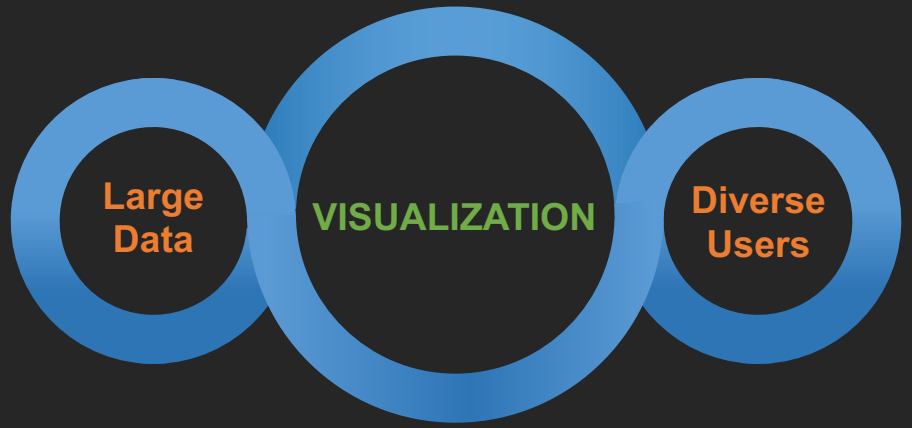
Scalable Visualization Systems for Broad Audiences



刘志成

Recent Trends

Data grow in size and complexity across problem domains

traditional visualizations are not scalable

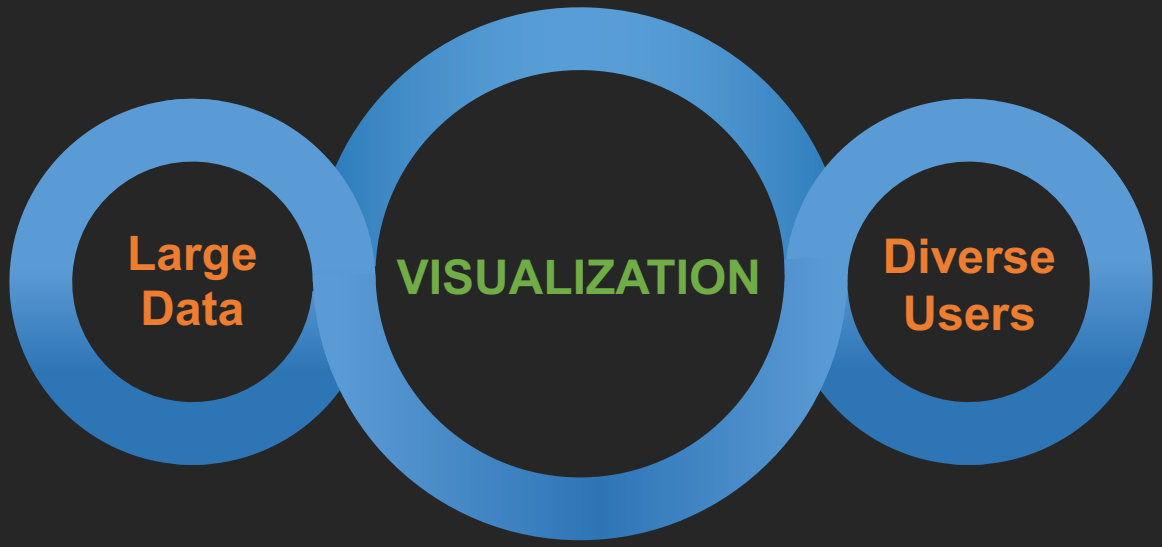
need to devise novel and generalizable techniques

Diverse users need to analyze data & communicate findings

scientists, analysts, journalists and designers

lower barrier of entry without sacrificing power

My Research Goal:
Scalable Visualization Systems for Broad Audiences



Scalable Interaction Techniques **Visualization Process Models**

Human-Centered Approach

Overview

Scalable Interaction Techniques

Multivariate linked analysis

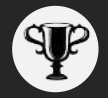
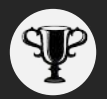
Event sequence data analysis

EuroVis ‘13, InfoVis ’14,  *CHI ‘15, VAST ‘16, EuroVis ’17, VAST ‘18*

Visualization Process Models

Natural language interaction

Graphical authoring tools

UIST ‘15,  *InfoVis ’16,*  *CHI’18, InfoVis ’19,*  *CHI’20*

Overview

Scalable Interaction Techniques

Multivariate linked analysis

Event sequence data analysis

EuroVis ‘13, InfoVis ’14,  *CHI ‘15, VAST ‘16, EuroVis ’17, VAST ‘18*

Visualization Process Models

Natural language interaction

Graphical authoring tools

UIST ‘15,  *InfoVis ’16,*  *CHI’18, InfoVis ’19,*  *CHI’20*

Scalable Visualization Systems: Goals

Perceptual Scalability

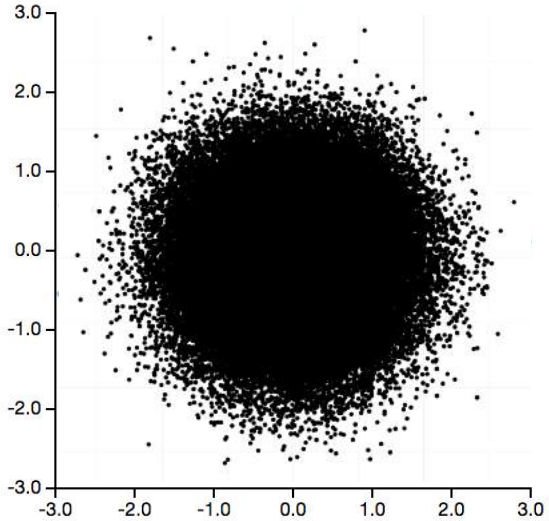
- Large number of data cases leads to over-plotting and cluttering
- Need to carefully choose data reduction methods for representation

Interactive Scalability

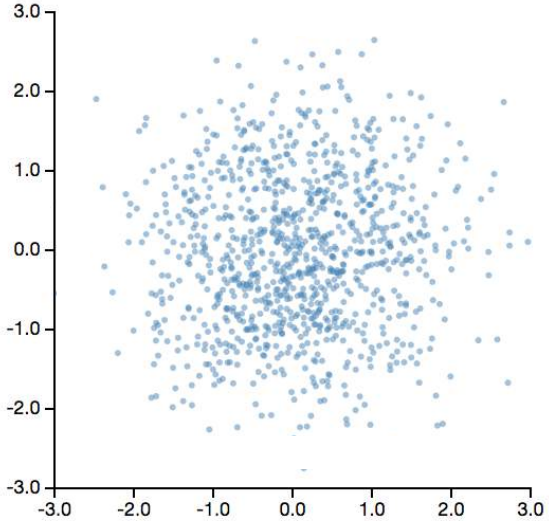
- +500ms leads to reduced user engagement & insight generation *
- Scalable interaction needs to reduce latency

** InfoVis '14*

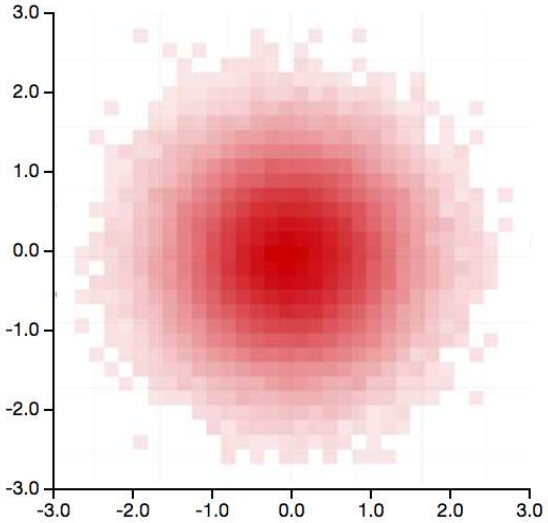
Data: 10K Points



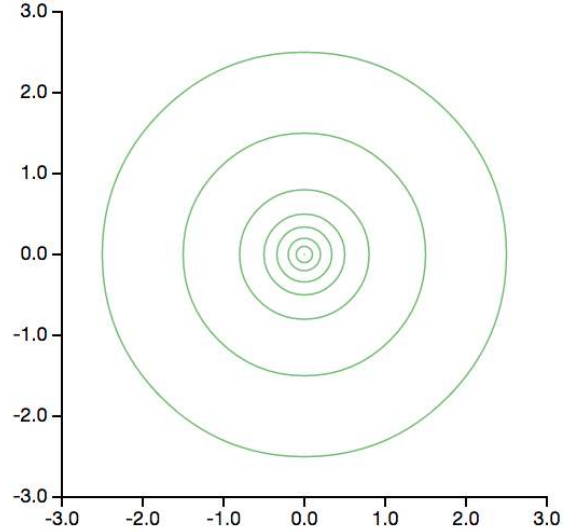
Sampling



Binned Aggregation



Modeling



Example: Location-based Mobile Check-ins

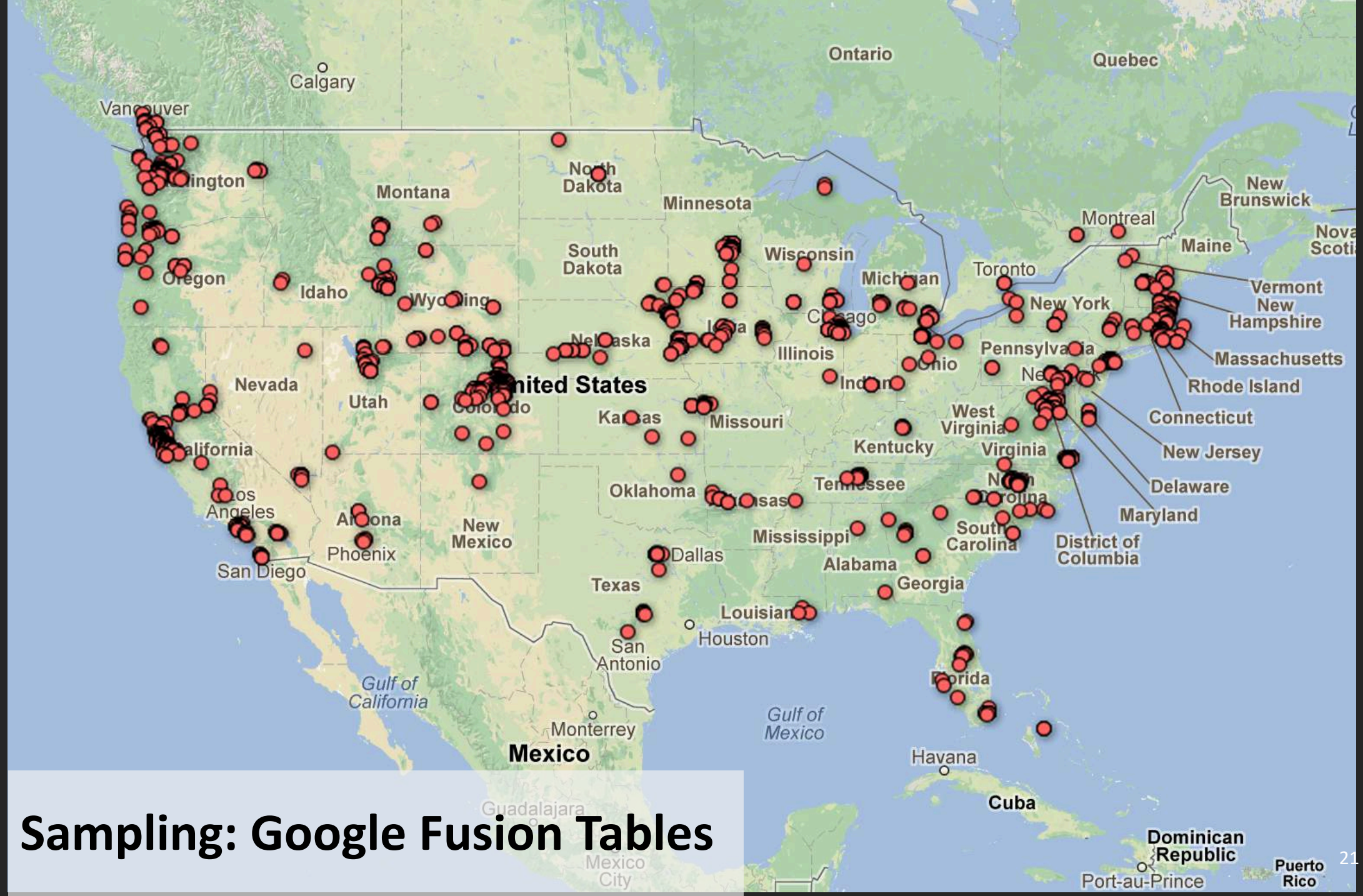
4.5 million records (2008-2010)

Date, Time, Lat, Lon, User ID

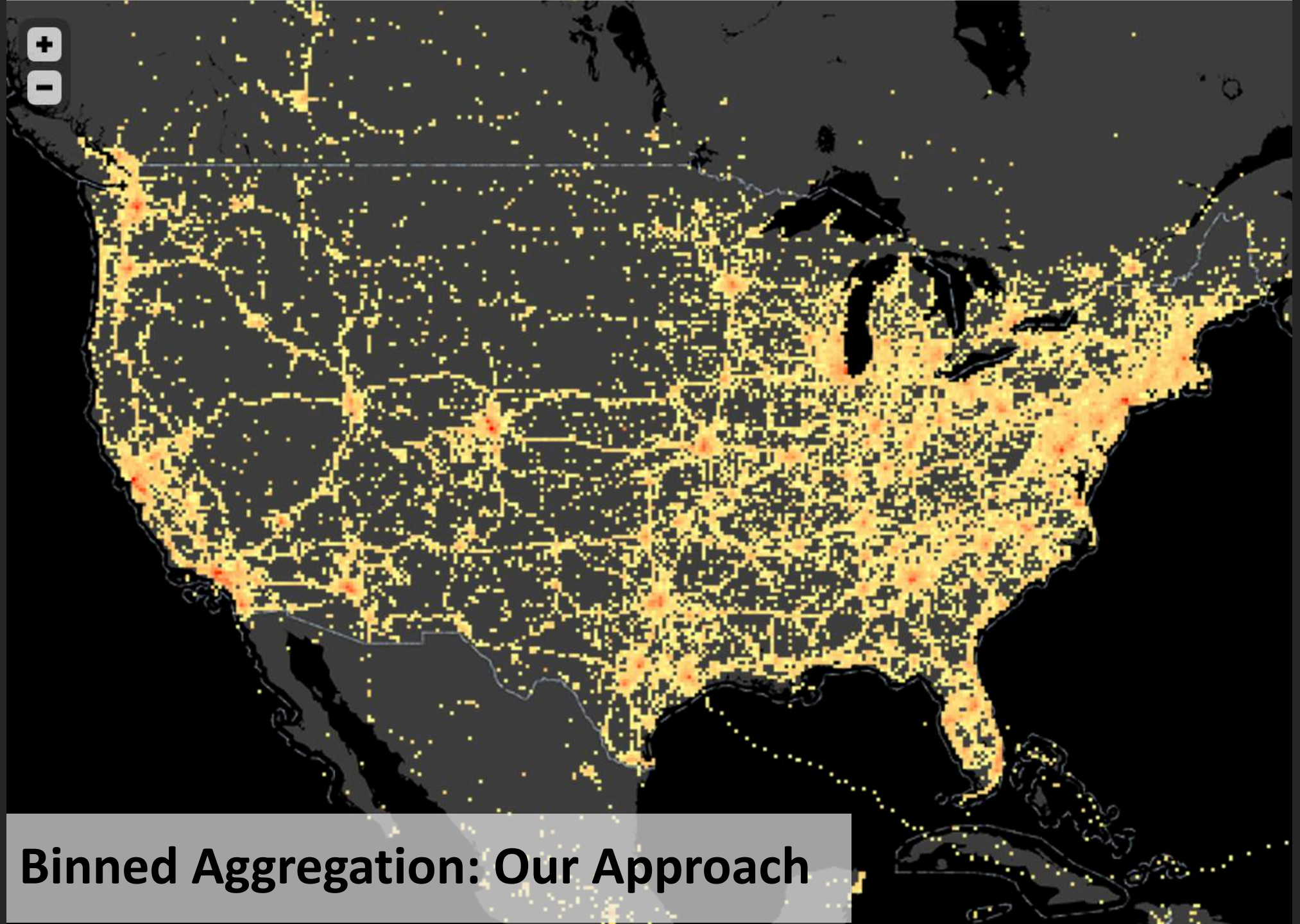
Analysis Goal:

Understand geographic distribution of check-ins

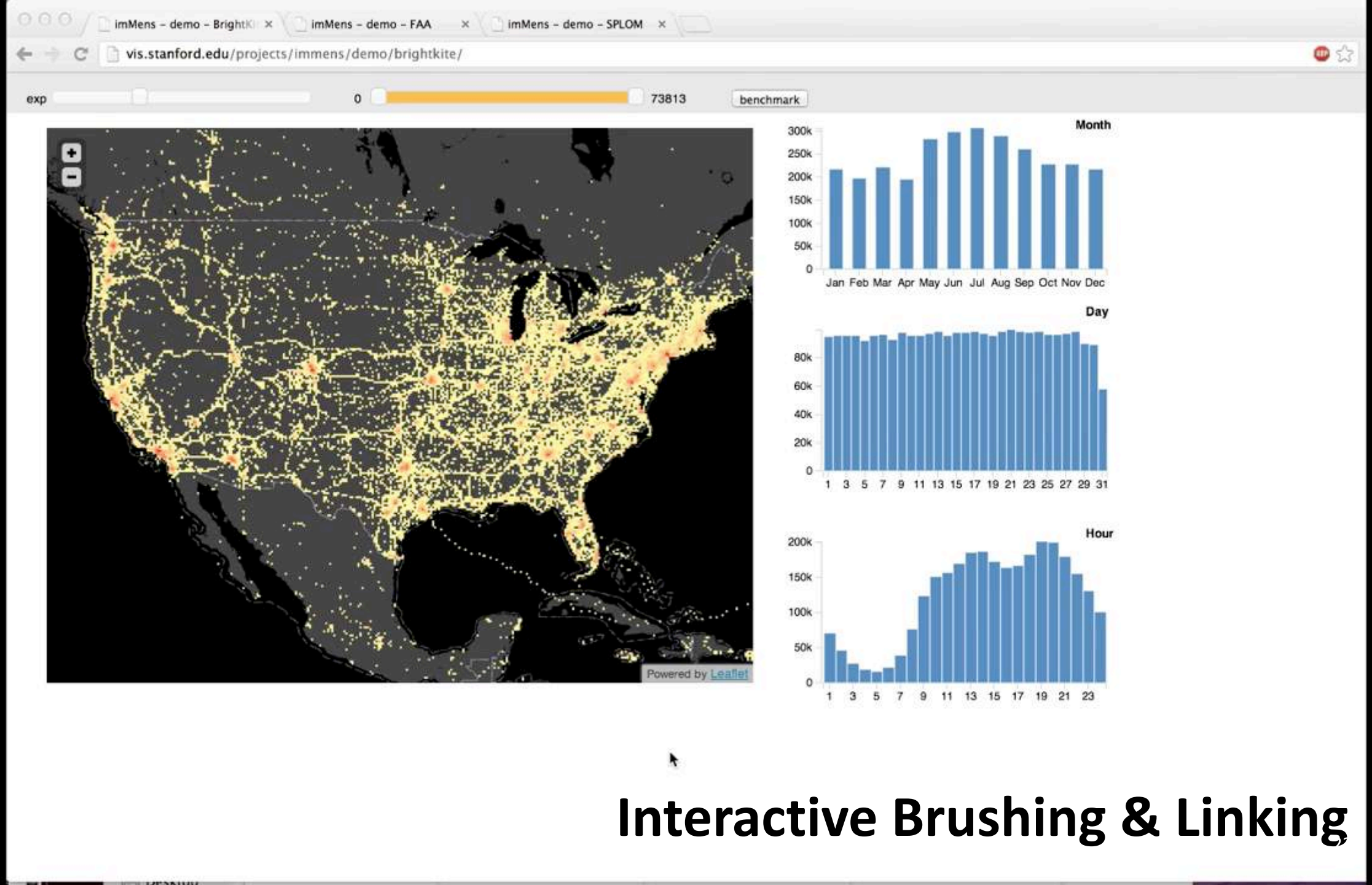
Find correlation between geographic and temporal dimensions



Sampling: Google Fusion Tables

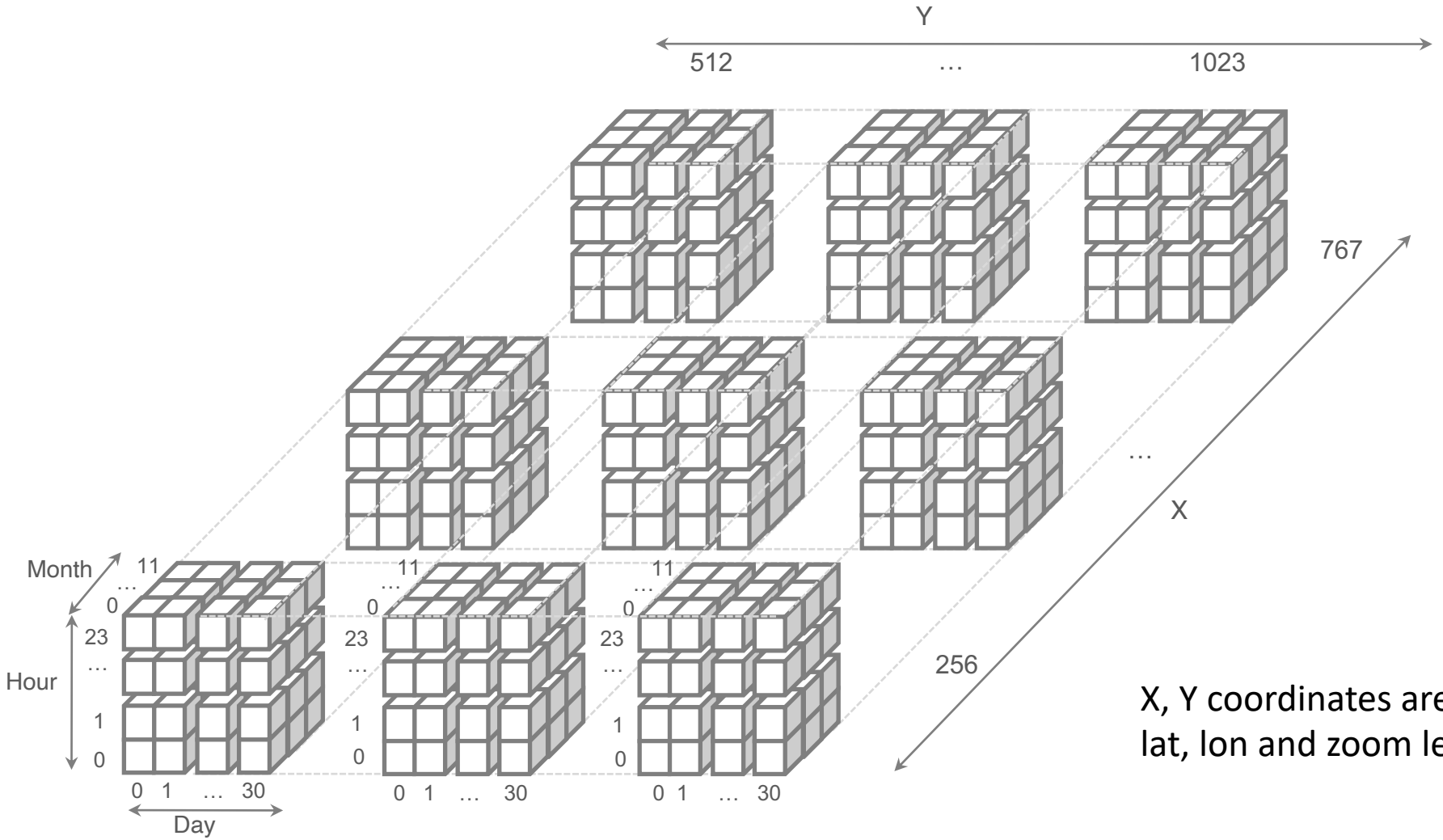


Binned Aggregation: Our Approach



Interactive Brushing & Linking

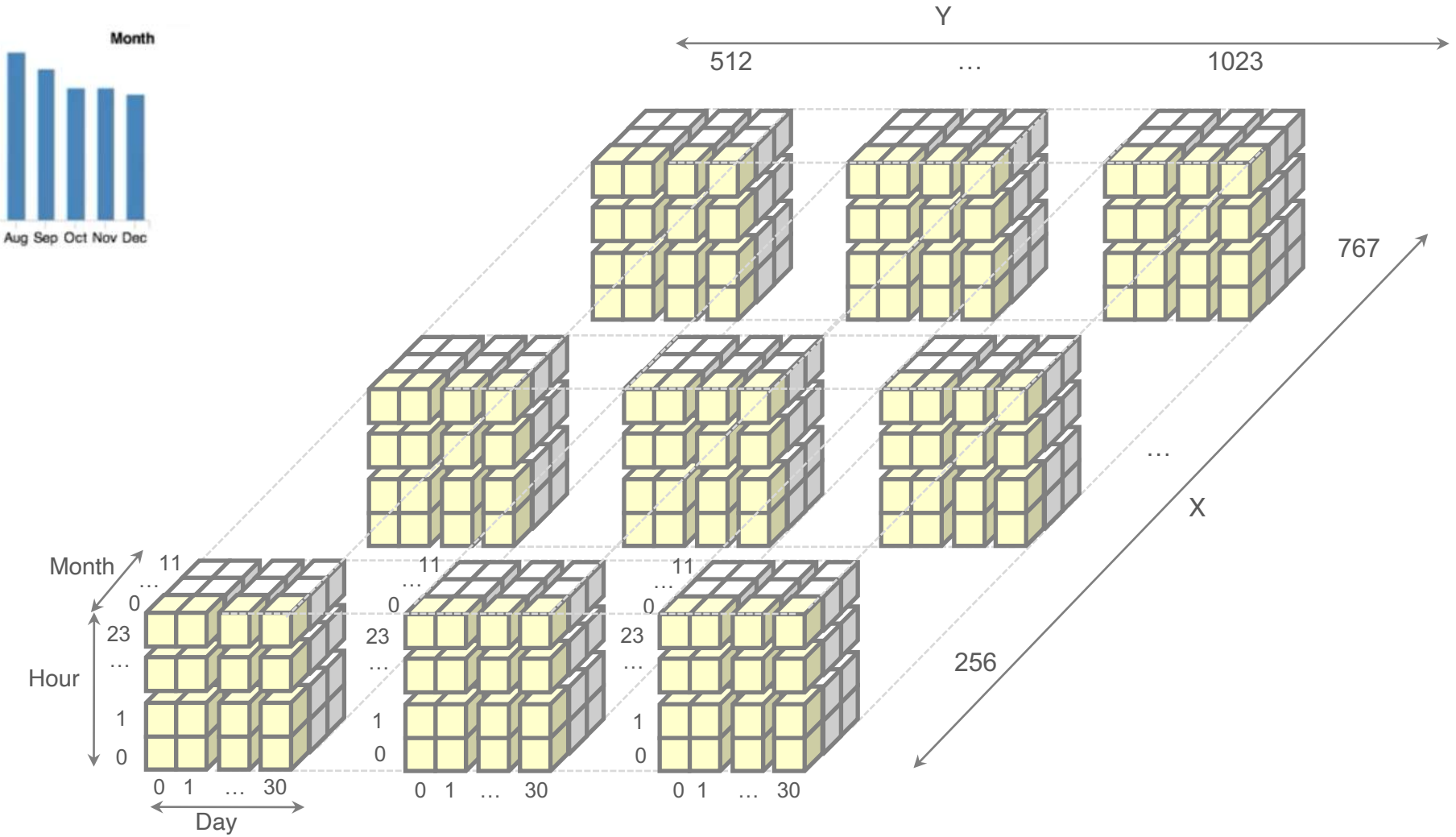
A Naïve Approach



X, Y coordinates are derived from lat, lon and zoom level

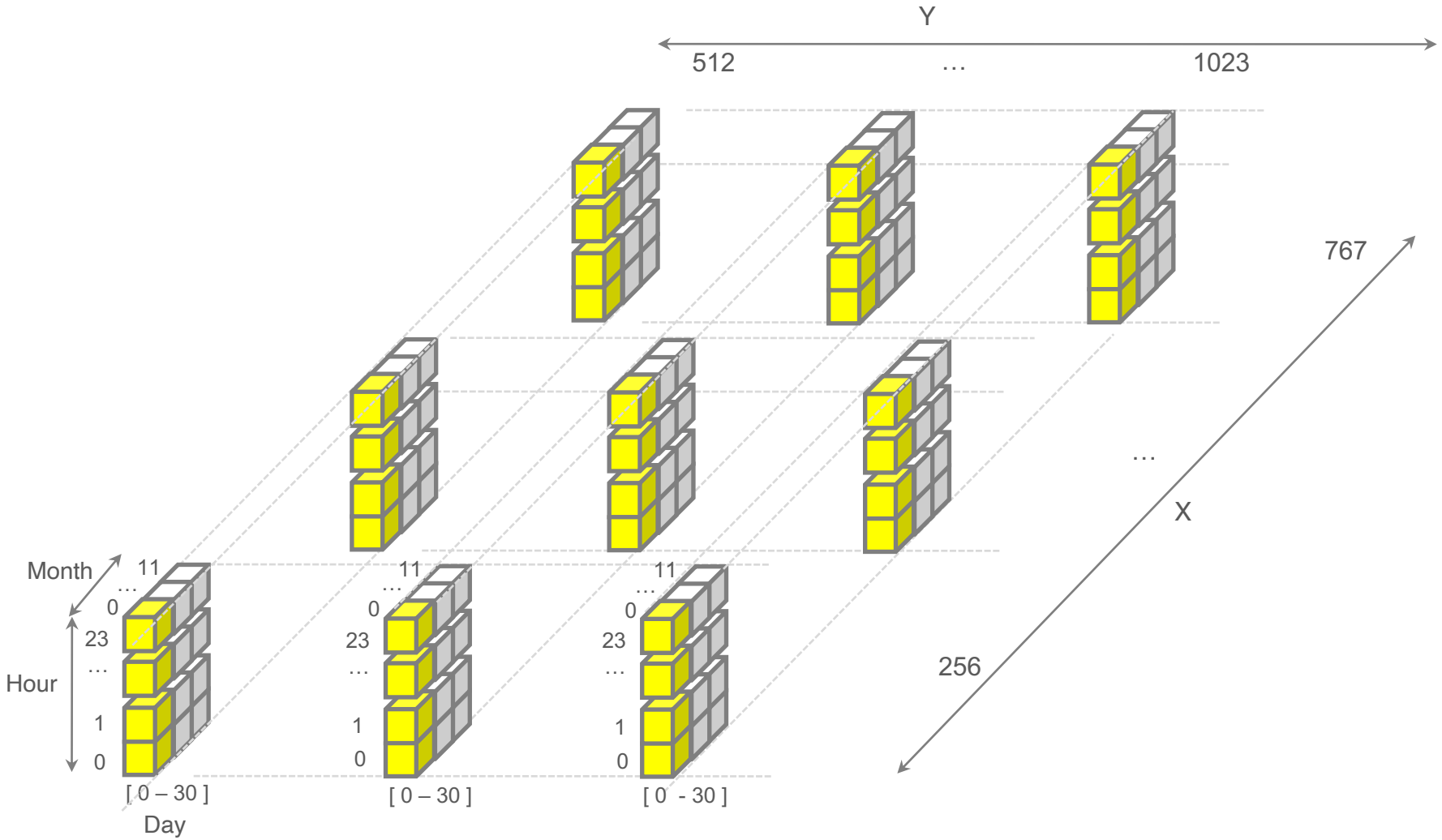
12 x 31 x 24 x 512 x 512 = 2 billion+ cells

Brushing over January



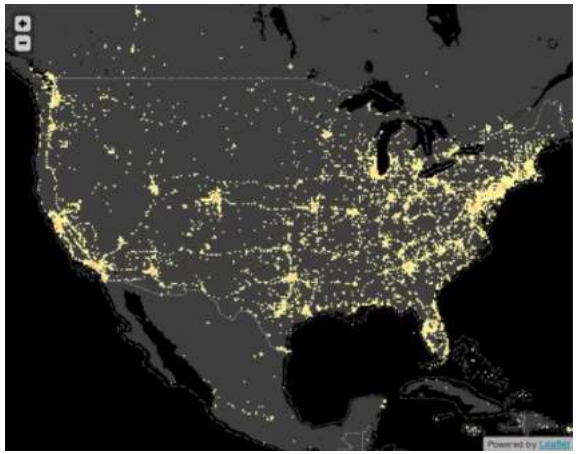
31 x 24 x 512 x 512 = 195 million+ cells

Sum-up along Day



24 x 512 x 512 = 6 million+ cells

Sum-up along Hour



512 x 512 cells

Full Data Cube: Limitations

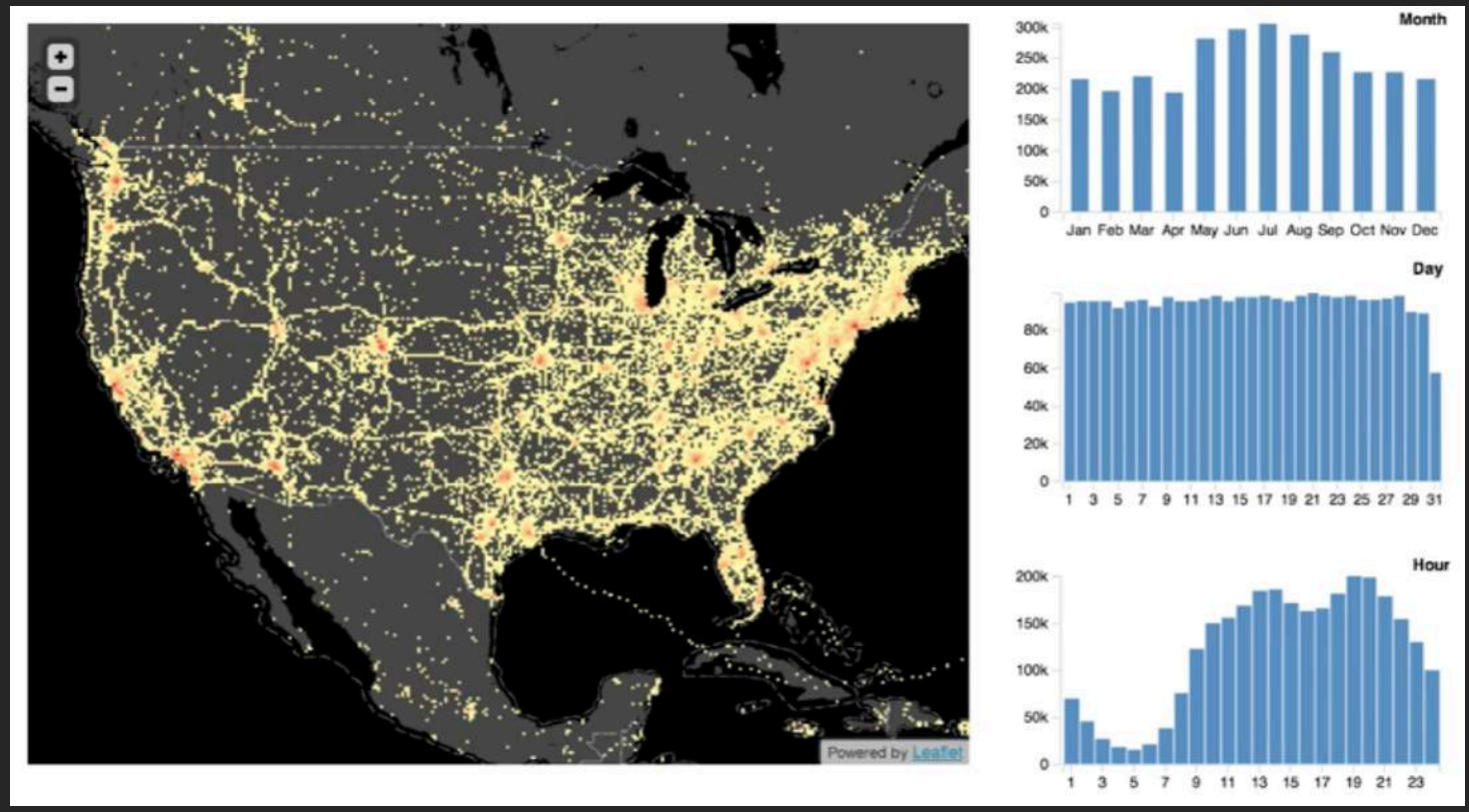
Unwieldy size (product of bin counts across all dimensions)

