# Interaction

**Start here**

***Note:*** *consider treating gender and sex data with more nuance than in these examples [see here]*

# Interaction as an aesthetic mapping

- In some cases interaction allows us to simply add another “dimension”: **time**
  - Very limited in scope
  - Not always the right choice!
  - Example

# Best practices for interaction

*Based on slides from Cody Dunne & Miriah Meyer*

- **Benefits** of interaction
    - Enables visualization of large amounts of data
    - Amplifies user cognition (supports sensemaking)
    - Increases engagement (vis becomes personal to user)
    - Increases deep learning and learning transfer

# Best practices for interaction

*Based on slides from Cody Dunne & Miriah Meyer*

- **Drawbacks** of interaction
  - Requires human time and attention
  - Increase perceptual and exploration costs (van Wijk 2005)
  - Interaction costs (Lam 2008)
  - Multiple user studies find no increase in performance in specific situations (Ragan et al. 2012,

“Overview first, zoom and filter, and details on demand.”

- Ben Shneiderman

*“The Shneiderman Mantra”*

“Overview first, zoom and filter, and details on demand.”

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**Overview**—provide high-level view/summary

**Zoom and Filter**—enable data discovery and exploration, support search/tasks

**Details on Demand**—do not overwhelm the viewer. Provide extra information as needed

“Search, show context, expand on demand”

- van Ham & Perer

“Search, show context, expand on demand”
- van Ham & Perer

**Search**—pick subset of data to focus on.

**Show context**—show connected or relevant data for the user’s current interests.

**Expand on demand**—user chooses to expand the context in a direction of interest.

# Taxonomy of interactions

*Based on slides from Jeffery Heer*

- **Data and view specification**
  - Filter, query, derive
- **View manipulation**
  - Select, Navigate, coordinate, organize
- **Process and provenance**
  - Record annotate, share, guide

# Querying and filtering

- Determine a subset of data to highlight by applying *filters*
  - Example: Simple filtering
  - Example: ZIP codes
  - Example: baby names
  - Example: Gapminder DimpVis
  - Example: Segregation in U.S. Cities

# Pointing and selection

Select an observation for more details

- Example: tooltips!
- Example: Airports
- Example: College mobility

# Brushing and linking

- Select a subset of data using a brush
  - See the selected data in other views
  - Views must be *linked*
  - Example: Stocks and IMDB
  - Example: Brushable scatterplot
  - Example: Crossfiltering
  - Example: Parallel coordinates

# Zooming and panning

- Allow user to manipulate the scales
  - Example: maps!
  - Example: Vega-Altair

# Sorting

- Allow user to manipulate the scales
  - Example: Sortable bar plot

# Scrollytelling

- Update visualization as a reader progresses through a story
  - Example: California fires

# Prompting reflection

- Allow user to set their own expectations
  - Example: college mobility

# Implementing interaction

# How do we implement interaction?

- Bootstrapping applet

wind speed

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    <option value="IMDB rating">IMDB rating</option>
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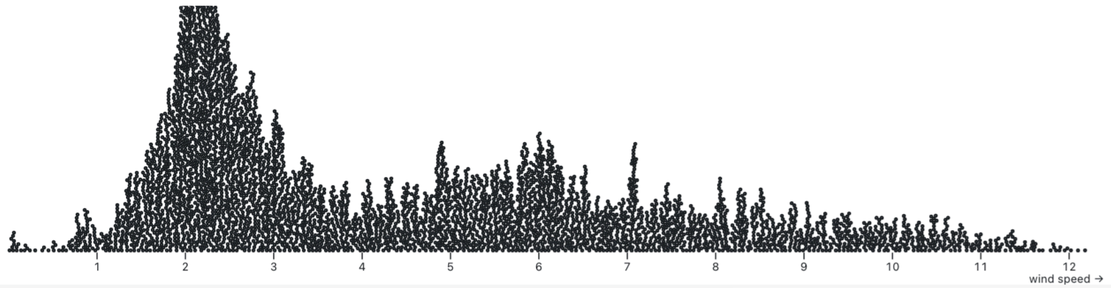


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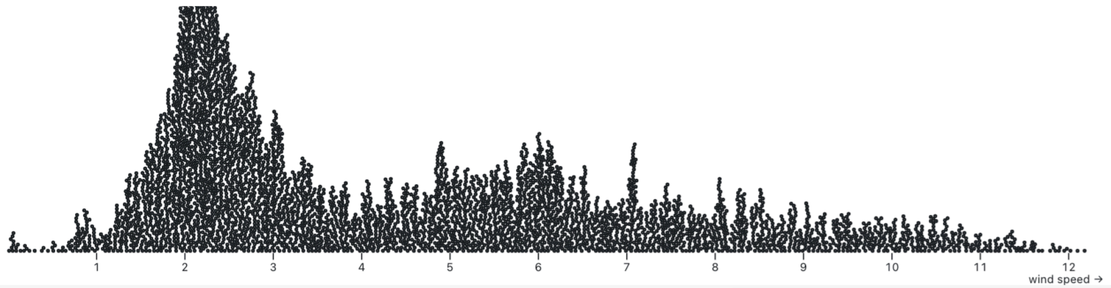


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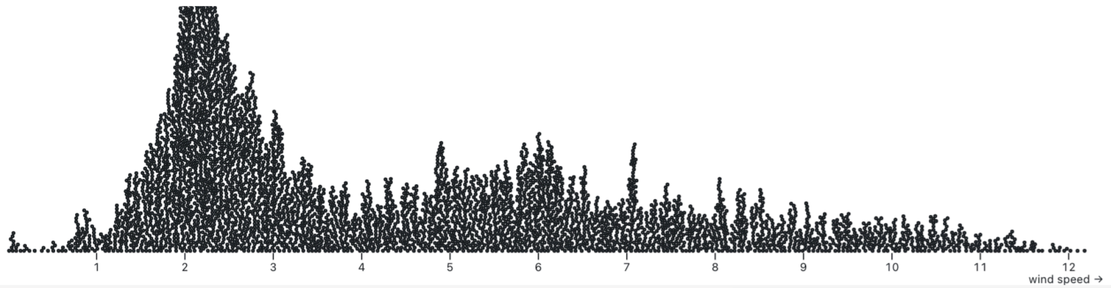


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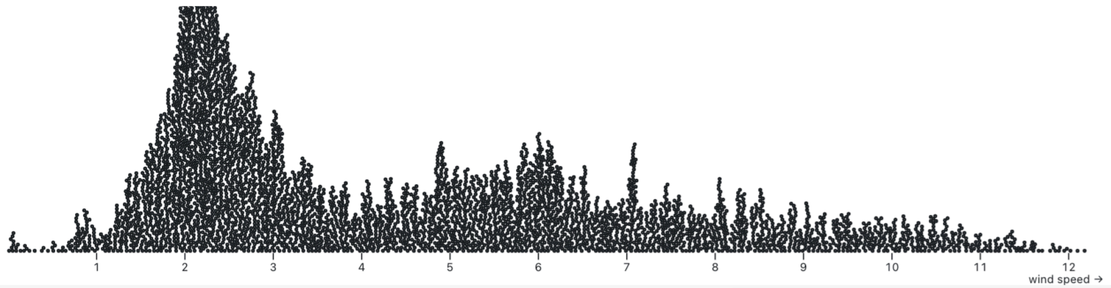


