Comp 324/424 - Client-side Web Design

Fall Semester 2019 - Week 14

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Final Demo and Presentation

- presentation and demo - live working app...
  - *final demo*
    - due on Tuesday 3rd December 2019 @ 7pm
  - *final report*
    - due on Tuesday 10th December 2019 @ 7pm
  - ***NO** content management systems (CMSs) such as Drupal, Joomla, WordPress...*
  - ***NO** PHP, Python, Ruby, C# & .Net, Java, Go, XML...*
  - ***NO** CSS frameworks such as Bootstrap, Foundation, Materialize...*
  - ***NO** CSS preprocessors such as Sass...*
  - ***NO** template tools such as Handlebars.js &c.*
  - *must implement data from either*
    - self hosted (MongoDB, Redis...)
    - APIs
    - cloud services (Firebase...)
    - **NO** SQL...e.g. (you may **NOT** use MySQL, PostgreSQL &c.)
  - *explain design decisions*
    - describe patterns used in design of UI and interaction
    - layout choices...
  - *show and explain implemented differences from DEV week*
    - where and why did you update the app?
    - perceived benefits of the updates?
  - *how did you respond to peer review?*
- anything else useful for final assessment...
- consider outline of content from final report outline
- ...

All project code must be pushed to a repository on GitHub.

n.b. present your own work contributed to the project, and its development...

Final Report

Report due on Tuesday 10th December 2019 @ 7pm

- final report outline - coursework section of website
  - *PDF*
  - *group report*
  - ***extra individual report*** *- optional*
- include repository details for project code on GitHub

Project Outline - Setup & Usage

intro

- consider task runners and build tools
  - *e.g. Grunt, Webpack...*
  - *relative to build distributions and development environments*
- for a new project, begin by initialising a *Git* repository
  - *initialise in the root directory*
- also add a `.gitignore` file to our local repository
  - *define files and directories not monitored by Git's version control*
- then initialise a new NodeJS based project using *NPM*
  - *execute the following terminal command*

```
npm init
```

- answer initial `npm init` questions or use suggested defaults
- `package.json` file created
  - *default metadata may be updated as project develops*

Project Outline - Setup & Usage

directory structure - part 1

- basic project layout may follow a sample directory structure,

```
.
|-- build
|   |-- css
|   |-- img
|   |-- js
|-- src
|   |-- assets
|   |-- css
|   |-- js
|   |__ app.js
|-- temp
|-- testing
|__ index.html //applicable for client-side, webview apps &c.
```

- sample needs to be modified relative to a given project
- `build`, `temp`, and `testing` will include files and generated content
  - *from various build tasks*
- `build` and `temp` directories may be created and cleaned automatically
  - *as part of the build tasks*
  - *do not need to be created as part of the initial directory structure*

Project Outline - Setup & Usage

directory structure - part 2

- example structure adds `index.html` file to root of project structure
  - *e.g. for client-side and webview based development*
- structure includes `build` directories
  - *may not add until build tasks for a `release` distribution*
  - *commonly include bundling, minification, uglifying, &c.*
- `build` directory will be part of a build task
- also update our project's `.gitignore` file

```
.DS_Store
node_modules/
*.log
build/
temp/
```

Project Outline - Setup & Usage

install and configure Grunt

- start by installing and configuring Grunt for the above sample project structure

```
npm install grunt --save-dev
```

- install assumes a global scope for the NPM package `grunt-cli`
  - *saves metadata to `package.json` for development builds only*
- to use Grunt with a project
  - *add a config file, `Gruntfile.js` to the project's root directory*
  - *includes initial exports for tasks and targets*
- we may then load and register the required tasks

Project Outline - Setup & Usage

`Gruntfile.js` - initial exports

- Grunt config is again dependent on specifics of the project
- we may add some common options
  - *e.g. linting, build distributions, minification and bundling, uglifying, sprites &c.*
- use of `rollup` will depend upon required support for modules
  - *including ES modules within JavaScript apps*

```
module.exports = function(grunt) {
    grunt.initConfig(
        {
            jshint: {
                all: ['src/**/*.js'],
                options: {
                    'esversion': 6,
                    'globalstrict': true,
                    'devel': true,
                    'browser': true
            }
            },
            rollup: {
                release: {
                options: {},
                files: {
                'temp/js/rolled.js': ['src/js/main.js'],
                },
                }
        },
            uglify: {
                release: {
                    files: {
                        'build/js/mini.js': 'temp/js/*.js'
                    },
                }
            },
            sprite: {
                release: {
                    src: 'src/assets/images/*',
                    dest: 'build/img/icons.png',
                    destCss: 'build/css/icons.css'
                }
            },
```

```
            clean: {
            folder: ['temp'],
            }
        }
    );

};
```

Project Outline - Setup & Usage

`Gruntfile.js` - custom task

- we may add custom tasks such as metadata generation,

```
buildMeta: {
    options: {
        file: './meta.md',
        developer: 'debug tester',
        build: 'debug'
    }
},
```

- we may add tasks for CSS &c. as we continue to develop the project

Project Outline - Setup & Usage

Gruntfile.js - use tasks - part I

- after defining the exports for tasks and targets,
  - *we can load the required Grunt plugin modules*
  - *register the required tasks*
  - ...
- we may run these registered tasks together
  - *or separately relative to distribution and environment*
- e.g. load the plugins for the required tasks,

```
// linting, module bundling, minification, directory cleanup...
grunt.loadNpmTasks('grunt-contrib-jshint');
grunt.loadNpmTasks('grunt-rollup');
grunt.loadNpmTasks('grunt-contrib-uglify-es');
grunt.loadNpmTasks('grunt-spritesmith');
grunt.loadNpmTasks('grunt-contrib-clean');
```

Project Outline - Setup & Usage

`Gruntfile.js` - use tasks - part 2

- plugins correspond to installed NPM packages for current project
  - e.g.

```
npm install grunt-contrib-jshint --save-dev
npm install grunt-rollup --save-dev
npm install grunt-contrib-uglify-es --save-dev
npm install grunt-spritesmith --save-dev
npm install grunt-contrib-clean --save-dev
```

Project Outline - Setup & Usage

`Gruntfile.js` - register custom task

- we may then register a custom task for various targets in the builds
  - e.g.

```
// custom task - build meta for default debug
grunt.registerTask('buildMeta', function() {
    console.log('debug build...');
    const options = this.options();
    metaBuilder(options);
});

//custom task - build meta for release
grunt.registerTask('buildMeta:release', function() {
    console.log('release build...');
    // define task options - incl. defaults
    const options = this.options({
        file: 'build/release_meta.md',
        developer: "spire & signpost",
        build: "release"
    });
    metaBuilder(options);
});
```

Project Outline - Setup & Usage

`Gruntfile.js` - register builds

- then register some build tasks
  - *tasks may combine the options from the config*
  - *provides the execution of staggered tasks for a single build call*
- e.g. a debug build may include
  - *linting, custom metadata, and a clean task*

```
// debug build tasks - default tasks during development...
grunt.registerTask('build:debug', ['jshint', 'buildMeta', 'clean']);
```

- we may also define a build process for staging or release

```
// build tasks with specific 'release' targets...
grunt.registerTask('build:release', ['jshint', 'rollup:release', 'uglify:release'
```

- we may run and test Grunt for the current project
  - *relative to project requirements, e.g. debug or release*

```
grunt build:debug
```

- or

```
grunt build:release
```

Project Outline - Setup & Usage

development with environments

- as we develop more complex apps
  - *need to consider how we configure and use such build tools*
- e.g. with various environments
  - *development*
  - *staging*
  - *production / release*
- we can define a *debug* or *release* distribution build
  - *use with each of these environments*

Project Outline - Setup & Usage

environment setup - development - part I

- app development will primarily focus on a `debug` distribution
  - *provide tasks such as linting, testing, metadata, watch, &c.*
  - *becomes common distribution for active, ongoing development*
- also need to ensure environment variables are aggregated
  - *allows the app to run as expected*
  - *stored in the same manner regardless of `debug` or `release`*
- difference is use of encryption
  - *and the nature of the required environment configs*
- bundling with minification and uglifying
  - *usually added to a project as part of `release` distribution*
  - *may serve little practical benefit for ongoing active development*

Project Outline - Setup & Usage

environment setup - development - part 2

- we may define a common structure for Node based apps as follows

```
.
|-- debug
|-- src
|   |-- assets
|   |-- js
|-- temp
|-- testing
|__ app.js
```

- develop the app, including the app source code, in the `src` directory
- build our app in the `debug` directory
  - *each time we need to check and debug usage*
- temporary build artifacts may be added to the `temp` directory
  - *cleaned after each build workflow has been completed*
- e.g. each time we complete a call to `build:debug`
  - *clean, where applicable, the build artifacts*
- we may also choose to combine `debug` and `temp`
  - *a single `temp` directory*
  - *depending upon project requirements*

Project Outline - Setup & Usage

environment setup - development - part 3

- for a client-side or mobile hybrid app
  - *slightly modify this directory structure, e.g.*

```
.
|-- debug
|   |-- css
|   |-- img
|   |-- js
|-- src
|   |-- assets
|   |-- css
|   |-- js
|   |__ app.js
|-- temp
|-- testing
|__ index.html
```

- `assets` directory may include raw image files, icons, &c.
- test builidng these image assets as sprites
  - *added to the `img` directory during the build*
- also use *image optimisation* at this stage
  - *e.g. test UI and UX performance*
- part of the `debug` distribution is the use of `watch` for live reloading
  - *`nodemon` for Node.js based apps*
- also consider tasks to aggregate logging within the app's code
- may include explicit `console.log()` statements, and error handling

Project Outline - Setup & Usage

environment setup - development Grunt config - part 1

- update our Grunt config
  - *use a `debug` distribution in current development environment*
- e.g. add any required build options for debug
  - *then integrate required environment config variables &c.*
- start with *unencrypted JSON* files
- may contain defaults for options
  - *e.g. current environment, server's port number &c.*

```
{
    "NODE_ENV": "development",
    "PORT": 3826
}
```

Project Outline - Setup & Usage

environment setup - development Grunt config - part 2

- define some additional project directories
  - *e.g. encrypted and decrypted config files*

```
.
|-- env
|   |-- defaults
|   |-- private
|   |-- secure
```

- `env/defaults` contains the unencrypted defaults
  - *as defined in `defaults.json`*
- `env/private` includes decrypted secure files
- `env/secure` should be reserved for encrypted files
  - *we may add to version control*
- `env/private` should **not** be commited to version control
- a few different options for file encryption
  - *e.g. RSA based public/private keys, GNU Privacy Guard (GPG, or GnuPG)*
- further details in the extra notes
  - *encryption, signatures, and verification of files*
  - *includes step by step examples for working with RSA*
  - *and extra layers of verification for a file with generated signatures*

Project Outline - Setup & Usage

merging config sources

- as a project develops, we may produce various sources of configuration
- may include sources such as
  - *JSON files*
  - *JavaScript objects*
  - *environment variables*
  - *process arguments*
  - ...
- to help merge such disparate config sources
  - *add an NPM module such as* `nconf`
  - *nconf*
- or we may simply load environment variables
  - *e.g. from a project's* `.env` *file using the package* `dotenv`
  - *dotenv*

Project Outline - Setup & Usage

sample waterfall with nconf

- with `nconf` we may bundle various config stages for a project
  - e.g.

```
const nconf = require('nconf');
nconf.argv();
nconf.env();
nconf.file('dev', 'development.json');
module.exports = nconf.get.bind(nconf);
```

- getting config variables and settings from defined stores in defined cascading order
- order is prioritised
  - *allowing overrides and defaults at various stages of the cascade*
  - *e.g. if a value is given in the command arguments, `argv`*

Project Outline - Setup & Usage

continuous development

- continuous development (CD)
  - *allows a developer to work on app code &c. without many customary interruptions*
  - *e.g. server reboots, code refreshes, debugging, linting &c.*
- CD often reduces repetitive tasks in a development flow
  - *helping to automate processes and development*
- build process may be automated and run whenever a pertinent change is detected

Project Outline - Setup & Usage

continuous development - add a `watch` task - part I

- add a *watch* task to a build flow
  - *allow a rebuild each time a given file is edited and then saved*
- e.g. for Grunt, we may add the plugin module `grunt-contrib-watch`

```
npm install grunt-contrib-watch --save-dev
```

- and update the Grunt config

```
grunt.loadNpmTasks('grunt-contrib-watch');
```

- plugin watches file system for code changes in a tracked project
  - *then runs the affected tasks as required*
- basic `watch` example might include the following

```
watch: {
    js: {
        tasks: ['jshint:client'],
        files: ['src/**/*.js']
    }
}
```

- continuously checks `src` directory for JavaScript file change or addition
  - *then runs the `jshint:client` task*
- this type of `watch` provides a broad approach to managing project changes

Project Outline - Setup & Usage

continuous development - add a `watch` task - part 2

- then include additional *targets* relative to project requirements
  - *e.g. add further JS specific targets, CSS, sprites &c.*
- we may also define separate build tasks to use `watch`
  - *e.g.*

```
// dev tasks - combine debug with watch
grunt.registerTask('dev', ['build:debug', 'watch']);
```

- which we may call as follows,

```
grunt dev
```

- executes the tasks for `build:debug`
- then starts *watching* the specified targets

Project Outline - Setup & Usage

continuous development - live reload - part I

- also use `watch` to add support for *live reloads*
- built-in support with the `grunt-contrib-watch` plugin
- reload option uses *web sockets*
  - *originally designed for browser based real-time communication and synchronisation*
- LiveReload option listens for changes to monitored files, directories &c.
  - *then reload and refresh the current active app*
- support for the LiveReload task may added as follows

```
livereload: {
    options: {
        livereload: true
    },
    files: ['build/**/*', './*.html'],
},
```

- provides a live reload server - usually runs at `localhost:35729`
- object includes a property to confirm `livereload`
  - *then defines files to watch to initiate a reload*
- e.g. in this example
  - *watching `build` directory, its children, then the root directory for any HTML files*
  - *includes any changes to default `index.html` file*
- *n.b.* this server does not actually reload the app for us
  - *need to use a server to host the app*
  - *host server is monitoring this `livereload` server*

Project Outline - Setup & Usage

continuous development - live reload - part 2

- `livereload` also provides a setup script for the test app
- two common options for use
  - *add a link to this script in our project's `index.html` file*

```
<script src="http://localhost:35729/livereload.js"></script>
```

- or
  - *use a Grunt plugin, `grunt-contrib-connect`*
- grunt-contrib-connect
  - *automatically injects script in our app's code*
  - *preferred option for ongoing development*
- install this plugin as follows

```
npm install grunt-contrib-connect --save-dev
```

- then update the `Gruntfile.js` config

```
connect: {
    server: {
        options: {
          port: 8080,
          base: '.',
          hostname: '*',
          protocol: 'http',
          livereload: true,
        }
    },
},
```

Project Outline - Setup & Usage

continuous development - live reload - part 3

- need to update the required build tasks to use these plugins
  - *e.g. add connect and livereload support to `dev` build task*

```
// dev tasks - combine debug with watch, live server, and live reload
grunt.registerTask('dev', ['build:debug', 'connect', 'watch']);
```

- then run this build task

```
grunt dev -v
```

- –v flag outputs verbose messages
  - *helps initially check everything is running as expected*

Project Outline - Setup & Usage

add CSS support - part 1

- app styles will, customarily, include a combination of options
  - *e.g. CSS stylesheets and dynamic JavaScript based style properties*
- to work with CSS stylesheets, similar to JavaScript files
  - *consider a Grunt task for minifying these files*
- we need to install the Grunt module, `grunt-contrib-cssmin`

```
npm install grunt-contrib-cssmin --save-dev
```

- then add the following to include this package in the `Gruntfile.js` config

```
grunt.loadNpmTasks('grunt-contrib-cssmin');
```

- and update the build task for a release distribution

```
// build tasks with specific 'release' targets...
  grunt.registerTask('build:release', ['rollup:release', 'cssmin:release', 'uglif
```

- referencing the following task for `cssmin`

```
cssmin: {
    release: {
        options: {
        banner: '/* minified css file - basic-es-modules */'
        },
        files: {
      'build/css/mini.css': [
        'src/css/main.css',
        ]
        }
    }
},
```

Project Outline - Setup & Usage

add CSS support - part 2

- with the minified CSS stylesheet built
  - *add a link to this stylesheet in the `index.html` file*

```
<!-- css styles - main -->
<link rel="stylesheet" href="./build/css/mini.css">
```

- then update the `watch` task by adding the following for CSS

```
css: {
    files: ['src/**/*.css'],
    tasks: ['cssmin:release']
},
```

- then run the usual Grunt build tasks
  - *e.g. to minify the CSS stylesheets, and watch for any updates and changes...*

Project Outline - Setup & Usage

Watch update

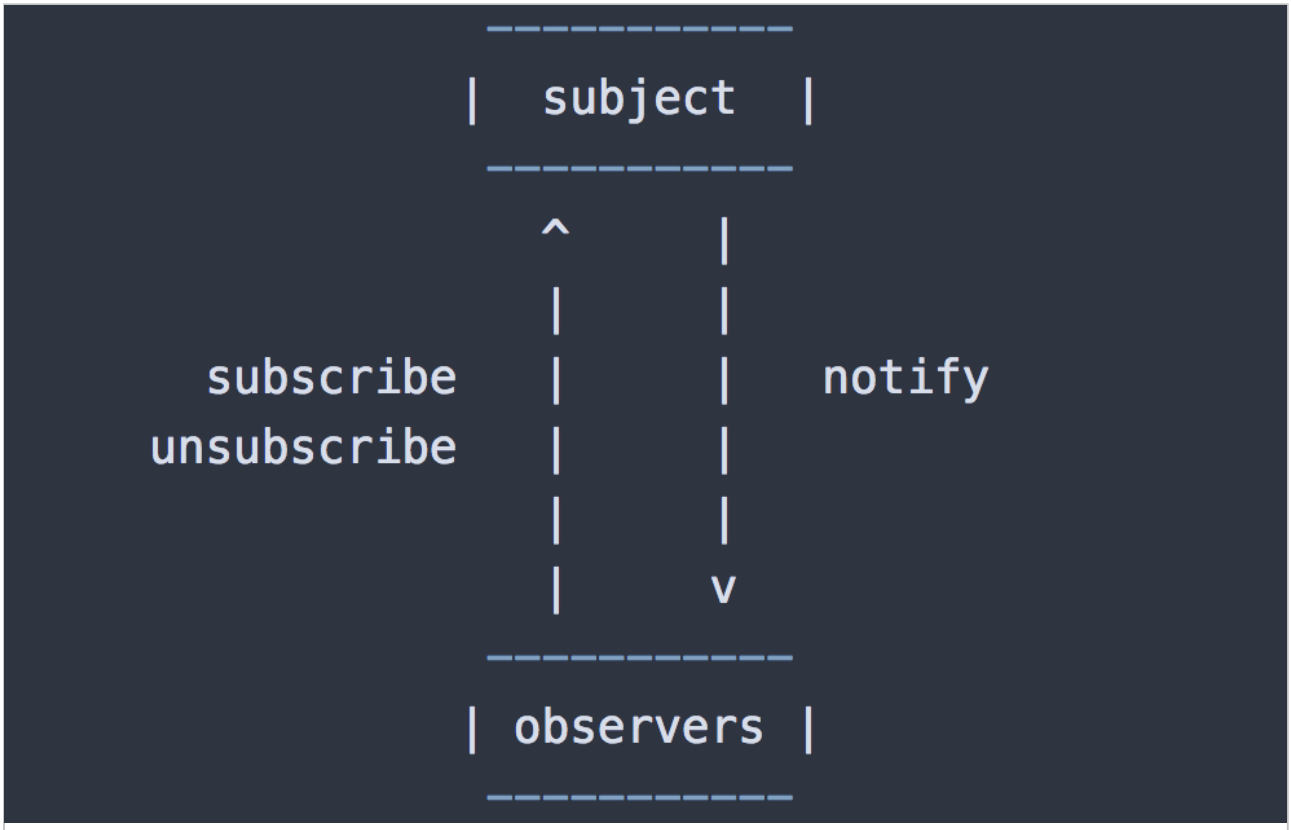
- current `watch` task includes support for CSS, JS, and HTML
- includes checks for modifications
  - *e.g. to any defined `src` directories for CSS and JS*
  - *monitors any HTML files in the app's root directory*
- a working `watch` task is as follows

```
watch: {
    js: {
        files: ['src/**/*.js'],
        tasks: ['jshint:client', 'rollup:release', 'uglify:release']
    },
    css: {
        files: ['src/**/*.css'],
        tasks: ['cssmin:release']
    },
    html: {
        files: ['./*.html']
    },
    livereload: {
        options: {
            livereload: true
        },
        files: ['build/**/*', './*.html'],
    },
},
```

