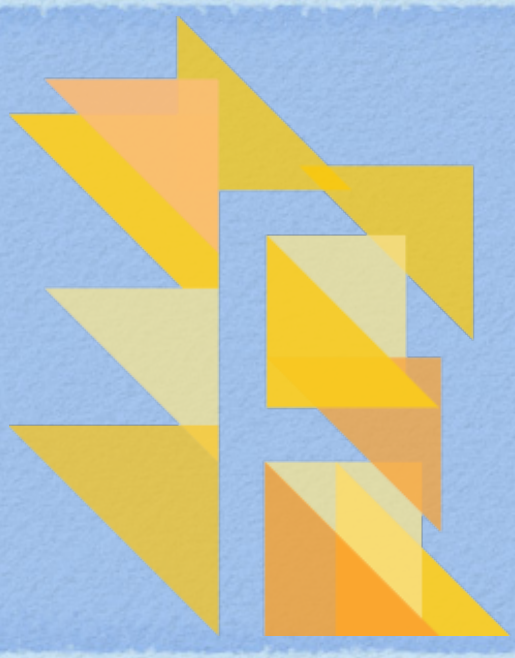
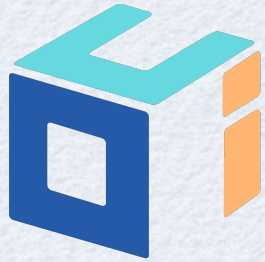


flow

Slides available at
https://github.com/mvolkmann/talks

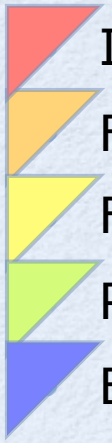
http://flow.org

R. Mark Volkmann
Object Computing, Inc.
http://objectcomputing.com
Email: mark@objectcompuing.com
Twitter: @mark_volkmann
GitHub: mvolkmann



OCI | TRAINING

Outline



- Introduction to Flow
- Flow Types
- Flow Server
- Project Setup and Example
- Bonus Material

Due to time constraints, some Flow topics
are omitted or only briefly mentioned.
These are covered more fully in an **article** I wrote at
https://objectcomputing.com/resources/publications/sett/may-2017-flow-javascript-type-checker/

Intro

Static vs. Dynamic

- **Types** specify the conditions under which code such as a function or class will run
- In **static** programming languages, type errors are detected at compile-time
- In **dynamic** programming languages, type errors are typically detected at runtime
- **Type checking tools** for dynamic languages allow detection of type errors before runtime
  - such as **Flow** and **TypeScript**

Why Use Types?

- Can find type errors before runtime
  - more convenient than waiting until runtime
- Types document expectations about code
  - types of variables, object properties, function parameters, and function return types
  - comments can be used instead, but those
    - are more verbose
    - tend to be applied inconsistently
    - easily go out of date when code is updated
- Increases refactoring confidence
  - don't have to wonder what assumptions callers made about supported types
- Removes need to write ...
  - error checking code for type violations
  - type-related unit tests
- Editor/IDE plugins can use types to highlight issues and provide code completion

Why Avoid Types?

- Takes time to ...
  - learn type syntax
  - master applying them
- Makes code more verbose
  - but also less verbose since there is no need to write error checking code for type violations
- Can hamper prototyping and rapid development
  - developers can lose focus when distracted by having to satisfy a compiler or type checker

Intro

When to Use Types

- Use types when
  - application is large, complex, or critical
  - expected lifetime of code is long and refactoring is likely
  - code will be written and maintained by a team of developers
- Avoid types when
  - the conditions above are not present

Intro

Flow Overview

- "A static type checker, designed to find type errors in JavaScript programs"
- Open source tool from Facebook
- Catches many errors without types
  - using **type inference** and **flow analysis**
  - "precisely tracks the types of variables as they flow through the program"
- Can gradually add types
- Most ES6+ features are supported
  - for a list, see https://github.com/facebook/flow/issues/560
- Supports React and JSX

For runtime type checking using Flow syntax, consider babel-plugin-tcomb
https://github.com/gcanti/babel-plugin-tcomb

TypeScript Overview

- Competing tool from Microsoft
  - implemented in TypeScript
- Superset of JavaScript syntax adding more than just types
  - class properties can be **`readonly`**
  - class members can have **`public`**, **`private`**, and **`protected`** modifiers
  - constructor parameter properties, decorators, enums, interfaces, mixins, namespaces (global objects), and more

Paul Graham's "blub paradox"
http://www.paulgraham.com/avg.html

- Compiles to JavaScript
- Use file extension **`.ts`** instead of **`.js`**
- Performs type checking and transpiling (from one version of JS to another)
  - Flow only focuses on type checking
  - with Flow, transpiling is typically handled by Babel
  - good because new JS features generally land in Babel (through plugins) before TypeScript

Comparing Flow & TypeScript

- Type definitions for libraries
  - TypeScript has a repository of type definitions for JavaScript libraries called "**DefinitelyTyped**"
  - Flow has a similar repository called "**flow-typed**", but it has far fewer entries
  - these allow your code to use
    third party JavaScript libraries that do not have type annotations
    and have type checking of those uses
  - as of May 21, 2017, Definitely Typed had types for over **2092** packages,
    while flow-typed had **570** and
    many of those are just for different versions of the same package
  - can **generate Flow type declaration files** from TypeScript `.d.ts` files
    - see https://github.com/joarwilk/flowgen

```
npm install -g flowgen
flow-gen name.d.ts -o name.flow.js
```

- Both have editor/IDE integrations
- Flow has goal of remaining compatible with TypeScript syntax

Installing Flow

- Options for installing Flow in a project
  are described at https://flow.org/en/docs/install/
  - can covered later here
- To install globally,
  `npm install -g flow-bin` or use **`yarn`**
- To get version installed
  `flow version`
- To get help
  `flow --help`

Running Flow

- To enable type checking a file
  - add one of these comments at top
    ```
    // @flow
    /* @flow */
    ```
  - files without this are not type checked

It's easy to forget to do this!