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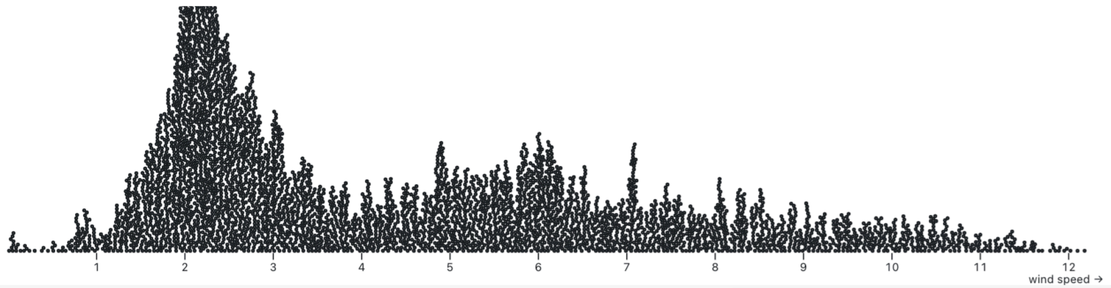


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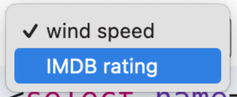


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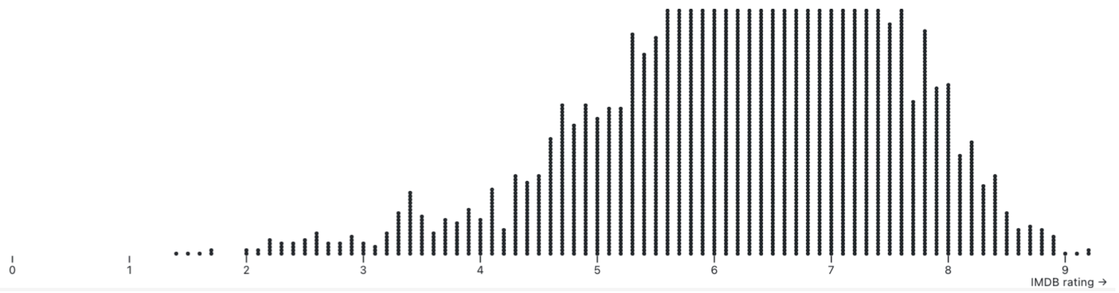


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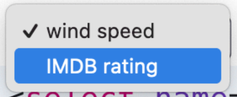


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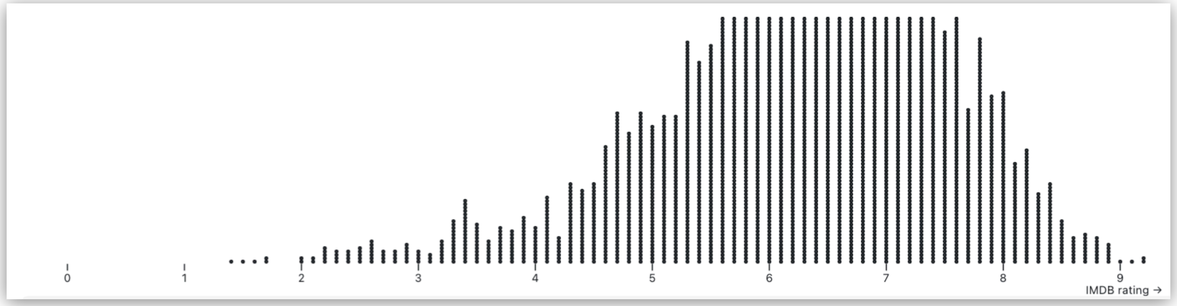


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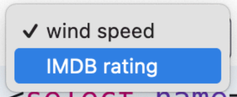


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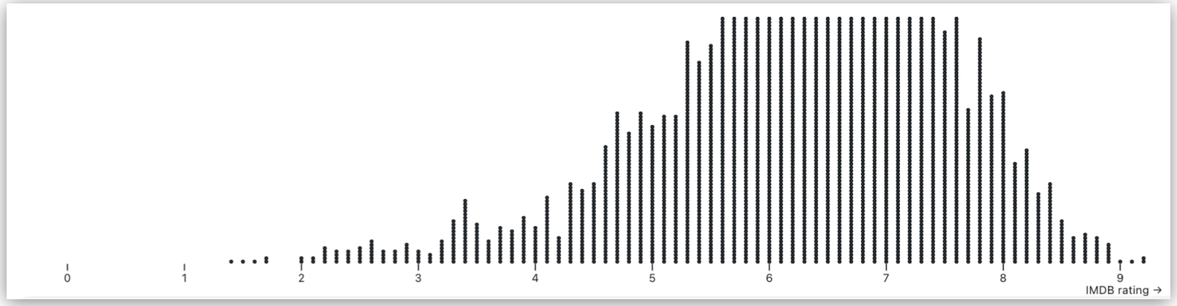


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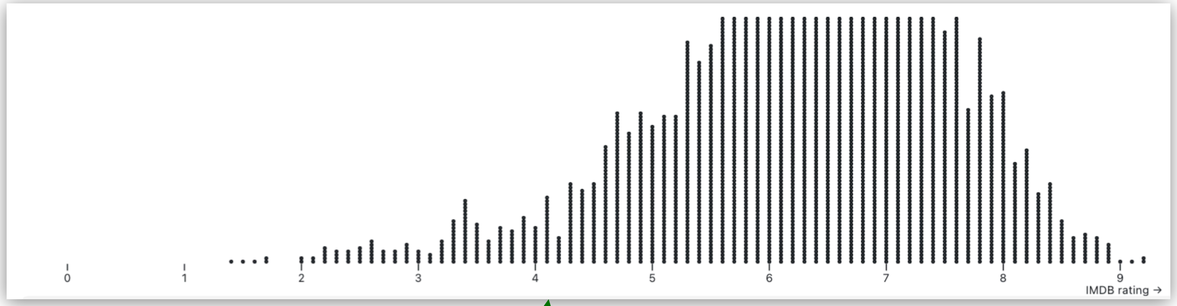
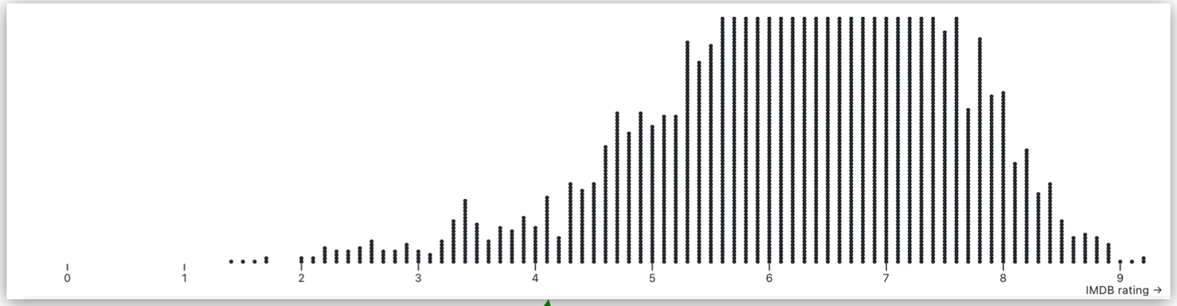



