ECSE 429 Software Validation (Fall 2018)

Hands-on Tutorials

McGill University

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Developed by Daniel Varro, Mathieu Boucher, and Marton Bur.

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Sections of the tutorial will continuously be published at this web page.

1. Git Recap

1.1. Git and GitHub

1.1.1. Installing Git

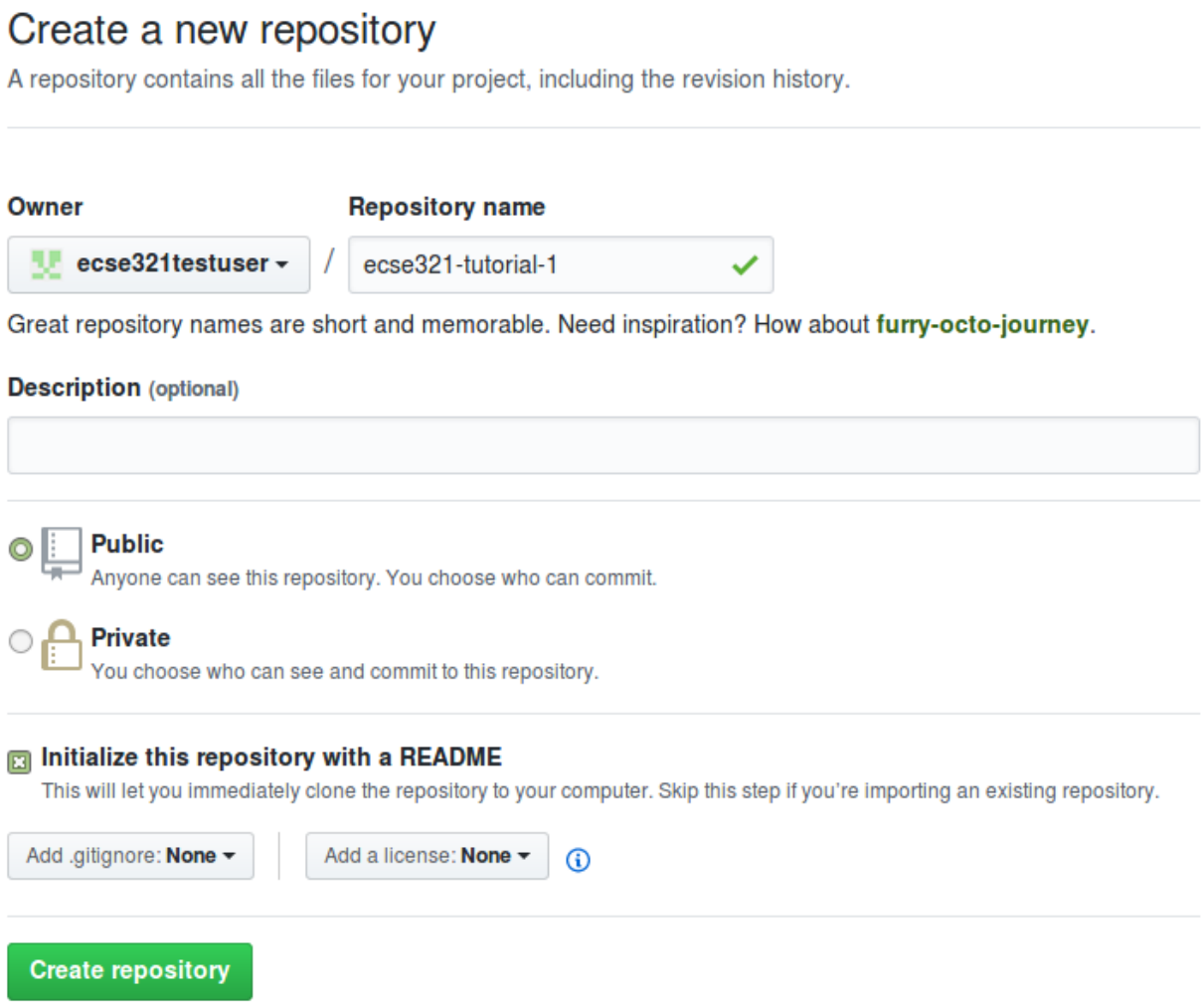
Install the Git version control system (VCS) from https://git-scm.com/downloads.

1.1.2. Logging in to GitHub

1. Create an account on https://github.com/.
2. Verify your e-mail, then log in using your credentials.

1.1.3. Creating a repository on GitHub

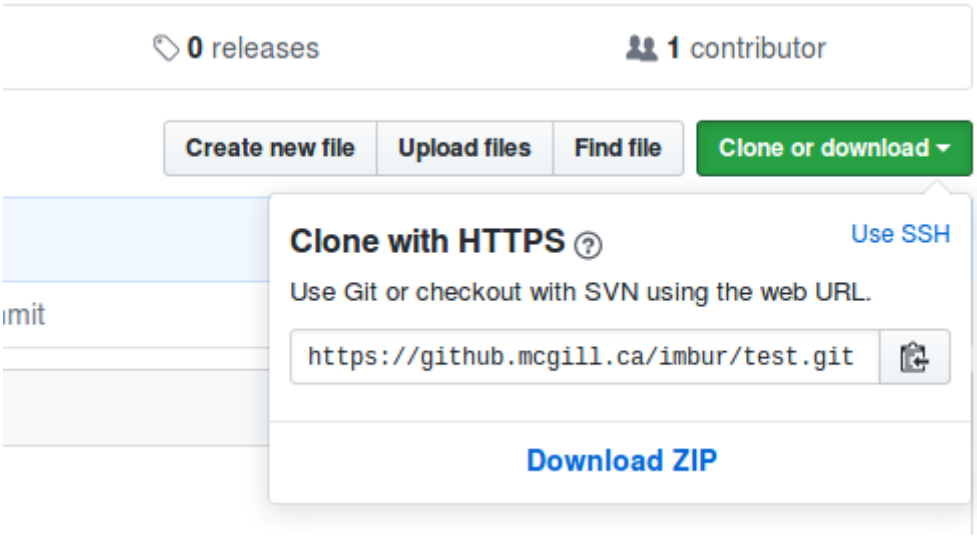
1. Visit https://github.com/ then click on *New repository* (green buttom on the right).
2. Set your user as the owner of the repository.
3. Give a name for the repository (e.g., ecse429-tutorial-1), leave it *public*, then check *Initialize this repository with a README*. Click on *Create repository* afterwards. At this point the remote repository is ready to use.



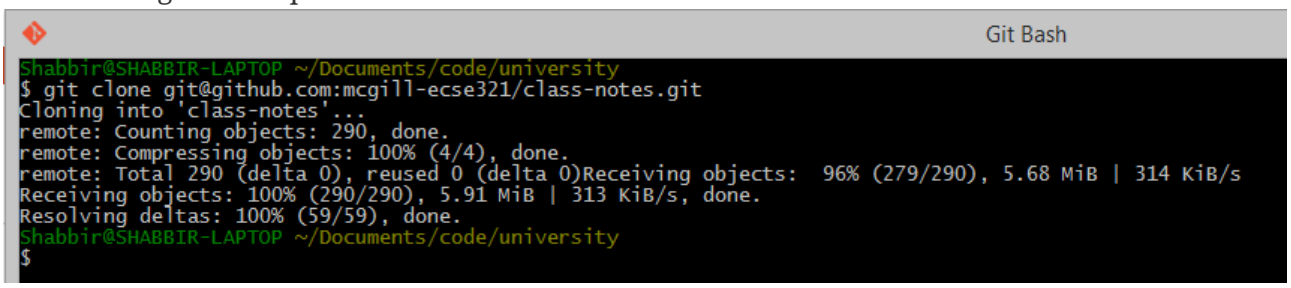
1.1.4. Cloning to a local repository

1. Open up a terminal (Git bash on Windows).

2. Navigate to the designated target directory (it is typical to use the `git` folder within the home directory for storing Git repositories, e.g., `cd /home/username/git`).
3. Using a Git client, clone this repository to your local Git repository. First, get the repository URL (use HTTPS for now).



