

Getting Started with Custom Visual Development



Student Introductions

- Basic Info
 - What's your name?
 - Where do you work? (optional)
 - How long have you been a developer?
- List skills with which you already feel comfortable
 - Working with the Power BI platform
 - Creating PBIX projects with Power BI Desktop
 - Programming with JavaScript and/or TypeScript
 - Working with the R platform
 - Developing with C# and ASP.NET MVC
 - Programming against REST and ODATA web APIs
 - Developing with Microsoft Azure



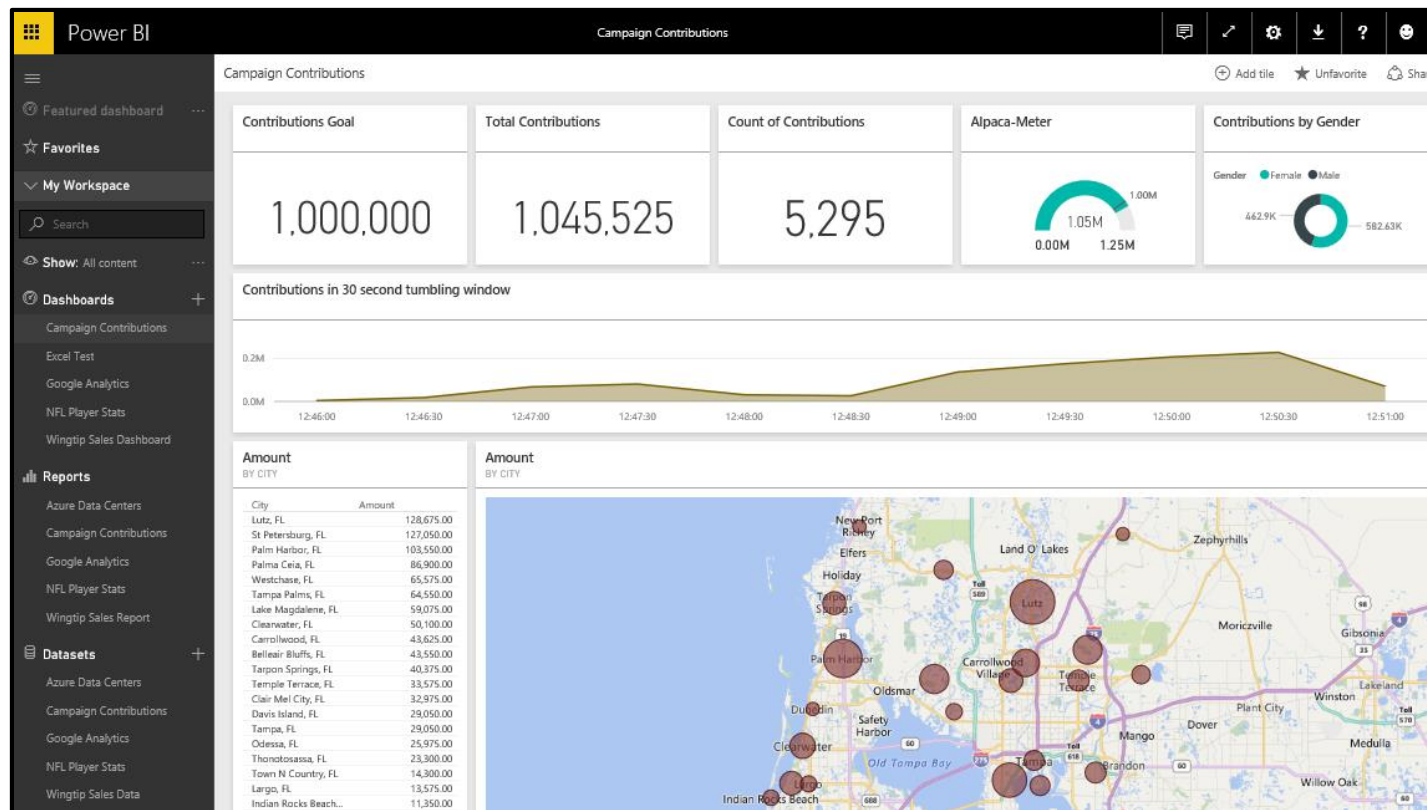
Agenda

- Getting Started with Power BI Development
- TypeScript Language Primer
- Creating Data-driven Visuals with D3.js
- Creating a Power BI Development Environment

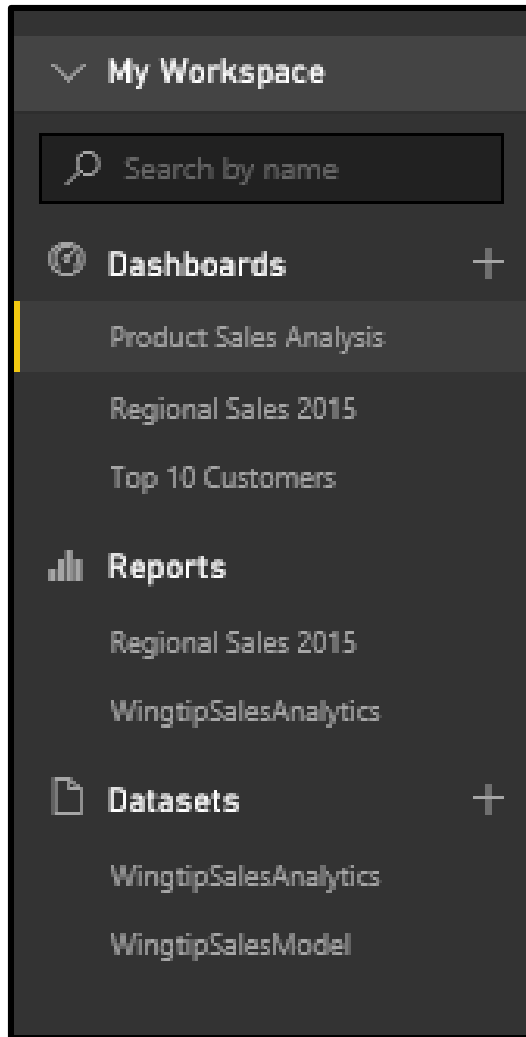


The Power BI Service

- The Power BI Service
 - Provides cloud-based foundation for Power BI platform
 - Accessible through browser at <https://app.powerbi.com>



Central Power BI Concepts

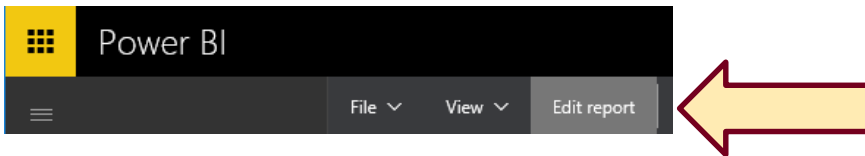


- **Workspace**
 - Provides user context and asset container
 - Every user has personal workspace
 - Team development requires group workspaces
- **Dashboard**
 - Consolidated view into reports and datasets
 - Custom solution entry point for mobile users
- **Report**
 - Collection of pages with tables & visualizations
 - Provides interactive control of filtering
- **Dataset**
 - Data model containing one or more tables
 - Can be very simple or very complex








Report Authoring

- Report initially opens in reading view
 - Click Edit report to switch to edit mode



- Report design tools appear on right side of page

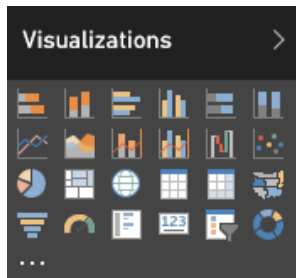
The image shows the Power BI report authoring interface in edit mode. The main area displays a table of product sales data. On the right side, there are panels for 'Visualizations' and 'Fields'.