Design Patterns - Observer - intro

- *observer* pattern is used to help define a *one to many* dependency between objects
- as **subject** (object) changes state
  - *any dependent **observers** (object/s) are then notified automatically*
  - *and then may update accordingly*
- managing changes in state to keep app in sync
- creating bindings that are event driven
  - *instead of standard push/pull*
- standard usage for this pattern with bindings
  - *one to many*
  - *one way*
  - *commonly event driven*

Image - Observer Pattern



Observer Pattern

Design Patterns - Observer - notifications

- observer pattern creates a model of event subscription with notifications
- benefit of this pattern
  - *tends to promote loose coupling in component design and development*
- pattern is used a lot in JavaScript based applications
  - *user events are a common example of this usage*
- pattern may also be referenced as *Pub/Sub*
  - *there are differences between these patterns - be careful...*

Design Patterns - Observer - Usage

The observer pattern includes two primary objects,

- **subject**
  - *provides interface for observers to subscribe and unsubscribe*
  - *sends notifications to observers for changes in state*
  - *maintains record of subscribed observers*
  - *e.g. a click in the UI*
- **observer**
  - *includes a function to respond to subject notifications*
  - *e.g. a handler for the click*

Design Patterns - Observer - Example

```
// constructor for subject
function Subject () {
  // keep track of observers
  this.observers = [];
}

// add subscribe to constructor prototype
Subject.prototype.subscribe = function(fn) {
  this.observers.push(fn);
};

// add unsubscribe to constructor prototype
Subject.prototype.unsubscribe = function(fn) {
  // ...
};

// add broadcast to constructor prototype
Subject.prototype.broadcast = function(status) {
  // each subscriber function called in response to state change...
  this.observers.forEach((subscriber) => subscriber(status));
};

// instantiate subject object
const domSubject = new Subject();

// subscribe & define function to call when broadcast message is sent
domSubject.subscribe((status) => {
  // check dom load
  let domCheck = status === true ? `dom loaded = ${status}` : `dom still loading.
  // log dom check
  console.log(domCheck)
});

document.addEventListener('DOMContentLoaded', () => domSubject.broadcast(true));
```

Design Patterns - Observer - Example

- Observer - Broadcast, Subscribe, & Unsubscribe

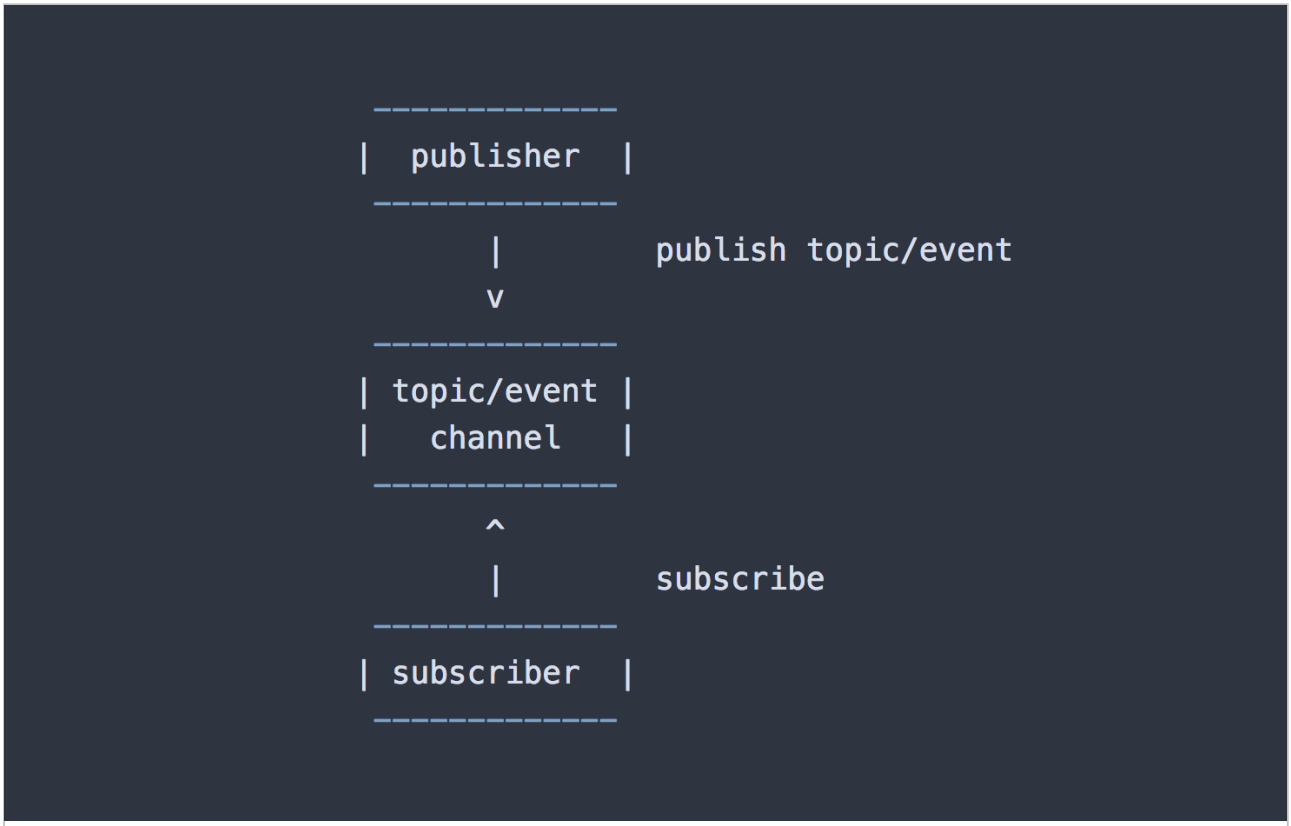
Design Patterns - Pub/Sub - intro

- variation of standard *observer* pattern is *publication and subscription*
  - *commonly known as PubSub pattern*
- popular usage in JavaScript
- *PubSub* pattern publishes a *topic* or *event* channel
- publication acts as a *mediator* or *event system* between
  - *subscriber objects wishing to receive notifications*
  - *and publisher object announcing an event*
- easy to define specific events with *event system*
- events may then pass custom arguments to a subscriber
- trying to avoid potential dependencies between objects
  - *subscriber objects and the publisher object*

Design Patterns - Pub/Sub - abstraction

- inherent to this pattern is the simple abstraction of responsibility
- publishers are unaware of nature or type of subscribers for messages
- subscribers are unaware of the specifics for a given publisher
- subscribers simply identify their interest in a given topic or event
  - *then receive notifications of updates for a given subscribed channel*
- primary difference with *observer* pattern
  - *PubSub abstracts the role of the subscriber*
- *subscriber* simply needs to handle data broadcasts by a *publisher*
- creating an abstracted *event system* between objects
  - *abstraction of concerns between publisher and subscriber*

Image - Publish/Subscribe Pattern



PubSub Pattern

Design Patterns - Pub/Sub - benefits

- *observer* and *PubSub* patterns help developers
  - *better understanding of relationships within an app's logic and structure*
- need to identify aspects of our app that contain direct relationships
- many direct relationships may be replaced with patterns
  - *subjects and observers*
  - *publishers and observers*
- tightly coupled code can quickly create issues
  - *maintenance, scale, modification, clarity of code and logic...*
  - *semmingly minor changes may often create a cascade or waterfall effect in code*
- a known side effect of tightly couple code
  - *frequent need to mock usage &c. in testing*
  - *time consuming and error prone as app scales...*
- *PubSub* helps create smaller, loosely coupled blocks
  - *helps improve management of an app*
  - *promotes code reuse*

Design Patterns - Pub/Sub - basic example - part 1 - event system

```
// constructor for pubsub object
function PubSub () {
  this.pubsub = {};
}

// publish - expects topic/event & data to send
PubSub.prototype.publish = function (topic, data) {
  // check topic exists
  if (!this.pubsub[topic]){
    console.log(`publish - no topic...`);
    return false;
  }
  // loop through pubsub for specified topic - call subscriber functions...
  this.pubsub[topic].forEach(function(subscriber) {
      subscriber(data || {});
    });
};

// subscribe - expects topic/event & function to call for publish notification
PubSub.prototype.subscribe = function (topic, fn) {
  // check topic exists
  if (!this.pubsub[topic]) {
    // create topic
    this.pubsub[topic] = [];
    console.log(`pubsub topic initialised...`);
  }
  else {
    // log output for existing topic match
    console.log(`topic already initialised...`);
  }
  // push subscriber function to specified topic
  this.pubsub[topic].push(fn);
};
```

Design Patterns - Pub/Sub - basic example - part 2 - usage

```
// basic log output
var logger = data => { console.log( `logged: ${data}` ); };

// test function for subscriber
var domUpdater = function (data) {
  document.getElementById('output').innerHTML = data;
}

// instantiate object for PubSub
const pubSub = new PubSub();

// subscriber tests
pubSub.subscribe( 'test_topic', logger );
pubSub.subscribe( 'test_topic2', domUpdater );
pubSub.subscribe( 'test_topic', logger );

// publisher tests
pubSub.publish('test_topic', 'hello subscribers of test topic...');
pubSub.publish('test_topic2', 'update notification for test topic2...');
```

- Demo - Pub/Sub

JavaScript - Proxy

intro

- use a *proxy* to control access to another object
  - *a surrogate relationship between the proxy and the object*
- proxy may be considered akin to a generalised *getter* and *setter*
- whilst *getters* and *setters* may control access to a single object property
  - *a proxy enables generic handling of interactions*
- interactions may even include method calls relative to an object
- we may use a proxy where we might otherwise use a getter and a setter
- proxy is considered broader and more powerful in its potential implementation and usage
- e.g.
  - *a proxy may be used to add profiling support to an object*
  - *measure performance*
  - *autopopulate code properties*
  - ...

JavaScript - Proxy

creating a proxy - part 1

- to create a proxy in JavaScript
  - *use the default, built-in Proxy constructor*

```
// plain object
const planet = {
  name: ['mercury'],
  codes: {
    iau: 'Me',
    unicode: 'U+263F'
  }
};

// proxy for passed target object - target = planet
const planetDetails = new Proxy(planet, {
  get: (target, key) => {
    return key in target ? target[key] :'planet does not exist...';
  },
  set: (target, key, value) => {
    key in target ? target[key].push(value) : 'key not found...';
  }
});

// check proxy access to target property
console.log(planetDetails.name);

// check proxy set against target property
// target = planet, key = name, value = earth
planetDetails.name = 'earth';

console.log(planetDetails.name);
```

JavaScript - Proxy

creating a proxy - part 2

- in the previous example
  - *we may access the object and its properties directly*
  - *but the proxy gives us extra utility*
- e.g for the getter and setter
  - *we may check keys, values, &c.*
  - *control how the object is updated*
  - *we may also add basic logging, if necessary...*
- after defining the initial plain object, `planet`
  - *we may then wrap it using the Proxy constructor*
- current proxy includes a getter and setter method
  - *contains checks for required key in the original object*
- also choose how we would like to compute values, log usage and return &c.

JavaScript - Proxy

proxy traps

- in the previous example
  - *we added a `get` and `set` trap for defined target object, `planet`*
- there are other traps we may use with a Proxy
- e.g.
  - *`apply` - activated for a function call*
    - e.g. measuring performance
  - *`construct` - activated for `new` keyword*
  - *`enumerate` - activated for `for-in` statements*
  - *`getPrototypeOf` - activated for getting prototype value*
  - *`setPrototypeOf` - activated for setting prototype value*
- these traps are in addition to existing `get` and `set` traps
- there are also traps that we cannot override using a proxy
- e.g.
  - *equality operators - `==` and `===` and not equivalents*
  - *`instanceof` and `typeof`*

JavaScript - Proxy

logging with proxies

- use logging in development as a convenient tool for debugging and checking code
- output checks, and add debugging statements to various points within our code
- quickly start to add many such logging statements to our code
- better option
  - *considering abstraction and reuse of code*
  - *is to use a proxy for such logging*

JavaScript - Proxy

custom proxy for logging - part 1

- to improve our code reuse and abstraction
  - *we may define a proxy for logging within an app.*
- e.g.
  - *define a custom function, which accepts a `target` object*
  - *returns a new Proxy object with a getter and setter method*

```
// logging with proxy - get and set traps defined
function logger(target) {
  return new Proxy(target, {
    get: (target, property) => {
      console.log(`property read - ${property}`);
      return target[property];
    },
    set: (target, property, value) => {
      console.log(`value '${value}' added to ${property}`);
      target[property] = value;
    }
  });
}
```

- this is a custom logger
  - *wraps passed target object in a proxy with defined getter and setter methods*

JavaScript - Proxy

custom proxy for logging - part 2

- we may then use this custom function as follows

```
// test object
let planet = {
  name: 'mercury'
};

// new planet object with proxy
planetLog = logger(planet);

// test getting - value for property returned by getter in logger() method...
console.log('default get = ', planetLog.name);

// test setting - value for property set against object
planet.code = 'Me';
```

- in this example
  - *we define the initial object*
  - *then create a new object with a proxy wrapper*
- this proxy includes the necessary logger
  - *set for both the setter and getter methods*
- as we read a property
  - *the `get` method will log access and return the requested data*
- as we set data
  - *we log this update, and then update the target*

JavaScript - Proxy

custom proxy for measuring performance - part 1

- another appropriate use of a Proxy is to test performance for a given function
- we may wrap a function with a Proxy, and then `apply` a trap
- this trap may include a simple timer
  - *or perhaps a detailed series of tests for the pass function*
- e.g.
  - *the following function simply loops through a passed counter*
  - *outputs a series of characters for each iteration*

```
// FN: test loop to output to terminal
function loopOutput(counter, marker = '-') {
  if (!counter) {
    return false;
  }
  // loop through passed counter - check number for even...
  for (i = 0; i <= counter; i++) {
    // check for even counter value
    if (i % 2 === 0) {
      process.stdout.write('+');
    } else {
      // console.log(marker);
      process.stdout.write(marker);
    }
  }
  console.log('\n');
  return true;
}
```

JavaScript - Proxy

custom proxy for measuring performance - part 2

- we may then wrap this function inside a Proxy
  - *adding a simple timer for the duration of the loop*

```
// wrap function inside custom Proxy
loopTest = new Proxy(loopOutput, {
  // apply simple timer to loop function
  apply: (target, thisArg, args) => {
    console.time("loopTest");
    /* invokes target function - thisArg defines the `this` value
    * if no `thisArg`, undefined will be used instead...
    * thisArg = value to use as `this` when executing a callback
    * args passed to target function loopOutput
    */
    const result = target.apply(thisArg, args);
    console.timeEnd("loopTest");
    return result;
  }
});
```

- `apply` property trap means function value will be executed each time `loopOutput` function is called
- handler will now be executed on function invocation for `loopTest`

JavaScript - Proxy

custom proxy for measuring performance - part 3

- we may then execute this function with its Proxy

```
// call function with counter value and custom marker...
loopTest(75, '-');
```

- markers are output to the terminal
  - *includes a record of the loop's performance in milliseconds*
- benefit of this approach
  - *we do not need to modify the original function, `loopOutput`*
  - *the return, logic, computation &c. will all remain the same*
- customisation in this example does not affect the passed function
  - *performance checking using the `apply` trap*
- `loopOutput` function is now routed through the custom proxy each time it is executed

JavaScript - Proxy

custom proxy for property autopopulate

- a proxy may also be used to autopopulate properties
- e.g.
  - *we might need to model a directory structure for a file save*
  - *will require verification of a defined file path*
  - *or creation of directories to ensure a path may be completed successfully*
- latter option may be achieved using a custom proxy
  - *create missing directories in a defined path structure*
- e.g.

```
// FN: recursive check for dir path and file...
function Directory() {
  return new Proxy({}, {
    get: (target, property) => {
      console.log(`reading property...${property}`);
      // check if property already exists
      if (!(property in target)) {
        // if not - simply add a new directory to target
        target[property] = new Directory();
      }
      // otherwise return property as is from target
      // - write method not implemented for actual directory...
      return target[property];
    }
  });
}

// create new Proxy for function
const rootDir = new Directory();

try {
  // check properties relative to root dir...
  rootDir.testDir.test2Dir.testFile = "test.md";
  console.log('exception not raised...');
} catch (event) {
  // error handling for null exception should be OK due to custom proxy...
  console.log(`exception raised...${event}`);
}
```

JavaScript - Proxy

Reflect a proxy - intro

- ES6 introduced a complement to Proxy usage
  - *a new built-in object, Reflect*
- Proxy traps are mapped one-to-one in the Reflect API
- allows an easy combination of Proxy and Reflect usage
- e.g. for each trap there is a matching reflect method

JavaScript - Proxy

Reflect a proxy - `get` trap

- e.g. use `Reflect.get` to define default behaviour for a Proxy getter.

```
const handler = {
    get(target, key) {
        if (key.startsWith('_')) {
           throw new Error(`Property "${ key }" is inaccessible.`)
        }
        return Reflect.get(target, key)
    }
}

const target = {}
const proxy = new Proxy(target, handler)
proxy._secret
```

- in this example, now unable to access the `_secret` property
- obvious benefit of this Reflect usage is the abstraction of `get` usage
  - *from Proxy getter to a default, re-usable Reflect `get` method*
- use the Proxy getter
  - *e.g. to check against data, type &c. in the target*
  - *then call the Reflect `get` method if successful*
- a useful option for restricting access to certain properties through a Proxy
- expose the Proxy instead of the underlying object
  - *setting access privileges according to requirements*
- if successful, a request will then be handled by the Reflect API method
- access must now go through the Proxy
  - *and meet its rules and requirements*

JavaScript - Proxy

Reflect a proxy - false return

- returning an error may still be an indication that the `_secret` property exists
- alternative is to return an explicit `false` boolean value for requested hidden property

```
const handler = {
    get(target, key) {
        if (key.startsWith('_')) {
           return false;
        }
        return Reflect.get(target, key)
    }
};

const library = {
    archive : 'waldzell',
    curator : 'knechts',
    _secret : true
};
const proxy = new Proxy(library, handler);
console.log(`secret = ${proxy._secret}`);
console.log(`archive = ${proxy.archive}`);
```

- a request for underscore value names may still be checked using

```
// _secret is not a private property in object -
console.log(proxy.hasOwnProperty('_secret'))
```

- *underscore* property names are still not private
  - *remain visible to specific property checks*

JavaScript - Proxy

Reflect a proxy - set trap - part 1

- we may also apply reflection to `set` traps
- reflected `set` method defines behaviour for a setter on a given Proxy object
- equivalent to the default behaviour for the proxy
- e.g.

```
set(target, key, value) {
  return Reflect.set(target, key, value)
}
```

- also add various checks for the passed key...

