Vega-Lite

A Grammar of Interactive Graphics




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Vega

Declarative Interactive Data Visualization

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Declarative Interactive Data Visualization

describes *what* the visualization should look like vs. *how* it should be computed.

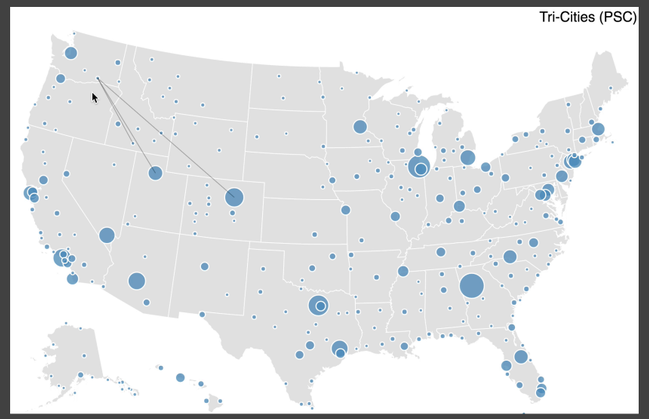
Vega: Declarative Interactive Data Visualization

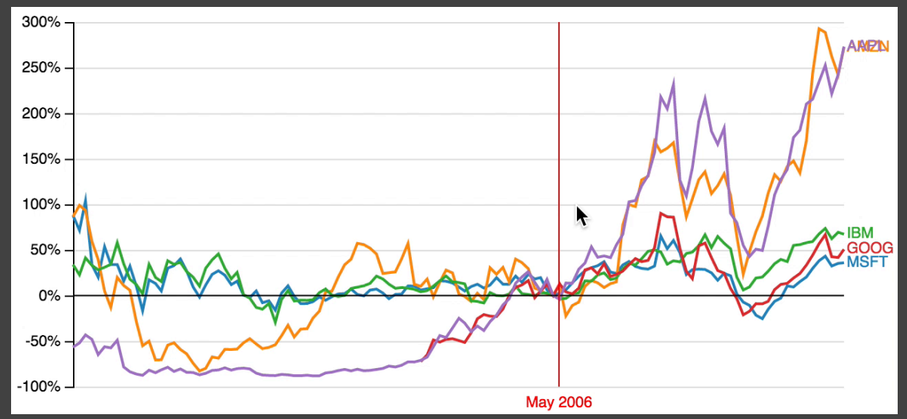
describes *what* the visualization should look like vs. *how* it should be computed.

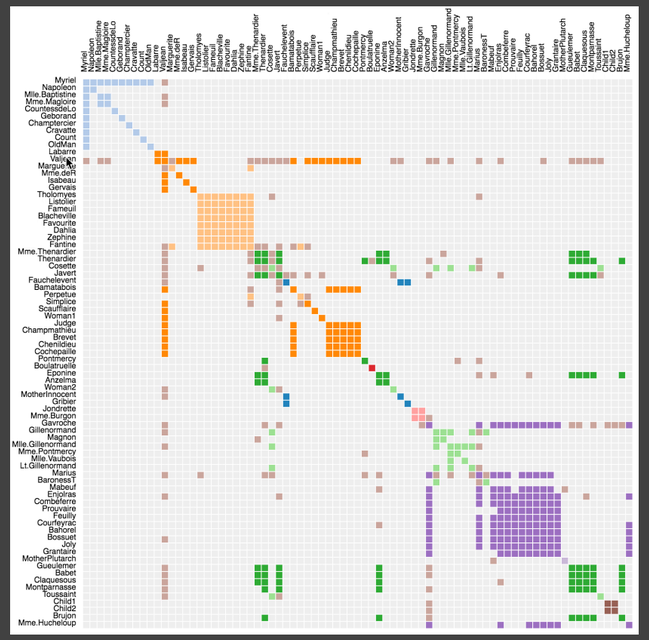
Data	Event Streams	`[mousedown, mouseup] > mousemove`
Transforms	Signals	`minX := min(downX, event.x)`
Scales	Scale Inversions	`minVal := xScale.invert(minX)`
Guides	Predicates	`p(t) := t.value ∈ [minVal, maxVal]`
Marks	Production Rules	`fill := p(t) → colorScale(t.category)` `∅ → gray`

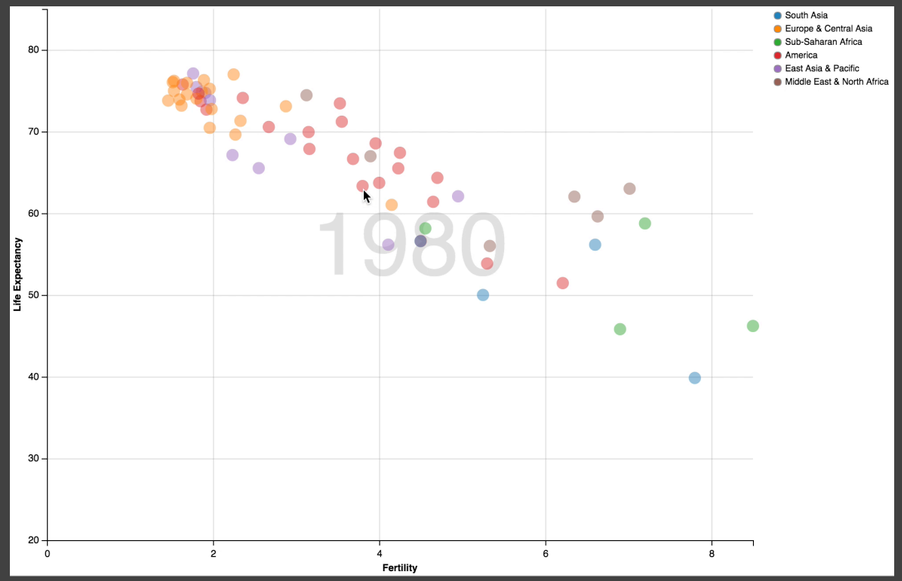
Declarative Interaction Design. Satyanarayan, Wongsuphasawat, Heer. *UIST 2014.*
Reactive Vega. Satyanarayan, et al. *InfoVis 2015.*

Vega: Maximize Expressivity and Performance



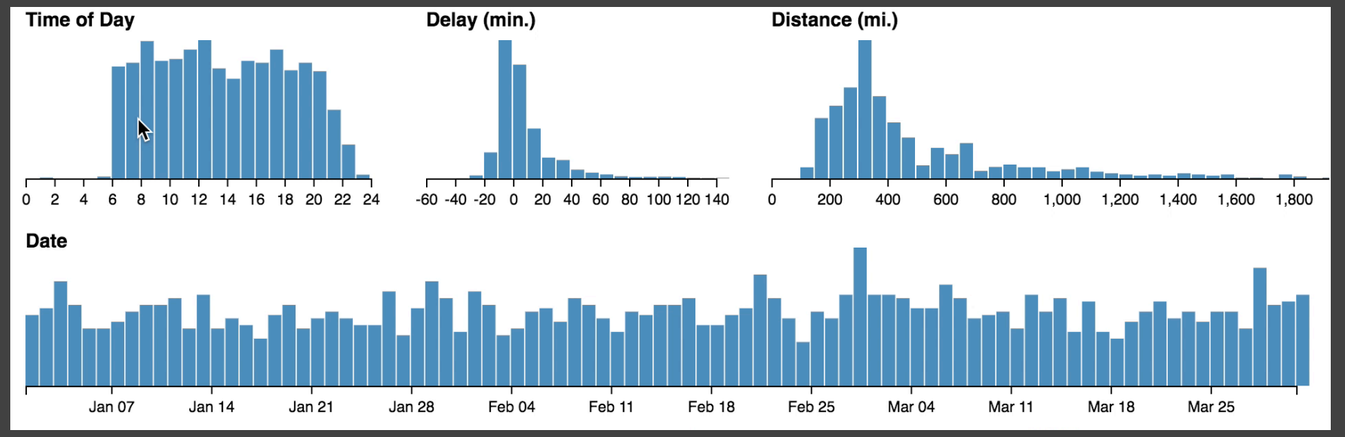






Interactive performance ~2x faster than D3.


Rob Story
@oceankidbilly
Following
It is both ridiculous and amazing that this can be expressed in 593 lines (!) of purely declarative spec: vega.github.io/vega-editor/in …
RETWEET
1
LIKES
13
9:09 PM - 1 Oct 2015
Reply to @oceankidbilly
Lynn Cherny @arnicas · 2 Oct 2015
@oceankidbilly sure… but no way do i want to hard code that for a specific case. it's tiny code in dc.js.




```
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  "height": 325,
  "padding": "strict",

  "data": [
    {
      "name": "flights",
      "url": "data/flights-2k.json",
      "format": {"type": "json", "parse": {"date": "date"}},
      "transform": [
        {"type": "formula", "field": "hour", "expr": "hours(datum.date)"},
        {
          "type": "formula",
          "field": "day",
          "expr": "datetime((month(datum.date)+1) + '/' + date(datum.date) + '/200
        },
        {
          "type": "bin",
          "field": "hour",
          "min": 0,
          "max": 24,
          "step": 1,
          "output": {"start": "bin_hour"}
```

Expressivity & performance are important.

But so is **concise specification**.

Rapid authoring critical for *exploratory* visualization.

Small language vocabulary promotes **alternative designs** and **systematic enumeration** for higher-level applications.

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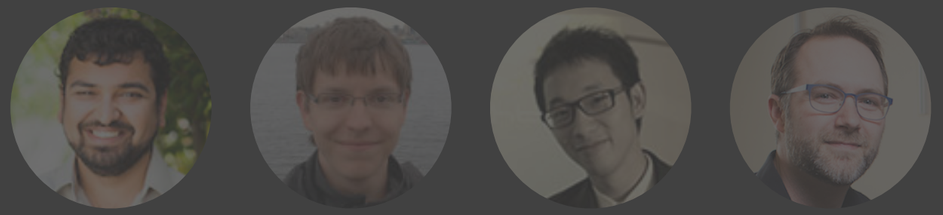
Vega-Lite

Grammar of Graphics + Grammar of Interaction

Concise, high-level Vega-Lite specifications

Complete, low-level Vega specifications

compiled to



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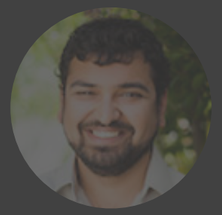


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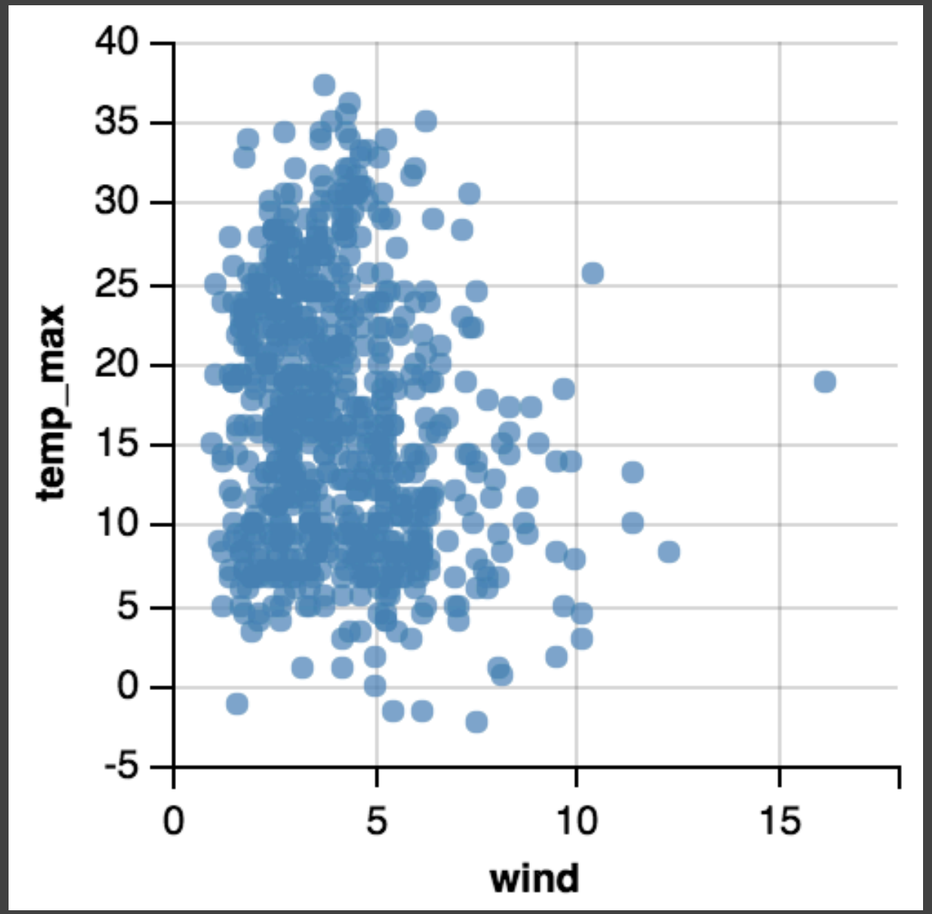
Single View: Unit Specification

```
{
  "data": {"url": "data/weather.csv"},
  "mark": "circle",
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative"
    },
    "y": {
      "field": "temp_max",
      "type": "quantitative"
    }
  }
}
```



Single View: Unit Specification

Data

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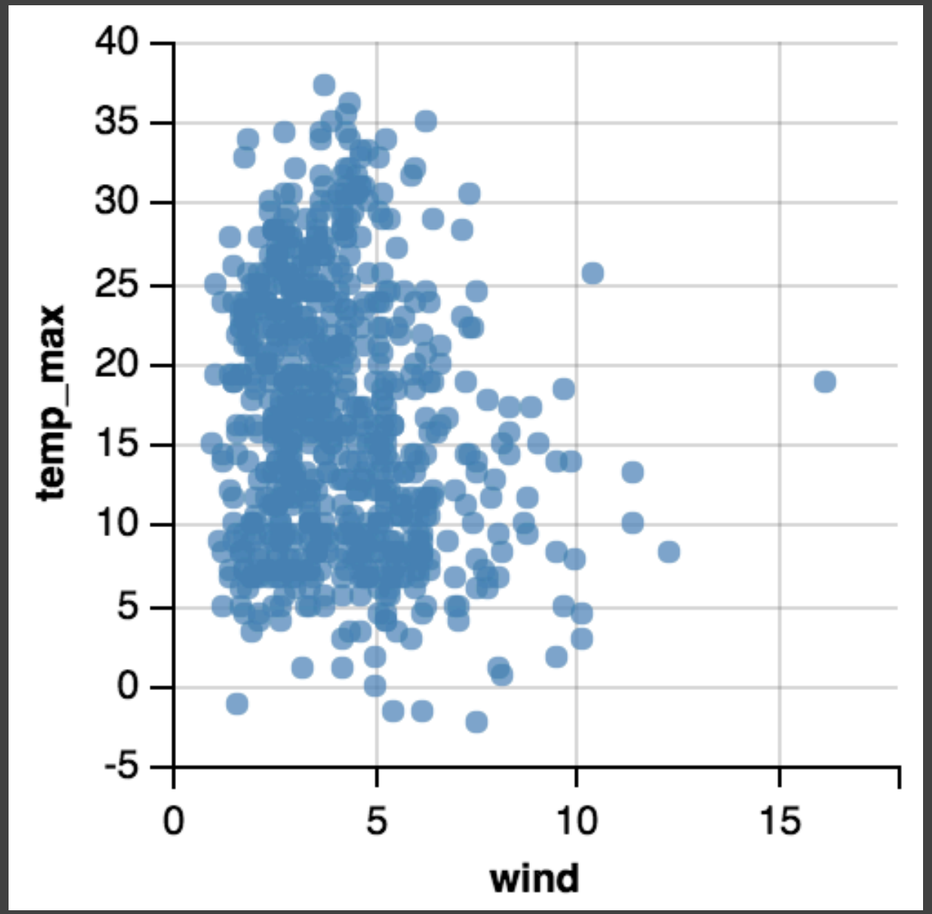
{
  "data": {"url": "data/weather.csv"},
  "mark": "circle",
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative"
    },
    "y": {
      "field": "temp_max",
      "type": "quantitative"
    }
  }
}
```



Single View: Unit Specification

Data

Mark

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{
  "data": {"url": "data/weather.csv"},
  "mark": "circle",
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative"
    },
    "y": {
      "field": "temp_max",
      "type": "quantitative"
    }
  }
}
```
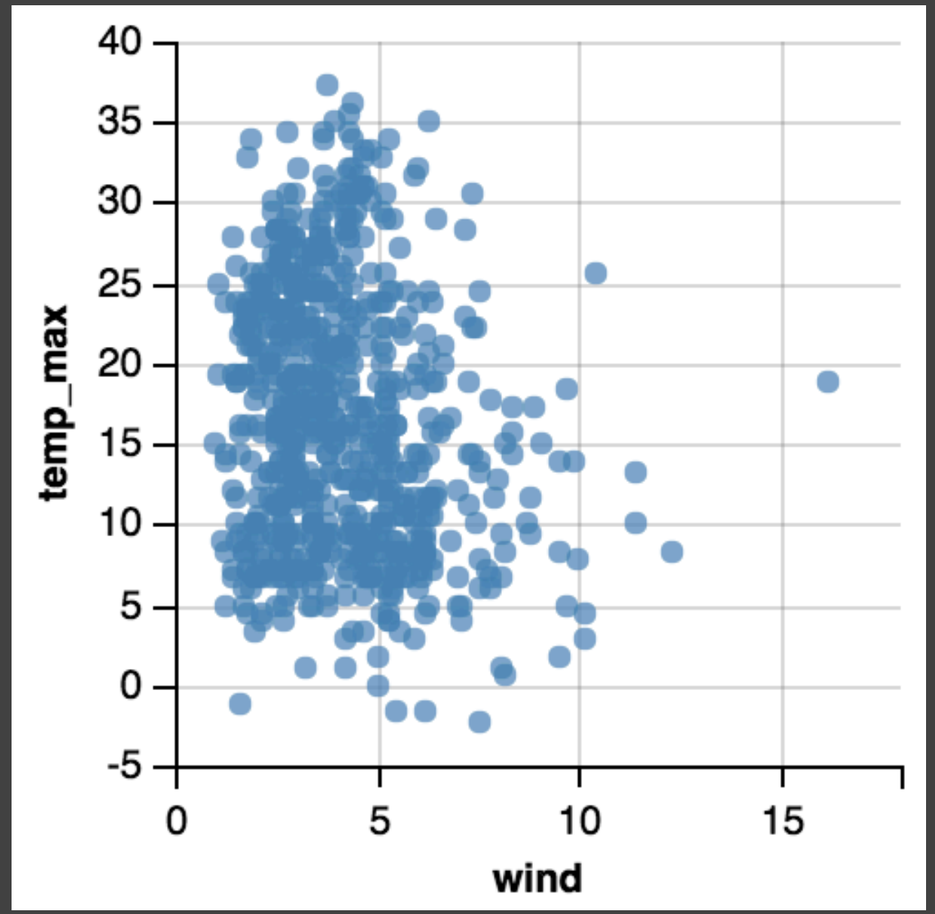