Product Rank	Product	Product Image	Sales Revenue
1	Godzilla Action Figure		\$1,379,383
2	Twitter Follower Action Figure		\$920,244
3	Captain America Action Figure		\$408,883
4	Perry the Platypus Action Figure		\$313,270
5	Spiderman Action Figure		\$287,516

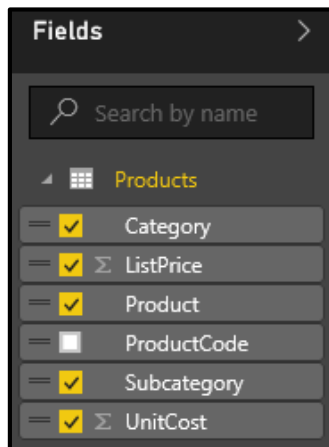
The 'Visualizations' panel on the right shows a list of visual types. The 'Fields' panel shows a list of fields, including 'Category', 'Product', 'Product Rank', and 'Sales Revenue'. The 'Filters' panel shows a list of filters, including 'Product Rank is less than or equal to 5' and 'Sales Revenue(All)'.

Visuals (aka Visualizations)

- Reports are designed using visual (aka visualizations)
 - Each visual is based on an underlying visualization type
 - Visualization type can be changed using **Visualizations** pane

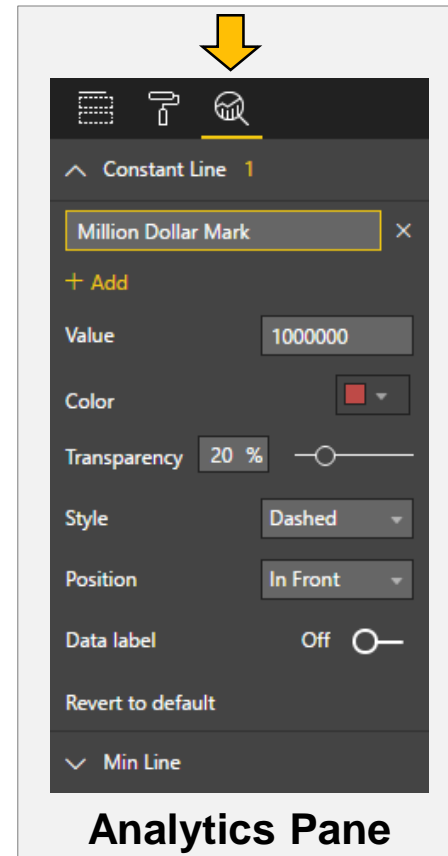
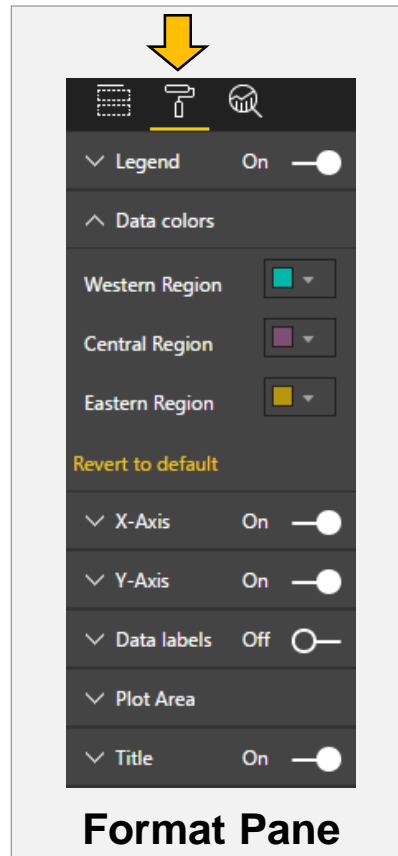
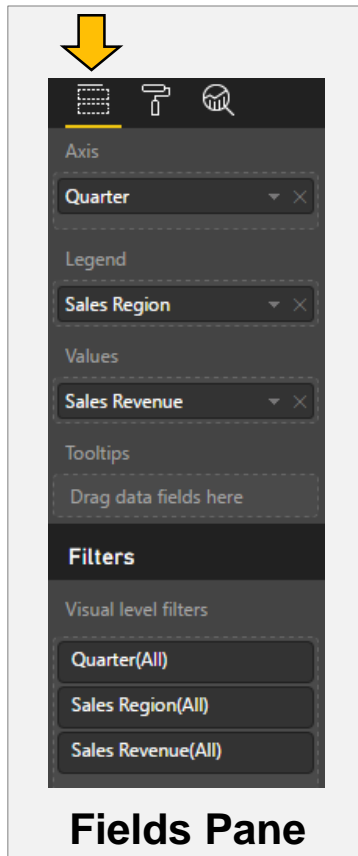


- Visuals creating by using fields from tables inside **Fields** list



Editing Visual Properties

- Visual properties modified using three property panes
 - Visual properties vary greatly depending on type of visualization



Developer Opportunities in Power BI

1. Developing Custom Visuals
2. Programming the Power BI Service API
3. Embedding Reports in Custom Applications
4. Developing Solutions with Real-time dashboards
5. Developing Custom Solutions using R
6. Developing Custom Solutions using Python
7. Developing Custom Connectors using M



Developing Custom Visuals

- What is involved?
 - Learning to program in TypeScript instead of JavaScript
 - Learning to use graphics libraries such as D3.js
 - Getting up to speed on the cross-platform toolchain
 - Creating and debugging custom visuals using Node.js
 - Packaging custom visuals for distribution



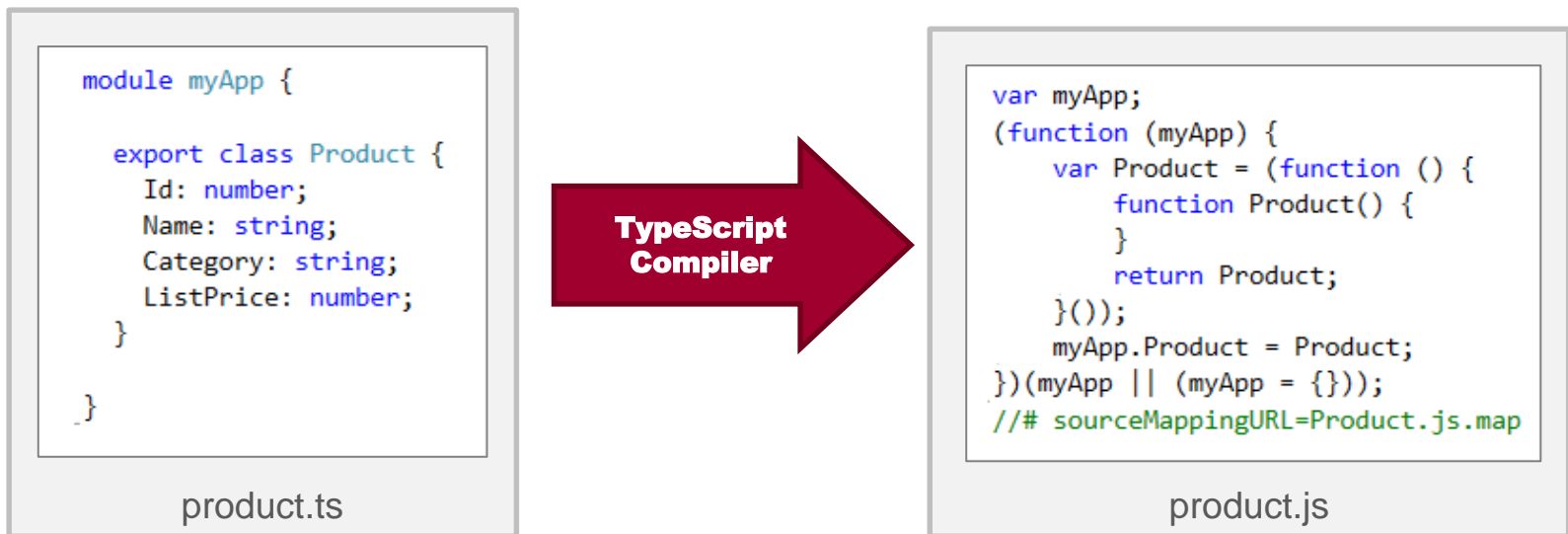
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What is TypeScript?

