CSE 442 - Data Visualization

Interaction

Jeffrey Heer  University of Washington
[There is an] apparent challenge that computational artifacts pose to the longstanding distinction between the physical and the social, in the special sense of those things that one designs, builds, and uses, on the one hand, and those things with which one communicates, on the other.

“Interaction”—in a sense previously reserved for describing a uniquely interpersonal activity—seems appropriately to characterize what goes on between people and certain machines as well.

Lucy Suchman, *Plans and Situated Actions*
Interaction between people and machines requires *mutual intelligibility* or shared understanding.
Gulf of Execution
The difference between the user’s intentions and the allowable actions.

Gulf of Evaluation
The amount of effort that the person must exert to interpret the state of the system and to determine how well the expectations and intentions have been met.

[Norman 1986]
Gulf of Evaluation

Conceptual model: x, y related?

Real world:

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Gulf of Evaluation

Conceptual model: $x, y$ related?

Real world:
Gulf of Evaluation

Conceptual model: x, y correlated?

Real world:

$$\rho = -0.29$$
Gulf of Execution

Conceptual model: Draw a scatterplot

Gulf

Execution

Real world

Move 90 30
Rotate 35
Pen down
...

Real world
Gulf of Execution

Conceptual model: Draw a scatterplot
Gulf of Execution
The difference between the user’s intentions and the allowable actions.

Gulf of Evaluation
The amount of effort that the person must exert to interpret the state of the system and to determine how well the expectations and intentions have been met.

[Norman 1986]
Interactive Visualization
Interaction Techniques

Are there “essential” interactive operations for exploratory data visualization?
Taxonomy of Interactions
Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive
<table>
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<tr>
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Sales and Profit values are not shown in the screenshot.
Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive
Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive

View Manipulation
Select, Navigate, Coordinate, Organize
Taxonomy of Interactions

Data and View Specification
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Taxonomy of Interactions

Data and View Specification
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View Manipulation
Select, Navigate, Coordinate, Organize

Process and Provenance
Record, Annotate, Share, Guide
Hours of footage lost each month due to dropped frames
Hours of footage lost each month due to dropped frames

- Framedrop problem discovered
- Issue announced publicly
- Upgrade causes glitch
Taxonomy of Interactions

Data and View Specification
Visualize, Filter, Sort, Derive

View Manipulation
Select, Navigate, Coordinate, Organize

Process and Provenance
Record, Annotate, Share, Guide
EXAMPLE:
Bertin’s Hotel Data
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1 % CLIENTELE FEMALE
2 % --- --- LOCAL
3 % --- --- U.S.A.
4 % --- --- SOUTH AMERICA
5 % --- --- EUROPE
6 % --- --- M. EAST, AFRICA
7 % --- --- ASIA
8 % BUSINESSMEN
9 % TOURISTS
10 % DIRECT RESERVATIONS
11 % AGENCY --- ---
12 % AIR CREWS
13 % CLIENTS UNDER 20 YEARS
14 % --- --- 20-35 --- ---
15 % --- --- 35-55 --- ---
16 % --- --- MORE THAN 55 --- ---
17 PRICE OF ROOMS
18 LENGTH OF STAY
19 % OCCUPANCY CONVENTIONS
20

[Graphics and Graphic Information Processing, Bertin 81]
[Graphics and Graphic Information Processing, Bertin 81]
10 % OCCUPANCY
18 LENGTH OF STAY
20 CONVENTIONS
 8 BUSINESSMEN
11 AGENCY RESERVATIONS
 4 SOUTH AMERICA

ACTIVE AND SLOW PERIODS

DISCOVERY FACTORS

18 AIR CREWS
18 CLIENTS UNDER 20 YEARS
18 CLIENTS MORE THAN 55 YEARS
14 CLIENTS FROM 20-35 YEARS
 1 FEMALE CLIENTELE
 2 LOCAL CLIENTELE

RECOVERY FACTORS

WINTER

17 PRICE OF ROOMS

WINTER-SUMMER

15 CLIENTS FROM 35-55 YEARS

SUMMER

[Graphics and Graphic Information Processing, Bertin 81]
[Graphics and Graphic Information Processing, Bertin 81]
[Graphics and Graphic Information Processing, Bertin 81]
[Graphics and Graphic Information Processing, Bertin 81]
EXAMPLE:
Tukey et al.'s PRIM-9
Basic Selection Methods
Basic Selection Methods