Updates

IMDB rating

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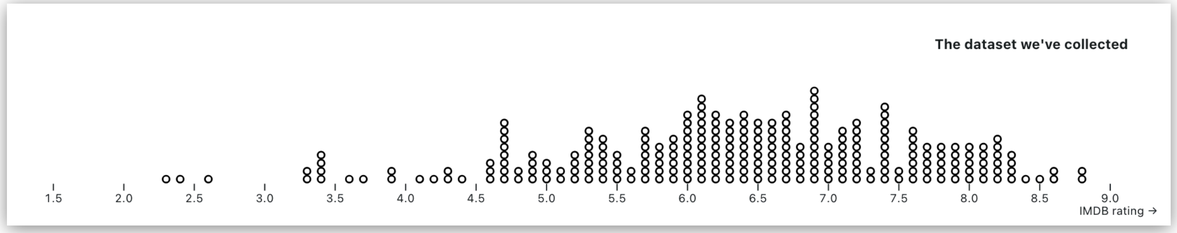
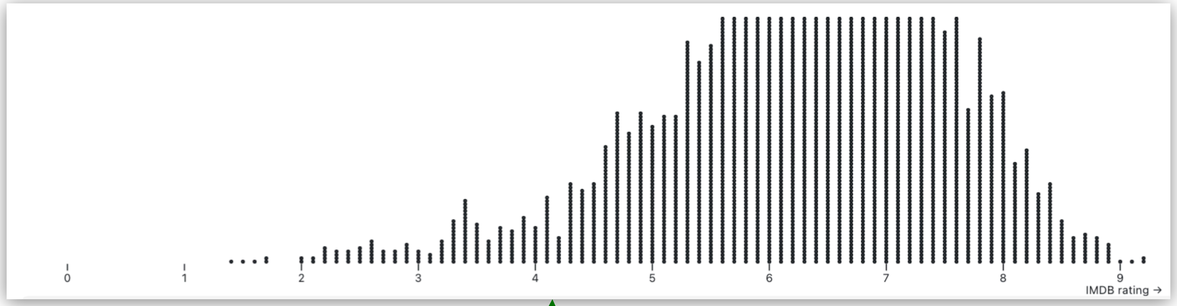
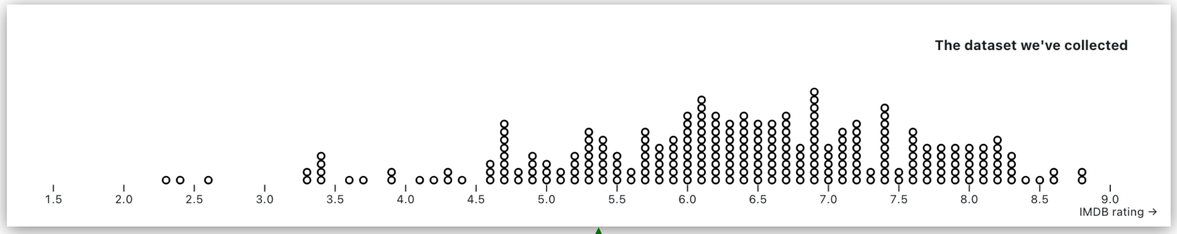


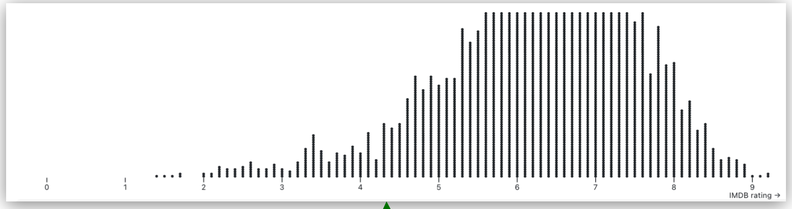


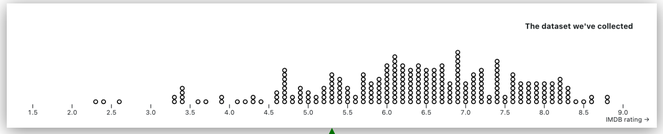



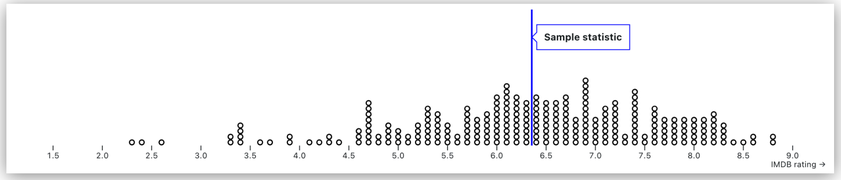

Population

Updates

IMDB rating

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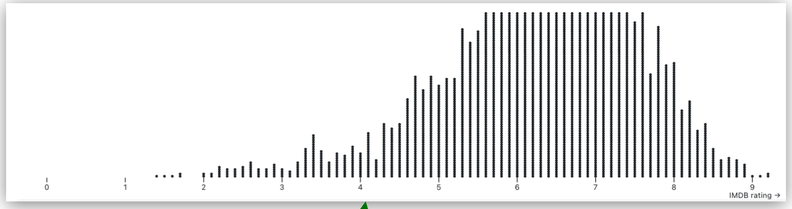
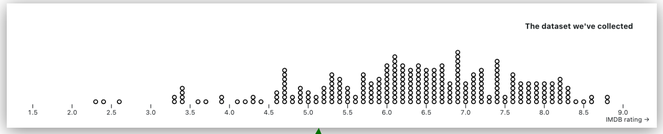
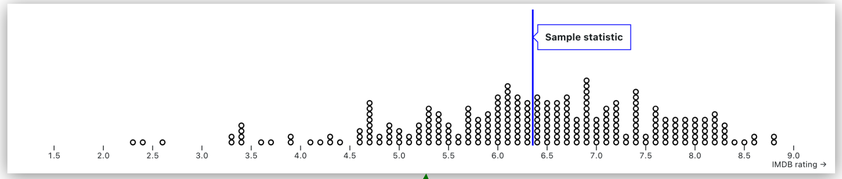


