Visualization Tools

Jane Hoffswell  University of Washington
How do people create visualizations?

**Chart Typology**
Pick from a stock of templates
Easy-to-use but limited expressiveness
Prohibits novel designs, new data types

**Component Architecture**
Permits more combinatorial possibilities
Novel views require new operators, which requires software engineering
Graphics APIs
Processing, OpenGL, Java2D
ey = y;
size = s;
}

void update(int mx, int my) {
    angle = atan2(my-ey, mx-ex);
}

void display() {
    pushMatrix();
    translate(ex, ey);
    fill(255);
    ellipse(0, 0, size, size);
    rotate(angle);
    fill(153);
    ellipse(size/4, 0, size/2, size/2);
    popMatrix();
}
Graphics APIs
Processing, OpenGL, Java2D
Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Data State Model

[Chi 98]
Prefuse & Flare

Operator-based toolkits for visualization design
Vis = (Input Data -> Visual Objects) + Operators

Prefuse (http://prefuse.org)  
Flare (http://flare.prefuse.org)
Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
# Data Sets: State Quick Facts

Uploaded By: zinggoat  
Data Source: US Census Bureau  
Description:  
Tags: people census

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1 Alabama</td>
<td>4557808</td>
<td>0.03</td>
<td>4447100</td>
<td>0.1</td>
<td>0.07</td>
<td>0.24</td>
<td>0.13</td>
</tr>
<tr>
<td>2 Alaska</td>
<td>663661</td>
<td>0.06</td>
<td>626932</td>
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<td>0.08</td>
<td>0.29</td>
<td>0.06</td>
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<tr>
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<td>59393292</td>
<td>0.16</td>
<td>5130632</td>
<td>0.4</td>
<td>0.08</td>
<td>0.27</td>
<td>0.13</td>
</tr>
<tr>
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<td>2673400</td>
<td>0.14</td>
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<tr>
<td>5 California</td>
<td>36132147</td>
<td>0.07</td>
<td>33871648</td>
<td>0.14</td>
<td>0.07</td>
<td>0.27</td>
<td>0.11</td>
</tr>
<tr>
<td>6 Colorado</td>
<td>4665177</td>
<td>0.08</td>
<td>4301261</td>
<td>0.31</td>
<td>0.07</td>
<td>0.26</td>
<td>0.1</td>
</tr>
<tr>
<td>7 Connecticut</td>
<td>3510297</td>
<td>0.03</td>
<td>3405565</td>
<td>0.04</td>
<td>0.06</td>
<td>0.24</td>
<td>0.14</td>
</tr>
<tr>
<td>8 Delaware</td>
<td>843524</td>
<td>0.08</td>
<td>783600</td>
<td>0.18</td>
<td>0.07</td>
<td>0.23</td>
<td>0.13</td>
</tr>
<tr>
<td>9 Florida</td>
<td>17789864</td>
<td>0.11</td>
<td>15982378</td>
<td>0.24</td>
<td>0.06</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td>10 Georgia</td>
<td>9072576</td>
<td>0.11</td>
<td>8186453</td>
<td>0.26</td>
<td>0.08</td>
<td>0.26</td>
<td>0.1</td>
</tr>
<tr>
<td>11 Hawaii</td>
<td>1275194</td>
<td>0.05</td>
<td>1211537</td>
<td>0.09</td>
<td>0.07</td>
<td>0.24</td>
<td>0.14</td>
</tr>
<tr>
<td>12 Idaho</td>
<td>1429096</td>
<td>0.1</td>
<td>1293953</td>
<td>0.29</td>
<td>0.07</td>
<td>0.27</td>
<td>0.11</td>
</tr>
<tr>
<td>13 Illinois</td>
<td>12763371</td>
<td>0.03</td>
<td>12419293</td>
<td>0.09</td>
<td>0.07</td>
<td>0.26</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Choosing a visualization type for State Quick Facts

Analyze a text

Tag Cloud
How are you using your words? This enhanced tag cloud will show you the words popularity in the given set of text.