Point Selection
Mouse Hover / Click
Touch / Tap
Select Nearby Element (e.g., Bubble Cursor)
Basic Selection Methods

Point Selection
Mouse Hover / Click
Touch / Tap
Select Nearby Element (e.g., Bubble Cursor)

Region Selection
Rubber-band (rectangular) or Lasso (freehand)
Area cursors ("brushes")
Brushing & Linking
Brushing

Direct attention to a subset of data [Wills 95]
Brushing & Linking

Select ("brush") a subset of data
See selected data in other views

The components must be **linked**
by *tuple* (matching data points), or
by *query* (matching range or values)
Brushing Scatterplots
Cross-Filtering

Arrival Delay (min)

Local Departure Time (hour)

Travel Distance (miles)
Baseball Statistics [Wills 95]
Baseball Statistics [Wills 95]

select high salaries
Baseball Statistics [Wills 95]

- Select high salaries
- Avg career HRs vs avg career hits (batting ability)
Baseball Statistics [Wills 95]

- How long in majors
- Select high salaries
- Avg career HRs vs avg career hits (batting ability)
Baseball Statistics [Wills 95]

- How long in majors
- Avg assists vs avg putouts (fielding ability)
- Select high salaries
- Avg career HRs vs avg career hits (batting ability)
Baseball Statistics [Wills 95]

- how long in majors
- select high salaries
- avg assists vs avg putouts (fielding ability)
- avg career HRs vs avg career hits (batting ability)
- distribution of positions played
Linking Assists to Positions
Dynamic Queries
SELECT house FROM seattle_homes
WHERE price < 1,000,000 AND bedrooms > 2
ORDER BY price
Issues with Textual Queries

1. For programmers
2. Rigid syntax
3. Only shows exact matches
4. Too few or too many hits
5. No hint on how to reformulate the query
6. Slow question-answer loop
7. Results returned as table
HomeFinder

The yellow dots above are homes in the DC area for sale. You may get more information on a home by selecting it.

You may drag the 'A' and 'B' distance markers to your office or any other location you want to live near.

Select distances, bedrooms, and cost ranges by dragging the corresponding slider boxes on the right.

Select specific home types and services by pressing the labeled buttons on the right.

[Williamson and Shneiderman 92]
Direct Manipulation

1. Visual representation of objects and actions
2. Rapid, incremental and reversible actions
3. Selection by pointing (not typing)
4. Immediate and continuous display of results
Popularity

Title: ALL
Actor: ALL
Actress: ALL
Director: ALL
Ratings: G, PG, PG-13, R
Films Shown: 1455

Copyright (C) 1993 HCIL

[Ahlberg and Shneiderman 94]
Alphaslider (?)

Title: Moonstruck

[Alhberg and Shneiderman 94]
Witches of Eastwick, The

Director: Miller, George
Year: 1987
Country: USA
Language: English
Actors:
- Nicholson, Jack
- Jenkins, Richard
- Joakum, Keith
- Struycker, Carel
Actresses:
- Cher
- Sarandon, Susan
- Pfeiffer, Michelle
- Cartwright, Veronica

Title: ALL
Actor: ALL
Actress: Pfeiffer, Michelle
Director: Miller, George
Length: 231
Ratings: G, PG, PG-13, R
Films Shown: 210

Copyright (C) 1993 HCIL
• The Attribute Explorer
• The Attribute Explorer
Attribute Explorer [Spence & Tweedie 96]

- Video Clip
Zipdecode [Fry 04]

Hit the letter z, or click the word zoom to enable or disable zooming.
Hold down shift while typing a number to replace the previous number (U.S. keyboards only).

http://benfry.com/zipdecode/
Parallel Coordinates [Inselberg]
Builds on Wattenberg’s [2001] idea for sketch-based queries of time-series data.
Query by Slope!
3D Dynamic Queries [Akers 04]
3D Dynamic Queries [Akers 04]
Pros & Cons