- A programming language which compiles into plain JavaScript
- A superset of JavaScript that adds a strongly-typed dimension
- It can be compiled into ECMAScript3, ECMAScript3 or ECMAScript 6
- It runs in any browser, in any host and on any OS



Type Annotation

- TypeScript allows you to annotate types
 - Provides basis for strongly-typed programming
 - Type annotations used by compiler for type checking
 - Type annotations are erased at the end of compile time

```
// define strongly-typed function
var myFunction = function (param1: number): string {
  | return "You passed " + param1;
};

// define strongly-typed variables
var myNumber: number = 2017;
var myMessage: string = myFunction(myNumber);
var myContent: JQuery = $("<p>").text(myMessage);
var contentBox: JQuery = $("#content-box");

contentBox.empty().append(myContent);
```



Arrow Function Syntax

- TypeScript supports arrow function syntax
 - Concise syntax to define anonymous functions
 - Can be used to retain this pointer in classes

```
// create anonymous function using function arrow syntax
let myFunction = () => {
  console.log("Hello world");
};

// use function arrow syntax with typed parameters
let myOtherFunction = (param1: number, param2: string) : string => {
  return param1 + " - " + param2;
};

// create function to assign to DOM event
window.onresize = (event: Event) => {
  let window: Window = event.target as Window;
  console.log("Window width: " + window.outerWidth);
  console.log("Window height: " + window.outerHeight);
};
```



Classes

- TypeScript supports defining classes
 - Class defines type for object
 - Export keyword makes class created across files
 - Class can be passed as factory function
 - Default accessibility is public

```
export class Product {  
  Id: number;  
  Name: string;  
  Category: string;  
  ListPrice: number;  
}
```

```
// create new Product instance  
let product1: Product = new Product();  
product1.Id = 1;  
product1.Name = "Batman Action Figure";  
product1.Category = "Action Figure";  
product1.ListPrice = 14.95;
```



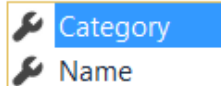
Class Constructors

- Constructor parameters become fields in class

```
export class Product {  
  
  constructor(private Id: number, public Name: string, public Category: string, private ListPrice: number) {  
    // no need to do anything here  
  }  
  
  MyPublicMethod() {  
    // access to private fields  
    let id: number = this.Id  
    let price: number = this.ListPrice  
  }  
  
}
```

- Client-side code calls constructor using new operator

```
// create new Product instance  
let product1: Product = new Product(1, "Batman Action Figure", "Action Figure", 14.95);  
  
// access public properties  
let product1Name: string = product1.Name;  
let product1Category: string = product1.
```



Interfaces

- Interface defines a programming contract
 - Classes can implement interfaces

```
export interface IProductDataService {  
  GetAllProducts(): Product[];  
  GetProduct(id: number): Product;  
  AddProduct(product: Product): void;  
  DeleteProduct(id: number): void;  
  UpdateProduct(product: Product): void;  
}
```

```
export class MyProductDataService implements IProductDataService {  
  
  private products: Product[] = [];  
  
  GetAllProducts(): Product[] {  
    return this.products;  
  }  
  
  GetProduct(id: number): Product {  
    return this.products.find(p => p.id === id);  
  }  
  
  AddProduct(product: Product): void {  
    this.products.push(product);  
  }  
  
  DeleteProduct(id: number): void {  
    this.products = this.products.filter(p => p.id !== id);  
  }  
  
  UpdateProduct(product: Product): void {  
    const index = this.products.findIndex(p => p.id === product.id);  
    this.products[index] = product;  
  }  
}
```

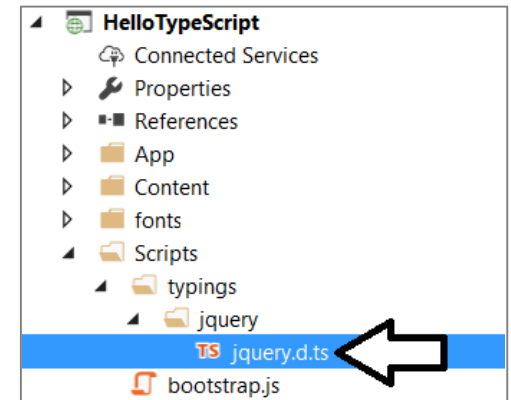
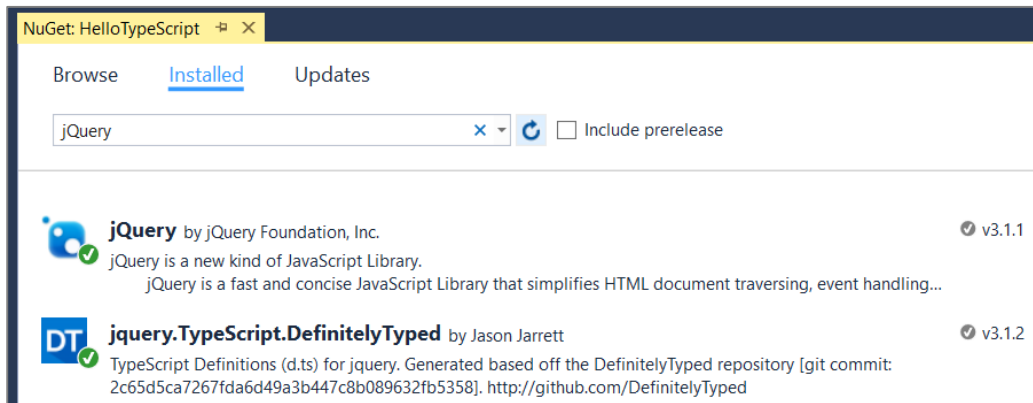
- Client code can be decoupled from concrete classes

```
// program against variables based on interface type  
let productService: IProductDataService = new MyProductDataService();  
  
// client code is decoupled from underlying data access class implementations  
let products: Product[] = productService.GetAllProducts();  
let product1: Product = productService.GetProduct(1);
```



TypeScript Definition Files (d.ts)

- What are TypeScript definition files
 - Typed definitions for 3rd party JavaScript libraries
 - DefinitelyTyped provides great community resource
 - Typed definition files have a **d.ts** extension



```
// define strongly-typed variables
var myNumber: number = 2017;
var myMessage: string = myFunction(myNumber);
var myContent: JQuery = $("<p>").text(myMessage);
var contentBox: JQuery = $("#content-box");
```



Interface-based Design

- Interfaces define programming contracts

```
export interface IViewPort {  
  width: number;  
  height: number;  
}
```

```
export interface ICustomVisual {  
  name: string;  
  load(container: HTMLElement): void;  
  update(viewport: IViewPort): void;  
}
```

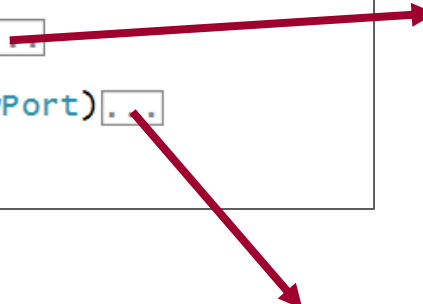
- Application design can use interfaces instead of concrete classes

```
module myApp {  
  
  var leftNavCollapsed: boolean = true;  
  var loadedVisual: ICustomVisual;  
  
  var visuals: ICustomVisual[] = [  
    new Viz01(), new Viz02(), new Viz03(), new Viz04()  
  ];  
  
  function LoadVisual(visual: ICustomVisual) ...  
  
  $(( ) => ...);  
}
```



Sample Custom Visual using jQuery

```
export class Viz01 implements ICustomVisual {  
    public name: string = "Visual 1: Hello jQuery";  
    private container: JQuery;  
    private message: JQuery;  
  
    load(container: HTMLElement) {  
        ...  
    }  
  
    public update(viewport: IViewport) {  
        ...  
    }  
}
```



```
load(container: HTMLElement) {  
    this.container = $(container);  
    this.message = $("

")  
        .text("Hello jQuery")  
        .css({  
            "display": "table-cell",  
            "text-align": "center",  
            "vertical-align": "middle",  
            "text-wrap": "none",  
            "background-color": "yellow"  
        });  
    this.container.append(this.message);  
}