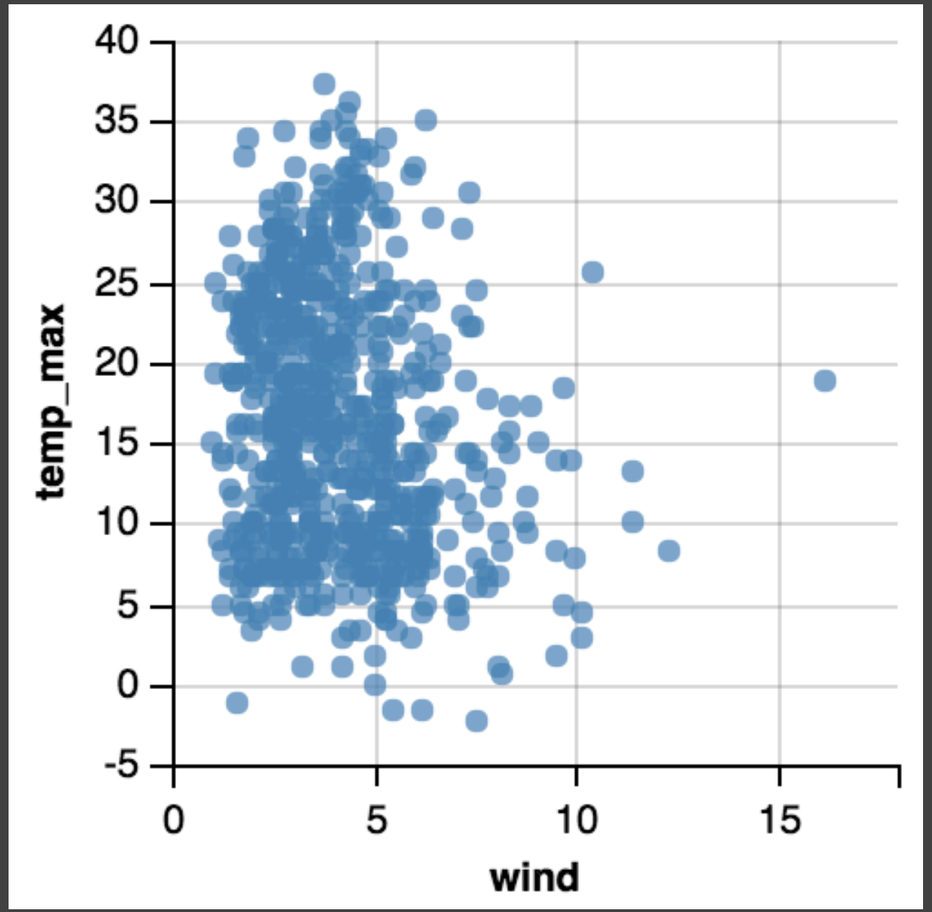
Single View: Unit Specification

Data

Mark

Encoding

```
{
  "data": {"url": "data/weather.csv"},
  "mark": "circle",
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative"
    },
    "y": {
      "field": "temp_max",
      "type": "quantitative"
    }
  }
}
```



Single View: Unit Specification

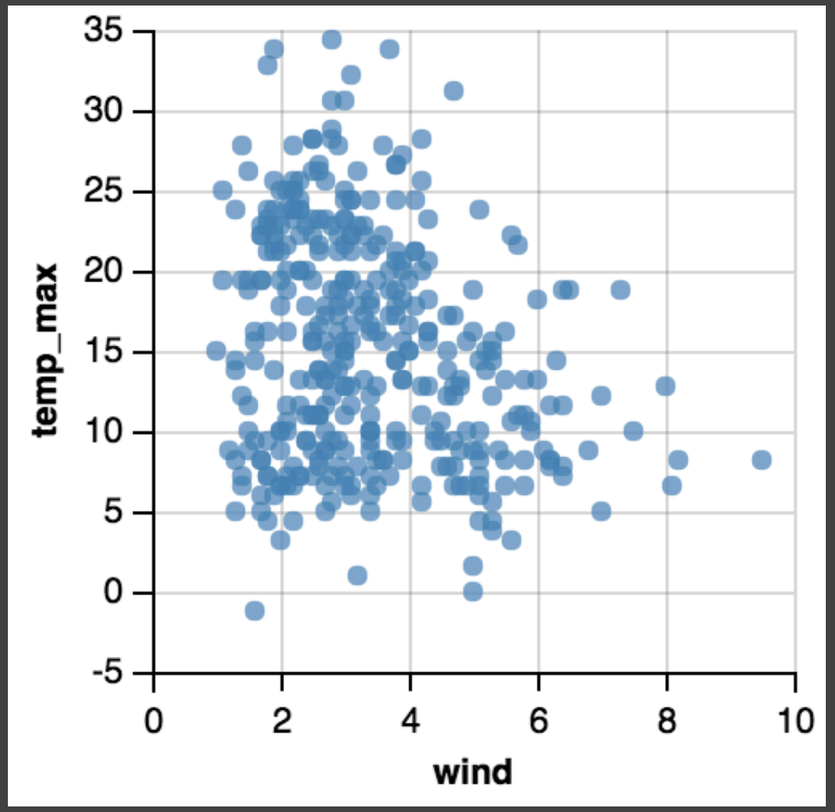
Data

Mark

Encoding

Transforms

```
{
  "data": {"url": "data/weather.csv"},
  "transform": {
    "filter": "datum.location === 'Seattle'"
  },
  "mark": "circle",
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative"
    },
    "y": {
      "field": "temp_max",
      "type": "quantitative"
    }
  }
}
```



Single View: Unit Specification

Data

Mark

Encoding

Transforms

```
{
  "data": {"url": “data/weather.csv"},
  "transform": {
    "filter": "datum.location === 'Seattle'"
  },
  "mark": "circle",
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative",
      "bin": true
    },
    "y": {
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      "type": "quantitative",
      "bin": true
    },
    "size": {
      "field": "*",
      "aggregate": "count",
      "type": "quantitative"
    }
  }
}
```
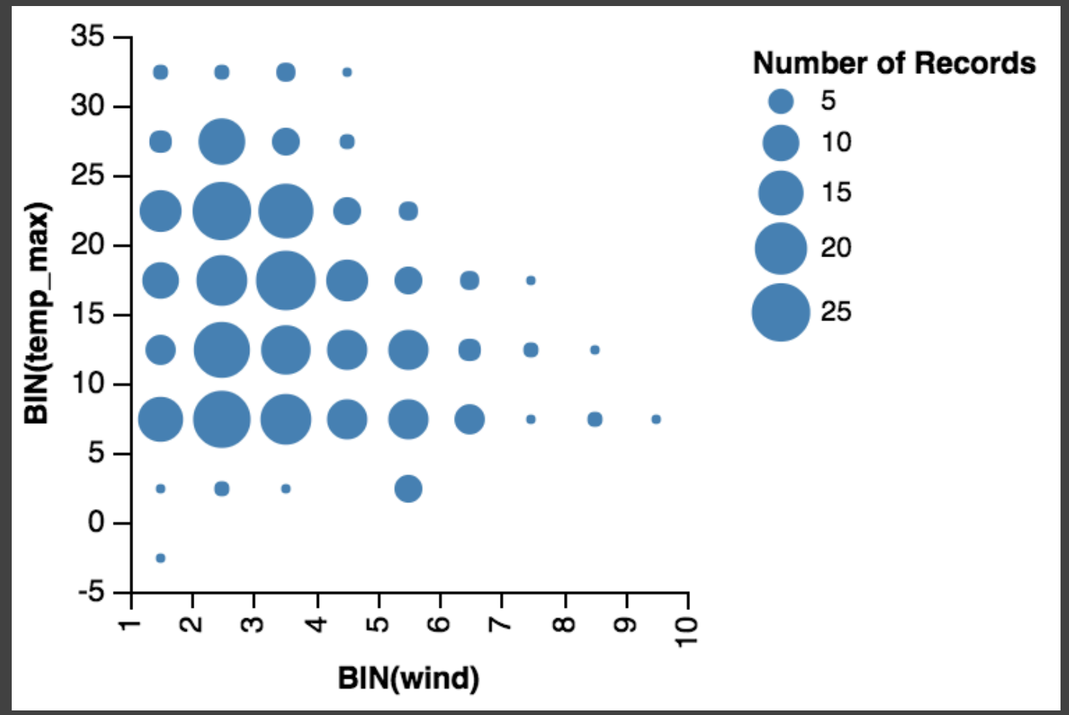



Single View: Unit Specification

Data

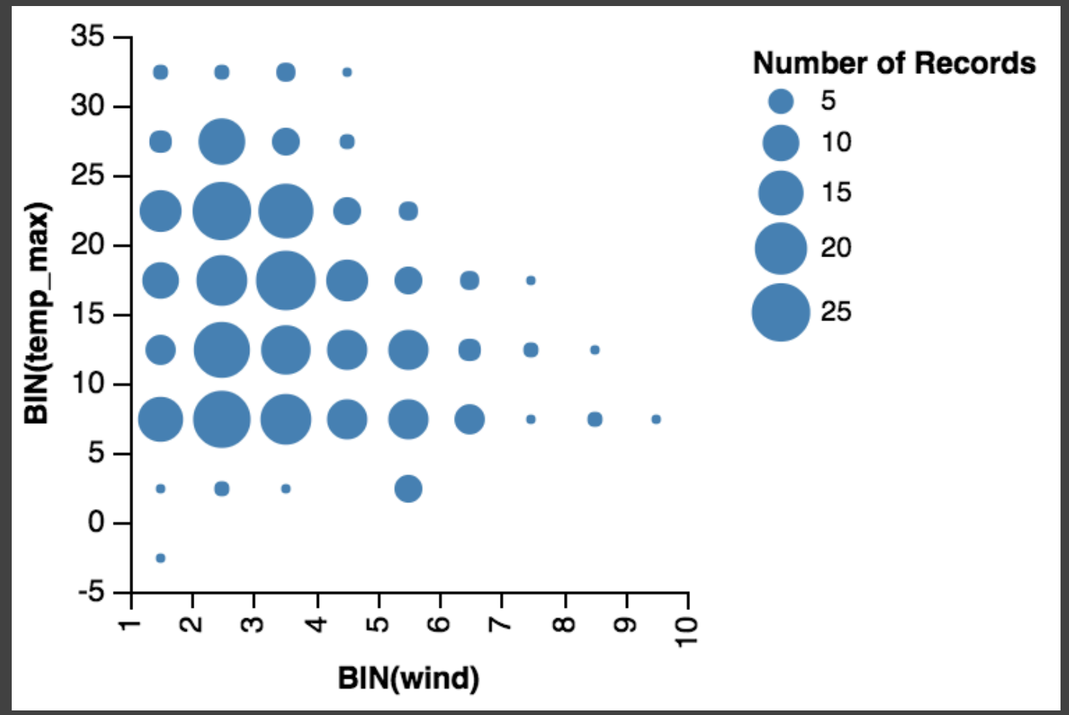
Mark

Encoding

Transforms

(Scales + Guides)

```
{
  "data": {"url": “data/weather.csv"},
  "transform": {
    "filter": "datum.location === 'Seattle'"
  },
  "mark": "circle",
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative",
      "bin": true
    },
    "y": {
      "field": "temp_max",
      "type": "quantitative",
      "bin": true
    },
    "size": {
      "field": "*",
      "aggregate": "count",
      "type": "quantitative"
    }
  }
}
```



Single View: Unit Specification

Data

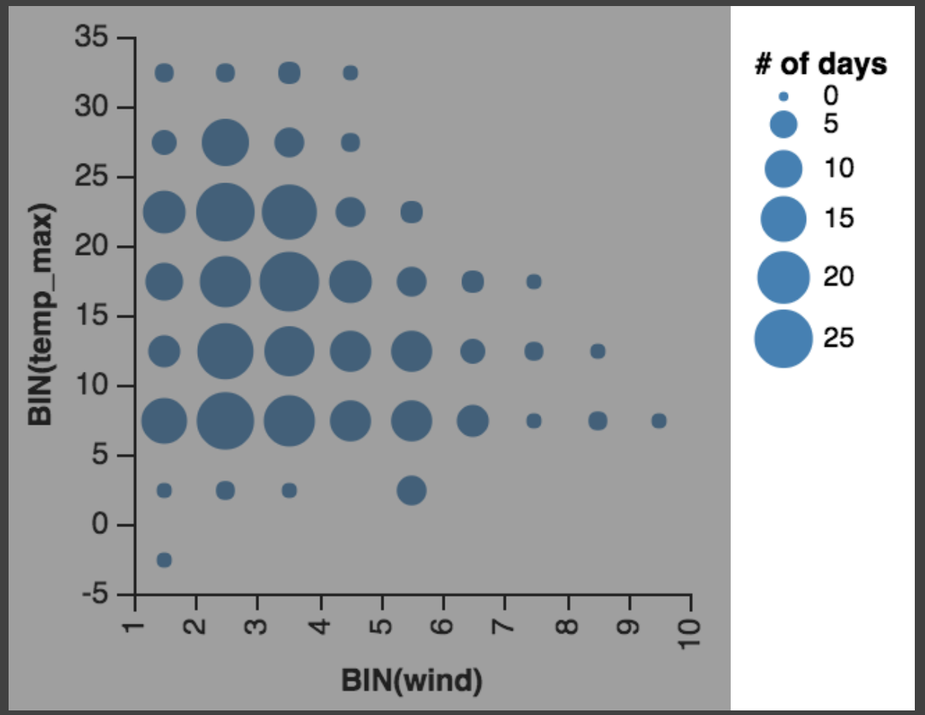
Mark

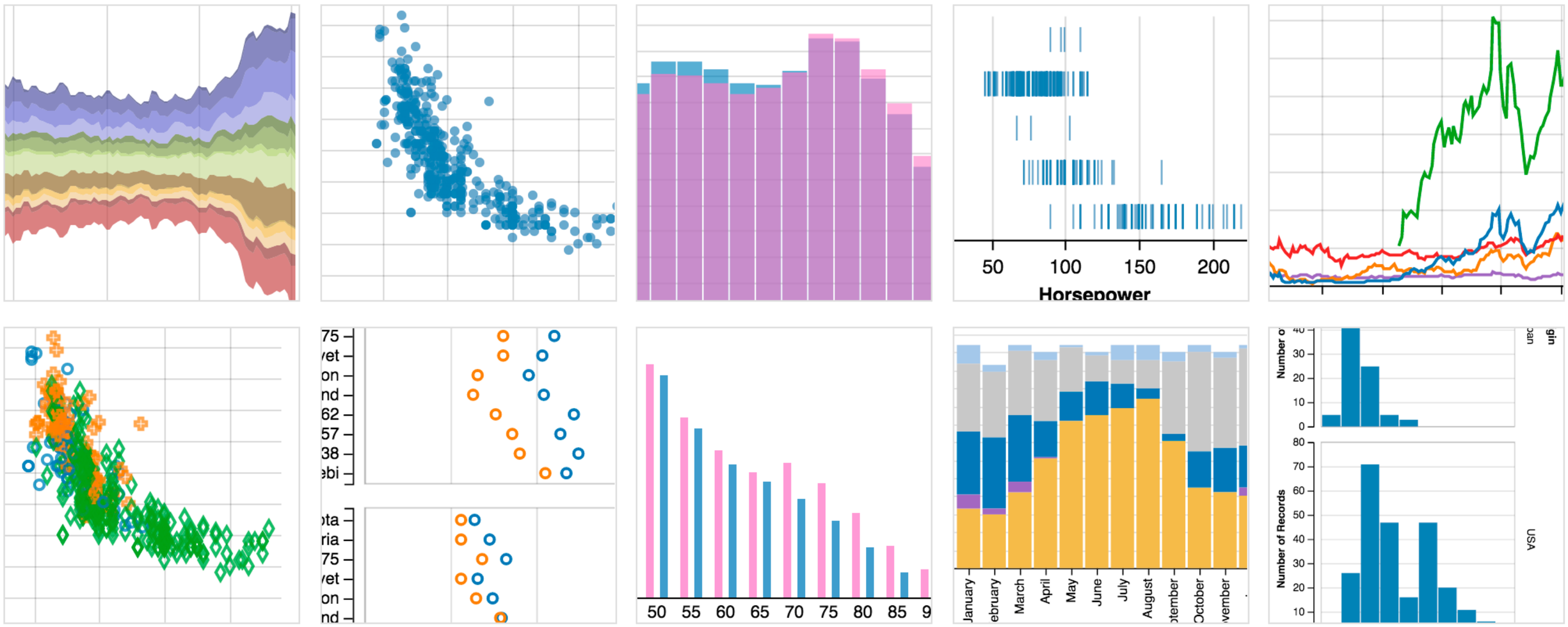
Encoding

Transforms

(Scales + Guides)

```
{
  ...
  "encoding": {
    "x": {
      "field": "wind",
      "type": "quantitative",
      "bin": true
    },
    "y": {
      "field": "temp_max",
      "type": "quantitative",
      "bin": true
    },
    "size": {
      "field": "*",
      "aggregate": "count",
      "type": "quantitative",
      "scale": {"zero": true},
      "legend": {"title": "# of days"}
    }
  }
}
```