Pros
Controls useful for both novices and experts
Quick way to explore data
Pros & Cons

Pros
Controls useful for both novices and experts
Quick way to explore data

Cons
Simple queries
Lots of controls
Amount of data shown limited by screen space

Who would use these kinds of tools?
Summary

Most visualizations are interactive
Even passive media elicit interactions

Good visualizations are task dependent
Pick the right interaction technique
Consider the semantics of the data domain

Fundamental interaction techniques
Selection / Annotation, Sorting, Navigation, Brushing & Linking, Dynamic Queries
Administrivia
Tutorials

Introduction to D3.js
Thursday, Oct. 19 - 5:00-6:20pm - Sieg 134
A3: Interactive Prototype

Create an interactive visualization. Choose a driving question for a dataset and develop an appropriate visualization + interaction techniques, then deploy your visualization on the web.

Due by 11:59pm on Monday, October 30.

Work in project teams of 3-4 people.
Requirements

**Interactive.** You must implement interaction methods! However, this is not only selection / filtering / tooltips. Also consider annotations or other narrative features to draw attention and provide additional context

**Web-based.** D3 is encouraged, but not required. Deploy your visualization using GitHub pages.

**Write-up.** Provide design rationale on your web page.
Form a **team of 3-4** for A3 and the Final Project. Start thinking about your Final Project, too!

A3 is open-ended, but you can use it to start exploring your FP topic if you like.

Submit signup form by **Friday 10/20, 11:59pm**.

If you do not have **team mates**, you should:
- Use the facilities on Canvas
- Stay after class/tutorial to meet potential partners
Team Member Roles

We encourage you to structure team responsibilities!

**Coordinator**: Organize meetings, track deadlines, etc.

**Data Lead**: Data wrangling, management, distillation

**Tech Lead**: Manage code integration, GitHub repo

**UX Lead**: Visualization/interaction design & evaluation

*One may have multiple roles, share work across roles…*
Interactive Prototype Tips

Start now. It will take longer than you think.

Keep it simple. Choose a minimal set of interactions that enables users to explore and generate interesting insights. Do not feel obligated to convey everything about the data: focus on a compelling subset.

Promote engagement. How do your chosen interactions reveal interesting observations?
An Interaction Grammar (Vega-Lite Selections)

Satyanarayan et al. *InfoVis’16 Best Paper*
Vega-Lite

A formal model for statistical graphics
Inspired by Grammar of Graphics & Tableau
Includes data transformation & encoding
Uses a simple, concise JSON format that compiles to complete Vega specifications
Easy programmatic generation
```json
{
  "mark": "point",
  "encoding": {
    "x": {"field": "Horse_Power", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"}
  }
}
```
{  
  "mark": "point",
  "encoding": {
    "x": {"field": "Horse_Power", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": {"field": "Cylinders", "type": "O"}
  }
}
{  
    "mark": "point",
    "encoding": {
        "x": {"field": "Horse_Power", "type": "Q"},
        "y": {"field": "Miles_per_Gallon", "type": "Q"},
        "column": {"field": "Cylinders", "type": "O"}
    }
}
```json
{
    "mark": "point",
    "encoding": {
        "x": {
            "field": "Horse_Power",
            "type": "Q"
        },
        "y": {
            "field": "Miles_per_Gallon",
            "type": "Q"
        }
    }
}
```
"mark": "point",
"encoding": {
  "x": {"field": "Horse_Power", "type": "Q", "bin": true},
  "y": {"field": "Miles_per_Gallon", "type": "Q", "bin": true},
  "size": {"field": "*", "type": "Q", "aggregate": "count"}
}
Specifying Interactions

Typically interactive behaviors are programmed using *imperative event handler callbacks*. When events occur, you must process the event, update the application state, re-draw, etc.

