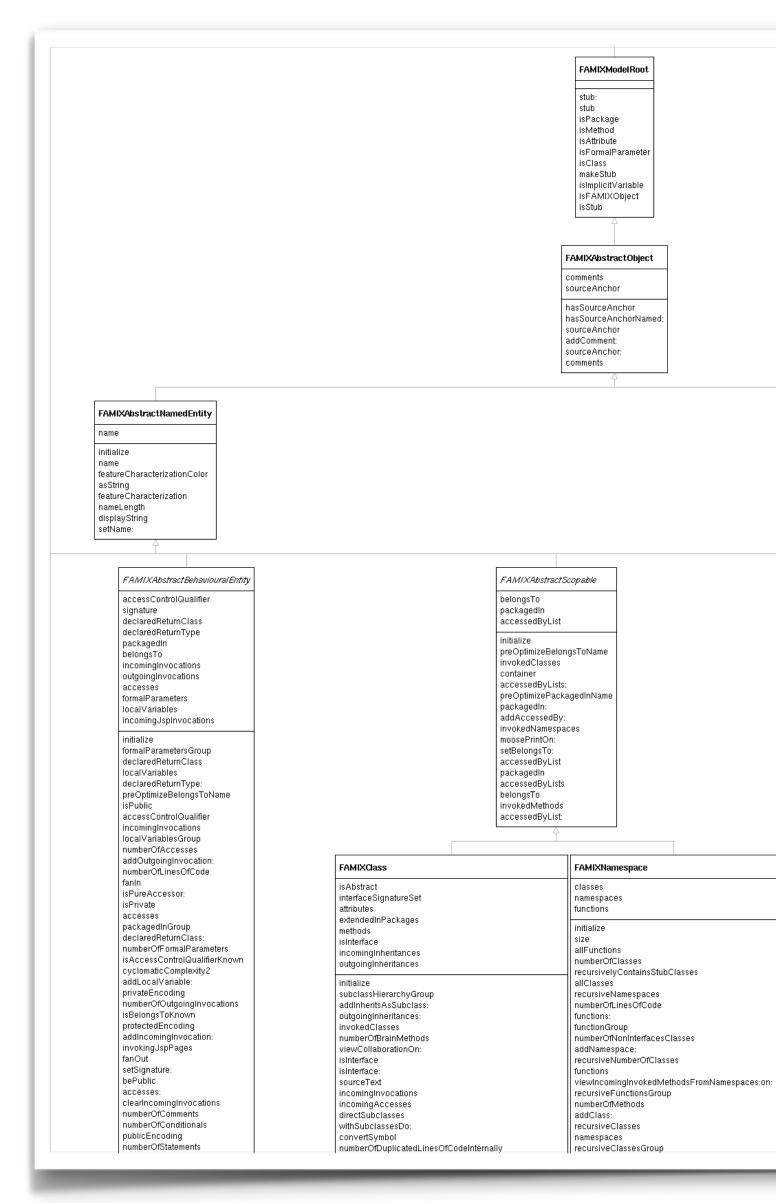
Open Access Paper

**Open Materials** 

Open Experiment Data



### Inheritance



### Ceci n'est pas une visualization

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tracesReferencingThisPackage definedClassesDo:								
extendedClasses: definedClassesContains:								
definedClassesGroup isStubPackage								
isHomeFor: preOptimizeDefinedClassesNames:								
definedClassesIncludes: extendedClassesGroup								
packagedIn: extendedClassesInject:into:								
definedClassesInject:into: definedClasses:								
protectedPackagedInNames preOptimizeDefinedClassesNames								
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definedClassesOccurrencesOf: childPackages								
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isStub								



### What you should know

- > What is pre-attentive processing?
- > What are the laws of Gestalt psychology?
- > What is information visualization?
- > Which aspects of software are usually visualized?
- > Which techniques allow to visualize software structure?
- > On what visualization features can we map evolution?
- > What kinds of problems can be solved with software visualization?





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