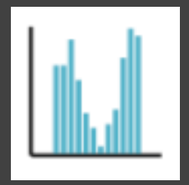




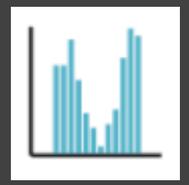
https://vega.github.io/vega-lite/docs/

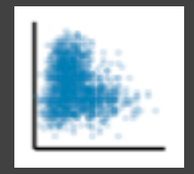
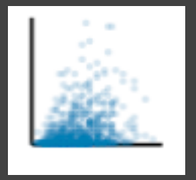
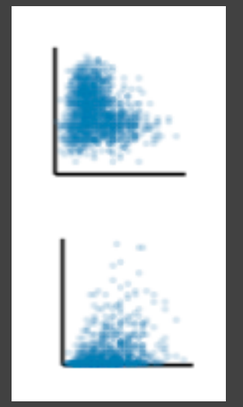
View Composition

View Composition

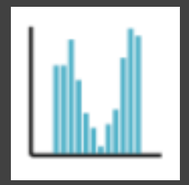
layer: [ , ] = 

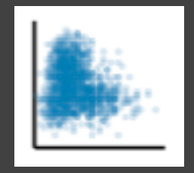
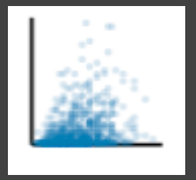
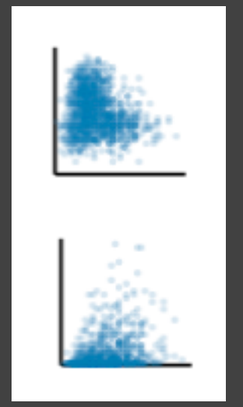
View Composition

layer: [ , ] = 

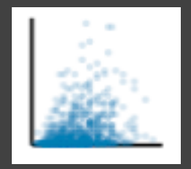
vconcat: [ , ] = 

View Composition

layer: [ , ] = 

vconcat: [ , ] = 

repeat row: [A,B]



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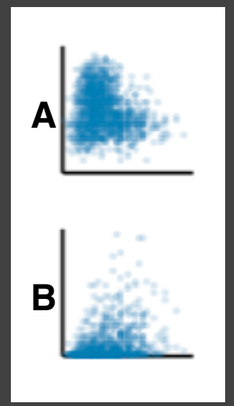
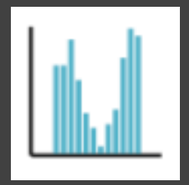
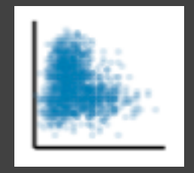
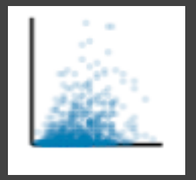
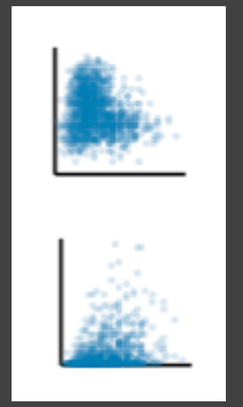
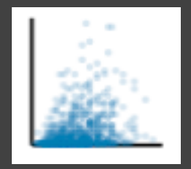


View Composition

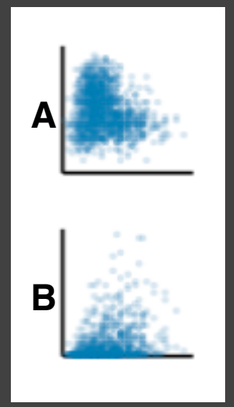
layer: [ , ] = 

vconcat: [ , ] = 

repeat row: [A,B]

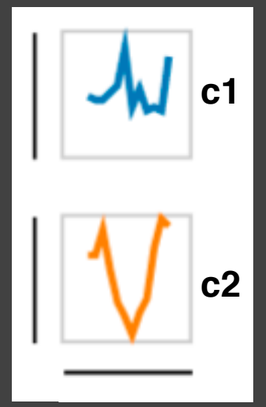


=

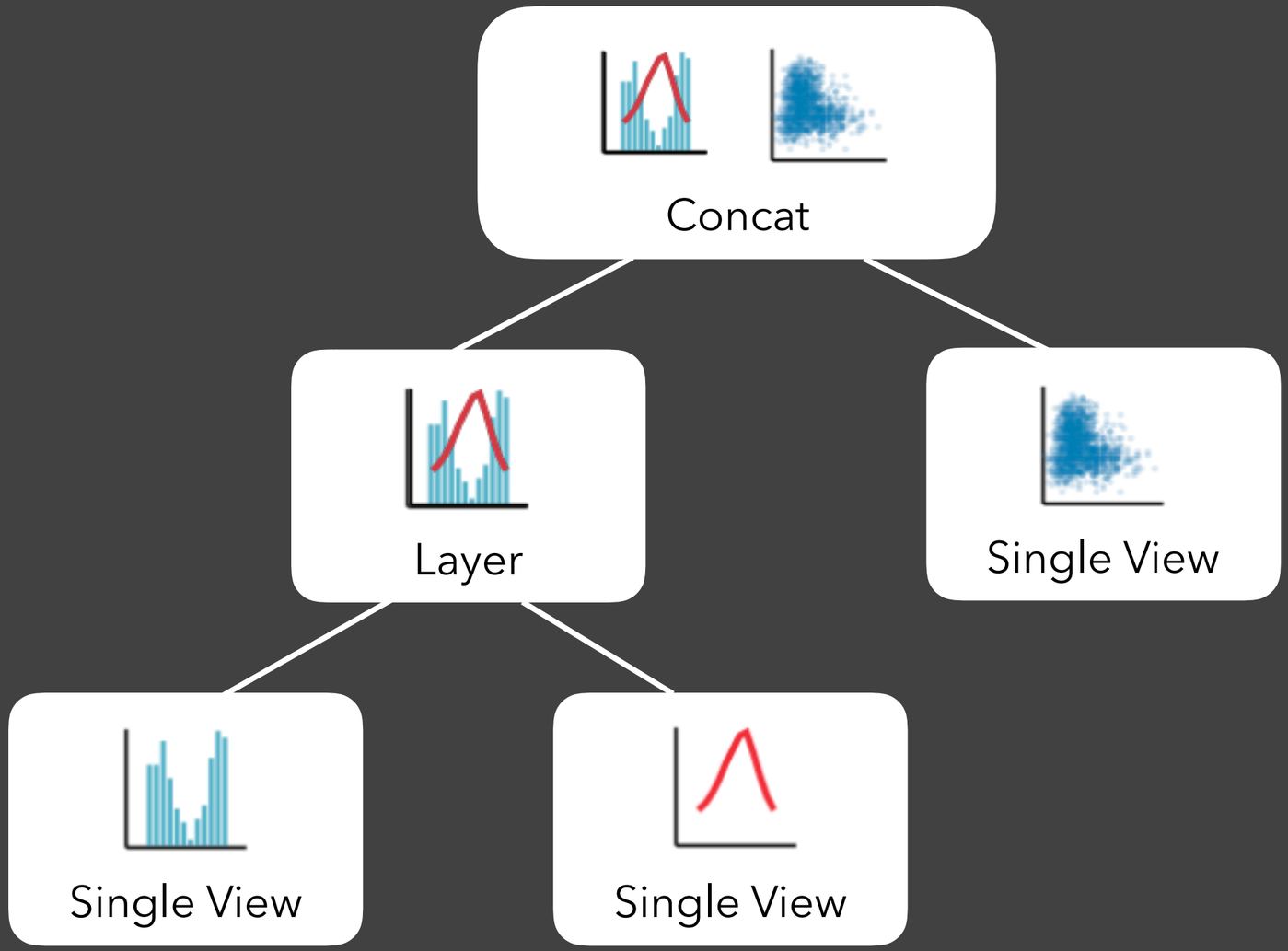


facet row: C

=

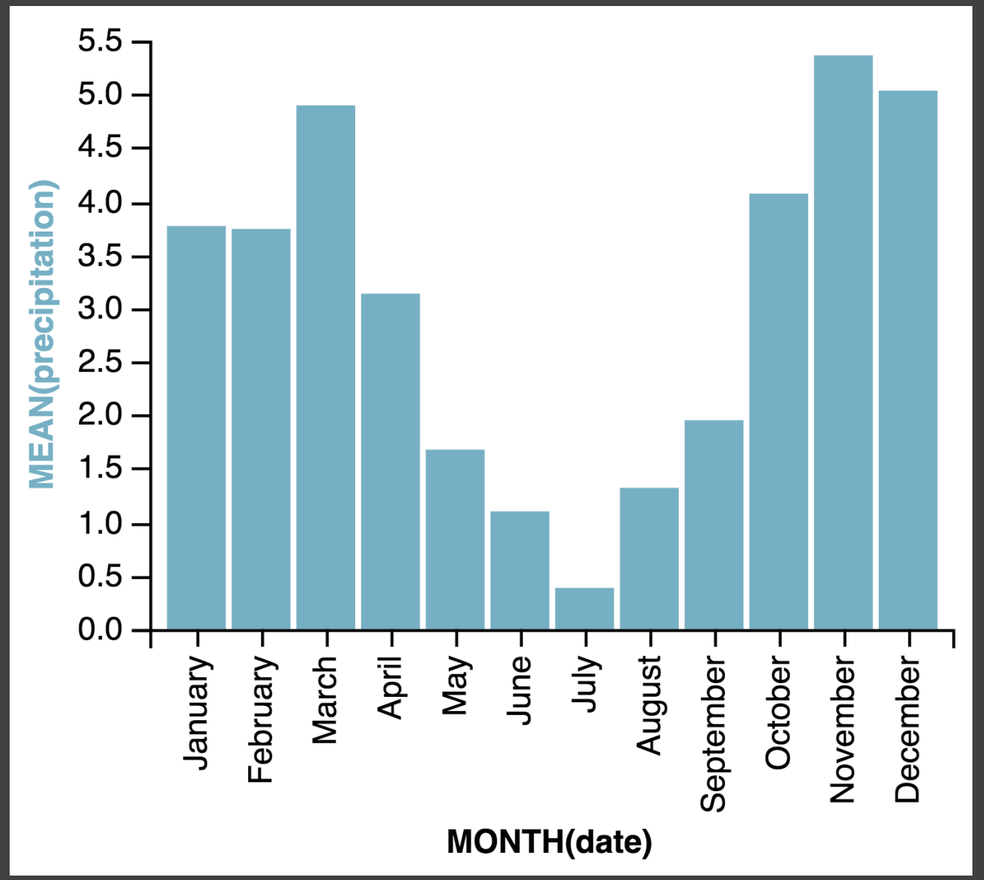


View Composition



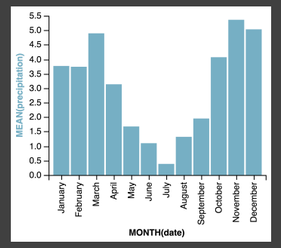
Layering

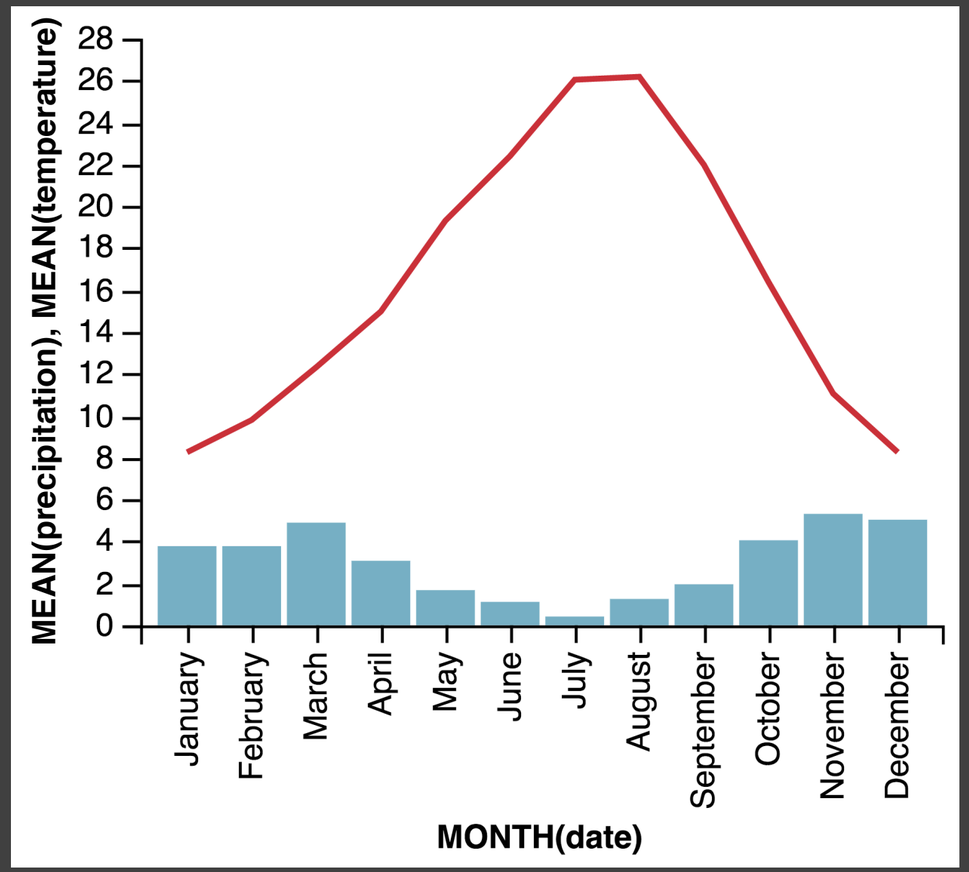
```
{
  "data": {"url": "data/weather-sea.csv"},
  "mark": "bar",
  "encoding": {
    "x": {
      "timeUnit": "month",
      "field": "date", "type": "T"
    },
    "y": {
      "aggregate": "mean",
      "field": "precipitation", "type": "Q"
    },
    "color": {"value": "#77b2c7"}
  }
}
```



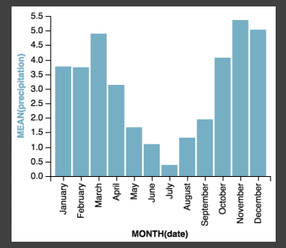
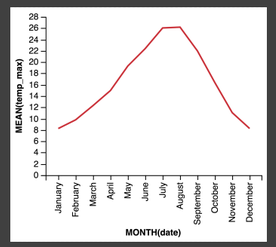
Layering