Inefficient query processing

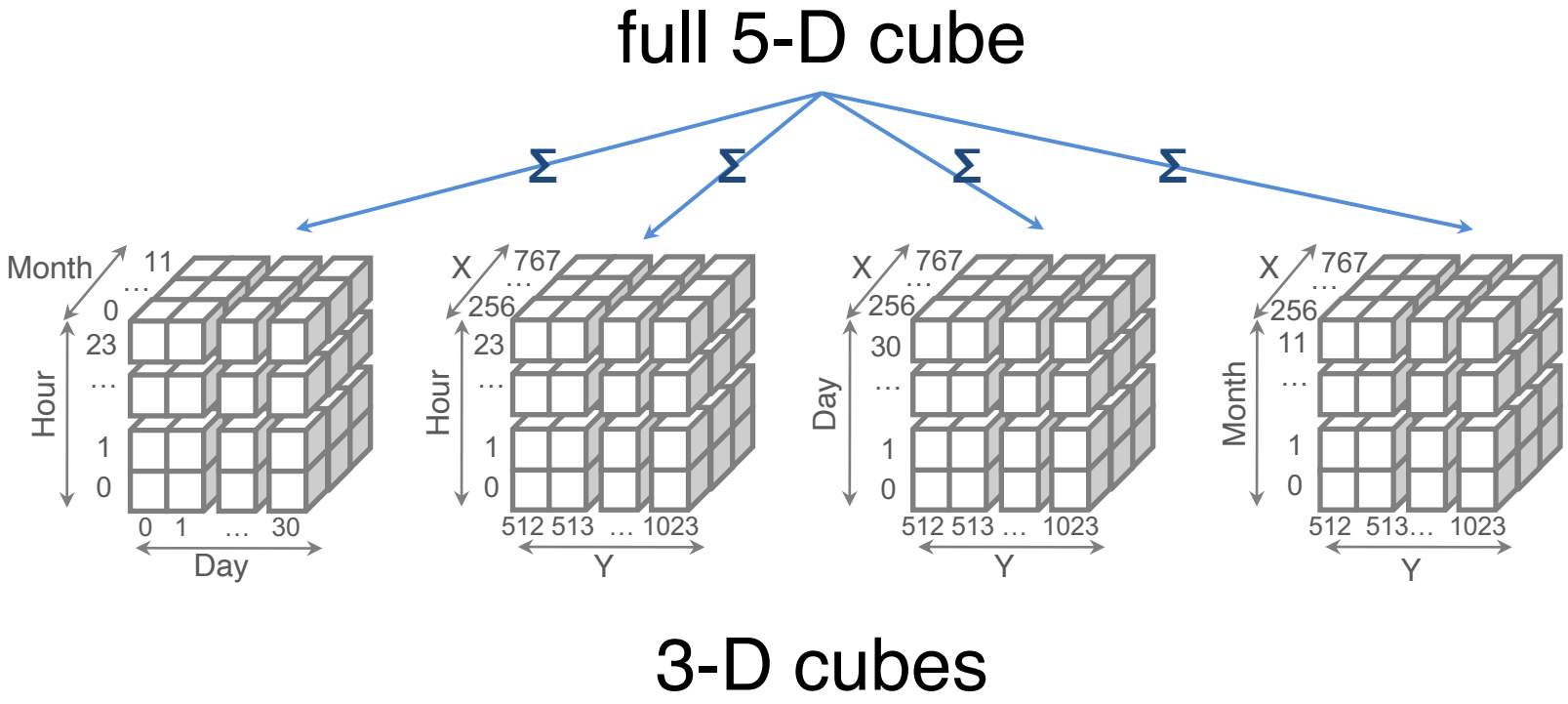
For any pair of plots

only 3 dimensions are involved

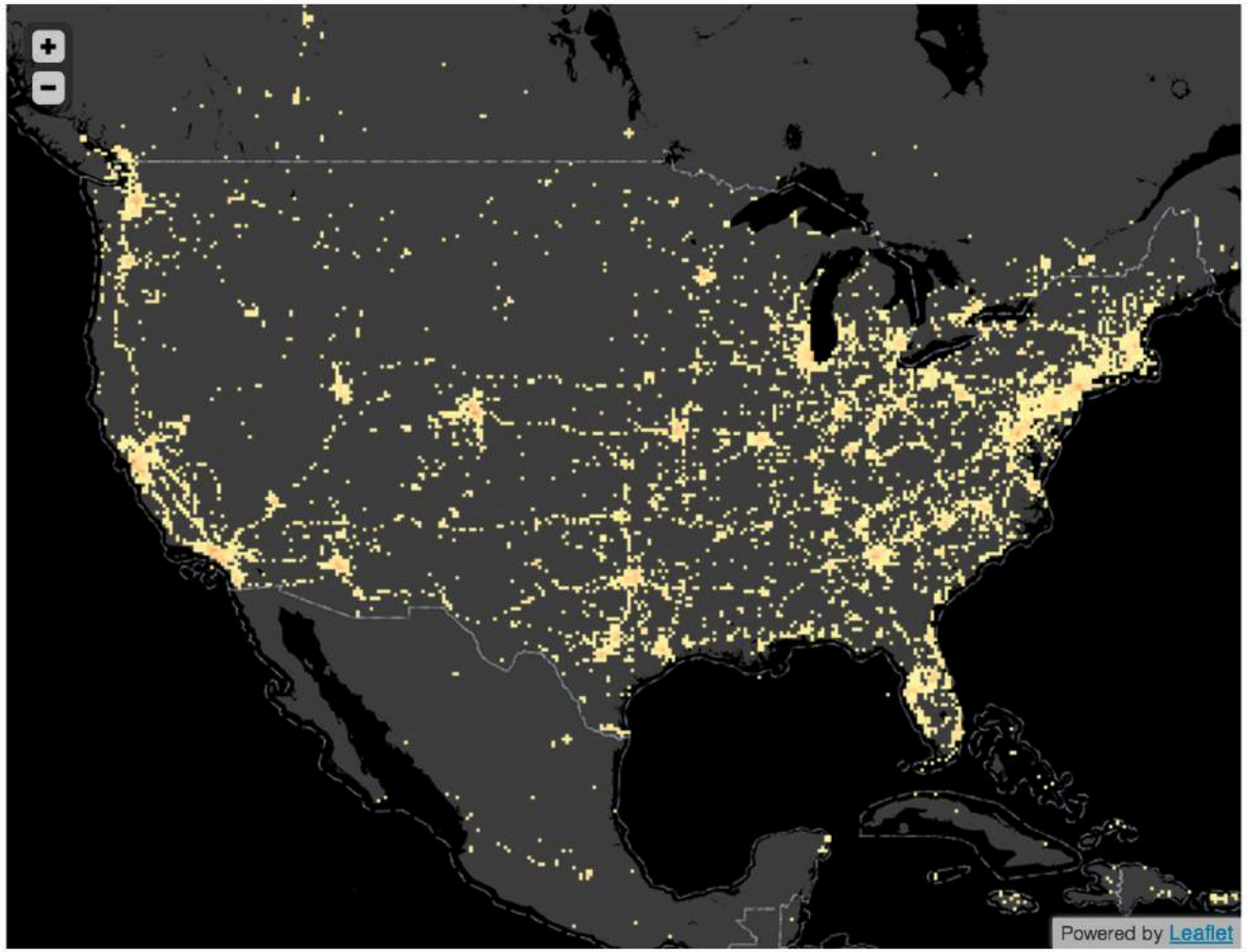
in brushing & linking.

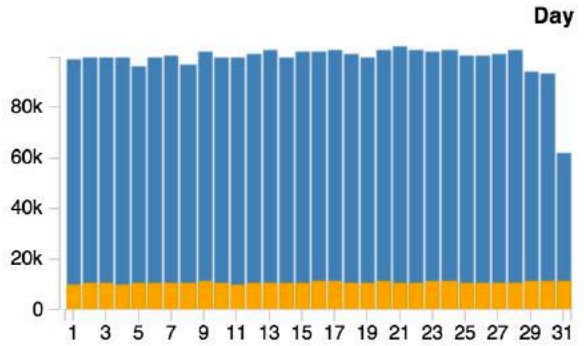


1. reduce number of dimensions

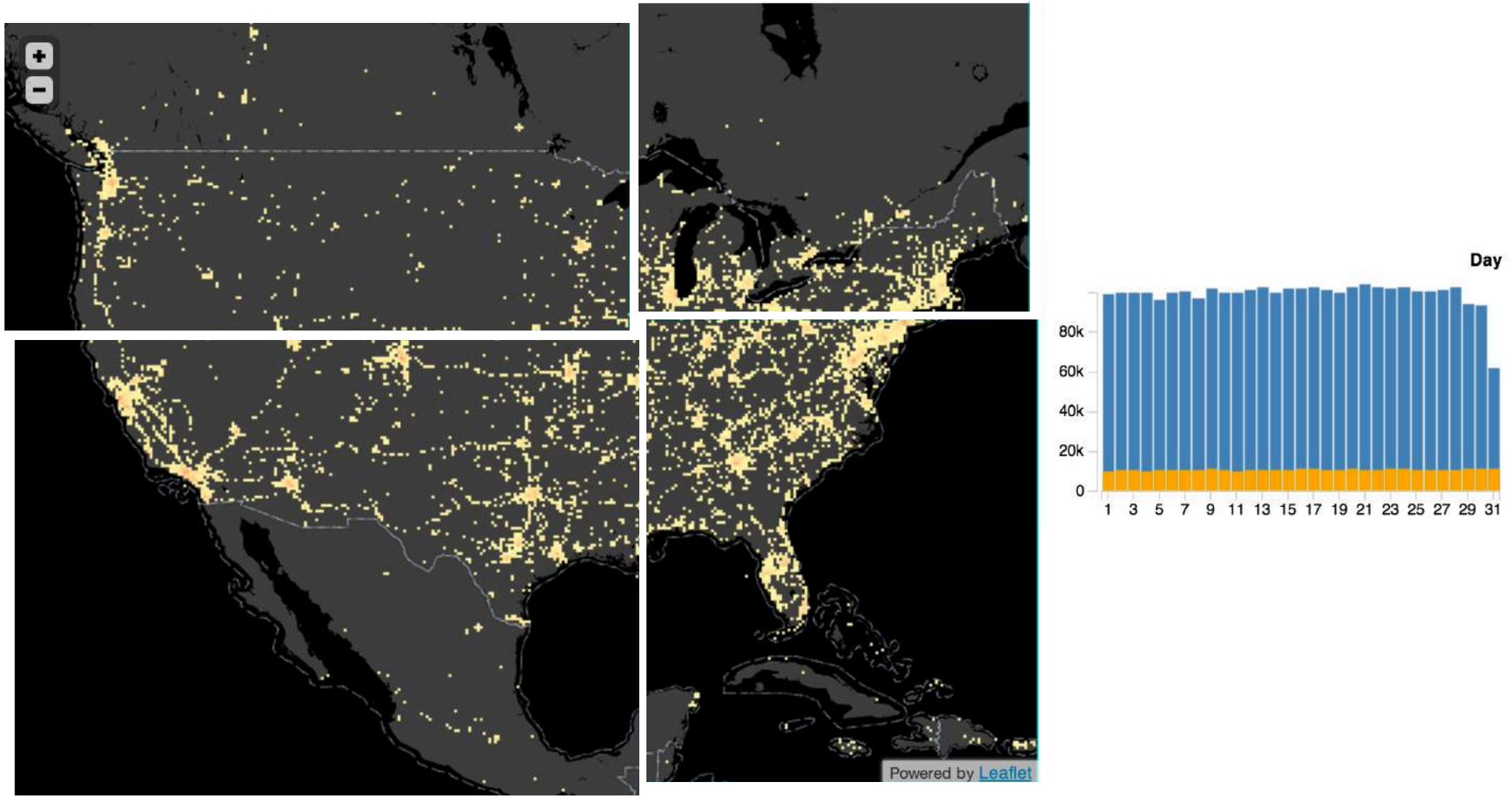


At low zoom levels, we still have potentially millions of bins





2. divide select dimension into ranges



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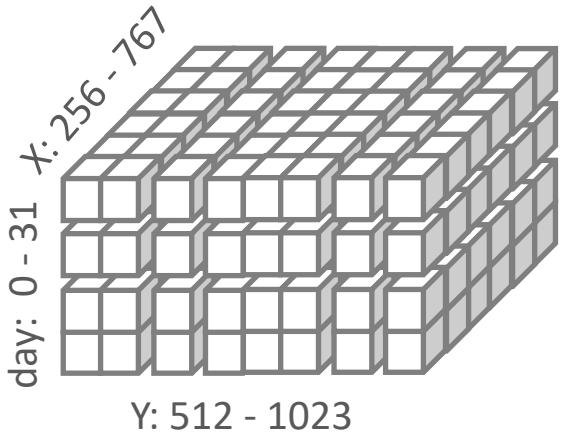
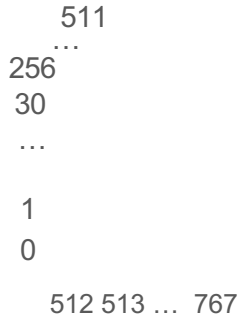
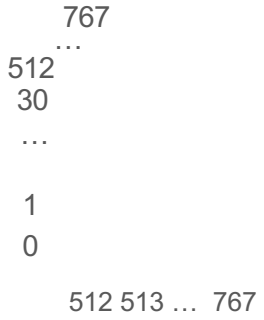
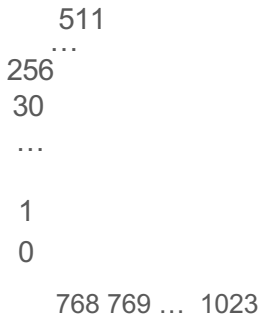
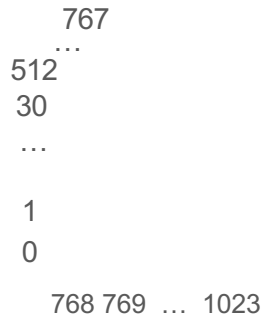






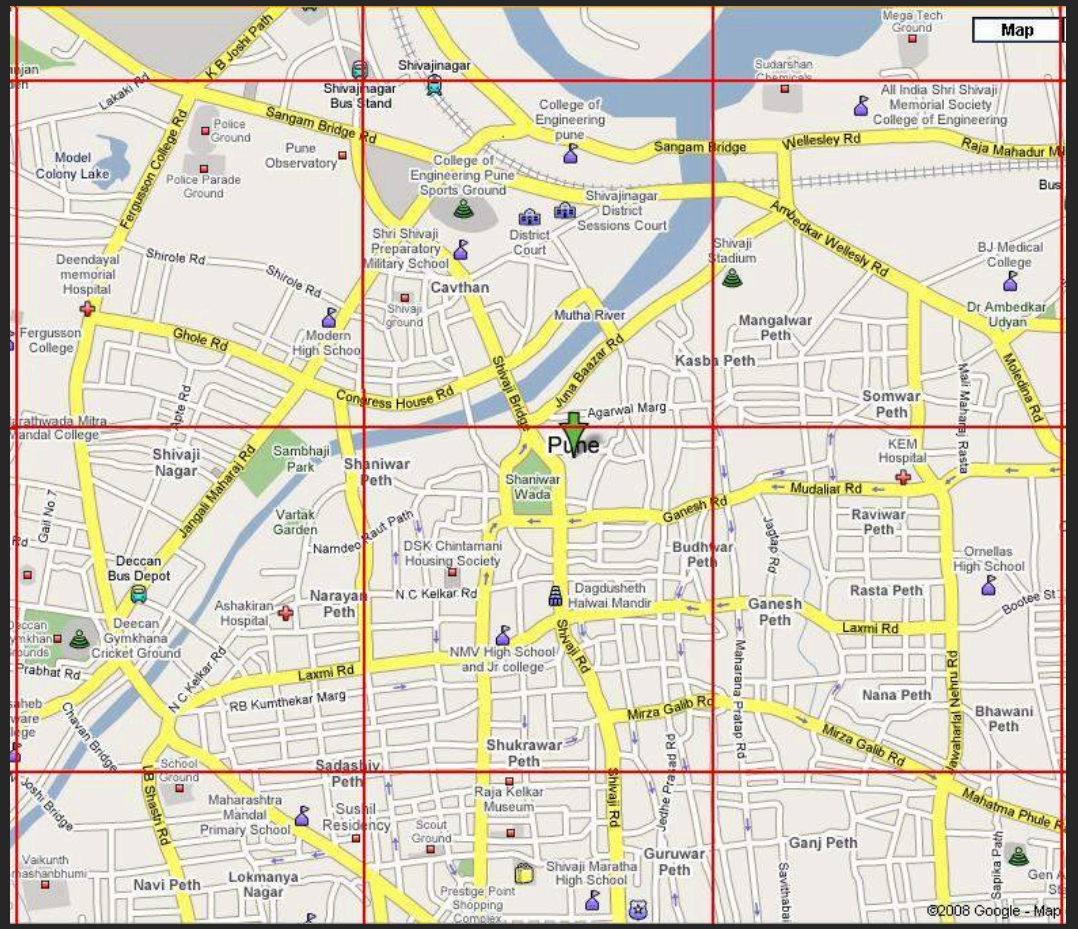




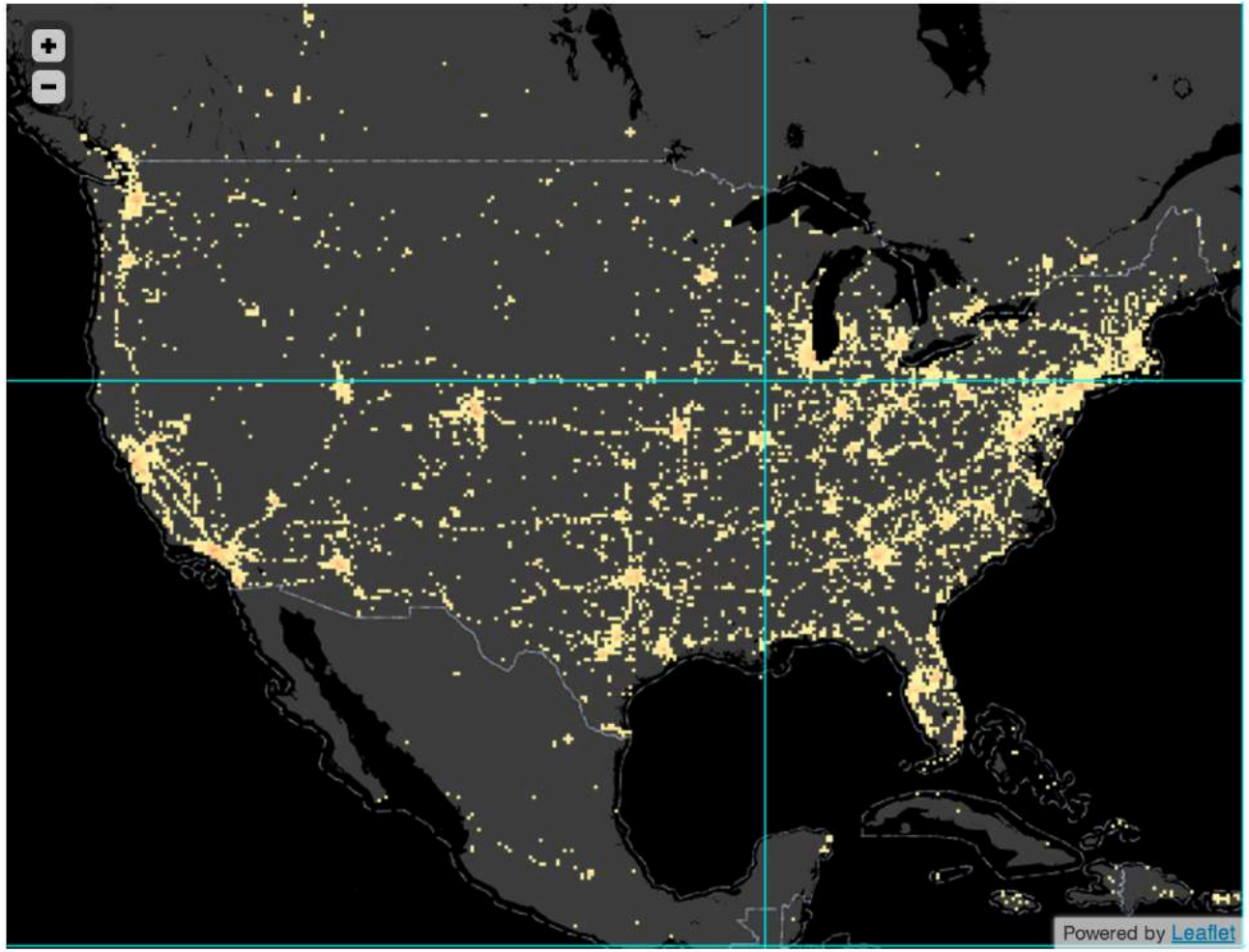
Data Tiles: Only Load what Users are Looking at