```

```
public update(viewport: IViewport) {  
    let paddingX: number = 2;  
    let paddingY: number = 2;  
    let fontSizeMultiplierX: number = viewport.width * 0.15;  
    let fontSizeMultiplierY: number = viewport.height * 0.4;  
    let fontSizeMultiplier: number = Math.min(...[fontSizeMultiplierX,  
                                                    fontSizeMultiplierY]);  
  
    this.message.css({  
        "width": viewport.width - paddingX,  
        "height": viewport.height - paddingY,  
        "font-size": fontSizeMultiplier  
    });  
}
```


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The D3 Library

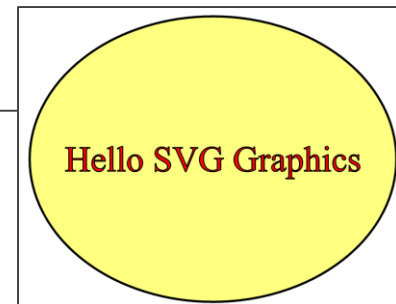
- What does the D3 library do?
 - Loading data into the browser's memory
 - Binding data to create new set of SVG elements
 - Adding and removing SVG elements as needed
 - Transforming SVG elements by setting properties
 - Transitioning SVG elements in response to user actions



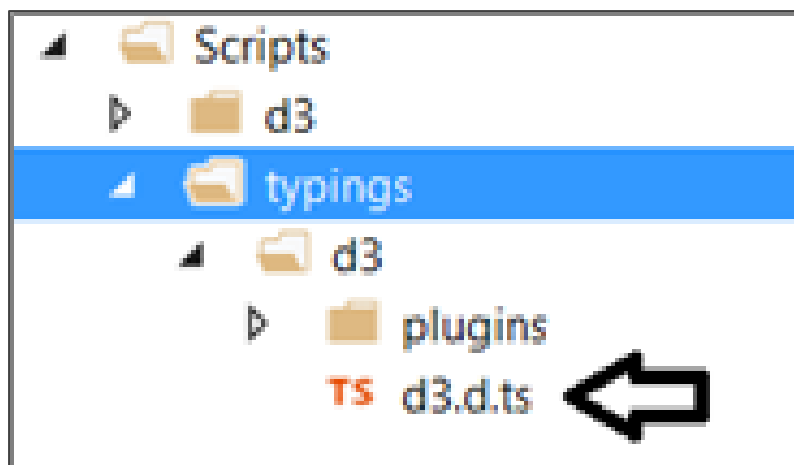
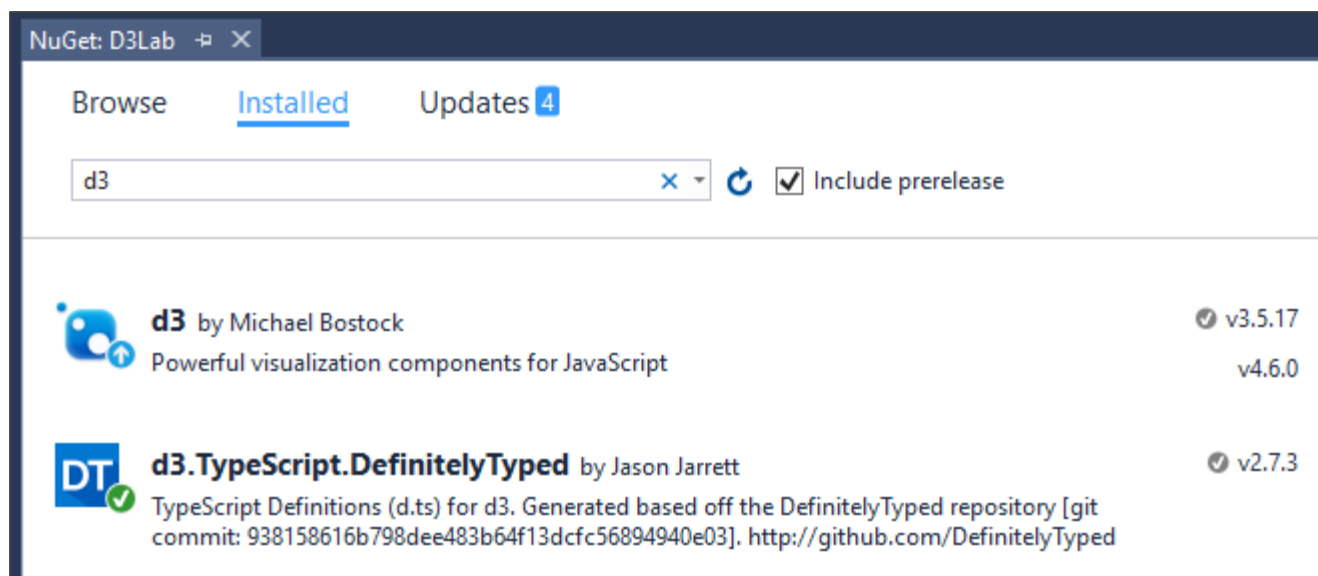
SVG Graphics

- SVG = Scalable Vector Graphics
 - Specialized type of HTML element
 - More reliable and consistent than other HTML elements

```
<svg width="700" height="550">
  <ellipse cx="350" cy="275" rx="330" ry="256"
    style="fill: rgba(255, 255, 0, 0.498039);
    stroke: rgb(0, 0, 0); stroke-width: 4;">
  </ellipse>
  <text x="350" y="275" width="660" height="512" font-size="132"
    text-anchor="middle" dominant-baseline="central"
    style="fill: rgb(255, 0, 0); stroke: rgb(0, 0, 0); stroke-width: 2;">
    Hello SVG Graphics
  </text>
</svg>
```

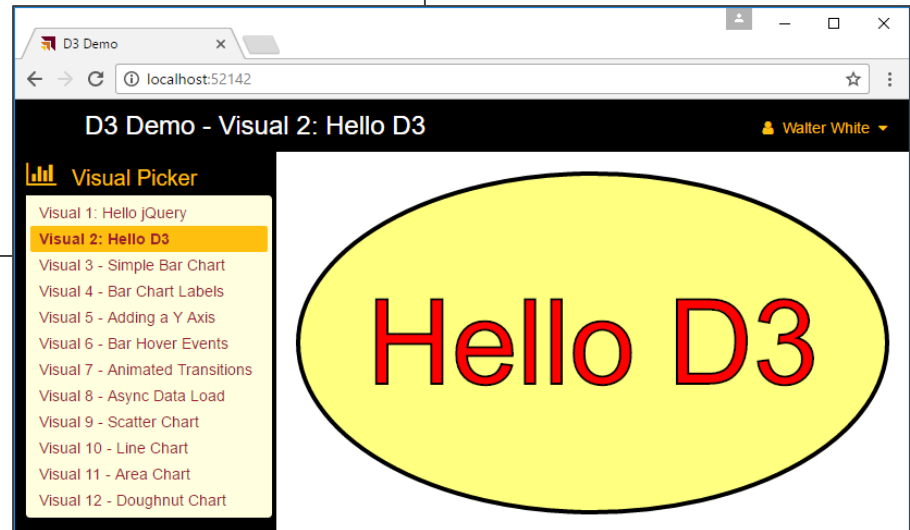


Adding d3 and d3 typings files



Designing a D3 Custom Visual

```
export class Viz02 implements ICustomVisual {  
  
  name = "Visual 2: Hello D3";  
  
  private svgRoot: d3.selection<SVGElementInstance>;  
  private ellipse: d3.selection<SVGElementInstance>;  
  private text: d3.selection<SVGElementInstance>;  
  private padding: number = 20;  
  
  load(container: HTMLElement) ...  
  
  update(viewport: IViewport) ...  
  
}
```