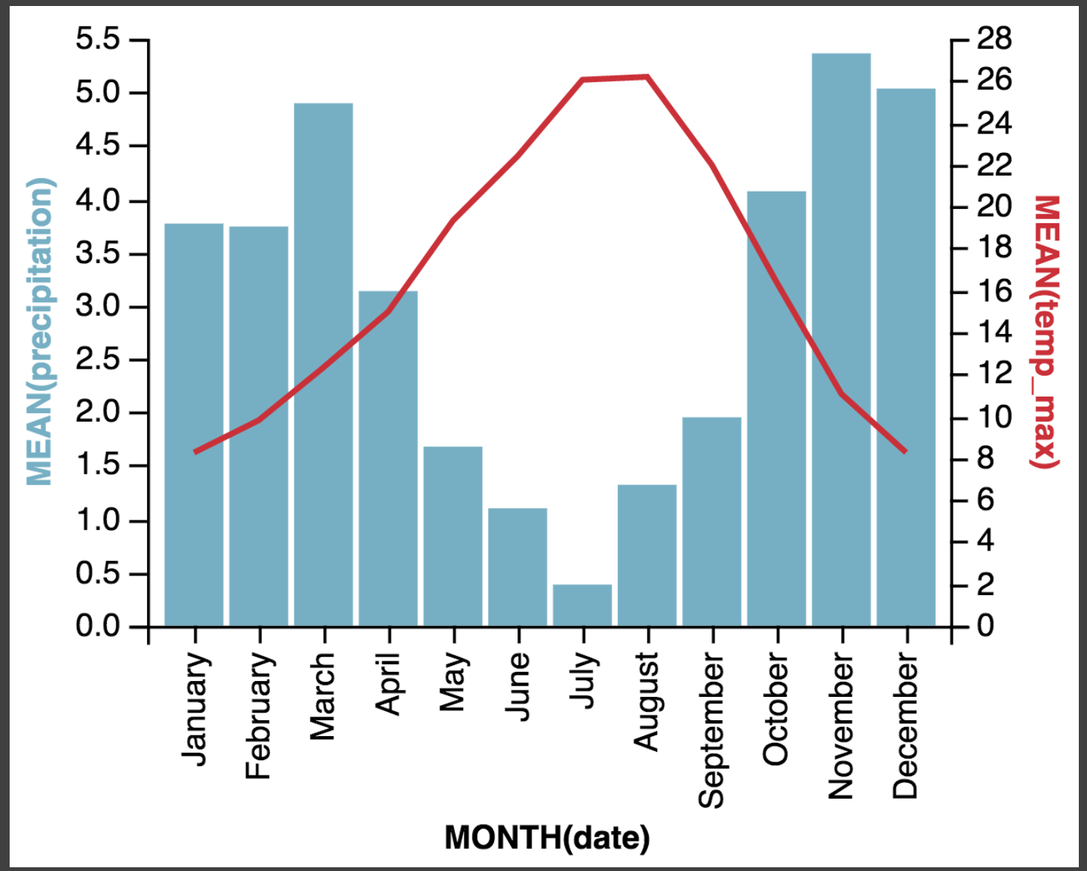
```
{
  "layer": [
    {
      "data": {"url": "data/weather-sea.csv"},
      "mark": "line",
      "encoding": {
        "x": {
          "timeUnit": "month",
          "field": "date", "type": "T"
        },
        "y": {
          "aggregate": "mean",
          "field": "temp_max", "type": "Q"
        }
      }
    }]
}
```





Layering

```
{
  "layer": [
    {
      
    },
    {
      
    }
  ],
  "resolve": {
    "y": {
      "scale": "independent"
    }
  }
}
```



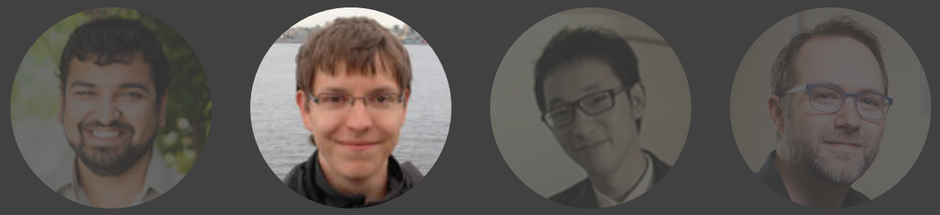
Vega-Lite

Grammar of Graphics + Grammar of Interaction

Concise, high-level Vega-Lite specifications

Complete, low-level Vega specifications

compiled to



Arvind Satyanarayan @arvindsatya1
Stanford University

Dominik Moritz @domoritz
Kanit "Ham" Wongsuphasawat @kanitw
Jeffrey Heer @jeffrey_heer
University of Washington

Vega-Lite

Grammar of Graphics + Grammar of Interaction

Concise, high-level Vega-Lite specifications

Complete, low-level Vega specifications

compiled to

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University of Washington

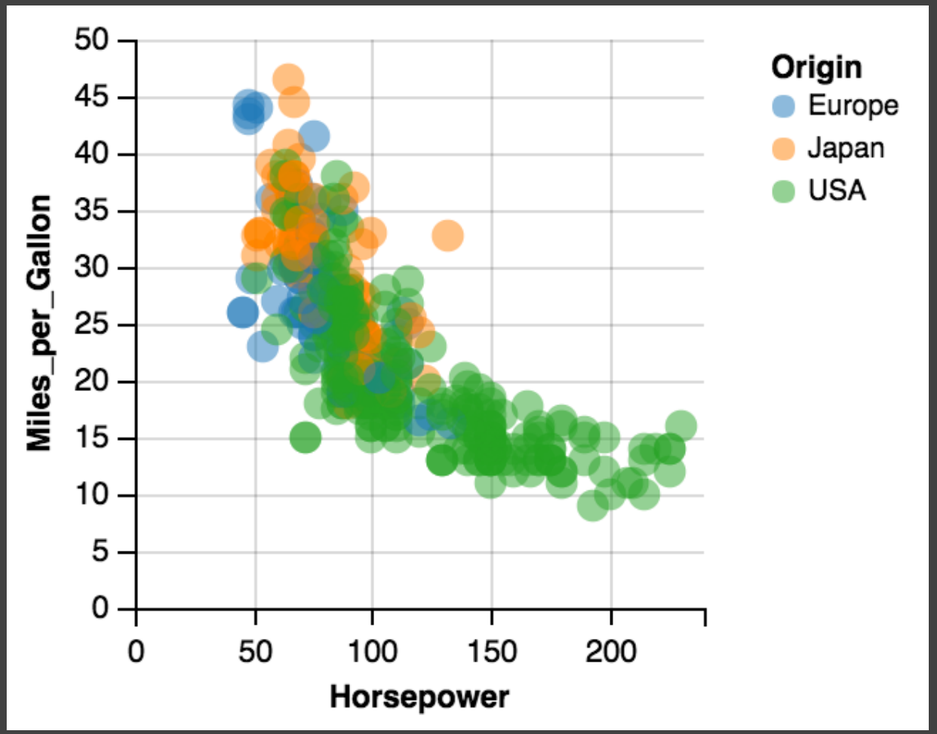
Selection

Selection

an abstraction that defines points of interest, event processing, and a predicate function for inclusion testing.

Vega-Lite Selections

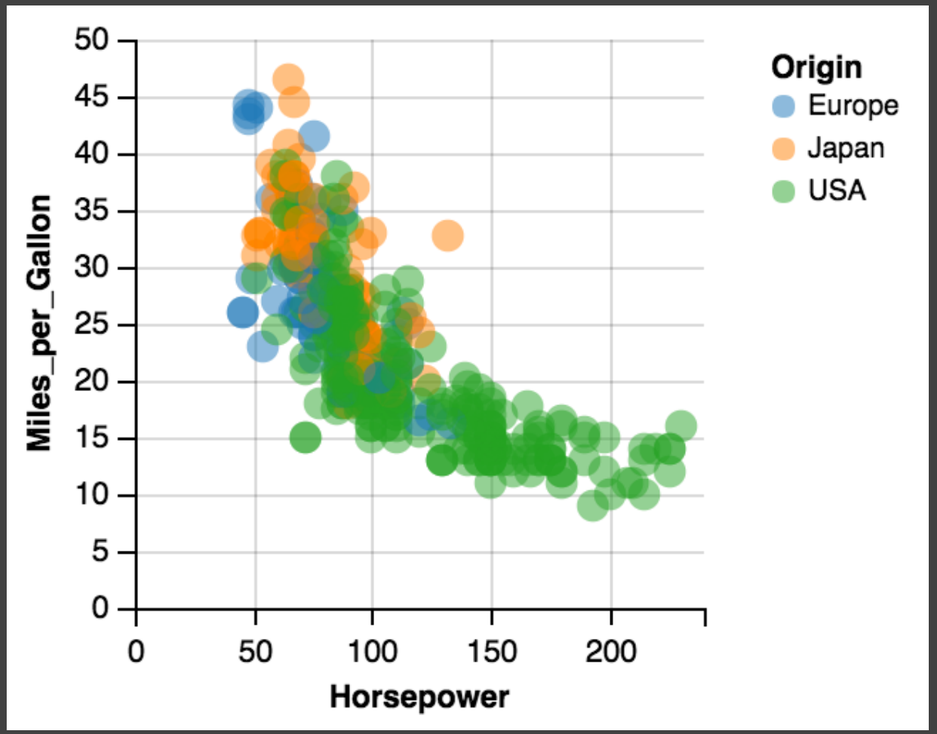
```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": {"field": "Origin", "type": "N"}
  }
}
```



Selections define backing data points, event processing, and a predicate function.

Vega-Lite Selections: A Single Point

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {"type": "point"}
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": {"field": "Origin", "type": "N"}
  }
}
```

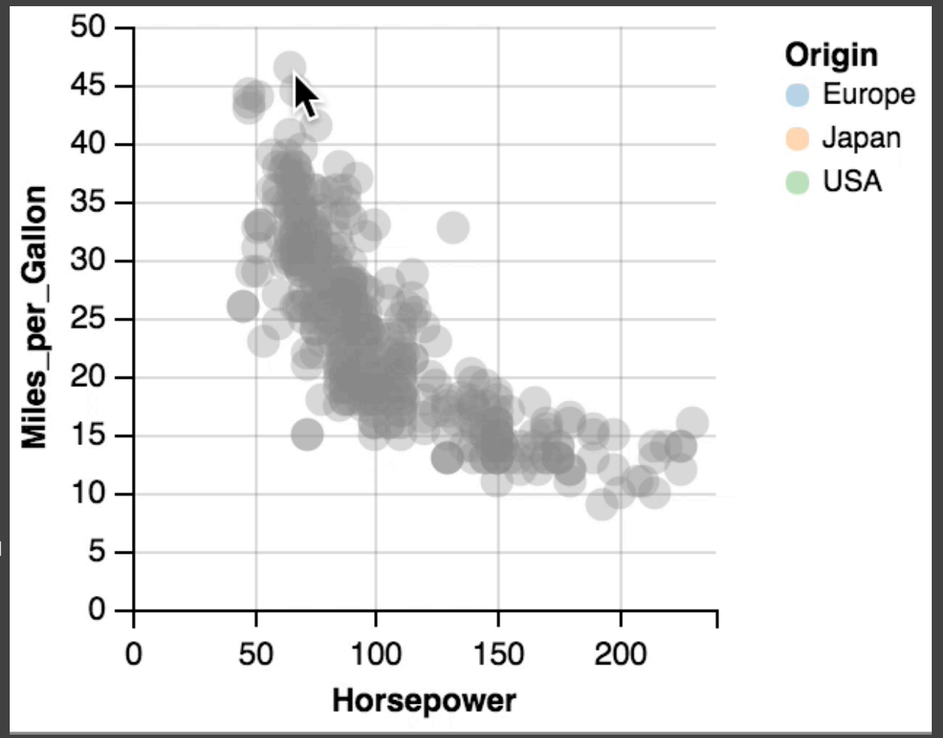


Selections define backing data points, event processing, and a predicate function.

Selection **types** provide defaults values for these three components.

Vega-Lite Selections: A Single Point

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {"type": "point"}
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```

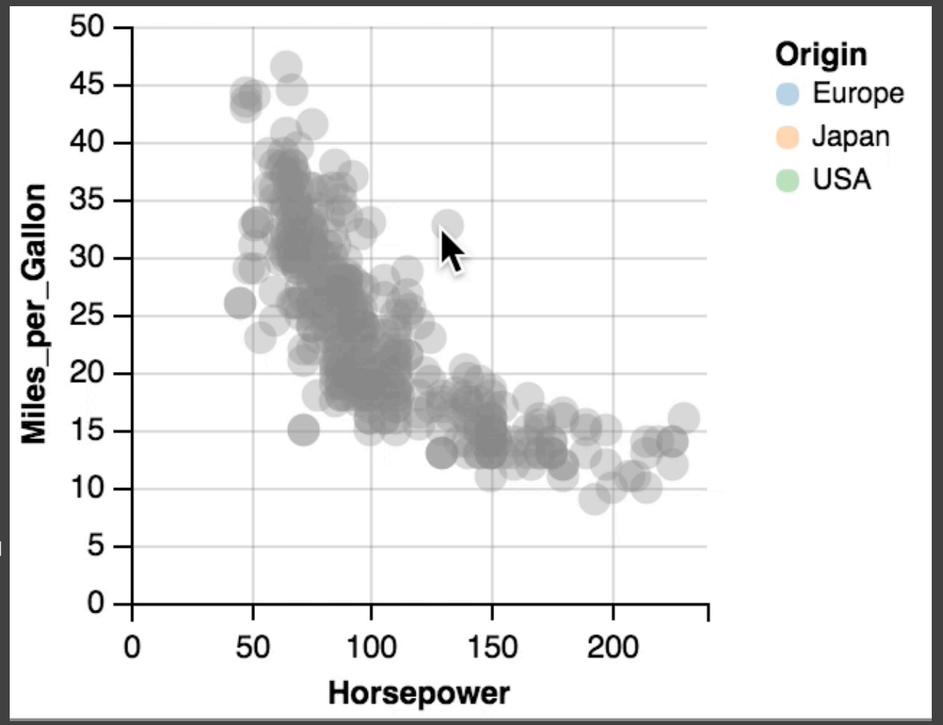


Selections define backing data points, event processing, and a predicate function.

Selection **types** provide defaults values for these three components.

Vega-Lite Selections: Multiple Points

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {"type": "list"}
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```

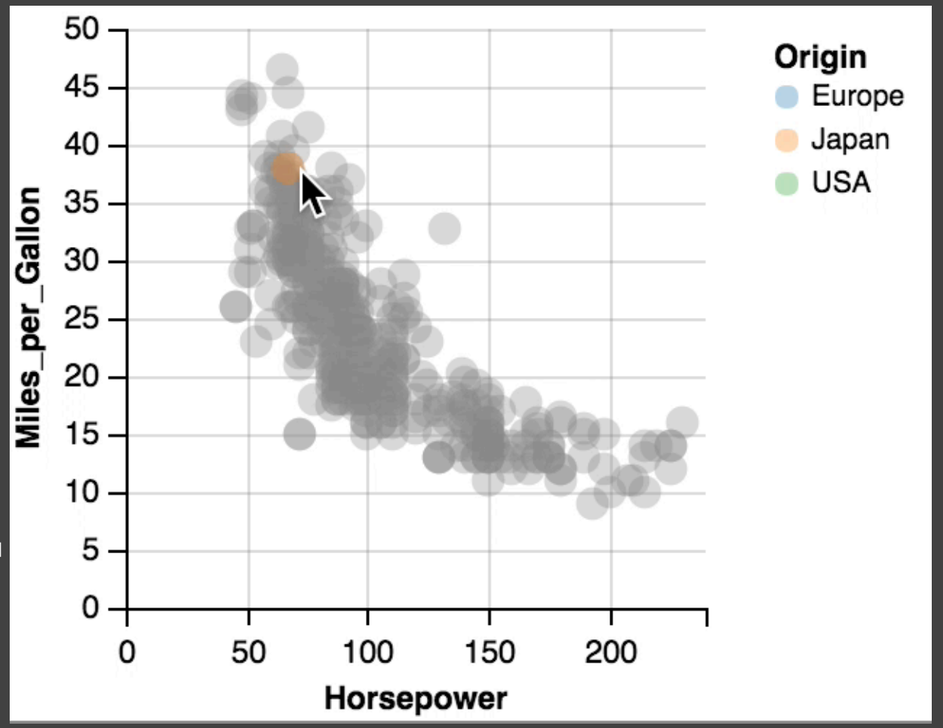


Selections define backing data points, event processing, and a predicate function.

Selection **types** provide defaults values for these three components.

Vega-Lite Selections: Multiple Points

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {"type": "list", "on": "mouseover"}
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```

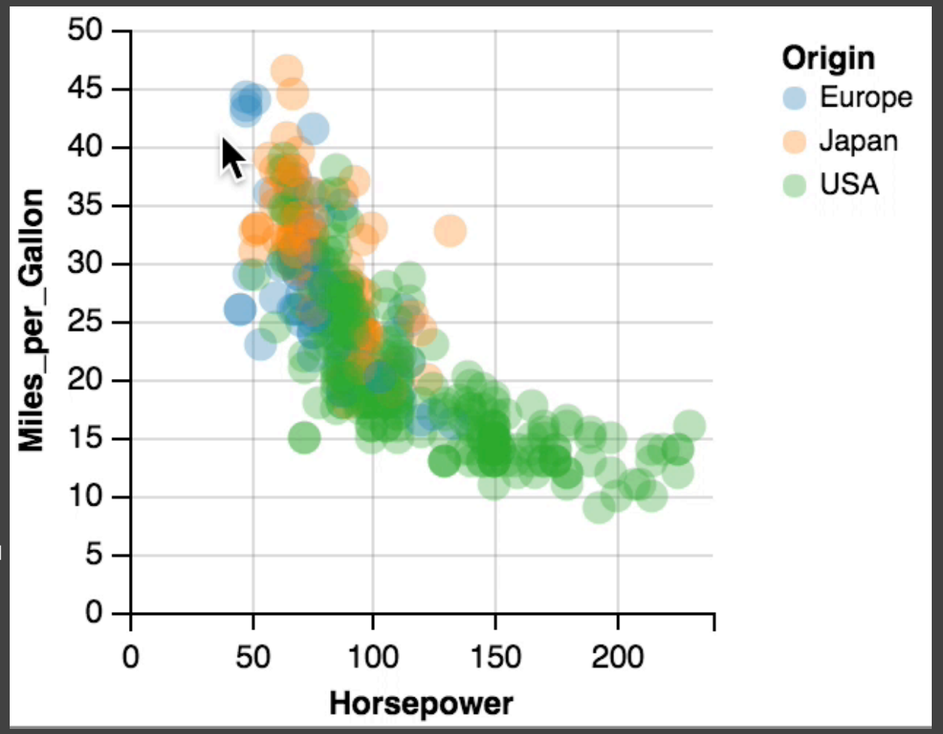


Selections define backing data points, event processing, and a predicate function.

Selection **types** provide defaults values for these three components.

Vega-Lite Selections: Continuous Region

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {"type": "interval"}
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```



Selections define backing data points, event processing, and a predicate function.

Selection **types** provide defaults values for these three components.

Selection Transforms

manipulate a selection's semantics (points of interest, event processing, or predicate function).

Selection Transforms

manipulate a selection's semantics (points of interest, event processing, or predicate function).

toggle — when events occurs, toggles a point in/out of selection;
automatically instantiated for *list* selections.

translate — when events occur, offsets spatial properties/data values;
automatically instantiated for *interval* selections.

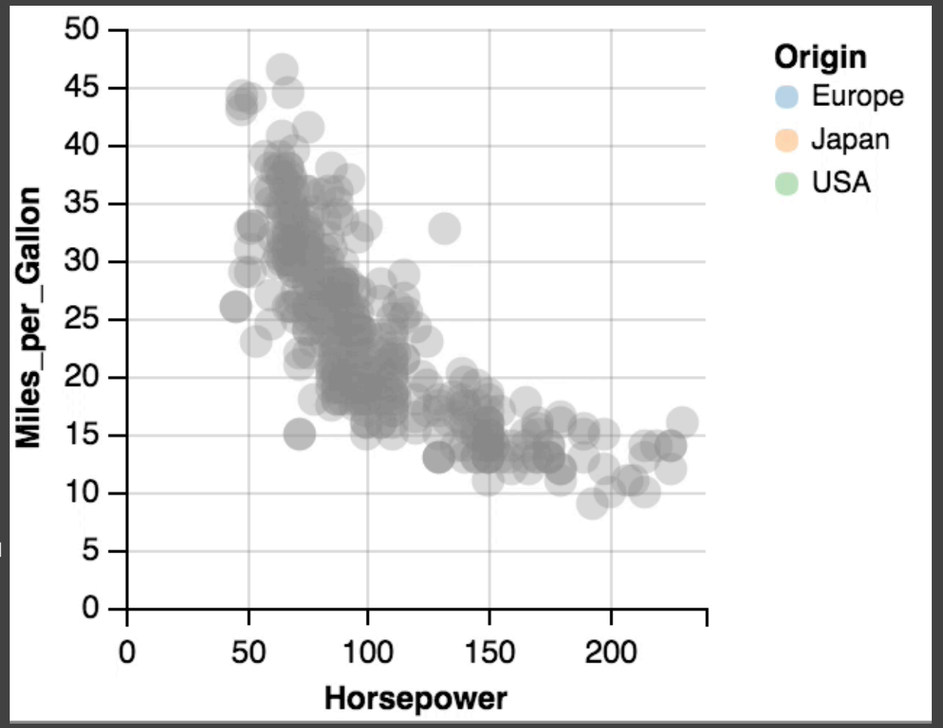
zoom — when events occur, applies a scale factor to selected points.

nearest — accelerates selection via voronoi tessellations.

project — modifies predicate to determine inclusion based on **fields** or **channels**.

Vega-Lite Selections: Multiple Points

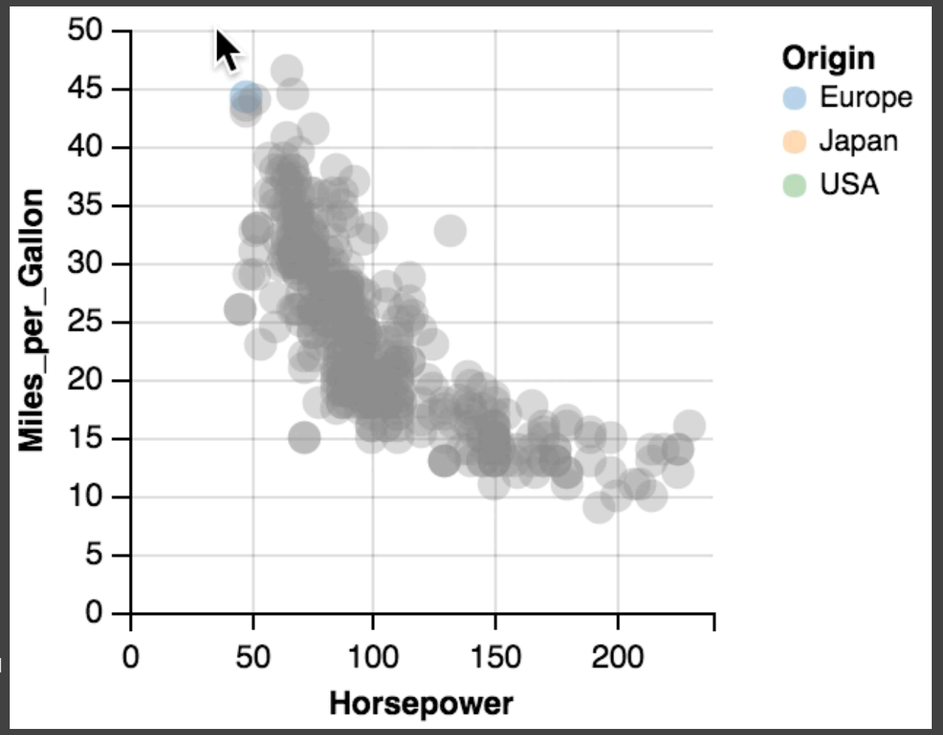
```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {"type": "list", "on": "mouseover"}
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```