Multivariate data projections

Not pre-rendered images



Data Tiles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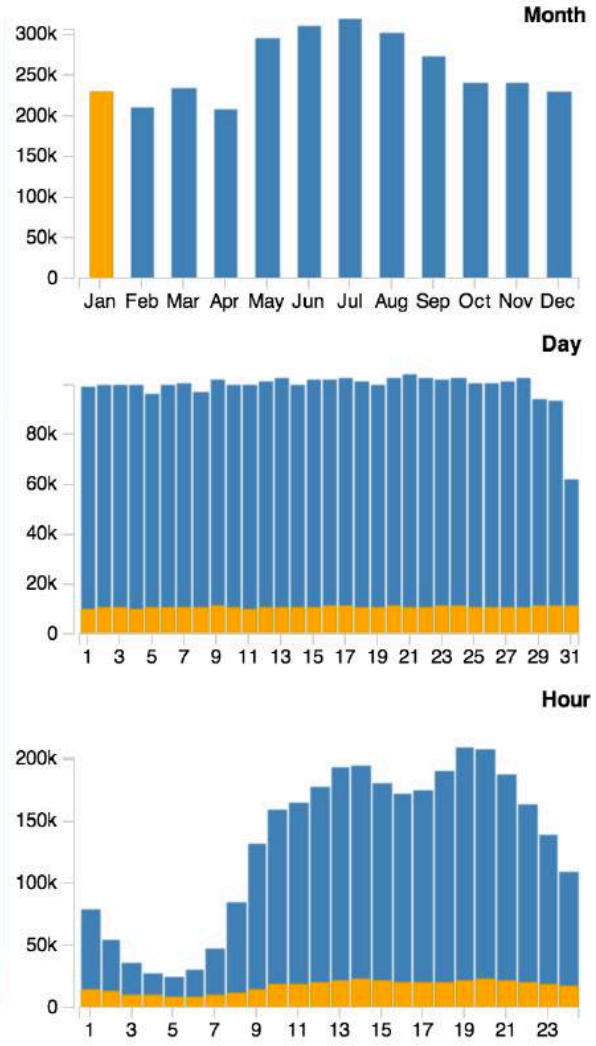
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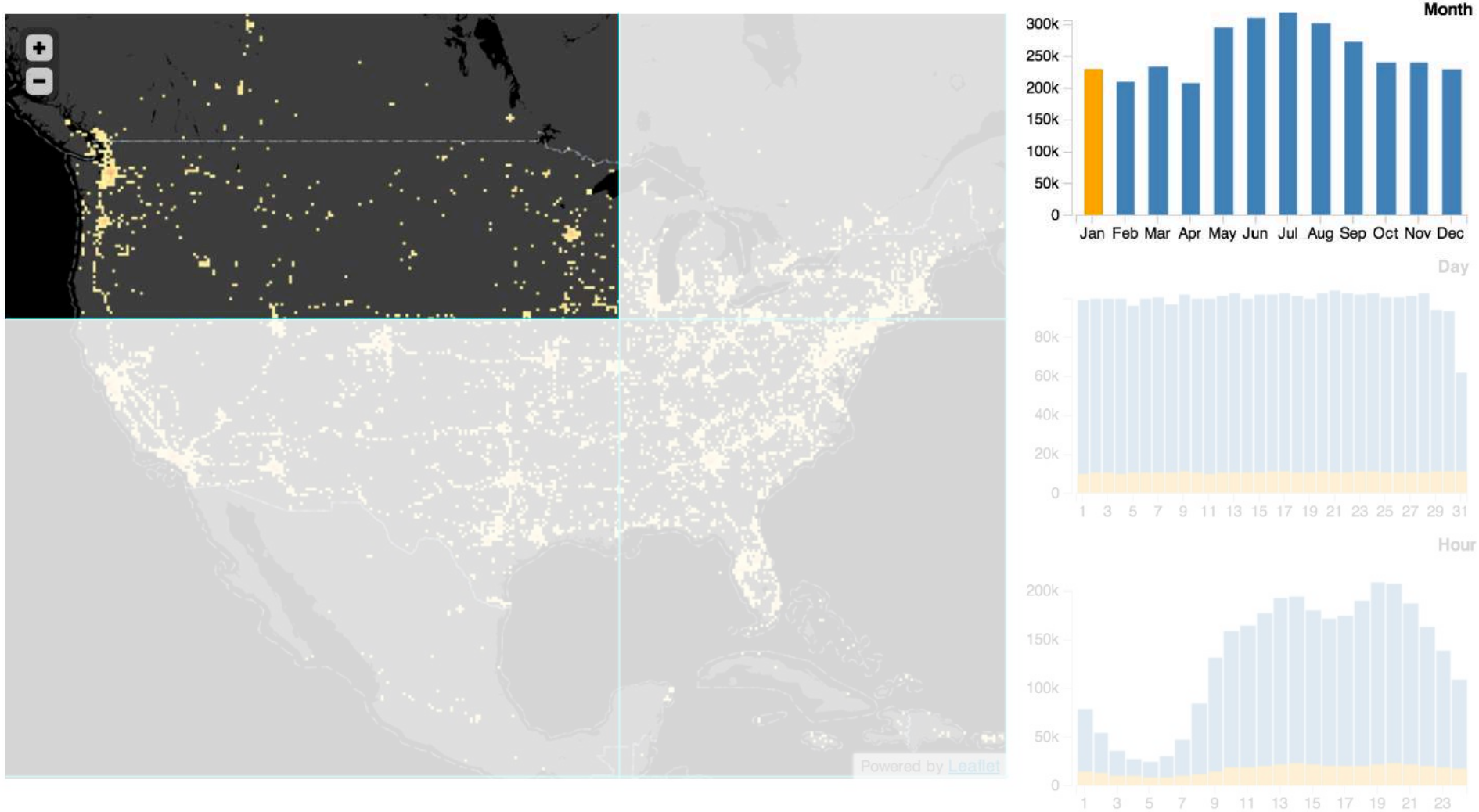
x1-y1-month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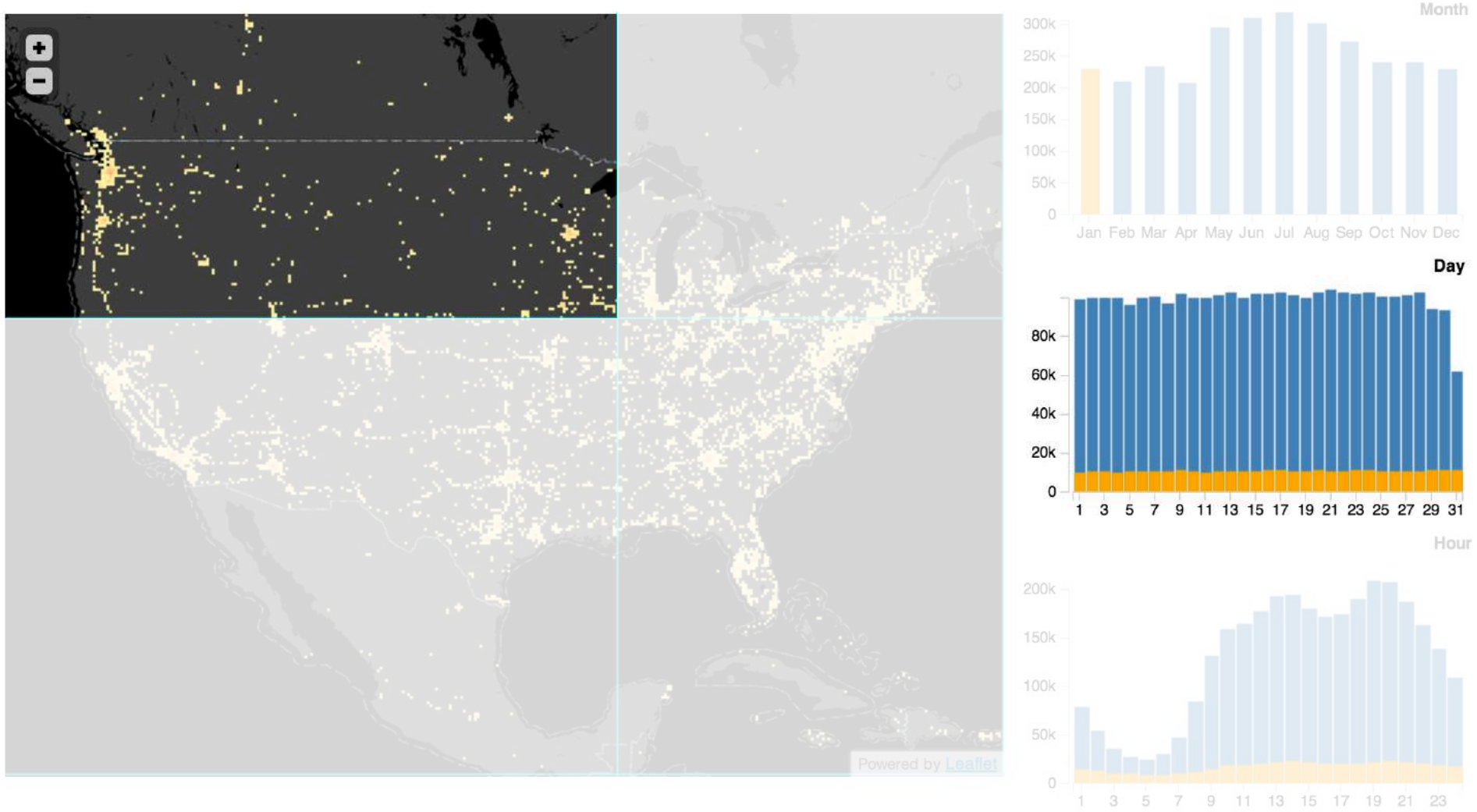
x1-y1-day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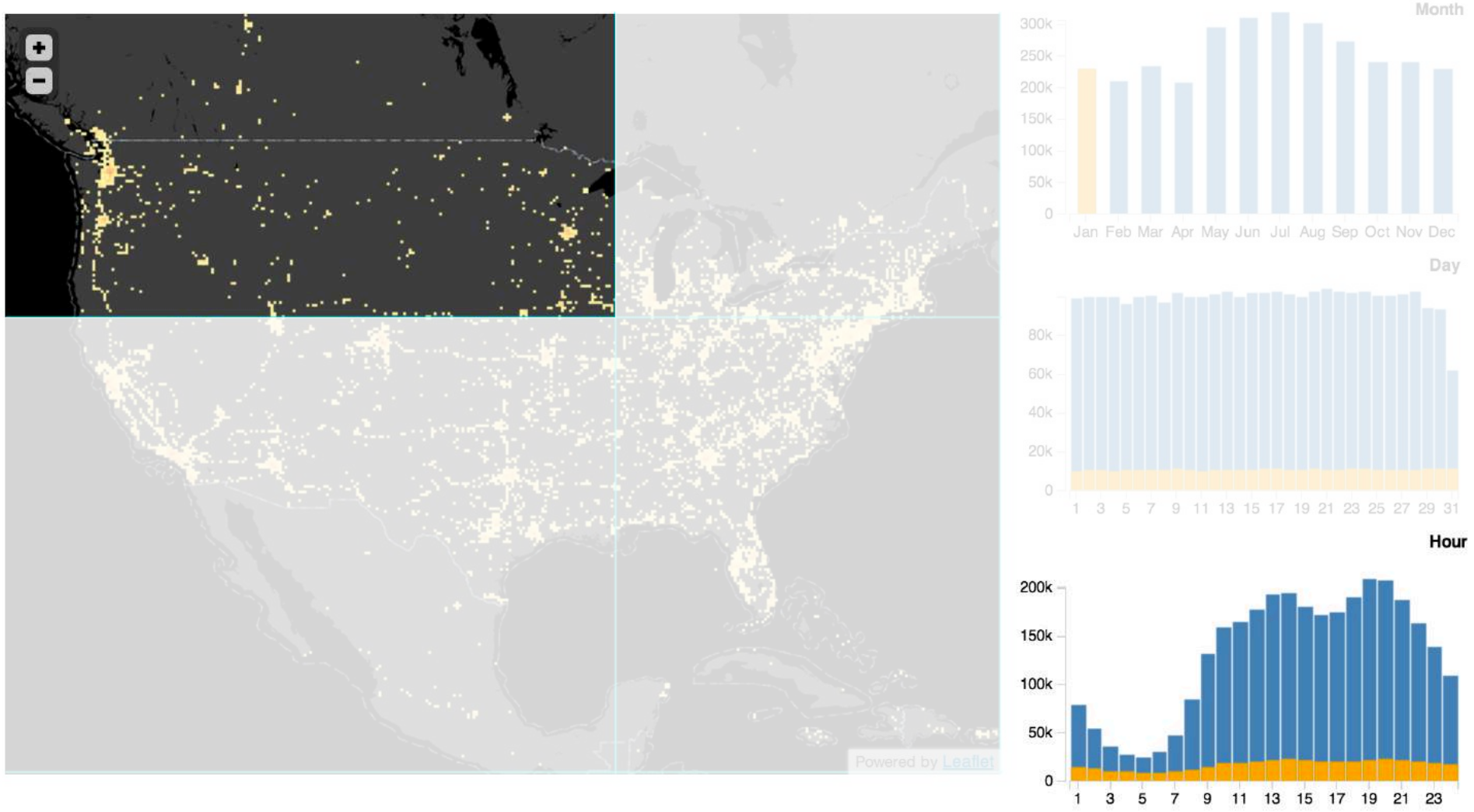
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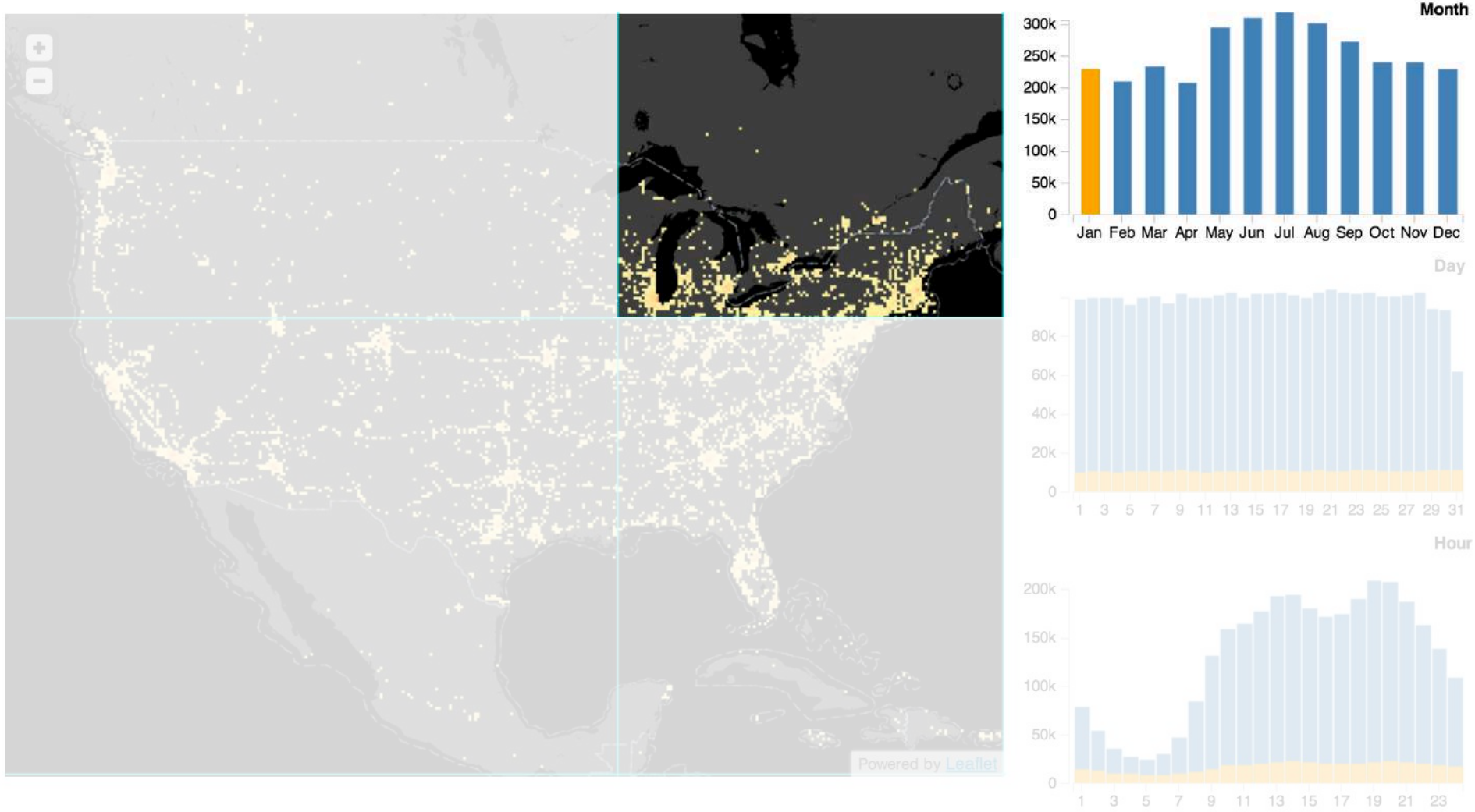
x1-y2-month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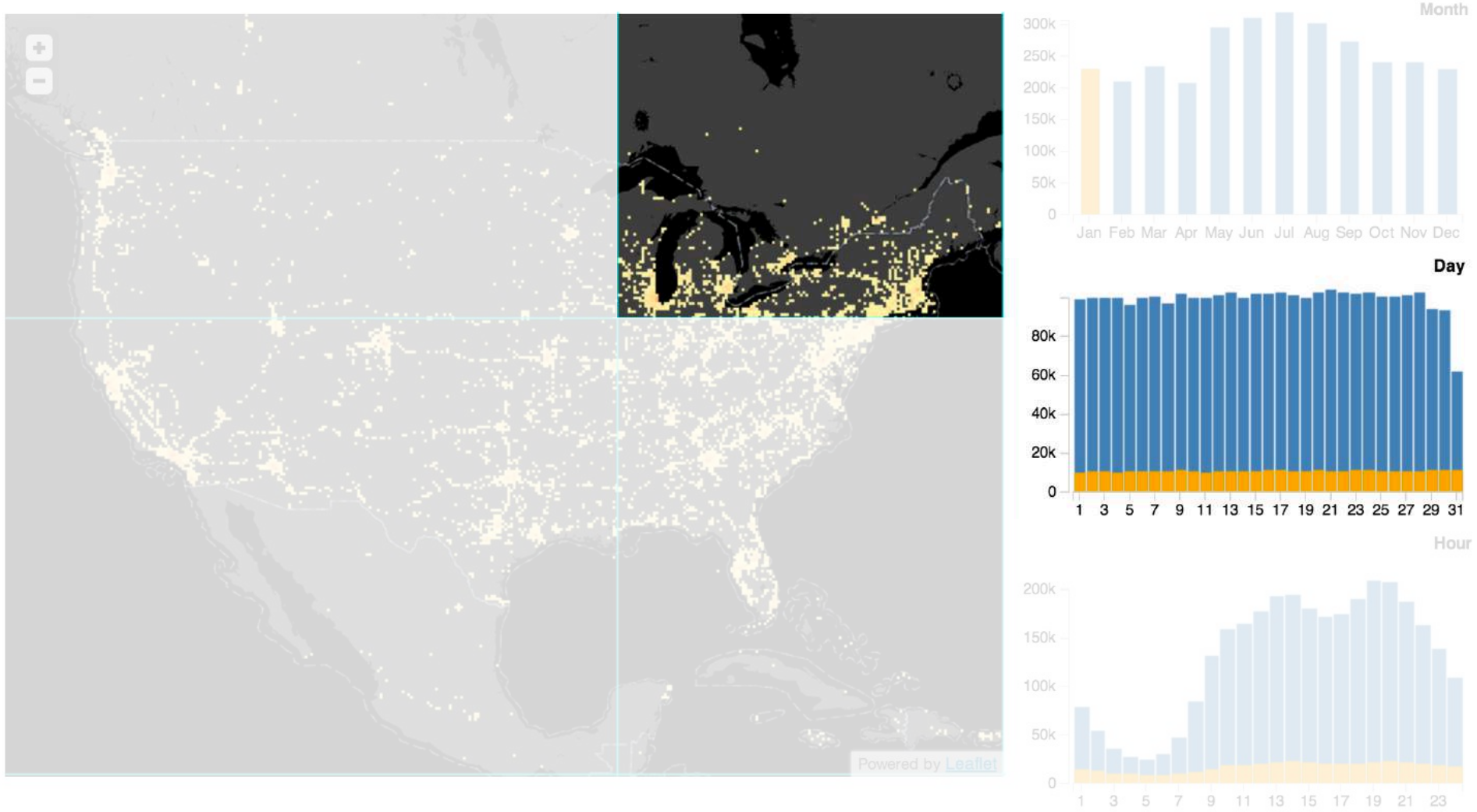
x1-y2-day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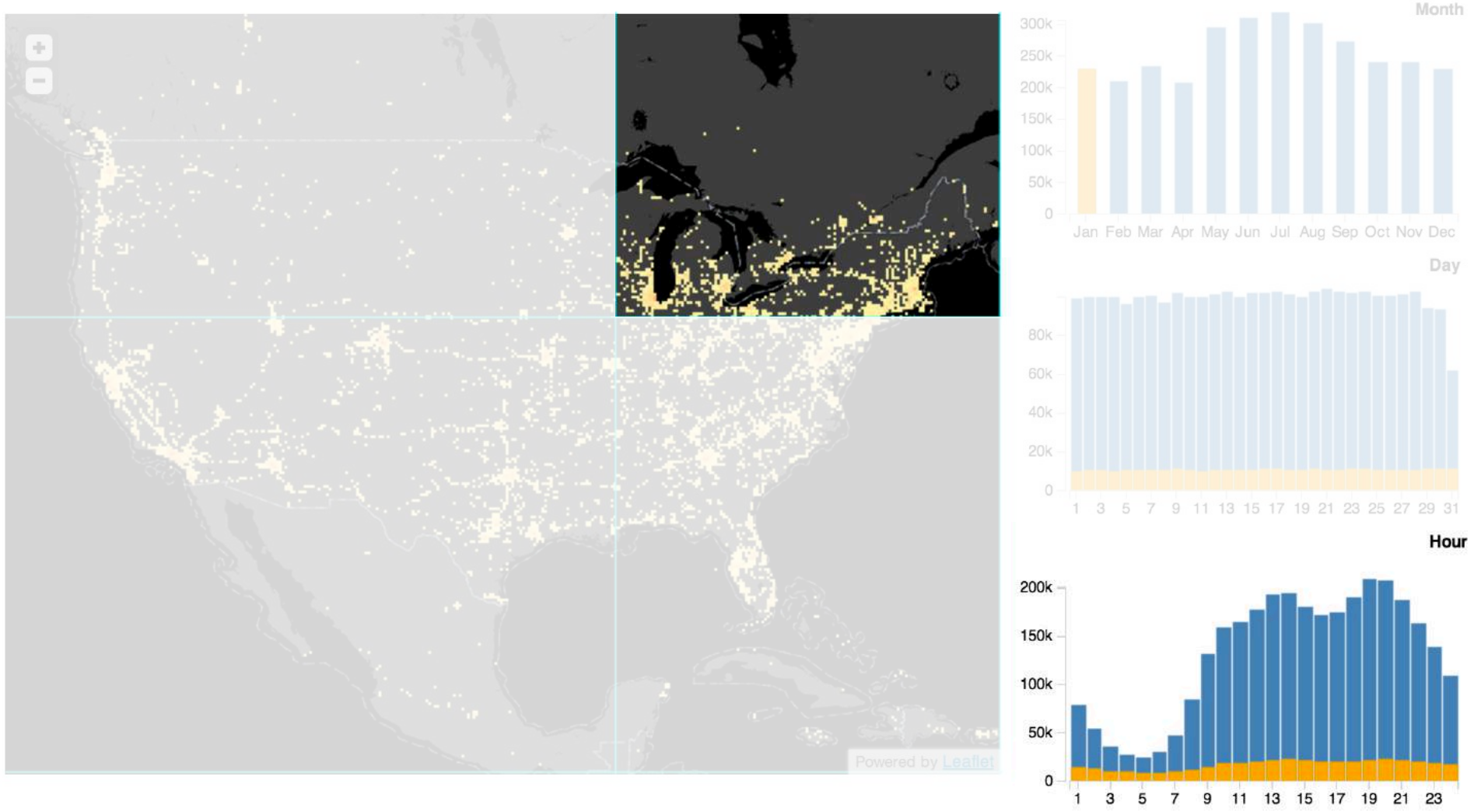
x1-y2-hour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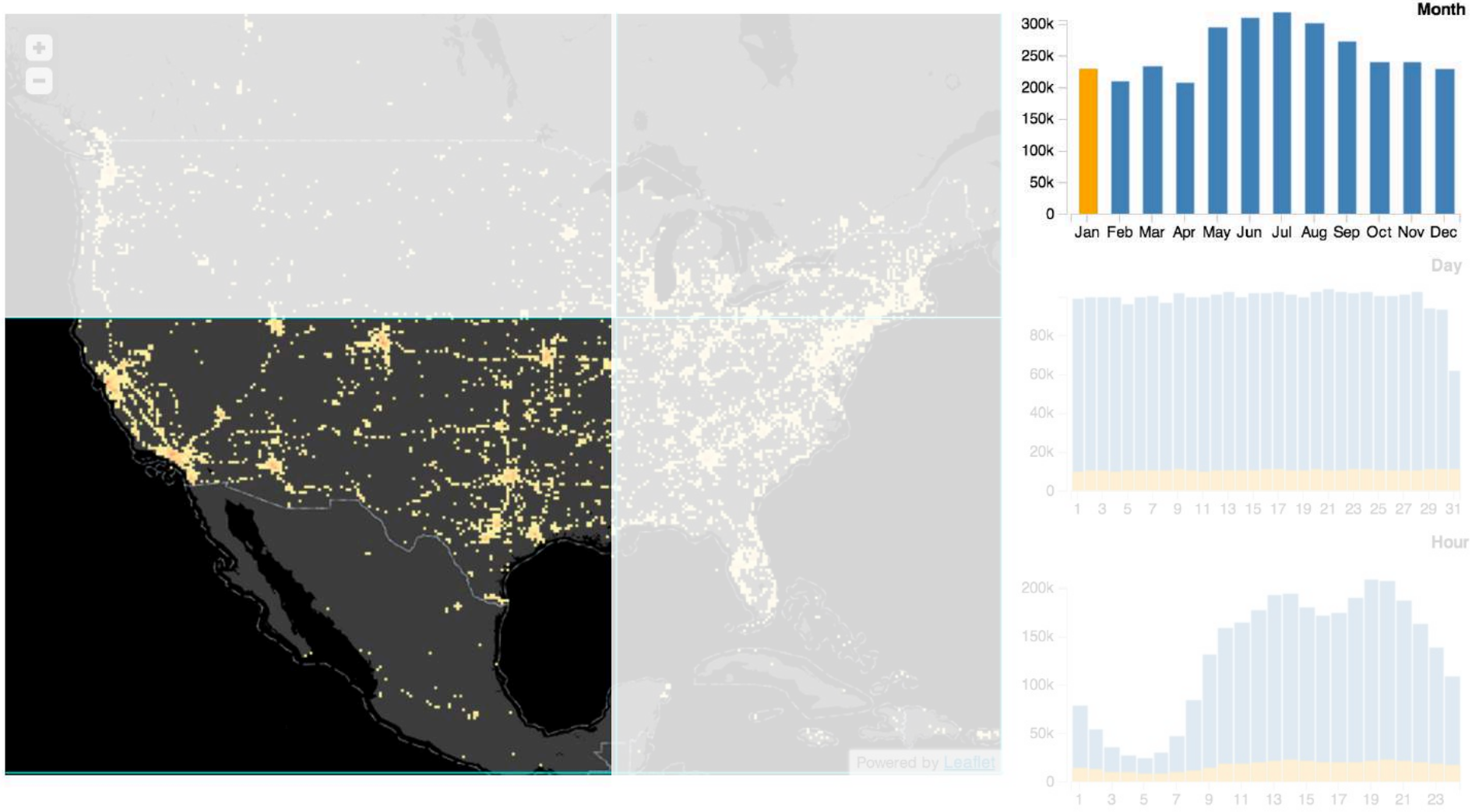
x2-y1-month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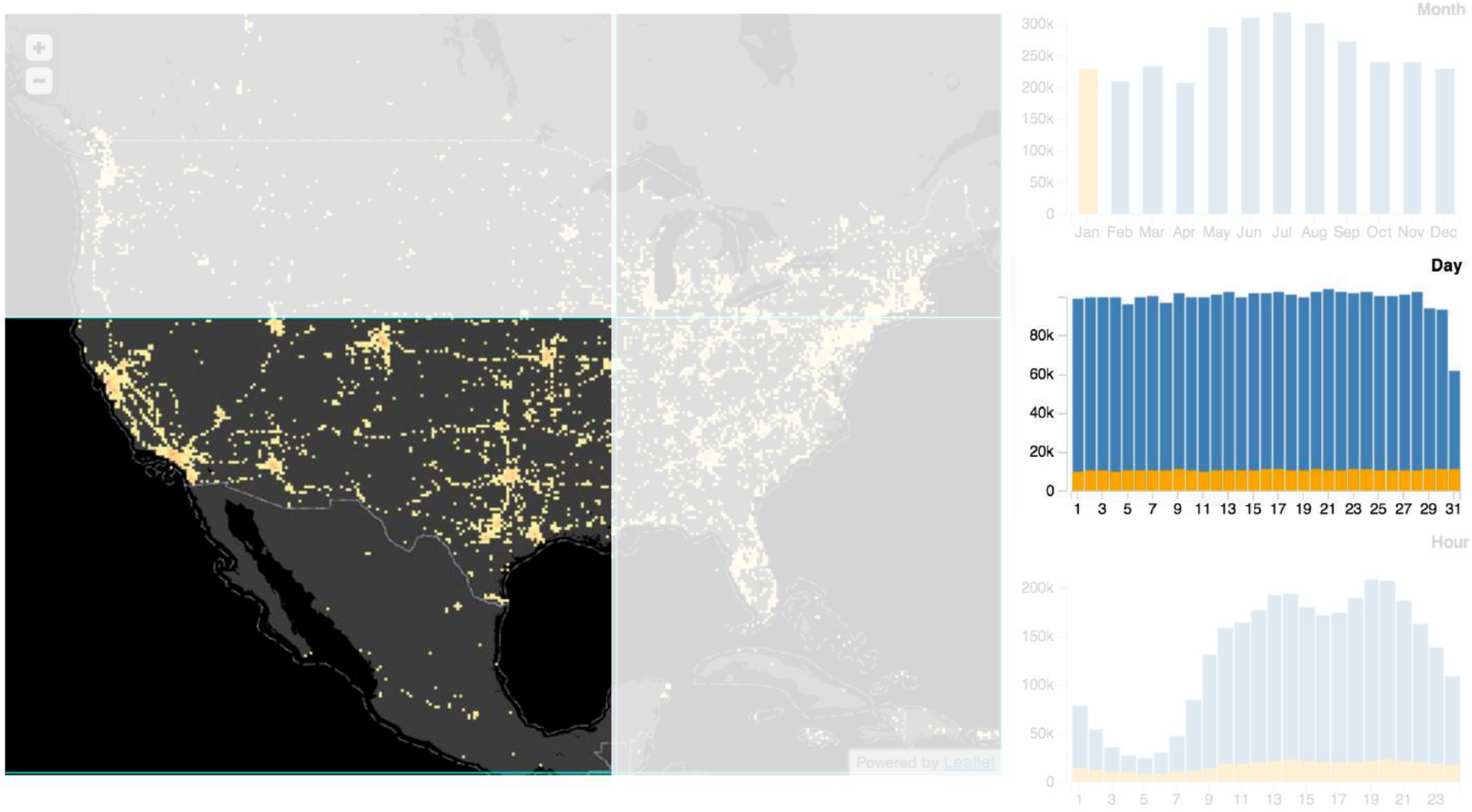
x2-y1-day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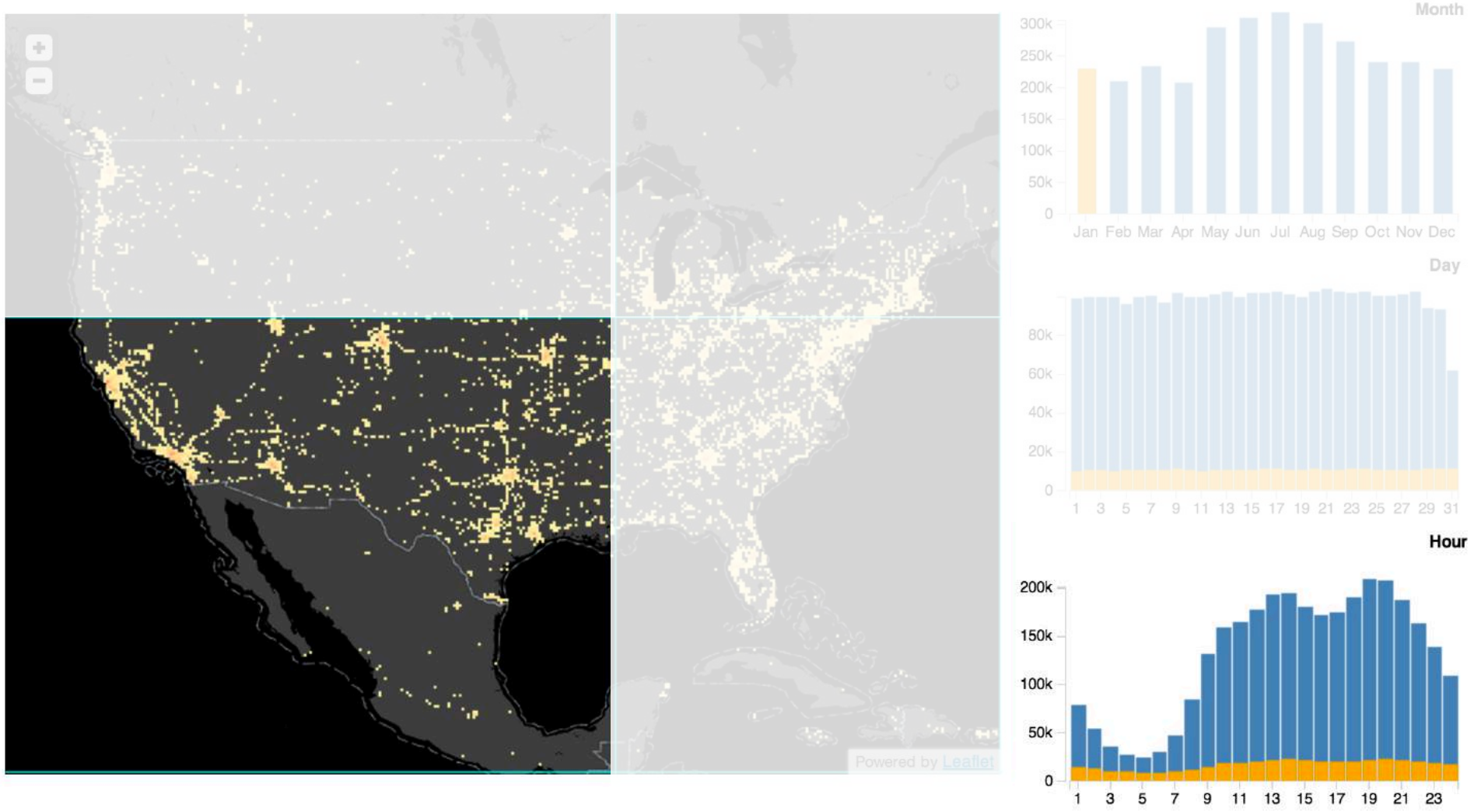
x2-y1-hour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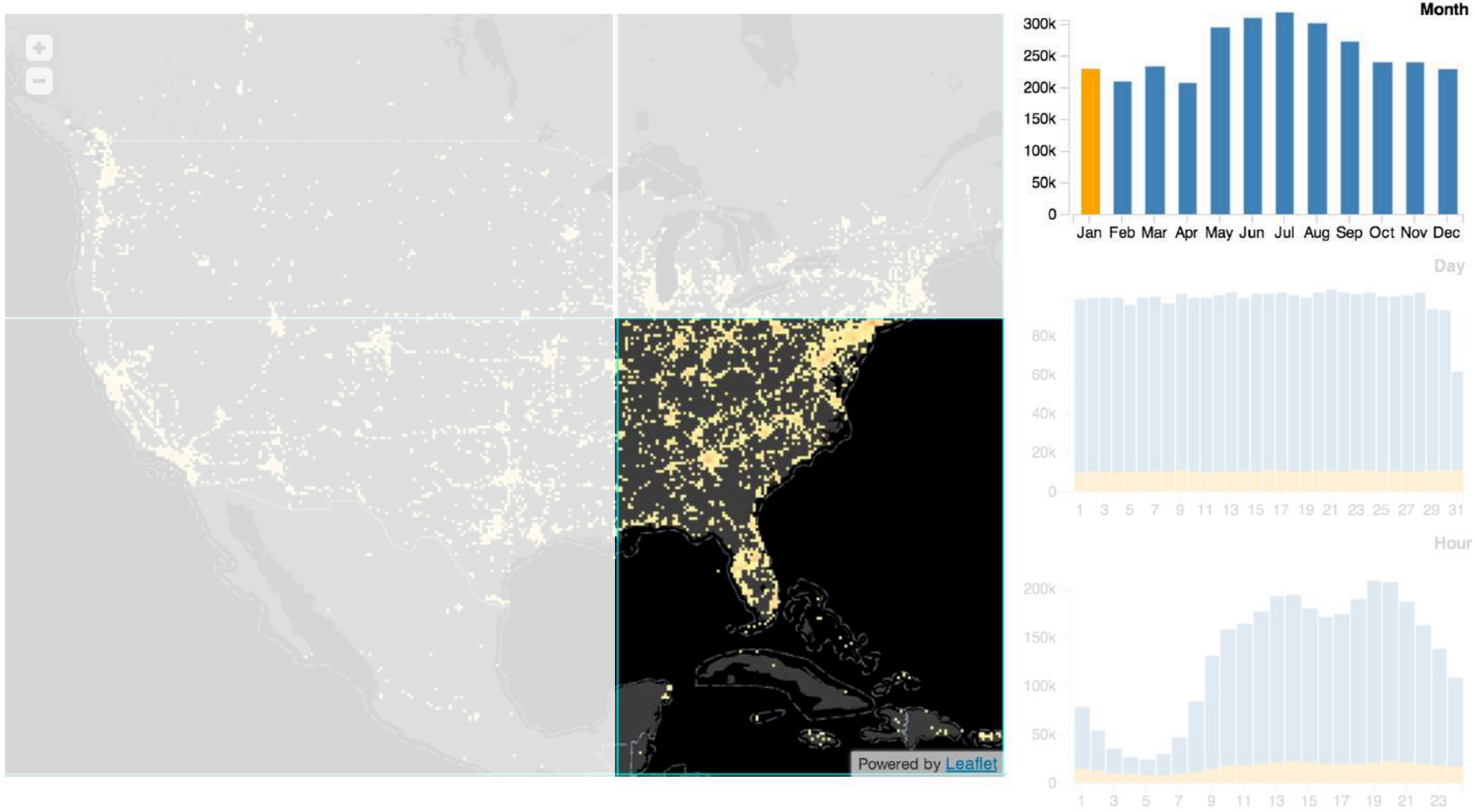
x2-y2-month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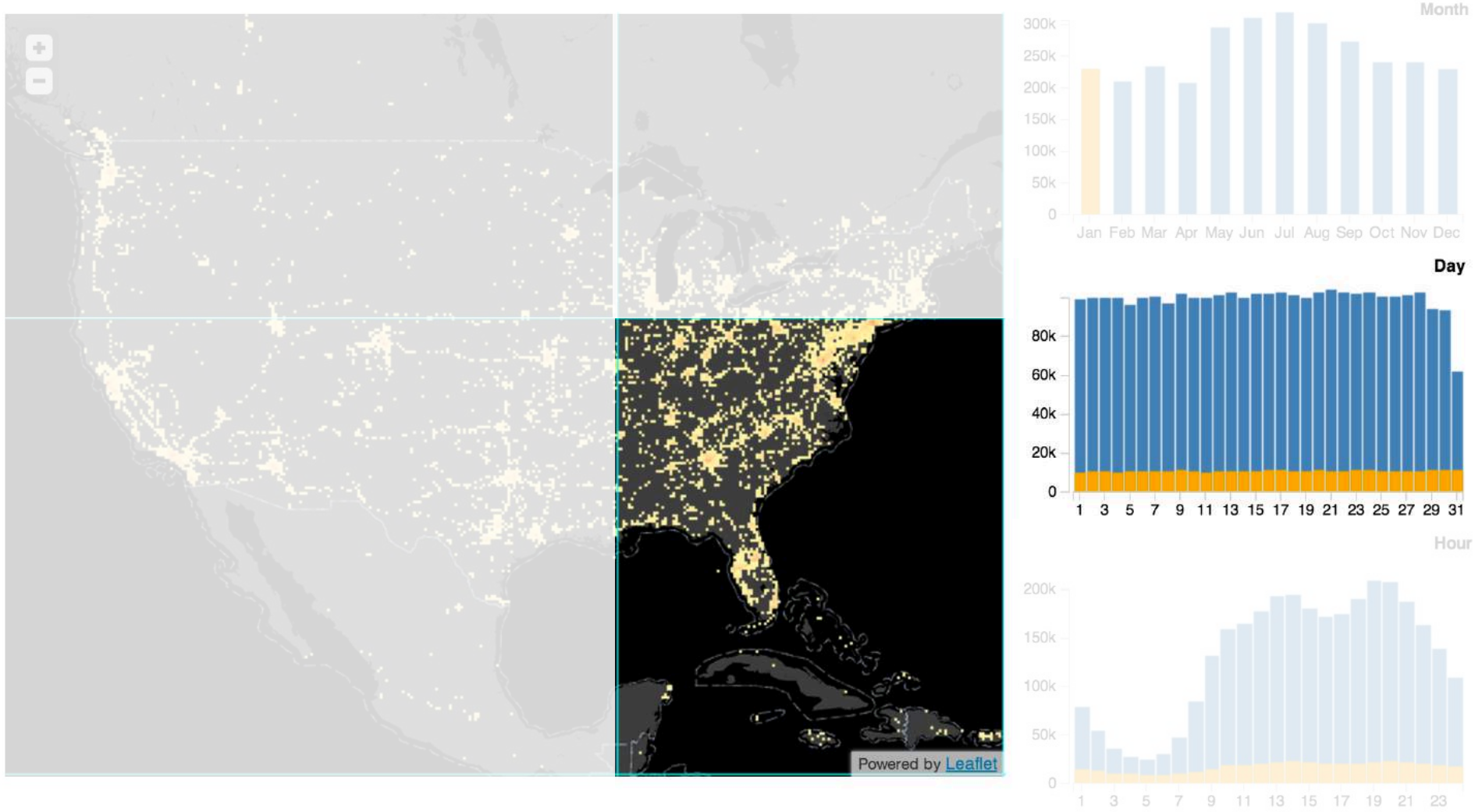
x2-y2-day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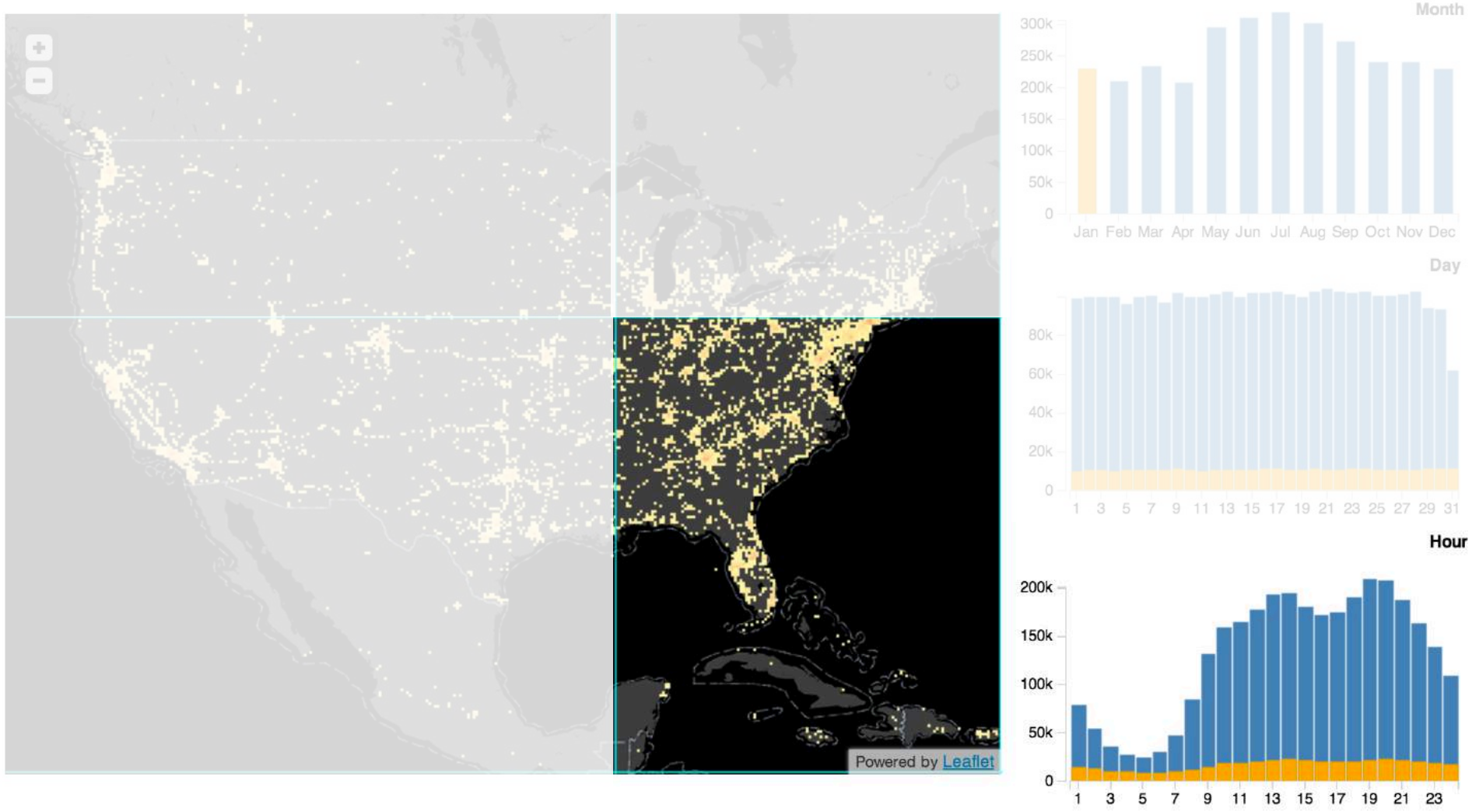
x2-y2-hour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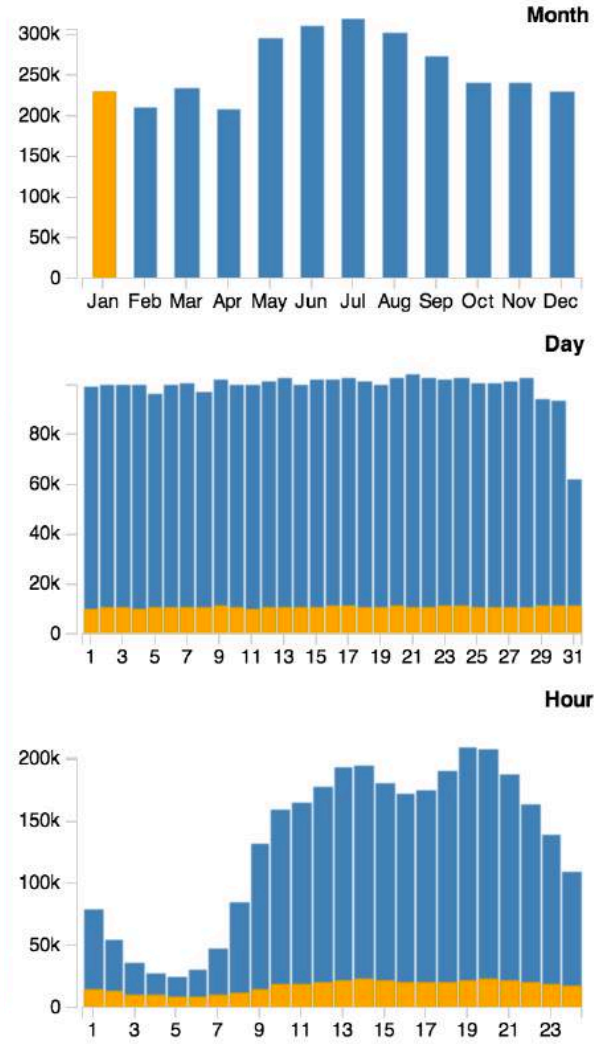
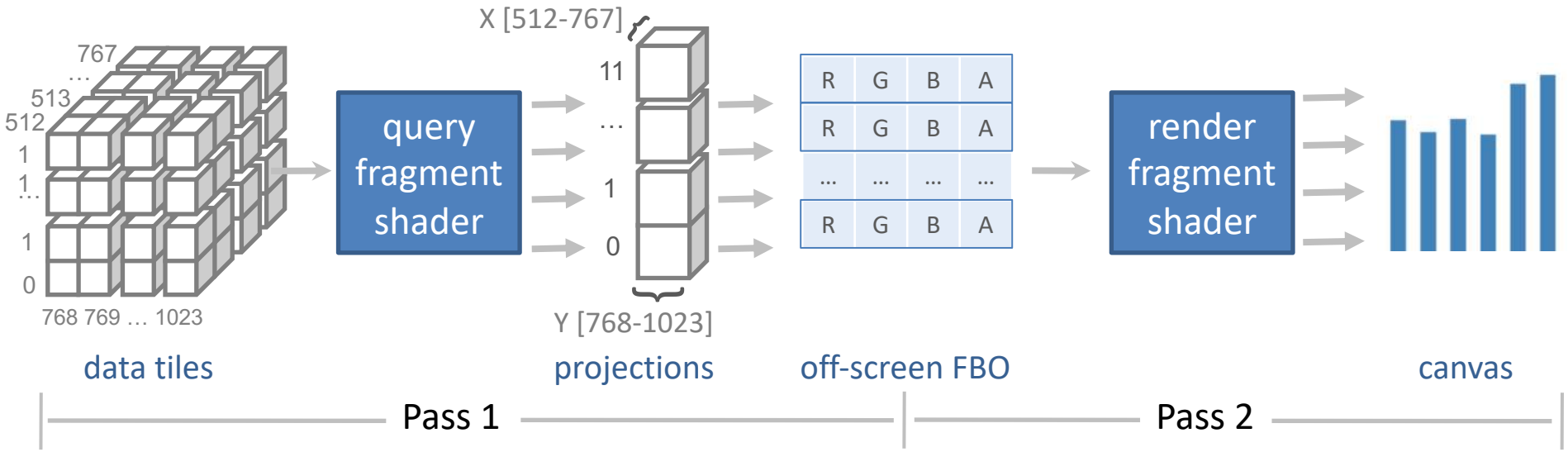
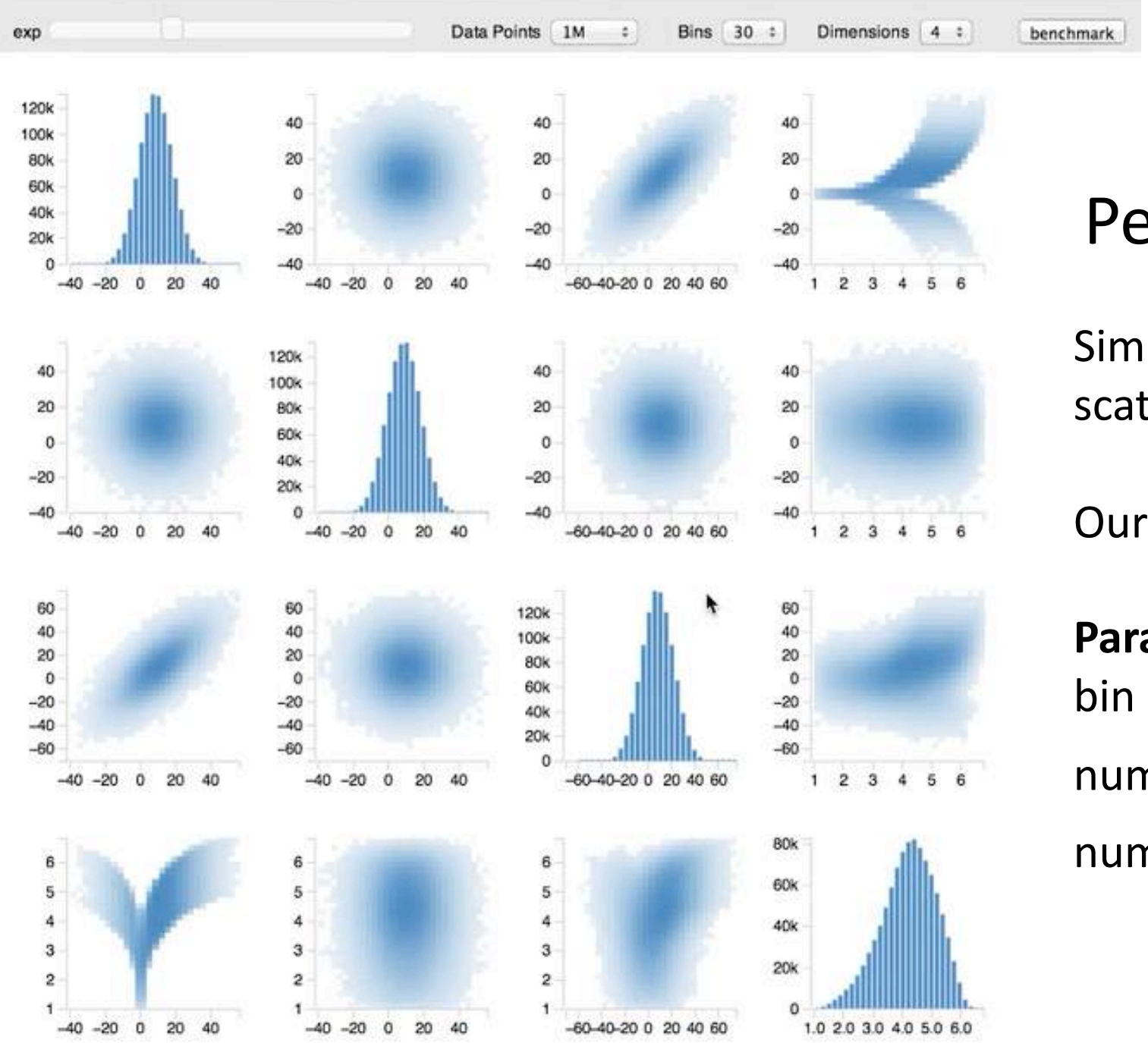
month-day-hour



Two-Pass Parallel Processing



Pack data tiles as images (352KB for 13 data tiles)
Bind to WebGL context as textures