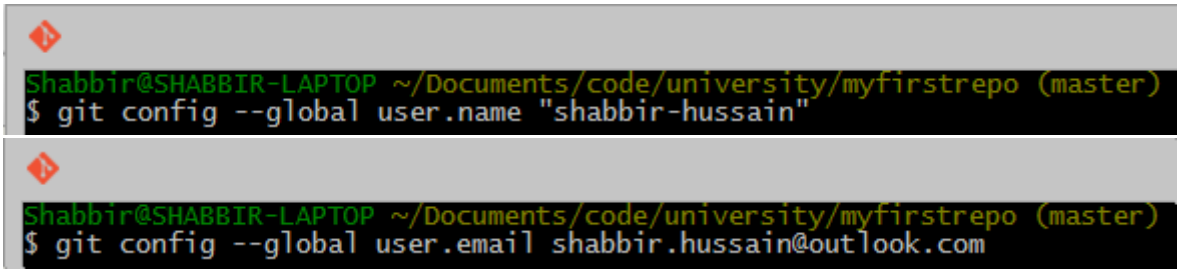
Then, issue `git clone https://url/of/the/repository.git`
You should get an output similar to this:



4. Verify the contents of the *working copy* of the repository by `ls -la ./repo-name`. The *.git* folder holds version information and history for the repository.

1.1.5. Git basics

1. Open up a terminal and configure username and email address. These are needed to identify the author of the different changes.



Glossary — Part 1:

- **Git** is your version control software
- **GitHub** hosts your repositories
- A **repository** is a collection of files and their history
- A **commit** is a saved state of the repository

2. Enter the working directory, then check the history by issuing `git log`. Example output:

```
commit 2a0735092cea1b7f7c850a48b86e8847bf979236
Author: Shabbir Hussain <mohd.husn001@gmail.com>
Date:   Thu Aug 28 15:33:09 2014 -0400

    almost finished seat checking

commit 90bfbac1c8134a87d16caf89c9ff66104f8b7fb7
Author: Shabbir Hussain <mohd.husn001@gmail.com>
Date:   Thu Aug 28 14:30:07 2014 -0400

    fixed wishlist null ptr exception

commit ca4a6921005e89dace34226560921c9770a82574
Author: Shabbir Hussain <mohd.husn001@gmail.com>
Date:   Thu Aug 28 11:03:19 2014 -0400

    grade checker hotfix
```

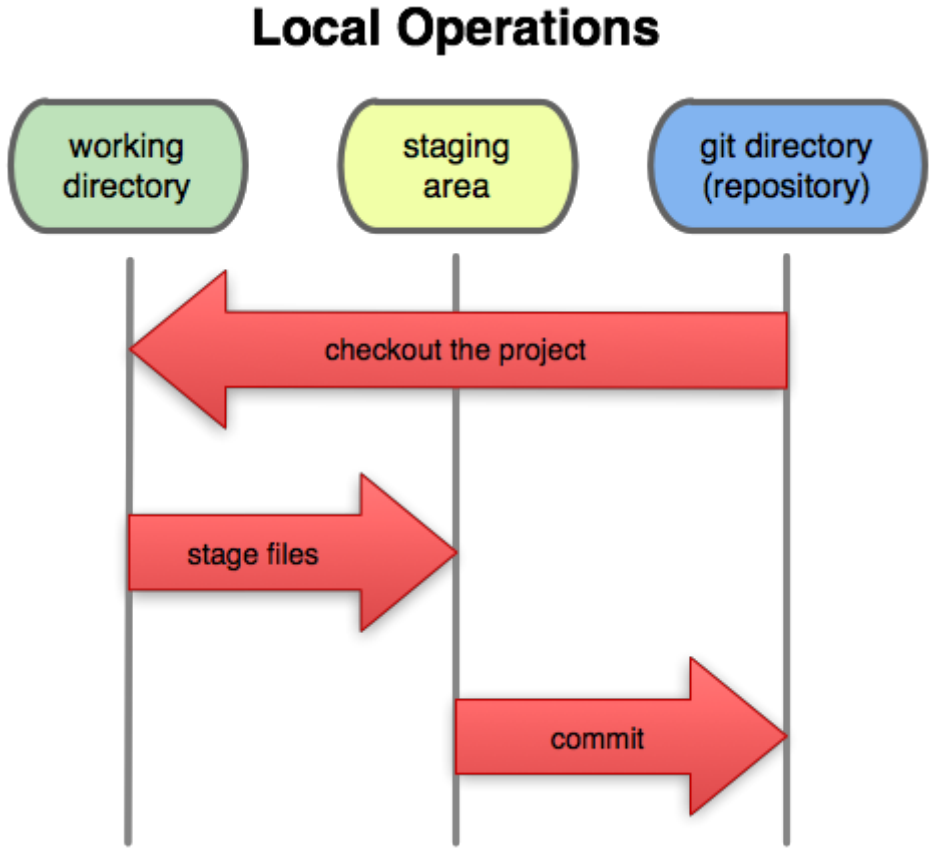
3. Adding and commiting a file: use the `git add` and `git commit` commands.

```
Shabbir@SHABBIR-LAPTOP ~/Documents/code/university/myfirstrepo (master)
$ touch helloworld.java
```

```
Shabbir@SHABBIR-LAPTOP ~/Documents/code/university/myfirstrepo (master)
$ git add helloworld.java
```

```
Shabbir@SHABBIR-LAPTOP ~/Documents/code/university/myfirstrepo (master)
$ git commit -m 'added hello world file to the project'
[master (root-commit) f4a1ddc] added hello world file to the project
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 helloworld.java
```

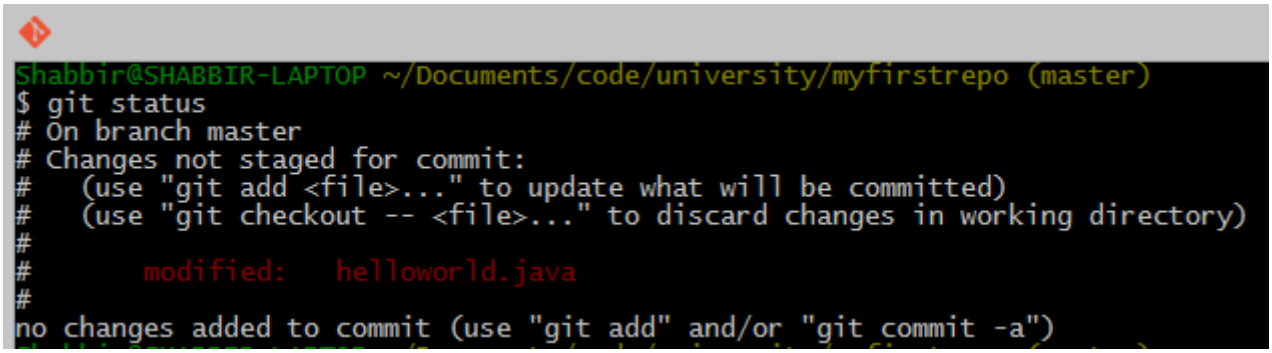
The effect of these commands are explained on the figure below:



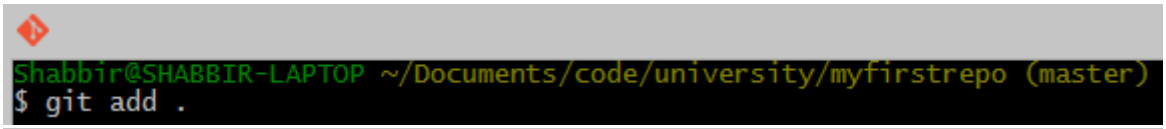
Glossary — Part 2:

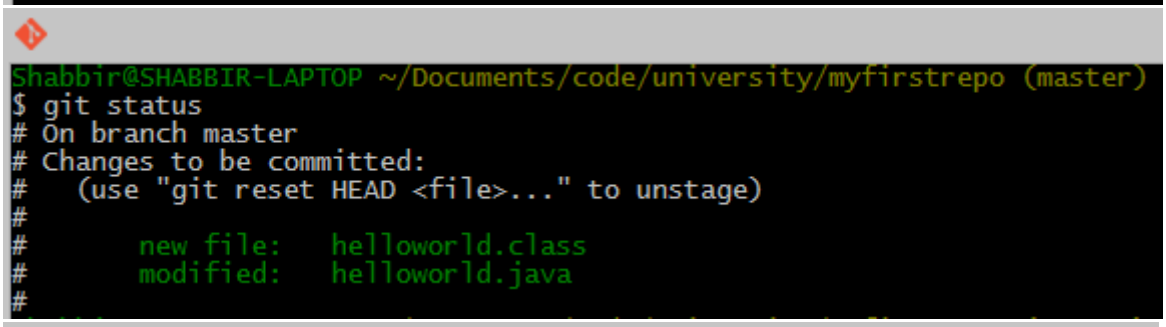
- **Working Directory**: files being worked on right now
- **Staging area**: files ready to be committed
- **Repository**: A collection of commits

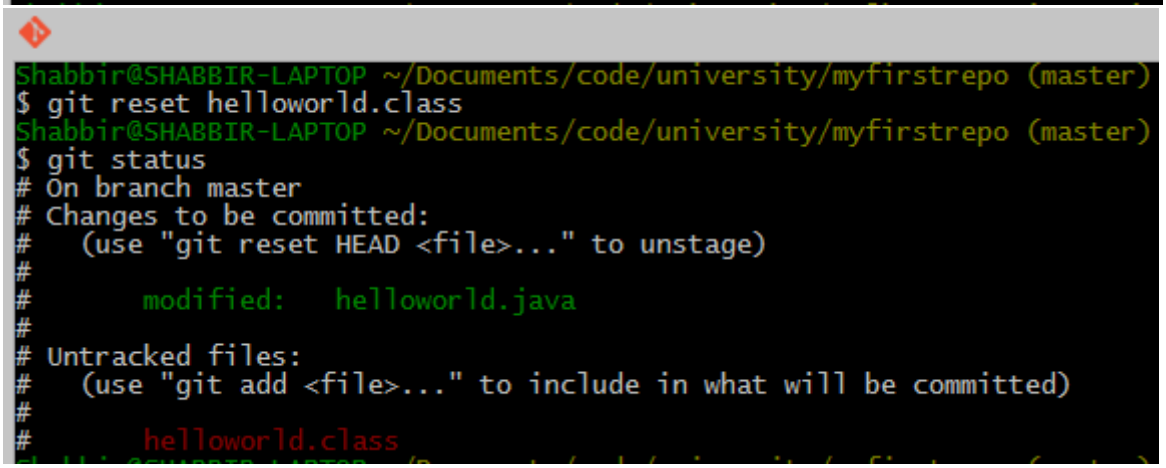
4. Checking current status is done with `git status`.



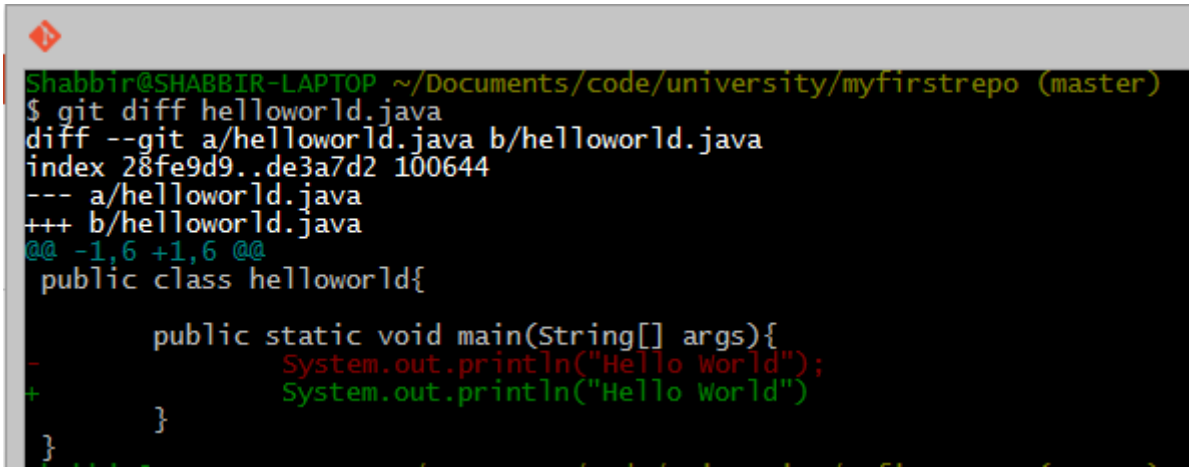
5. Staging and unstaging files: use `git reset` to remove files from the staging area.