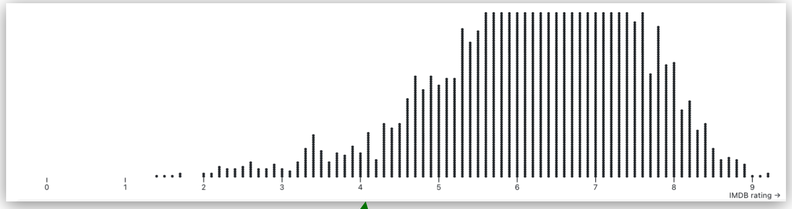



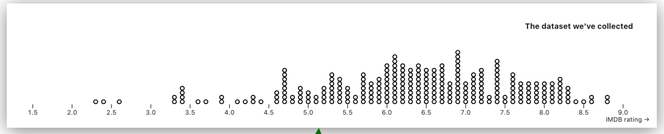

Sample

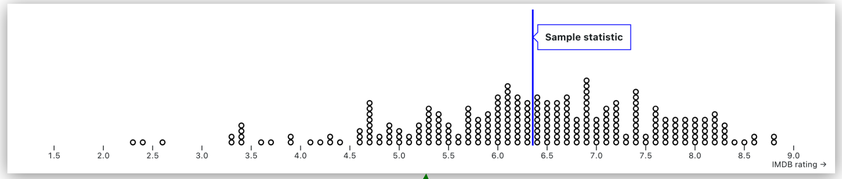
Population

Updates

IMDB rating



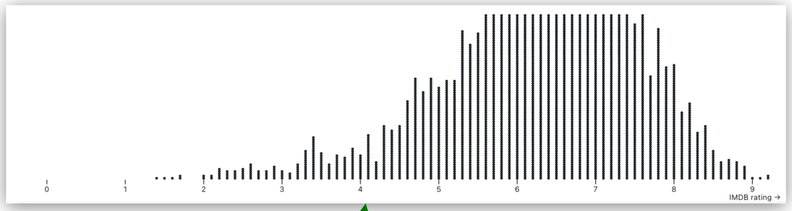

Sample

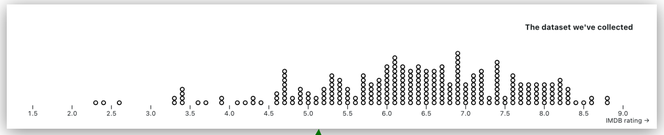
Population

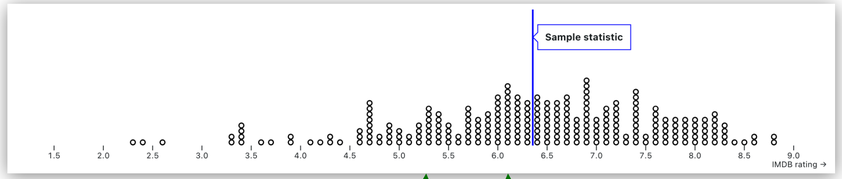
Updates

IMDB rating

Mean



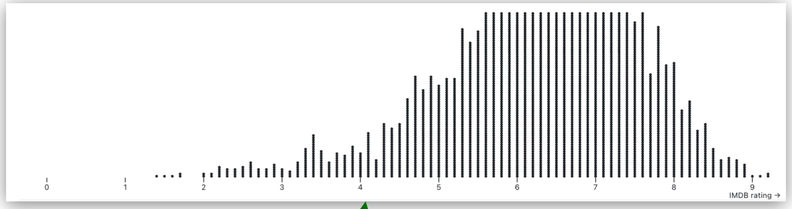

Sample

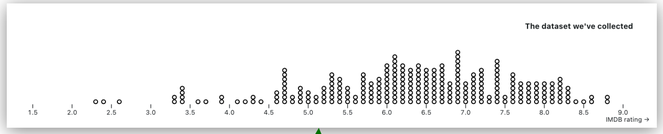
Population

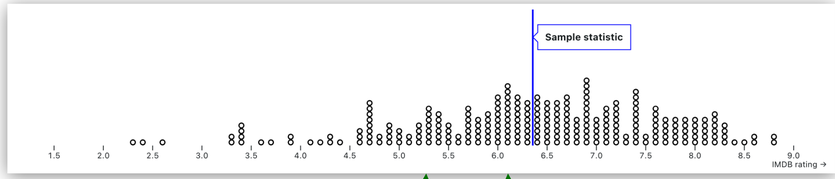
Updates

IMDB rating

Mean




Sample

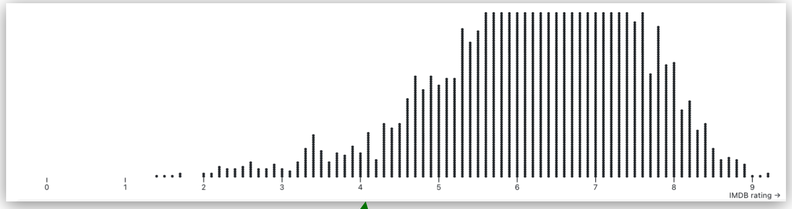
Population

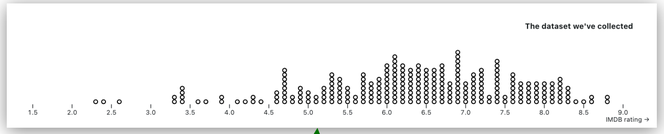
Updates

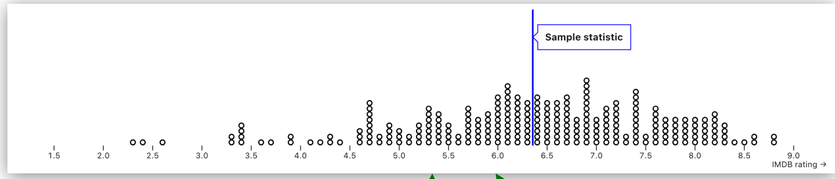
*Here our **Mean** of `IMDB rating` is 6.35*

IMDB rating

Mean




Sample

Statistic

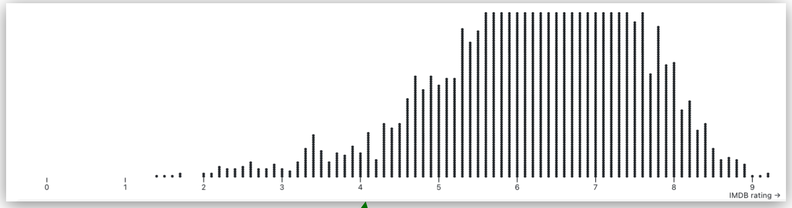
Population

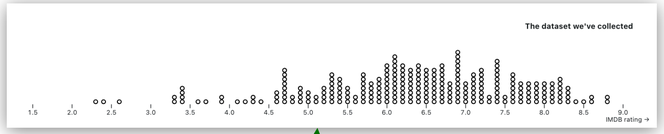
Updates

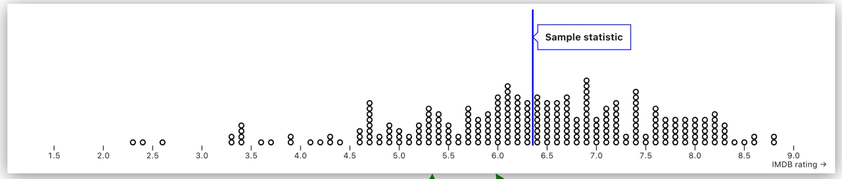
*Here our **Mean** of `IMDB rating` is 6.35*

IMDB rating

Mean




Here we needed to:

- Add *statistic* to our state
- Change *sample* code to update the *statistic*
- Change *statistic type selector* code to update text
- Change *statistic* code to update text
- ...

Sample

Statistic

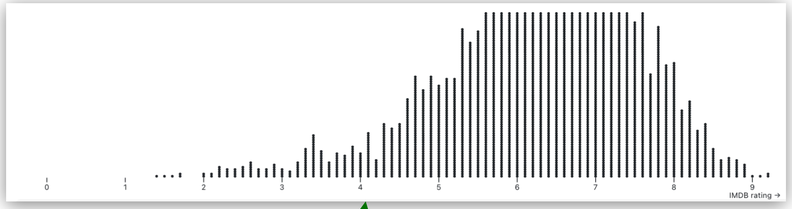
Population

Updates

*Here our **Mean** of `IMDB rating` is 6.35*

IMDB rating

Mean






Adding new components gets very complicated very quickly

Here we needed to:

- Add *statistic* to our state
- Change *sample* code to update the *statistic*
- Change *statistic type selector* code to update text
- Change *statistic* code to update text
- ...