JavaScript - Proxy

Reflect a proxy - set trap - part 2

- now update our previous example to include a `set` trap with Proxy support

```
const handler = {
    get(target, key) {
        if (key.startsWith('_')) {
           // return false to show prop doesn't exist...
           return false;
        }
        return Reflect.get(target, key)
    },
    set(target, key, value) {
        return Reflect.set(target, key, value);
    }
};
```

- then test property access using the `get` and `set` traps

```
const library = {};
const proxy = new Proxy(library, handler);
proxy.archive = 'mariafels';
proxy._secret = true;
```

JavaScript - Proxy

Reflect a proxy - defaults and checks

- as we use the Reflect object as the default for traps
  - *we may add checks, updates &c. to the Proxy trap itself*
- e.g. we might add a conditional check to the Proxy
  - *then pass a successful update or query to the Reflect method*
- default Reflect method allows abstraction for traps from the Proxy
- e.g. we might update each trap with a call to the following conditional check

```
function keyCheck(key, action) {
    if (key.startsWith('_')) {
        throw new Error(`${action} action is not permitted on '${ key }'`)
     }
}
```

- function is called in each trap before continuing to the Reflect method for `get` or `set`

JavaScript - Proxy

proxy wrapper - part I

- to ensure we restrict access to a `target` object to the defined proxy and reflect traps
  - *need to wrap the `target` itself in a Proxy*
- target object may have been accessed directly in certain contexts
  - *might be beneficial for an admin mode and access*
- to restrict access
  - *wrap such objects in the Proxy to restrict access to the defined traps and handlers*

JavaScript - Proxy

proxy wrapper - part 2

- e.g. we can modify our previous example for `get` and `set` traps

```
function proxyWrapper() {
    const target = {};
    const handler = {
        get(target, key) {
            if (key.startsWith('_')) {
               // return false to show prop doesn't exist...
               return false;
            }
            return Reflect.get(target, key)
        },
        set(target, key, value) {
            return Reflect.set(target, key, value);
        }
    };
    return new Proxy(target, handler);
}
```

JavaScript - Proxy

proxy wrapper - part 3

- `target` may now be accessed and managed using an instantiated proxy

```
const proxiedObject = proxyWrapper();
// set prop & value on target using proxy set trap
proxiedObject.archive = 'waldzell';
// target accessible using proxy get trap
console.log(`target archive = ${proxiedObject.archive}`);
```

- `target` may not be accessed directly using standard property access

```
// target not directly accessible
console.log(`target = ${target}`);
```

JavaScript - Proxy

proxy wrapper - pass object to wrapper

- we may modify this wrapper to also accept an existing object
  - *may then be returned wrapped in a Proxy*
- e.g.

```
const archive = {
    name: 'waldzell'
}

const proxiedArchive = proxyWrapper(archive);
```

JavaScript - Proxy

proxy wrapper - check object - part 1

- add a further check to ensure we always have a target object to work with..
  - *regardless of passed argument value*
- e.g. add a check to the `proxyWrapper` function to ensure target is always an object

```
// check object & return empty object if necessary...
function checkTarget(original) {
    // check for existing target object
    if (original.typeof !== 'object' || original === undefined) {
        console.log('not object...');
        const target = {};
        return target;
    } else {
        const target = original;
        return target;
    }
}
```

JavaScript - Proxy

proxy wrapper - check object - part 2

- if we pass a string instead of a target object
  - *we can now create a proxy wrapper with an empty object*

```
const proxiedArchive = proxyWrapper('archives');
// set prop & value on target using proxy set trap
proxiedArchive.admin = 'knechts';
proxiedArchive._secret = '1235813';
```

- properties for `admin` and `_secret` may now be set against an empty object
  - *due to the passed `archives` string*
- we can call this function at the top of the `proxyWrapper` function

```
function proxyWrapper(original) {
    // check target for proxy wrapper - original must be object
  const target = checkTarget(original);
  ...
}
```

JavaScript - Proxy

proxy wrapper - update property access check

- also abstract initial check for property access using a defined character delimiter
- e.g.

```
// check property access using defined char delimiter
function checkDelimiter(key, char) {
    // check key relative to specified char delimiter
    if (key.startsWith(char)) {
        // return false to show prop not available
        return true;
     }
}
```

- simply check defined delimiter character relative to passed property key
  - *may then be called in the `proxyWrapper` function*

```
if (checkDelimiter(key, '_')){
  return false;
}
```

JavaScript - Proxy

proxy wrapper - restricting access

- in the previous examples
  - *we define the `target` object both inside and outside the `proxyWrapper` function*
- both may be effective options for restricting object access depending upon context
- internal object declaration for `target` restricts full access to the Proxy object
- any traps for the object will only be accessible using the Proxy object
- consumer must use the instantiated Proxy object to read, write, query &c.
- external `target` object may still be useful after it has been wrapped by a Proxy object
- restricted access is controlled by only exposing the target as a Proxy object
- e.g. if we exposed the target as an access point for a pubic API
  - *proxy object will be exposed and not the original target object*

JavaScript - Proxy

proxy and schema validation

- objects may be defined for a specific purpose or context
  - *requires control over stored properties and values*
- validation allows us define the structure of an object
  - *e.g. its properties, types, permitted values &c.*
- we may use a third party module or custom function
  - *may return an error for invalid input and data...*
- still need to ensure that the object storing the input data is restricted
  - *e.g. to authorised access both internal and external to the app*
- another option is to use a Proxy with validation of the object
  - *proxy object may be used to provide access to the model object for validation*
- another benefit of a proxy with validation is the separation of concerns
  - *data object remains separate from the validation*
- consumer never accesses the input object directly
  - *given a proxy object with validation checks and balances*
- original input object remains a plain object due to nature of Proxy object usage
- defined proxy handlers for validation &c. may also be referenced and reused
  - *reuse across multiple Proxies...*

JavaScript - Proxy

proxy and validator - part I

- create an initial validator
  - *using a Proxy, a map, and defined handlers for required object properties*
- e.g. as a property is set through a proxy object
  - *its key may be checked against the map*
  - *if there is a rule for the key, its handler value will be executed*
  - *handler executed to check that the property is valid*

```
// MAP - validation rules for properties
const validationMap = new Map();

// TRAPS - define traps for proxy
const validator = {
    // set trap
    set(target, key, value) {
        // check map for matching handler
        if (validationMap.has(key)) {
            // return handler function if available...pass value as parameter
            return validationMap.get(key)(value);
        }

        // else - default reflect set method for proxy
        return Reflect.set(target, key, value);
    }
};
```

JavaScript - Proxy

proxy and validator - part 2

- value may be passed as a parameter to the handler function
  - *stored in the map for the requested key*
  - *function may include a validation, check &c.*

```
// RULES - define executable rules for permitted object properties
// e.g. log, update state, get state, broadcast, subscribe...
// e.g. sample validation for text to log
function validateLog(text) {
    if (typeof text === 'string') {
        console.log(`logger = ${text}`);
    } else {
        throw new TypeError(`logger requires text input...`);
    }
}
```

JavaScript - Proxy

proxy and validator - part 3

- we may then use this proxy and map as follows

```
// set key and handler function in map
validationMap.set('logger', validateLog);
// empty object to wrap with proxy
const process = {};
// instantiate proxy object
const proxyProcess = new Proxy(process, validator);

// string set using handler for logger
proxyProcess.logger = 'test string = hello proxy...';
// number will not be set - fails validation
proxyProcess.logger = 96;
```

Client-side - Data - Firebase

Firebase - intro

- Firebase is hosted platform, acquired by Google
  - *provides options for data starage, authentication, real-time database querying...*
- it provides and API for data access
  - *access and query JavaScript object data stores*
  - *query in real-time*
  - *listeners available for all connected apps and users*
  - *synchronisation in milliseconds for most updates...*
  - *notifications*

Client-side - Data - Firebase

Firebase - authentication

- **authentication** with Firebase provides various backend services and SDKs
  - *help developers manage authentication for an app*
  - *service supports many different providers, including Facebook, Google, Twitter &c.*
  - *using industry standard **OAuth 2.0** and **OpenID Connect** protocols*
- custom solutions also available per app
  - *email*
  - *telephone*
  - *messaging*
  - ...

Client-side - Data - Firebase

Firebase - cloud storage

- **Cloud Storage** used for uploading, storing, downloading files
  - *accessed by apps for file storage and usage...*
  - *features a useful safety check if and when a user's connection is broken or lost*
  - *files are usually stored in a Google Cloud Storage bucket*
  - *files accessible using either Firebase or Google Cloud*
  - *consider using Google Cloud platform for image filtering, processing, video editing...*
  - *modified files may then become available to Firebase again, and connected apps*
  - *e.g. Google's Cloud Platform*

Client-side - Data - Firebase

Firebase - Real-time database

- **Real-time Database** offers a hosted NoSQL data store
  - *ability to quickly and easily sync data*
  - *data synchronisation is active across multiple devices, in real-time*
  - *available as and when the data is updated in the cloud database*
- other services and tools available with Firebase
  - *analytics*
  - *advertising services such as adwords*
  - *crash reporting*
  - *notifications*
  - *various testing options...*

Client-side - Data - Firebase

Firebase - basic setup

- start using Firebase by creating an account with the service
  - *using a standard Google account*
  - *Firebase*
- login to Firebase
  - *choose either Get Started material or navigate to Firebase console*
- at *Console* page, get started by creating a new project
  - *click on the option to* `Add project`
  - *enter the name of this new project*
  - *and select a region*
- then redirected to the *console dashboard* page for the new project
  - *access project settings, config, maintenance...*
- reference documentation for the Firebase Real-Time database,
  - *https://firebase.google.com/docs/reference/js/firebase.database*

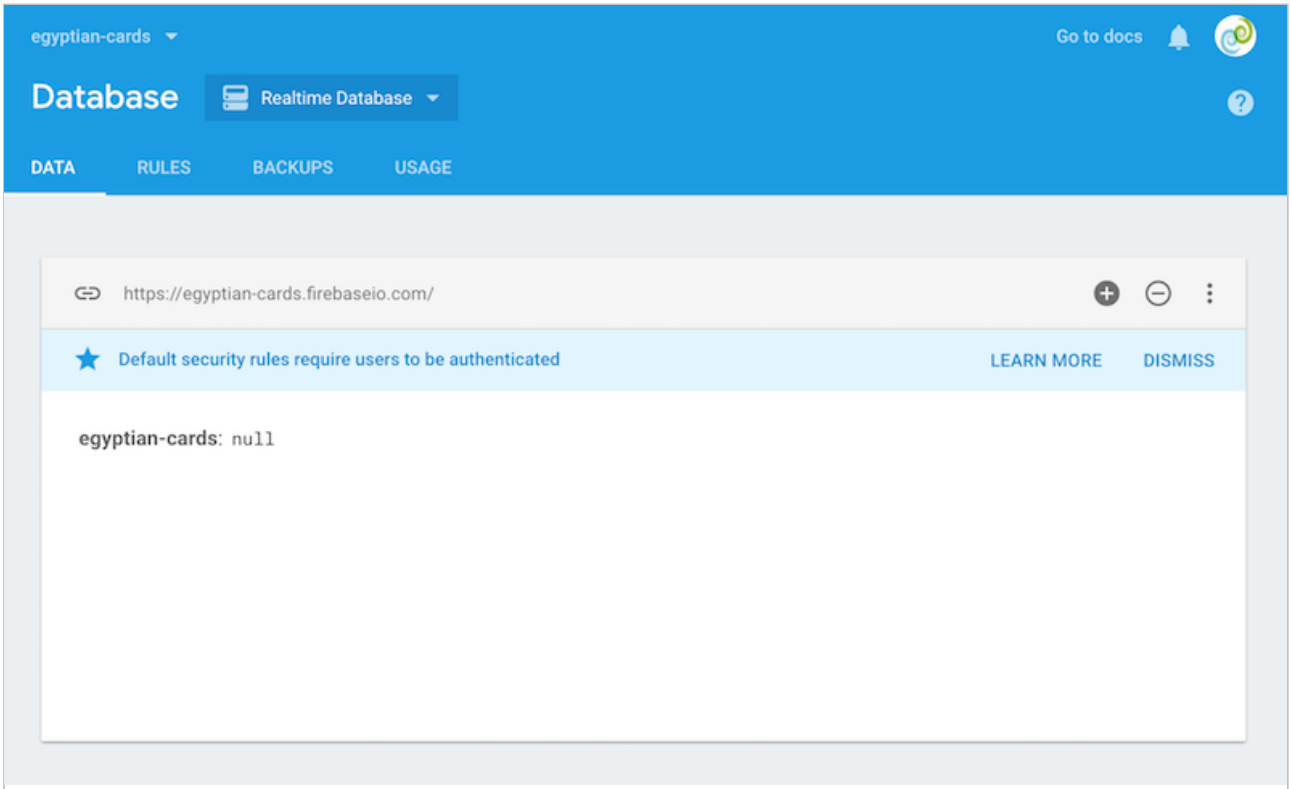
Client-side - Data - Firebase

Firebase - create real-time database

- now setup a database with Firebase for a test app
- start by selecting *Database* option from left sidebar on the Console Dashboard
  - *available under the DEVELOP option*
- then select *Get Started* for the real-time database
- presents an empty database with an appropriate name to match current project
- data will be stored in a JSON format in the real-time database
- working with Firebase is usually simple and straightforward for most apps
- get started quickly direct from the Firebase console
  - *or import some existing JSON...*

Image - Firebase

create a database



Firebase - create a database

Client-side - Data - Firebase

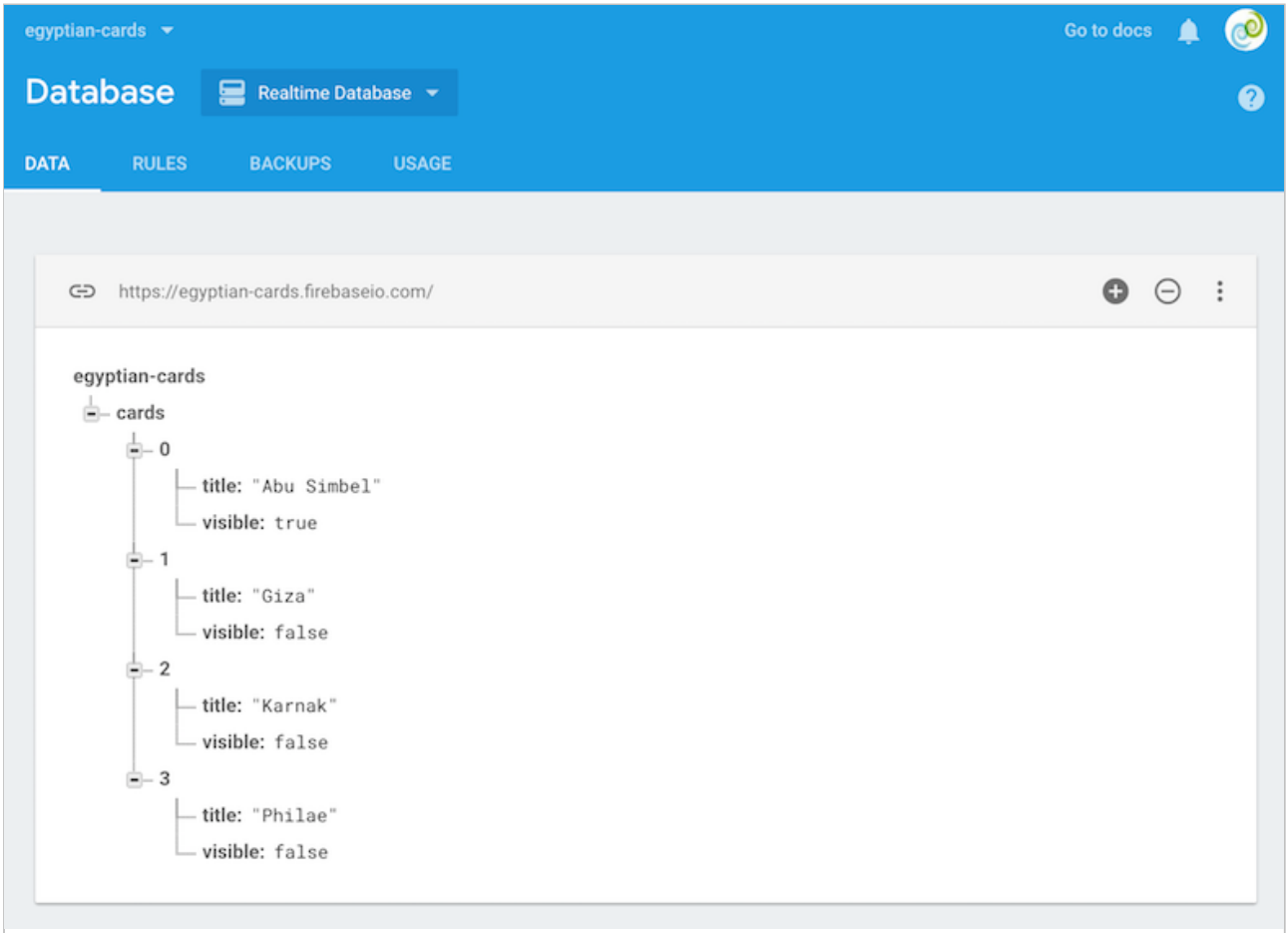
Firebase - import JSON data

- we might start with some simple data to help test Firebase
- import JSON into our test database
  - *then query the data &c. from the app*

```
{
  "cards": [
    {
      "visible": true,
      "title": "Abu Simbel",
      "card": "temple complex built by Ramesses II"
    },
    {
      "visible": false,
      "title": "Amarna",
      "card": "capital city built by Akhenaten"
    },
    {
      "visible": false,
      "title": "Giza",
      "card": "Khufu's pyramid on the Giza plateau outside Cairo"
    },
    {
      "visible": false,
      "title": "Philae",
      "card": "temple complex built during the Ptolemaic period"
    }
  ]
}
```