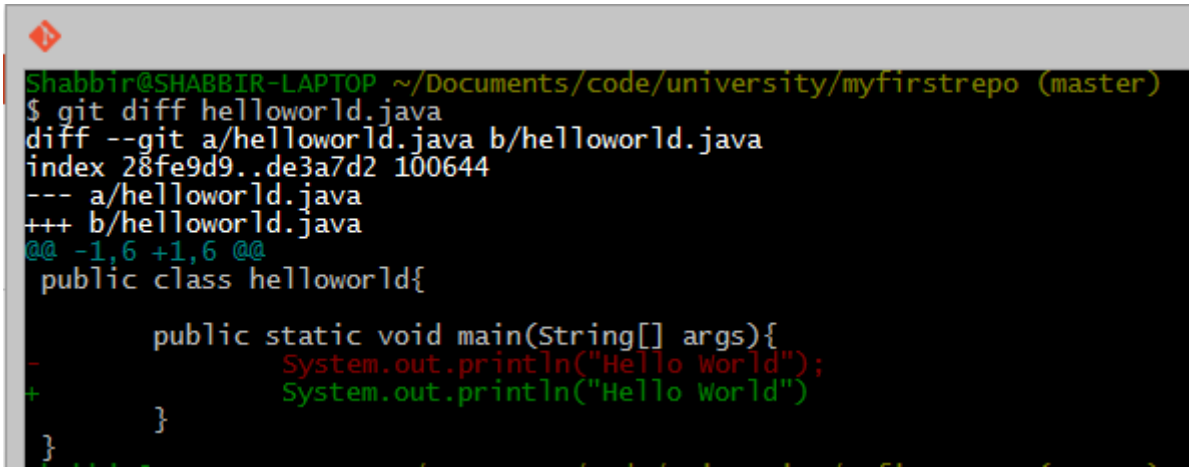




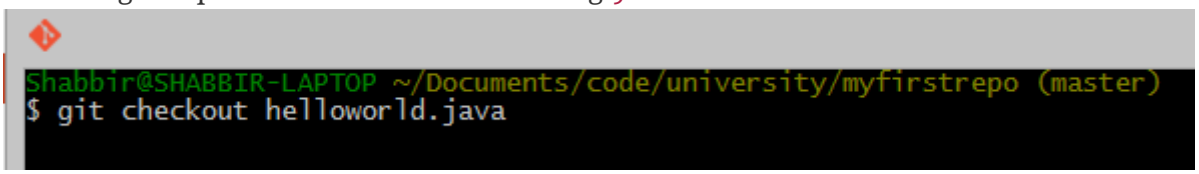
Important: only staged files will be commited.



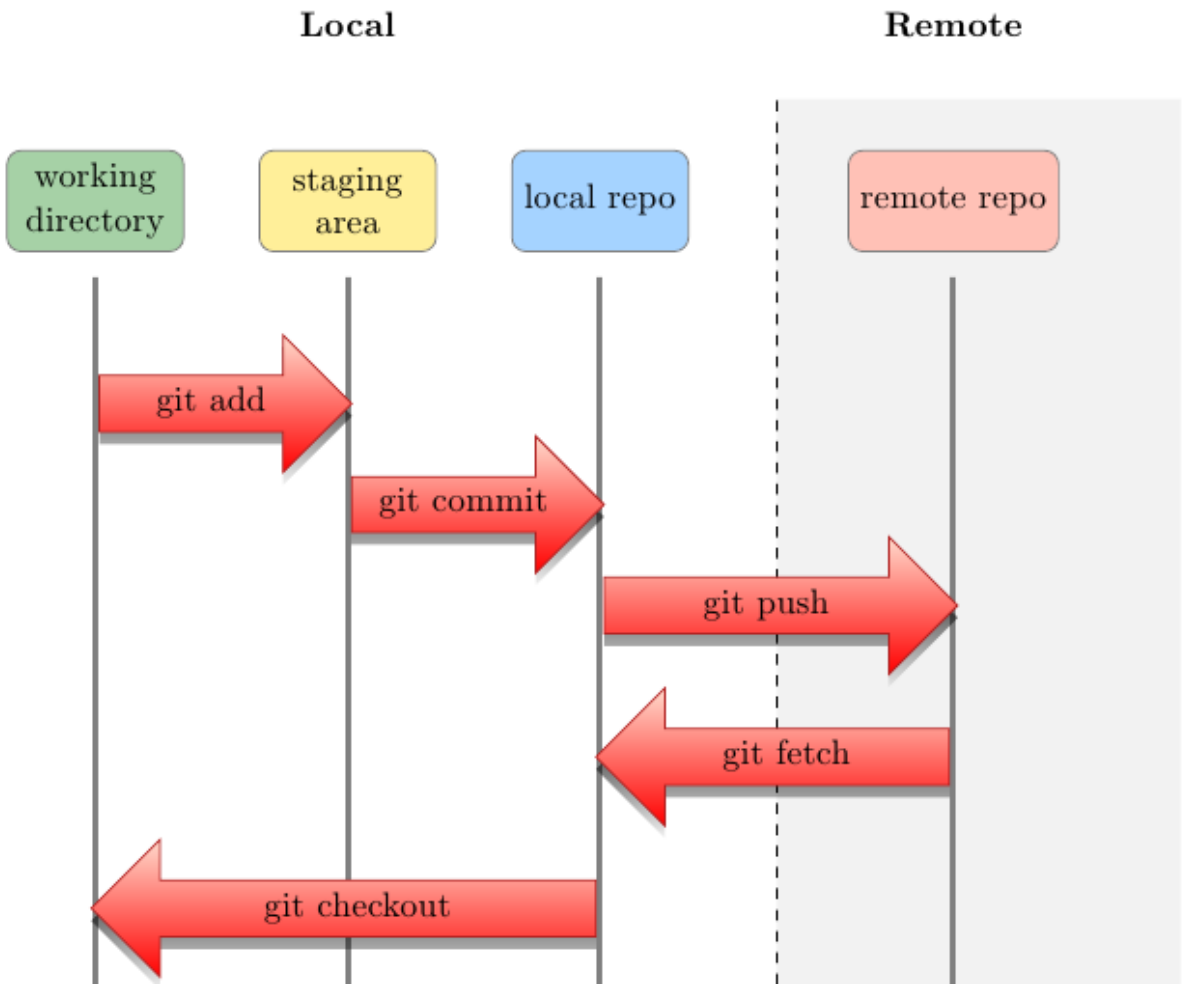
6. To display detailed changes in unstaged files use `git diff`, while use `git diff --staged` to show changes within files staged for commit.



7. Reverting to a previous version is done using `git checkout`.

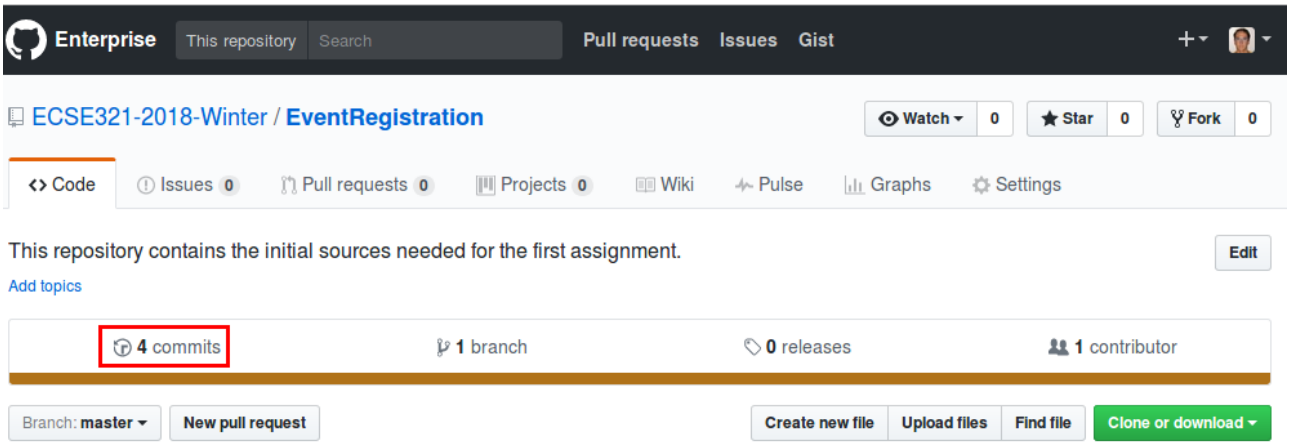


8. The commands `git pull` (or the `git fetch` + `git rebase` combination) and `git push` are used to synchronize local and remote repositories.