Selection Transforms – manipulate a selection's semantics (backing data points, event processing, or predicate function).

Vega-Lite Selections: Multiple Points

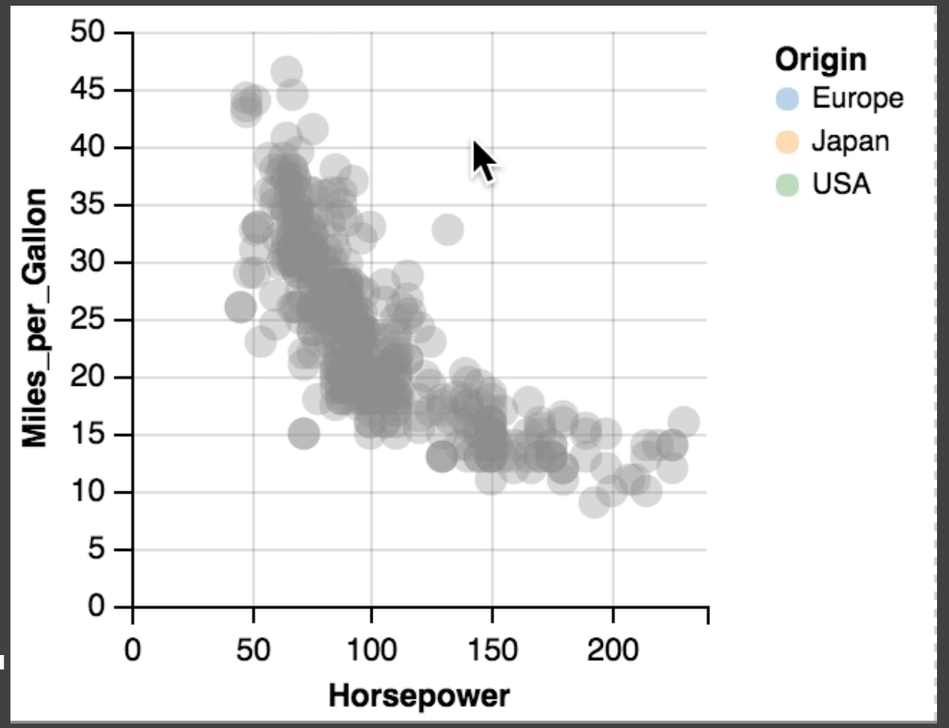
```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {
      "type": "list", "on": "mouseover",
      "nearest": true
    }
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```



Selection Transforms – manipulate a selection's semantics (event processing).

Vega-Lite Selections: Multiple `Origins`

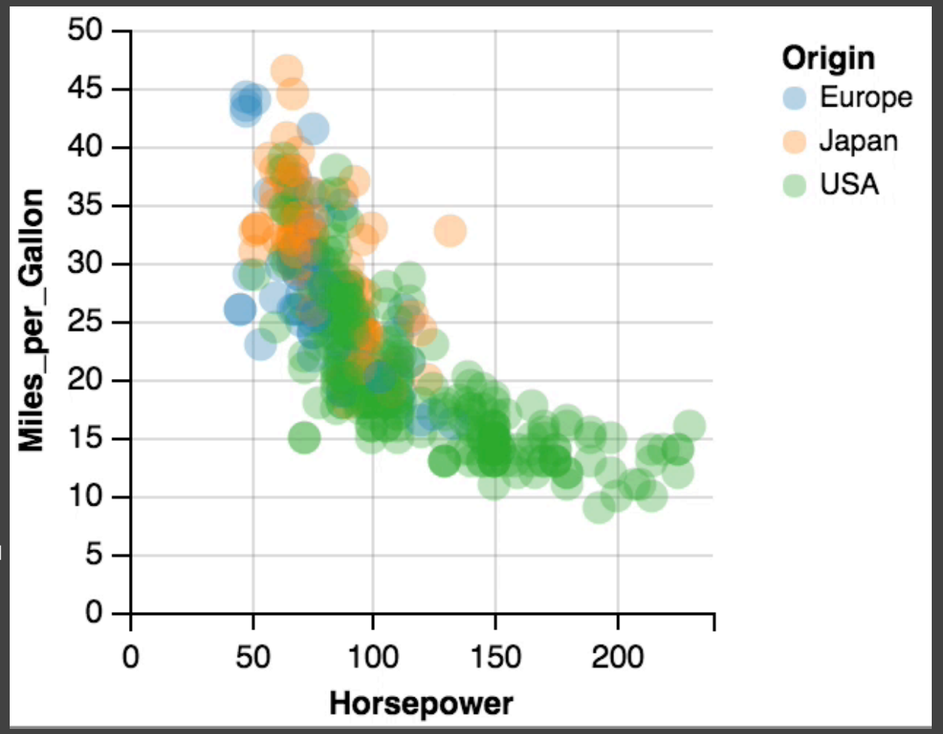
```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {
      "type": "list", "nearest": true,
      "project": {"fields": ["Origin"]}
    }
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```



Selection Transforms – manipulate a selection's semantics (predicate function).

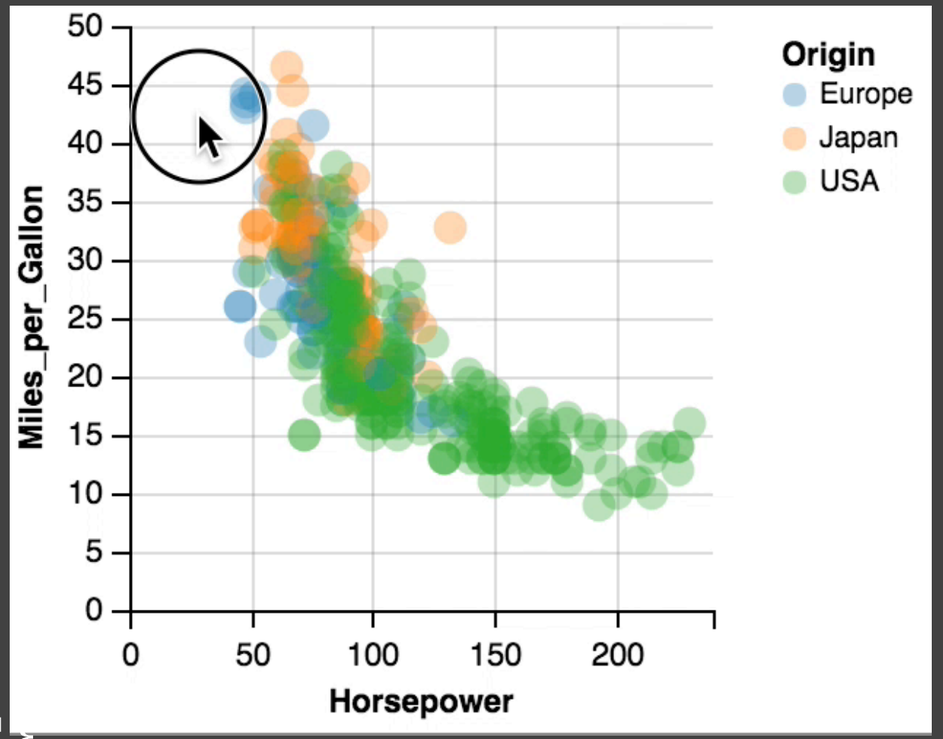
Vega-Lite Selections: Continuous Region

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {"type": "interval"}
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"
      {"value": "grey"}
    ]
  }
}
```



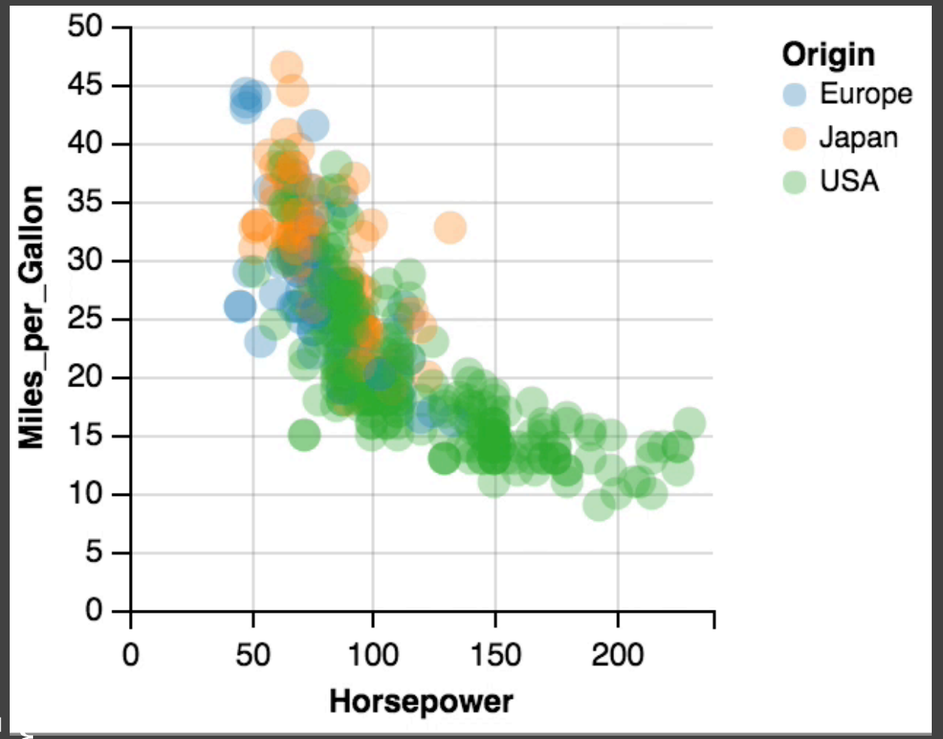
Vega-Lite Selections: Continuous Region (X)

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {
      "type": "interval",
      "project": {"channels": ["x"]}
    }
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"},
      {"value": "grey"}
    ]
  }
}
```



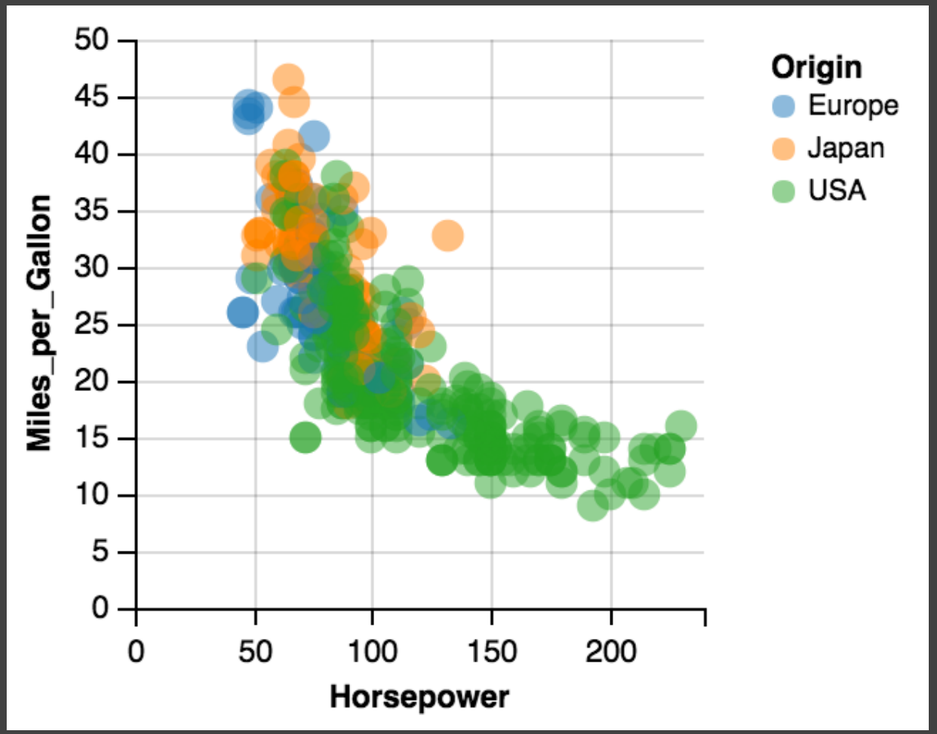
Vega-Lite Selections: Continuous Region (Y)