- To run on a single file instead of all files in project
  - `flow check-contents < file-path`
  - doesn't require comment at top
- To run on multiple files in a project
  - described later

I created a bash script alternative that can be run with `flow1 file-path`

Type Suggestions

untyped.js

- To get suggested type annotations for a given file
  - **`flow suggest`** ***`file-path`***
  - if everything is good, only the file path is output (weird)
- Example

```
function rectangleArea(width, height) {
  return width * height;
}

const area = rectangleArea(100, 50);
console.log('area =', area);
```

```
flow suggest untyped.js
--- old
+++ new
@@ -1,6 +1,6 @@
-function rectangleArea(width, height) {
+function rectangleArea(width: number, height: number) : number{
   return width * height;
 }

-const area = rectangleArea(100, 50);
+const area: number = rectangleArea(100, 50);
 console.log('area =', area);
```

doesn't really output code in color

Executing Code With Types ...

- Node.js cannot directly run code that is annotated with Flow types
  - likewise for web browsers (covered later)
- Simple approach for individual files
  - **`npm install -g flow-remove-types`**
  - installs both **`flow-node`** and **`flow-remove-types`** executables
  - to remove types and execute code
    - **`flow-node`** ***`file-path`***

    for Typescript, see https://github.com/TypeStrong/ts-node
  - to generate a file without types
    - **`flow-remove-types --pretty`** ***`file-path`*** **`>`** ***`new-file-path`***
    - **`node`** ***`new-file-path`***

    replaces types with spaces; **`--pretty`** removes whitespace
  - either way, input files must contain **`// @flow`**

… Executing Code With Types

- Comment approach
  - tedious and ugly, but eliminates need to remove types
  - surround types with `/*:  */`
  - surround type aliases with `/*::  */`
- Project-based approach
  - alternative to processing individual files
  - described later

Flow Analysis Example

flow-analysis-wo-types.js

```
// @flow

function product(n1, n2) {
  return n1 * n2;
}

console.log(product(2, 'foo'));
```

```
4:   return n1 * n2;
                 ^^ string. The operand of an arithmetic operation must be a number.
```

TypeScript does not catch this!

Uninitialized References

unintialized.js

```
// @flow

function getLastInitial(person) {
  const {lastName} = person; // fails if person not defined
  return lastName ? lastName[0] : '';
}}

const person = {
  firstName: 'Richard',
  middleName: 'Mark',
  lastName: 'Volkmann'
};
console.log(getLastInitial(person)); // good; outputs "V"

let p;
console.log(getLastInitial(p)); // error
```

```
16: console.log(getLastInitial(p)); // error
                ^^^^^^^^^^^^^^^^^ function call
 4:   const {lastName} = person;
             ^^^^^^^^ property `lastName`. Property cannot be accessed on possibly undefined value
 4:   const {lastName} = person;
                         ^^^^^^ uninitialized variable
```

Types

Flow Types

- Details are at http://flowtype.org/docs/quick-reference.html
- The following slides provide an overview

- Types are specified by appending a colon and type description
  - can specify on variables, properties, parameters, and functions (for return type)
  - ex. `let score: number = 0;`
  - type can be inferred here, but it's only `number` if no other type is ever assigned to this variable

Types

Maybe Type

- By default, **`null`** and **`undefined`** are not allowed by any type
  - to allow, precede type with `?`
  - ex. `let score: ?number;`
  - Flow calls this a "**maybe type**"
- TypeScript
  - TypeScript 2 has a setting called "strictNullChecks" that causes it to behave in the same way, but this is not the default behavior

Basic Types

- primitives: **`boolean`**, **`number`**, **`string`**
  - **`number`** includes **`Infinity`** and **`NaN`**
- wrappers: **`Boolean`**, **`Number`**, **`String`** - rarely used
- **`null`**: only matches JavaScript **`null`** value
- **`void`**: type of **`undefined`** and functions that don't return anything
- Specific values (literals) - rarely used
  - ex. **`true`**, **`7`**, **`'foo'`**
- **`any`**: means any type is allowed
  - typically used when being too lazy to specify proper type
- **`mixed`**: similar to **`any`**, but must perform runtime type checks before using value
  - preferred over **`any`**

a.k.a type refinements

```
// @flow
function foo(v: mixed) {
  if (typeof v === 'number') return v * 2;
  if (typeof v === 'string') return v.length;
  return v;
}
```

Basic Types Example

basic-types.js

```
// @flow

function getChars(text: string, count: number, fromStart: boolean) {
  return fromStart ? text.substring(0, count) : text.substr(-count);
}

console.log(getChars('abcdefg', 3, true)); // good; outputs 'abc'
console.log(getChars('abcdefg', 3, false)); // good; outputs 'efg'
console.log(getChars(3, false, 'foobar')); // error
```