Performance Benchmarks

Simulate brush & linking across plots in a scatter plot matrix

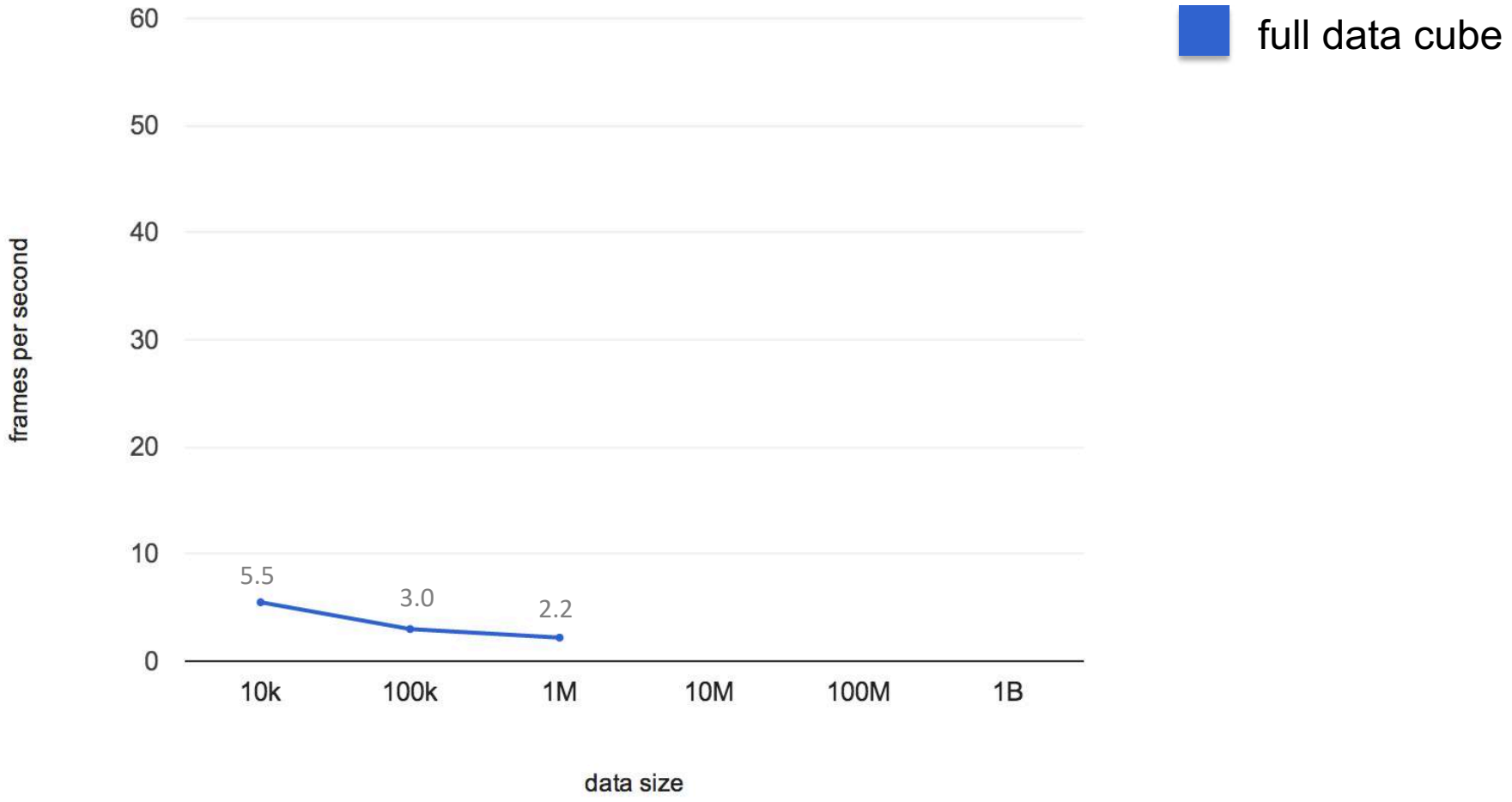
Our approach vs. full data cube

Parameters

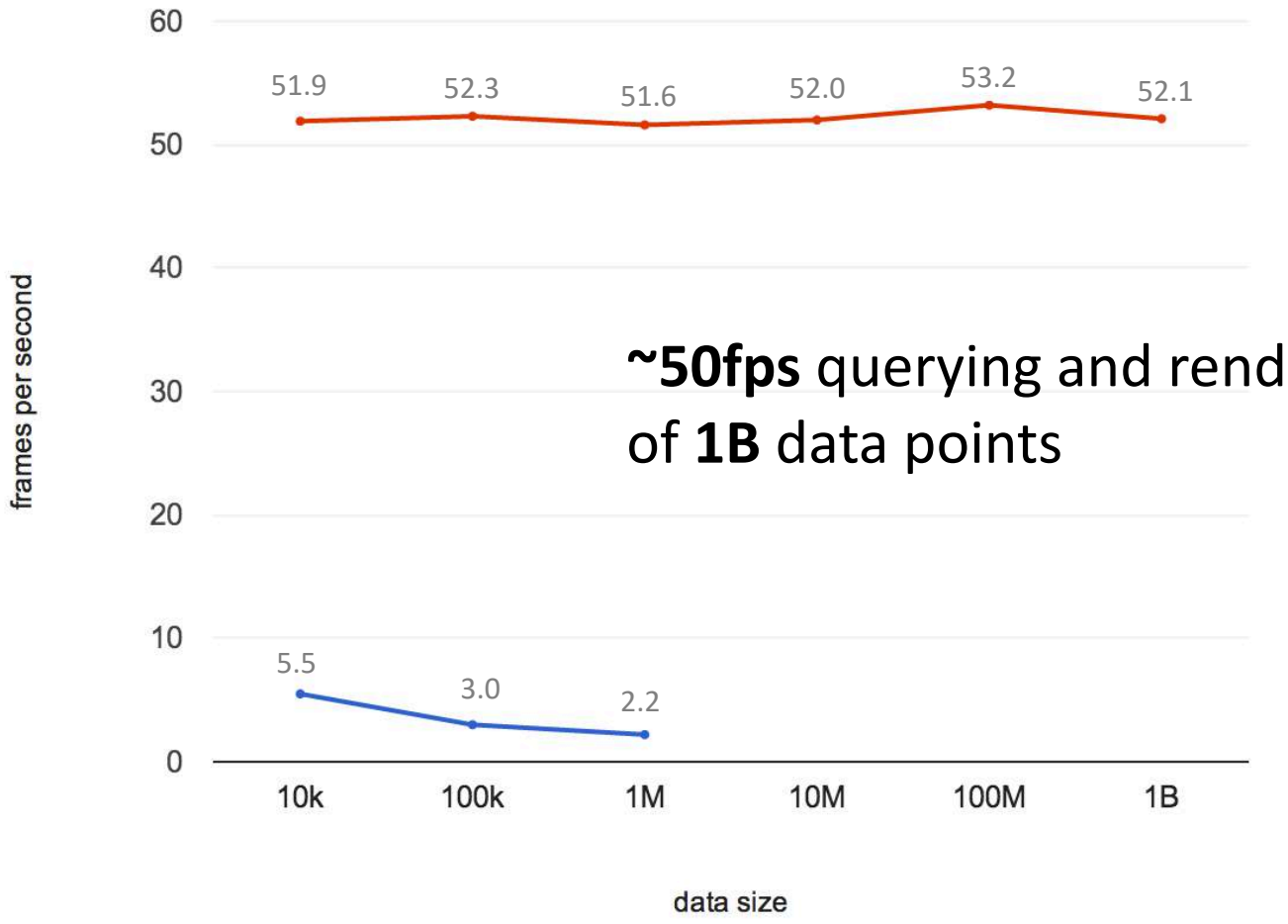
bin count per dimension (10 - 50)

number of records (10K - 1B)

number of dimensions (4,5)



Google Chrome v.23.0.1271.95 on a quad-core 2.3 GHz MacBook Pro (OS X 10.8.2) with per-core 256K L2 caches, shared 6MB L3 cache and 8GB RAM. PCI Express NVIDIA GeForce GT 650M graphics card with 1024MB video RAM.



full data cube

imMens (our approach)

~50fps querying and rendering of **1B** data points

Google Chrome v.23.0.1271.95 on a quad-core 2.3 GHz MacBook Pro (OS X 10.8.2) with per-core 256K L2 caches, shared 6MB L3 cache and 8GB RAM. PCI Express NVIDIA GeForce GT 650M graphics card with 1024MB video RAM.

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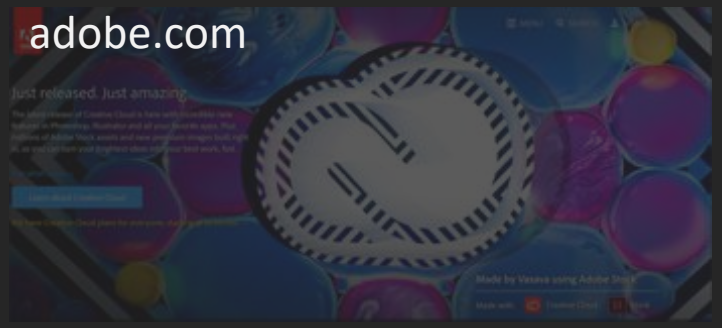
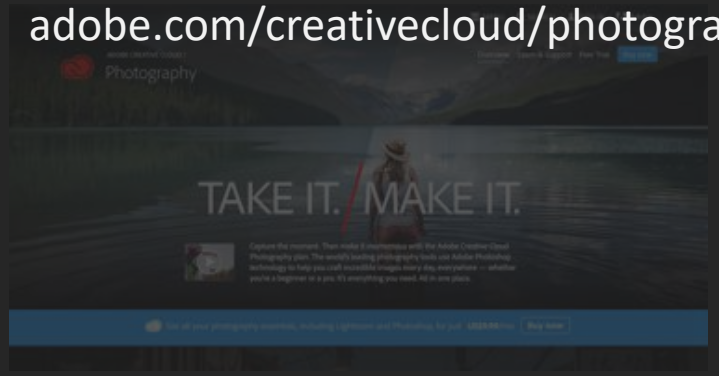
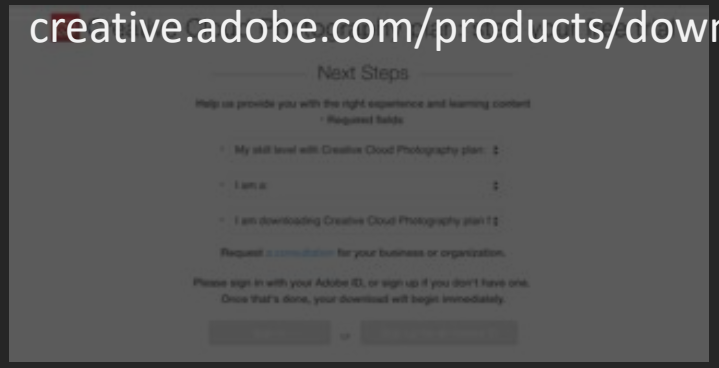
06/29/2016 16:01:20	adobe.com 
06/29/2016 16:03:04	adobe.com/creativecloud/photography.html 
06/29/2016 16:03:29	creative.adobe.com/products/download/ccpp 

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06/29/2016 16:19:03	Account:IMS:SignIn:Error_EmptyEmail
06/29/2016 16:19:44	Account:IMS:SignIn:Error_EmptyEmail
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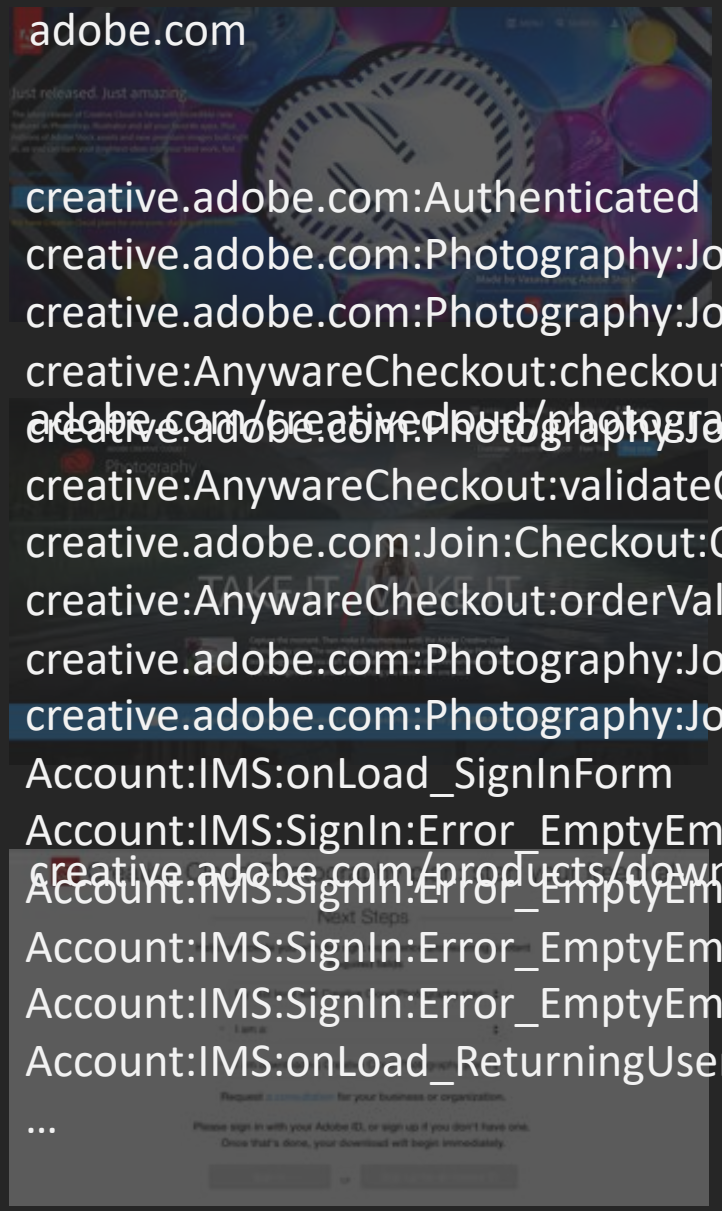
....	...



06/29/2016 16:03:04 adobe.com/creativecloud/photography.html

06/29/2016 16:03:29 creative.adobe.com/products/download/ccpp

Event Sequence Data: Web Clickstreams

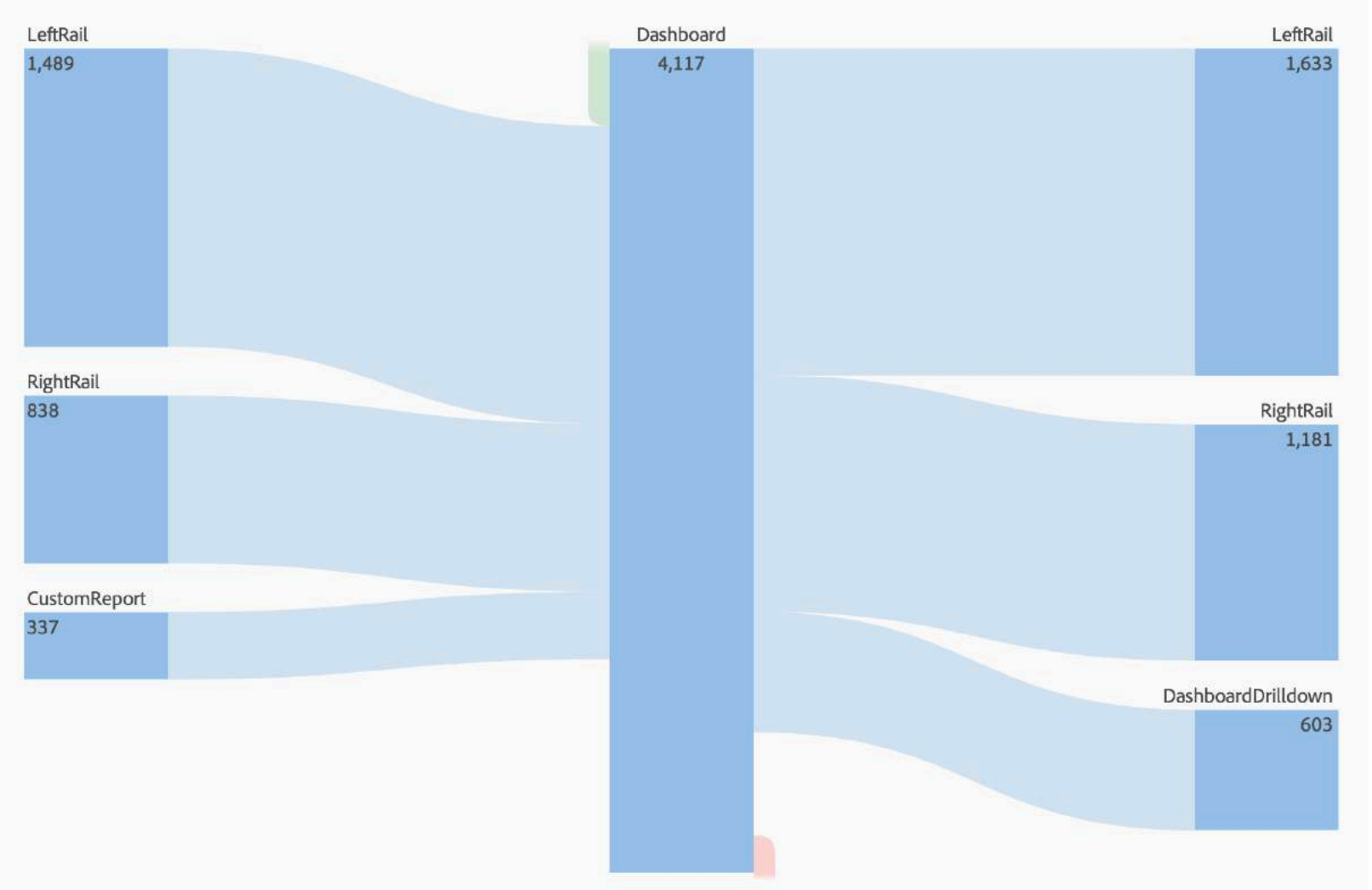
Analysis Goals:

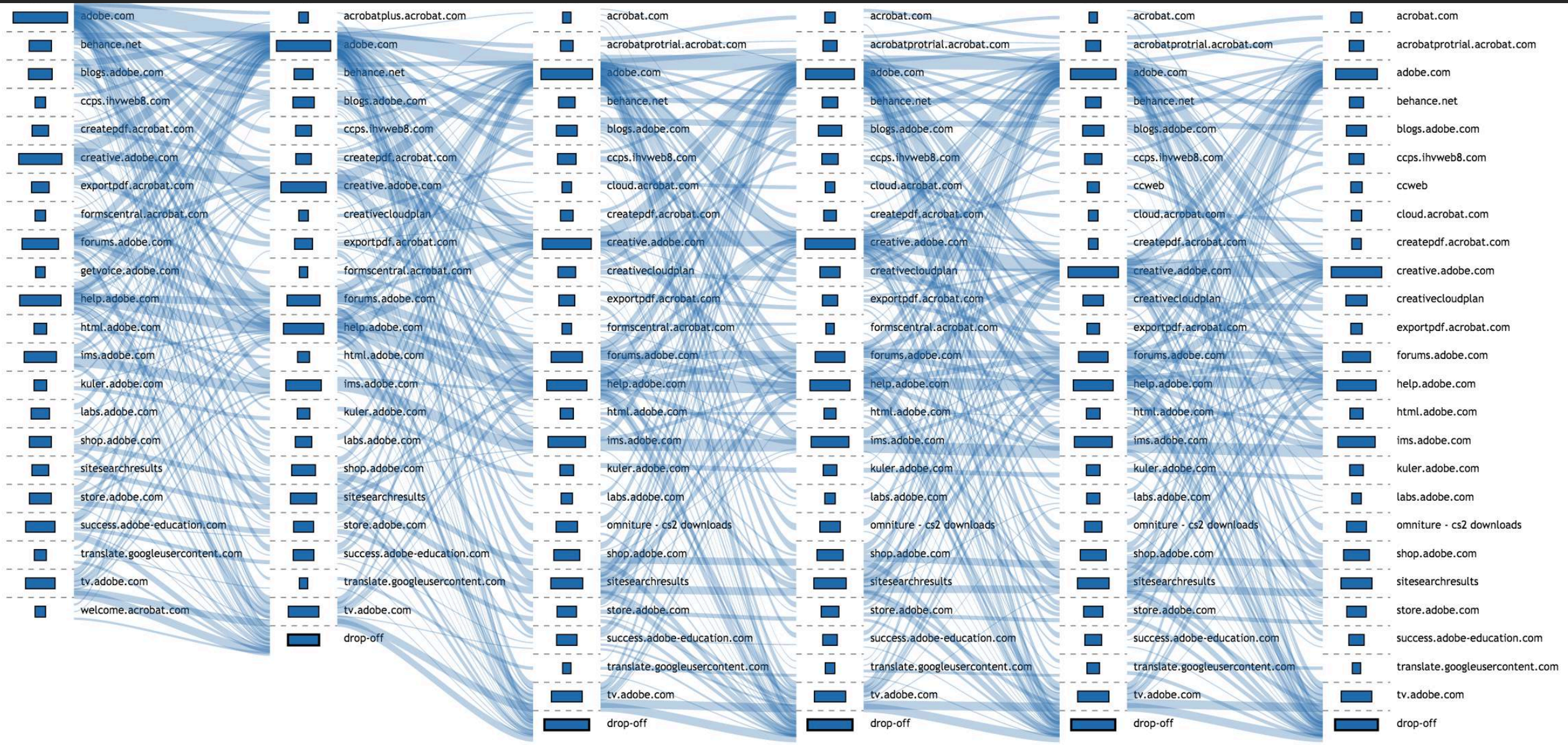
What are the most common paths taken by visitors?

What did people do before reaching page Y?

For those people who have done A and B, what do they do next?

Sankey Diagram




adobe.com
behance.net
blogs.adobe.com
ccps.ihvweb8.com
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creative.adobe.com
exportpdf.acrobat.com
formscentral.acrobat.com
forums.adobe.com
getvoice.adobe.com
help.adobe.com
html.adobe.com
ims.adobe.com
kuler.adobe.com
labs.adobe.com
shop.adobe.com
sitesearchresults
store.adobe.com
success.adobe-education.com
translate.googleusercontent.com
tv.adobe.com
welcome.acrobat.com
acrobatplus.acrobat.com
adobe.com
behance.net
blogs.adobe.com
ccps.ihvweb8.com
createpdf.acrobat.com
creative.adobe.com
creativecloudplan
exportpdf.acrobat.com
formscentral.acrobat.com
forums.adobe.com
help.adobe.com
html.adobe.com
ims.adobe.com
kuler.adobe.com
labs.adobe.com
shop.adobe.com
sitesearchresults
store.adobe.com
success.adobe-education.com
translate.googleusercontent.com
tv.adobe.com
drop-off
acrobat.com
acrobatprotrial.acrobat.com
adobe.com
behance.net
blogs.adobe.com
ccps.ihvweb8.com
cloud.acrobat.com
createpdf.acrobat.com
creative.adobe.com
creativecloudplan
exportpdf.acrobat.com
formscentral.acrobat.com
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html.adobe.com
ims.adobe.com
kuler.adobe.com
labs.adobe.com
omniture - cs2 downloads
shop.adobe.com
sitesearchresults
store.adobe.com
success.adobe-education.com
translate.googleusercontent.com
tv.adobe.com
drop-off
acrobat.com
acrobatprotrial.acrobat.com
adobe.com
behance.net
blogs.adobe.com
ccps.ihvweb8.com
cloud.acrobat.com
createpdf.acrobat.com
creative.adobe.com
creativecloudplan
exportpdf.acrobat.com
formscentral.acrobat.com
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help.adobe.com
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ccps.ihvweb8.com
ccweb
cloud.acrobat.com
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creativecloudplan
exportpdf.acrobat.com
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shop.adobe.com
sitesearchresults
store.adobe.com
success.adobe-education.com
translate.googleusercontent.com
tv.adobe.com
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ccps.ihvweb8.com
ccweb
cloud.acrobat.com
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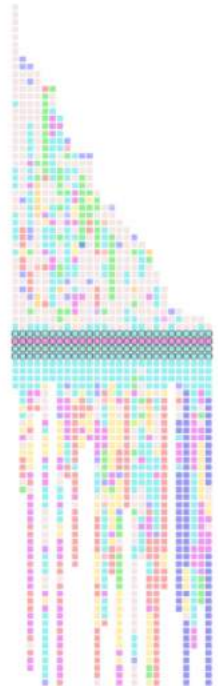
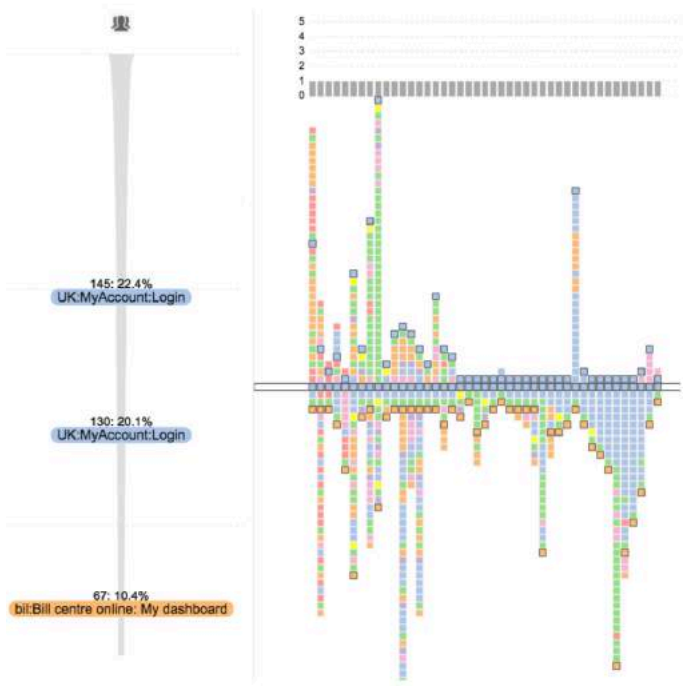
sitesearchresults
store.adobe.com
success.adobe-education.com
translate.googleusercontent.com
tv.adobe.com
drop-off

Perceptual Scalability: Choosing Data Resolution

Sequence Clustering **Motif Extraction** **Sequential Pattern Mining**





Patterns & Sequences
VAST '16

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06/29/2016 16:04:12	creative.adobe.com:Authenticated
06/29/2016 16:06:23	creative.adobe.com:Photography:Join:1:AdobeIDForm:Page
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06/29/2016 16:07:58	creative:AnywareCheckout:checkoutLoaded
06/29/2016 16:08:24	creative.adobe.com:Photography:Join:3:PaymentInfo:Page
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06/29/2016 16:16:00	Account:IMS:onLoad_SignInForm
06/29/2016 16:17:52	Account:IMS:SignIn:Error_EmptyEmail
06/29/2016 16:19:03	Account:IMS:SignIn:Error_EmptyEmail
06/29/2016 16:19:44	Account:IMS:SignIn:Error_EmptyEmail
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What to Show?

adobe.com
adobe.com/creativecloud/photography.html
creative.adobe.com/products/download/ccpp
creative.adobe.com:Authenticated
creative.adobe.com:Photography:Join:1:AdobeIDForm:Page
creative.adobe.com:Photography:Join:2:ReviewMembershipDetails:Page
creative:AnywareCheckout:checkoutLoaded
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creative:AnywareCheckout:validateOrder
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Account:IMS:SignIn:Error_EmptyEmail
Account:IMS:SignIn:Error_EmptyEmail
Account:IMS:SignIn:Error_EmptyEmail
Account:IMS:SignIn:Error_EmptyEmail
Account:IMS:onLoad_ReturningUserSignedInSuccessfully:Remember_Me_Checked
…

What to Show?

1 adobe.com
2 adobe.com/creativecloud/photography.html
3 creative.adobe.com/products/download/ccpp
4 creative.adobe.com:Authenticated
5 creative.adobe.com:Photography:Join:1:AdobeIDForm:Page
6 creative.adobe.com:Photography:Join:2:ReviewMembershipDetails:Page
7 creative:AnywareCheckout:checkoutLoaded
8 creative.adobe.com:Photography:Join:3:PaymentInfo:Page
9 creative:AnywareCheckout:validateOrder
10 creative.adobe.com:Join:Checkout:Order:Validated
11 creative:AnywareCheckout:orderValidated
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13 creative.adobe.com:Photography:Join:2:ReviewMembershipDetails:Page
14 account:IMS:onLoad_SignInForm
15 account:IMS:SignIn:Error_EmptyEmail
15 account:IMS:SignIn:Error_EmptyEmail
15 account:IMS:SignIn:Error_EmptyEmail
15 account:IMS:SignIn:Error_EmptyEmail
16 account:IMS:onLoad_ReturningUserSignedInSuccessfully:Remember_Me_Checked
…

What to Show?

e1	e7	e1	e7	e10
e2	e1	e1	e6	e11
e3	e5	e1	e7	e15
e4	e11	e11	e6	e1
e5	e2	e12	e1	e2
e6	e6	e13	e2	e6
e7	e3	e15	e3	e6
e8	e8	e3	e8	e18
e9	e4	e6	e10	e24
e10	e10	e2	e2	e12
e11	e11	e2	e5	e2
e12	e12	e3	e4	e3
e13	e13	e4	e6	e9
e14	e9	e9	e4	e8
e15	e15	e5	e6	e4
e15	e20	e4	e9	e1
e15	e6	e4	e6	e2
e15	e6	e2	e11	e9
e16	e10	e7	e15	e3
…	…	…	…	…

What to Show?

e1	e7	**e1**	e7	e10
e2	**e1**	e1	e6	e11
e3	e5	e1	e7	e15
e4	e11	e11	e6	**e1**
e5	**e2**	e12	**e1**	**e2**
e6	e6	e13	**e2**	e6
e7	**e3**	e15	**e3**	e6
e8	e8	e3	e8	e18
e9	**e4**	e6	e10	e24
e10	e10	**e2**	e2	e12
e11	e11	e2	e5	e2
e12	e12	**e3**	**e4**	**e3**
e13	e13	**e4**	e6	e9
e14	**e9**	**e9**	e4	e8
e15	e15	e5	e6	**e4**
e15	e20	e4	**e9**	e1
e15	e6	e4	e6	e2
e15	e6	e2	e11	**e9**
e16	e10	e7	e15	e3
…	…	…	…	…

e1 → e2 → e3 → e4 → e9 (100%)

Patterns & Sequences
VAST '16

What to Show?

e1	e7	**e1**	e7	e10
e2	**e1**	e1	e6	e11
e3	**e5**	e1	e7	e15
e4	e11	e11	e6	**e1**
e5	**e2**	e12	**e1**	**e2**
e6	e6	e13	**e2**	e6
e7	**e3**	e15	**e3**	e6
e8	e8	e3	e8	e18
e9	**e4**	e6	e10	e24
e10	e10	**e2**	e2	e12
e11	**e11**	e2	**e5**	e2
e12	e12	**e3**	**e4**	**e3**
e13	e13	**e4**	e6	e9
e14	**e9**	**e9**	e4	e8
e15	**e15**	e5	e6	**e4**
e15	e20	e4	**e9**	e1
e15	e6	e4	e6	e2
e15	e6	e2	**e11**	**e9**
e16	e10	e7	**e15**	e3
…	…	…	…	…

e1 → e2 → e3 → e4 → e9 (100%)

e5 → e11 → e15 (60%)

Patterns & Sequences
VAST '16

What to Show?

e1	e7	e1	e7	e10
e2	e1	e1	e6	e11
e3	e5	e1	e7	e15
e4	e11	e11	e6	e1
e5	e2	**e12**	e1	e2
e6	e6	e13	e2	e6
e7	e3	e15	e3	e6
e8	e8	e3	e8	e18
e9	e4	**e6**	e10	e24
e10	e10	e2	e2	e12
e11	e11	e2	e5	e2
e12	**e12**	e3	e4	e3
e13	e13	e4	e6	e9
e14	e9	e9	e4	e8
e15	e15	e5	e6	e4
e15	e20	e4	e9	e1
e15	**e6**	e4	e6	e2
e15	e6	e2	e11	e9
e16	e10	e7	e15	e3
…	…	…	…	…

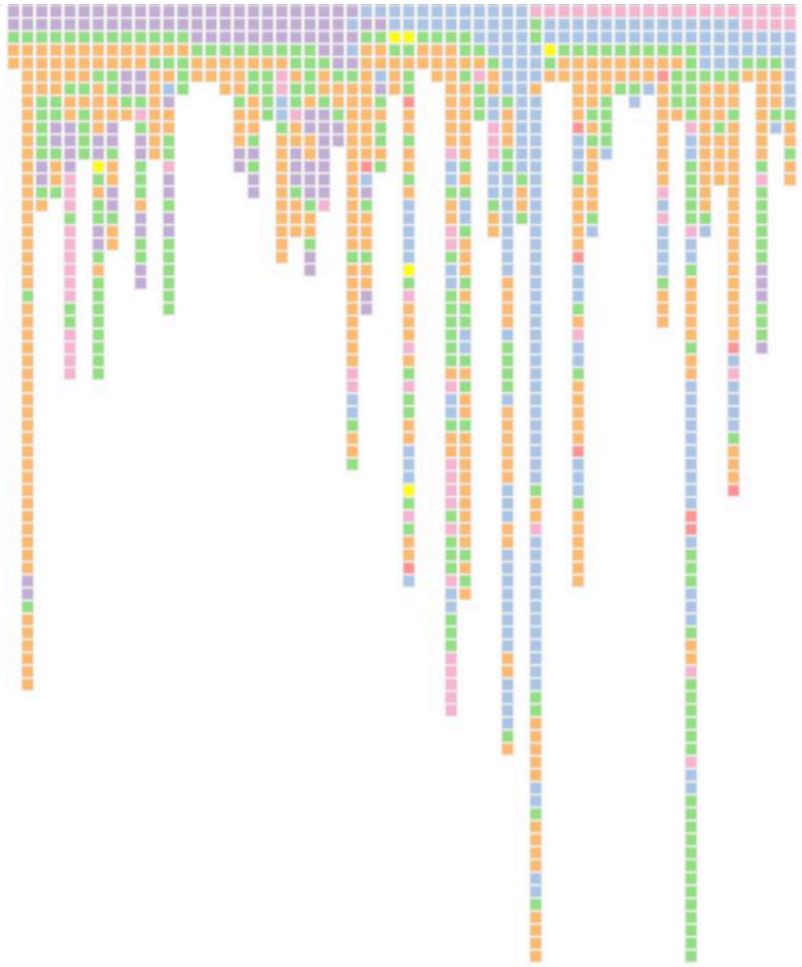
e1 → e2 → e3 → e4 → e9 (100%)

e5 → e11 → e15 (60%)

e12 → e6 (40%)

Patterns & Sequences
VAST '16

How to Show?

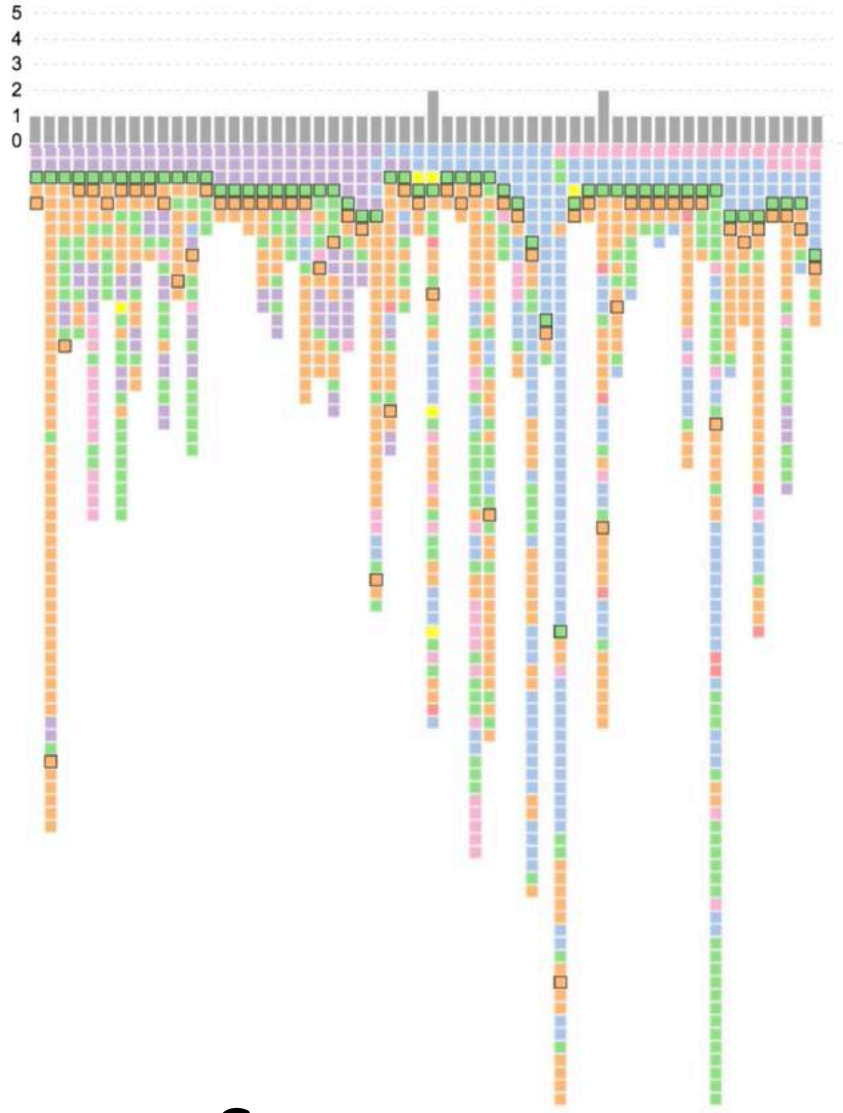


Patterns & Sequences
VAST '16

Patterns

Sequences

How to Show?