Image - Firebase

JSON import



Firebase - import JSON file

Client-side - Data - Firebase

Firebase - permissions

- initial notification in Firebase console after creating a new database
  - *Default security rules require users to be authenticated*
- permissions with Firebase database
  - *select RULES tab for current database*
- lots of options for database rules
  - *Firebase - database rules*
- e.g. for testing initial app we might remove authentication rules
- change rules as follows

from

```
{
  "rules": {
    ".read": "auth != null",
    ".write": "auth != null"
  }
}
```

to

```
{
  "rules": {
    ".read": "true",
    ".write": "true"
  }
}
```

Client-side - Data - Firebase

add data with plain JS objects

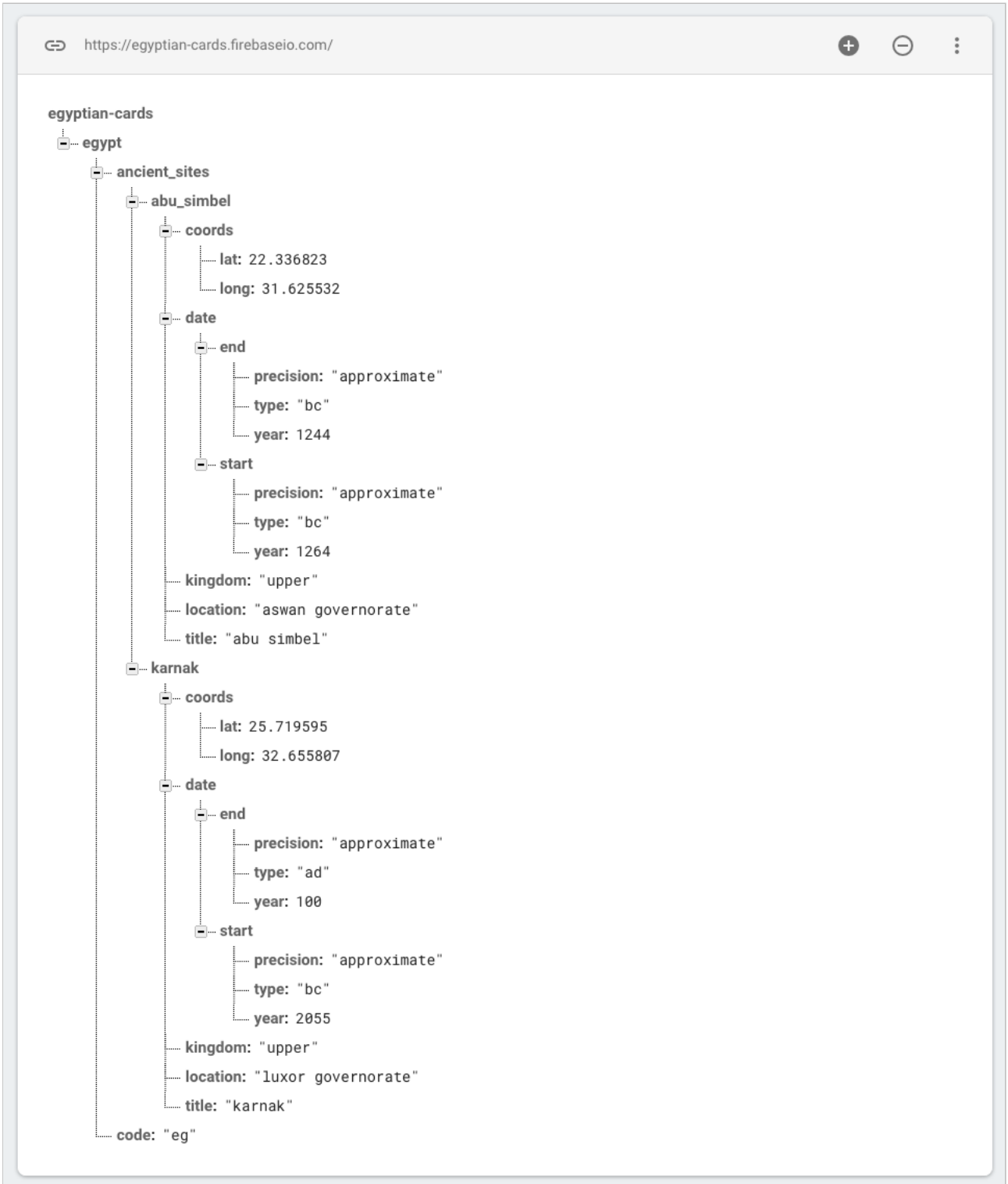
- plain objects as standard Firebase storage
  - *helps with data updating*
  - *helps with auto-increment pushes of data...*

```
{
  "egypt": {
    "code": "eg",
    "ancient_sites": {
      "abu_simbel": {
        "title": "abu simbel",
        "kingdom": "upper",
        "location": "aswan governorate",
        "coords": {
          "lat": 22.336823,
          "long": 31.625532
        },
        "date": {
          "start": {
            "type": "bc",
            "precision": "approximate",
            "year": 1264
          },
          "end": {
            "type": "bc",
            "precision": "approximate",
            "year": 1244
          }
        }
      },
      "karnak": {
        "title": "karnak",
        "kingdom": "upper",
        "location": "luxor governorate",
        "coords": {
          "lat": 25.719595,
          "long": 32.655807
        },
        "date": {
          "start": {
            "type": "bc",
            "precision": "approximate",
```

```
            "year": 2055
          },
          "end": {
            "type": "ad",
            "precision": "approximate",
            "year": 100
          }
        }
      }
    }
  }
}
```

Image - Firebase

JSON import



Firebase - import JSON file

Client-side - Data - Firebase

add to app's `index.html`

- start testing setup with default config in app's `index.html` file
  - e.g.

```
<!-- JS - Firebase app -->
<script src="https://www.gstatic.com/firebasejs/5.5.8/firebase.js"></script>
<script>
  // Initialise Firebase
  var config = {
    apiKey: "YOUR_API_KEY",
    authDomain: "422cards.firebaseapp.com",
    databaseURL: "https://422cards.firebaseio.com",
    projectId: "422cards",
    storageBucket: "422cards.appspot.com",
    messagingSenderId: "282356174766"
  };
  firebase.initializeApp(config);
</script>
```

- example includes initialisation information so the SDK has access to
  - *Authentication*
  - *Cloud storage*
- Realtime Database
- Cloud Firestore

n.b. don't forget to modify the above values to match your own account and database...

Client-side - Data - Firebase

customise API usage

- possible to customise required components per app
- allows us to include only features required for each app
  - *e.g. the only **required** component is*
- `firebase-app` - core Firebase client (required component)

```
<!-- Firebase App is always required and must be first -->
<script src="https://www.gstatic.com/firebasejs/5.5.8/firebase-app.js"></script>
```

- we may add a mix of the following optional components,
- `firebase-auth` - various authentication options
- `firebase-database` - realtime database
- `firebase-firestore` - cloud Firestore
- `firebase-functions` - cloud based function for Firebase
- `firebase-storage` - cloud storage
- `firebase-messaging` - Firebase cloud messaging

Client-side - Data - Firebase

modify JS in app's `index.html`

```
<!-- Add additional services that you want to use -->
<script src="https://www.gstatic.com/firebasejs/5.5.3/firebase-auth.js"></script>
<script src="https://www.gstatic.com/firebasejs/5.5.3/firebase-database.js"></scr
<script src="https://www.gstatic.com/firebasejs/5.5.3/firebase-firestore.js"></sc
<script src="https://www.gstatic.com/firebasejs/5.5.3/firebase-messaging.js"></sc
<script src="https://www.gstatic.com/firebasejs/5.5.3/firebase-storage.js"></scri

<script src="https://www.gstatic.com/firebasejs/5.5.3/firebase-functions.js"></sc
```

- then define an object for the `config` of the required services and options,

```
var config = {
  // add API key, services &c.
};
firebase.initializeApp(config);
```

Client-side - Data - Firebase

initial app usage - DB connection

- after defining required config and initialisation
  - *start to add required listeners and calls to app's JS*

define DB connection

- we can establish a connection to our Firebase DB as follows,

```
const db = firebase.database();
```

- then use this reference to connect and query our database

Client-side - Data - Firebase

initial app usage - `ref()` method

- with the connection to the database
  - *we may then call the `ref()`, or reference, method*
  - *use this method to read, write &c. data in the database*
- by default, if we call `ref()` with no arguments
  - *our query will be relative to the root of the database*
  - *e.g. reading, writing &c. relative to the whole database*
- we may also request a specific reference in the database
  - *pass a location path, e.g.*

```
db.ref('egypt/ancient_sites/abu_simbel/title').set('Abydos');
```

- allows us to create multiple parts of the Firebase database
- such parts might include,
  - *multiple objects, properties, and values &c.*
- a quick and easy option for organising and distributing data

Client-side - Data - Firebase

write data - intro

- also write data to the connected database
  - *again from a JavaScript based application*
- Firebase supports many different JavaScript datatypes, including
  - *strings*
  - *numbers*
  - *booleans*
  - *objects*
  - *arrays*
  - ...
- i.e. any values and data types we add to JSON
  - *n.b. Firebase may not maintain the native structure upon import*
  - *e.g. arrays will be converted to plain JavaScript objects in Firebase*

Client-side - Data - Firebase

write data - set all data

- `set` data for the whole database by calling the `ref()` method at the *root*
  - e.g.

```
db.ref().set({
  site: 'abu-simbel',
  title: 'Abu Simbel',
  date: 'c.1264 B.C.',
  visible: true,
  location: {
    country: 'Egypt',
    code: 'EG',
    address: 'aswan'
  }
  coords: {
    lat: '22.336823',
    long: '31.625532'
  }
});
```

Client-side - Data - Firebase

write data - set data for a specific data location

- also write data to a specific location in the database
- add an argument to the `ref()` method
  - *specifying required location in the database*
  - *e.g.*

```
db.ref('egypt/ancient_sites/abu_simbel/location').set('near aswan');
```

- `ref()` may be called relative to any depth in the database from the *root*
- allows us to update anything from whole DB to single property value

Client-side - Data - Firebase

Promises with Firebase

- Firebase includes native support for Promises and associated chains
  - *we do not need to create our own custom Promises*
- we may work with a return Promise object from Firebase
  - *using a standard chain, methods...*
- e.g. when we call the `set()` method
  - *Firebase will return a Promise object for the method execution*
- `set()` method will not explicitly return anything except for success or error
  - *we can simply check the return promise as follows,*

```
db.ref('egypt/ancient_sites/abu_simbel/title')
  .set('Abu Simbel')
  .then(() => {
    // log data set success to console
    console.log('data set...');
  })
  .catch((e) => {
    // catch error from Firebase - error logged to console
    console.log('error returned', e);
  });
```

Client-side - Data - Firebase

remove data - intro

- we may also delete and remove data from the connected database
- various options for removing such data, including
  - *specific location*
  - *all data*
  - *`set()` with `null`*
  - *by updating data*
  - *...*

Client-side - Data - Firebase

remove data - specify location

- we may also delete data at a specific location in the connected database
  - e.g.

```
db.ref('egypt/ancient_sites/abu_simbel/kingdom')
  .remove()
  .then(() => {
    // log data removed success to console
    console.log('data removed...');
  })
  .catch((e) => {
    // catch error from Firebase - error logged to console
    console.log('error returned', e);
  });
```

Client-side - Data - Firebase

remove data - all data

- also remove all of the data in the connected database
  - e.g.

```
db.ref()
  .remove()
  .then(() => {
    // log data removed success to console
    console.log('data removed...');
  })
  .catch((e) => {
    // catch error from Firebase - error logged to console
    console.log('error returned', e);
  });
```

Client-side - Data - Firebase

remove data - `set()` with null

- another option specified in the Firebase docs for deleting data
  - *by using `set()` method with a `null` value*
  - *e.g.*

```
db.ref('egypt/ancient_sites/abu_simbel/kingdom')
  .set(null)
  .then(() => {
    // log data removed success to console
    console.log('data set to null...');
  })
  .catch((e) => {
    // catch error from Firebase - error logged to console
    console.log('error returned', e);
  });
```

Client-side - Data - Firebase

update data - intro

- also combine setting and removing data in a single pattern
  - *using the `update()` method call to the defined database reference*
- meant to be used to update multiple items in database in a single call
- we must pass an object as the argument to the `update()` method

Client-side - Data - Firebase

update data - existing properties

- to update multiple existing properties
  - e.g.

```
db.ref('egypt/ancient_sites/abu_simbel/').update({
  title: 'The temple of Abu Simbel',
  visible: false
});
```

Client-side - Data - Firebase

update data - add new properties

- also add a new property to a specific location in the database

```
db.ref('egypt/ancient_sites/abu_simbel/').update({
  title: 'The temple of Abu Simbel',
  visible: false,
  date: 'c.1264 B.C.'
});
```

- still set new values for the two existing properties
  - *`title` and `visible`*
- add a new property and value for `data`
- `update()` method will only update the specific properties
  - *does not override everything at the reference location*
  - *compare with the `set()` method...*

Client-side - Data - Firebase

update data - remove properties

- also combine these updates with option to remove an existing property
  - *e.g.*

```
db.ref('egypt/ancient_sites/abu_simbel/').update({
  card: null,
  title: 'The temple of Abu Simbel',
  visible: false,
  date: 'c.1264 B.C.',
});
```

- `null` used to delete specific property from reference location in DB
- at the reference loaction in the DB, we're able to combine
  - *creating new property*
  - *updating a property*
  - *deleting existing properties*

Client-side - Data - Firebase

update data - multiple properties at different locations

- also combine updating data in multiple objects at different locations
  - *locations relative to initial passed reference location*
  - *e.g.*

```
db.ref().update({
  'egypt/ancient_sites/abu_simbel/visible': true,
  'egypt/ancient_sites/karnak/visible': false
});
```

- relative to the root of the dabatase
  - *now updated multiple `title` properties in different objects*
- *n.b.* update is only for child objects relative to specified ref location
  - *due to character restrictions on the property name*
  - *e.g. the name may not begin with `.`, `/` &c.*

Client-side - Data - Firebase

update data - Promise chain

- `update()` method will also return a Promise object
  - *allows us to chain the standard methods*
  - *e.g.*

```
db.ref().update({
  'egypt/ancient_sites/abu_simbel/visible': true,
  'egypt/ancient_sites/karnak/visible': false
}).then(() => {
  console.log('update success...');
}).catch((e) => {
  console.log('error = ', e);
});
```

- as with `set()` and `remove()`
  - *Promise object itself will return success or error for method call*

Client-side - Data - Firebase

read data - intro

- fetch data from the connected database in many different ways, e.g.
  - *all of the data*
  - *or a single specific part of the data*
- also connect and retrieve data once
- another option is to setup a listener
  - *used for polling the database for live updates...*

Client-side - Data - Firebase

read data - all data, once

- retrieve all data from the database a single time

```
// ALL DATA ONCE - request all data ONCE
// - returns Promise value
db.ref().once('value')
  .then((snapshot) => {
    // snapshot of the data - request the return value for the data at the time o
    const data = snapshot.val();
    console.log('data = ', data);
  })
  .catch((e) => {
    console.log('error returned - ', e);
  });
```

Client-side - Data - Firebase

read data - single data, once

- we may query the database once for a single specific value
  - e.g.

```
// SINGLE DATA - ONCE
db.ref('egypt/ancient_sites/abu_simbel/').once('value')
  .then((snapshot) => {
    // snapshot of the data - request the return value for the data at the time o
    const data = snapshot.val();
    console.log('single data = ', data);
  })
  .catch((e) => {
    console.log('error returned - ', e);
  });
```

- returns value for object at the specified location
  - *egypt/ancient_sites/abu_simbel/*

Client-side - Data - Firebase

read data - listener for changes - subscribe

- also setup listeners for changes to the connected database
  - *then continue to poll the DB for any subsequent changes*
  - *e.g.*

```
// LISTENER - poll DB for data changes
// - any changes in the data
db.ref().on('value', (snapshot) => {
  console.log('listener update = ', snapshot.val());
});
```

- `on()` method polls the DB for any changes in `value`
- then get the current snapshot value for the data stored
- any change in data in the online database
  - *listener will automatically execute defined success callback function*

Client-side - Data - Firebase

read data - listener for changes - subscribe - error handling

- also add some initial error handling for subscription callback
  - e.g.

```
// LISTENER - SUBSCRIBE
// - poll DB for data changes
// - any changes in the data
db.ref().on('value', (snapshot) => {
  console.log('listener update = ', snapshot.val());
}, (e) => {
  console.log('error reading db', e);
});
```

Client-side - Data - Firebase

read data - listener - why not use a Promise?

- as listener is notified of updates to the online database
  - *we need the callback function to be executed*
- callback may need to be executed multiple times
  - *e.g. for many updates to the stored data*
- a Promise may only be resolved a single time
  - *with either* `resolve` *or* `reject`
- to use a Promise in this context
  - *we would need to instantiate a new Promise for each update*
  - *would not work as expected*
  - *therefore, we use a standard callback function*
- a callback may be executed as needed
  - *each and every time there is an update to the DB*

Client-side - Data - Firebase

read data - listener for changes - unsubscribe

- need to *unsubscribe* from all or specific changes in online database
  - e.g.

```
db.ref().off();
```

- removes *all* current subscriptions to defined DB connection

Client-side - Data - Firebase

read data - listener for changes - unsubscribe

- also *unsubscribe* a specific subscription by passing callback
  - *callback as used for the original subscription*
- abstract the callback function
  - *pass it to both `on()` and `off()` methods for database `ref()` method*
  - *e.g.*

```
// abstract callback
const valChange = (snapshot) => {
  console.log('listener update = ', snapshot.val());
};
```

Client-side - Data - Firebase

read data - listener for changes - unsubscribe

- then pass this variable as callback argument
  - *for both subscribe and unsubscribe events*
  - *e.g.*

```
// subscribe
db.ref().on('value', valChange);
// unsubscribe
db.ref().off(valChange);
```

- allows our app to maintain the DB connection
  - *and unsubscribe a specific subscription*