Builtin Types

defined in files in https://github.com/facebook/flow/blob/master/lib/

- Flow understands ...
- **Built-in** JavaScript constants, functions, objects, and classes defined in `core.js`
  - ex. `Array`, `console`, `Date`, `*Error`, `Function`, `JSON`, `Map`, `Math`, `Promise`, `RegExp`, `Set`, `String`, ...
- Types from browser Document Object Model (**DOM**) defined in `dom.js`
  - ex. `Document`, `Element`, `*Event`, `HTML*Element`, `Image`, `Node`, `Text`, ...
- Types from **browser API** defined in `bom.js`
  - ex. `GeoLocation`, `History`, `Location`, `Navigator`, `Request`, `Response`, `Screen`, `SharedWorker`, `WebSocket`, `Worker`, `XMLHttpRequest`, ...
- Types from **Node.js** standard library defined in `node.js`
  - ex. `Buffer`, `events`, `fs`, `http`, `https`, `net`, `os`, `path`, `process`, `querystring`, `stream`, `url`, ...
- Types from **React** defined in `react.js`
  - ex. `Synthetic*Event` classes
- and more

Don't need to add type annotations for these.
For example, this is enough:

```
const fs = require('fs');
```

Type Aliases

- Useful for custom types that are used multiple times
  - most are
- Often used for
  - objects with certain properties that aren't instances of a specific class
    - can describe required properties, but extra properties are allowed
  - callback function signatures
- To define a type alias
  - `type SomeNameType = some-type;`
  - common convention is for type names to have "`Type`" suffix

known as "width subtyping"

Flow "`interface`" keyword is similar.
For the difference, see https://stackoverflow.com/questions/43023941/flow-interfaces-versus-types

Functions

- Can specify parameter and return types

`ResultType` is an object type defined elsewhere.

```
function monopoly(passGo: boolean, dice: number, piece: string): ResultType { ... }
```

- Can use in type aliases
  - useful when passing functions to others and returning functions from them

```
type MyFnType = (passGo: boolean, dice: number, piece: string) => ResultType;
```

  - note => instead of : before return type
- Add ? after names of optional parameters

```
type DistanceFromOriginFnType = (x: number, y: number, z?: number) => number;
```

- Add ? before parameter types where **null** and **undefined** are allowed

```
type CallbackType = (err: ?Error, result?: mixed) => void;
```

Arrays

- `Array<element-type>` or `element-type[]`
  - ex. `Array<Date>` or `Date[]`
- Can nest these
  - ex. `Array<Array<number>>` or `number[][]`

array-of-array.js

```
type ArrayOfArraysOfNumbersType = Array<Array<number>>;
const aoaon: ArrayOfArraysOfNumbersType = [[1, 2], [3, 4, 5]];
```

- Tuples
  - fixed-size arrays where elements at specific indexes have specific types
  - not necessarily the same type at every index
  - ex. `type PointType = [number, number];`
  - can set value at a specific index
  - cannot use `Array` methods that mutate it

Objects

- 1) `Object` or `{}`
  - can have any properties
- 2) Object signature
  - list of properties and their types
  - required by default;
    follow names of optional properties with `?`
  - actual objects can have additional properties
  - to disallow additional properties, use
    `{| ... |}` or `$Exact<{ ... }>`
- 3) class or constructor function name
  - specifies type of objects allowed
  - can be a built-in or custom class
    - ex. `Array`, `Date`, `Error`, `Map`, `RegExp`, and `Set`

```
// @flow

type PersonType = {
  name: string,
  birthday: Date,
  spouse?: ?PersonType
};

const tami: PersonType = {
  name: 'Tami',
  birthday: new Date(1961, 8, 9),
  height: 65
};

const mark: PersonType = {
  name: 'Mark',
  birthday: new Date(1961, 3, 16),
  height: 74,
  spouse: tami
};
```

`height` was purposely omitted to show that objects of this type can have additional properties

add `?` before types where `null` or `undefined` is allowed

Classes

class.js

```
// @flow
class Person {
  name: string;
  birthday: Date;
  height: number;
  spouse: Person;

  constructor(name: string, birthday: Date, height: number): void {
    this.name = name;
    this.birthday = birthday;
    this.height = height;
  }

  marry(person: Person): void {
    this.spouse = person;
    person.spouse = this;
  }
}

const tami: Person = new Person('Tami', new Date(1961, 8, 9), 65);
const mark: Person = new Person('Mark', new Date(1961, 3, 16), 74);
tami.marry(mark);

function logPerson(person: Person): void {
  const status: string = person.spouse ?
    'married to ' + person.spouse.name : 'single';
  console.log(person.name + ' is ' + status + '.');
}
logPerson(mark); // good
logPerson(new Date()); // error
```

declarations of properties that are in each instance

Values for class properties are optional and there isn't a way to make them required.