Implementing load

```
load(container: HTMLElement) {  
  this.svgRoot = d3.select(container).append("svg");  
  
  this.ellipse = this.svgRoot.append("ellipse")  
    .style("fill", "rgba(255, 255, 0, 0.5)")  
    .style("stroke", "rgba(0, 0, 0, 1.0)")  
    .style("stroke-width", "4");  
  
  this.text = this.svgRoot.append("text")  
    .text("Hello D3")  
    .attr("text-anchor", "middle")  
    .attr("dominant-baseline", "central")  
    .style("fill", "rgba(255, 0, 0, 1.0)")  
    .style("stroke", "rgba(0, 0, 0, 1.0)")  
    .style("stroke-width", "2");  
}
```



Hello D3



Implementing update

```
update(viewport: IViewport) {  
  
  this.svgRoot  
    .attr("width", viewport.width)  
    .attr("height", viewport.height);  
  
  var plot = {  
    xoffset: this.padding,  
    yoffset: this.padding,  
    width: viewport.width - (this.padding * 2),  
    height: viewport.height - (this.padding * 2),  
  };  
  
  this.ellipse  
    .attr("cx", plot.xoffset + (plot.width * 0.5))  
    .attr("cy", plot.yoffset + (plot.height * 0.5))  
    .attr("rx", (plot.width * 0.5))  
    .attr("ry", (plot.height * 0.5))  
  
  var fontSizeForWidth: number = plot.width * .20;  
  var fontSizeForHeight: number = plot.height * .35;  
  var fontSize: number = d3.min([fontSizeForWidth, fontSizeForHeight]);  
  
  this.text  
    .attr("x", plot.xoffset + (plot.width / 2))  
    .attr("y", plot.yoffset + (plot.height / 2))  
    .attr("width", plot.width)  
    .attr("height", plot.height)  
    .attr("font-size", fontSize);  
}
```



Hello D3



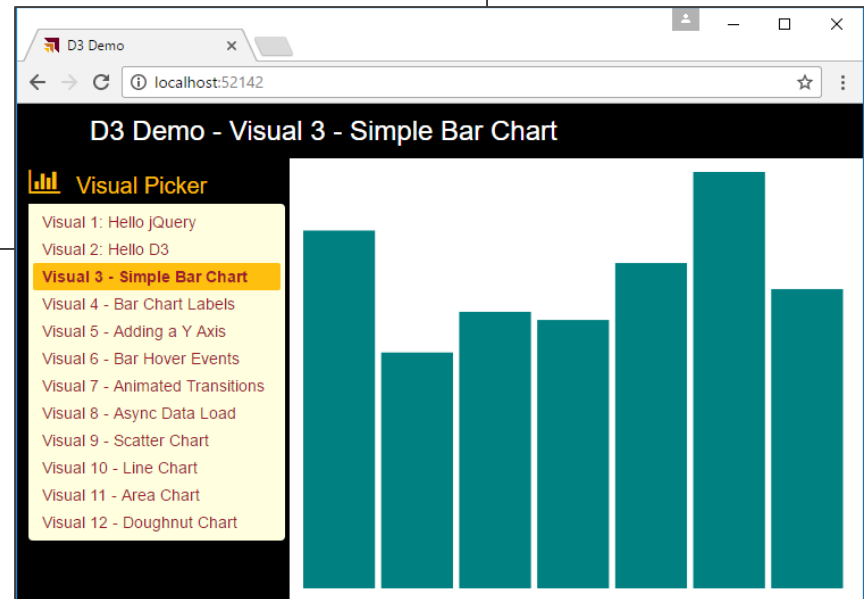
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- ✓ TypeScript Language Primer
- ✓ Getting Started with D3 and SVG Graphics
- Creating Data-driven Visuals
 - Enhancing Visuals with Scales and Axes
 - Event Handling and Transitions
 - Using D3 Layouts



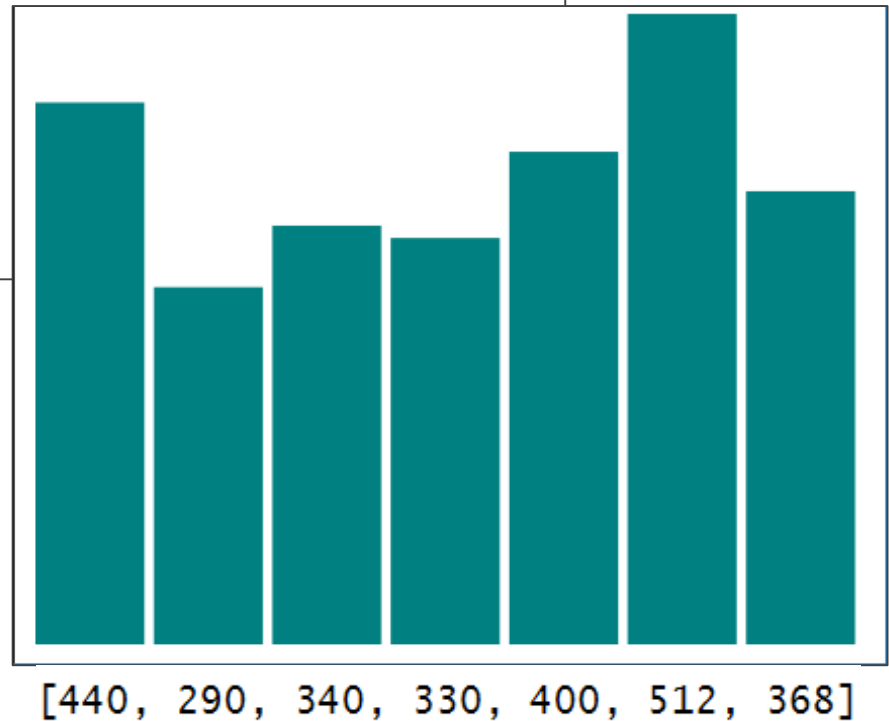
Designing a D3 Visual with a Bar Chart

```
export class Viz03 implements ICustomVisual {  
    name = "Visual 3 - Simple Bar Chart";  
  
    private dataset = [440, 290, 340, 330, 400, 512, 368];  
  
    private svgRoot: d3.Selection<SVGElementInstance>;  
    private bars: d3.Selection<number>;  
    private padding: number = 12;  
  
    load(container: HTMLElement) ...  
    update(viewport: IViewport) ...  
}
```



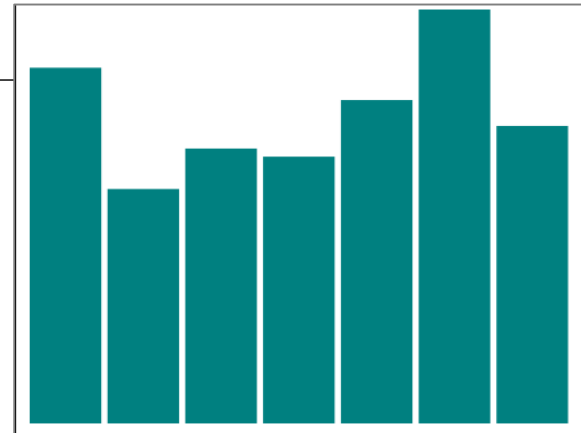
Implementing load

```
load(container: HTMLElement) {  
  this.svgRoot = d3.select(container).append("svg");  
  this.bars = this.svgRoot  
    .selectAll("rect")  
    .data(this.dataset)  
    .enter()  
    .append("rect");  
}
```



Implementing update

```
update(viewport: IViewport) {  
  this.svgRoot  
    .attr("width", viewport.width)  
    .attr("height", viewport.height);  
  
  var plot = {  
    xOffset: this.padding,  
    yOffset: this.padding,  
    width: viewport.width - (this.padding * 2),  
    height: viewport.height - (this.padding * 2),  
  };  
  
  var datasetSize = this.dataset.length;  
  var xScaleFactor = plot.width / datasetSize;  
  var yScaleFactor = plot.height / d3.max(this.dataset);  
  var barWidth = (plot.width / datasetSize) * 0.92;  
  
  this.bars  
    .attr("x", (d, i) => { return plot.xOffset + (i * (xScaleFactor)); })  
    .attr("y", (d, i) => { return plot.yOffset + plot.height - (Number(d) * yScaleFactor); })  
    .attr("width", (d, i) => { return barWidth; })  
    .attr("height", (d, i) => { return (Number(d) * yScaleFactor); })  
    .attr("fill", "teal");  
}
```