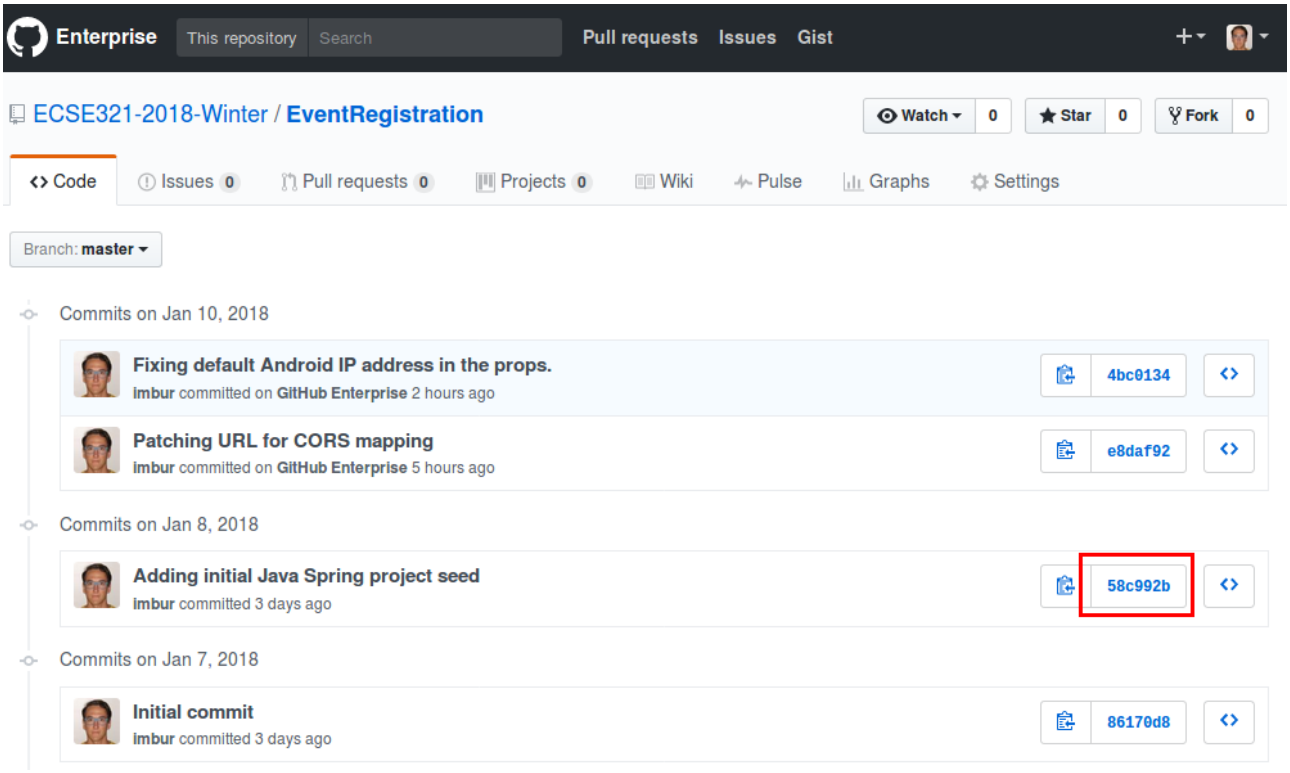


1.1.6. Browsing commit history on GitHub

1. You can browse pushed commits in the remote repository online using GitHub. You can select the *commits* menu for a repository.



To get a link for a specific commit, click on the button with the first few characters of the hash of the commit.



1.1.7. Linux commands cheat sheet:

- `cd`: change/navigate directory
- `ls`: list contents of a directory
- `ls -la`: list all contents of a directory in long listing format
- `touch`: create a file
- `cp`: copy a file
- `mv`: move a file
- `rm`: remove a file
- `mkdir`: create a directory
- `cp -r`: copy a directory recursively with its contents
- `rmdir`: remove a directory
- `rm -rf`: force to recursively delete a directory (or file) and all its contents
- `cat`: concatenate and print contents of files
- `nano`: an easy-to-use text editor

The source for most of the images in the Git documentation: https://github.com/shabbir-hussain/ecse321tutorials/blob/master/01-githubTutorial1.pptx

1.2. Travis CI

1. Go to https://travis-ci.com/, click on Sign up with GitHub.
2. Click on the green authorize button at the bottom of the page.
3. Activate Travis-CI on your GitHub account
4. Select the repositories you want to build with Travis (make sure to include your repository that you created for this tutorial). You can modify this setting anytime later as well.
5. In your working copy of your repository, create a small Maven project with Spring Boot.
   - Make sure you have Maven 3 installed (`mvn --version`).
   - Create the `src/main/java/Main.java` file with the content

```
import org.springframework.boot.autoconfigure.EnableAutoConfiguration;
import org.springframework.boot.SpringApplication;
import org.springframework.context.annotation.Configuration;
import org.springframework.web.bind.annotation.RestController;
import org.springframework.web.bind.annotation.RequestMapping;

@Configuration
@EnableAutoConfiguration
@RestController
public class Main {
  public static void main(String[] args) {
    SpringApplication.run(Main.class, args);
  }

  @RequestMapping("/")
  public String greeting(){
    return "Hello world!";
  }
}
```

   - Create a `pom.xml` in the root of the working copy.

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns="http://maven.apache.org/POM/4.0.0"
  xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
http://maven.apache.org/maven-v4_0_0.xsd">
  <modelVersion>4.0.0</modelVersion>
  <groupId>ca.mcgill.ecse429</groupId>
  <artifactId>tutorial1</artifactId>
  <version>1.0</version>

  <parent>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-parent</artifactId>
```

```
    <version>2.0.4.RELEASE</version>
    <relativePath/>
  </parent>

  <name>tutorial1</name>

  <properties>
    <java.version>1.8</java.version>
  </properties>

  <dependencies>
    <dependency>
      <groupId>org.springframework.boot</groupId>
      <artifactId>spring-boot-starter-web</artifactId>
    </dependency>
  </dependencies>
  <build>
    <plugins>
      <plugin>
        <groupId>org.springframework.boot</groupId>
        <artifactId>spring-boot-maven-plugin</artifactId>
        <executions>
          <execution>
            <goals>
              <goal>build-info</goal>
            </goals>
            <configuration>
              <additionalProperties>
                <java.source>${maven.compiler.source}</java.source>
                <java.target>${maven.compiler.target}</java.target>
              </additionalProperties>
            </configuration>
          </execution>
        </executions>
      </plugin>
    </plugins>
  </build>
</project>
```

- Add a `.gitignore` to ignore generated resources by Git:

```
*.class
target/
```

- Make sure your application is compiling by running `mvn clean install`

6. Create a file called `.travis.yml`:

```
language: java
script:
- mvn clean install
```

7. Commit and push your work. If everything is set up correctly, the build should trigger and Travis should run your build using Maven.

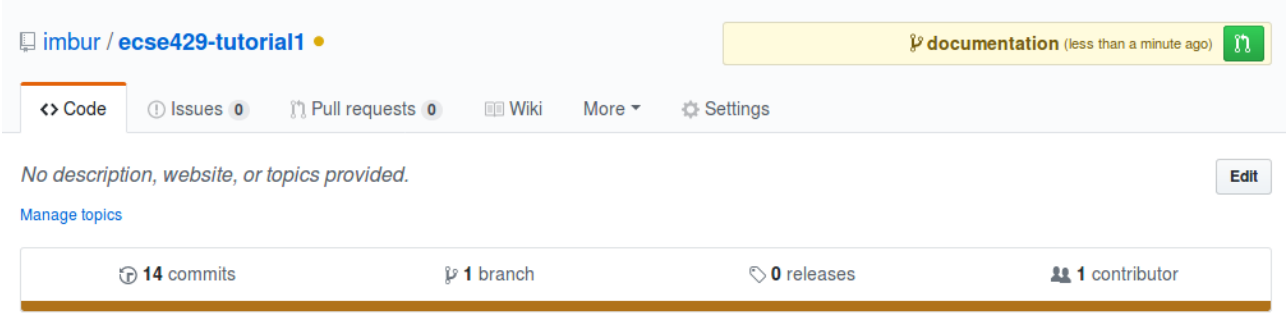
2. Code Reviews

2.1. GitHub Code Reviews

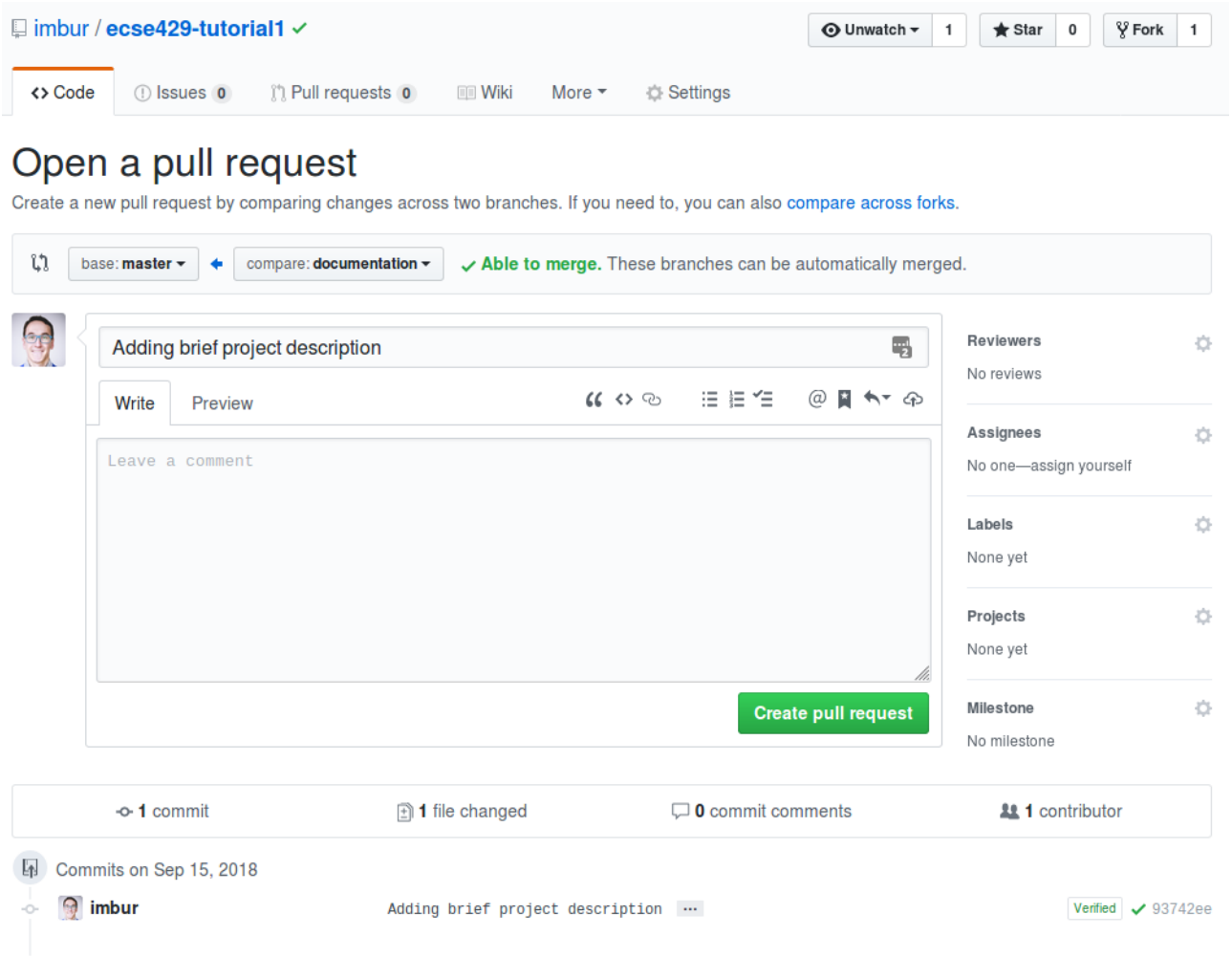
1. Navigate to the folder for the working copy of your *ecse429-tutorial1* from the previous tutorial.
2. Create & checkout a new branch named called `documentation`. (`git branch documentation && git checkout documentation`)
3. Edit `README.md`.