Sample

Statistic

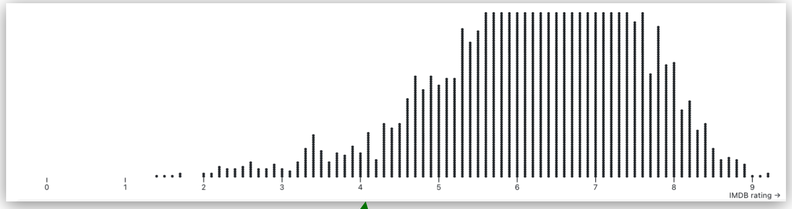
Population

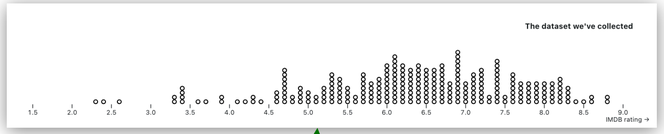
Updates

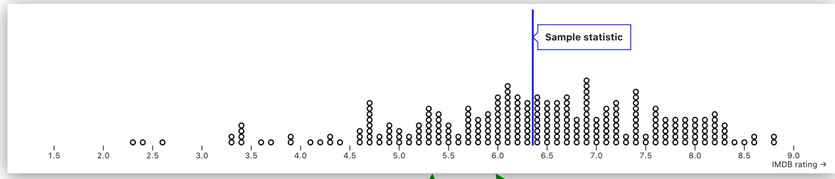
*Here our **Mean** of `IMDB rating` is 6.35*

IMDB rating

Mean




Sample

Statistic

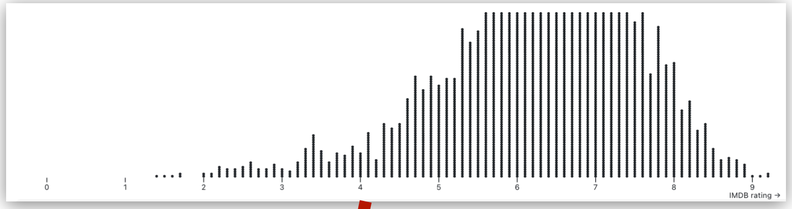
Population

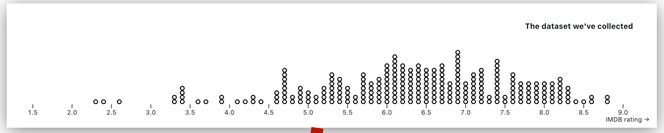
Updates

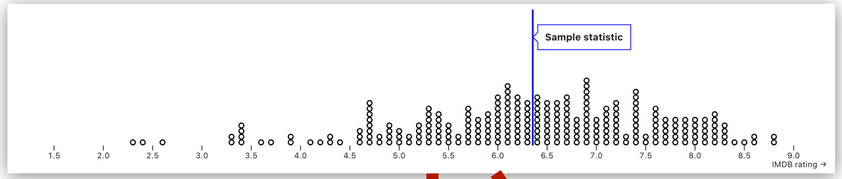
*Here our **Mean** of `IMDB rating` is 6.35*

IMDB rating

Mean




Sample

Statistic

Population

Observes

*Here our **Mean** of `IMDB rating` is 6.35*

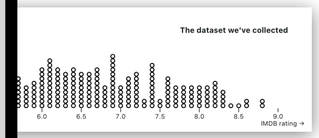
IMDB rating

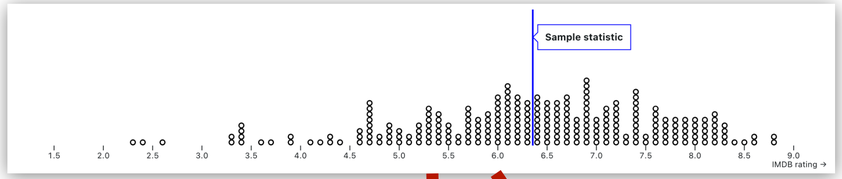
Mean

# Observer pattern: *flip responsibility*

Each *component* is responsible for knowing what other pieces of state it depends on

- When parent state changes - *recompute*!




Sample

Statistic

Population

Observes

*Here our **Mean** of `IMDB rating` is 6.35*

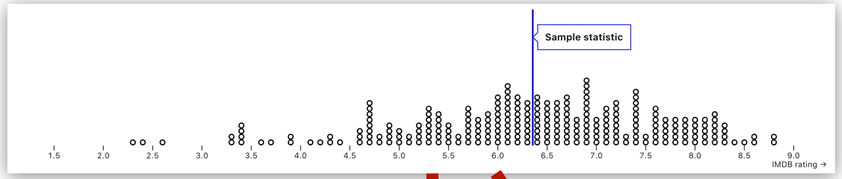
IMDB rating

Mean

# Observer pattern: *implementation*

Each component *registers* itself as an observer of its parent

- When parent state changes - *signal all observers*!


Python

```python
class Observable:
    def __init__(self):
        self._observers = []

    def register_observer(self, observer) -> None:
        self._observers.append(observer)

    def notify_observers(self, *args, **kwargs) -> None:
        for observer in self._observers:
            observer.notify(self, *args, **kwargs)


class Observer:
    def __init__(self, observable):
        observable.register_observer(self)

    def notify(self, observable, *args, **kwargs) -> None:
        print("Got", args, kwargs, "From", observable)


subject = Observable()
observer = Observer(subject)
subject.notify_observers("test", kw="python")

# prints: Got ('test',) {'kw': 'python'} From <__main__.Observable object at
0x0000019757826FD0>
```

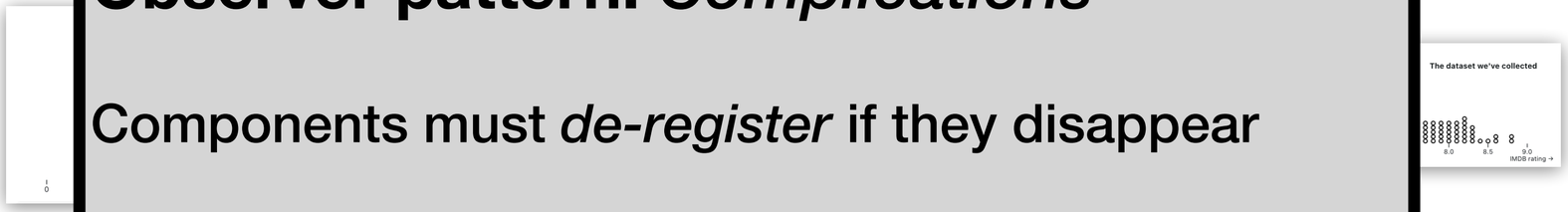
Javascript

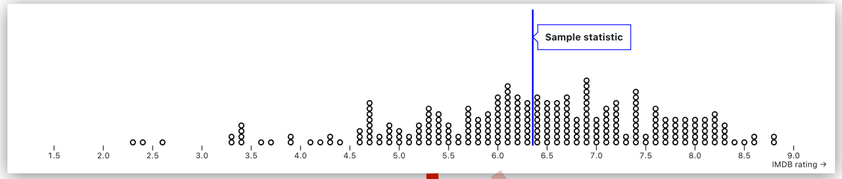
```javascript
let Subject = {
    _state: 0,
    _observers: [],
    add: function(observer) {
        this._observers.push(observer);
    },
    getState: function() {
        return this._state;
    },
    setState: function(value) {
        this._state = value;
        for (let i = 0; i < this._observers.length; i++)
        {
            this._observers[i].signal(this);
        }
    }
};

let Observer = {
    signal: function(subject) {
        let currentValue = subject.getState();
        console.log(currentValue);
    }
}

Subject.add(Observer);
Subject.setState(10);
//Output in console.log - 10
```