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "picked": {
      "type": "interval",
      "project": {"channels": ["y"]}
    }
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": [
      {"if": "picked", "field": "Origin", "type": "N"},
      {"value": "grey"}
    ]
  }
}
```



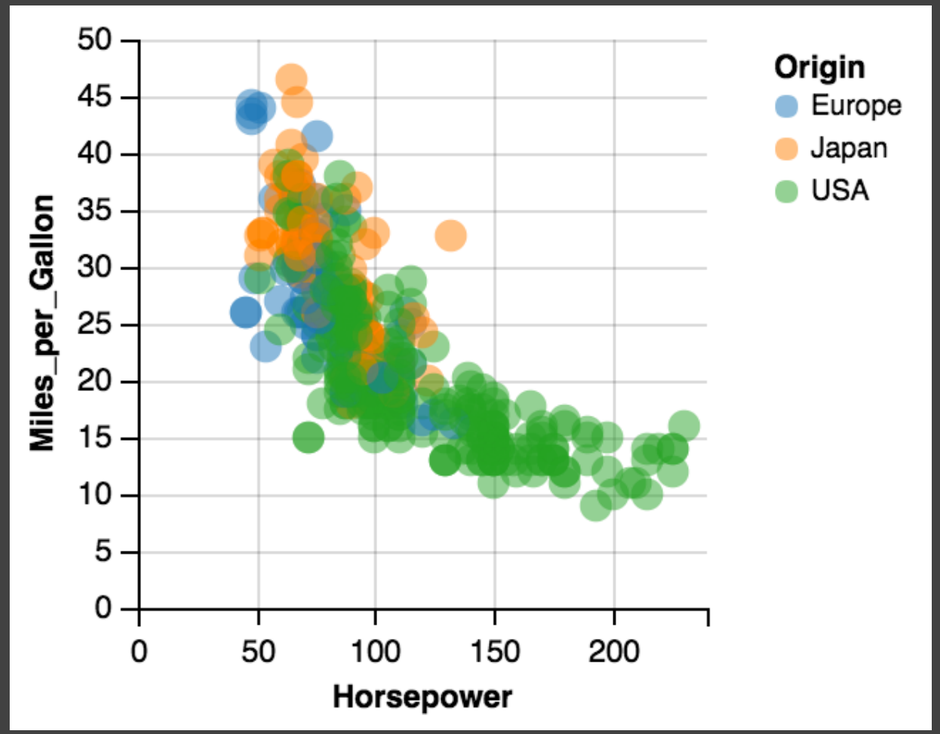
Vega-Lite Selections

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": {"field": "Origin", "type": "N"}
  }
}
```



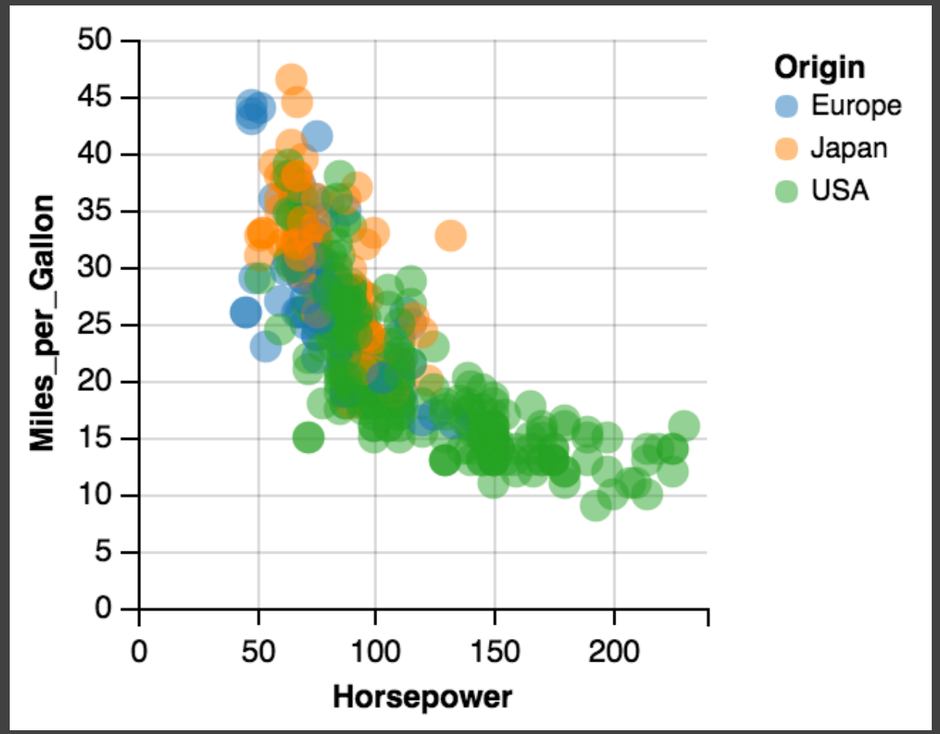
Vega-Lite Selections

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "grid": {
      "type": "interval"
    }
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": {"field": "Origin", "type": "N"}
  }
}
```



Vega-Lite Selections can be initialized

```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "grid": {
      "type": "interval",
      "init": {"scales": true}
    }
  },
  "encoding": {
    "x": {"field": "Horsepower", "type": "Q"},
    "y": {"field": "Miles_per_Gallon", "type": "Q"},
    "color": {"field": "Origin", "type": "N"}
  }
}
```

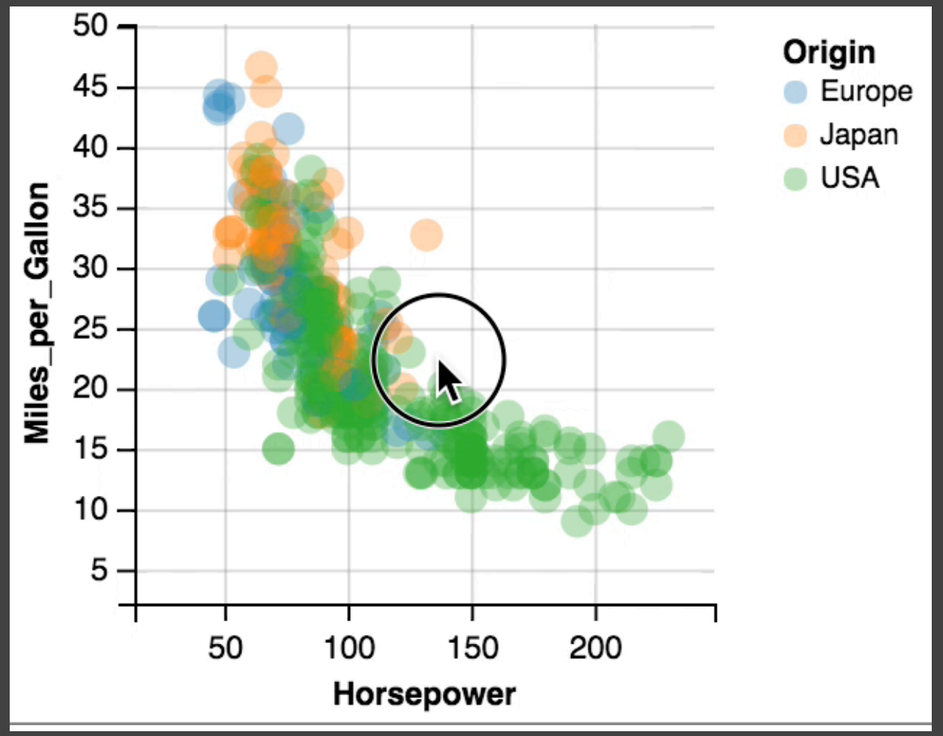


(1) Selection is **populated** with **scale domains**.

(2) Selection now drives scale domains.

Vega-Lite Selections can be initialized

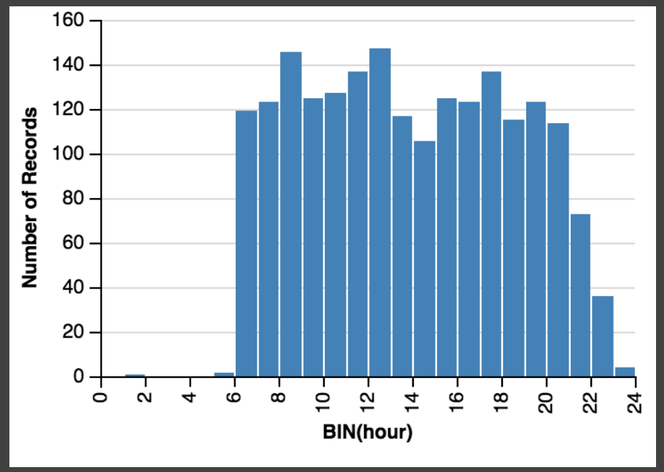
```
{
  "data": {"url": "data/cars.json"},
  "mark": "circle",
  "select": {
    "grid": {
      "type": "interval","zoom": true,
      "init": {"scales": true}
    }
  },
  "encoding": {
    "x": {
      "field": "Horsepower", "type": "Q",
      "scale": {"domain": {"selection": "grid"}}
    },
    "y": {
      "field": "Miles_per_Gallon", "type": "Q",
      "scale": {"domain": {"selection": "grid"}}
    },
    "color": {"field": "Origin", "type": "N"}
```



(1) Selection is **populated** with **scale domains**. (2) Selection now drives scale domains.

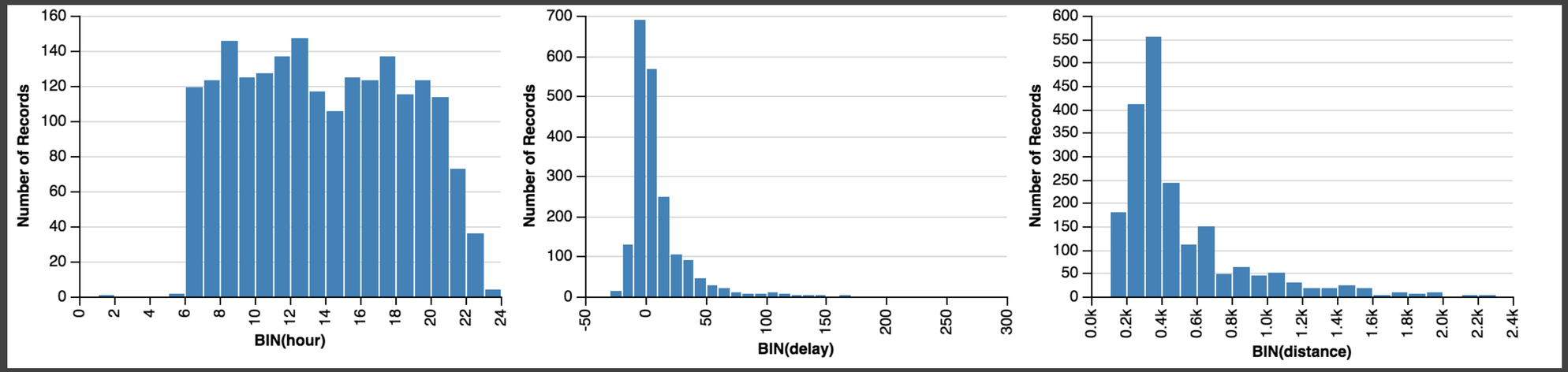
Vega-Lite Layered CrossFilter

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



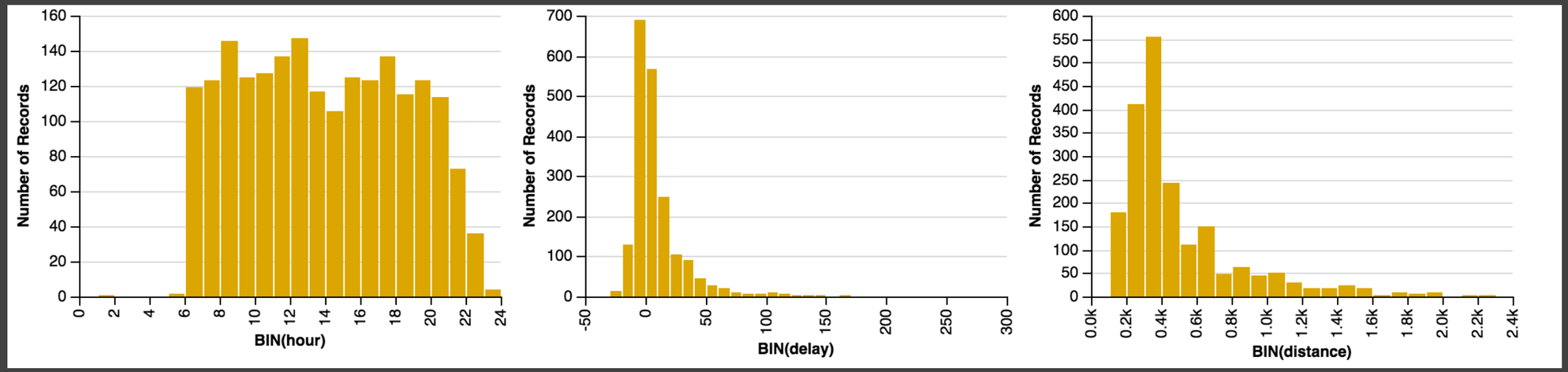
Vega-Lite Layered CrossFilter

```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "data": {"url": "data/flights.json"},
    "mark": "bar",
    "encoding": {
      "x": {"field": {"repeat": "column"}, "type": "Q", "bin": true},
      "y": {"aggregate": "count", "field": "*", "type": "Q"}
    }
  }
}
```



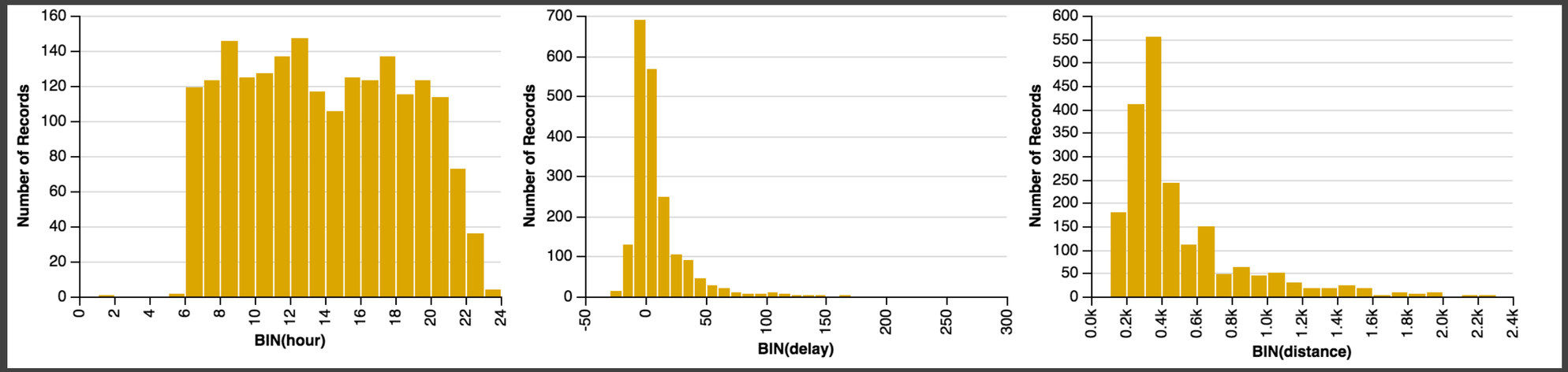
Vega-Lite Layered CrossFilter

```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      "data": {"url": "data/flights.json"},
      "mark": "bar",
      "encoding": {
        "x": {"field": {"repeat": "column"}, "type": "Q", "bin": true},
        "y": {"aggregate": "count", "field": "*", "type": "Q"}
      }
    }, {
      ...,
        "color": {"value": "goldenrod"}
    }]
  }
}
```



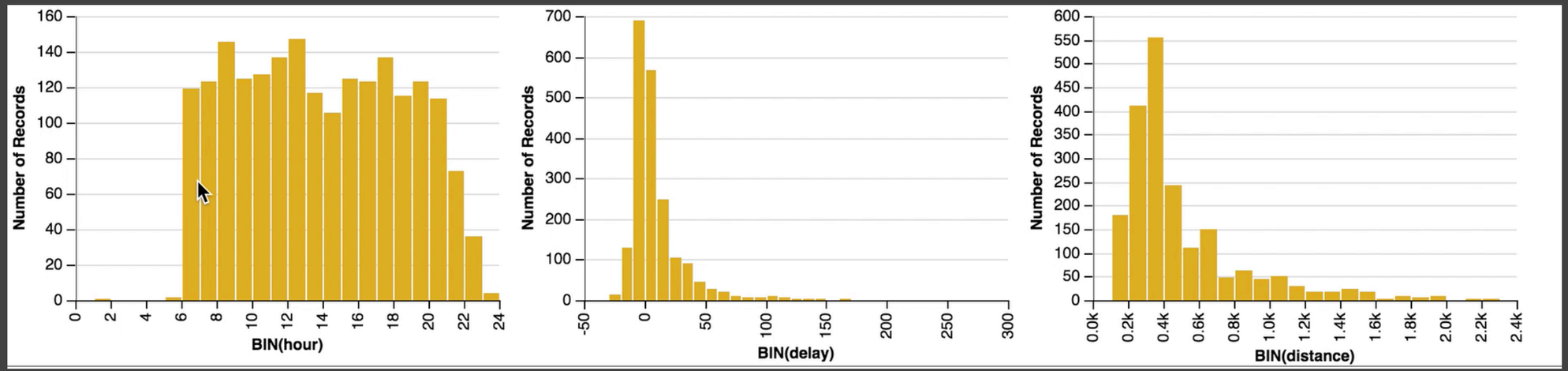
Vega-Lite Layered CrossFilter