Client-side - Data - Firebase

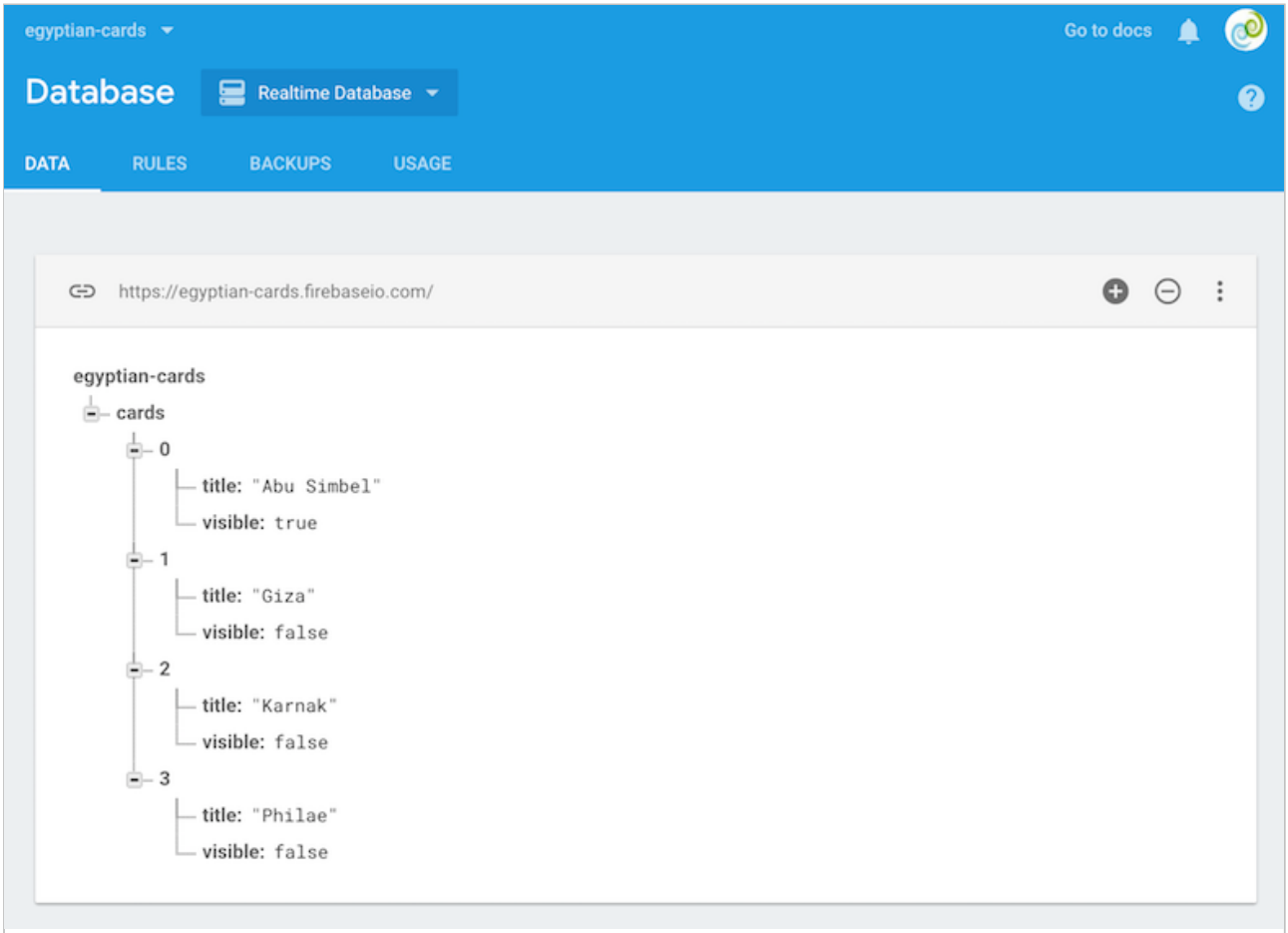
working with arrays

- Firebase does not explicitly support array data structures
  - *converts array objects to plain JavaScript objects*
- e.g. import the following JSON with an array

```
{
  "cards": [
    {
      "visible": true,
      "title": "Abu Simbel",
      "card": "temple complex built by Ramesses II"
    },
    {
      "visible": false,
      "title": "Amarna",
      "card": "capital city built by Akhenaten"
    },
    {
      "visible": false,
      "title": "Giza",
      "card": "Khufu's pyramid on the Giza plateau outside Cairo"
    },
    {
      "visible": false,
      "title": "Philae",
      "card": "temple complex built during the Ptolemaic period"
    }
  ]
}
```

Image - Firebase

JSON import with array



Firebase - import JSON file

Client-side - Data - Firebase

working with arrays - index values

- each index value will now be stored as a plain object
  - *with an auto-increment value for the property*
  - *e.g.*

```
cards: {
  0: {
    card: "temple complex built by Ramesses II",
    title: "Abu Simbel",
    visible: "true"
  }
}
```

Client-side - Data - Firebase

working with arrays - access index values

- we may still access each index value from the original array object
  - *without easy access to pre-defined, known unique references*
- e.g. to access the title value of a given card
  - *need to know its auto-generated property value in Firebase*

```
db.ref('cards/0')
```

- reference will be the path to the required object
  - *then access a given property on the object*
- even if we add a unique reference property to each card
  - *still need to know assigned property value in Firebase*

Client-side - Data - Firebase

working with arrays - `push()` method

- add new content to an existing Firebase datastore
- we may use the `push()` method to add this data
- a unique property value will be auto-generated for pushed data
  - e.g.

```
// push new data to specific reference in db
db.ref('egypt/ancient_sites/').push({
  "philae": {
    "kingdom": "upper",
    "visible": false
  }
});
```

- new data created with auto-generated ID for parent object
  - e.g.

```
LPcdS31H_u9NOdIn27_
```

- may be useful for dynamic content pushed to a datastore
- e.g. notes, tasks, calendar dates &c.

Client-side - Data - Firebase

working with arrays - Firebase `snapshot` methods

- various data snapshot methods in the Firebase documentation
- commonly used method with `snapshot` is the `val()` method
- many additional methods specified in API documentation for *DataSnapshot*
  - *e.g. `forEach()` - iterator for plain objects from Firebase*
  - *Firebase Docs - DataSnapshot*

Client-side - Data - Firebase

working with arrays - create array from Firebase data

- as we store data as plain objects in Firebase
  - *need to consider how we may work with array-like structures*
  - *i.e. for technologies and patterns that require array data structures*
  - *e.g. Redux*
- need to get data from Firebase, then prepare it for use as an array
- to help us work with Firebase object data and arrays
  - *we may call `forEach()` method on the return `snapshot`*
  - *provides required iterator for plain objects stored in Firebase*
  - *e.g.*

```
// get ref in db once
// call forEach() on return snapshot
// push values to local array
// unique id for each DB parent object is `key` property on snapshot
db.ref('egypt/ancient_sites')
  .once('value')
  .then((snapshot) => {
    const sites = [];
    snapshot.forEach((siteSnapshot) => {
      sites.push({
        id: siteSnapshot.key,
        ...siteSnapshot.val()
      });
    });
    console.log('sites array = ', sites);
  });
```

Image - Firebase

snapshot `forEach()` - creating a local array

Firebase - local array

- we now have a local array from the Firebase object data
  - *use with options such as Redux...*

Client-side - Data - Firebase

add listeners for value changes

- as we modify objects, properties, values &c. in Firebase
  - *set listeners to return notifications for such updates*
  - *e.g. add a single listener for any update relative to full datastore*

```
// LISTENER - SUBSCRIBE - v.2
// - get all data & then push return data to local array...
db.ref('egypt').on('value', (snapshot) => {
  const sites = [];
  snapshot.forEach((siteSnapshot) => {
    sites.push({
      id: siteSnapshot.key,
      ...siteSnapshot.val()
    });
  });
  console.log('sites array after update = ', sites);
});
```

- the on( ) method does not return a Promise object
  - *we need to define a callback for the return data*

Client-side - Data - Firebase

listener events - intro

- for subscriptions and updates
  - *Firebase provides a few different events*
- for the `on()` method, we may initially consult the following documentation
- Firebase docs - `on()` events
- need to test various listeners for datastore updates

Client-side - Data - Firebase

listener events - `child_removed` event

- add a subscription for event updates
  - *as a child object is removed from the data store.*
- `child_removed` event may be added as follows,

```
// - listen for child_removed event relative to current ref path in DB
db.ref('egypt/ancient_sites/').on('child_removed', (snapshot) => {
  console.log('child removed = ', snapshot.key, snapshot.val());
});
```

Client-side - Data - Firebase

listener events - `child_changed` event

- also listen for the `child_changed` event
  - *relative to the current path passed to `ref()`*
  - *e.g.*

```
// - listen for child_changed event relative to current ref path in DB
db.ref('egypt/ancient_sites/').on('child_changed', (snapshot) => {
  console.log('child changed = ', snapshot.key, snapshot.val());
});
```

Client-side - Data - Firebase

listener events - `child_added` event

- another common event is adding a new child to the data store
  - *a user may create and add a new note or to-do item...*
  - *e.g. new child added to specified reference*

```
// - listen for child_added event relative to current ref path in DB
db.ref('egypt/ancient_sites/').on('child_added', (snapshot) => {
  console.log('child added = ', snapshot.key, snapshot.val());
});
```

Client-side - Data - Firebase

extra notes

- Firebase - authentication
- Firebase - setup & usage

Data visualisation

intro - part 1

- data visualisation - study of how to visually communicate and analyse data
- covers many disparate aspects
  - *including infographics, exploratory tools, dashboards...*
- already some notable definitions of data visualisation
- one of the better known examples,

> *"Data visualisation is the representation and presentation of data that exploits our visual perception in order to amplify cognition."*
>
> *(Kirk, A. "Data Visualisation: A successful design process." Packt Publishing. 2012.)*

- several variants of this general theme exist
  - *the underlying premise remains the same*
- simply, data visualisation is a visual representation of the underlying data
- visualisation aims to impart a better understanding of this data
  - *by association, its relevant context*

Data visualisation

intro - part 2

- an inherent flip-side to data visualisation
- without a correct understanding of its application
  - *it can simply impart a false perception, and understanding, on the dataset*
- run the risk of creating many examples of standard **areal unit** problem
  - *perception often based on creator's base standard and potential bias*
- inherently good at seeing what we want to see
- without due care and attention visualisations may provide false summations of the data

Data visualisation

types - part 1

- many different ways to visualise datasets
  - *many ways to customise a standard infographic*
- some standard examples that allow us to consider the nature of visualisations
  - *infographics*
  - *exploratory visualisations*
  - *dashboards*
- perceived that data visualisation is simply a variation between
  - *infographics, exploratory tools, charts, and some data art*

1. infographics
   - *well suited for representing large datasets of contextual information*
   - *often used in projects more inclined to exploratory data analysis,*
   - *tend to be more interactive for the user*
   - *data science can perceive infographics as improper data visualisation because*
   - *they are designed to guide a user through a story*
   - *the main facts are often already highlighted*
   - ***NB:*** *such classifications often still only provide tangible reference points*

Data visualisation

types - part 2

2. exploratory visualisations
   - *more interested in the provision of tools to explore and interpret datasets*
   - *visualisations can be represented either static or interactive*
   - *from a user perspective these charts can be viewed*
   - *either carefully*
   - *simply become interactive representations*
   - *both perspectives help a user discover new and interesting concepts*
   - *interactivity may include*
   - *option for the user to filter the dataset*
   - *interact with the visualisation via manipulation of the data*
   - *modify the resultant information represented from the data*
   - *often perceived as more objective and data oriented than other forms*
3. dashboards
   - *dense displays of charts*
   - *represent and understand a given issue, domain...*
   - *as quickly and effectively as possible*
   - *examples of dashboards*
   - *display of server logs, website users, business data...*

Data visualisation

Dashboards - intro

- dashboards are dense displays of charts
- allow us to represent and understand the key **metrics** of a given issue
  - *as quickly and effective as possible*
  - *eg: consider display of server logs, website users, and business data...*
- one definition of a dashboard is as follows,

> *"A dashboard is a visual display of the most important information needed to achieve one or more objective; consolidated and arranged on a single screen so the information can be monitored at a glance."*
>
> *Few, Stephen. Information Dashboard Design: The Effective Visual Communication of Data. O'Reilly Media. 2006.*

- dashboards are visual displays of information
  - *can contain text elements*
  - *primarily a visual display of data rendered as meaningful information*

Data visualisation

Dashboards - intro

- information needs to be consumed quickly
- often simply no available time to read long annotations or repeatedly click controls
- information needs to be visible, and ready to be consumed
- dashboards are normally presented as a complementary environment
- an option to other tools and analytical/exploratory options
- design issues presented by dashboards include effective distribution of available space
- compact charts that permit quick data retrieval are normally preferred
- dashboards should be designed with a purpose in mind
- generalised information within a dashboard is rarely useful
- display most important information necessary to achieve their defined purpose
- a dashboard becomes a central view for collated data
- represented as meaningful information

Data visualisation

Dashboards - good practices

- to help promote our information
  - *need to design the dashboard to fully exploit available screen space*
- need to use this space to help users absorb as much information as possible
- some visual elements more easily perceived and absorbed by users than others
- some naturally convey and communicate information more effectively than others
- such attributes are known as **pre-attentive attributes of visual perception**
- for example,
  - *colour*
  - *form*
  - *position*

Data visualisation

Dashboards - visual perception

- pre-attentive attributes of visual perception

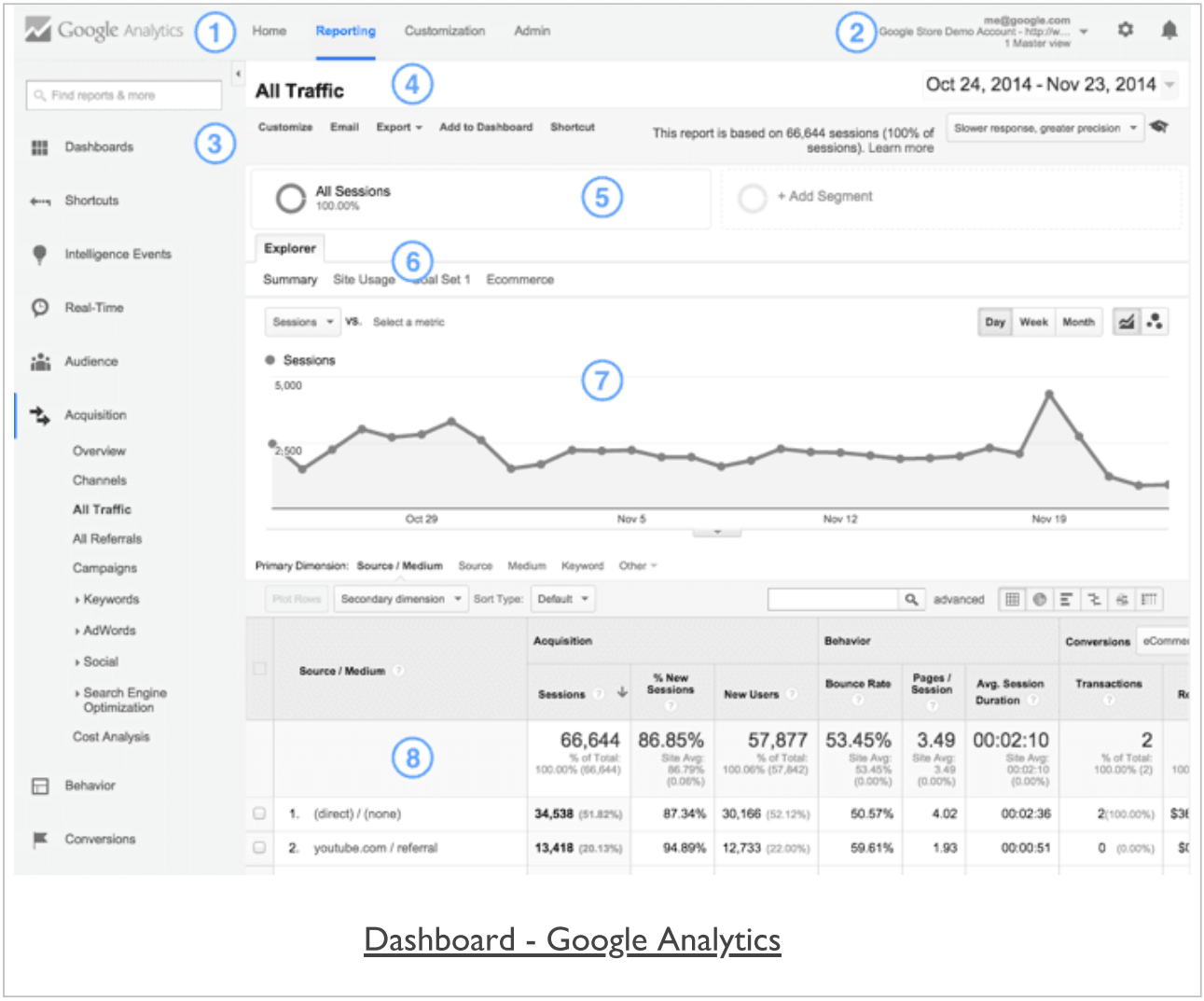
1. *Colour*
   - *many different colour models currently available*
   - *most useful relevant to dashboard design is the HSL model*
   - *this model describes colour in terms of three attributes*
     - *hue*
     - *saturation*
     - *lightness*
   - *perception of colour often depends upon context*
2. *Form*
   - *correct use of length, width, and general size can convey quantitative dimensions*
   - *each with varying degrees of precision*
   - *use the Laws of Prägnanz to manipulate groups of similar shapes and designs*
   - *thereby easily grouping like data and information for the user*
3. *Position*
   - *relative positioning of elements helps communicate dashboard information*
   - *laws of Prägnanz teach us*
   - *position can often infer a perception of relationship and similarity*
   - *higher items are often perceived as being better*
   - *items on the left of the screen traditionally seen first by a western user*

Data visualisation

Building a dashboard

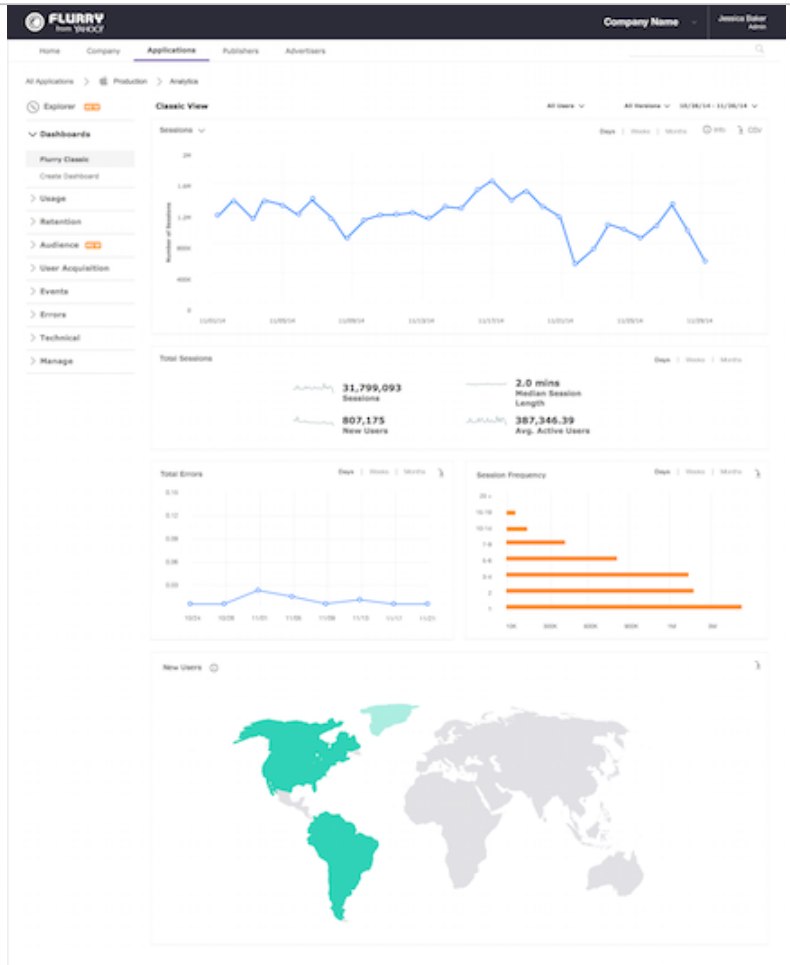
- need to clearly determine the questions that need to be answered
  - *given the information collated and presented within the dashboard*
- need to ensure that any problems can be detected on time
- be certain why we actually need a dashboard for the current dataset
- then begin to collect the requisite data to help us answer such questions
  - *data can be sourced from multiple, disparate datasets*
- chosen visualisations help us tell this story more effectively
- present it in a manner appealing to our users
- need to consider information visualisations familiar to our users
  - *helps reduce any potential user's cognitive overload*
- carefully consider organisation of data and information
- organise the data into logical units of information
  - *helps present dashboard information in a meaningful manner*
- dashboard sections should be organised
  - *to help highlight and detect any underlying or prevailing issues*
  - *then present them to the user*