*From Wikipedia*

# Observer pattern: *Complications*

Components must *de-register* if they disappear




Sample

Population

Observes

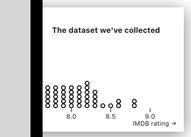
*Here our **Mean** of `IMDB rating` is 6.35*

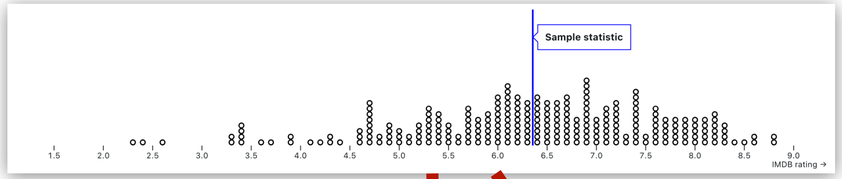
IMDB rating

Mean

# Observer pattern: *Complications*

Cycles cannot be allowed!




Sample

Statistic

Population

Observes

*Here our **Mean** of `IMDB rating` is 6.35*

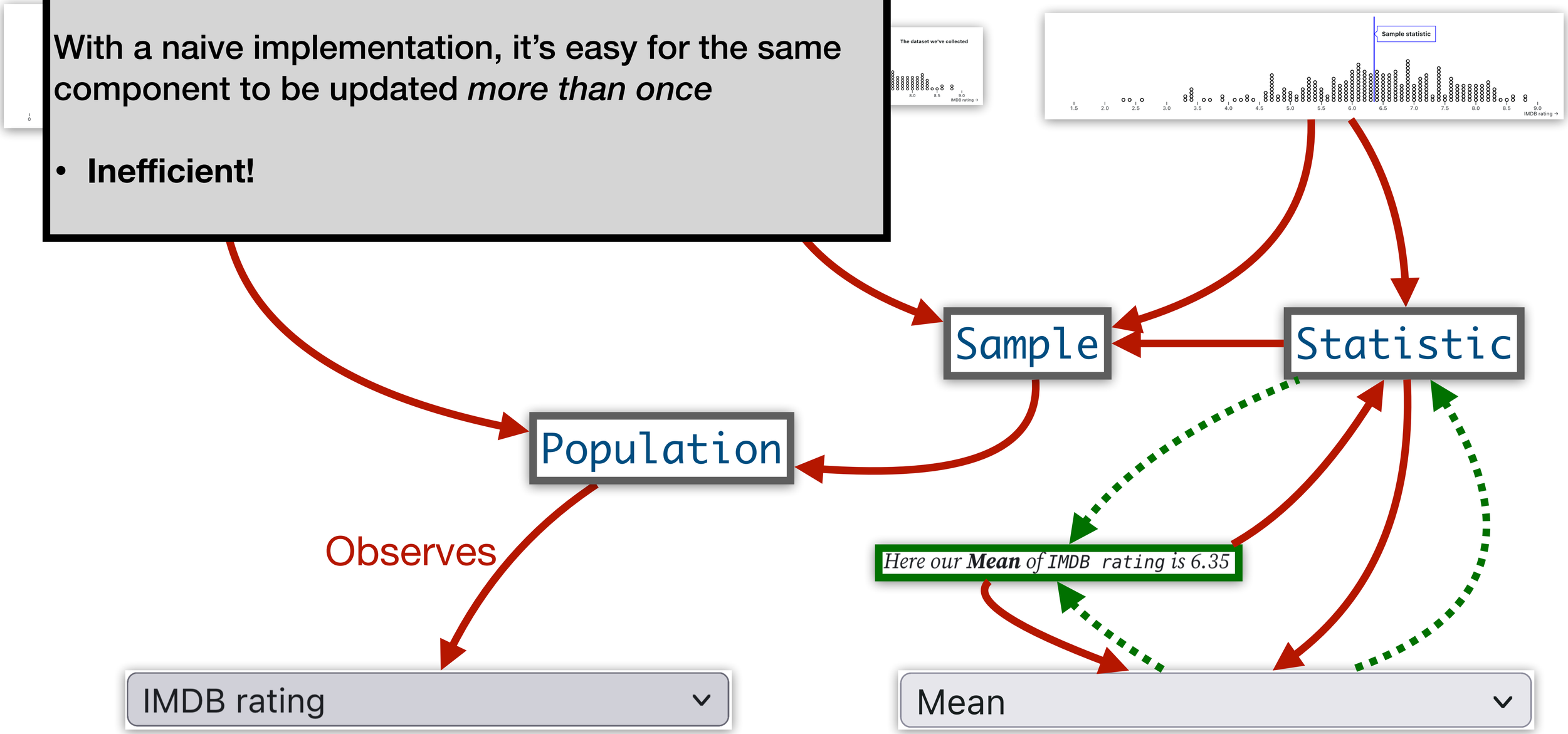
IMDB rating

Mean

# Observer pattern: *Complications*

With a naive implementation, it's easy for the same component to be updated *more than once*

- **Inefficient!**



# Observer pattern: *Complications*

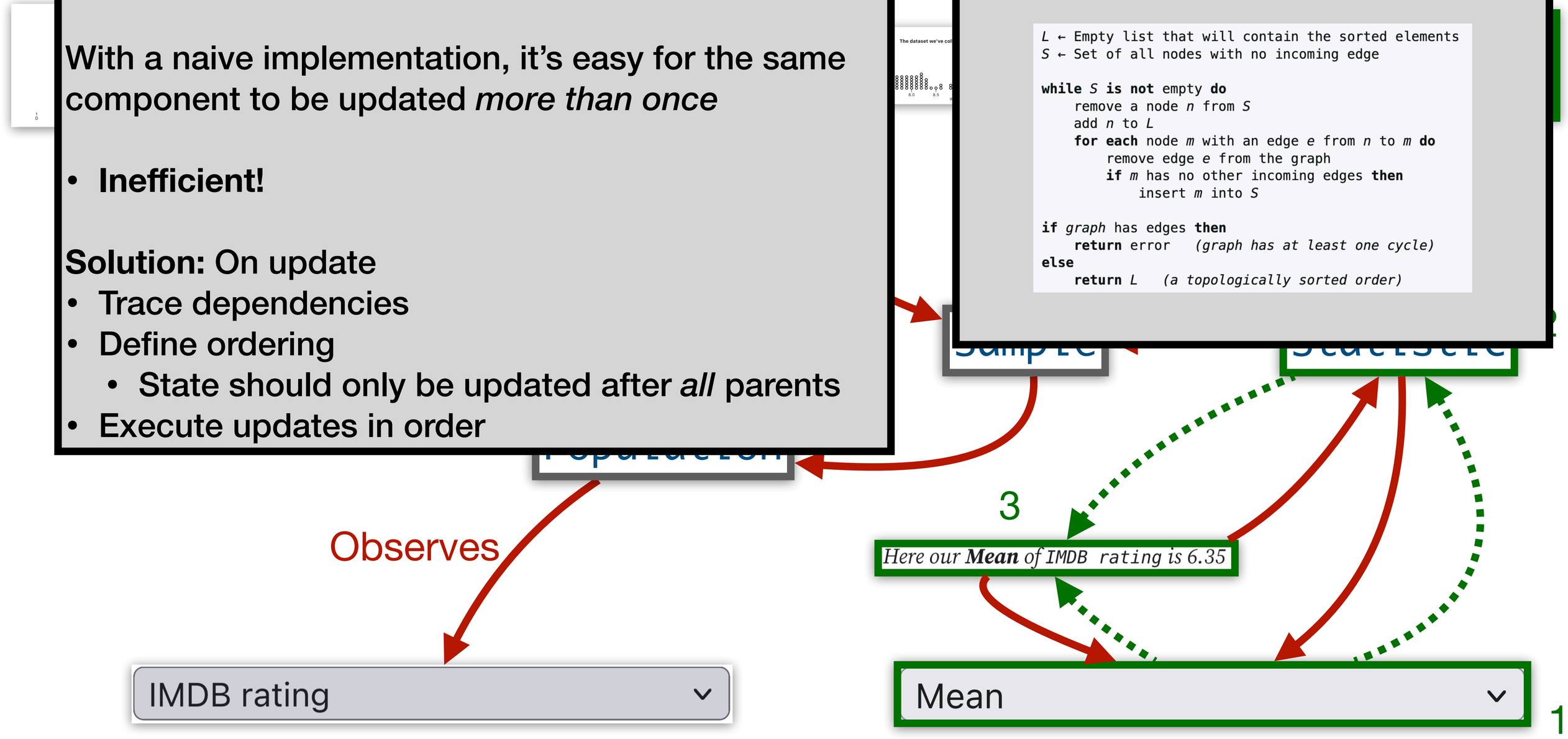
With a naive implementation, it's easy for the same component to be updated *more than once*