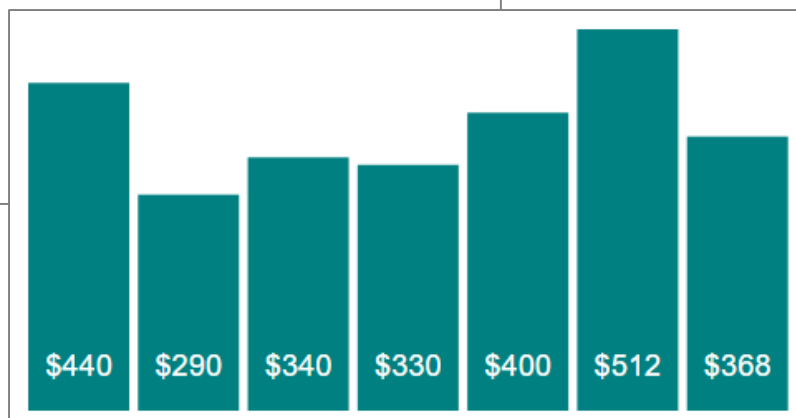


[440, 290, 340, 330, 400, 512, 368]



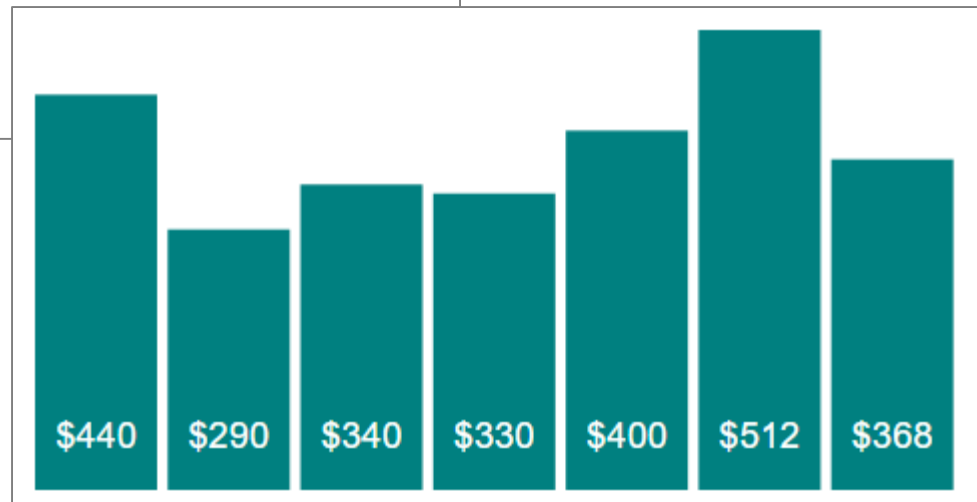
Adding Labels to the Bar Chart

```
export class Viz04 implements ICustomVisual {  
  name = "Visual 4 - Bar Chart Labels";  
  private dataset = [440, 290, 340, 330, 400, 512, 368];  
  private svgRoot: d3.Selection<SVGElementInstance>;  
  private bars: d3.Selection<number>;  
  private labels: d3.Selection<number>;  
  private padding: number = 12;  
  
  load(container: HTMLElement) ...  
  update(viewport: IViewport) ...  
}
```

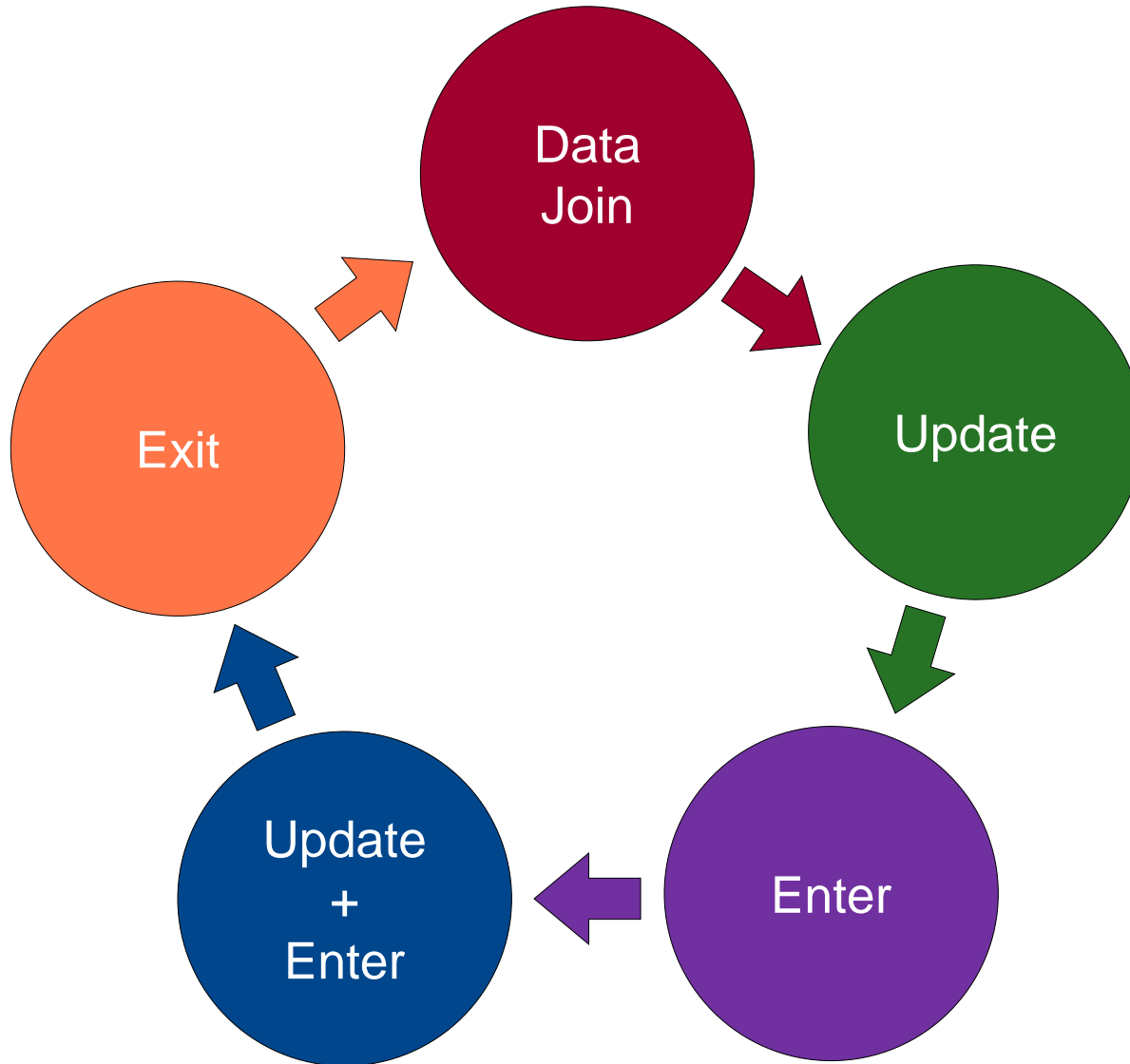


Implementing load

```
load(container: HTMLElement) {  
  this.svgRoot = d3.select(container).append("svg");  
  
  this.bars = this.svgRoot  
    .selectAll("rect")  
    .data(this.dataset)  
    .enter()  
    .append("rect");  
  
  this.labels = d3.select("svg").selectAll("text")  
    .data(this.dataset)  
    .enter()  
    .append("text");  
}
```