```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      ...,




    }, {
      ...,

    }]
  }
}
```



Vega-Lite Layered CrossFilter

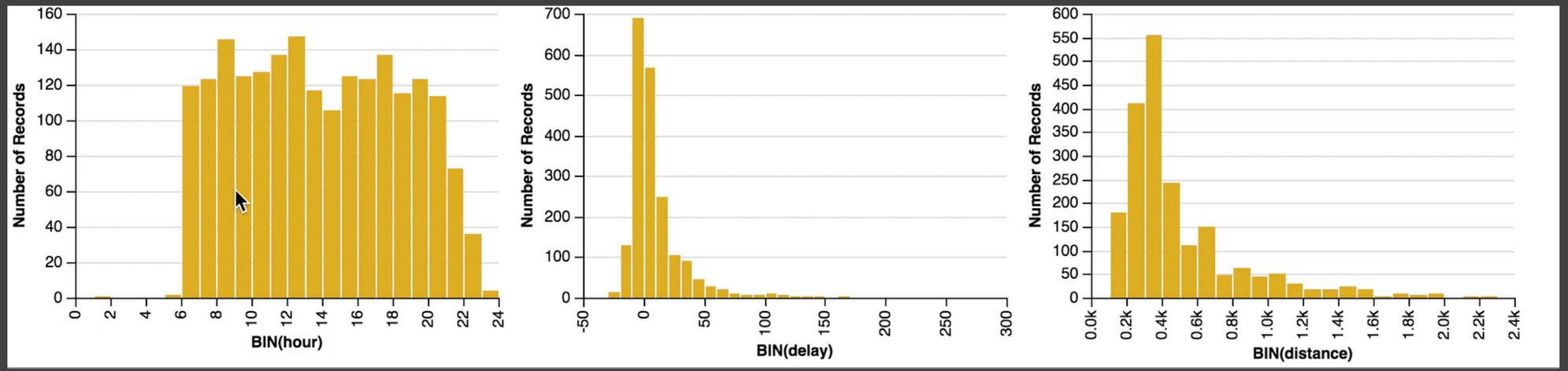
```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      ...,
      "select": {
        "region": {
          "type": "interval", "project": {"channels": ["x"]}, ...
        }
      }
    }, {
      ...,