Unions

unions.js

- Can declares that a value can have one of a list of types

```
type PrimitiveType = boolean | number | string;
let value: PrimitiveType = true;
value = 7; // good
value = 'foo'; // good
value = {}; // error

type AnimalType = {name: string, type: 'animal'};
type MineralType = {name: string, type: 'mineral'};
type VegetableType = {name: string, type: 'vegetable'};
type ThingType = AnimalType | MineralType | VegetableType;

const dog: AnimalType = {name: 'Dasher', type: 'animal'};
const mineral: MineralType = {name: 'amethyst', type: 'mineral'};
const vegetable: VegetableType = {name: 'corn', type: 'vegetable'};

let thing: ThingType = dog; // good
console.log(thing.name); // Dasher
thing = mineral; // good
console.log(thing.name); // amethyst
thing = vegetable; // good
console.log(thing.name); // corn
thing = {name: 'bad', type: 'other'}; // error
```

`ThingType` is a "**disjoint union**". Each type in the union is an object that is distinguished from the others based on a property with a specific value (`type` in this case).

Functions that have parameters of a union type must handle all possible types

Unions For Enums

enum-union.js

- Can declare that a value can be one of a list of literal values

```
type ActivityType = 'swim' | 'bike' | 'run';

let activity: ActivityType = 'swim'; // good
console.log('Your current activity is', activity);

activity = 'bike'; // good
console.log('Your current activity is', activity);

activity = 'run'; // good
console.log('Your current activity is', activity);

activity = 'collapse'; // error
```

- To define an enum type whose values come from the keys of an object at runtime

```
type MyType = $Keys<typeof myObj>;
```

Sharing Type Aliases

- Allows types to be used in many source files
- Use **`export type`** in files where they are defined
- Use **`import type`** in other files to use them
- Requires a module bundler like webpack
- For more information, see http://flowtype.org/docs/modules.html#type-imports-exports

Sharing Type Aliases Example

type-alias-export.js

```
// @flow

// This type matches any object that has
// a name property with a type of string.
export type NamedType = {name: string};

export function sayHello(thing: NamedType): void {
  console.log('Hello, ' + thing.name + '!');
}
```

type-alias-import.js

```
// @flow

import type {NamedType} from './type-alias-export';
import {sayHello} from './type-alias-export';


const mark: NamedType = {name: 'Mark', hobby: 'running'};
sayHello(mark); // good
sayHello({name: 'Tami', hobby: 'swimming'}); // good
sayHello('Mark'); // error
```

Types

Escape Hatch

- Sometimes, not often, Flow can't be easily satisfied
- To disable Flow type checking for a single line, precede the line with this comment

```
// $FlowFixMe optional description of why
```

Server

Flow Server ...

- The brains behind Flow
- Analyzes and stores many things about the flow of code in an application
  - variable/function types, locations of their definitions, references to them, ...
  - performs parallel evaluation of multiple files in the background for performance
    - starting the flow server starts several "`flow`" processes, based on # of cores and `server.max_workers` option
- Considers all `.js` files under directory containing `.flowconfig`
  - unless specified differently in `.flowconfig` file
- Initially checks all files, then only checks ...
  - files that have changed
  - files that import from files that have changed
  - newly created files
- Doesn't output error messages, just collects them
  - queried by Flow CLI, editors, and IDEs

creating this file is discussed later

Server

… Flow Server

- To start server
  - in background, **`flow start`**
  - in foreground, **`flow server`**
- To output errors collected by server
  - **`flow status`** or just **`flow`**
  - if server is not running, these start it and run a full check
- To check all files and output errors
  - **`flow check`**
  - if server is not running, this starts one, performs checking, and stops it
- To stop server
  - **`flow stop`** from directory where it is running

Project

Flow Project Checklist

- 1) Install "dev dependencies"
- 2) Add npm scripts to **`package.json`**
- 3) Setup ESLint
- 4) Setup Babel
- 5) Create **`.flowconfig`** file
- 6) Use **`flow-typed`** to get dependency type declarations
- 7) Configure editors/IDEs to use Flow

Project

Browser vs. Server Apps

- The example that follows is a Node.js project that uses CommonJS modules
- A web UI project that uses ES Modules would need a module bundler like **Webpack** or **Rollup**
  - configuring that is beyond the scope here
  - if targeting React, consider using **create-react-app** which configures Webpack and much more for you

Project

Dev Dependencies

- `cd` to top project directory containing `package.json`
  - if that file doesn't exist yet, enter "`npm init`" to create it
- For each of these, enter
  `npm install -D name` or `yarn add -D name`
  - **babel-cli** - command-line interface to Babel transpiler
  - ✓ **babel-eslint** - alternate parser for ESLint that understands ES6+ syntax
  - ✓ **babel-plugin-transform-flow-strip-types** - removes Flow type annotations from Babel output
  - ✓ **babel-preset-env** - automatically determines needed Babel plugins and polyfills based on target environment
  - ✓ **eslint** - JavaScript linter
  - ✓ **eslint-plugin-flowtype** - implements ESLint rules to check usage of Flow types
  - **flow-bin** - the Flow type checker
  - **flow-watch** - "file watcher that clears the console (terminal) and runs flow on each change"
  - **npm-run-all** - "runs multiple npm-scripts in parallel or sequentially"

create-react-app provides most of this setup for you!