Learn more

Wordle
Wordle is a toy for generating "word clouds" from text that you provide. The clouds give greater prominence to words that appear more frequently in the source text.

Learn more

Word Tree
See a branching view of how a word or phrase is used in a text. Navigate the text by zooming and clicking.

Learn more

Compare a set of values

Bar Chart
How do the items in your data set stack up? A bar chart is a simple and recognizable way to compare values. You can display several sets of bars for multivariate comparisons.

Learn more

Block Histogram
This versatile chart lets you get a quick sense of how a single set of data is distributed. Each item in the data is an individually identifiable block.

Learn more
Every Wednesday, when I get home from school, I have a piano lesson. My teacher is a very strict house. Her name is Hillary Clinton. Our piano is a Steinway Concert tree and it has 88 cups. It also has a soft pedal and a/smile pedal. When I have a lesson, I sit down on the piano Alberto and play for 16 minutes. I do scales to exercise my cats, and then I usually play a minuet by Johann Sebastian Washington. Teacher says I am a natural Haunted House and have a good musical leg. Perhaps when I get better I will become a concert vet and give a recital at Carnegie hospital.
Most charting packages channel user requests into a **rigid array of chart types**. To atone for this lack of flexibility, they offer a kit of post-creation editing tools to return the image to what the user originally envisioned. They give the user an impression of having explored data rather than the experience.

Leland Wilkinson
Chart Typologies
Excel, Many Eyes, Google Charts

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
ggplot(diamonds, aes(x=price, fill=cut)) + geom_bar(position="dodge")
ggplot(diamonds, aes(x=price, fill=cut)) + geom_bar(position="dodge")
ggplot(diamonds, aes(x=price, fill=cut)) + geom_bar(position="dodge")
qplot(long, lat, data = expo, geom = "tile", fill = ozone,
    facets = year ~ month) +
scale_fill_gradient(low = "white", high = "black") + map
Chart Typologies
Excel, Many Eyes, Google Charts

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VizQL, ggplot2

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Ease-of-Use

Expressiveness
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Protovis & D3
Today's first task is not to invent wholly new \textit{graphical} techniques, though these are needed. Rather we need most vitally to recognize and reorganize the \texttt{essential of old techniques}, to make easy their assembly in new ways, and to modify their external appearances to fit the new opportunities.

J. W. Tukey, M. B. Wilk
\textit{Data Analysis & Statistics, 1965}
Protovis: A Grammar for Visualization

A graphic is a composition of data-representative marks.

with Mike Bostock & Vadim Ogievetsky
MARKS: Protovis graphical primitives
<table>
<thead>
<tr>
<th>MARK</th>
<th>$\lambda : D \rightarrow R$</th>
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<tbody>
<tr>
<td>data</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>visible</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>left</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>bottom</td>
<td>$\lambda$</td>
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<td>lineWidth</td>
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<tr>
<td>...</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>property</td>
<td>value</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>
data| 1 | 1.2 | 1.7 | 1.5 | 0.7 |
visible| true |
left| \( \lambda \): index * 25 |
bottom| 0 |
width| 20 |
height| \( \lambda \): datum * 80 |
fillStyle| blue |
strokeStyle| black |
lineWidth| 1.5 |

...
<table>
<thead>
<tr>
<th>RECT</th>
<th>( \lambda : D \rightarrow R )</th>
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</thead>
<tbody>
<tr>
<td>data</td>
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<td>height</td>
<td>1 * 80</td>
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<td>strokeStyle</td>
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<td>lineWidth</td>
<td>1.5</td>
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<td>...</td>
<td>...</td>
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<td>RECT</td>
<td>(\lambda : D \rightarrow R)</td>
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<tr>
<td>-------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>data</td>
<td>1  1.2  1.7  1.5  0.7</td>
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</table>