```
# ecse429-tutorial1

A default java project generated by Maven.
```

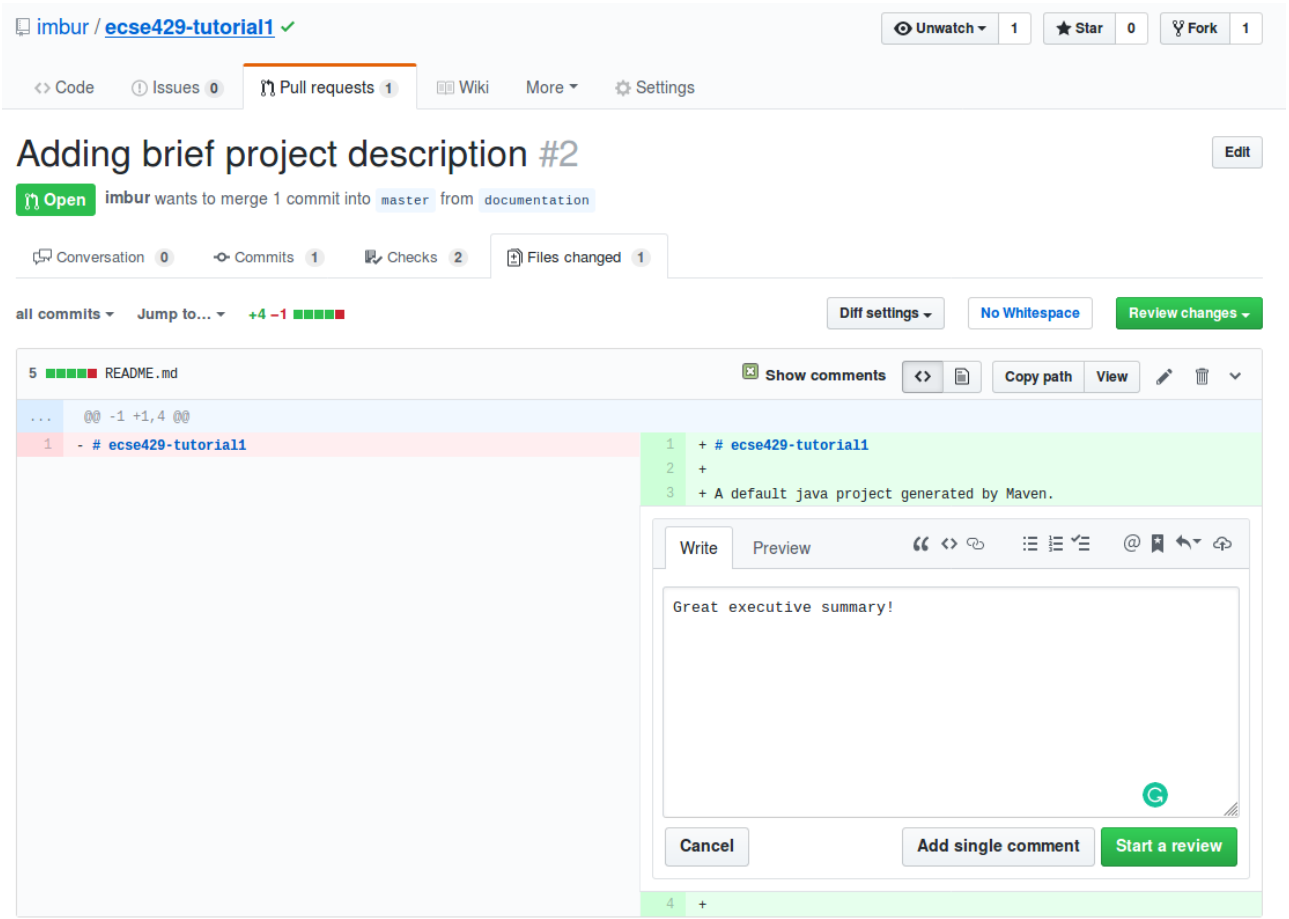
1. Commit your changes and push this `documentation` branch. (`git add . && git commit -m "Adding brief project description" && git push`)
2. Open the main page for the repository on Github. Click on the green button in the upper right corner to open a *pull request*.



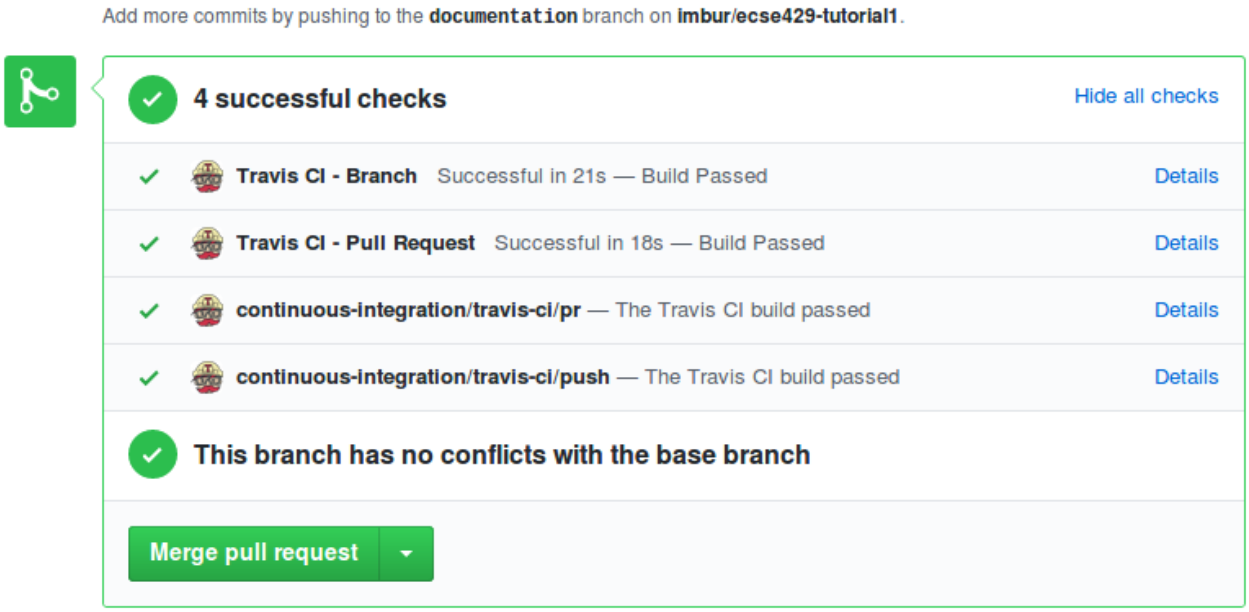
3. Study the possible settings, then create the pull request.



4. On the next page, click on *Files changed*. Place a comment in the updated file and start a review.



5. Normally, the owner and the reviewer are two different participants, and GitHub offers more options when completing a review: *approve changes* or *request changes*. This time simply click on *Finish review* and *Comment*.
6. Merge the pull request. Delete the branch afterwards.

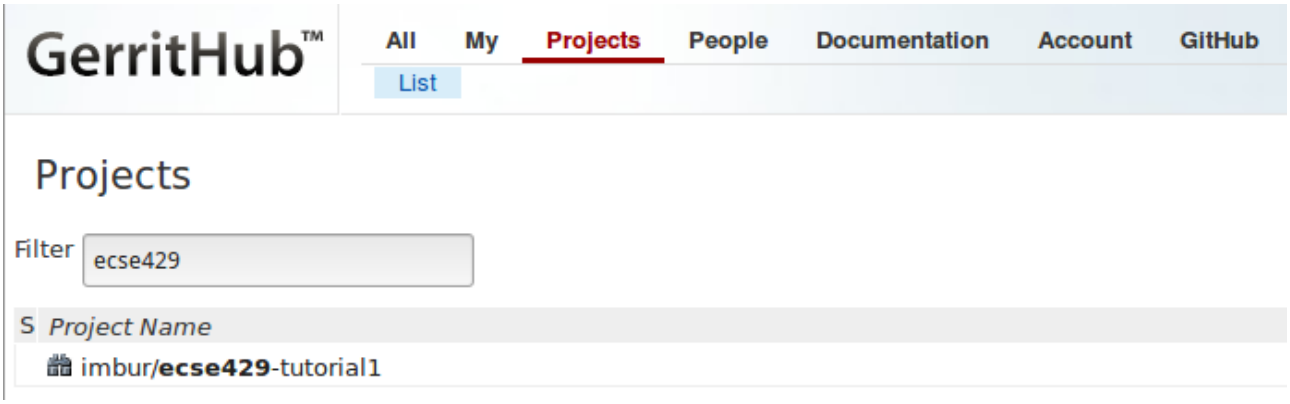


2.2. Gerrit Code Reviews

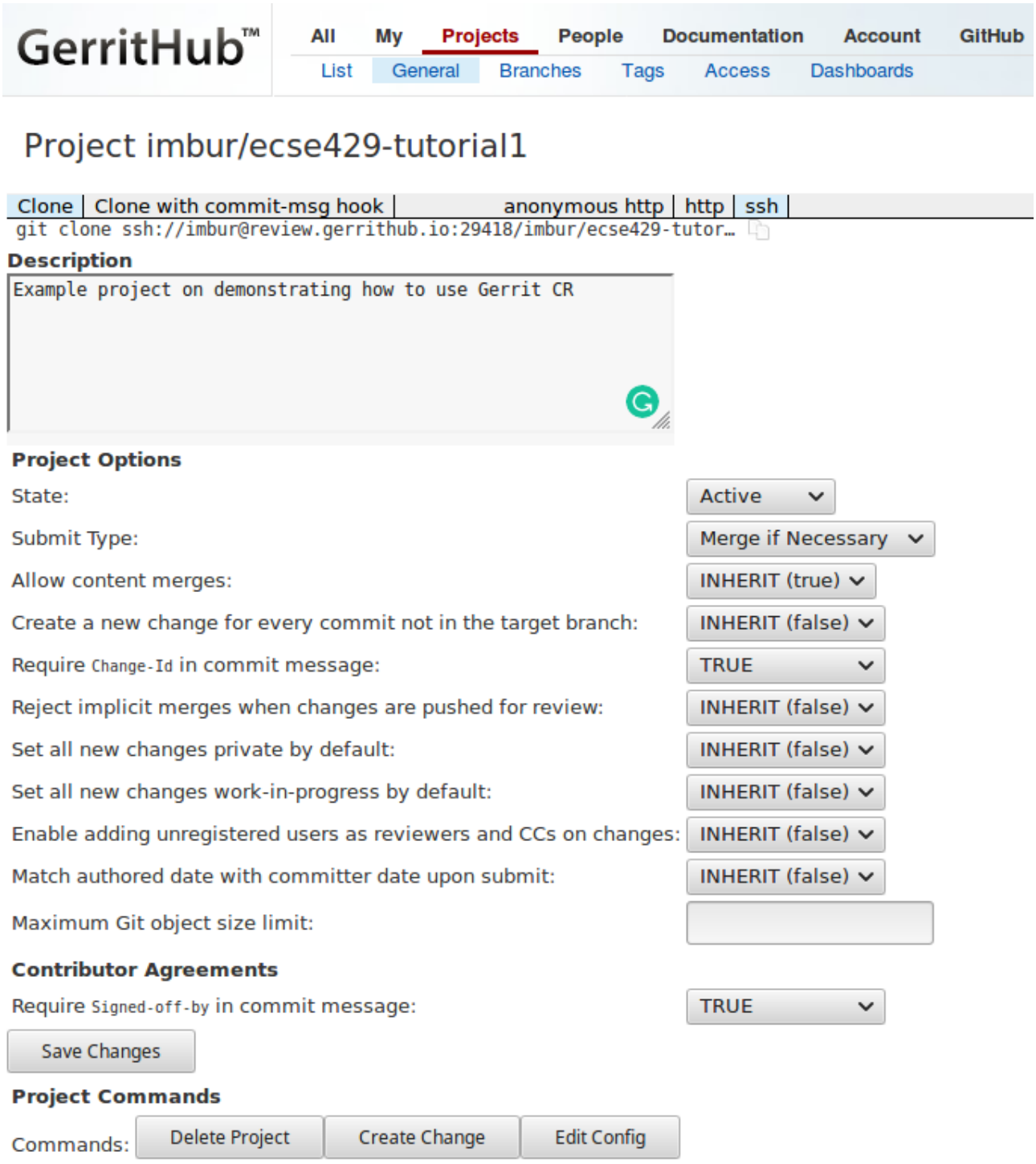
1. Go to http://gerrithub.io/, click on *First time Sign In*.
2. Authenticate with GitHub, then select the repositories you want to replicate with Gerrit. It is best to select the the public *[your GitHub user]/ecse429-tutorial1* repository created previously to follow the steps of this tutorial.

NOTE	You can select repositories to replicate anytime by navigating to *gerrithub.io* > *Open Gerrit Code Review* > *GitHub (in the top menubar)* > *Repositories*

3. Create a GerritHub password for HTTP access. Go to *your profile (upper right corner)* > *Settings* > *HTTP Password*, then click on *Generate password*. Make sure to save it somewhere, otherwise you need to generate it again next time.
4. Click on *Projects* > *List*, then search for your repository.

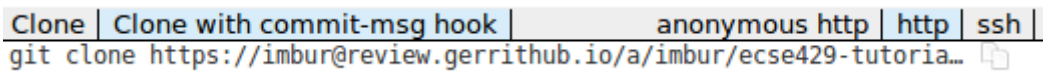


5. Select your project named after your repository, then set the settings below and click on *Save Changes*.