✓ = installed by create-react-app

Project

Recommended npm Scripts

- `"babel": "babel src -d build"`
  - transpiles all `.js` files under `src` directory into `build` directory
- `"flow": "flow"`
  - runs `flow` on all `.js` files in the project or only those specified in `.flowconfig`
- `"floww": "flow-watch"` not needed if editor/IDE plugin does this
  - same as `flow`, but keeps running, watching files for changes
- `"lint": "eslint --quiet src"` `--quiet` only reports errors
  - runs `eslint` on all `.js` files under `src` directory
- `"run": "node build/index.js"`
  - runs transpiled version of application
- `"start": "npm-run-all lint flow babel run"`
  - combines previous steps

Project

ESLint Setup

.eslintrc.json

```
{
  ...
  "parser": "babel-eslint",
  ...
  "plugins": [
    "flowtype"
  ],
  ...
  "rules": {
    ...
  }
}
```

modify these settings
based on personal preference

```
...
"flowtype/boolean-style": ["error", "boolean"],
"flowtype/define-flow-type": ["error", {"no-undef": "error"}],
"flowtype/delimiter-dangle": ["error", "never"],
"flowtype/generic-spacing": ["error", "never"],
"flowtype/no-dupe-keys": "error",
"flowtype/no-primitive-constructor-types": "error",
"flowtype/no-weak-types": "warn",
"flowtype/object-type-delimiter": ["error", "comma"],
"flowtype/require-parameter-type": "off",
"flowtype/require-return-type": "off",
"flowtype/require-valid-file-annotation": "off",
"flowtype/semi": ["error", "always"],
"flowtype/sort-keys": "off",
"flowtype/space-after-type-colon": ["error", "always"],
"flowtype/space-before-generic-bracket": ["error", "never"],
"flowtype/space-before-type-colon": ["error", "never"],
"flowtype/type-id-match": "error",
"flowtype/union-intersection-spacing": ["error", "always"],
"flowtype/use-flow-type": "error",
"flowtype/valid-syntax": "error",
...
```

For rule details, see
https://github.com/gajus/eslint-plugin-flowtype#eslint-plugin-flowtype-rules

Project

Babel Setup

.babelrc

```
{
  "presets": [
    ["env", {
      "targets": {
        "node": 8.0
      }
    }]
  ],
  "plugins": [
    "transform-flow-strip-types"
  ]
}
```

change for a different Node version or a web app

`.flowconfig` File

- cd to top project directory
- Run **`flow init`**
- Creates **`.flowconfig`** file
  - with all sections empty
- Comment lines start with **`#`** or **`;`** optionally preceded by whitespace
- Ignores are processed after includes
- For more information, see https://flow.org/en/docs/config/

```
[ignore]
<PROJECT_ROOT>/node_modules

[include]

[libs]

[options]

[version]
```

- **`[ignore]`**: directories/files to ignore; doesn't ignore **`node_modules`** directory by default
- **`[include]`**: directories/files to check; includes top project directory by default
- **`[libs]`**: directories/files with declaration files; by default looks in **`flow-typed`**
- **`[options]`**: see https://flow.org/en/docs/config/options/
- **`[version]`**: pins project to a specific version or version range of Flow

It is **essential** to have a **`.flowconfig`** file in the project root directory!
Flow searches upward until this file is found.
If it reaches the top directory without finding one, Flow will check every JavaScript file below that, which **will heavily tax your computer**.
If this happens, **kill the Flow server** by entering **`flow stop`** or **`killall flow`** (on *nix systems).

Project

flow-typed

- "A central repository for Flow library definitions"
  - https://github.com/flowtype/flow-typed
- Steps to use in a project
  - 1) `npm install -g flow-typed`
  - 2) cd to project directory
  - 3) `flow-typed install`
    - creates `flow-typed` directory if not present
    - installs type declaration files there for all dependencies found in `package.json`
    - generates "stubs" for dependencies that do not yet have type declaration files in the `flow-typed` repository
  - 4) add `flow-typed` directory to version control
  - to update previously installed type definitions
    `flow-typed update`

Examples include Axios, Chalk, Enzyme, Express, Jasmine, Jest, Lodash, Moment, pg (Postgresql library), react-redux, React Router, Redux, and RxJS.

Project

Editor/IDE Setup ...

Note: Many of these only check types on save.

- **Atom**
  - search for these at https://atom.io/packages:
    flow-ide, Nuclide (from Facebook), linter-flow, autocomplete-flow
    - the package "flow" is for the haxe flow build tool, not Facebook Flow

You might also like vim-mode-plus.

- **emacs**
  - https://github.com/flowtype/flow-for-emacs
  - https://github.com/lbolla/emacs-flycheck-flow
- **Sublime**
  - https://github.com/SublimeLinter/SublimeLinter-flow
- **Visual Studio Code**
  - search for these at https://marketplace.visualstudio.com/:
    "Flow Language Support" and vscode-flow-ide

Disable default syntax validation in TypeScript section:
`"javascript.validate.enable": false`
This runs Flow on file saves.
Can hover over a variable or function name to see its type.

You might also like VsCodeVim. Press "Reload" button to enable.

- **WebStorm**
  - see https://blog.jetbrains.com/webstorm/2016/11/using-flow-in-webstorm/
    and https://www.jetbrains.com/help/webstorm/2017.1/flow-type-checker.html

Project

... Editor/IDE Setup

- **Vim** It is beneficial to use both options.
  - **option #1** - Asynchronous Linting Environment (**ALE**)
    - https://github.com/w0rp/ale
    - integrates with a large number of linters for many syntaxes
    - make sure `'flow'` is one of the enabled linters for JavaScript

In .vimrc

```
let g:ale_linters = {
\   'javascript': ['eslint', 'flow'],
\}
```

ALE plugin starts a flow server
when the first JavaScript file is opened.
Exiting Vim does not stop it.
Entering "`flow stop`" also doesn't stop it.
Enter "`killall flow`" to stop it.