![Graph](image-url)
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<td>2 * 25</td>
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<tr>
<td><strong>bottom</strong></td>
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<td><strong>lineWidth</strong></td>
<td>1.5</td>
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<td>RECT</td>
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</tr>
<tr>
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<td>visible</td>
<td>true</td>
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<td>left</td>
<td>$3 \times 25$</td>
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<td>bottom</td>
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<td>width</td>
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<td>height</td>
<td>$1.5 \times 80$</td>
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<tr>
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<td>blue</td>
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<td>strokeStyle</td>
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<td>lineWidth</td>
<td>1.5</td>
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<td>...</td>
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<tr>
<td>RECT</td>
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</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>data</td>
<td>1  1.2  1.7  1.5  0.7</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
</tr>
<tr>
<td>left</td>
<td>$4 \times 25$</td>
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<tr>
<td>bottom</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>20</td>
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<tr>
<td>height</td>
<td>$0.7 \times 80$</td>
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<tr>
<td>fillStyle</td>
<td>blue</td>
</tr>
<tr>
<td>strokeStyle</td>
<td>black</td>
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<tr>
<td>lineWidth</td>
<td>1.5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
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</tbody>
</table>
### RECT

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
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<tbody>
<tr>
<td>data</td>
<td>1 1.2 1.7 1.5 0.7</td>
</tr>
<tr>
<td>visible</td>
<td>true</td>
</tr>
<tr>
<td>left</td>
<td>$\lambda: \text{index} \times 25$</td>
</tr>
<tr>
<td>bottom</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>20</td>
</tr>
<tr>
<td>height</td>
<td>$\lambda: \text{datum} \times 80$</td>
</tr>
<tr>
<td>fillStyle</td>
<td>blue</td>
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<td>lineWidth</td>
<td>1.5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
var vis = new pv.Panel();
vis.add(pv.Bar)
  .data([1, 1.2, 1.7, 1.5, 0.7])
  .visible(true)
  .left((d) => this.index * 25);
  .bottom(0)
  .width(20)
  .height((d) => d * 80)
  .fillStyle("blue")
  .strokeStyle("black")
  .lineWidth(1.5);
vis.render();
var army = pv.nest(napoleon.army, "dir", "group");
var vis = new pv.Panel();

var lines = vis.add(pv.Panel).data(army);
lines.add(pv.Line)
  .data((d) => army[this.idx])
  .left(lon).top(lat).size((d) => d.size/8000)
  .strokeStyle((d) => color[army[paneIndex][0].dir]);

vis.add(pv.Rule).data([0,-10,-20,-30])
  .top((d) => 300 - 2*d - 0.5).left(200).right(150)
  .lineWidth(1).strokeStyle("#ccc")
  .anchor("right").add(pv.Label)
  .font("italic 10px Georgia")
  .text((d) => d.temp+"°").textBaseline("center");

vis.add(pv.Line).data(napoleon.temp)
  .left(lon).top(tmp).strokeStyle("#0")
  .add(pv.Label)
  .top((d) => 5 + tmp(d))
  .text((d) => d.temp+"° "+d.date.substr(0,6))
  .textAlign("center").textBaseline("middle");

vis.add(pv.Label).data(napoleon.cities)
  .left(lon).top(lat)
  .text((d) => d.city).font("italic 10px Georgia")
  .textAlign("center").textBaseline("middle");
PRELUDE NO.1 IN C MAJOR, BWV 846
(FROM WELL-TEMPERED CLAVIER, BOOK 1)

BY J.S. BACH

Bach's Prelude #1 in C Major | Jieun Oh
Obesity Map | Vadim Ogievetsky
d3.js  Data-Driven Documents

with Mike Bostock, Jason Davies & Vadim Ogievetsky
Protovis

**Specialized mark types**
- Streamlined design
- Limits expressiveness
- More overhead (slower)
- Harder to debug
- Self-contained model

**Specify a scene (nouns)**
- Quick for static vis
- Delayed evaluation
- Animation, interaction are more cumbersome
## Protovis

**Specialized mark types**
- Streamlined design
- Limits expressiveness
- More overhead (slower)
- Harder to debug
- Self-contained model

**Specify a scene (nouns)**
- Quick for static vis
- Delayed evaluation
- Animation, interaction are more cumbersome

## D3

**Bind data to DOM**
- Exposes SVG/CSS/…
- Less overhead (faster)
- Debug in browser
- Use with other tools

**Transform a scene (verbs)**
- More complex model
- Immediate evaluation
- Dynamic data, anim, and interaction natural
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D
Administrivia
Reminders!