D3 Update Pattern



D3 Update Pattern Details

- D3 Data Operator provides 3 virtual selections
 - Three sections include Update, Enter and Exit

```
// update => d3.selection.data(...);  
// enter  => d3.selection.data(...).enter();  
// exit   => d3.selection.data(...).exit();
```

- Update selection contains all of the existing DOM elements that had their data attributes updated
- Enter selection contains placeholder elements for data not yet bound to DOM elements
- Exit selection contains all of the existing DOM elements which did not have their data attributes updated



Generating Labels in update

```
var yTextOffset = (d3.min(this.dataset) * yScaleFactor) * 0.2;
var textSize = (barWidth * 0.3) + "px";

this.labels.text((d, i) => { return "$" + d; })
  .attr("x", (d, i) => { return plot.xOffset + (i * (xScaleFactor)) + (barWidth / 2); })
  .attr("y", (d, i) => { return plot.yOffset + plot.height - yTextOffset; })
  .attr("fill", "white")
  .attr("font-size", textSize)
  .attr("text-anchor", "middle")
  .attr("alignment-baseline", "middle");
```



Agenda

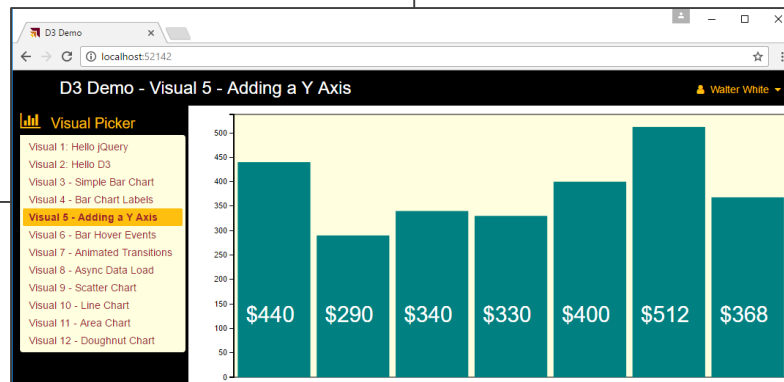
- ✓ TypeScript Language Primer
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Adding a Scale and an Axis

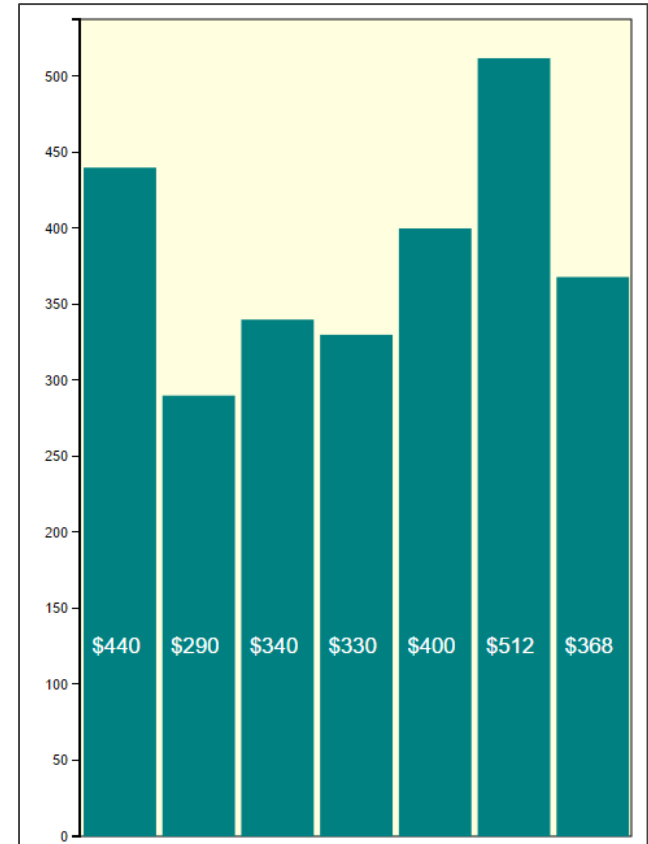
- **Scale** is a function that maps input domain to output range
- **Axis** is a function used to generate the HTML elements of visual axis

```
export class Viz05 implements ICustomVisual {  
    name = "Visual 5 - Adding a Y Axis";  
  
    private dataset = [440, 290, 340, 330, 400, 512, 368];  
  
    private svgRoot: d3.Selection<SVGElementInstance>;  
    private plotArea: d3.Selection<SVGElementInstance>;  
    private axisGroup: d3.Selection<SVGElementInstance>;  
    private bars: d3.Selection<number>;  
    private labels: d3.Selection<number>;  
    private padding: number = 12;  
    private xAxisOffset: number = 50;  
    private yScale: d3.scale.Linear<number, number>;  
    private yAxis: d3.svg.Axis;  
  
    load(container: HTMLElement) ...  
    update(viewport: IViewport) ...  
}
```



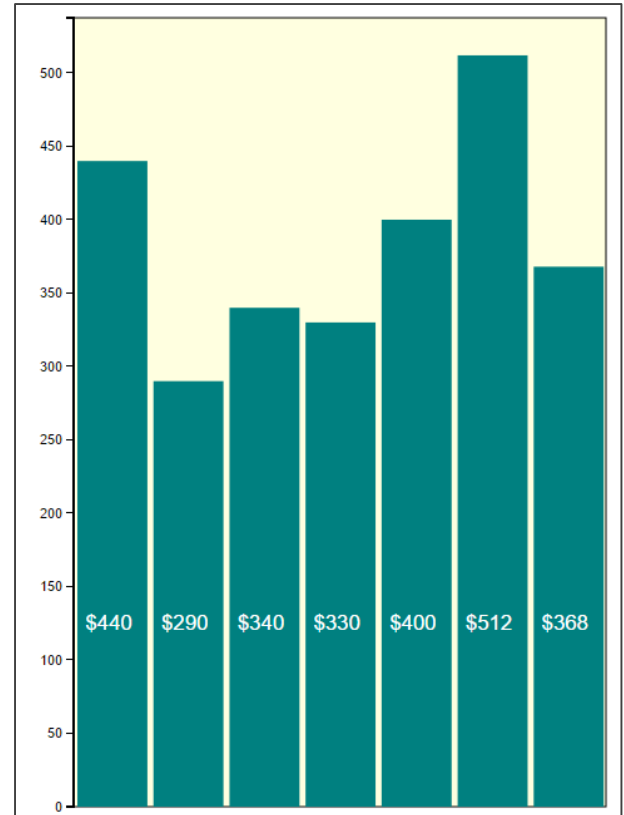
Implementing load

```
load(container: HTMLElement) {  
  this.svgRoot = d3.select(container).append("svg");  
  
  this.plotArea = this.svgRoot.append("rect")  
    .attr("fill", "lightyellow")  
    .attr("stroke", "black")  
    .attr("stroke-width", 1);  
  
  this.bars = this.svgRoot.append("g")  
    .selectAll("rect")  
    .data(this.dataset)  
    .enter()  
    .append("rect");  
  
  this.labels = this.svgRoot  
    .selectAll("text")  
    .data(this.dataset)  
    .enter()  
    .append("text");  
  
  this.axisGroup = this.svgRoot.append("g");  
  this.yScale = d3.scale.linear();  
  this.yAxis = d3.svg.axis();  
}
```



Implementing update (part 1)

```
update(viewport: IViewport) {  
  
  this.svgRoot  
    .attr("width", viewport.width)  
    .attr("height", viewport.height);  
  
  var plot = {  
    xOffset: this.padding + this.xAxisOffset,  
    yOffset: this.padding,  
    width: viewport.width - this.xAxisOffset - (this.padding * 2),  
    height: viewport.height - (this.padding * 2),  
  };  
  
  var yDomainStart: number = d3.max(this.dataset) * 1.05;  
  var yDomainStop: number = 0;  
  var yRangeStart: number = 0;  
  var yRangeStop: number = plot.height;  
  
  this.yScale  
    .domain([yDomainStart, yDomainStop])  
    .range([yRangeStart, yRangeStop]);  
  
  var datasetSize = this.dataset.length;  
  var xScaleFactor = plot.width / datasetSize;  
  var barXStart = (plot.width / datasetSize) * 0.05;  
  var barWidth = (plot.width / datasetSize) * 0.92;  
  var yScaleFactor = plot.height / d3.max(this.dataset);  
  
  // to be continued...  
}
```