  - **option #2** - **vim-flow** plugin
    - https://github.com/flowtype/vim-flow
    - adds object property and method completions
      using "Omni completion" which must be enabled
      - to trigger, press c-x c-o
      - move up and down in list of completions with tab/shift-tab, c-n/c-p, or down/up arrows
      - continue typing to use selection
    - commands
      - `:FlowMake` - runs Flow on all files in project with `@flow` annotation and displays results in quickfix window
      - `:FlowToggle` - toggles type checking on save
      - `:FlowType` - displays type of variable under cursor (I mapped to <leader>ft)
      - `:FlowJumpToDef` - jumps to definition of variable under cursor (I mapped to <leader>fj)

The first time one of these commands is run, it may take about 10 seconds for a Flow server to be started, and run the initial check.

Project

Sample Project

- Uses a popular npm package (**lodash**)
  and an unpopular one (**liner**)
- Reads lines from a text file using **liner**,
  uses the **lodash** function `startCase` to capitalize each word,
  outputs each line,
  and outputs the number of lines read
- To run **ESLint**, **Flow**, **Babel**, and the application,
  enter `npm start`
  - assumes npm scripts described earlier

Project

Project Dependencies

- `cd` to top project directory containing `package.json`
- For each of these, enter
  `npm install -S name` or `yarn add name`
  - **liner** - reads lines from files and streams
  - **lodash** - "modern JavaScript utility library delivering modularity, performance & extras"

Project

The Code ...

writes each line in the file to the console

index.js

```
// @flow
import filer from './filer';

filer('./haiku.txt', (lineCount: number) => {
  console.log('line count is', lineCount);
});
```

haiku.txt

```
Out of memory.
We wish to hold the whole sky,
But we never will.
```

note the case changes

Output

```
Out Of Memory
We Wish To Hold The Whole Sky
But We Never Will
line count is 3
```

`_.startCase` removes punctuation at ends of lines

Project

... The Code

filer.js

```
// @flow
const Liner = require('liner');
const _ = require('lodash/string');

/**
 * Outputs each line in the text file at the given path,
 * capitalizing the first letter of each word,
 * and calls cb with the number of lines read.
 */
function processFile(path: string, cb: (number) => void): void {
  let count = 0;
  const liner = new Liner(path);

  liner.on('readable', () => {
    while (true) {
      const line = liner.read();
      if (line === null) break;
      console.log(_.startCase(line));
      count++;
    }
  });

  liner.on('end', () => cb(count));

  liner.on('error', err => console.error(err));
}

export default processFile;
```

Summary

- Do the benefits derived from types
  justify the extra work required to specify them?
- In my experience with Flow I have been surprised at
  how often adding types uncovered issues in existing code
  and how helpful it has been when refactoring code
- I highly recommend giving Flow, or TypeScript, a try!
- Start simple, perhaps just adding types for
  function parameters and return types
- Over time your confidence in the quality of the code will increase
  and the number of errors you discover at runtime will decrease!

Bonus

Bonus Slides

- The following slides cover information about Flow that we didn't have time to cover in the talk

Bonus

React/JSX Support

- React supports two ways of defining components,
  class-based and stateless functional
- In stateless functional components, Flow can be used to
  specify the types of props obtained through destructuring of the props object
- In class-based components, Flow can be used to
  specify the types of props, default props, and state
- For more details, see https://flowtype.org/docs/react.html

Bonus

Type of `this.props` ...

- In a **functional component**,
  declare type of the `props` object, not types within destructuring
  - this does not work

```
const MyComponent = ({foo: string, bar: number}) => { ... };
```

  - this does work

```
const MyComponent = ({foo, bar}: {foo: string, bar: number}) => { ... };
```

  - better yet

```
type PropsType = {foo: string, bar: number};
const MyComponent = ({foo, bar}: PropsType) => { ... };
```

Bonus

... Type of `this.props`

- In a **class component**, declare props, state, and methods as "public class fields"

```
// @flow
import React from 'react';
type PropsType = {foo: string, bar: number};
class MyComponent extends React.Component {
  props: PropsType;
  handleClick: () => void;

  handleClick = () => console.log('got click');

  render() {
    const {bar, foo} = this.props;
    return (
      <div onClick={this.handleClick}>
        <div>foo = {foo}</div>
        <div>bar = {bar}</div>
      </div>
    );
  }
}

export default MyComponent;
```

could declare state the same way ...
`state: StateType;`

Bonus

Built-in React Types

- See https://github.com/facebook/flow/blob/master/lib/react.js
- **`Component`** class - includes lifecycle methods
- **`Element`** class - instances are typically created using JSX
- **`PropTypes`** object type - for declaring types of component props in the React way
  - includes **`any`**, **`array`**, **`arrayOf`**, **`bool`**, **`element`**, **`func`**, **`instanceof`**, **`node`**, **`number`**, **`object`**, **`objectOf`**, **`oneOf`**, **`oneOfType`**, **`shape`**, and **`string`**
- **`react`** module
  - includes **`createElement`**, **`renderToString`**, and more
- **`react-dom`** module
  - includes **`findDOMNode`** and more
- Events
  - **`SyntheticEvent`** and subclasses including **`SyntheticDragEvent`**, **`SyntheticInputEvent`**, **`SyntheticKeyboardEvent`**, **`SyntheticMouseEvent`**, **`SyntheticTouchEvent`**, **`SyntheticWheelEvent`**, and more

These are the actual types of the event objects used by React. They contain a **`nativeEvent`** property for accessing the DOM event object.