Image - Google Analytics



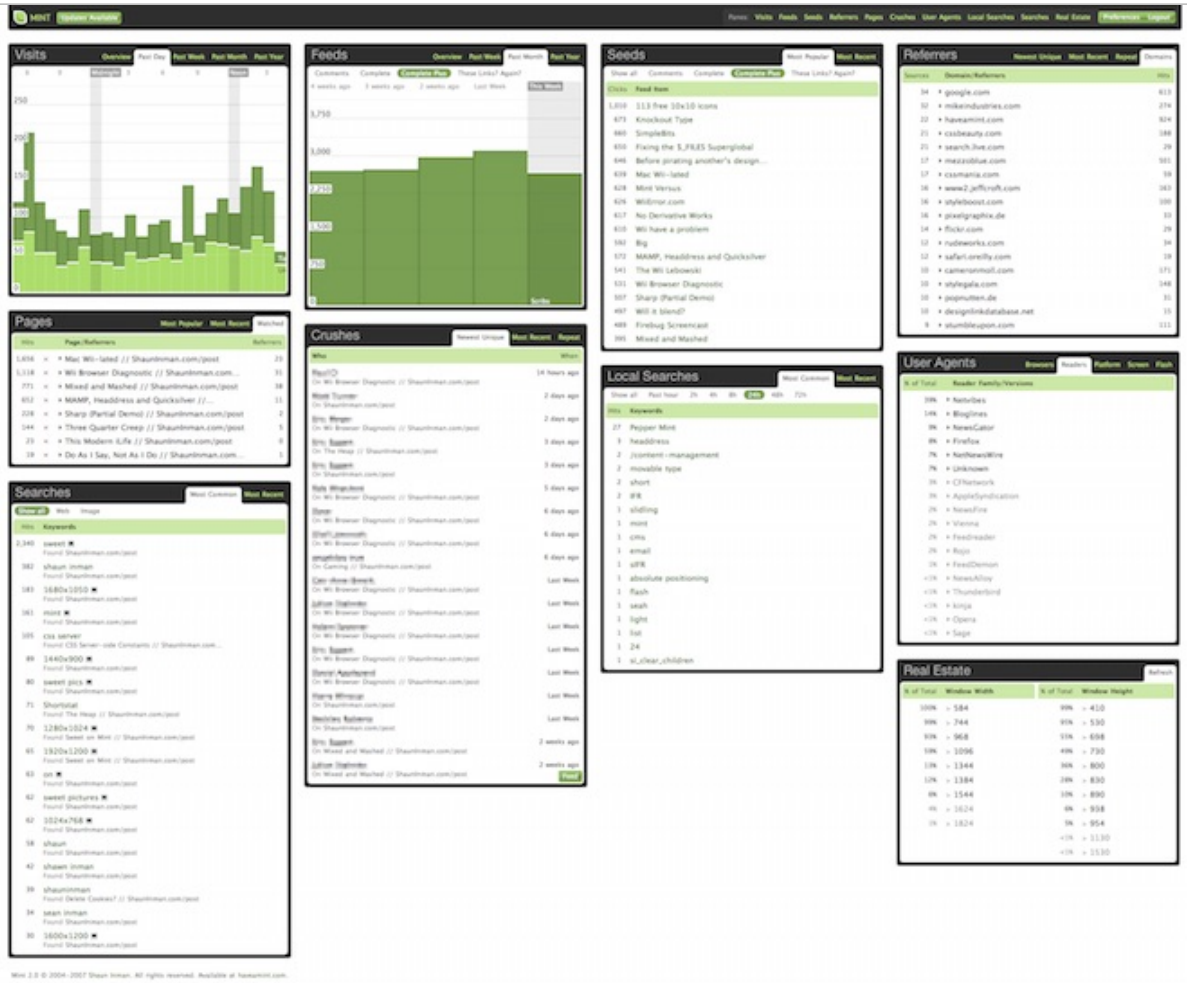
Dashboard - Google Analytics

Image - Yahoo Flurry



Dashboard - Yahoo Flurry

Image - Mint



Dashboard - Mint

Data visualisation - D3

Intro - part 1

- D3 is a custom JavaScript library
  - *designed for the manipulation of data centric documents*
  - *uses a custom library with HTML, CSS, and SVG*
  - *creates graphically rich, informative documents for the presentation of data*
- D3 uses a data-driven approach to manipulate the DOM
- Setup and configuration of D3 is straightforward
  - *most involved aspect is the configuration of a web server*
- D3.js works with standard HTML files
  - *requires a web server capable of parsing and rendering HTML...*
- to parse D3 correctly we need
  - *UTF-8 encoding reference in a meta element in the head section of our file*
  - *reference D3 file, CDN in standard script element in HTML*

Data visualisation - D3

intro - part 2

- D3 Wiki describes the underlying functional concepts as follows,

> *D3's functional style allows code reuse through a diverse collection of components and plugins.*
>
> *D3 Wiki*

- in JS, functions are objects
  - *as with other objects, a function is a collection of a name and value pair*
- real difference between a function object and a regular object
  - *a function can be invoked, and associated, with two hidden properties*
  - *include a function context and function code*
- variable resolution in D3 relies on variable searching being performed locally first
- if a variable declaration is not found
  - *search will continue to the parent object*
  - *continue recursively to the next static parent*
  - *until it reaches global variable definition*
  - *if not found, a reference error will be generated for this variable*
- important to keep this static scoping rule in mind when dealing with D3

Data visualisation - D3

Data Intro - part 1

- Data is structured information with an inherent perceived potential for meaning
- consider data relative to D3
  - *need to know how data can be represented*
  - *both in programming constructs and its associated visual metaphor*
- what is the basic difference between data and information?

> *Data are raw facts. The word raw indicates that the facts have not yet been processed >>> to reveal their meaning...Information is the result of processing raw data to reveal >>> its meaning.*
>
> *Rob, Morris, and Coronel. 2009*

- a general concept of data and information
- consider them relative to visualisation, impart a richer interpretation
- information, in this context, is no longer
  - *the simple result of processed raw data or facts*
  - *it becomes a visual metaphor of the facts*
- same data set can generate any number of visualisations
  - *may lay equal claim in terms of its validity*
- visualisation is communicating creator's insight into data...

Data visualisation - D3

Data Intro - part 2

- relative to development for visualisation
  - *data will often be stored simply in a text or binary format*
- not simply textual data, can also include data representing
  - *images, audio, video, streams, archives, models...*
- for D3 this concept may often simply be restricted to
  - *textual data, or text-based data...*
  - *any data represented as a series of numbers and strings containing alpha numeric characters*
- suitable textual data for use with D3
  - *text stored as a comma-separated value file (.csv)*
  - *JSON document (.json)*
  - *plain text file (.txt)*
- data can then be *bound* to elements within the DOM of a page using D3
  - *inherent pattern for D3*

Data visualisation - D3

Data Intro - Enter-Update-Exit Pattern

- in D3, connection between data and its visual representation
  - *usually referred to as the* ***enter-update-exit*** *pattern*
- concept is starkly different from the standard imperative programming style
- pattern includes
  - *enter mode*
  - *update mode*
  - *exit mode*

Data visualisation - D3

Data Intro - Enter-Update-Exit Pattern

Enter mode

- `enter()` function returns all specified data that not yet represented in visual domain
- standard modifier function chained to a selection method
  - *create new visual elements representing given data elements*
  - *eg: keep updating an array, and outputting new data bound to elements*

Update mode

- `selection.data(data)` function on a given selection
  - *establishes connection between data domain and visual domain*
- returned result of intersection of data and visual will be a **data-bound** selection
- now invoke a modifier function on this newly created selection
  - *update all existing elements*
  - *this is what we mean by an **update** mode*

Exit mode

- invoke `selection.data(data).exit` function on a data-bound selection
  - *function computes new selection*
  - *contains all visual elements no longer associated with any valid data element*
- eg: create a bar chart with 25 data points
  - *then update it to 20, so we now have 5 left over*
  - ***exit mode** can now remove excess elements for 5 spare data points*

Data visualisation - D3

Data Intro - binding data - part 1

- consider standard patterns for working with data
- we can iterate through an array, and then bind the data to an element
  - *most common option in D3 is to use the **enter-update-exit** pattern*
- use same basic pattern for binding object literals as data
- to access our data we call the required attribute of the supplied data

```
var data = [
    {height: 10, width: 20},
    {height: 15, width: 25}
];

function (d) {
    return (d.width) + "px";
}
```

- then access the **height** attribute per object in the same manner
- we can also bind functions as data
  - *D3 allows functions to be treated as data...*

Data visualisation - D3

Data Intro - binding data - part 2

- D3 enables us to bind data to elements in the DOM
  - *associating data to specific elements*
  - *allows us to reference those values later*
  - *so that we can apply required mapping rules*
- use D3's `selection.data()` method to bind our data to DOM elements
  - *we obviously need some data to bind, and a selection of DOM elements*
- D3 is particularly flexible with data
  - *happily accepts various types*
- D3 also has a built-in function to handle loading JSON data

```
d3.json("testdata.json", function(json) {
    console.log(json); //do something with the json...
});
```

Data visualisation - D3

Data Intro - working with arrays - options

- min and max = return the min and max values in the passed array

```
d3.select("#output").text(d3.min(ourArray));
d3.select("#output").text(d3.max(ourArray));
```

- extent = retrieves both the smallest and largest values in the the passed array

```
d3.select("#output").text(d3.extent(ourArray));
```

- sum

```
d3.select("#output").text(d3.sum(ourArray));
```

- median

```
d3.select("#output").text(d3.median(ourArray));
```

- mean

```
d3.select("#output").text(d3.mean(ourArray));
```

- asc and desc

```
d3.select("#output").text(ourArray.sort(d3.ascending));
d3.select("#output").text(ourArray.sort(d3.descending));
```

- & many more...

Data visualisation - D3

Data Intro - working with arrays - nest

- D3's nest function used to build an algorithm
  - *transforms a flat array data structure into a hierarchical nested structure*
- function can be configured using the key function chained to **nest**
- nesting allows elements in an array to be grouped into a hierarchical tree structure
  - *similar in concept to the group by option in SQL*
  - ***nest** allows multiple levels of grouping*
  - *result is a tree rather than a flat table*
- levels in the tree are defined by the *key* function
- leaf nodes of the tree can be sorted by value
- internal nodes of the tree can be sorted by key

Data visualisation - D3

Selections - intro

- **Selection** is one of the key tasks required within D3 to manipulate and visualise our data
- simply allows us to target certain visual elements on a given page
- Selector support is now standardised upon the W3C specification for the Selector API
  - *supported by all of the modern web browsers*
  - *its limitations are particularly noticeable for work with visualising data*
- Selector API only provides support for selector and not selection
  - *able to select an element in the document*
  - *to manipulate or modify its data we need to implement a standard loop etc*
- D3 introduced its own selection API to address these issues and perceived shortcomings
  - *ability to select elements by ID or class, its attributes, set element IDs and class, and so on...*

Data visualisation - D3

Selections - single element

- select a single element within our page

```
d3.select("p");
```

- now select the first <p> element on the page, and then allow us to modify as necessary
  - *eg; we could simply add some text to this element*

```
d3.select("p")
.text("Hello World");
```

- selection could be a generic element, such as <p>
  - *or a specific element defined by targeting its ID*
- use additional modifier functions, such as `attr`, to perform a given modification on the selected element

```
//set an attribute for the selected element
d3.select("p").attr("foo");
//get the attribute for the selected element
d3.select("p").attr("foo");
```

- also add or remove classes on the selected element

```
//test selected element for specified class
d3.select("p").classed("foo")
//add a class to the selected element
d3.select("p").classed("goo", true);
//remove the specified class from the selected element
d3.select("p").classed("goo", function(){ return false; });
```

Data visualisation - D3

Selections - multiple elements

- also select all of the specified elements using D3

```
d3.selectAll("p")
.attr("class", "para");
```

- use and implement multiple element selection
  - *same as single selection pattern*
- also use the same modifier functions
- allows us to modify each element's attributes, style, class...

Data visualisation - D3

Selections - iterating through a selection

- D3 provides us with a selection iteration API
  - *allows us to iterate through each selection*
  - *then modify each selection relative to its position*
  - *very similar to the way we normally loop through data*

```
d3.selectAll("p")
.attr("class", "para")
.each(function (d, i) {
    d3.select(this).append("h1").text(i);
});
```

- D3 selections are essentially like arrays with some enhancements
  - *use the iterative nature of Selection API*

```
d3.selectAll('p')
.attr("class", "para2")
.text(function(d, i) {
    return i;
});
```

Data visualisation - D3

Selections - performing sub-selection

- for selections - often necessary to perform specific scope requests
  - *eg: selecting all <p> elements for a given element*

```
//direct css selector (selector level-3 combinators)
d3.select("div > p")
    .attr("class", "para");

//d3 style scope selection
d3.select("div")
    .selectAll("p")
    .attr("class", "para");
```

- both examples produce the same effect and output, but use very different selection techniques
  - *first example uses the CSS3, level-3, selectors*
  - *`div > p` is known as combinators in CSS syntax*

Data visualisation - D3

Selections - combinators

Example combinators..

1. descendant combinator

- uses the pattern of `selector selector` - describing loose parent-child relationship
- loose due to possible relationships - parent-child, parent-grandchild...

```
d3.select("div p");
```

- select the <p> element as a child of the parent element
  - *relationship can be generational*

2. child combinator

- uses same style of syntax, `selector > selector`
- able to describe a more restrictive **parent-child** relationship between two elements

```
d3.select("div > p");
```

- finds <p> element if it is a direct child to the element

Data visualisation - D3

Selections - D3 sub-selection

- sub-selection using D3's built-in selection of child elements
- a simple option to select an element, then chain another selection to get the child element
- this type of chained selection defines a scoped selection within D3
  - *eg: selecting a <p> element nested within our selected element*
  - *each selection is, effectively, independent*
- D3 API built around the inherent concept of function chaining
  - *can almost be considered a Domain Specific Language for dynamically building HTML/SVG elements*
- a benefit of chaining = easy to produce concise, readable code

```
var body = d3.select("body");

body.append("div")
    .attr("id", "div1")
  .append("p")
    .attr("class", "para")
  .append("h5")
    .text("this is a paragraph heading...");
```

Data visualisation - D3

Data Intro - page elements

- generation of new DOM elements normally fits
  - *either circles, rectangles, or some other visual form that represents the data*
- D3 can also create generic structural elements in HTML, such as a <p>
  - *eg: we can append a standard p element to our new page*

```
d3.select("body").append("p").text("sample text...");
```

- used D3 to select `body` element, then append a new <p> element with text "new paragraph"
- D3 supports *chain syntax*
  - *allowed us to `select`, `append`, and add `text` in one statement*

Data visualisation - D3

Data Intro - page elements

```
d3.select("body").append("p").text("sample text...");
```

- `d3`
  - *references the D3 object, access its built-in methods*
- `.select("body")`
  - *accepts a CSS selector, returns first instance of the matched selector in the document's DOM*
  - *`.selectAll()`*
  - ***NB:** this method is a variant of the single `select()`*
  - *returns all of the matched CSS selectors in the DOM*
- `.append("p")`
  - *creates specified new DOM element*
  - *appends it to the end of the defined select CSS selector*
- `.text("new paragraph")`
  - *takes defined string, "new paragraph"*
  - *adds it to the newly created <p> DOM element*

Data visualisation - D3

Binding data - making a selection

- choose a selector within our document
  - *eg: we could select all of the paragraphs in our document*

```
d3.select("body").selectAll("p");
```

- if the element we require does not yet exist
  - *need to use the method* `enter()`

```
d3.select("body").selectAll("p").data(dataset).enter().append("p").text("new para
```

- we get new paragraphs that match total number of values currently available in the **dataset**
  - *akin to looping through an array*
  - *outputting a new paragraph for each value in the array*
- create new, data-bound elements using `enter()`
  - *method checks the current DOM selection, and the data being assigned to it*
- if more data values than matching DOM elements
  - `enter()` *creates a new placeholder element for the data value*
  - *then passes this placeholder on to the next step in the chain, eg:* `append()`
- data from dataset also assigned to new paragraphs
- **NB:** when D3 binds data to a DOM element, it does not exist in the DOM itself
  - *it does exist in the memory*

Data visualisation - D3

Binding data - using the data

- change our last code example as follows,

```
d3.select("body").selectAll("p").data(dataset).enter().append("p").text(function(
```

- then load our HTML, we'll now see dataset values output instead of fixed text
- anytime in the chain after calling the `data()` method
  - *we can then access the current data using d*
- also bind other things to elements with D3, eg: CSS selectors, styles...

```
.style("color", "blue");
```

- chain the above to the end of our existing code
  - *now bind an additional css style attribute to each <p> element*
  - *turning the font colour blue*
- extend code to include a conditional statement that checks the value of the data
  - *eg: simplistic striped colour option*

```
.style("color", function(d) {
if (d % 2 == 0) {
return "green";
} else {
 return "blue";
}
});
```

- DEMO - D3 basic elements

Image - D3 Basic Elements

D3 - basic elements

Data visualisation - D3

Drawing - intro - part 1

1. drawing divs

- one of the easiest ways to draw a rectangle, for example, is with a HTML `<div>`
- an easy way to start drawing a bar chart for our stats
- start with standard HTML elements, then consider more powerful option of drawing with SVG
- semantically incorrect, we could use `<div>` to output bars for a bar chart
  - *use of an empty `<div>` for purely visual effect*
- using D3, add a class to an empty element using `selection.attr()` method

2. setting attributes

- `attr()` is used to set an HTML attribute and its value on an element
- After selecting the required element in the DOM
  - *assign an attributes as follows*

```
.attr("class", "barchart")
```

Data visualisation - D3

Drawing - intro - part 2

- use D3 to draw a set of bars in divs as follows

```
var dataset = [ 1, 2, 3, 4, 5 ];

d3.select("body").selectAll("div")
    .data(dataset)
    .enter()
    .append("div")
    .attr("class", "bar");
```

- above sample outputs the values from our dataset with no space between them
  - *effectively as a bar chart of equal height*
- modify the height of each representative bar
  - *by setting height of each bar as a function of its corresponding data value*
  - *eg: append the following to our example chain*

```
.style("height", function(d) {
    return d + "px";
});
```

- make each bar in our chart more clearly defined by modifying `style`

```
.style("height", function(d) {
    var barHeight = d * 3;
    return barHeight + "px";
});
```

Data visualisation - D3

Drawing - intro - part 3

1. drawing SVGs

- properties of SVG elements are specified as **attributes**
- represented as property/value pairs within each element tag

```
<element property="value">...</element>
```

- SVG elements exist in the DOM
  - *we can still use D3 methods `append()` and `attr()`*
  - *create new HTML elements and set their attributes*