For a variety of visual analysis operations, what if you could *declaratively* specify the *semantics* of an interaction and have the event handling logic automatically *synthesized*?
{ "data": {"url": "data/flights.json"}, "mark": "bar", "encoding": { "x": {"field": "hour", "bin": true, "type": "Q"}, "y": {"field": ", "aggregate": "count", "type": "Q"} } }
Data

```json
{
  "data": {
    "url": "data/flights.json"},
  "mark": "bar",
  "encoding": {
    "x": {
      "field": "hour",
      "bin": true,
      "type": "Q"
    },
    "y": {
      "field": "*",
      "aggregate": "count",
      "type": "Q"
    }
  }
}
```
{
  "data": {"url": "data/flights.json"},
  "mark": "bar",
  "encoding": {
    "x": {
      "field": "hour",
      "bin": true,
      "type": "Q"
    },
    "y": {
      "field": "*",
      "aggregate": "count",
      "type": "Q"
    }
  }
}
"data": {"url": "data/flights.json"},
"mark": "bar",
"encoding": {
  "x": {
    "field": "hour",
    "bin": true,
    "type": "Q"
  },
  "y": {
    "field": "*",
    "aggregate": "count",
    "type": "Q"
  }
}

Transforms
{  
  "data": {"url": "data/flights.json"},  
  "mark": "bar",  
  "encoding": {  
    "x": {"field": "hour", "bin": true, "type": "Q"},  
    "y": {"field": "*", "aggregate": "count", "type": "Q"}  
  }  
}  

Data

Mark

Transforms + Scales & Guides (not shown)
```json
{
  "repeat": {
    "column": ["hour", "delay", "distance"]
  },
  "spec": {
    "data": {
      "url": "data/flights.json"
    },
    "mark": "bar",
    "encoding": {
      "x": {
        "field": {
          "repeat": "column"
        },
        "bin": true,
        "type": "Q"
      },
      "y": {
        "field": "*",
        "aggregate": "count",
        "type": "Q"
      }
    }
  }
}
```
`{  "repeat": {"column": ["hour", "delay", "distance"]},  "spec": {    "data": {"url": "data/flights.json"},    "mark": "bar",    "encoding": {      "x": {"field": {"repeat": "column"}, "bin": true, "type": "Q"},      "y": {"field": "*", "aggregate": "count", "type": "Q"}    }  }}
`
can be initialized
can be initialized
```json
{
    "repeat": {
        "column": ["hour", "delay", "distance"]
    },
    "spec": {
        "layer": [
            {
                "mark": "bar",
                "encoding": {
                    "x": {
                        "field": {
                            "repeat": "column"
                        },
                        "type": "Q",
                        "bin": true
                    },
                    "y": {
                        "aggregate": "count",
                        "field": "*",
                        "type": "Q"
                    }
                }
            },
            ...
        ],
        ...
    }
}
```
```json
{
  "repeat": {
    "column": ["hour", "delay", "distance"]
  },
  "spec": {
    "layer": [
      {
        ...,
        "select": {
          "region": {
            "type": "interval",
            "project": {
              "channels": ["x"], ...
            }
          }
        }
      }, {
        ...
      }
    ]
  }
}
```
can be initialized

```json
{
  "repeat": {
    "column": [
      "hour",
      "delay",
      "distance"
    ]
  },
  "spec": {
    "layer": [
      {
        ...
      },
      {
        ...
      }
    ],
    ...
  }
}
```
```json
{
    "repeat": {
        "column": [
            "hour",
            "delay",
            "distance"
        ]
    },
    "spec": {
        "layer": [
            {
                "select": {
                    "region": {
                        "type": "interval",
                        "project": {
                            "channels": [
                                "x"
                            ]
                        }
                    }
                },
                "transform": [
                    {
                        "filter": {
                            "selection": "region"
                        }
                    }
                ]
            }
        ]
    }
}
```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layer": [{
      ...
      "select": {
        "region": {
          "type": "interval", "project": {"channels": ["x"]}, ...
        }
      }
    }, {
      ...
      "transform": [{"filter": {selection: "region"}}]
    }]
  }
}
{  
  "repeat": {"column": ["hour", "delay", "distance"]},  
  "spec": {  
    "layer": [{  
      ...  
      "select": {  
        "region": {  
          "type": "interval", "project": {"channels": ["x"]}, ...  
        }  
      },  
      ...
    }, {  
      "transform": [{"filter": {selection: "region"}}]  
    }]  
  }  
}
Panning & Zooming

Interactive Transformation

Overview + Detail
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Overview + Detail

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