Assignment 3 Due **tonight, Mon 2/8, 11:59pm**

Final Project Proposal Due **Fri 2/12, 11:59pm**
https://courses.cs.washington.edu/courses/cse412/21wi/fp.html

Four Peer Evaluations Due **Mon 2/15, 11:59pm**
https://courses.cs.washington.edu/courses/cse412/21wi/a3b.html
A3 Assignment Peer Critiques

Review four A3 submissions (assigned on Canvas)

Submit four critique forms by Mon 2/15, 11:59

Assignments will be posted tomorrow afternoon after the A3 deadline (announced on Ed).

Please submit A3 on time! Assignments submitted late will not receive any peer evaluations.
A3 Assignment Peer Critiques

Review **four** A3 submissions (assigned on Canvas)

Submit **four** critique forms by **Mon 2/15, 11:59**

Follow **I like / I wish / What if?** format for critiques
Be positive! Be constructive! Share crazy ideas!

Results discussed in class on Wed 2/17

https://courses.cs.washington.edu/courses/cse412/21wi/a3b.html
Critique Questions

What is the purpose of the visualization?
Does it serve its purpose well?
Does it convey the data honestly?
Does it show the appropriate level of detail?
Are expressive & effective visual encodings used?
Is the design well-organized? Is it innovative?
What would you like to change or refine?
How might things be done differently?
I Like… / I Wish… / What If?

I LIKE…
Praise for design ideas and/or well-executed implementation details. Example: "I like the navigation through time via the slider; the patterns observed as one moves forward are compelling!"

I WISH…
Constructive statements on how the design might be improved or further refined. Example: "I wish moving the slider caused the visualization to update immediately, rather than the current lag."

WHAT IF?
Suggest alternative design directions, or even wacky half-baked ideas. Example: "What if we got rid of the slider and enabled direct manipulation navigation by dragging data points directly?"
Critique Categories

Visualization Design (Visual Encodings)
Choice of visual encodings (expressive, effective?)
Is the appropriate information visible by default?

Overall Design Quality
Organization, legibility, fitness for chosen goals

Task Effectiveness
Is the viewer readily able to answer the question?
Is the *ethical* design clear and transparent?
Is the *deceptive* design subtly misleading?
A Visualization Tool Stack
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

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Protovis, D3.js

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What is a Declarative Language?

Programming by describing what, not how.

Separate specification (what you want) from execution (how it should be computed).

In contrast to imperative programming, where you must give explicit steps.
What is a Declarative Language?

Programming by describing what, not how

Separate specification (what you want) from execution (how it should be computed)

In contrast to imperative programming, where you must give explicit steps.

d3.selectAll("rect")
  .data(my_data)
  .join("rect")
  .attr("x", d => xscale(d.foo))
  .attr("y", d => yscale(d.bar))
SELECT customer_id, customer_name, COUNT(order_id) as total
FROM customers
INNER JOIN orders ON customers.customer_id = orders.customer_id
GROUP BY customer_id, customer_name
HAVING COUNT(order_id) > 5
ORDER BY COUNT(order_id) DESC
Why Declarative Languages?

Faster iteration. Less code. Larger user base.

Better visualization. *Smart defaults.*

Reuse. *Write-once, then re-apply.*

Performance. *Optimization, scalability.*

Portability. *Multiple devices, renderers, inputs.*

Programmatic generation. *Write programs which output visualizations.*

Automated search & recommendation.
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

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Processing, OpenGL, Java2D
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2, **Vega-Lite**

Visualization Grammars
Protovis, D3.js, **Vega**

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D

**Charting Tools**

**Declarative Languages**

**Programming Toolkits**
Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2, **Vega-Lite**

Visualization Grammars
Protovis, D3.js, **Vega**

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Interactive Data Exploration
  Tableau, *Lyra, Polestar, Voyager*

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Graphical Interfaces

Declarative Languages

Programming Toolkits