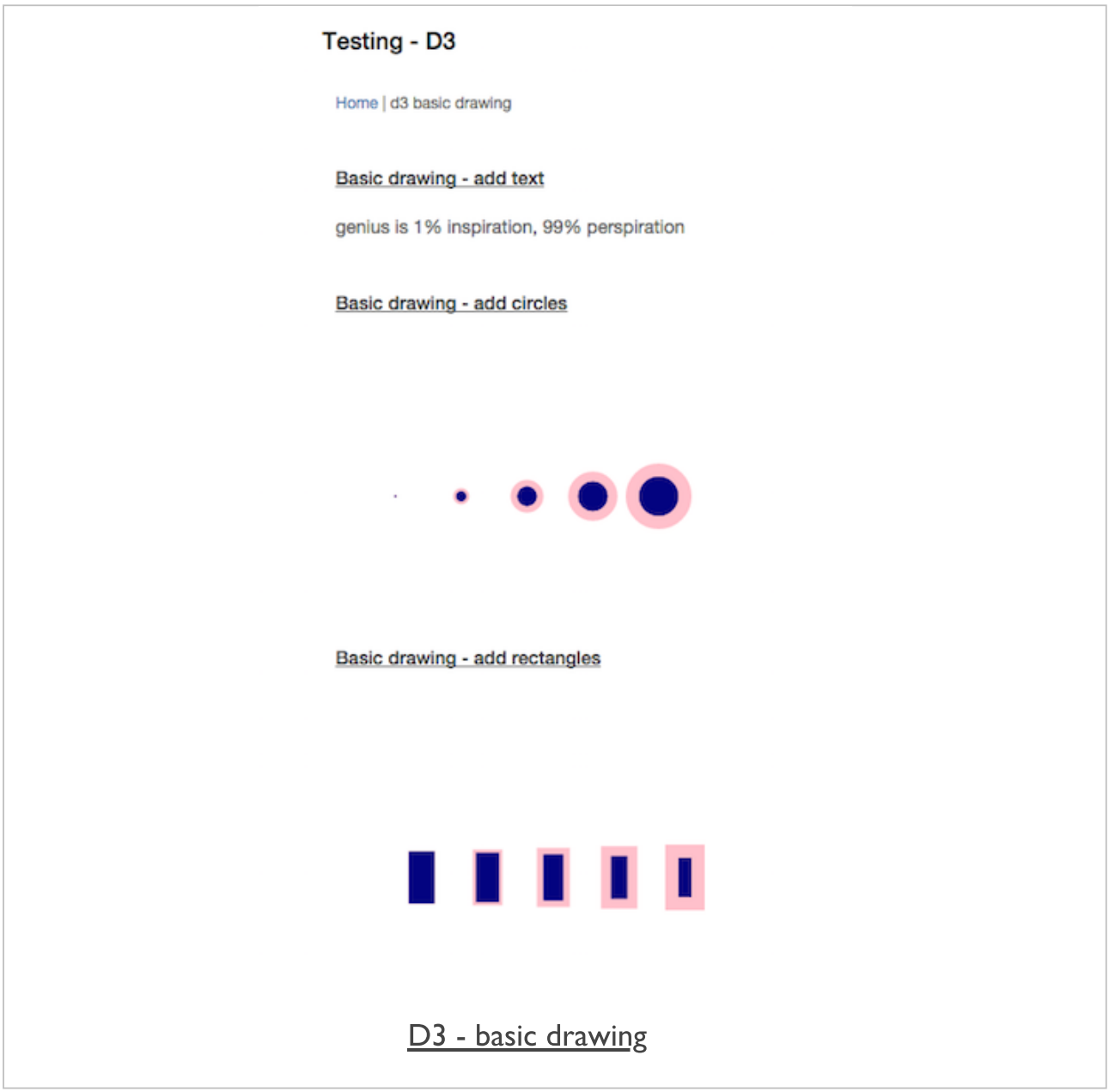
2. create SVG

- need to create an element for our SVG
- allows us to draw and output all of our required shapes

```
d3.select("body").append("svg");
```

- variable effectively works as a reference
  - *points to the newly created SVG object*
  - *allows us to use this reference to access this element in the DOM*
- DEMO - Drawing with SVG

Image - D3 Basic Drawing



D3 - basic drawing

Data visualisation - D3

Drawing - SVG barchart - part 1

- create a new barchart using SVG, need to set the required size for our SVG output

```
//width & height
var w = 750;
var h = 200;
```

- then use D3 to create an empty SVG element, and add it to the DOM

```
var svg = d3.select("body")
    .append("svg")
    .attr("width", w)
    .attr("height", h);
```

- instead of creating DIVs as before, we generate *rects* and add them to the *svg* element.

```
svg.selectAll("rect")
    .data(dataset)
    .enter()
    .append("rect")
    .attr("x", 0)
    .attr("y", 0)
    .attr("width", 10)
    .attr("height", 50);
```

Data visualisation - D3

Drawing - SVG barchart - part 2

- this code selects all of the `rect` elements within `svg`
- initially none, D3 still needs to select them before creating them
- `data()` then checks the number of values in the specified dataset
  - *hands those values to the `enter` method for processing*
- `enter` method then creates a placeholder
  - *for each data value without a corresponding `rect`*
  - *also appends a rectangle to the DOM for each data value*
- then use `attr` method to set `x, y, width, height` values for each rectangle
- still only outputs a single bar due to an overlap issue
- need to amend our code to handle the width of each bar
  - *implement flexible, dynamic coordinates to fit available SVG width and height*
  - *visualisation scales appropriately with the supplied data*

```
.attr("x", function(d, i) {
    return i * (w / dataset.length);
})
```

Data visualisation - D3

Drawing - SVG barchart - part 3

- now linked the `x` value directly to the width of the SVG `w`
  - *and the number of values in the dataset, `dataset.length`*
  - *the bars will be evenly spaced regardless of the number of values*
- if we have a large number of data values
  - *bars still look like one horizontal bar*
  - *unless there is sufficient width for parent SVG and space between each bar*
- try to solve this as well by setting the bar width to be proportional
  - *narrower for more data, wider for less data*

```
var w = 750;
var h = 200;
var barPadding = 1;
```

- now set each bar's width
  - *as a fraction of the SVG width and number of data points, minus our padding value*

```
.attr("width", w / dataset.length - barPadding)
```

- our bar widths and x positions scale correctly regardless of data values

Data visualisation - D3

Drawing - SVG barchart - part 4

- encode our data as the *height* of each bar

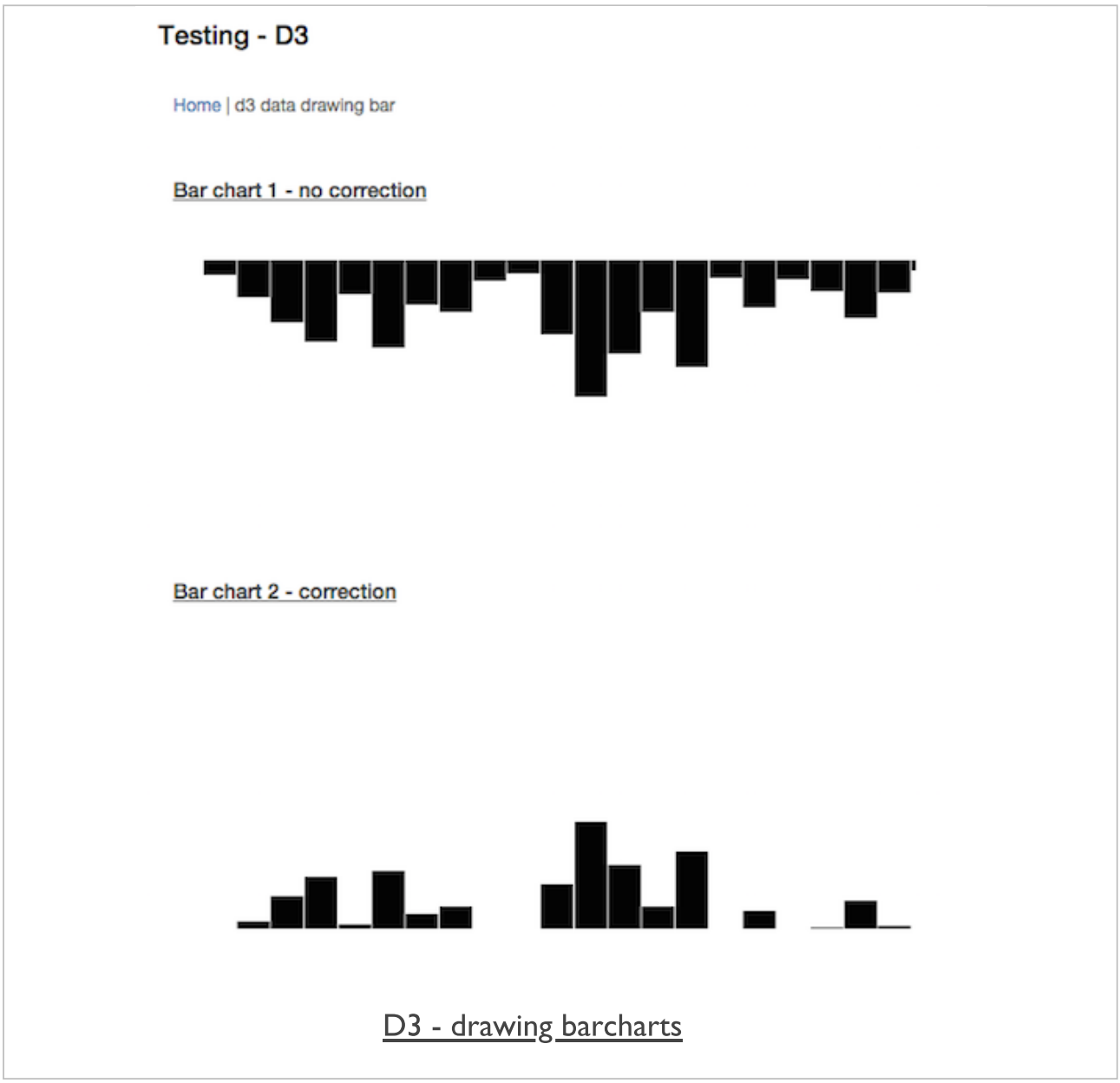
```
.attr("height", function(d) {
    return d * 4;
});
```

- our bar chart will size correctly, albeit from the top down
  - *due to the nature of SVG*
  - *SVG adheres to a top left pattern for rendering shapes*
- to correct this issue
  - *need to calculate the top position of our bars relative to the SVG*
- top of each bar expressed as a relationship
  - *between the height of the SVG and the corresponding data value*

```
.attr("y", function(d) {
    //height minus data value
    return h - d;
})
```

- bar chart will now display correctly from the bottom upwards
- DEMO - Drawing with SVG - barcharts

Image - D3 Barcharts



D3 - drawing barcharts

Data visualisation - D3

Drawing - SVG barchart - part 5

1. add some colour

- adding a colour per bar simply a matter of setting an attribute for the fill colour

```
.attr("fill", "blue");
```

- set many colours using the data itself to determine the colour

```
.attr("fill", function(d) {
    return "rgb(0, 0, " + (d * 10) + ")";
});
```

2. add text labels

- also set dynamic text labels per bar, which reflect the current dataset

```
svg.selectAll("text")
.data(dataset)
.enter()
.append("text")
```

- extend this further by positioning our text labels

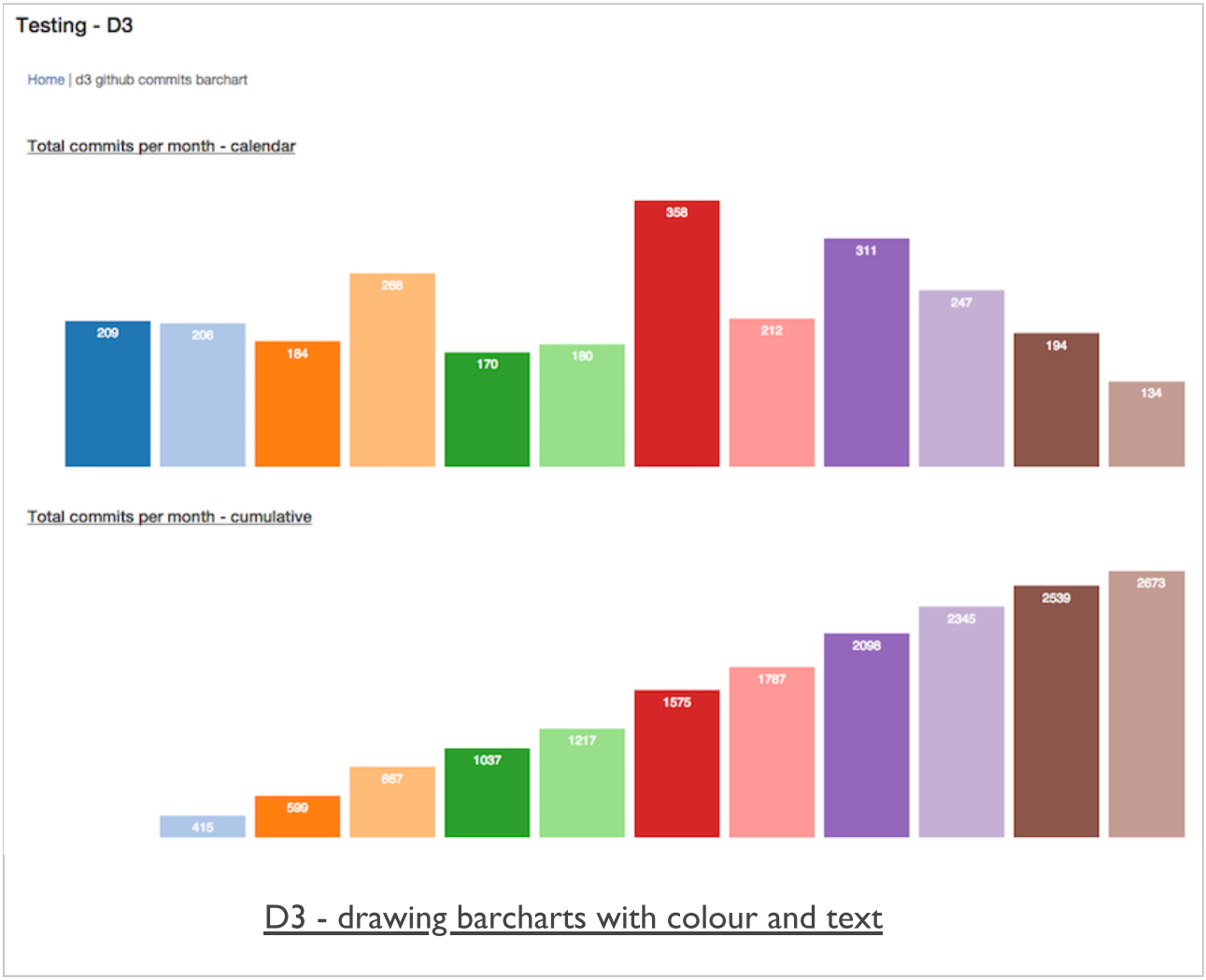
```
.attr("x", function(d, i) {
    return i * (w / dataset.length);
})
.attr("y", function(d, i) {
    return h - (d * 4);
});
```

- then position them relative to the applicable bars, add some styling, colours...

```
.attr("font-family", "sans-serif")
.attr("font-size", "11px")
.attr("fill", "white");
```

- DEMO - Drawing with SVG - barcharts, colour, and text labels

Image - D3 Barcharts



D3 - drawing barcharts with colour and text

Data visualisation - D3

Drawing - add interaction - listeners

- event listeners apply to any DOM element for interaction
  - *from a button to a <p> with the body of a HTML page*

```
<p>this is a HTML paragraph...</p>
```

- add a listener to this DOM element

```
d3.select("p")
    .on("click", function() {
    //do something with the element...
    });
```

- above sample code selects the <p> element
  - *then adds an event listener to that element*
- *event listener* is an anonymous function
  - *listens for* `.on` *event for a specific element or group of elements*
- in our example,
  - `on()` *function takes two arguments*

Data visualisation - D3

Drawing - add interaction - update visuals

- achieved by combining
  - *event listener*
  - *modification of the visuals relative to changes in data*

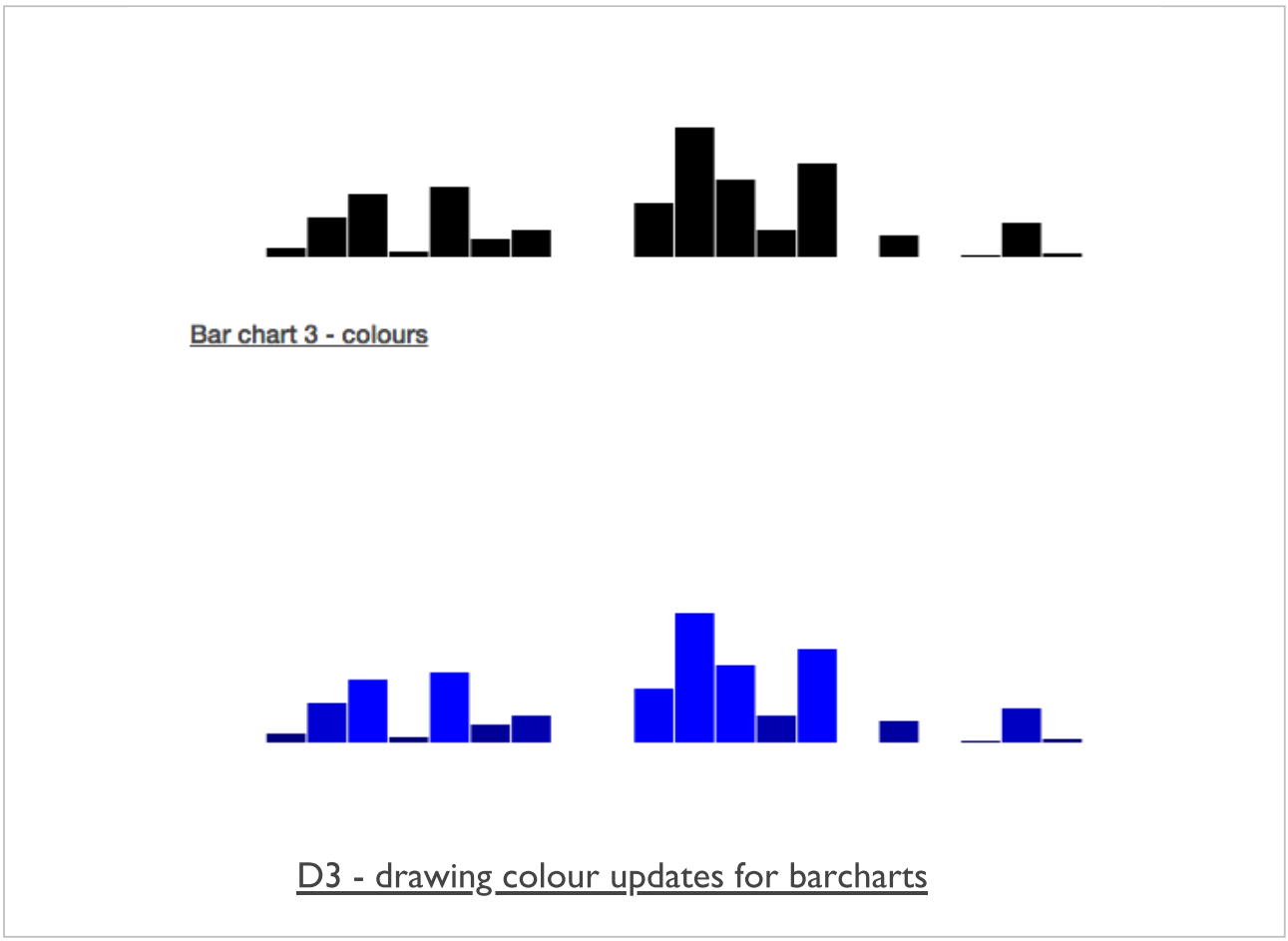
```
d3.select("p")
    .on("click", function() {

    dataset = [....];

    //update all of the rects
    svg.selectAll("rect")
    .data(dataset)
    .attr("y", function(d) {
    return h - yScale(d);
    });
    .attr("height", function(d) {
    return yScale(d);
    });
});
```