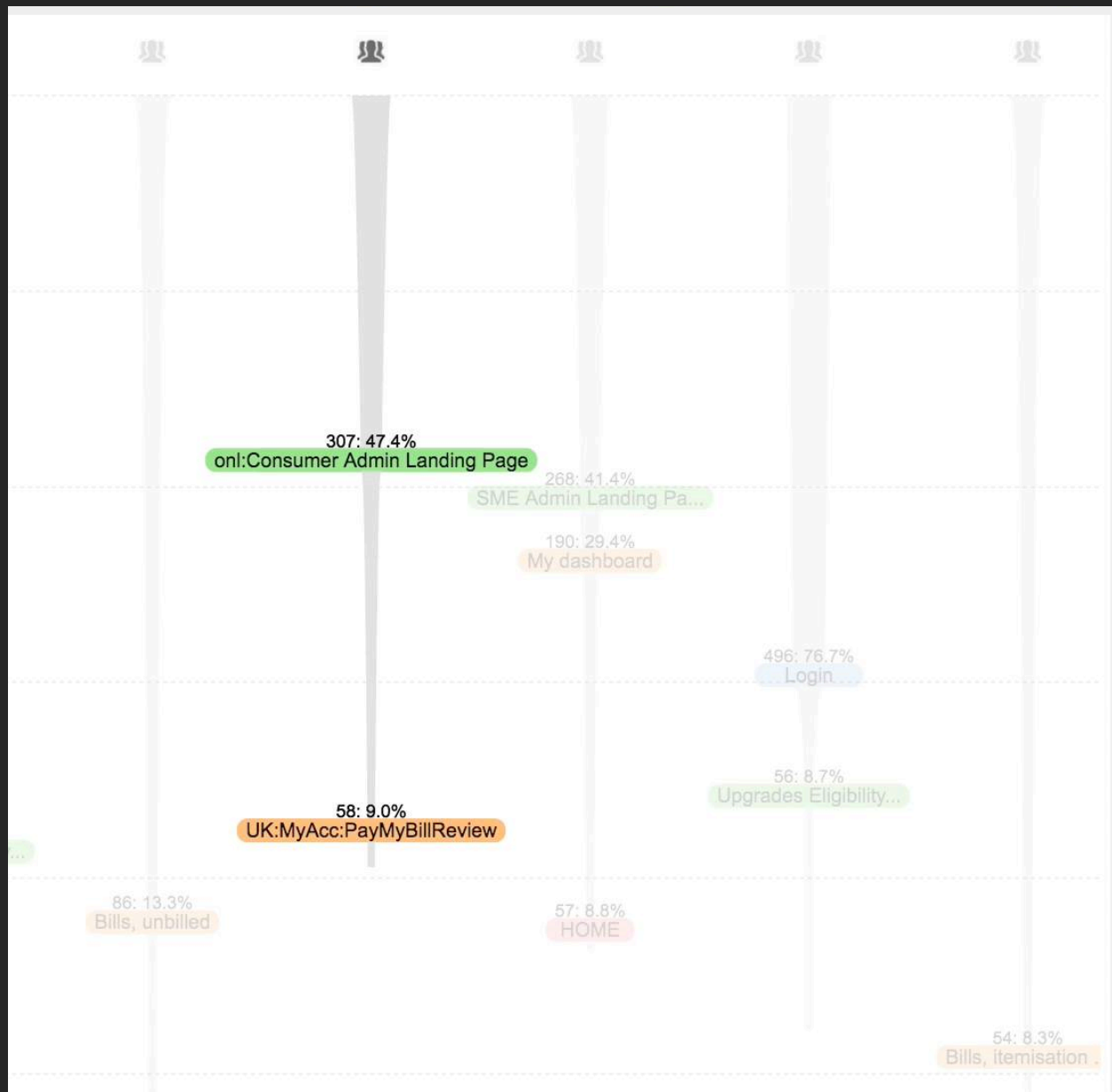


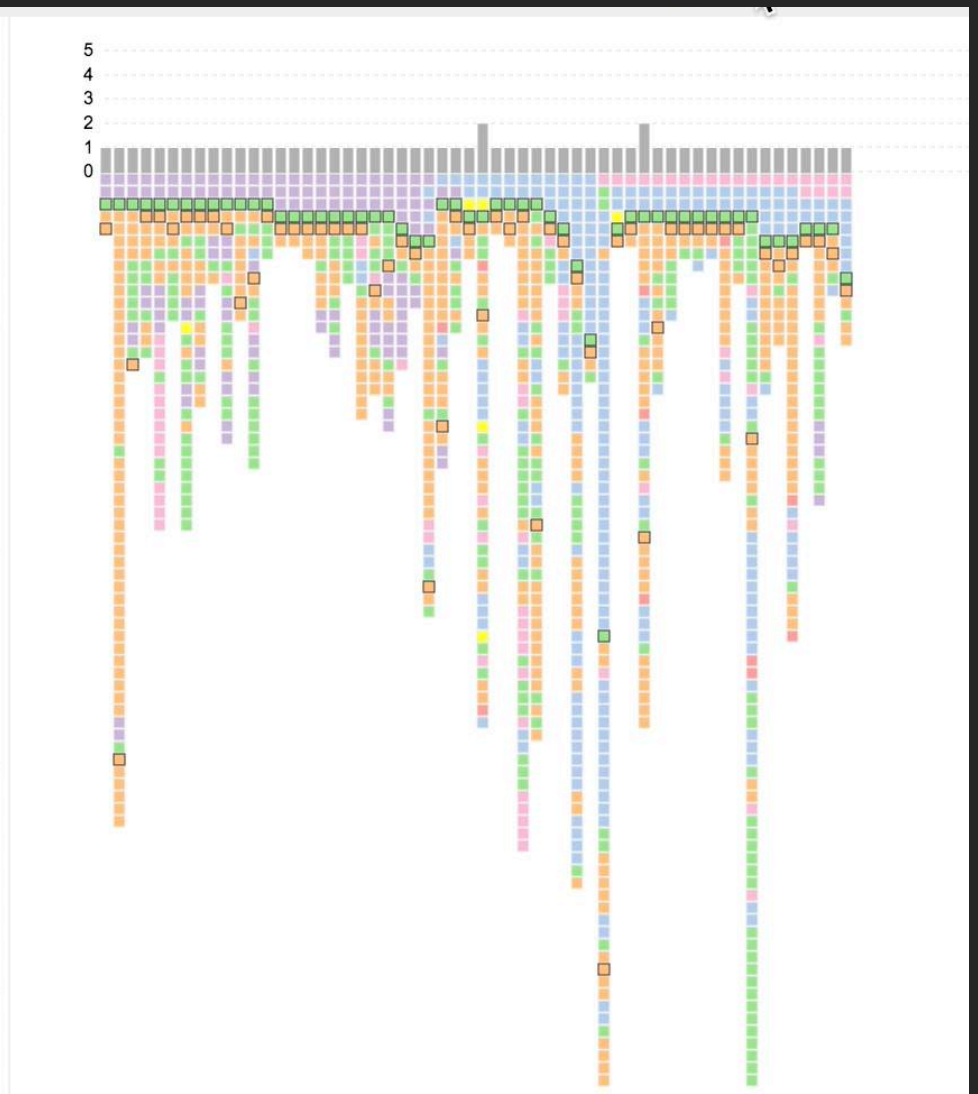
Patterns & Sequences
VAST '16

Patterns

Sequences

How to Show?

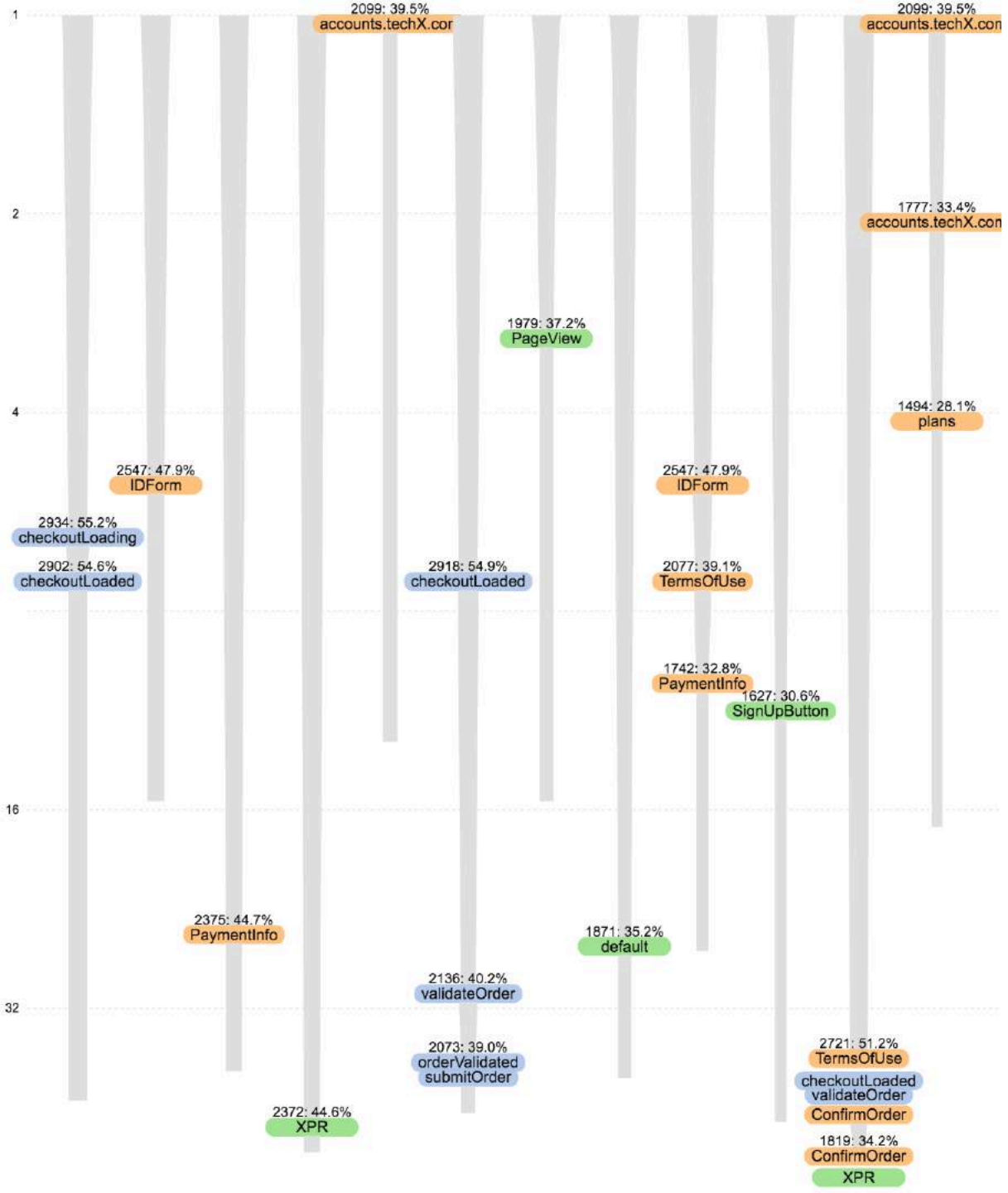




Align Sequences by Event

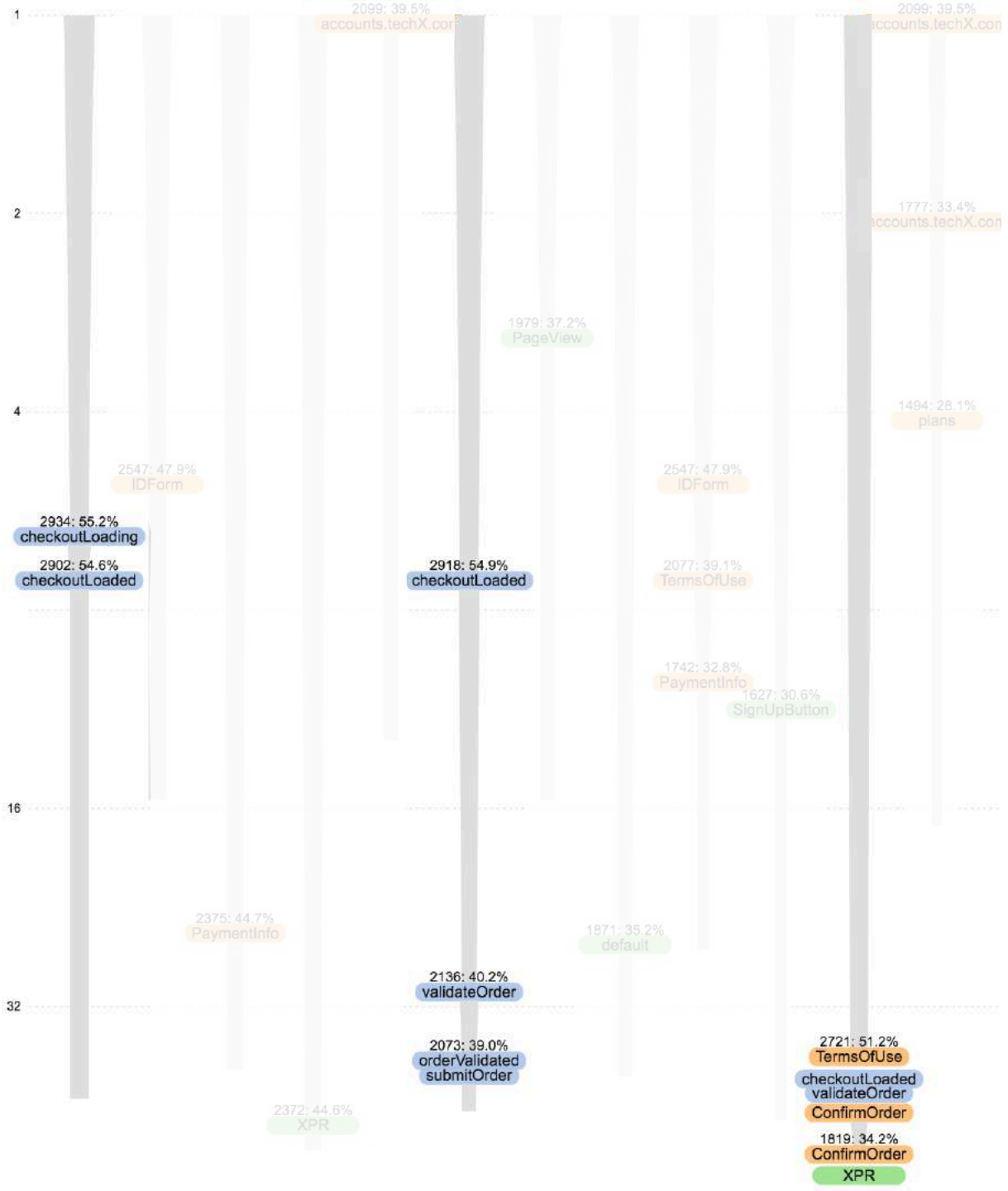
Follow-up Work (1)

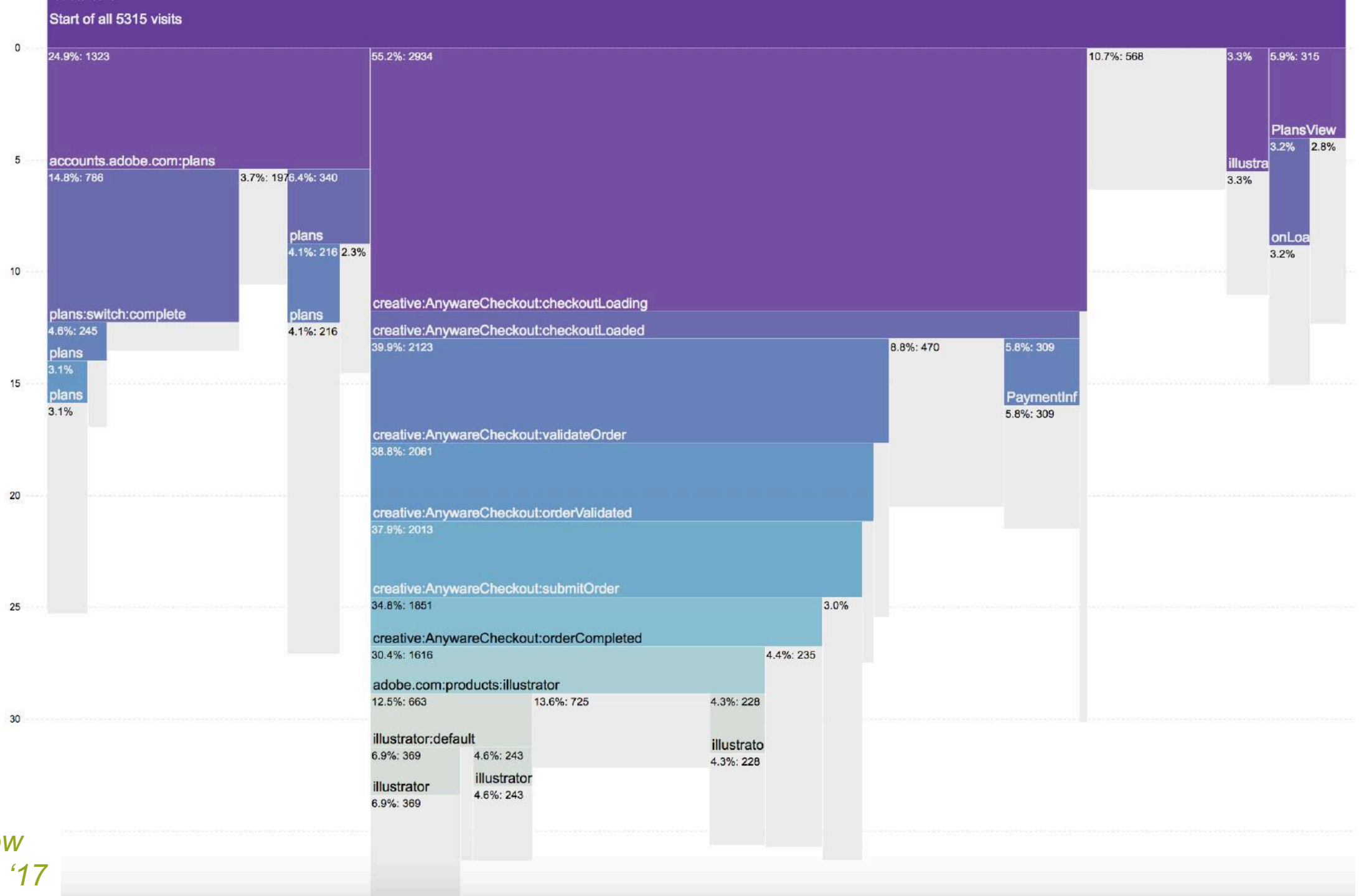
Beyond disjoint, overlapping sequential patterns



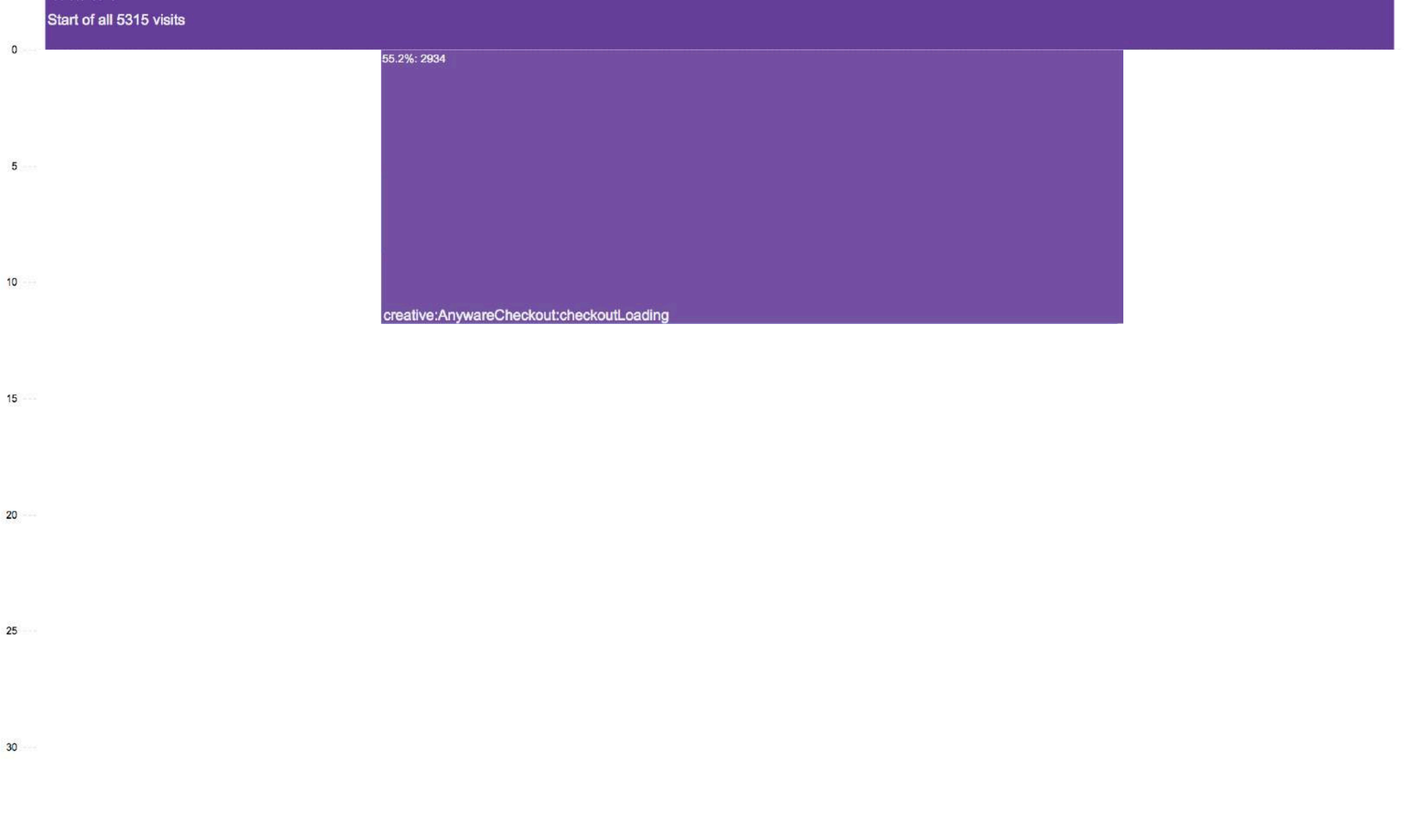
Follow-up Work (1)

Beyond disjoint, overlapping sequential patterns





CoreFlow
EuroVis '17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55.2%: 2934
creative:AnywareCheckout:checkoutLoading
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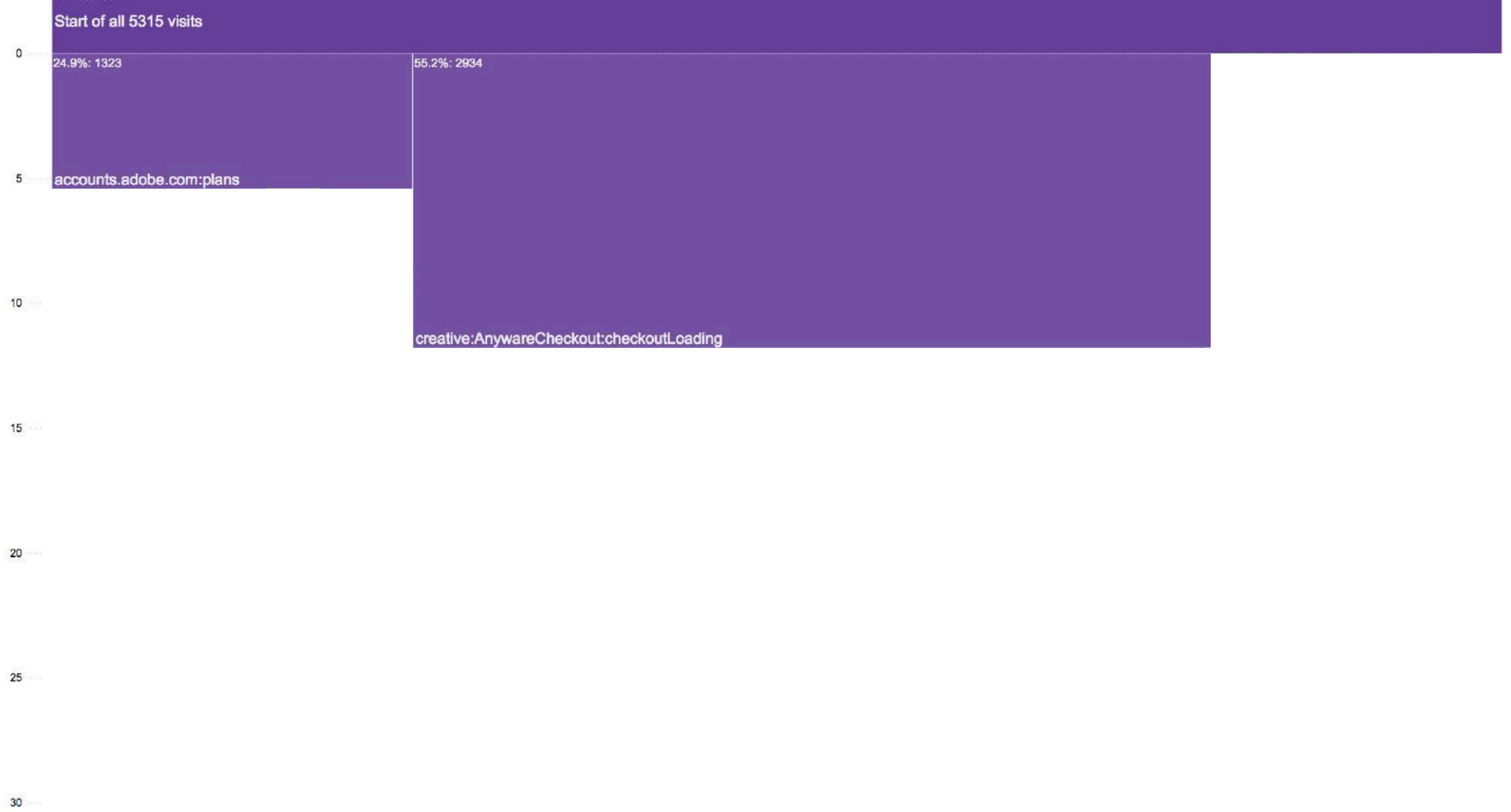
5
10
15
20
25
30


Start of all 5315 visits
24.9%: 1323
accounts.adobe.com:plans
55.2%: 2934
creative:AnywareCheckout:checkoutLoading
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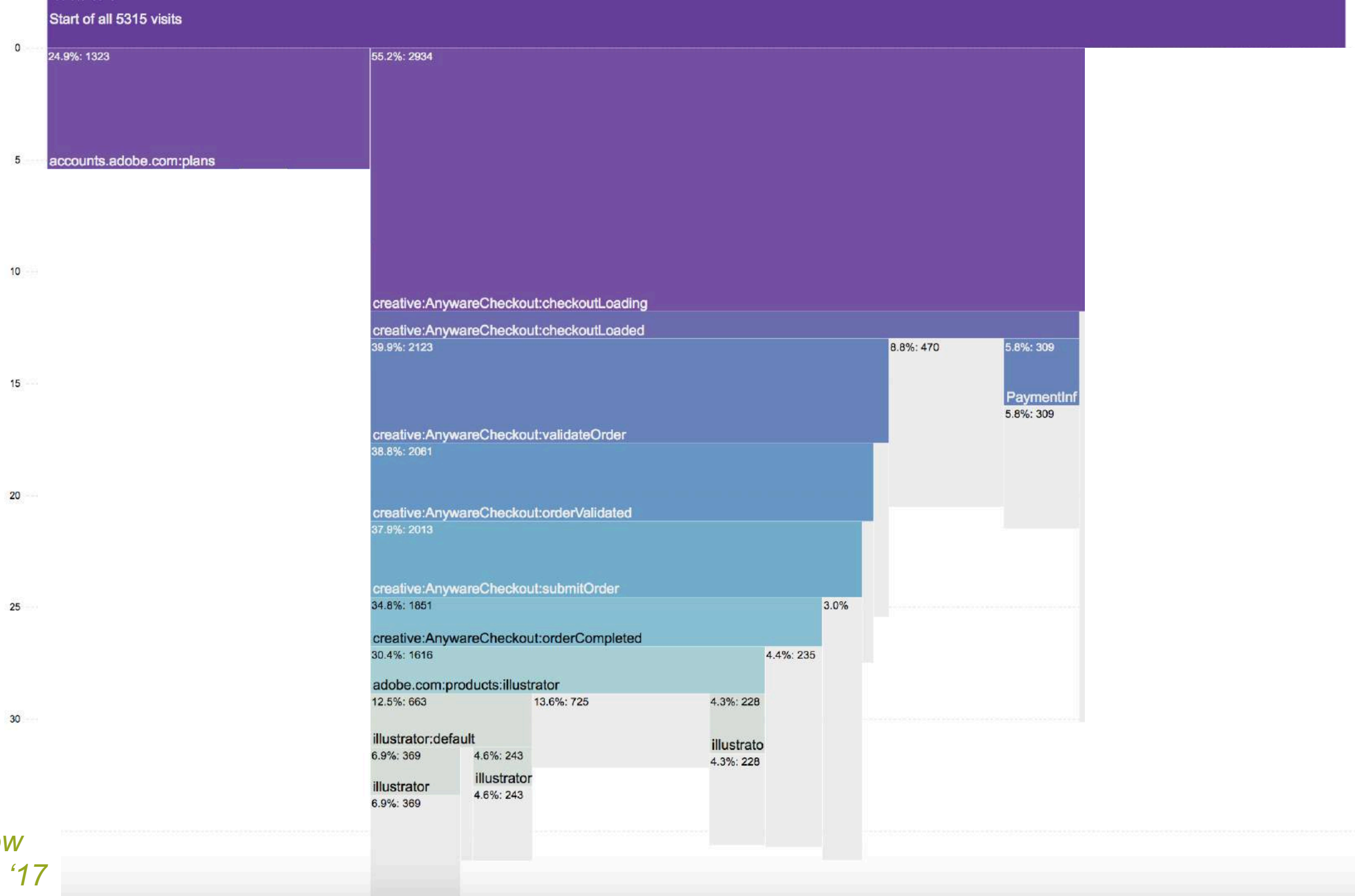
20
25
30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24.9%: 1323
accounts.adobe.com:plans
5
55.2%: 2934
10
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creative:AnywareCheckout:checkoutLoaded
39.9%: 2123
8.8%: 470
5.8%: 309
15
PaymentInf
5.8%: 309
creative:AnywareCheckout:validateOrder
38.8%: 2061
20
creative:AnywareCheckout:orderValidated
37.9%: 2013
creative:AnywareCheckout:submitOrder
25
34.8%: 1851
3.0%
creative:AnywareCheckout:orderCompleted
30.4%: 1616
4.4%: 235
adobe.com:products:illustrator
12.5%: 663
13.6%: 725
4.3%: 228
30
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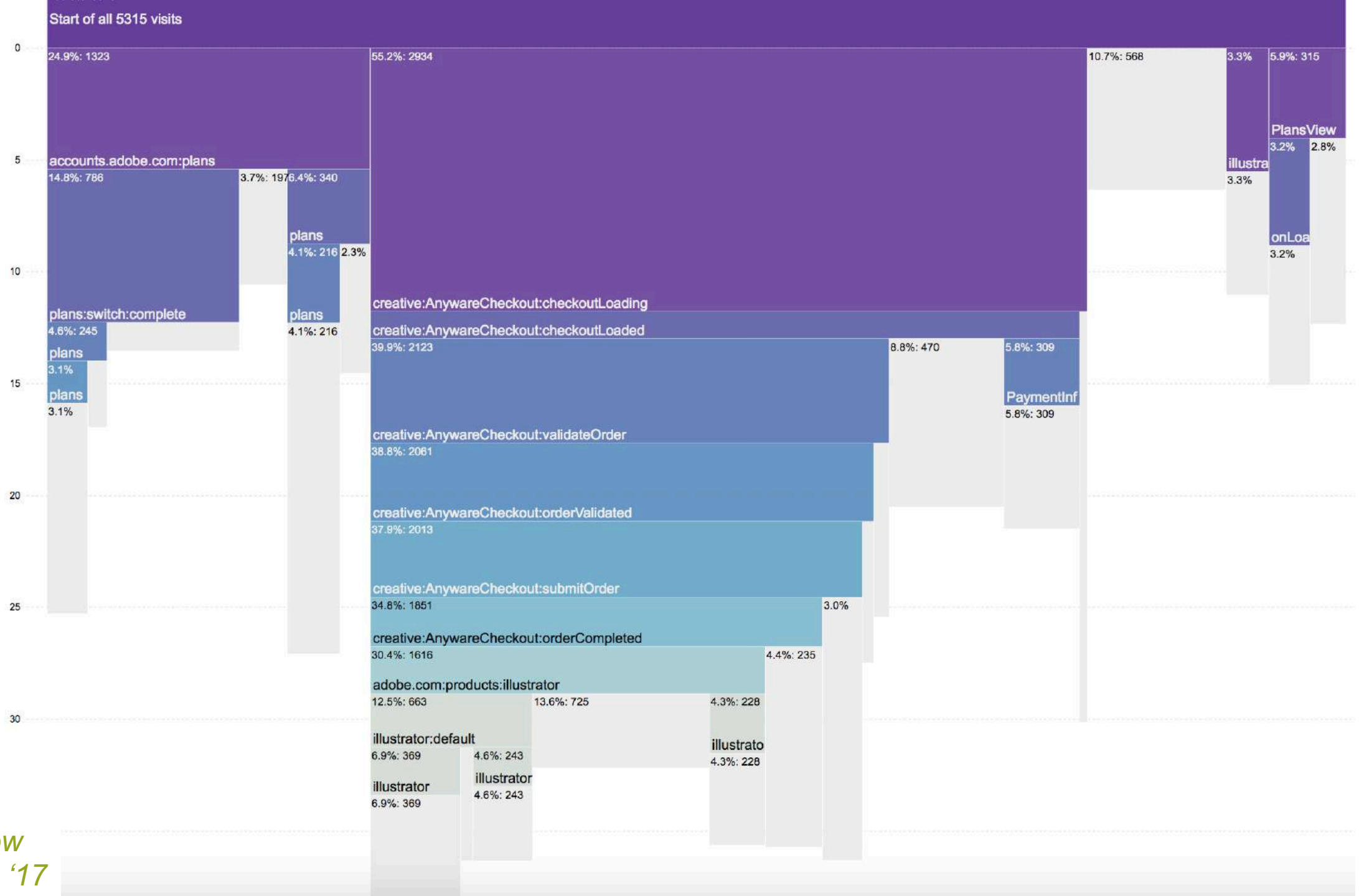


CoreFlow
EuroVis '17

Follow-up Work (2)

Help analysts incorporate their own knowledge

Automatically mined patterns may not be interesting / useful

Combine ad hoc querying with pattern mining

MAQUI
VAST '18

Interactive Scalability for Event Sequence Analysis

Construct Event Dictionary

Map each event to a Unicode symbol
More frequent events are assigned smaller code point (fewer bytes)
variable-length coding

Represent Sequences as Strings

More efficient pattern mining

Ad hoc queries through regular expression and substring functions

Scalable Visualization System: Lessons Learned

Perceptual Scalability:

Choose data reduction and summarization methods
that reduce visual clutter & preserve salient structures

Interactive Scalability:

Choose data representation & computational techniques

based on vis design to optimize user experience

Overview

Scalable Interaction Techniques

Multivariate linked analysis

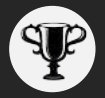
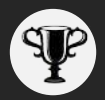
Event sequence data analysis

EuroVis ‘13, InfoVis ’14,  *CHI ‘15, VAST ‘16, EuroVis ’17, VAST ‘18*

Visualization Process Models

Natural language interaction

Graphical authoring tools

UIST ‘15,  *InfoVis ’16,*  *CHI’18, InfoVis ’19,*  *CHI’20*

The Importance of Iteration

Finding an effective visualization requires iterations on data configuration and visualization design

Current way to do such iteration: programming

Martin Burch
@seecmb

Follow

The trouble with D3 is to build a visualization you must also have a deep understanding of SVG, DOM, JavaScript, geometry, color spaces, data structures, the standard model, and quantum physics

3:48 AM - 5 Jun 2018

75 Retweets **278** Likes

21 75 278

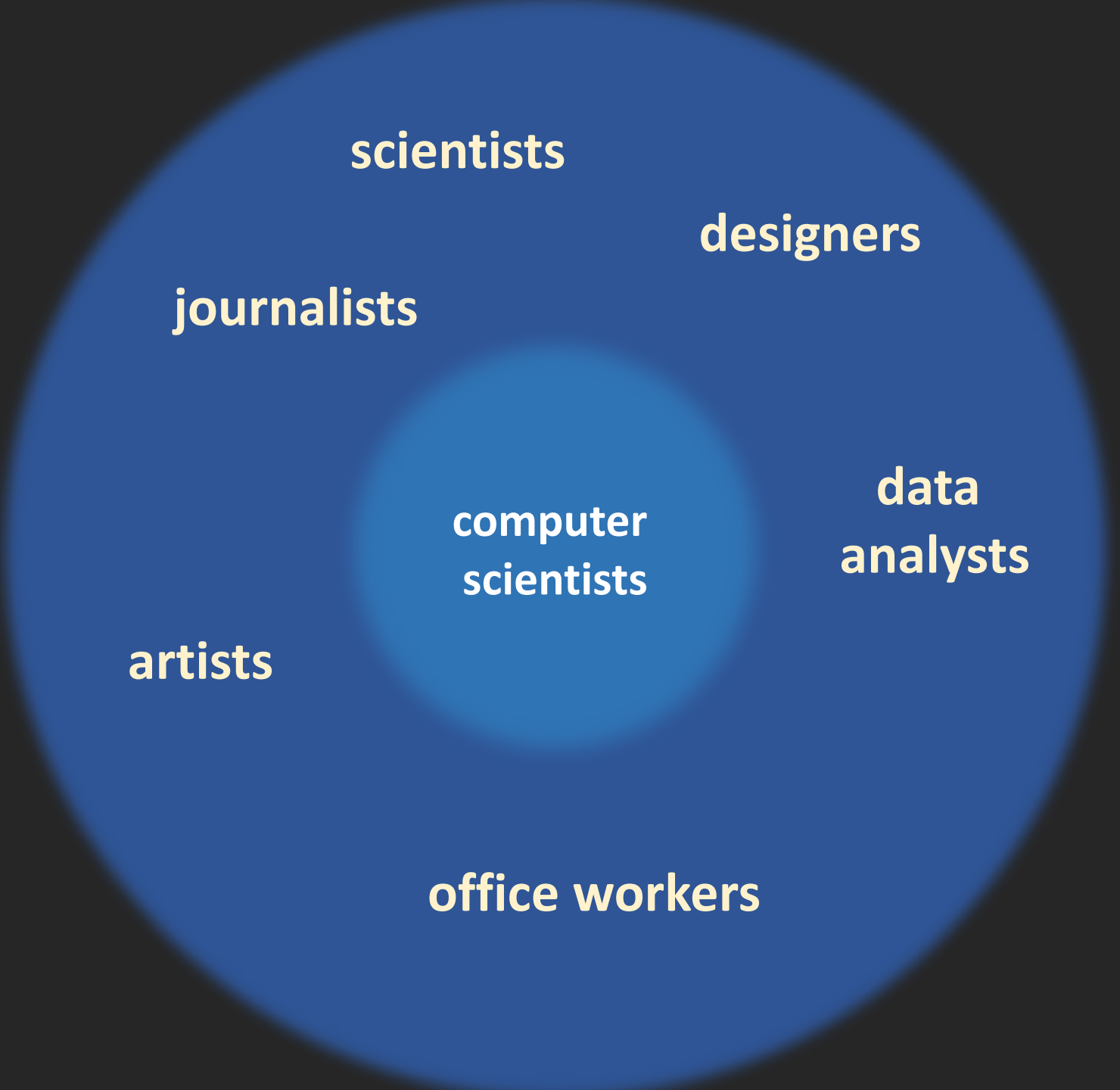
Martin Burch @seecmb · Jun 5

ahem, can anyone tell me if I need all this code just to put a dot at the end of the last line on my chart? 😅

```
this.marker = this.svg
  .append('svg:defs')
  .append('svg:marker')
  .attr('markerHeight', 12)
  .attr('markerWidth', 12)
  .attr('refX', 2)
  .attr('refY', 2)
  .attr('orient', 'auto')
  .attr('markerUnits', 'strokeWidth')
  .attr('id', 'end-dot')
  .append('svg:circle')
  .attr('r', 2)
  .attr('cx', 2)
  .attr('cy', 2)
  .attr('fill-opacity',1)
  .style('fill',this.colorScale(this.peaks[this.peaks.length -

this.paths = series.append('path')
.style('marker-end', d => {
  if (d.id === this.peaks[this.peaks.length - 1]) {
    return 'url(#end-dot)';
  } else {
    return 'none';
  }
})
```

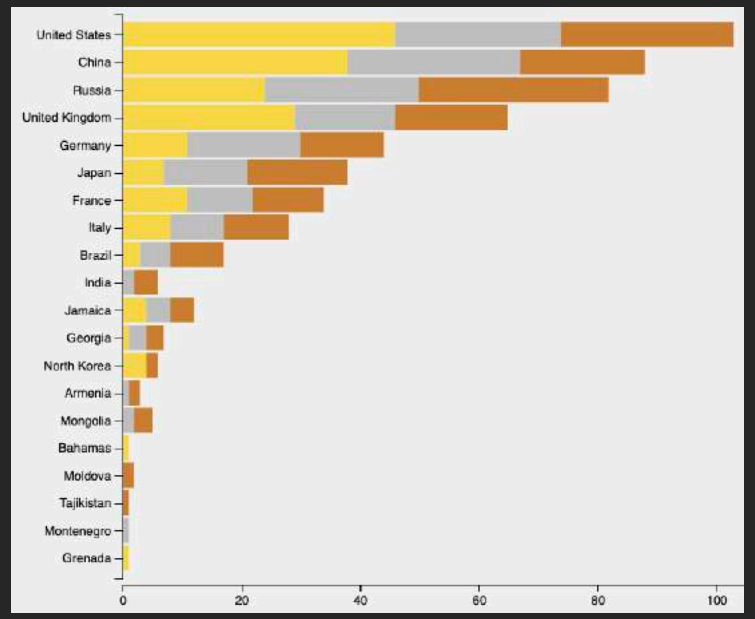
5 3 18



How we enable the masses to create expressive visualizations without having to program?