- **Inefficient!**

**Solution:** On update
- Trace dependencies
- Define ordering
  - State should only be updated after *all* parents
- Execute updates in order

## Define ordering: *topological sort*

```
L ← Empty list that will contain the sorted elements
S ← Set of all nodes with no incoming edge

while S is not empty do
    remove a node n from S
    add n to L
    for each node m with an edge e from n to m do
        remove edge e from the graph
        if m has no other incoming edges then
            insert m into S

if graph has edges then
    return error   (graph has at least one cycle)
else
    return L   (a topologically sorted order)
```



# Reactive programming

Build observer pattern into core language or framework



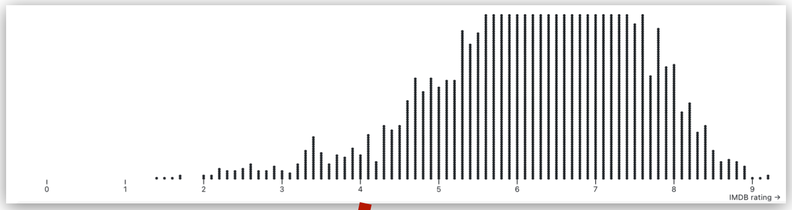


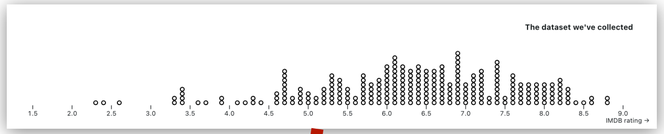

# Reactive programming

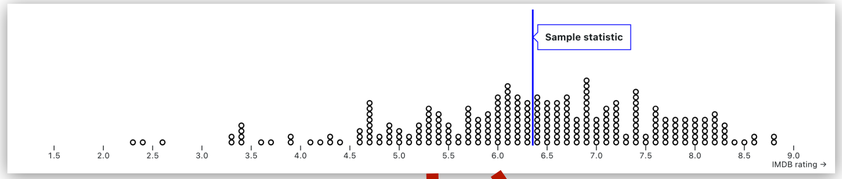
Build observer pattern into core language or framework






```
sample = resample(population)
```

```
stat = computeStat(sample)
```

Sample

Statistic

```
population = (dataset == "wind speed") ? windpopulation : imdbpopulation;
```

Population

```
*Here our **${statistic}** of `${dataset}` is ${estimate}*
```

*Here our **Mean** of IMDB rating is 6.35*

Observes

IMDB rating

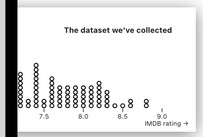
Mean

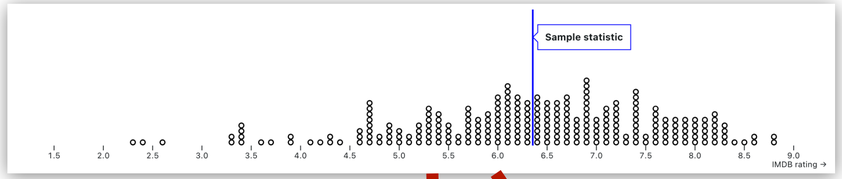
```
viewof dataset = Inputs.select(["wind speed", "IMDB rating"], {label: "Dataset"});
```

```
viewof statistic = Inputs.select(["Mean", "Median"])
```

# Reactive framework

Each line re-runs when variables it uses change!

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```

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stat = computeStat(sample)
```

Sample

Statistic

```
population = (dataset == "wind speed") ? windpopulation : imdbpopulation;
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Population

Observes

```
*Here our **${statistic}** of `${dataset}` is ${estimate}*
```

*Here our **Mean** of IMDB rating is 6.35*

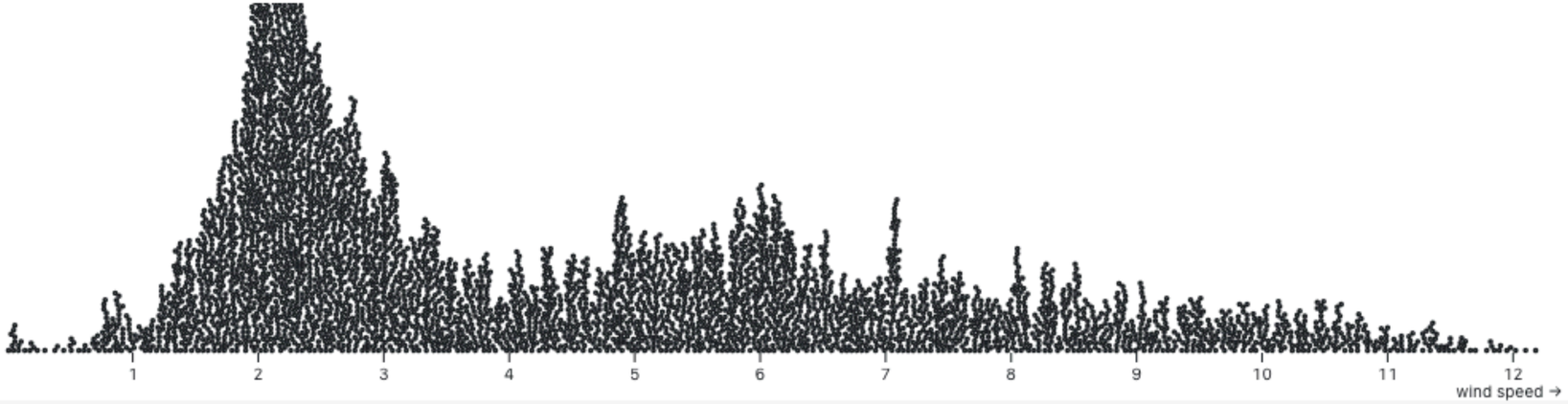
IMDB rating

Mean

```
viewof dataset = Inputs.select(["wind speed", "IMDB rating"], {label: "Dataset"});
```

```
viewof statistic = Inputs.select(["Mean", "Median"])
```