- above code triggers a change to visuals for each call to the event listener
- eg: change the colours
  - *add call to `fill()` to update bar colours*

```
.attr("fill", function( d) {
    return "rgb( 0, 0, " + (d * 10) + ")";
});
```

- DEMO - update bar colours

Image - D3 Barcharts



D3 - drawing colour updates for barcharts

Data visualisation - D3

Drawing - add interaction - transitions

- adding a fun transition in D3 is as simple as adding the following,

```
.transition()
```

- add this to above code chain to get a fun and useful transition in the data
- animation reflects the change from the old to the new data
- add a call to the `duration()` function
  - *allows us to specify a time delay for the transition*
  - *quick, slow...we can specify each based upon time*
- chain the `duration()` function after `transition()`

```
.transition().duration(1000)
```

- if we want to specify a constant easing to the transition
  - *use `ease()` with a `linear` parameter*

```
.ease(linear)
```

- other built-in options, including
  - *circle - gradual ease in and acceleration until elements snap into place*
  - *elastic - best described as springy*
  - *bounce - like a ball bouncing, and then coming to rest...*

Data visualisation - D3

Drawing - add interaction - transitions

- add a delay using the `delay()` function

```
.transition()
.delay(1000)
.duration(2000)
```

- also set the `delay()` function dynamically relative to the data,

```
.transition()
.delay( function( d, i) {
return i * 100;
})
.duration( 500)
```

- when passed an anonymous function
  - *datum bound to the current element is passed into `d`*
  - *index position of that element is passed into `i`*
- in the above code example, as D3 loops through each element
  - *delay for each element is set to `i * 100`*
  - *meaning each subsequent element will be delayed 100ms more than preceding element*
- DEMO - transitions - interactive sort

Data visualisation - D3

Drawing - add interaction - adding values and elements

- select all of the bars in our chart
  - *we can rebind the new data to those bars*
  - *and grab the new update as well*

```
var bars = svg.selectAll("rect")
    .data(dataset);
```

- if more new elements, bars in our example, than original length
  - *use `enter()` to create references to those new elements that do not yet exist*
- with these reserved elements
  - *we can use `append()` to add those new elements to the DOM*
  - *now updates our bar chart as well*
- now made the new `rect` elements
  - *need to update all visual attributes for our `rects`*
  - *set x, and y position relative to new dataset length*
  - *set width and height based upon new xScale and yScale*
  - *calculated from new dataset length*

Data visualisation - D3

Drawing - add interaction - removing values and elements

- more DOM elements than provided data values
  - *D3's **exit** selection contains references to those elements without specified data*
  - ***exit** selection is simply accessed using the `exit()` function*
- grab the *exit* selection
- then transition exiting elements off the screen
  - *for example to the right*
- then finally remove it

```
bars.exit()
.transition()
.duration(500)
.attr("x", w)
.remove();
```

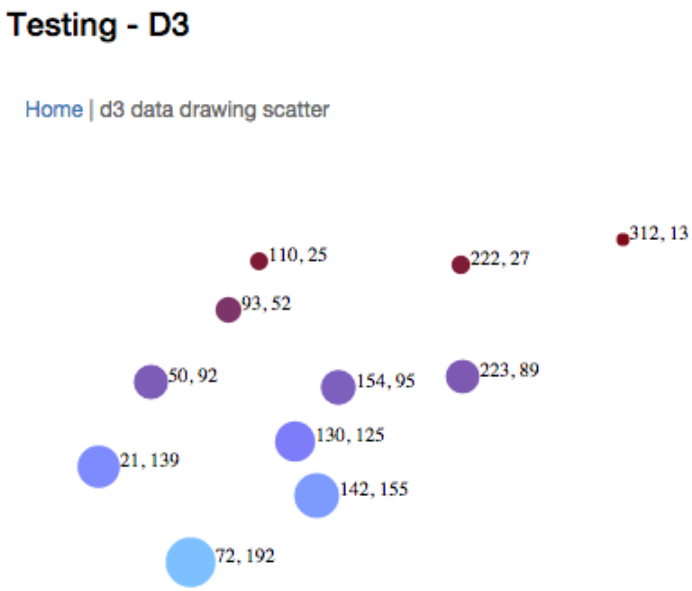
- `remove()` is a special transition method that awaits until transition is complete
- then deletes element from DOM forever
  - *to get it back, we'd need to rebuild it again*

Data visualisation - D3

Drawing - SVG scatterplot - intro

- scatterplot allows us to visualise two sets of values on two different axes
  - *one set of data against another*
- plot one set of data on *x* axis, and the other on the *y* axis
- often create dimensions from our data
  - *helps us define patterns within our dataset*
  - *eg: date against age, or age against fitness...*
- dimensions will also be represented relative to *x* and *y* axes
- create our scatterplot using SVG
  - *add our SVG to a selected element*

Image - D3 Scatterplot



D3 - drawing a basic scatterplot

Data visualisation - D3

Drawing - SVG scatterplot - data

- data for the scatterplot is normally stored as a multi-dimensional representation
  - *comparison x and y points*
- eg: we could store this data in a multi-dimensional array

```
var dataset = [
        [10, 22], [33, 8], [76, 39], [4, 15]
      ];
```

- in such a multi-dimensional array
  - *inner array stores the comparison data points for our scatterplot*
  - *each inner array stores x and y points for scatterplot diagram*
- we can also stroe such data in many different structures
  - *eg: JSON...*

Data visualisation - D3

Drawing - SVG scatterplot - create SVG

- need to create an element for our SVG
  - *allows us to draw and output all of our required shapes*

```
d3.select("body").append("svg");
```

- appends to the body an SVG element
  - *useful to encapsulate this new DOM element within a variable*

```
var svg = d3.select("body").append("svg");
```

- variable effectively works as a reference
  - *points to the newly created SVG object*
  - *allows us to use this reference to access element in the DOM*

Data visualisation - D3

Drawing - SVG scatterplot - build scatterplot

- as with our barchart, we can set the width and height for our scatterplot,

```
//width & height
var w = 750;
var h = 200;
```

- we will need to create circles for use with scatterplot instead of rectangles

```
svg.selectAll('circle')
   .data(dataset)
   .enter()
   .append('circle');
```

- corresponding to drawing circles
  - *set `cx`, the x position value of the centre of the circle*
  - *set `cy`, the y position value of the centre of the circle*
  - *set `r`, the radius of the circle*

Data visualisation - D3

Drawing - SVG scatterplot - adding circles

- draw circles for scatterplot

```
.attr('cx', function(d) {
    return d[0]; //get first index value for inner array
})
.attr('cy', function(d) {
    return d[1]; //get second index value for inner array
})
.attr('r', 5);
```

- outputs simple circle for each inner array within our supplied multi-dimensional dataset
- start to work with creating circle sizes relative to data quantities
- set a dynamic size for each circle
  - *representative of the data itself*
  - *modify the circle's area to correspond to its y value*
- as we create SVG circles, we cannot directly set the area
  - *so we need to calculate the radius* `r`
  - *then modify that for each circle*

Data visualisation - D3

Drawing - SVG scatterplot - calculate dynamic area

- assuming that `d[1]` is the original area value of our circles
  - *get the square root and set the radius for each circle*
- instead of setting each circle's radius as a static value
  - *now use the following*

```
.attr('r', function(d) {
    return Math.sqrt(d[1]);
});
```

- use the JavaScript `Math.sqrt()` function to help us with this calculation

Data visualisation - D3

Drawing - SVG scatterplot - add colour

- as with a barchart
- also set a dynamic colour relative to a circle's data

```
.attr('fill', function (d) {
    return 'rgb(125,' + (d[1]) + ', ' + (d[1] * 2) + ')';
});
```

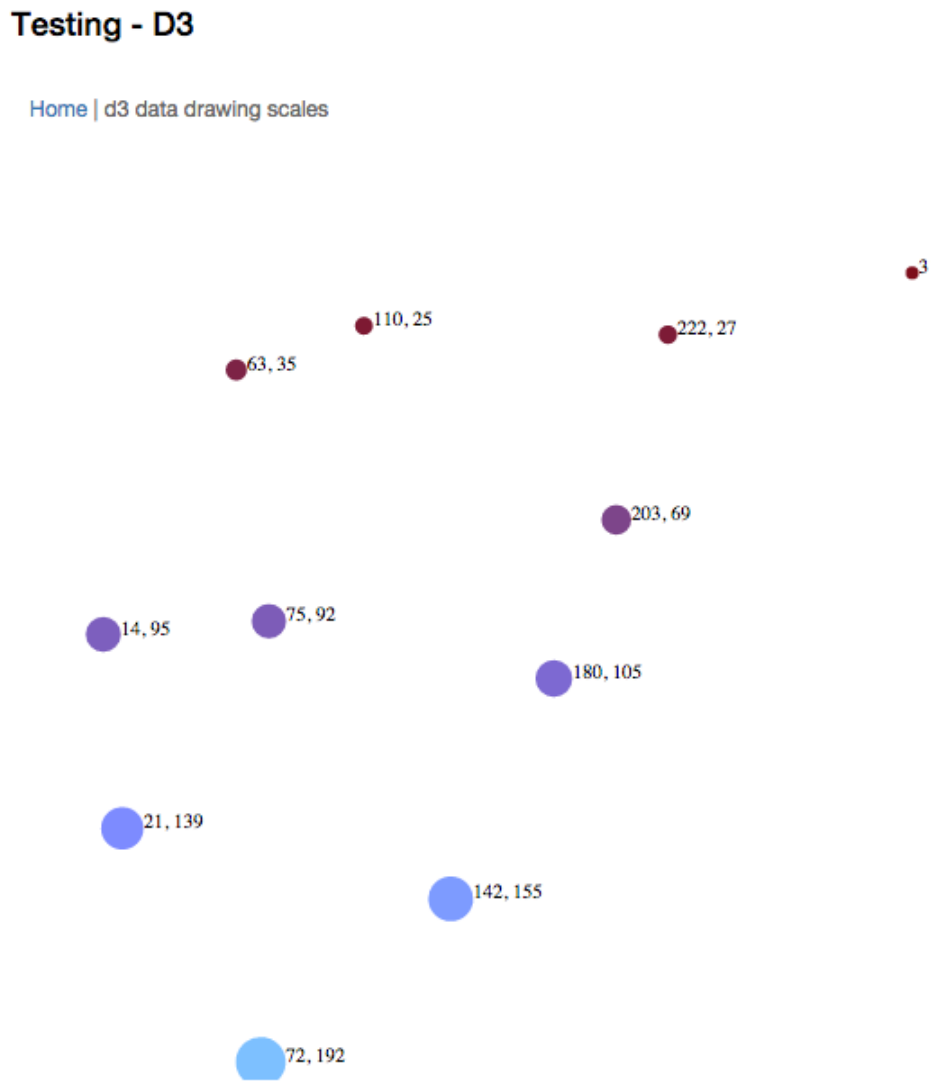
Data visualisation - D3

Drawing - SVG scatterplot - add labels

```
//add labels for each circle
svg.selectAll('text')
   .data(dataset)
   .enter()
   .append('text')
   .text(function(d) {
    return d[0] + ', ' + d[1];//set each data point on the text label
   })
   .attr('x', function(d) {
    return d[0];
   })
   .attr('y', function(d) {
    return d[1];
   })
   .attr('font-family', 'serif')
   .attr('font-size', '12px')
   .attr('fill', 'navy');
```

- start by adding text labels for our data
  - *adding new text elements where they do not already exist*
- then set the text label itself for each circle
  - *using the data values stored in each inner array*
- make the label easier to read
  - *set x and y coordinates relative to data points for each circle*
- set some styles for the labels

Image - D3 Scatterplot



D3 - drawing a basic scatterplot 2

Data visualisation - D3

Drawing - SVG - scales

- in D3, *scales* are defined as follows,

> *"Scales are functions that map from an input domain to an output range"*
>
> *Bostock, M.*

- you can specify your own scale for the required dataset
  - *eg: to avoid massive data values that do not translate correctly to a visualisation*
  - *scale these values to look better within you graphic*
- to achieve this result, you simply use the following pattern.
  - *define the parameters for the scale function*
  - *call the scale function*
  - *pass a data value to the function*
  - *the scale function returns a scaled output value for rendering*
- also define and use as many scale functions as necessary for your visualisation
- important to realise that a scale has no direct relation to the visual output
  - *it is a mathematical relationship*
- need to consider scales and axes
  - *two separate, different concepts relative to visualisations*

Data visualisation - D3

Drawing - SVG - domains and ranges

- *input domain* for a scale is its possible range of input data values
  - *in effect, initial data values stored in your original dataset*
- *output range* is the possible range of output values
  - *normally use as the pixel representation of the data values*
  - *a personal consideration of the designer*
- normally set a minimum and maximum *output range* for our scaled data
- scale function then calculates the scaled output
  - *based upon original data and defined range for scaled output*
- many different types of scale available for use in D3
- three primary types
  - *quantitative*
  - *ordinal*
  - *time*
- *quantitative* scale types also include other built-in scale types
- many methods available for the scale types

Data visualisation - D3

Drawing - SVG - building a scale

- start building our scale in D3
  - *use `d3.scale` with our preferred scale type*

```
var scale = d3.scale.linear();
```

- to use the scale effectively, we now need to set our input domain

```
scale.domain([10, 350]);
```

- then we set the output range for the scale

```
scale.range([1, 100]);
```

- we can also chain these methods together

```
var scale = d3.scale.linear()
          .domain([10, 350])
              .range([1, 100]);
```

Data visualisation - D3

Drawing - SVG - adding dynamic scales

- we could pre-define values for our scale relative to a given dataset
- makes more sense to abstract these values relative to the defined dataset
- we can now use the D3 array functions to help us set these scale values
  - *eg; find highest number in array dataset*

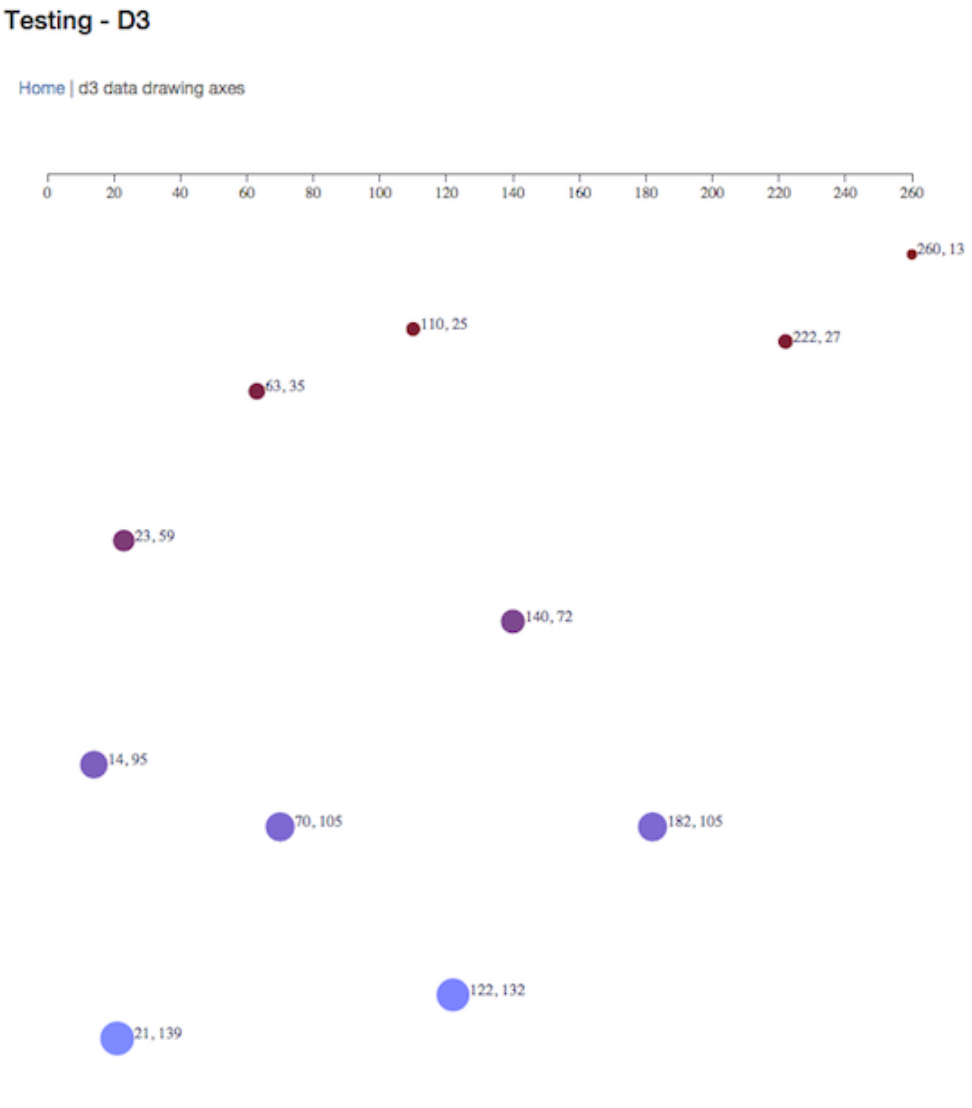
```
d3.max(dataset, function(d) {
    return d[0];
});
```

- returns highest value from the supplied array
- getting minimum value in array works in the same manner
  - *with `d3.min()` being called instead*
- now create a scale function for `x` and `y` axes

```
var scaleX = d3.scale.linear()
        .domain([0, d3.max(dataset, function(d) { return d[0]; })])
        .range([0, w]);//set output range from 0 to width of svg
```

- Y axis scale modifies above code relative to provided data, `d[1]`
  - *range uses height instead of width*
- for a scatterplot we can use these values to set `cx` and `cy` values

Image - D3 Scatterplot



D3 - add axis

Data visualisation - D3

Drawing - SVG - adding dynamic scales

- a few data visualisation examples
- Tests 1
- Tests 2

Data Visualisation

general examples

Sample dashboards and visualisations

- gaming dashboard
- schools and education
- students and grades
- D3 examples

Example datasets

- Chicago data portal

Article example

- dashboard designs
- replace jQuery with D3

Data Visualisation

projects examples

A few examples from recent projects,

- GitHub API tests
- check JSON return
- early test examples
- metrics test examples