Natural Language Interaction

“Show me the medal counts by country”



“show me revenue by marketing channel for the winter campaign”

1-grams: “show”, “me”, “revenue”, “by”, “marketing”, “channel”, …

2-grams: “show me”, “me revenue”, “revenue by”, “by marketing”, …

n-grams: ...

Natural Language Question → n-grams → Visualizations

DataTone, UIST ‘15

{n-grams}

classifier

data attributes

data cell values

numbers

time expressions

visualization key phrases

data operators and functions

direct manipulation terms

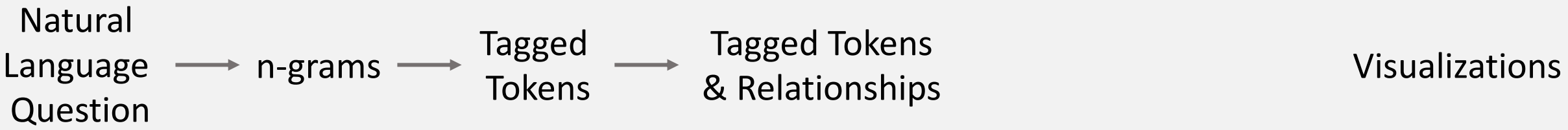
conjunction & disjunction terms

pairwise similarity between
n-gram *i* and lexicon entry *j*:

$Sim(i, j) = max \{Sim_{wordnet}, Sim_{spelling}\}$

Natural Language Question → n-grams → Tagged Tokens → Visualizations

{tagged n-grams} → **dependency parser** → constituency parse tree & the typed dependencies



DataTone, UIST '15

“show me the states that had total sales greater than 20000”

“total”	“sales”
data operator and function	data attribute

noun phrase

“greater than”	“20000”
data operator and function	number

adjective phrase

Natural Language Question → n-grams → Tagged Tokens → Tagged Tokens & Relationships → Visualizations

DataTone, UIST ‘15

“total”	“sales”
data operator and function	data attribute

noun phrase

```
sum(sales)
```

“greater than”	“20000”
data operator and function	number

adjective phrase

```
> 20000
```

```
sum(sales) > 20000
```

Natural Language Question → n-grams → Tagged Tokens → Tagged Tokens & Relationships → Formal Specifications → Visualizations

DataTone, UIST ‘15

Ambiguities

Question will likely be underspecified

- does “product” mean product category or product name?

Ambiguities

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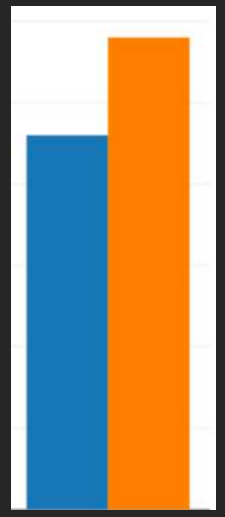
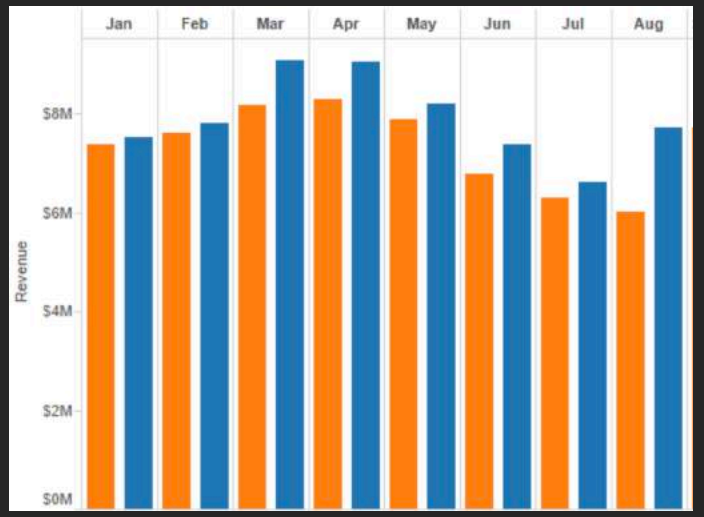
- does “product” mean product category or product name?

Many possible answers to the user’s question

- show revenue for New York City and Washington DC in 2012





Ambiguities

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- does “product” mean product category or product name?

Many possible answers to the user’s question

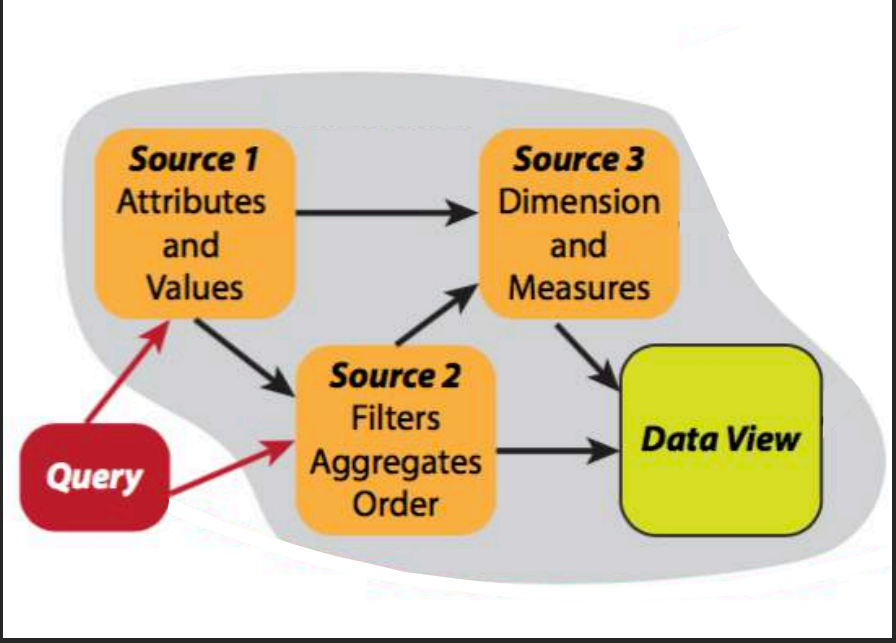
- show revenue for New York City and Washington DC in 2012

Inference mistakes in natural language processing

Sources of Ambiguity

Data

1. Recognition of data attributes and text values
2. Recognition of filters, sorting and aggregates
3. Dimension and measure selection



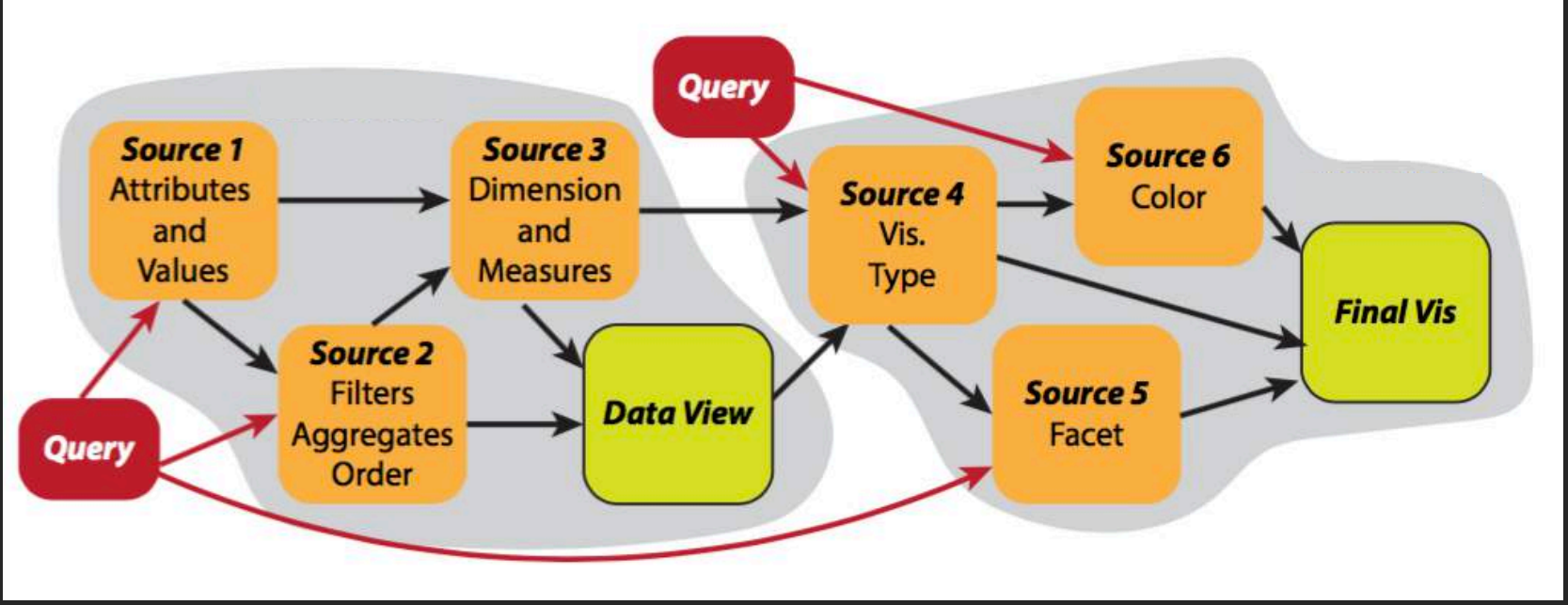
Sources of Ambiguity

Data

1. Recognition of data attributes and text values
2. Recognition of filters, sorting and aggregates
3. Dimension and measure selection

Visualization Design

4. Choose visualization parameters
5. Facet data for small multiples
6. Choose encoding methods



Olympic Athletes

show me medals for hockey and skating by country

Click to Speak | Submit

Data Overview:

Athlete:Michael Phelps, Natalie Coughlin, Sun Yang, ...
Age: 15-61
Country: United States, Australia, Russia, ...
Year: 2000-2012
Sport: Swimming, Diving, Cycling, ...
Gold Medal: 0-8
Silver Medal: 0-3
Bronze Medal: 0-3
Total Medal: 1-8

Sample Queries:

show me **medal** for **hockey** and **skating** by **country**

medal	hockey	skating
TotalMedals	Hockey (Sport)	FigureSkating (Sport)
BronzeMedals	IceHockey (Sport)	Short-TrackSpeedSkating (Sport)
SilverMedals		SpeedSkating (Sport)
GoldMedals		

Dimensions

Country | Sport

Country

Chart Templates

Color

Color by **Country**

Color by **Sport**

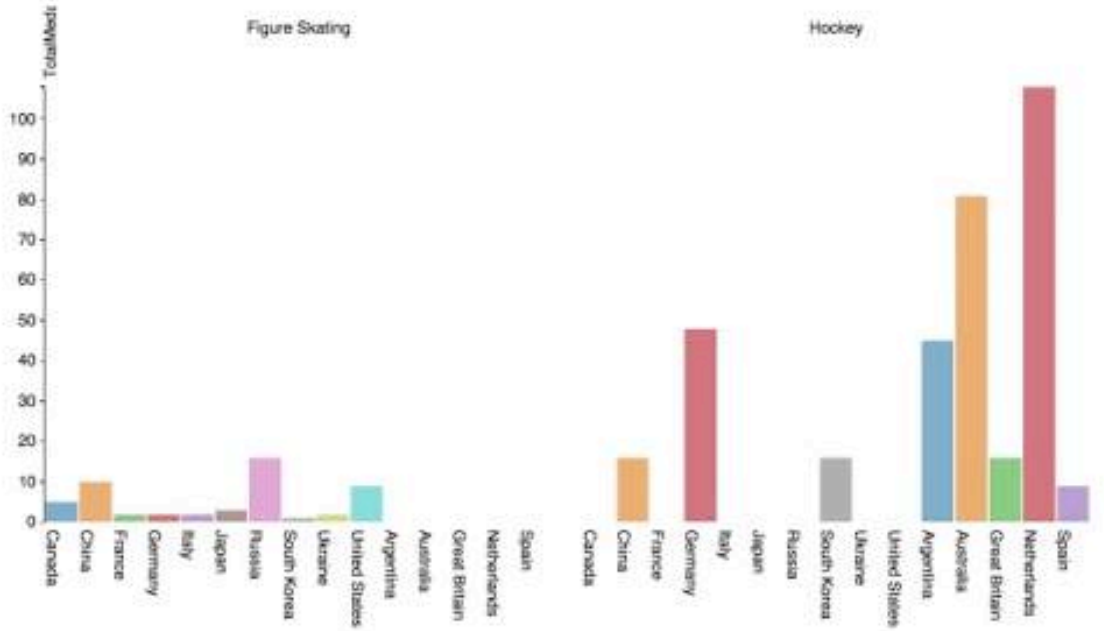
Single Color

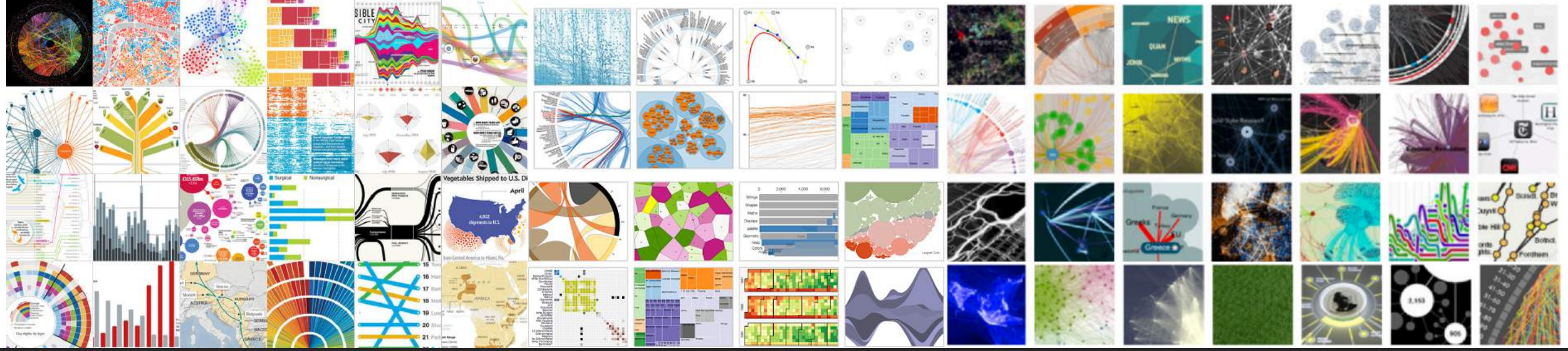
Group Order

Group by **Sport** then by **Country**

Group by **Country** then by

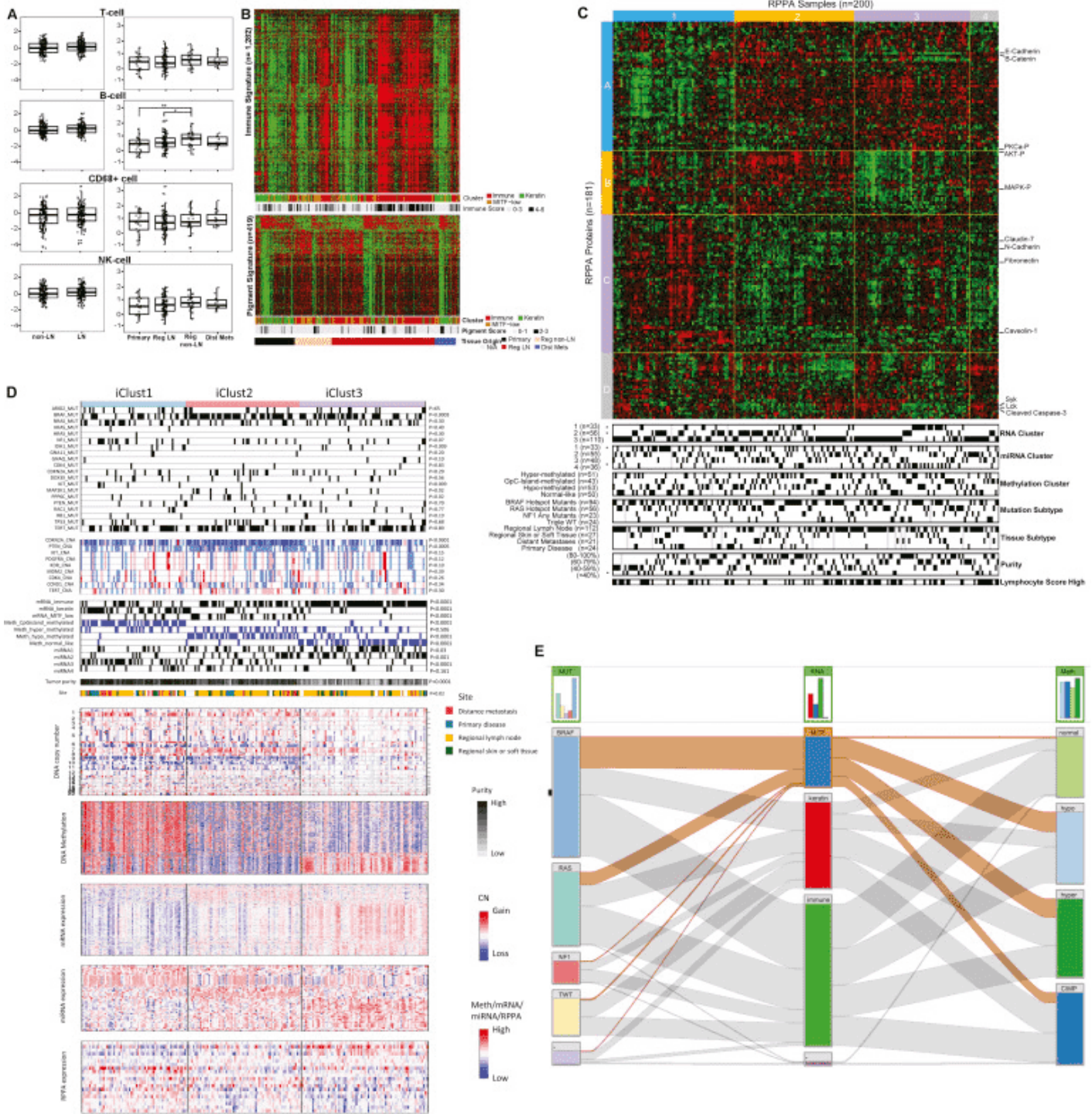
Sum of **TotalMedals** (Sport: Figure Skating and Hockey) by **Sport, Country**





Expressivity

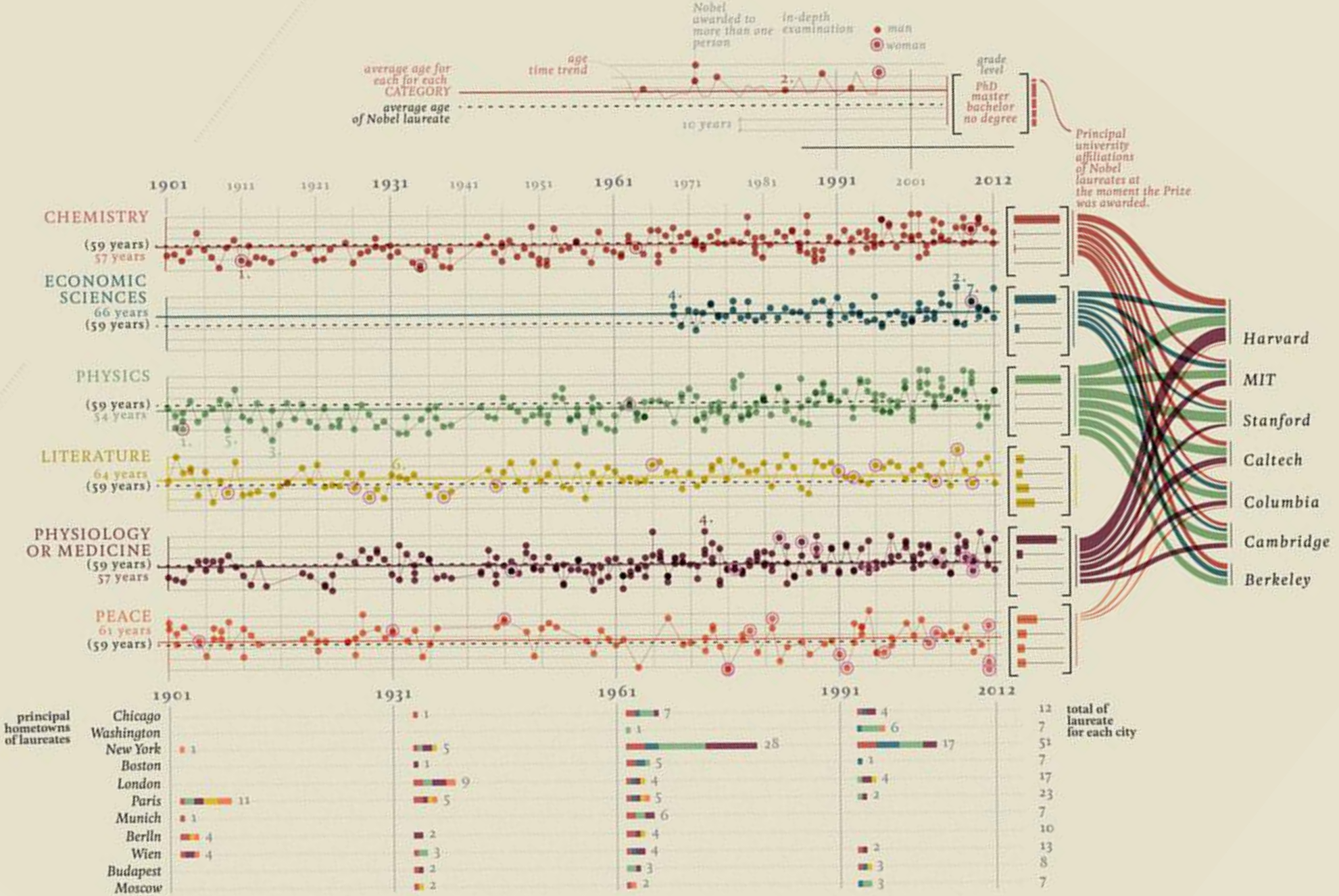
The range of visualizations that can be created in a tool



“Genomic Classification of Cutaneous Melanoma”
Cell 161:1681-96 (2015)

A Field Guide to Red and Blue America

THE WALL STREET JOURNAL.



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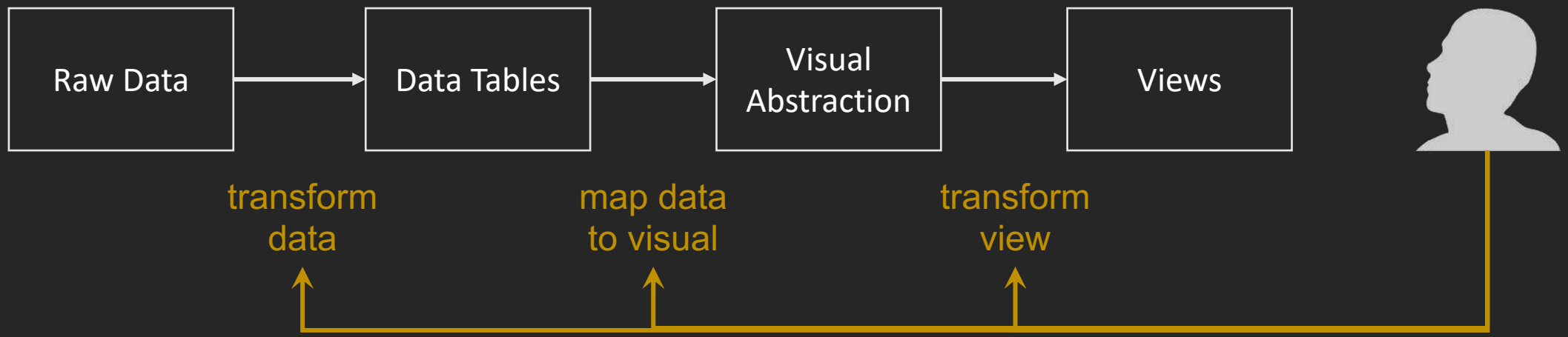
accurat

Visualization Process Models

The InfoVis Reference Model

[Card, Mackinlay & Shneiderman, 1999]



The Grammar of Graphics [Wilkinson, 1999]

CaseID	Response
1	Frequently
2	Not Sure
3	Frequently
...	...
3834	Rarely
3835	Infrequently

CaseID	Gender
1	Male
2	Female
3	Male
...	...
3834	Male
3835	Female

Data → Variables → Algebra → Scales → Statistics → Geometry → Coordinates → Aesthetics → **Renderer**

The Grammar of Graphics [Wilkinson, 1999]

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response = `Response`
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response = `Response`
gender = `Gender`
cross(response, gender)

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CaseID	Gender
1	Male
2	Female
3	Male
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3834	Male
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```
response = Response
gender = Gender
cross(response, gender)
cat(dim(1), values("Rarely","Infrequently",
  "Occasionally","Frequently","Not Sure"))
cat(dim(2), values("Female","Male"))
```

Data → Variables → Algebra → Scales → Statistics → Geometry → Coordinates → Aesthetics → Renderer

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cat(dim(1), values("Rarely","Infrequently",
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cat(dim(2), values("Female","Male"))
summary.proportion(Response*Gender)
```

Data → Variables → Algebra → Scales → **Statistics** → Geometry → Coordinates → Aesthetics → Renderer

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summary.proportion(Response*Gender)
interval.stack(summary.proportion(response*gender))
```

Data → Variables → Algebra → Scales → Statistics → Geometry → Coordinates → Aesthetics → Renderer

The Grammar of Graphics [Wilkinson, 1999]

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rect(dim(2), polar.theta(dim(1)))
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Data → Variables → Algebra → Scales → Statistics → Geometry → Coordinates → Aesthetics → Renderer

The Grammar of Graphics [Wilkinson, 1999]

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cat(dim(2), values("Female","Male"))
summary.proportion(Response*Gender)
rect(dim(2), polar.theta(dim(1)))
interval.stack(position(summary.proportion(response*gender)),
label(response), color(response))
```

Data → Variables → Algebra → Scales → Statistics → Geometry → Coordinates → Aesthetics → Renderer

The Grammar of Graphics [Wilkinson, 1999]

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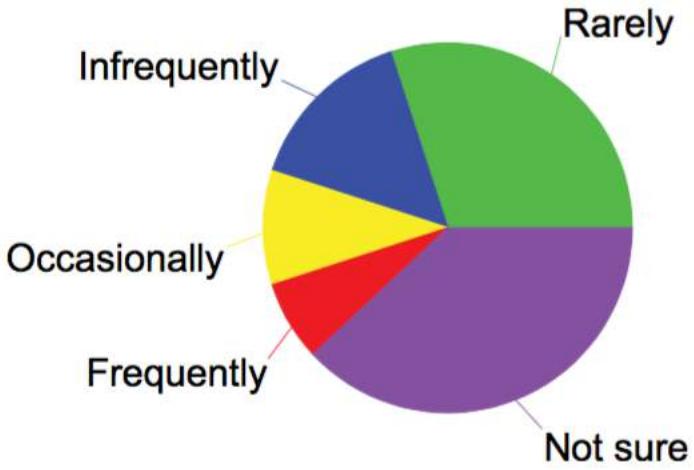
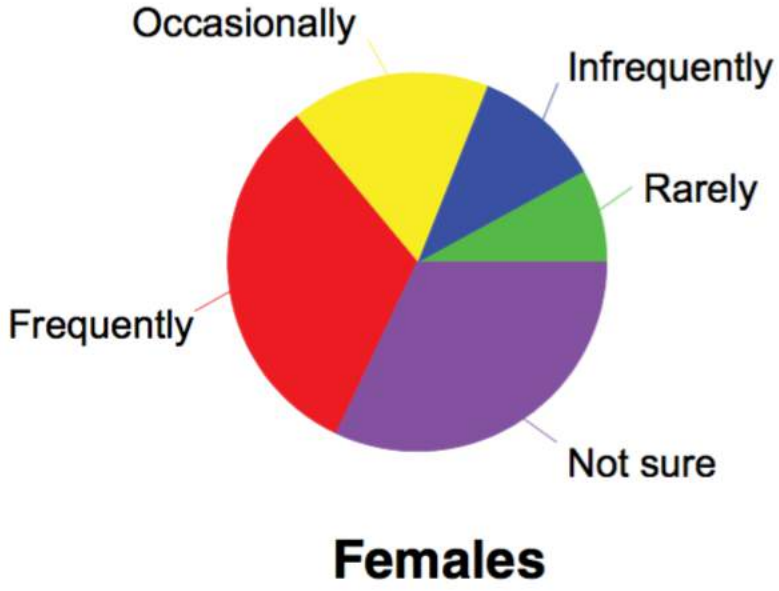




Data → Variables → Algebra → Scales → Statistics → Geometry → Coordinates → Aesthetics → **Renderer**

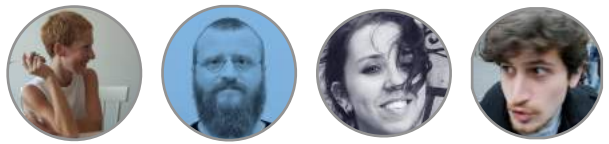
Data-to-Display Process Models

start with data, visualization rendered in the end

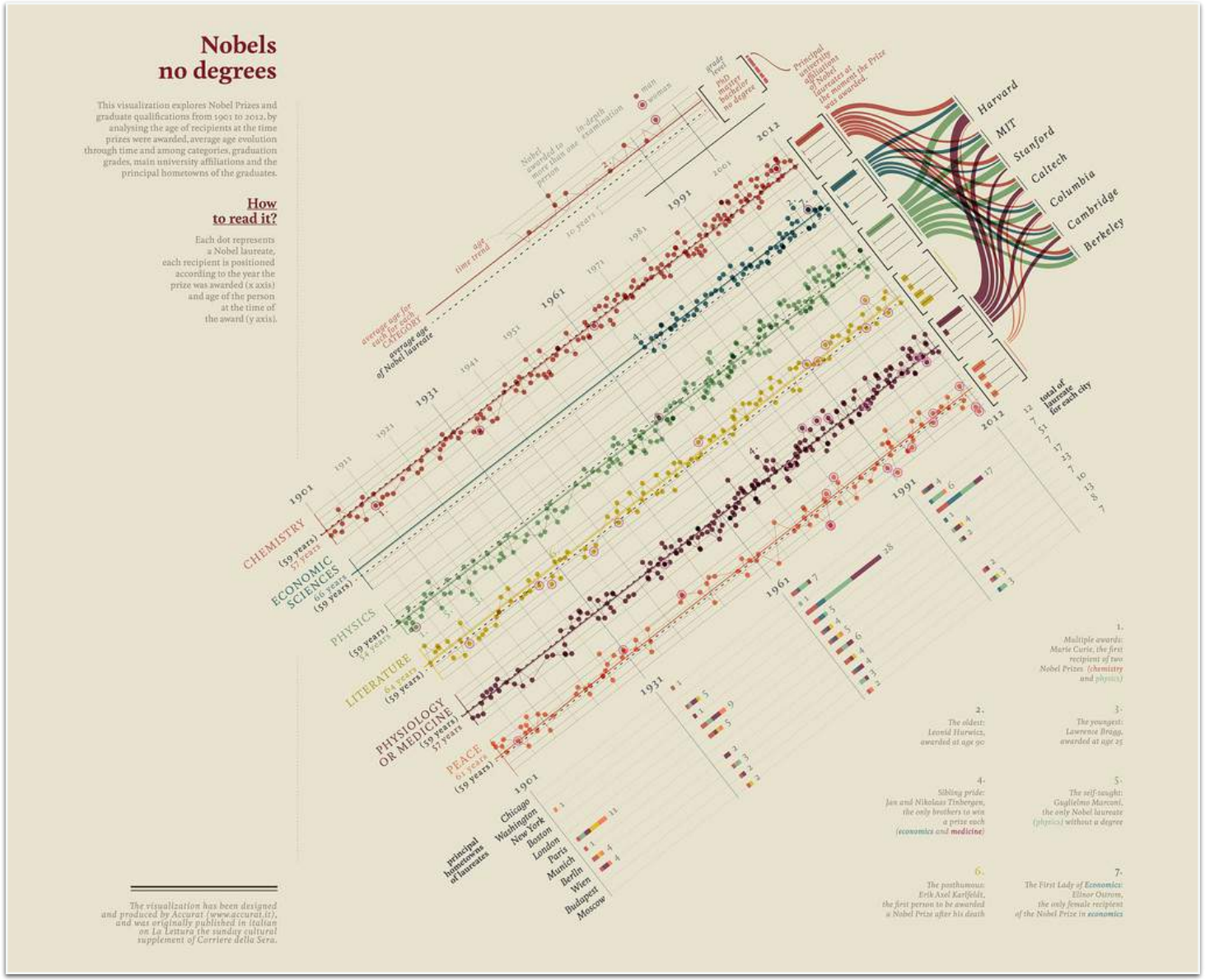
intermediate abstraction such as specifications

“For this visualization, we took a lot of inspiration from musical scores and their elegant aesthetics.

Particularly, John Cage, a famous contemporary composer, was a true source of fascination.”

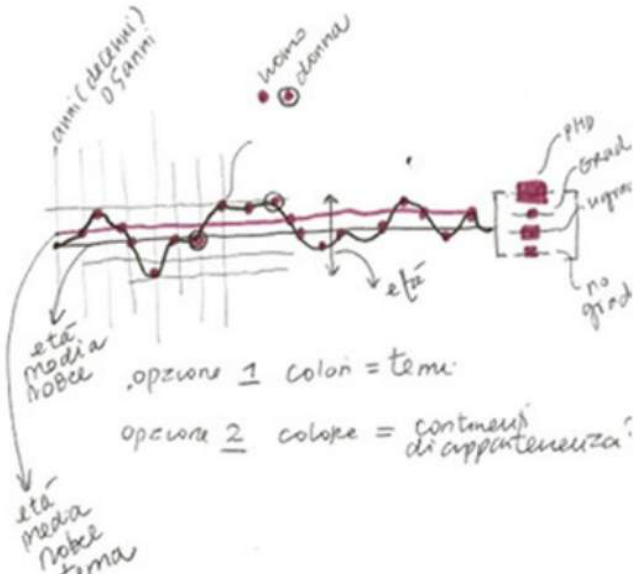


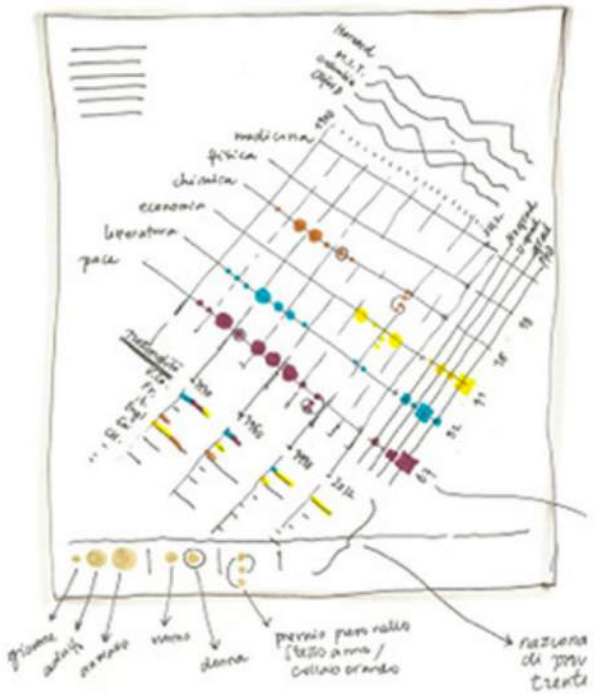
Giorgia Lupi, Gabriele Rossi,
Federica Fragapane, Francesco Majno.