Bonus

Flow vs. PropTypes

- There are benefits to using Flow types in place of React PropTypes,
  but there are also downsides
- **Flow types** allow type errors in props to be detected in Flow-aware editors
- **Flow** can also be run as part of the build process
  and a build can be aborted if any errors are found
- **React PropTypes** allow errors to be flagged in tests
  and when the app is run
  by displaying messages in the browser console
- Can specify types for props **using both** Flow types
  and React PropTypes to get both sets of benefits
- React developers may gradually shift to only using Flow types for props
  - it is tedious to specify types of props in two ways
    and keep them in sync when changes are needed

Bonus

Library Definitions

- Declare types of globals (types, variables, functions, and classes) and modules (CommonJS or ES) without modifying the code where they are defined
  - used when definitions cannot be modified to add type declarations
  - for example, libraries like lodash
- Allows usages to be type-checked
- For details, see https://flow.org/en/docs/libdefs/creation/

Bonus

Locations For Types

- In source files
  - what we have seen so far
  - preferred when source files can be modified
- In **`flow-typed`** directory
  - installed using "**`flow-typed install`**" command described next
  - preferred when source files cannot be modified
- In files in directories listed in **`.flowconfig`** under "**`include`**"
- In other files in same directory with same name, but with **`.flow`** appended
  - ex **`foo.js`** and **`foo.js.flow`**

Bonus

Kinds of Declarations

This is Flow-specific syntax, not JavaScript!

- Variable

```
declare var name: type;
```

- Function

```
declare function name(p1-name: p1-type, ...): return-type;
```

- Class / Interface

```
declare [class|interface] class-name {
  constructor(p1-name: p1-type): class-name;
  static method-name(p1-name: p1-type, ...): return-type;
  method-name(p1-name: p1-type, ...): return-type;
}
```

- Flow Type

```
declare type name = type;
```

- Modules
  - see next slide

Bonus

Modules

- Provide a named scope for variables, functions, classes, types, and interfaces
- Otherwise those are global
- Defined in a file with the same name as module they describe
- Uses Flow-specific syntax, not JavaScript!
- Reference in other files using ***`module-name.thing-name`***
- For more detail, see https://flow.org/en/docs/config/

Bonus

CommonJS Module Example

math.js

```
function double(n) {
  return n * 2;
}

exports.double = double;
```

implementation file

demo.js

```
// @flow
const math = require('./math');

console.log(math.double(3)); // good
console.log(math.double('bad')); // error
```

math.js

```
declare module './math' {
  declare module.exports: {
    double(n: number): number;
  }
}
```

type declaration file

Bonus

ES Module Example

math.js

```
export function double(n) {
  return n * 2;
}
```

implementation file

demo.js

```
// @flow
import * as math from './math';

console.log(math.double(3)); // good
console.log(math.double('bad')); // error
```

math.js

```
declare module './math' {
  declare export function double(n: number): number;
}
```

type declaration file

Bonus

`.js.flow` Declarations

- Colocated with implementation file
  - ex. `math.js` and `math.js.flow`
- Declares types for anything that is exported
- Types declared in `.js.flow` file are used in place of those in `.js` file, if any
  - useful when `.js` file doesn't include type annotations or they are incorrect and cannot be modified
  - supports keeping `.js` files free of Flow-specific syntax
  - allows them to be used without tooling to strip out type annotations

math.js.flow

```
// @flow

declare export function double(n: number): number;
```

This is Flow-specific syntax, not JavaScript!

Bonus

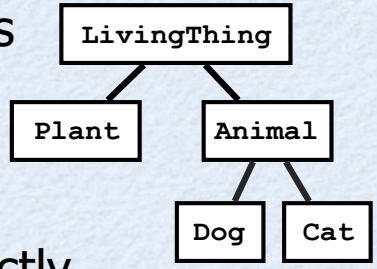
Nominal vs. Structural Typing

- Nominal typing
  - determines whether values are compatible based on the name of their type
  - ex. objects from `Plant` class are not compatible with objects from `Dog` class
- Structural typing
  - determines whether values are compatible by their set of allowed values
  - in the case of objects this includes properties and methods
  - objects from two classes are compatible if they have the same properties and methods
- TypeScript
  - only uses structural typing
- Flow
  - functions and literal objects are structurally typed
  - objects from classes are nominally typed
  - can get structural typing between objects from classes by using interfaces
  - see https://flow.org/en/docs/lang/nominal-structural/

Bonus

Variance

- Consider a hierarchy of living things



- **Invariant** - types must match exactly
  - if type is `Dog`, only `Dog` objects can be used
- **Covariant** - can uses subtype in place of supertype
  - can use `Dog` anywhere `LivingThing` is allowed
- **Contravariant** - can use supertype in place of subtype
  - can use `LivingThing` anywhere `Dog` is allowed