    }]
  }
}
```

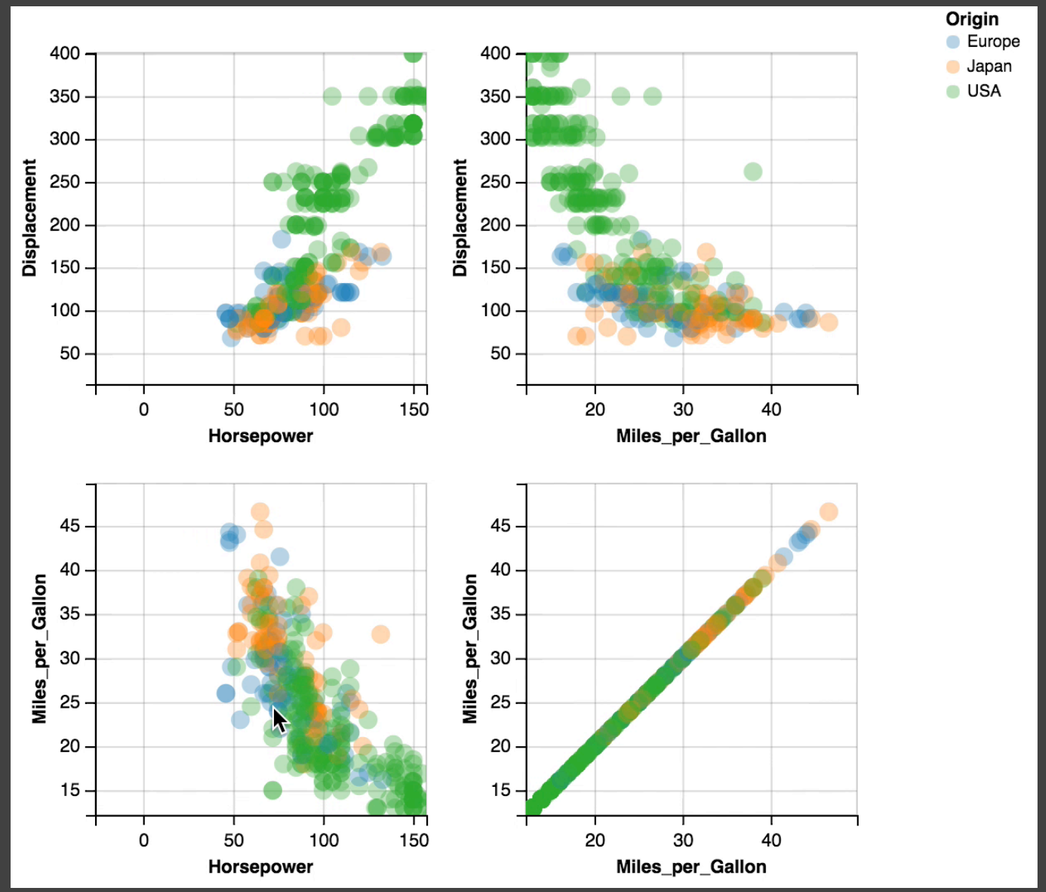


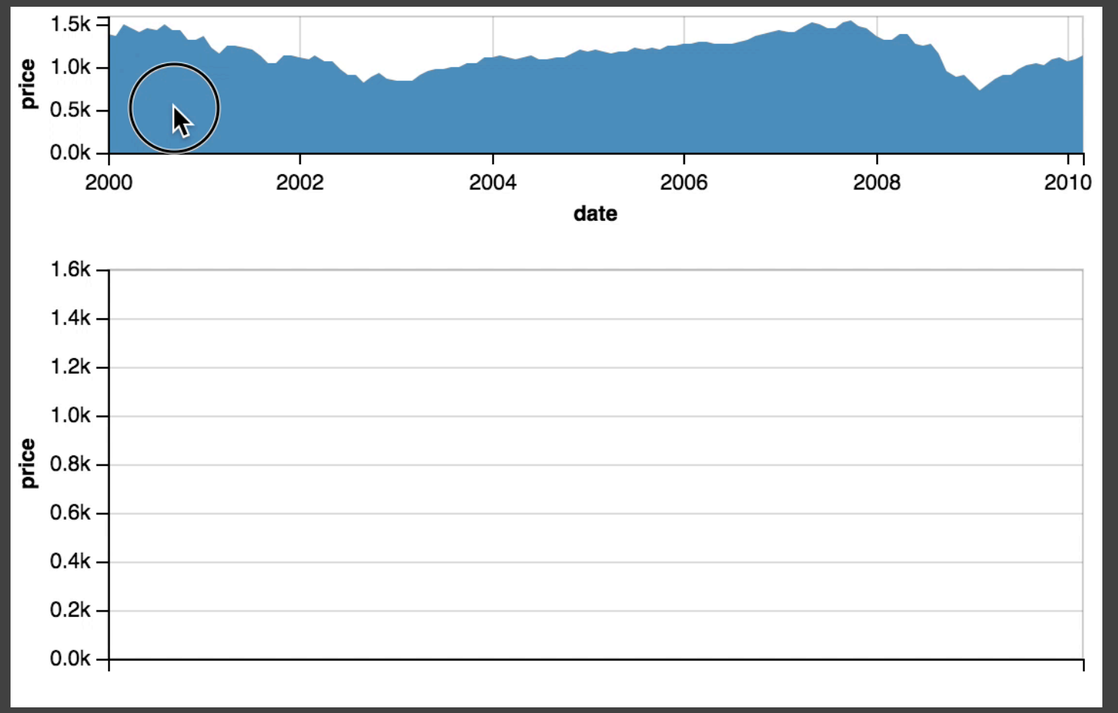
Vega-Lite Layered CrossFilter

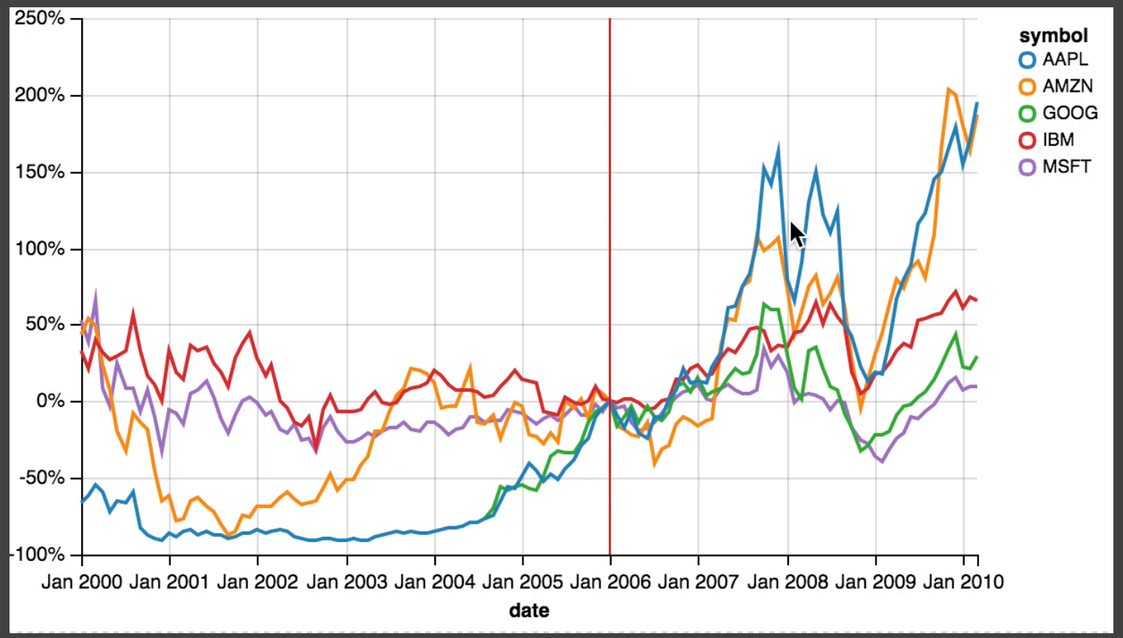
```
{
  "repeat": {"column": ["hour", "delay", "distance"]},
  "spec": {
    "layers": [{
      ...,
      "select": {
        "region": {
          "type": "interval", "project": {"channels": ["x"]}, ...
        }
      }
    }, {
      ...,
      "transform": {"filterWith": "region"}
    }]
  }
}
```

35 Lines of JSON!

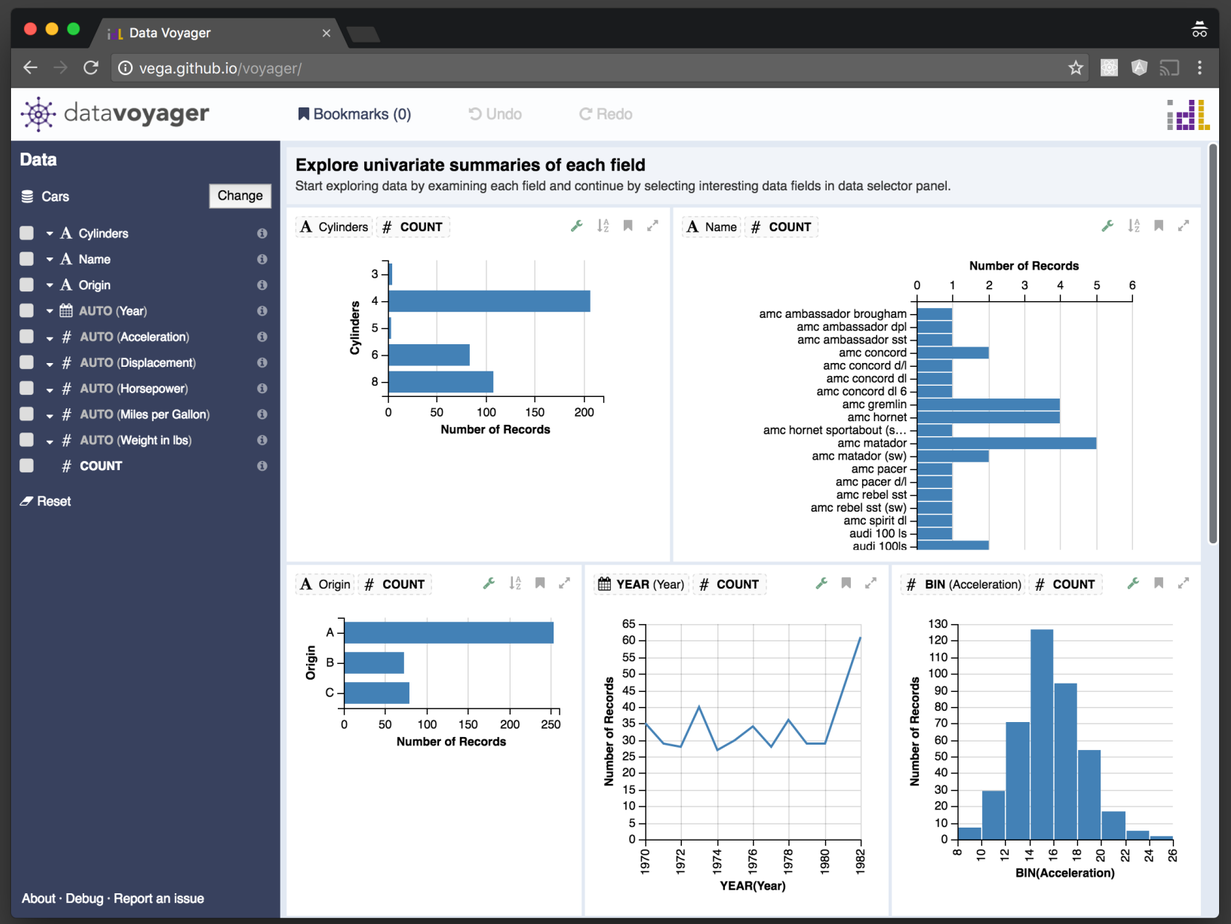


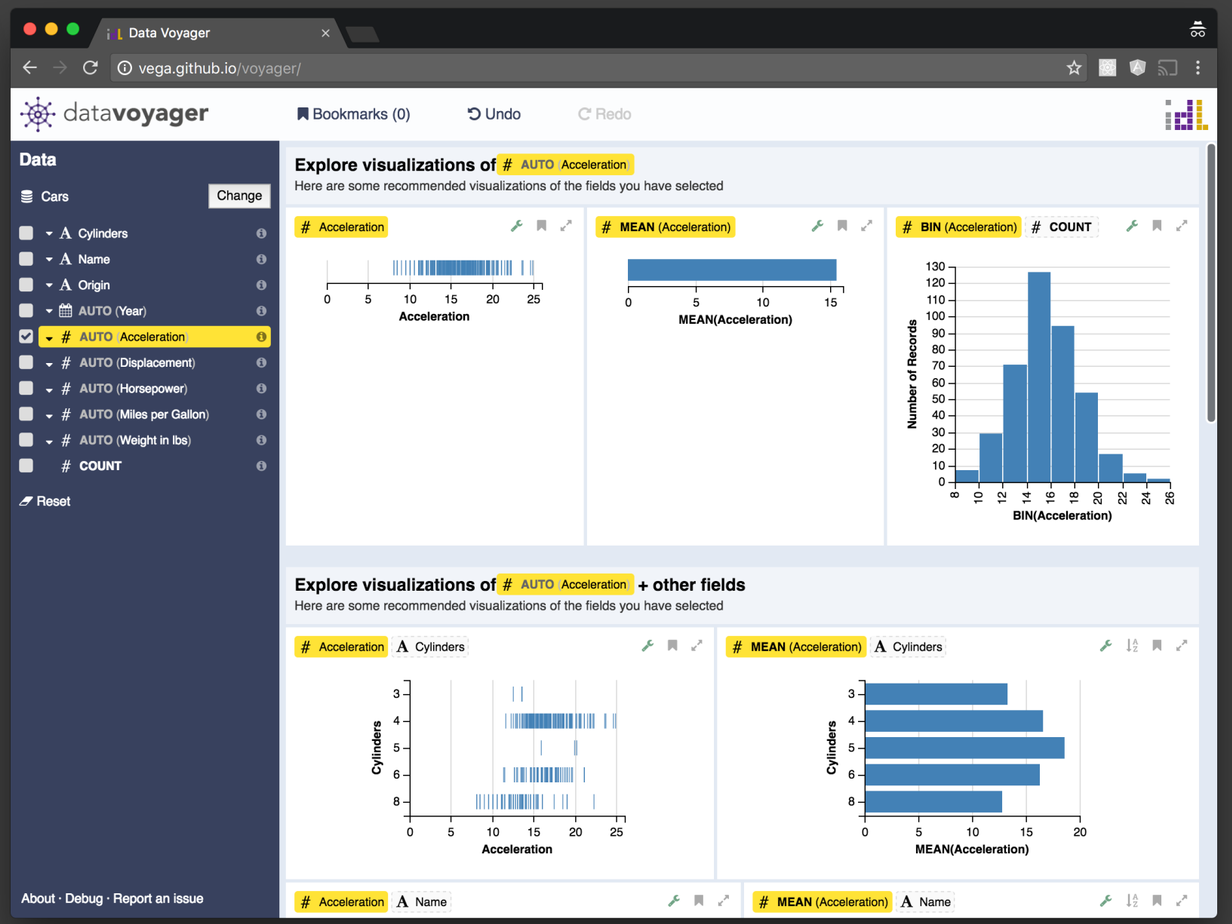

Origin
Europe
Japan
USA
Displacement
Horsepower
Displacement
Miles_per_Gallon
Miles_per_Gallon
Horsepower
Miles_per_Gallon
Miles_per_Gallon


price
date
price


symbol
AAPL
AMZN
GOOG
IBM
MSFT
date

Vega-Lite: Systematically Enumerate Designs

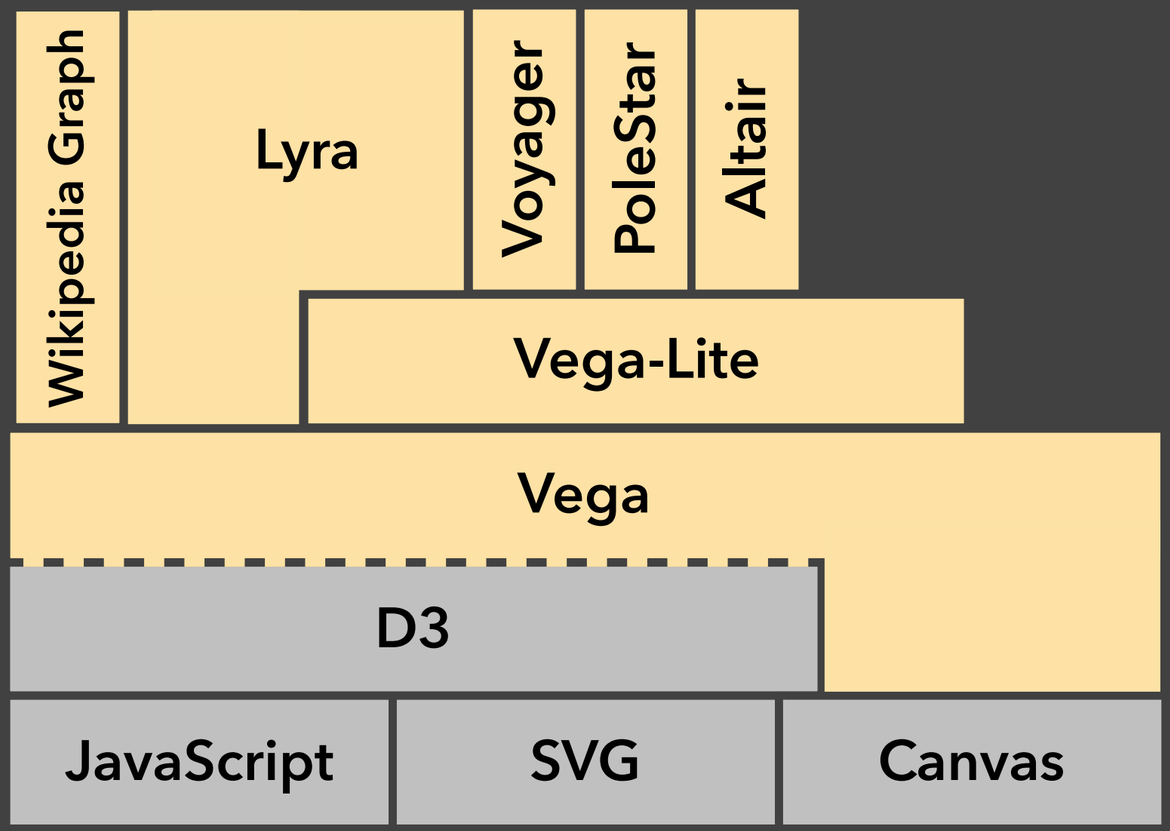




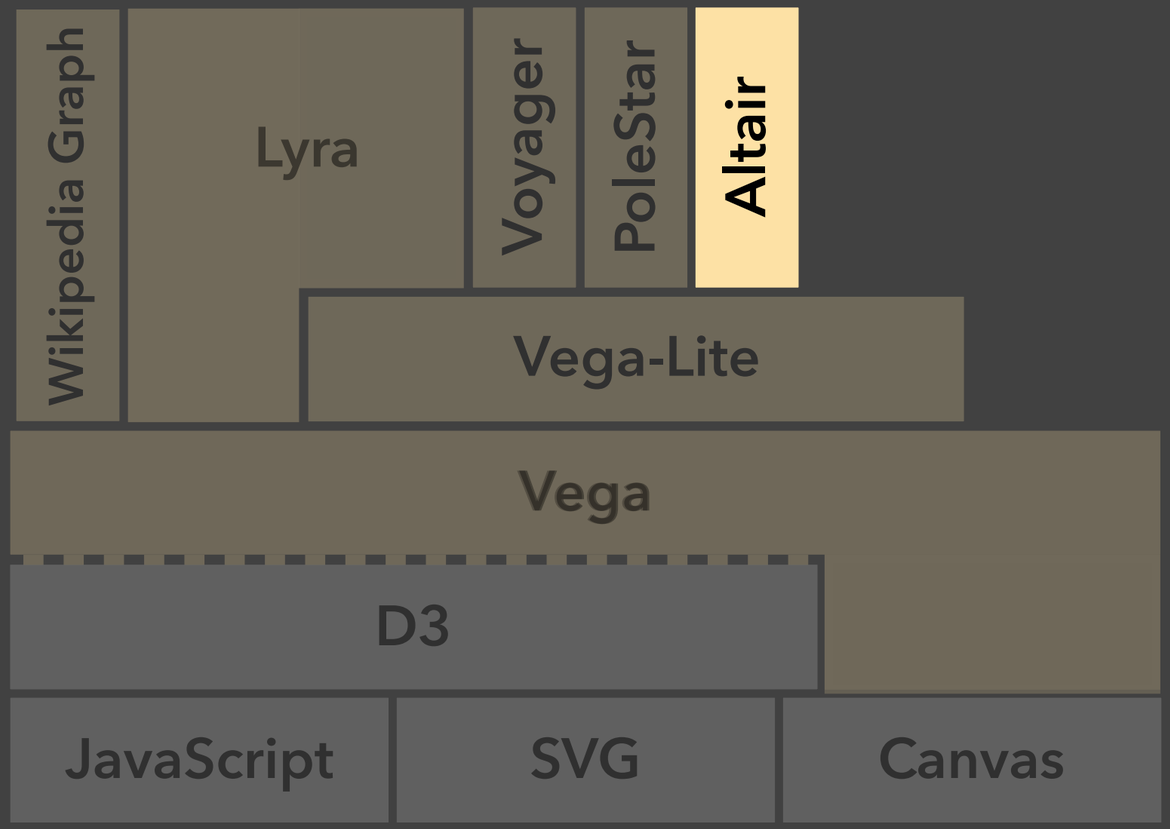
Voyager. Wongsuphasawat, Moritz, et al. *InfoVis 2015.*

CompassQL. Wongsuphasawat, Moritz, et al. *HILDA 2016.*

An Ecosystem of Tools



An Ecosystem of Tools



Led by Brian Granger and Jake VanderPlas.

Python API automatically generated from the Vega-Lite JSON schema.

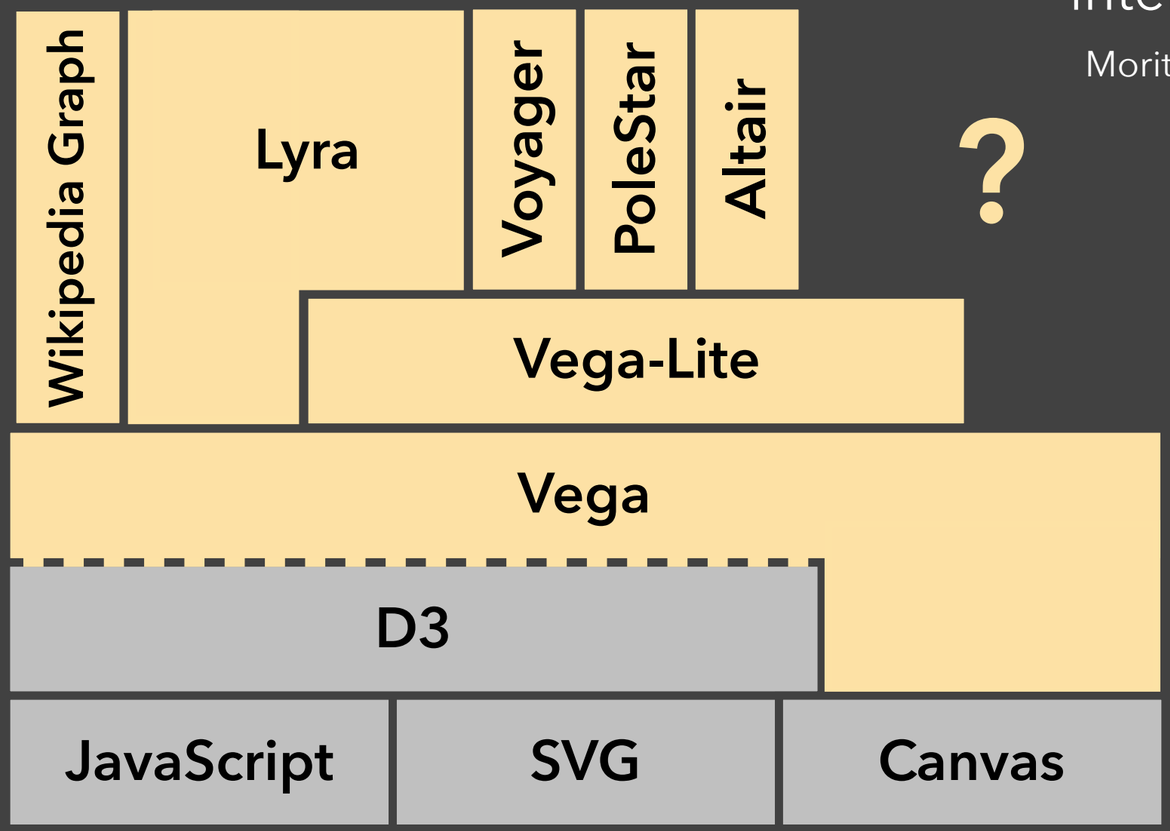
"*It is this type of 1:1:1 mapping between thinking, code, and visualization that is my favorite thing about [Altair]*" – Dan Saber.

https://dansaber.wordpress.com/2016/10/02/a-dramatic-tour-through-pythons-data-visualization-landscape-including-ggplot-and-altair/

Interest from other Python visualization vendors (Matplotlib, Bokeh, Plotly) to make their own Vega-Lite renderers.

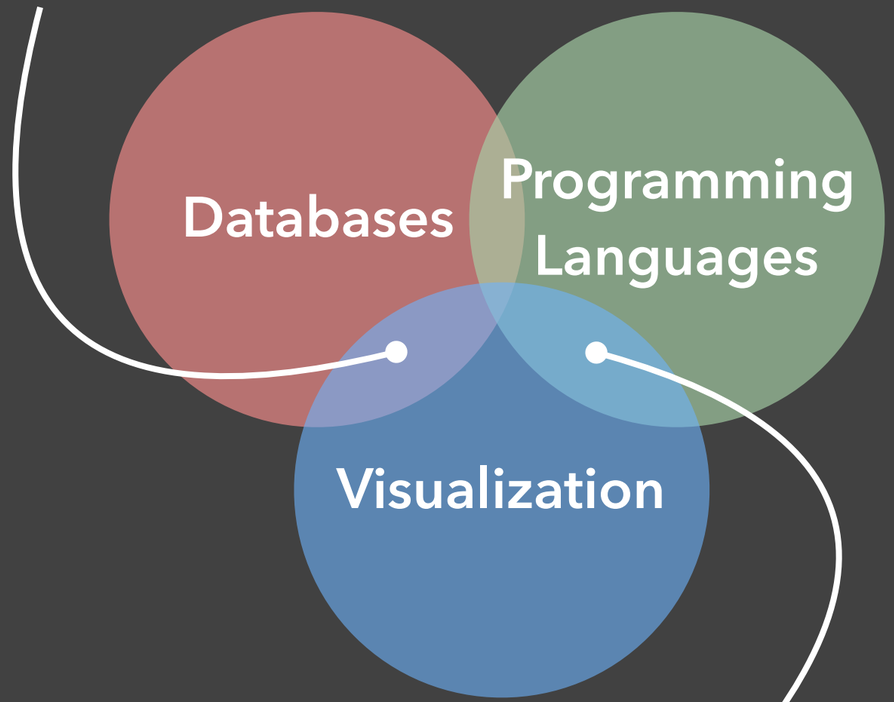
"*We see this portion of the effort as much bigger than Altair itself: the Vega and Vega-Lite specifications are perhaps the best existing candidates for a principled* lingua franca *of data visualization*" – Altair Team.

An Ecosystem of Tools

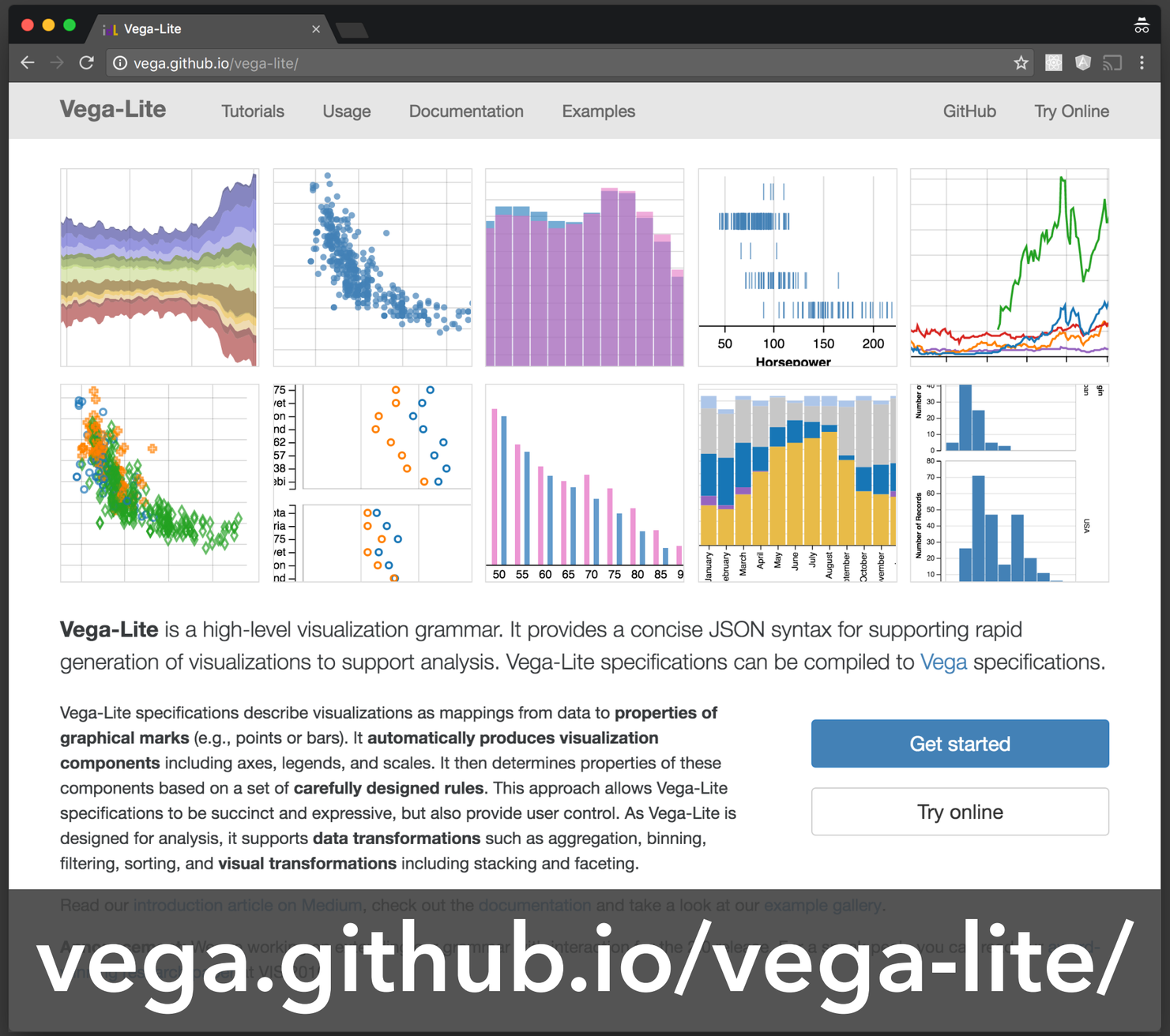


How can we **automatically partition** interactive workloads between client and server?

Moritz et al. *IEEE VIS Data Systems for Interactive Analysis Workshop 2015.*



What **inference** can we perform over interactive visualization to accelerate analysis and design?



vega.github.io/vega-lite/

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Prototype in supplementary material, a release by the end of the year!