Implementing update (part 2)

```
// to be continued...

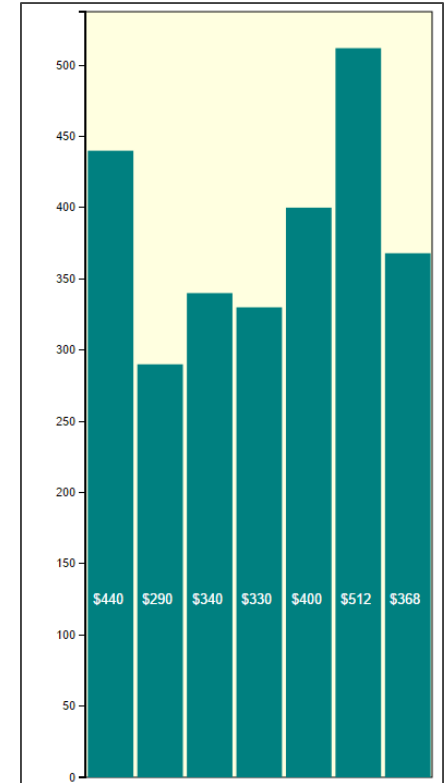
this.plotArea
  .attr("x", plot.xOffset)
  .attr("y", plot.yOffset)
  .attr("width", plot.width)
  .attr("height", plot.height);

this.bars
  .attr("x", (d, i) => { return plot.xOffset + barXStart + (i * (xScaleFactor)); })
  .attr("y", (d, i) => { return plot.yOffset + this.yScale(Number(d)); })
  .attr("width", (d, i) => { return barWidth; })
  .attr("height", (d, i) => { return (plot.height - this.yScale(Number(d))); })
  .attr("fill", "teal");

var yTextOffset = this.yScale(d3.min(this.dataset)) * 0.5;
var textSize = (barWidth * 0.3) + "px";

this.labels
  .text((d, i) => { return "$" + d; })
  .attr("x", (d, i) => { return plot.xOffset + (i * (xScaleFactor)) + (barWidth / 2); })
  .attr("y", (d, i) => { return plot.yOffset + plot.height - yTextOffset; })
  .attr("fill", "white")
  .attr("font-size", textSize)
  .attr("text-anchor", "middle")
  .attr("alignment-baseline", "middle");

this.yAxis.scale(this.yScale).orient('left').ticks(10);
var transform = "translate(" + (this.padding + this.xAxisOffset) + "," + this.padding + ")";
this.axisGroup.attr("class", "axis").call(this.yAxis).attr({ 'transform': transform });
}
```



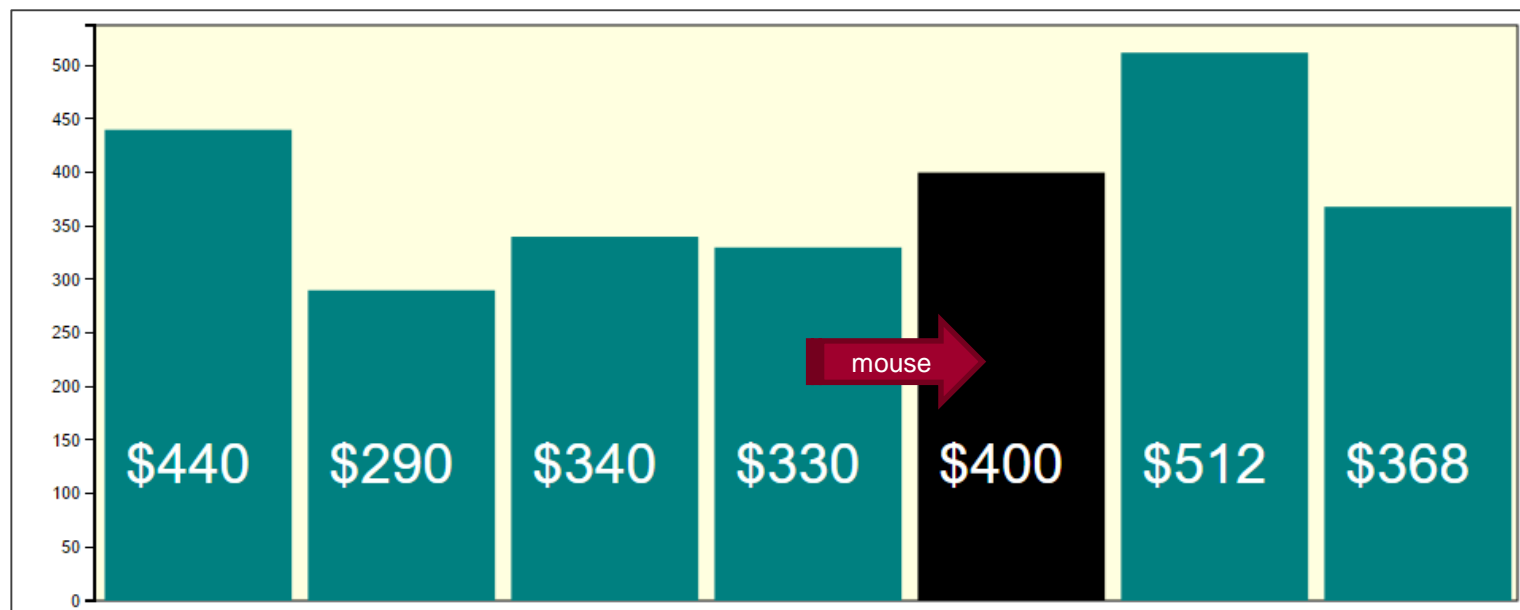
Agenda

- ✓ TypeScript Language Primer
- ✓ Getting Started with D3 and SVG Graphics
- ✓ Creating Data-driven Visuals
- ✓ Enhancing Visuals with Scales and Axes
- Event Handling and Transitions
 - Using D3 Layouts



Adding Mouse Event Handlers

```
this.bars
.attr("x", (d, i) => { return plot.xOffset + barXStart + (i * (xScaleFactor)); })
.attr("y", (d, i) => { return plot.yOffset + this.yScale(Number(d)); })
.attr("width", (d, i) => { return barWidth; })
.attr("height", (d, i) => { return (plot.height - this.yScale(Number(d))); })
.attr("fill", "teal")
.on("mouseover", function () { d3.select(this).attr("fill", "black") })
.on("mouseout", function () { d3.select(this).attr("fill", "teal") });
```



Programming D3 Animation

```
.on("mouseover", function () { d3.select(this).attr("fill", "black") })
.on("mouseout", function () { d3.select(this).attr("fill", "teal") })
.on("click", function (d, i) {
  // get reference to current bar
  var currentBar = d3.select(this);
  // determine current bar Y position and height
  var currentY: number = parseInt(currentBar.attr("y"));
  var currentHeight: number = parseInt(currentBar.attr("height"));
  // transition bar to height of zero
  currentBar.transition().duration(1000)
    .attr("y", currentY + (currentHeight))
    .attr("height", 0)
    .each("end", () => {
      // transition bar back to previous height
      currentBar.transition().duration(500).delay(100)
        .attr("y", currentY)
        .attr("height", currentHeight);
    });
});
```



Agenda

- ✓ Getting Started with Power BI Development
- ✓ TypeScript Language Primer
- ✓ Creating Data-driven Visuals with D3.js
- Creating a Power BI Development Environment



Summary

- ✓ Getting Started with Power BI Development
- ✓ TypeScript Language Primer
- ✓ Creating Data-driven Visuals with D3.js
- ✓ Creating a Power BI Development Environment