Bonus

Variance in Flow & TypeScript

```
// @flow

class LivingThing {}
class Plant extends LivingThing {}
class Animal extends LivingThing {}
class Dog extends Animal {}
class Cat extends Animal {}

const animals: Animal[] = [];
// In Flow, adding elements to arrays is covariant (can add subtypes).
animals.push(new Dog());
animals.push(new Cat());
animals.push(new Plant()); // error in Flow, but not TS

// In Flow, extracting elements from arrays is contravariant
// (get type of array which is the supertype of the elements)
const dog: Dog = animals[0]; // error in Flow, but not TS
//const dog: Animal = animals[0]; // works
console.log('dog =', dog);

const plant: Plant = animals[0]; // error in Flow, but not TS
console.log('plant =', plant);
```

TypeScript relies on structural typing rather nominal. It views all these classes as equivalent because they have the same properties and methods.

Bonus

Soundness vs. Correctness

- **Soundness**
  - "ability for a type checker to catch every single error that **might** happen at runtime"
  - "comes at the **cost** of sometimes **catching errors that will not actually happen** at runtime"
- **Completeness**
  - "ability for a type checker to only ever catch errors that **would** happen at runtime"
  - "comes at the **cost** of sometimes **missing errors** that will happen at runtime"
- Ideally want both
  - to catch every error that **will** happen at runtime
  - but this is not possible in JavaScript
- Flow
  - "tries to be as sound and complete as possible ... but ... has to make a tradeoff"
  - "tends to favor soundness over completeness, ensuring that code doesn't have any bugs"
- TypeScript
  - favors completeness, only reporting real errors, possibly missing errors

Bonus

Sealed Objects

- Object literals with at least one property are sealed
  - cannot add properties later
  - can change existing property values,
    but their types are inferred from initial values
    and non-compatible values cannot be assigned later
- Empty object literals are not sealed
  - can add properties later with values of any type

```
// @flow

// Sealed object
const obj1 = {foo: 1};
obj1.bar = 2; // error
obj1.foo = 2; // okay
obj1.foo = 'test'; // error

// Unsealed object
const obj2 = {};
obj2.foo = 1; // okay
obj2.foo = 'test'; // okay
```

Type Discrimination

```
// @flow
type Action1Type = {
  type: 'A1',
  payload: {name: string}
};
type Action2Type = {
  type: 'A2',
  payload: {score: number}
};
type ActionType = Action1Type | Action2Type;

function processAction(action: ActionType) {
  switch (action.type) {
    case 'A1':
      console.log('name =', action.payload.name);
      //console.log('score =', action.payload.score); // error
      break;
    case 'A2':
      //console.log('name =', action.payload.name); // error
      console.log('score =', action.payload.score);
      break;
    default:
      console.log('unsupported action');
      break;
  }
}

processAction({type: 'A1', payload: {name: 'Matt'}});
processAction({type: 'A2', payload: {score: 100}});
```

Type Casting

- Useful when a function returns a more less-specific type that must be used as a more specific type
- Can only cast from a more-specific type to a less-specific one
- Exception: Can cast any type to **`any`**
- Cast through **`any`** in order to cast a less-specific type to a more-specific one
- Example

```
const pet: AnimalType = getPet();
const dog = ((animal: any): DogType;
```

Intersection Types

- Opposite of union types
- Define new types that have all the properties found in two or more other types
- Useful for defining types that are just like another, but have extra properties
- Example

```
type Point2DType = {x: number, y: number};
type Point3DType = Point2DType & {z: number};
```

Flow Linter ...

https://flow.org/en/docs/linting/

- Adds type-aware linting rules to Flow
  - introduced in version 52
  - to upgrade a project, **`npm install -D flow-bin`**
- Not a replacement for ESLint
- Provides warnings about possible type issues
  - as opposed to definite type issues flagged by Flow
- Requires opt-in
- To use, modify **`.flowconfig`**
  - can also configure from command-line and in source files

```
...
[lints]
all=warn

[options]
include_warnings=true
...
```

can configure specific rule names instead of **`all`**

valid values are **`off`**, **`warn`**, and **`error`**

also see https://medium.com/flow-type/linting-in-flow-7709d7a7e969

… Flow Linter

- Only two rules in version 52
  - **`sketchy-null`**
    - "when you do an existence check on a value that can be either null/undefined or falsey"
    - and more granular variants
      `sketchy-null-bool`, **`sketchy-null-number`**, **`sketchy-null-string`**, and **`sketchy-null-mixed`**
  - **`untyped-type-import`**
    - "when you import a type from an untyped file"

Reasons to Prefer Flow Over TS

- Catches more errors without adding types
  - via better flow analysis
- Strict null checking is the default
  - also true for new TS projects that use "`tsc --init`"
- Uses nominal rather than structural type checking for classes
  - the right thing to do
- Just does type checking, not transpiling,
  so Babel can be used for transpiling
  - can tell TS to target ES6 and then run that output through Babel,
    but that feels awkward
- More compact syntax for optional properties and nullable types
  - using question marks
- Just adds types
  - TS extends the language with features that may not be added to JavaScript

Bonus

Resources

- Main site
  - https://flow.org/
- Flow type cheat sheet
  - http://www.saltycrane.com/blog/2016/06/flow-type-cheat-sheet/