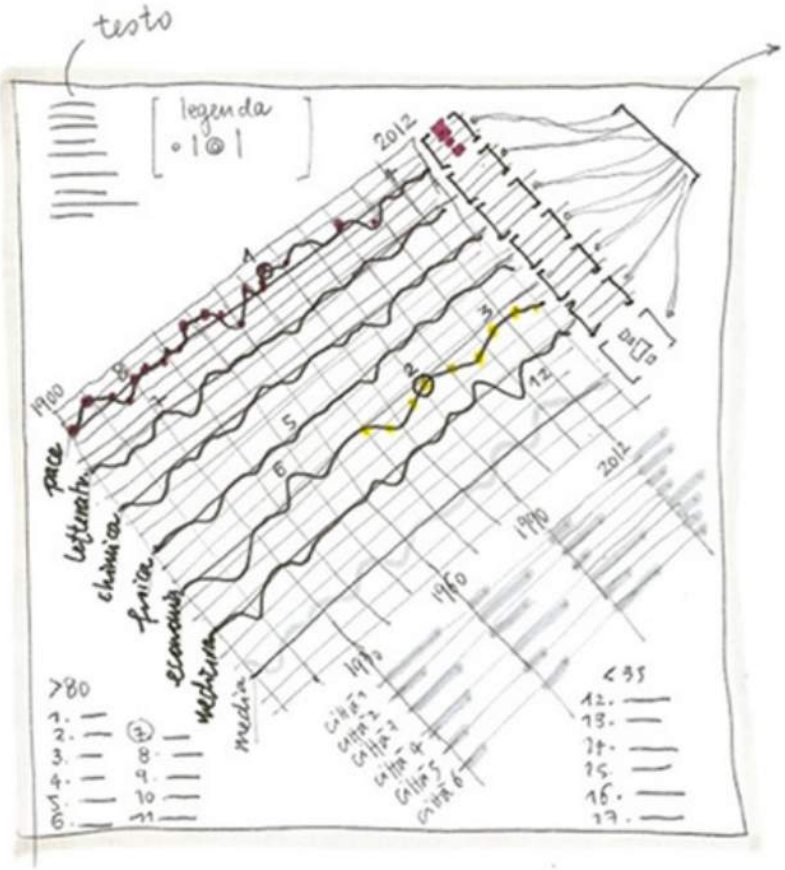


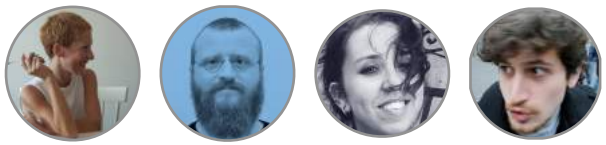
Quoted from https://www.behance.net/gallery/14159439/Nobel-no-degrees

Nobels, no degrees









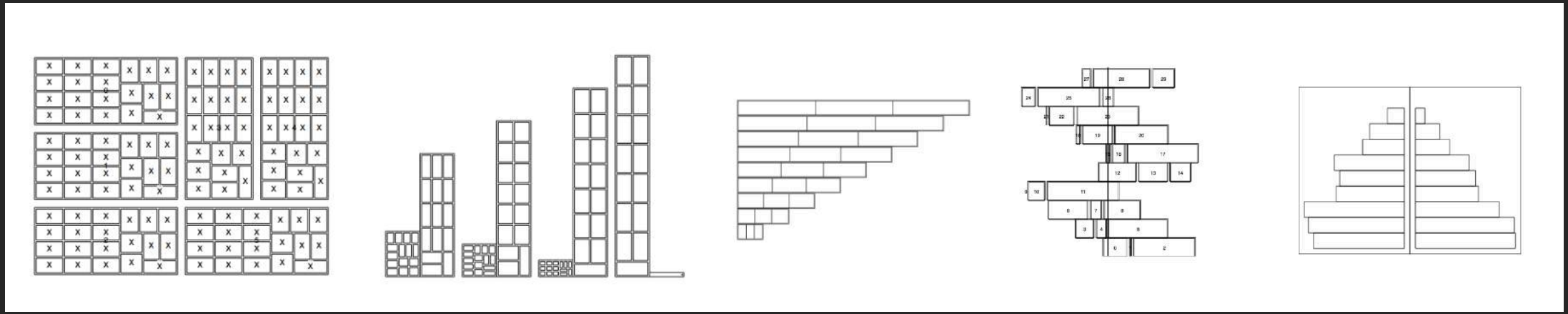
Giorgia Lupi, Gabriele Rossi,
Federica Fragapane, Francesco Majno.

Source: https://www.behance.net/gallery/14159439/Nobel-no-degrees

Limited time & technical resources

Data may not be available

Use mature tools (e.g. Adobe Illustrator) to do mock-ups



Structuring Visualization Mock-ups at the Graphical Level by Dividing the Display Space
Vuillemont and Boy, 2017

Data-to-Display Process Models

start with data, visualization rendered in the end

intermediate abstraction such as specifications

Lazy Data Binding

~~start with data, visualization rendered in the end~~

start with drawing, apply data as constraints when necessary

intermediate abstraction such as specifications

Lazy Data Binding

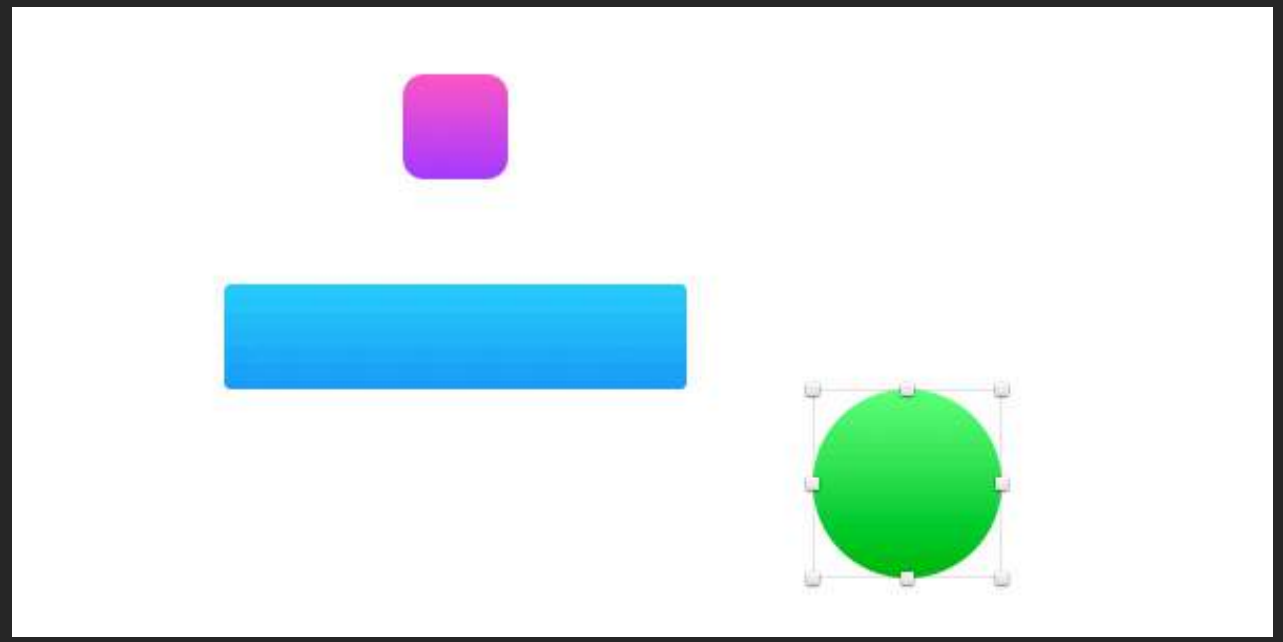
~~start with data, visualization rendered in the end~~

start with drawing, apply data as constraints when necessary

~~intermediate abstraction such as specifications~~

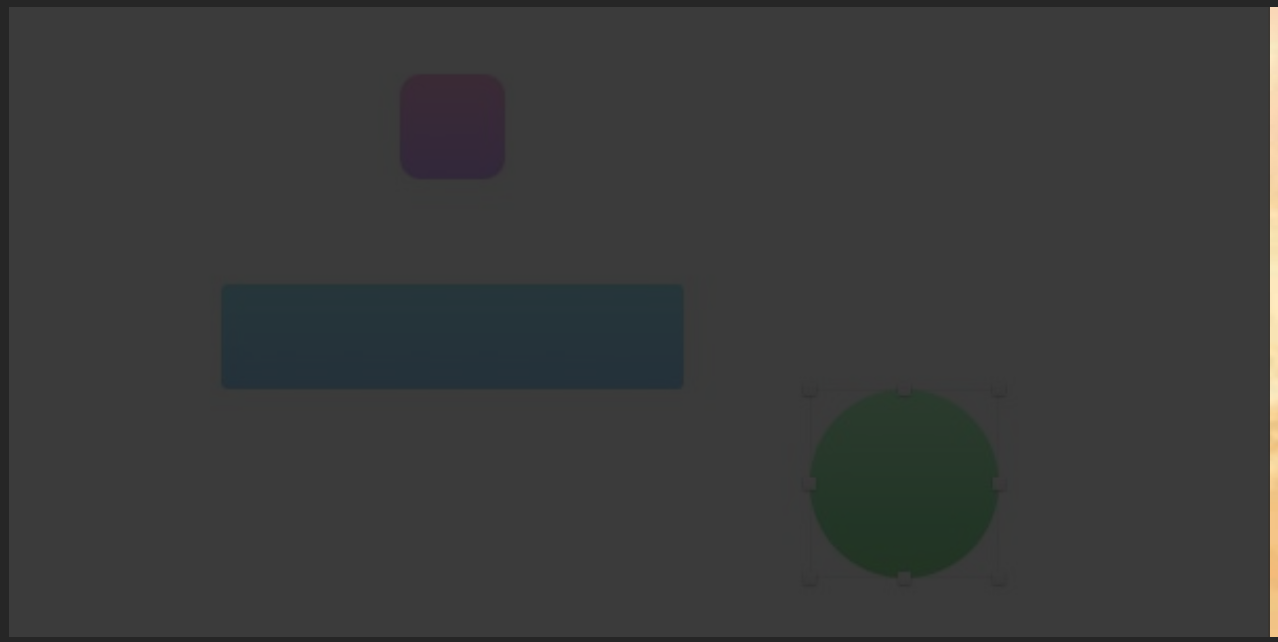
direct interaction with visual items on canvas

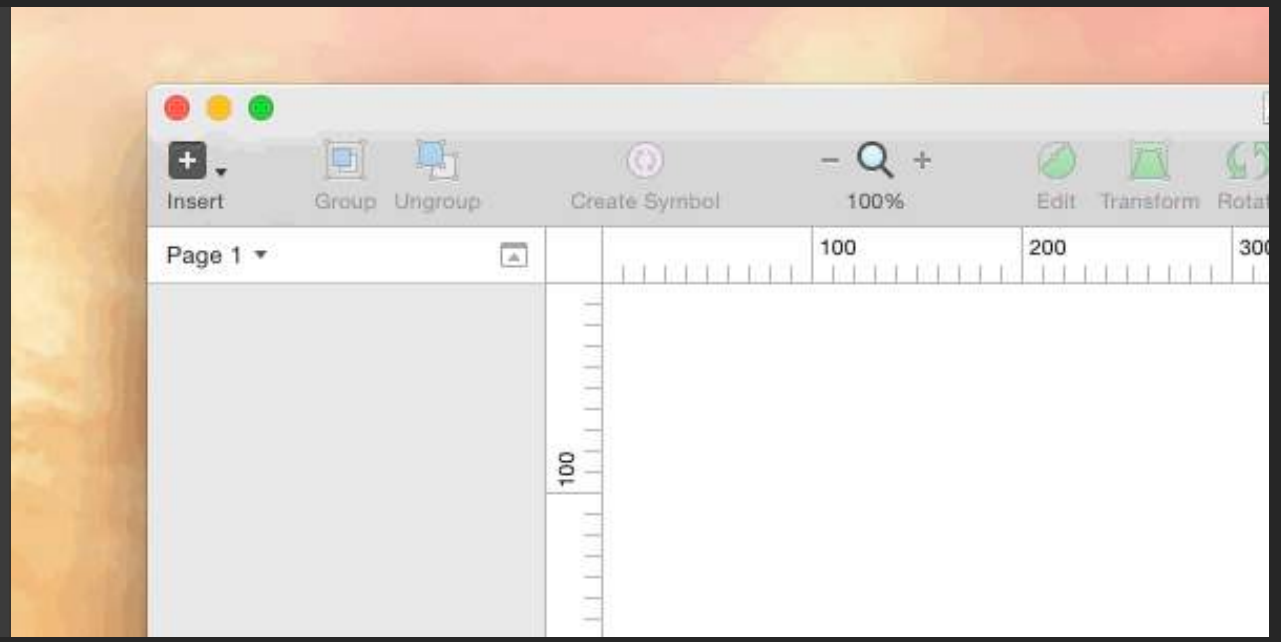
Inspirations: Rulers, Guides, Grids



Data-Driven Guides
InfoVis ‘16

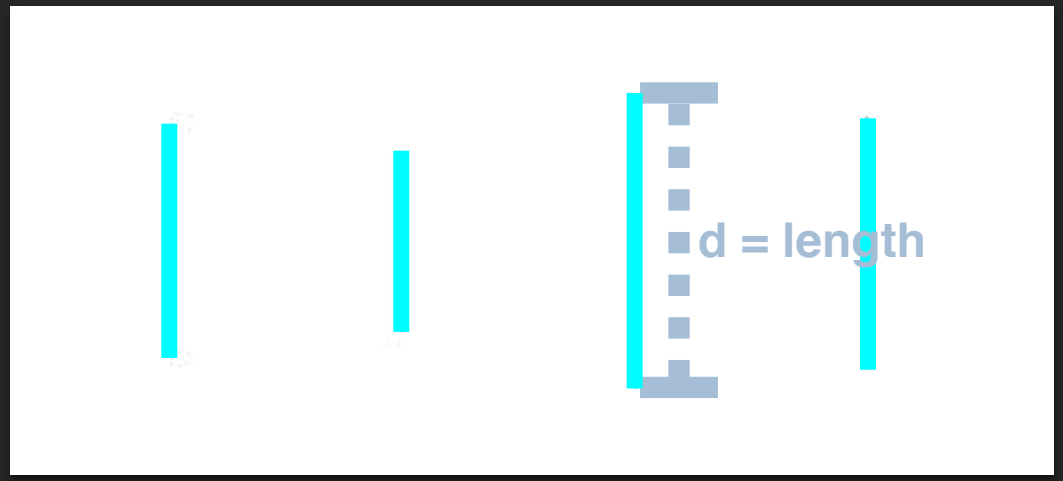
Inspirations: Rulers, Guides, Grids



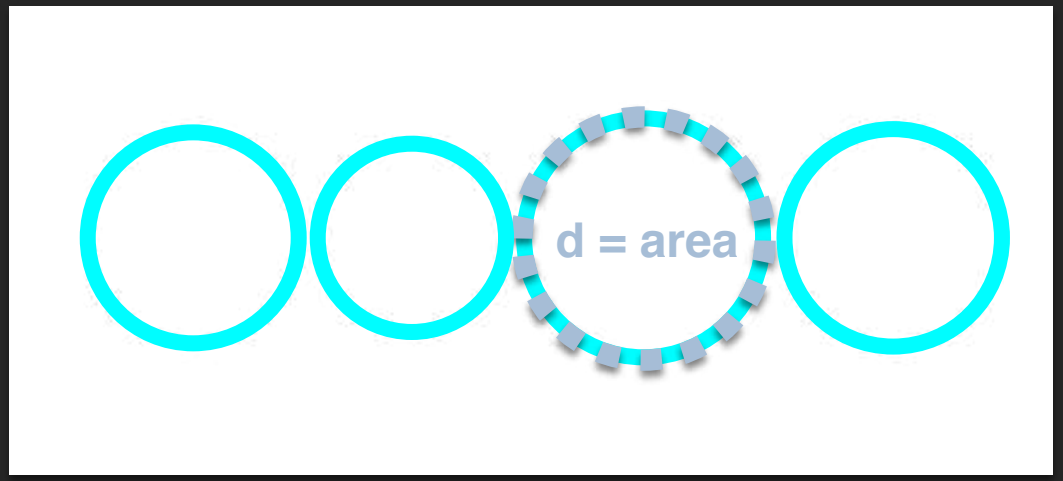


Data-Driven Guides
InfoVis '16

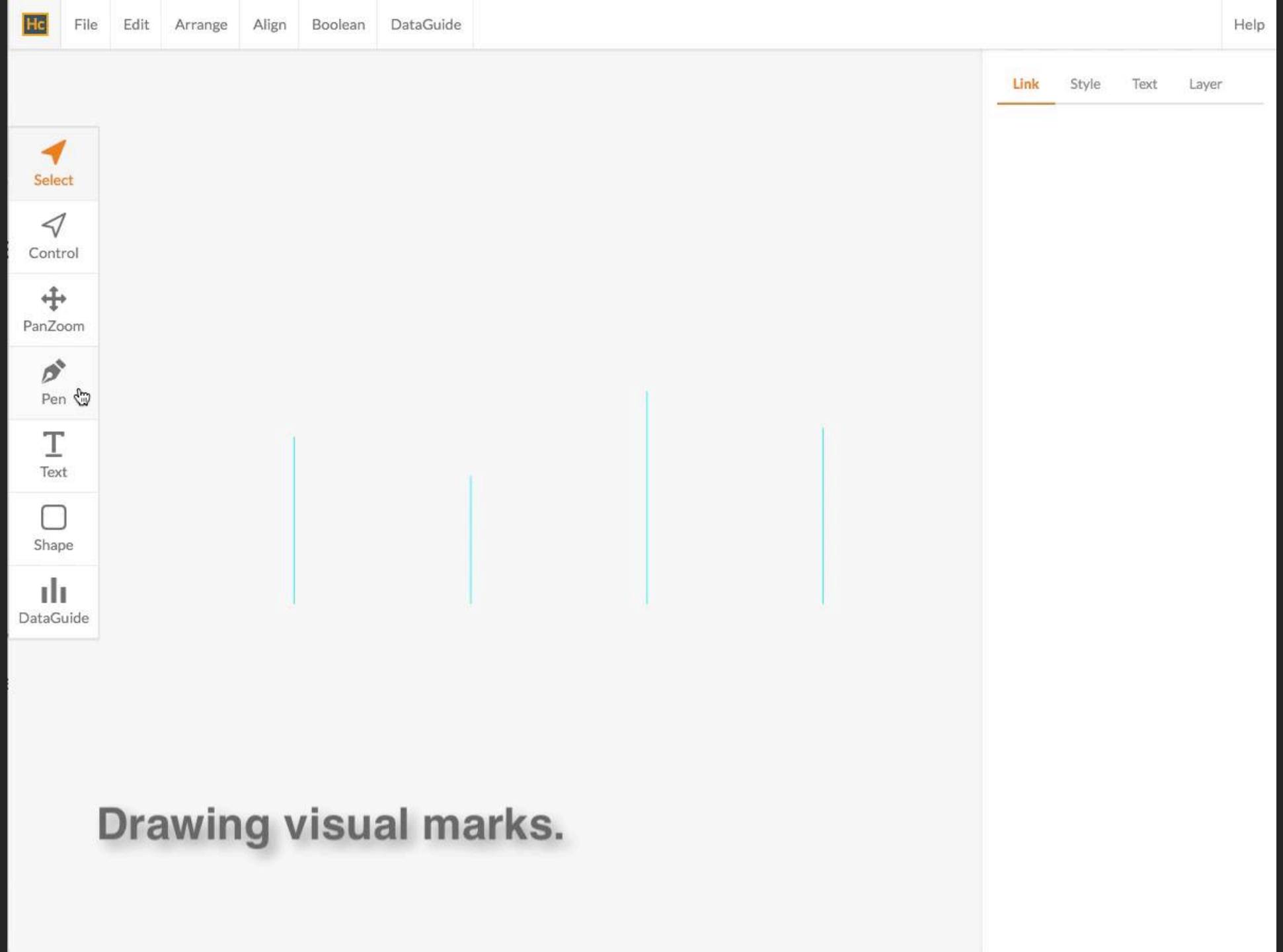
Data-Driven Guides as Constraints

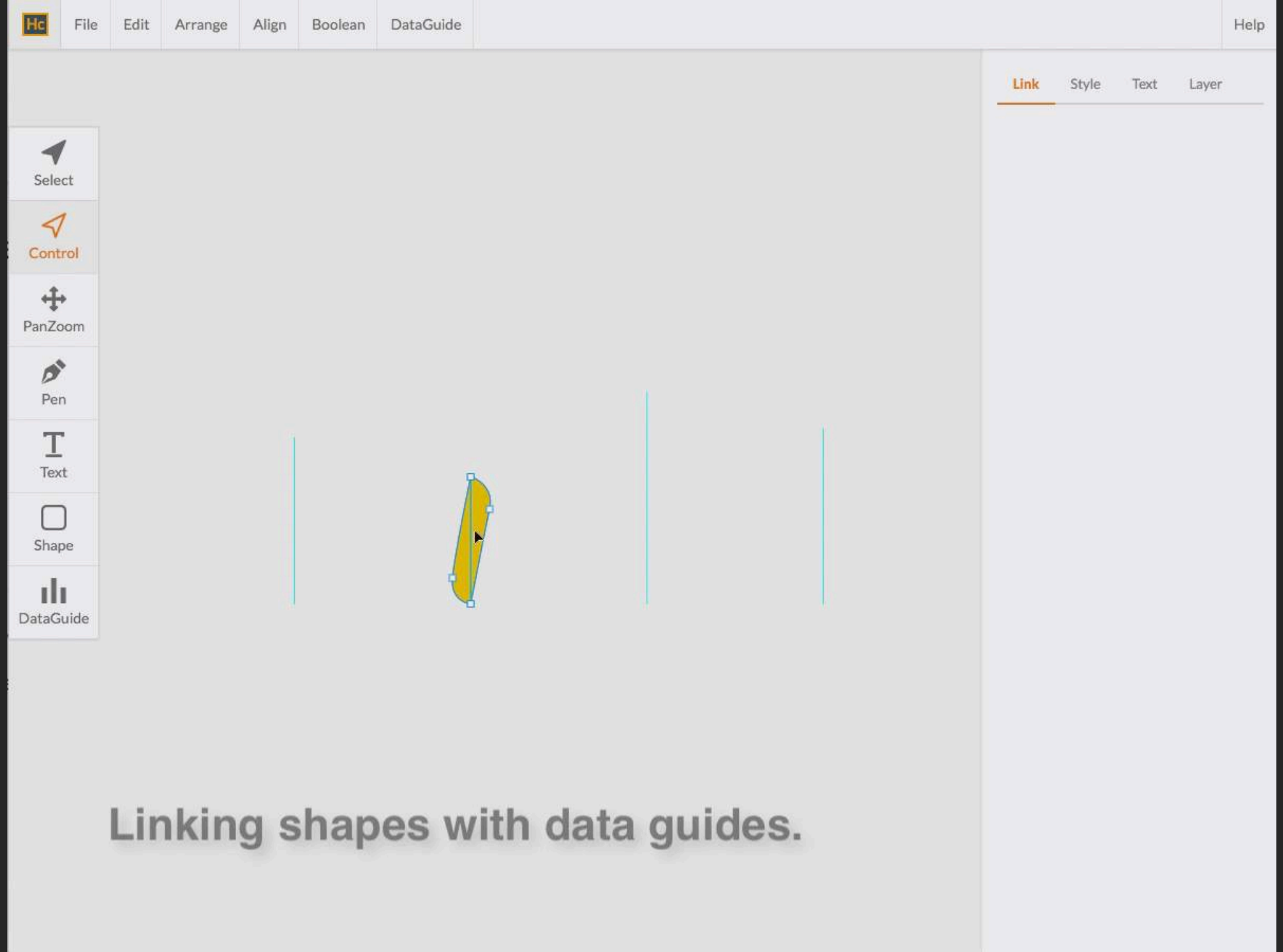


Length guide



Area guide


Hc
File
Edit
Arrange
Align
Boolean
DataGuide
Help
Link
Style
Text
Layer
Select
Control
PanZoom
Pen
Text
Shape
DataGuide
Drawing visual marks.


File
Edit
Arrange
Align
Boolean
DataGuide
Help
Link
Style
Text
Layer
Select
Control
PanZoom
Pen
Text
Shape
DataGuide
Linking shapes with data guides.

Linking a guide and a shape

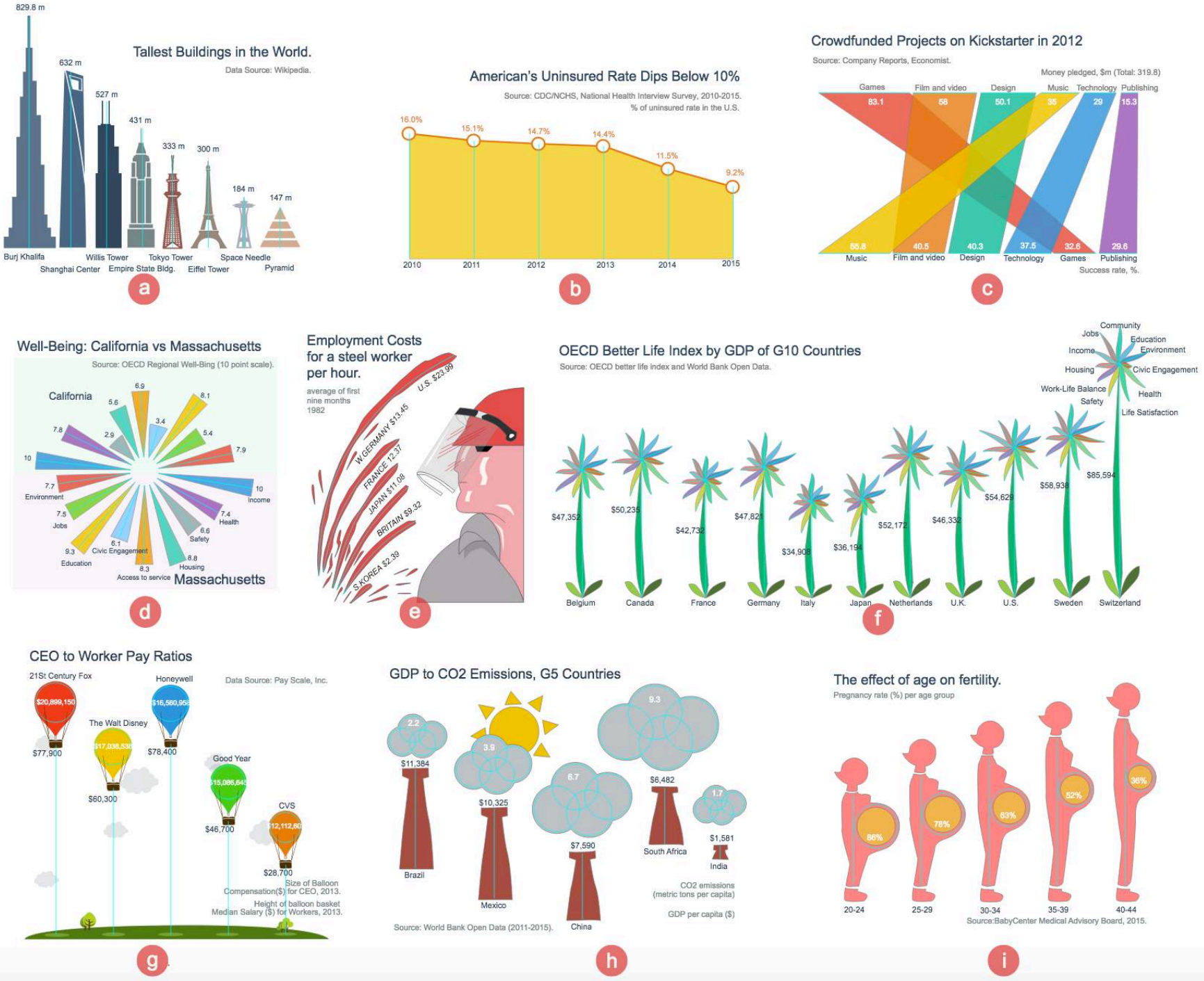
$$p_i' = \sum_{j=1}^{m} w_{ij} T_j p_i,$$

Linear blend skinning

Related Work

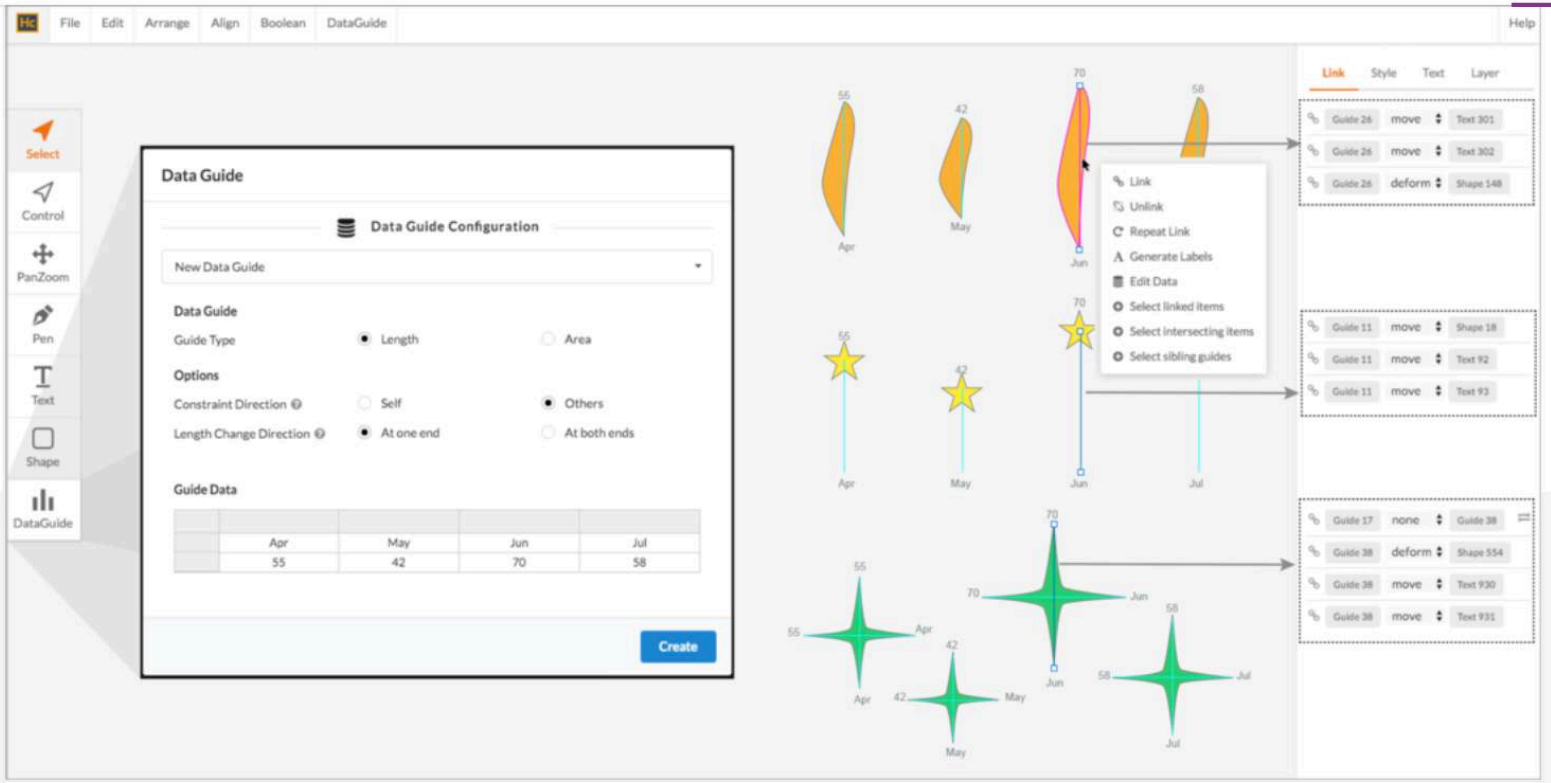
Bounded biharmonic weights for real-time deformation. Jacobson, Alec, et al. ACM Trans. Graph., 2011

Skinning cubic Bézier splines and Catmull-Clark subdivision surfaces. Liu, Songrun, et al. ACM Trans. Graph., 2014.