# Dataset choice




```
Plot.plot({
  height: 250,
  width: 1000,
  x: {label: dataset, domain: [Math.min(...populations[dataset]),
                               Math.max(...populations[dataset])]},
  marks: [
    Plot.dot(populations[dataset], Plot.dodgeY({x: "0", r:1}))
  ]
})
```

Updated on change!

wind speed

```
viewof dataset = Inputs.select(["wind speed", "IMDB rating"])
```

```
populations = ▸ Object {wind speed: Array(4800), IMDB rating: Array(3201)}
```

```
 populations = ({
      "wind speed": winddata.map(d => [d['speed']]),
      "IMDB rating": imdb.map(d => [d['IMDB Rating']]),
    })
```

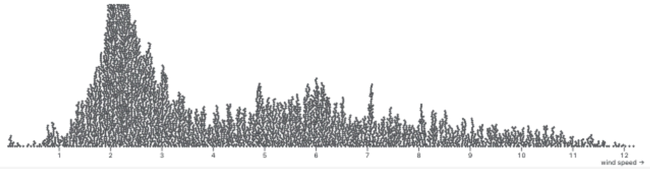
```
▸ Array(3201) [6.1, 6.9, 6.8, null, 3.4, null, 7.7, 3.8, 5.8, 7, 7, 7.5, 8.4, null, 6.8, null, 7, 6.1, 2.5, 8.9, …]
```

```
imdb.map(d => d['IMDB Rating'])
```

```
import {windpopulation, imdbpopulation, imdb, wind, winddata, tf, windspeedDistributionPlot, imdbDistributionPlot} from
"3523e4b3244dbb93"
```

# Traditional

## Dataset choice




```
<figure id='population-figure'></figure>
```

wind speed

```
<select name="dataset-select" id="dataset-select">
    <option value="wind speed">wind speed</option>
    <option value="IMDB rating">IMDB rating</option>
  </select>
```

```
undefined
```

```
{
  let figure = document.getElementById('population-figure');

  let select = document.getElementById('dataset-select');

  function updatePlot(dataset) {
    let populations = ({
      "wind speed": winddata.map(d => [d['speed']]),
      "IMDB rating": imdb.map(d => [d['IMDB Rating']]),
    })

    let newPlot = Plot.plot({
      height: 250,
      width: 1000,
      x: {label: dataset, domain: [Math.min(...populations[dataset]),
                                   Math.max(...populations[dataset])]},
      marks: [
        Plot.dot(populations[dataset], Plot.dodgeY({x: "0", r:1}))
      ]
    })
    figure.innerHTML = ""; // Clear the current plot
    figure.appendChild(newPlot); // Add in the new plot
  }
  updatePlot(select.value);

  select.addEventListener("change", (d) => updatePlot(d.target.value));
}
```

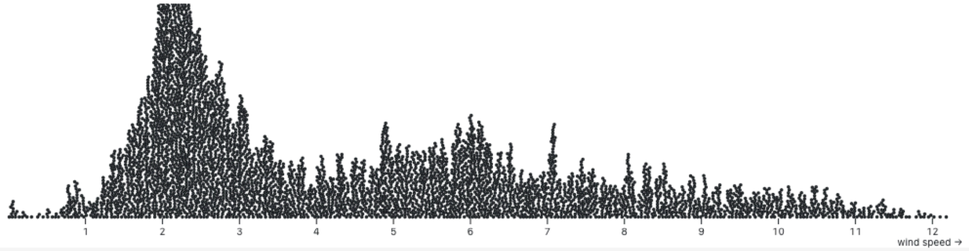
```
▸ Array(3201) [6.1, 6.9, 6.8, null, 3.4, null, 7.7, 3.8, 5.8, 7, 7, 7.5, 8.4, null, 6.8, null, 7, 6.1, 2.5, 8.9, …]
```

```
imdb.map(d => d['IMDB Rating'])
```

```
import {windpopulation, imdbpopulation, imdb, wind, winddata, tf, windspeedDistributionPlot, imdbDistributionPlot} from
"3523e4b3244dbb93"
```

# Reactive

## Dataset choice

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  x: {label: dataset, domain: [Math.min(...populations[dataset]),
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  marks: [
    Plot.dot(populations[dataset], Plot.dodgeY({x: "0", r:1}))
  ]
})
```

wind speed

```
viewof dataset = Inputs.select(["wind speed", "IMDB rating"])
```

```
populations = ▸ Object {wind speed: Array(4800), IMDB rating: Array(3201)}
```

```
 populations = ({
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    })
```

```
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```

```
imdb.map(d => d['IMDB Rating'])
```

```
import {windpopulation, imdbpopulation, imdb, wind, winddata, tf, windspeedDistributionPlot, imdbDistributionPlot} from
"3523e4b3244dbb93"
```

# Each *top-level* variable is a reactive value

- Can be computed with a *chunk* of code

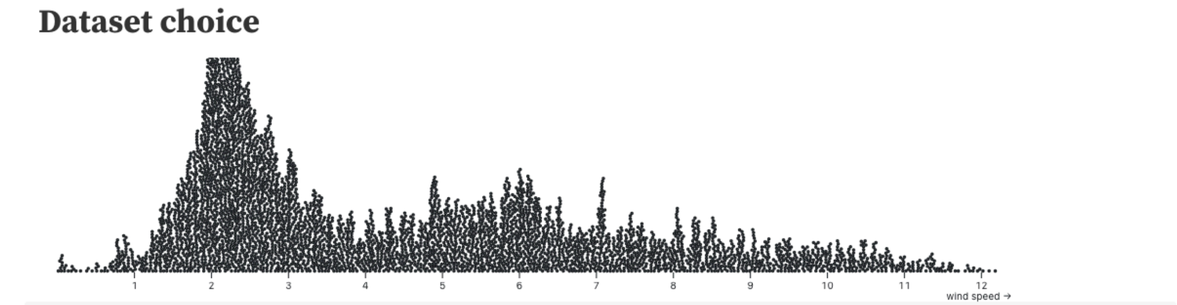
Reactive value

Dependencies

Code chunk

```
resampled = {
  resampleToggle2
  step2
  let x = resample(weights);
  let est = computeStat(x);
  estimates.push([est]);
  let output = x.arraySync();
  x.dispose()
  return output;
}
```

## Reactive

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```

wind speed

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    })
```

```
▸ Array(3201) [6.1, 6.9, 6.8, null, 3.4, null, 7.7, 3.8, 5.8, 7, 7, 7.5, 8.4, null, 6.8, null, 7, 6.1, 2.5, 8.9, …]
```

```
imdb.map(d => d['IMDB Rating'])
```

```
import {windpopulation, imdbpopulation, imdb, wind, winddata, tf, windspeedDistributionPlot, imdbDistributionPlot} from
"3523e4b3244dbb93"
```

# Your turn!