Tallest Buildings in the World.
Data Source: Wikipedia.
829.8 m
632 m
527 m
431 m
333 m
300 m
184 m
147 m
Burj Khalifa
Shanghai Center
Willis Tower
Empire State Bldg.
Tokyo Tower
Eiffel Tower
Space Needle
Pyramid
a
American's Uninsured Rate Dips Below 10%
Source: CDC/NCHS, National Health Interview Survey, 2010-2015.
% of uninsured rate in the U.S.
16.0%
15.1%
14.7%
14.4%
11.5%
9.2%
2010
2011
2012
2013
2014
2015
b
Crowdfunded Projects on Kickstarter in 2012
Source: Company Reports, Economist.
Money pledged, $m (Total: 319.8)
Games
Film and video
Design
Music
Technology
Publishing
83.1
58
50.1
35
29
15.3
55.8
40.5
40.3
37.5
32.6
29.6
Music
Film and video
Design
Technology
Games
Publishing
Success rate, %.
c
Well-Being: California vs Massachusetts
Source: OECD Regional Well-Bing (10 point scale).
California
Massachusetts
Environment
Income
Jobs
Health
Safety
Civic Engagement
Education
Housing
Access to service
d
Employment Costs for a steel worker per hour.
average of first nine months 1982
U.S. $23.99
W.GERMANY $13.45
FRANCE 13.37
JAPAN $11.08
BRITAIN $9.32
S.KOREA $2.39
e
OECD Better Life Index by GDP of G10 Countries
Source: OECD better life index and World Bank Open Data.
Community
Jobs
Education
Income
Environment
Housing
Civic Engagement
Work-Life Balance
Health
Safety
Life Satisfaction
$47,352
$50,235
$42,732
$47,821
$34,908
$36,194
$52,172
$46,332
$54,629
$58,938
$85,594
Belgium
Canada
France
Germany
Italy
Japan
Netherlands
U.K.
U.S.
Sweden
Switzerland
f
CEO to Worker Pay Ratios
Data Source: Pay Scale, Inc.
21St Century Fox
$20,899,150
$77,900
The Walt Disney
$17,038,536
$60,300
Honeywell
$16,580,959
$78,400
Good Year
$15,086,645
$46,700
CVS
$12,112,603
$28,700
Size of Balloon
Compensation($) for CEO, 2013.
Height of balloon basket
Median Salary ($) for Workers, 2013.
g
GDP to CO2 Emissions, G5 Countries
2.2
$11,384
Brazil
3.9
$10,325
Mexico
6.7
$7,590
China
9.3
$6,482
South Africa
1.7
$1,581
India
CO2 emissions
(metric tons per capita)
GDP per capita ($)
Source: World Bank Open Data (2011-2015).
h
The effect of age on fertility.
Pregnancy rate (%) per age group
86%
78%
63%
52%
36%
20-24
25-29
30-34
35-39
40-44
Source:BabyCenter Medical Advisory Board, 2015.
i

KANTAR
Information is Beautiful
Awards 2017

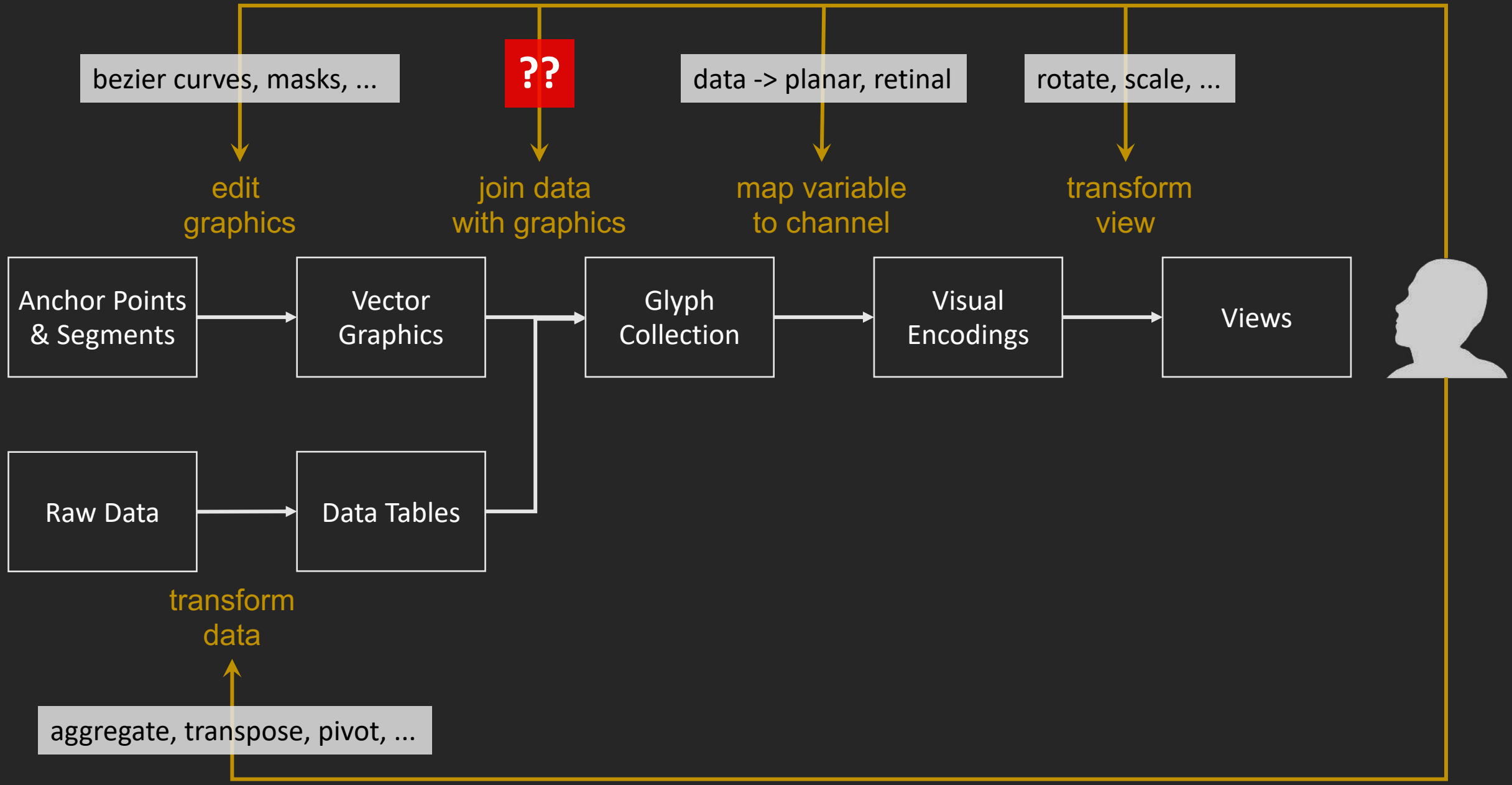
About News Awards Entry Showcase



Data-Driven Guides: Supporting Expressive Design for Information Graphics

Rising Star BRONZE:
Nam Wook Kim

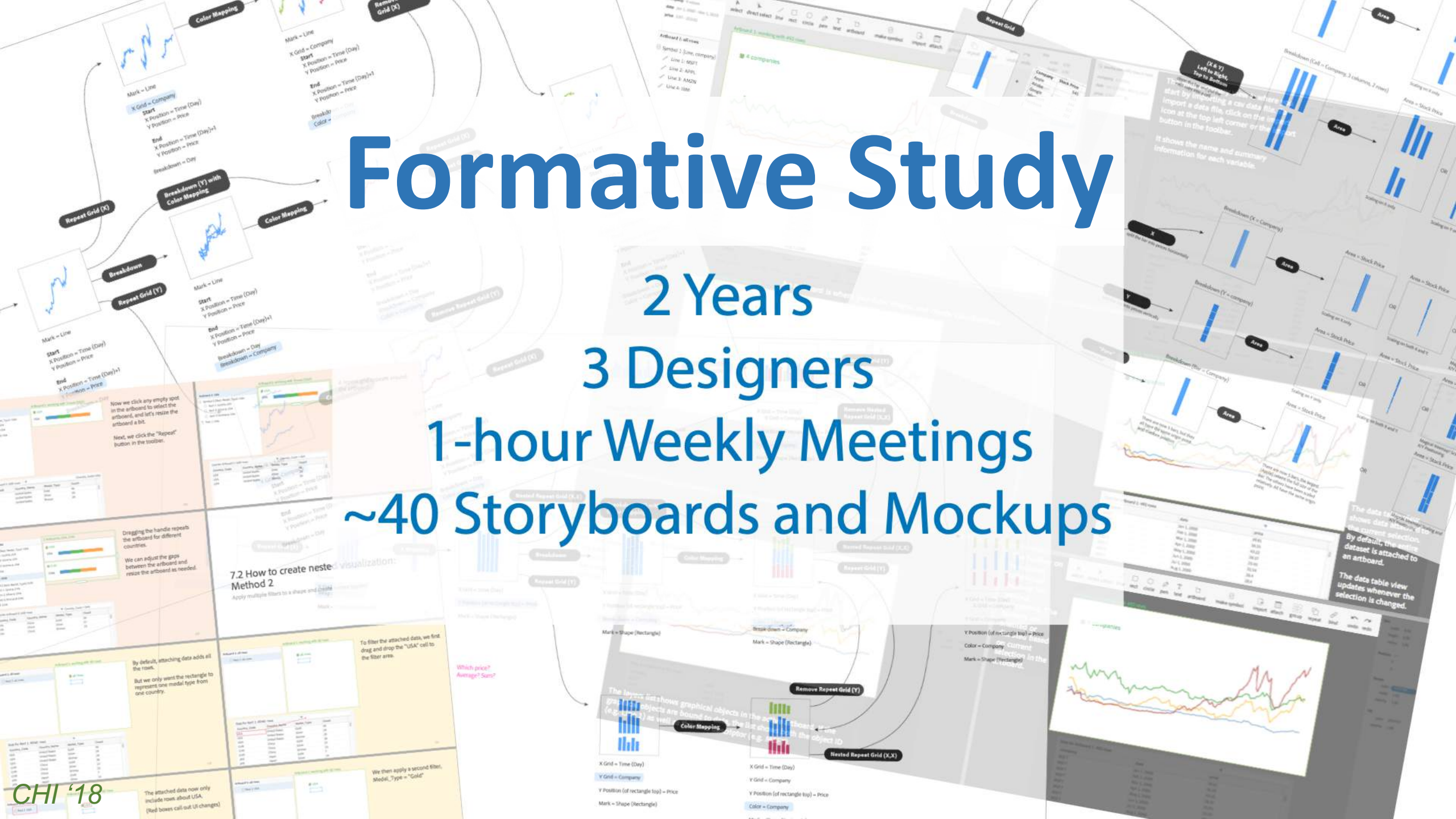
Lazy data binding:
A process model for 2D visualizations


bezier curves, masks, ...
??
data -> planar, retinal
rotate, scale, ...
edit graphics
join data with graphics
map variable to channel
transform view
Anchor Points & Segments
Vector Graphics
Glyph Collection
Visual Encodings
Views
Raw Data
Data Tables
transform data
aggregate, transpose, pivot, ...

Consistent with existing design applications

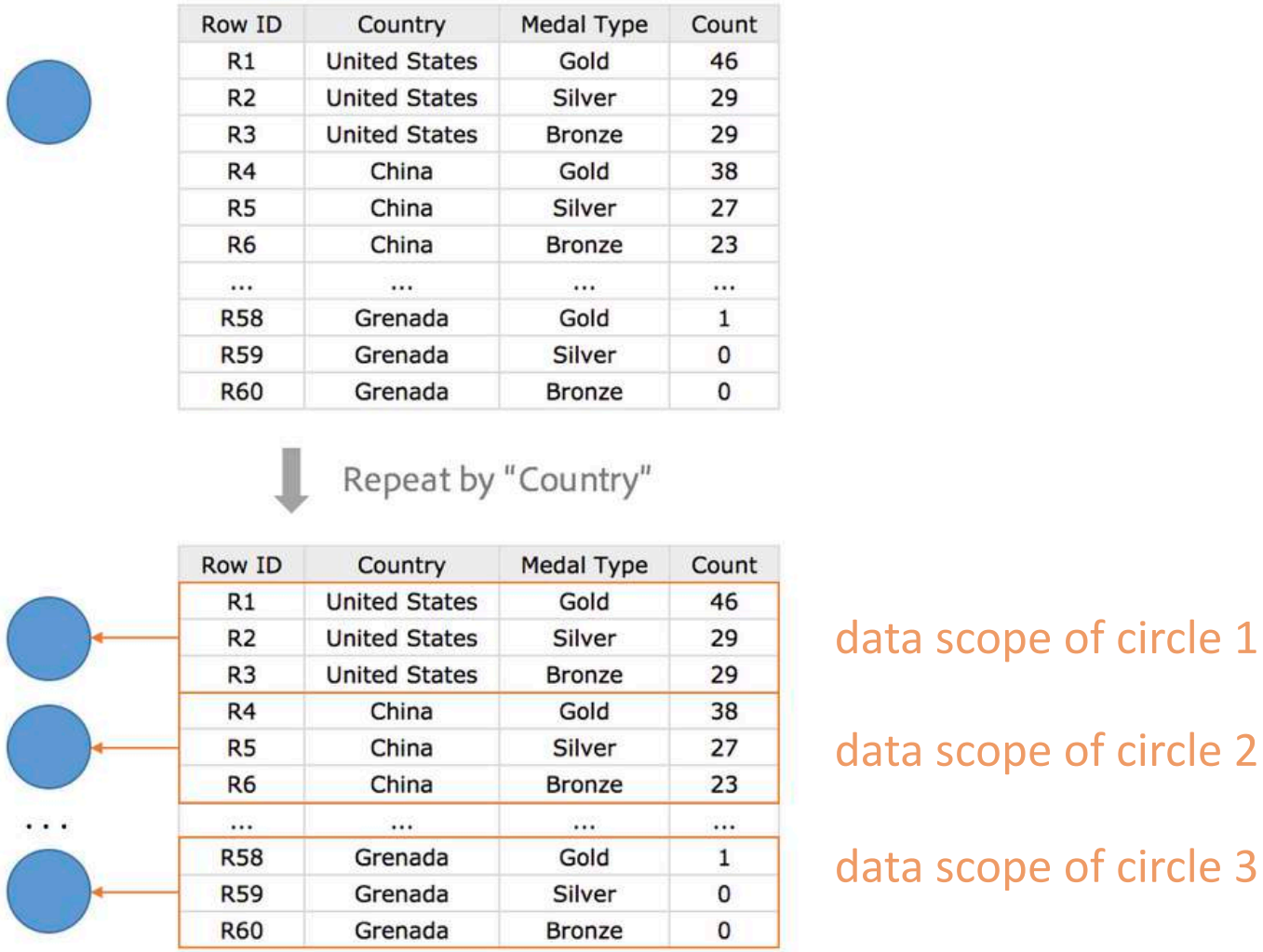
Interpretable by non-programmers

Composable to create novel visualizations


Formative Study
2 Years
3 Designers
1-hour Weekly Meetings
~40 Storyboards and Mockups
CHI '18

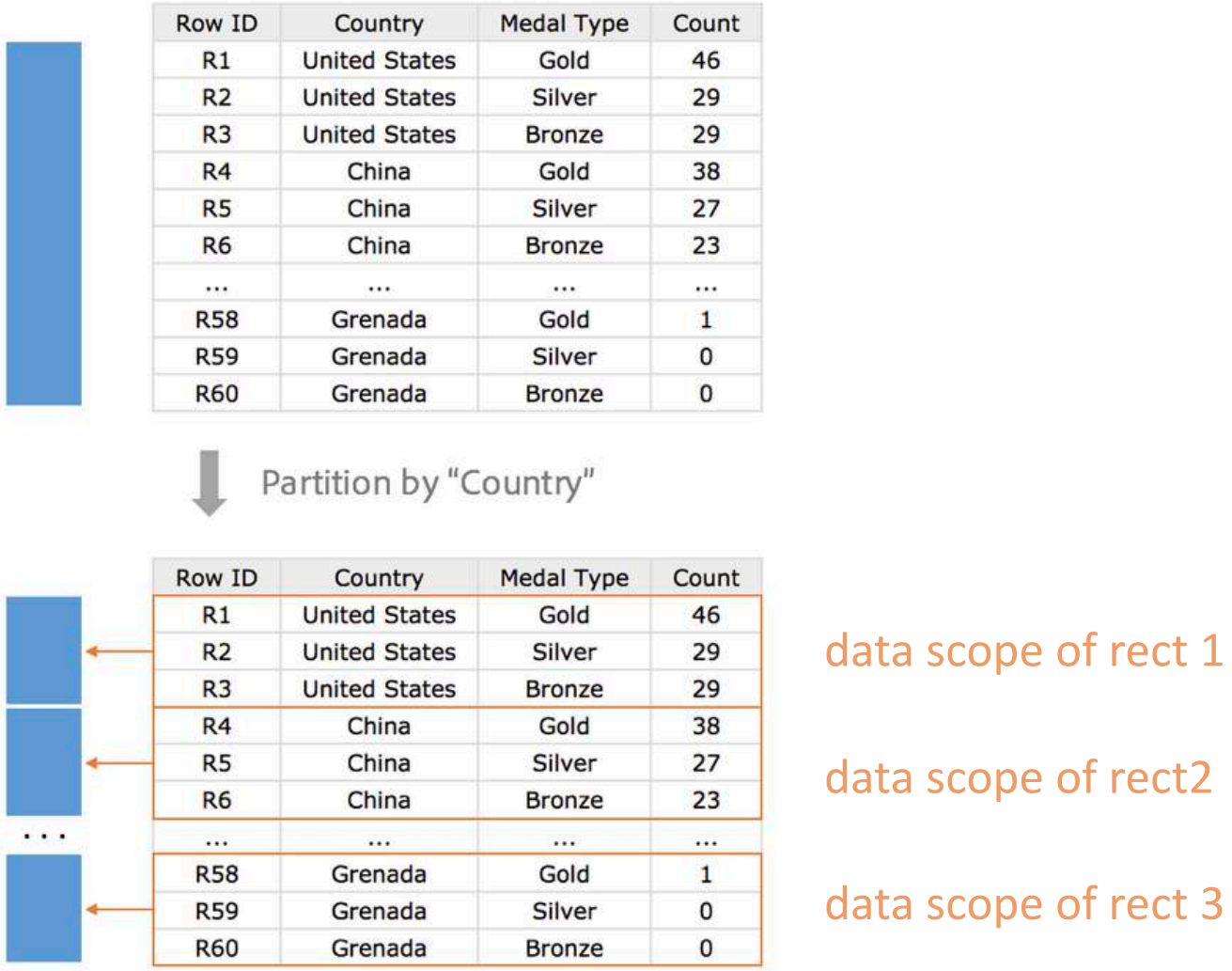
	Repeat	Partition
Concept	creates multiple copies of a shape	divides a shape into constituent parts
Example (line)		
Example (rectangle)		
Example (circle)		

Generative Operator: Repeat by Data



Data Illustrator
CHI '18

Generative Operator: Partition by Data

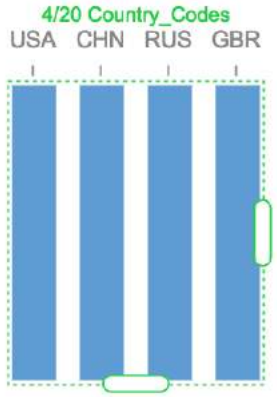


Data Illustrator
CHI '18

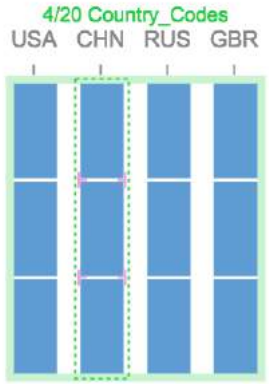
Repeat + Partition

Repeat + Repeat

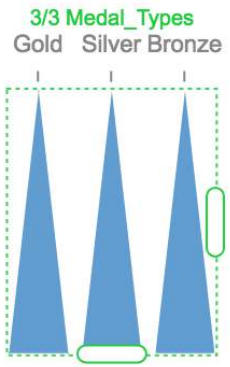
Repeat(rect)



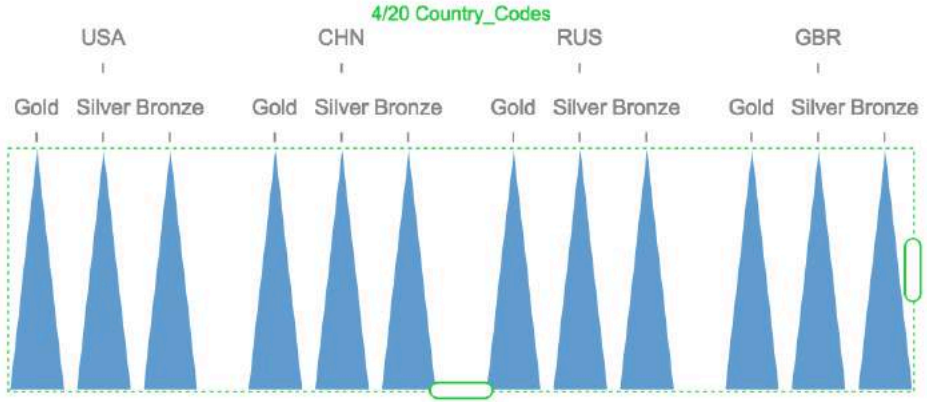
Partition(rect)



Repeat(path)



Repeat(grid)



Data Illustrator
CHI '18

File Edit View Help

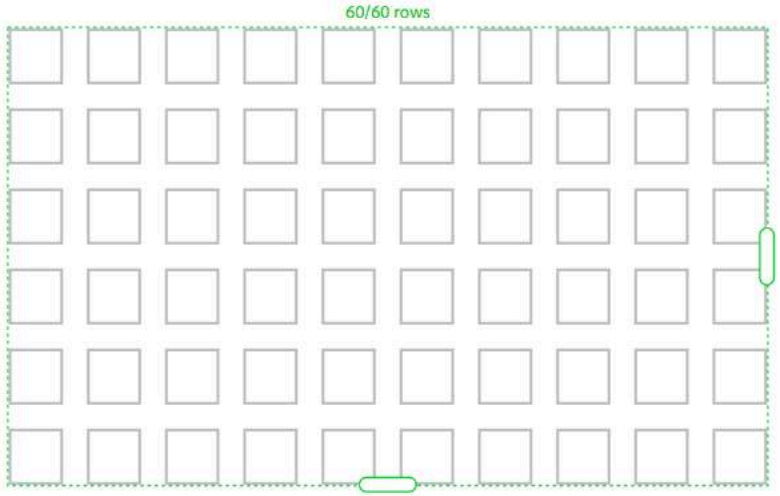
Olympic Medals Change

60 rows in total

- Abc Country_Code 20 values
- Abc Country_Name 20 values
- Abc Medal_Type 3 values
- # Count 0 - 46
- Abc Row_ID 60 values

LAYERS

- Repeat Grid 1
  - Rectangle 1: row 1
  - Rectangle 2: row 2
  - Rectangle 3: row 3
  - Rectangle 4: row 4
  - Rectangle 5: row 5
  - Rectangle 6: row 6
  - Rectangle 7: row 7
  - Rectangle 8: row 8
  - Rectangle 9: row 9
  - Rectangle 10: row 10
  - Rectangle 11: row 11
  - Rectangle 12: row 12
  - Rectangle 13: row 13
  - Rectangle 14: row 14
  - Rectangle 15: row 15
  - Rectangle 16: row 16
  - Rectangle 17: row 17
  - Rectangle 18: row 18



Repeat
Partition
Break Grid
Group

COLLECTION POSITION

X 717.5
Y 252.5

STYLE

Descriptor Show

LAYOUT

Type Grid
Row Gap 15.0
Column Gap 15.0

Data represented by Repeat Grid 1: 60/60 rows

Row_ID	Country_Code	Country_Name	Medal_Type	Count
1	USA	United States	Gold	46
2	USA	United States	Silver	29
3	USA	United States	Bronze	29
4	CHN	China	Gold	38
5	CHN	China	Silver	27
6	CHN	China	Bronze	23
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File Edit View Help

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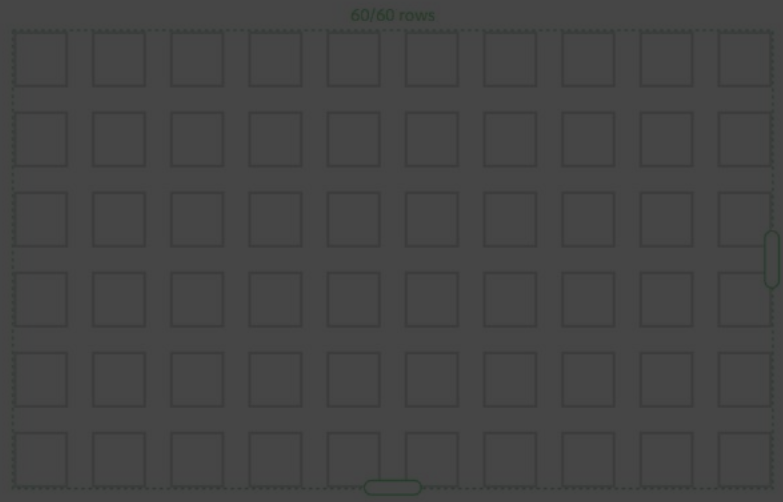
- Rectangle 10: row 10
- Rectangle 11: row 11
- Rectangle 12: row 12
- Rectangle 13: row 13
- Rectangle 14: row 14
- Rectangle 15: row 15
- Rectangle 16: row 16
- Rectangle 17: row 17
- Rectangle 18: row 18



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Partition
Break Grid
Group

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Y 252.5

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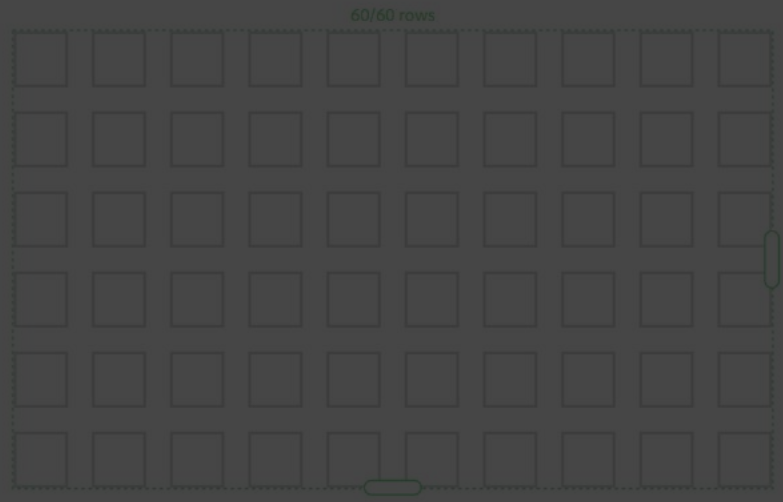

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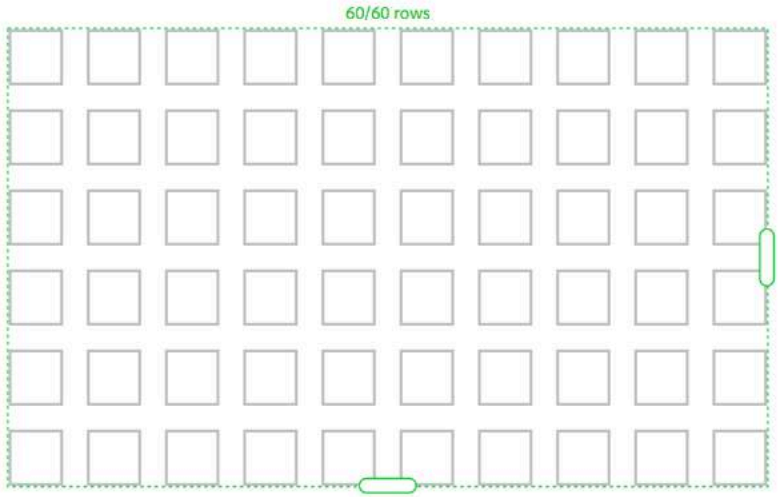

Repeat
Partition
Break Grid
Group

COLLECTION POSITION

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Y 252.5

STYLE

Descriptor Show

LAYOUT

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Column Gap 15.0

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3	USA	United States	Bronze	29
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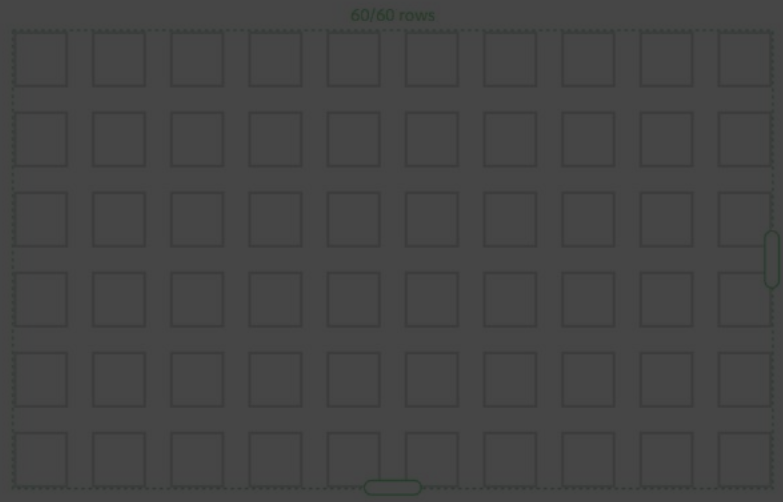

Repeat
Partition
Break Grid
Group

COLLECTION POSITION

X 717.5
Y 252.5

STYLE

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LAYOUT

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Column Gap 15.0

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4	CHN	China	Gold	38
5	CHN	China	Silver	27
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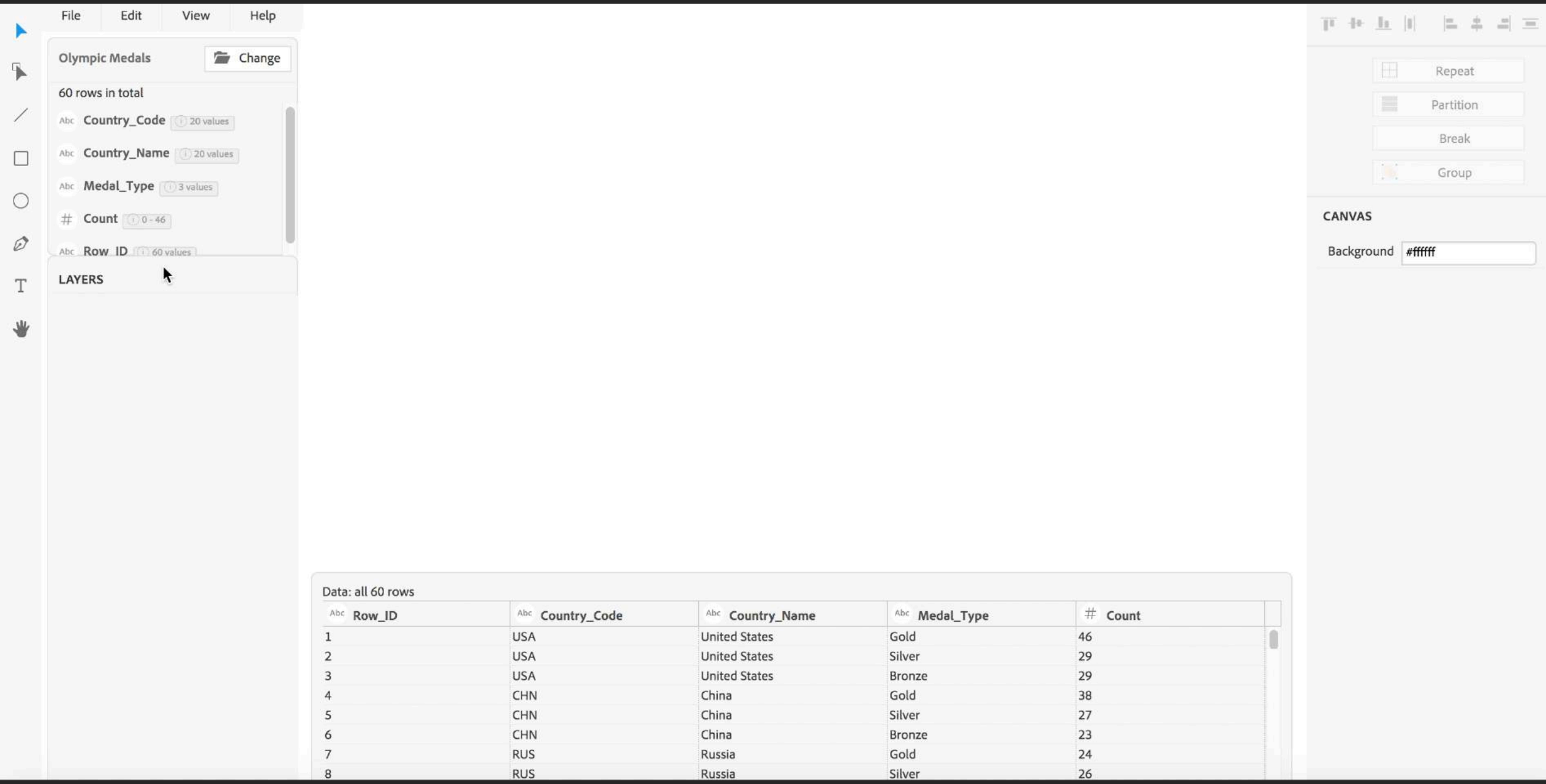
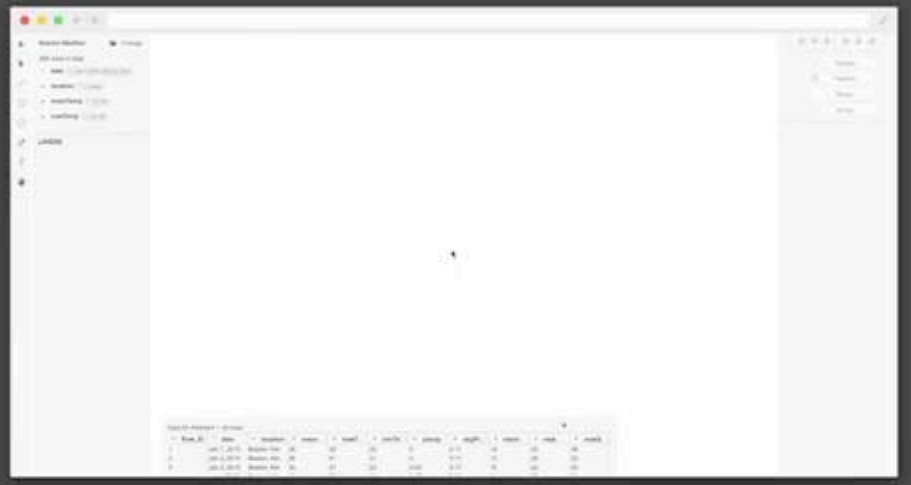
7	RUS	Russia	Gold	24

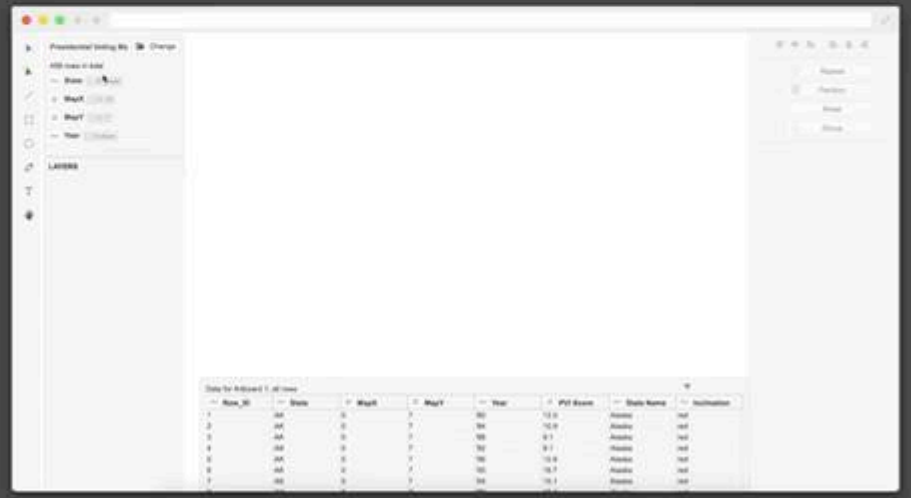

File
Edit
View
Help
Olympic Medals
Change
60 rows in total
Country_Code 20 values
Country_Name 20 values
Medal_Type 3 values
Count 0 - 46
Row_ID 60 values
LAYERS
Repeat
Partition
Break
Group
CANVAS
Background #ffffff
Data: all 60 rows
Row_ID | Country_Code | Country_Name | Medal_Type | Count
1 | USA | United States | Gold | 46
2 | USA | United States | Silver | 29
3 | USA | United States | Bronze | 29
4 | CHN | China | Gold | 38
5 | CHN | China | Silver | 27
6 | CHN | China | Bronze | 23
7 | RUS | Russia | Gold | 24
8 | RUS | Russia | Silver | 26

Data Illustrator allows you to create incredible data visualizations without programming.

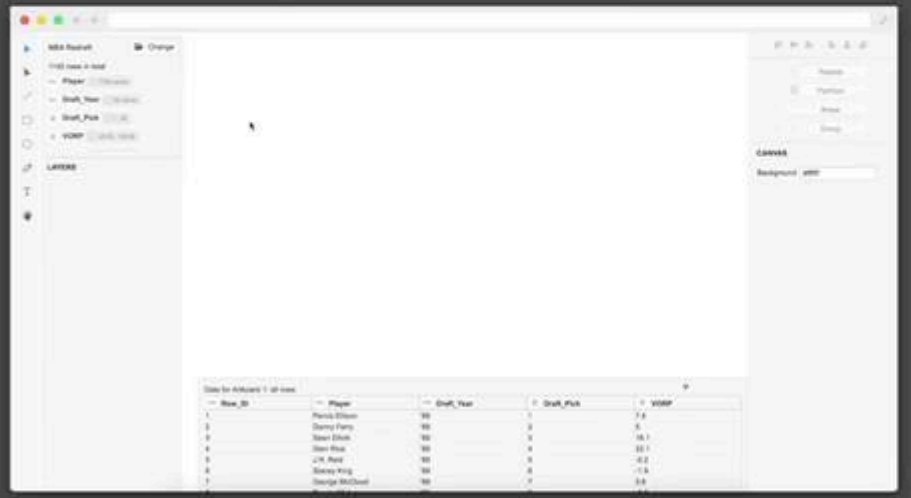
Nobels, No Degrees by Accurat Studio



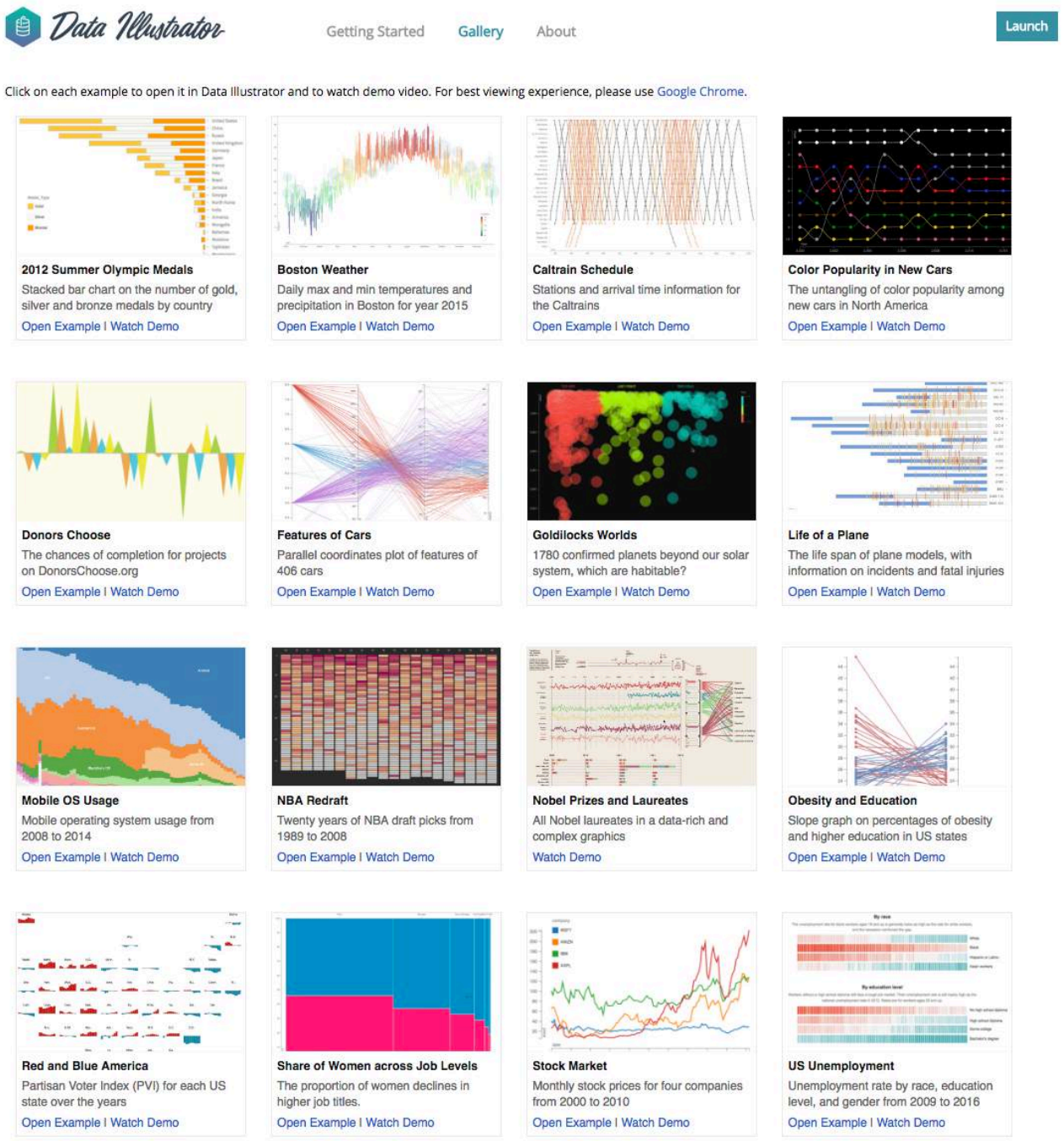
Weather Radials by Raureif



A Field Guide to Red and Blue America by WSJ



Twenty Years of the NBA Redrafted by Pudding



CHI 2018

Released app with tutorials & gallery
http://www.data-illustrator.com/

Used in graduate visualization classes

More than 35,000 users so far

Frédérik Ruys @fruys

Information designer @Vizualism, lecturer visual storytelling
Dutch Infographic Conference & Dataviz Festival

“The original infographic was published in 2017 in Vrij Nederland and took me **several hours** to complete in Illustrator.

Using Data Illustrator it would have taken me **just a few minutes**.”

Data Illustrator
CHI ‘18

Thank you. Questions?

Scalable Interaction Techniques

Multivariate linked analysis

Event sequence data analysis

Visualization Process Models

Natural language interaction

Graphical authoring tools

http://www.zcliu.org