6. Copy the command from the `git clone` command shown above the *Description* text box after changing to *Clone with commit-msg hook* and *http*.

NOTE	Make sure you are issuing the `git clone` command in a folder that *is not part of any git repository working copy* in your file system. (In other words, you should do it in your `~/git` folder or the like.)



NOTE	Optionally, if you have SSH key installed to GitHub, you can import it to GerritHub and use that for authentication.

7. Paste the command to the terminal. Enter your generated password when prompted.

2.2.1. Making a Change with Gerrit

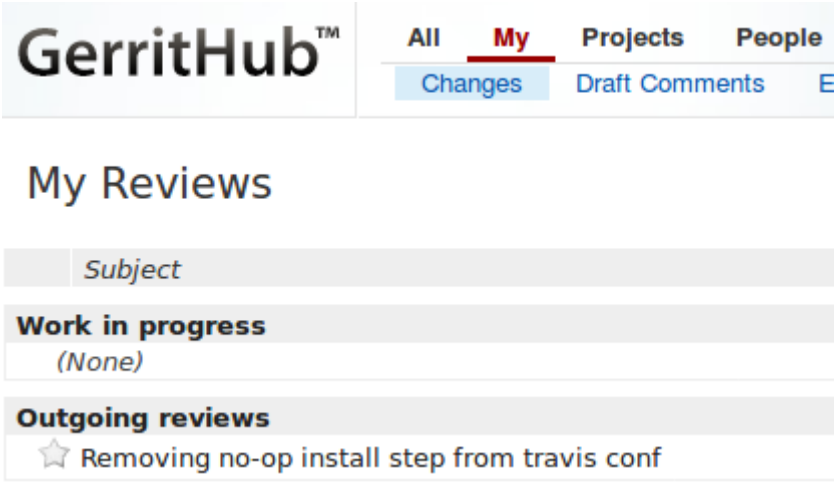
1. Navigate to the repository. Edit the `.travis.yml` file:

```
language: java
install: true
script:
 - cd tutorial1
 - mvn clean install
```

2. Add, commit and push the changes. (One-liner: `git add . && git commit -m "Making Travis skip the install step" && git push`)
3. Observe the created commit message with `git log`. Observe the changes synced to GitHub, too.
4. Create a new change to the code, remove the recently added `install: true` line from `.travis.yml` and create a new commit. Do not push it yet!
5. Issue `git push origin HEAD:refs/for/master`. The outputs should show that a new Gerrit change is created.

```
Counting objects: 3, done.
Delta compression using up to 8 threads.
Compressing objects: 100% (3/3), done.
Writing objects: 100% (3/3), 1.01 KiB | 0 bytes/s, done.
Total 3 (delta 1), reused 0 (delta 0)
remote: Resolving deltas: 100% (1/1)
remote: Processing changes: new: 1, done
remote:
remote: New Changes:
remote:   https://review.gerrithub.io/#/c/imbur/ecse429-tutorial1/+/425671 Removing
no-op install step from travis conf
remote:
To https://imbur@review.gerrithub.io/a/imbur/ecse429-tutorial1
 * [new branch]      HEAD -> refs/for/master
```

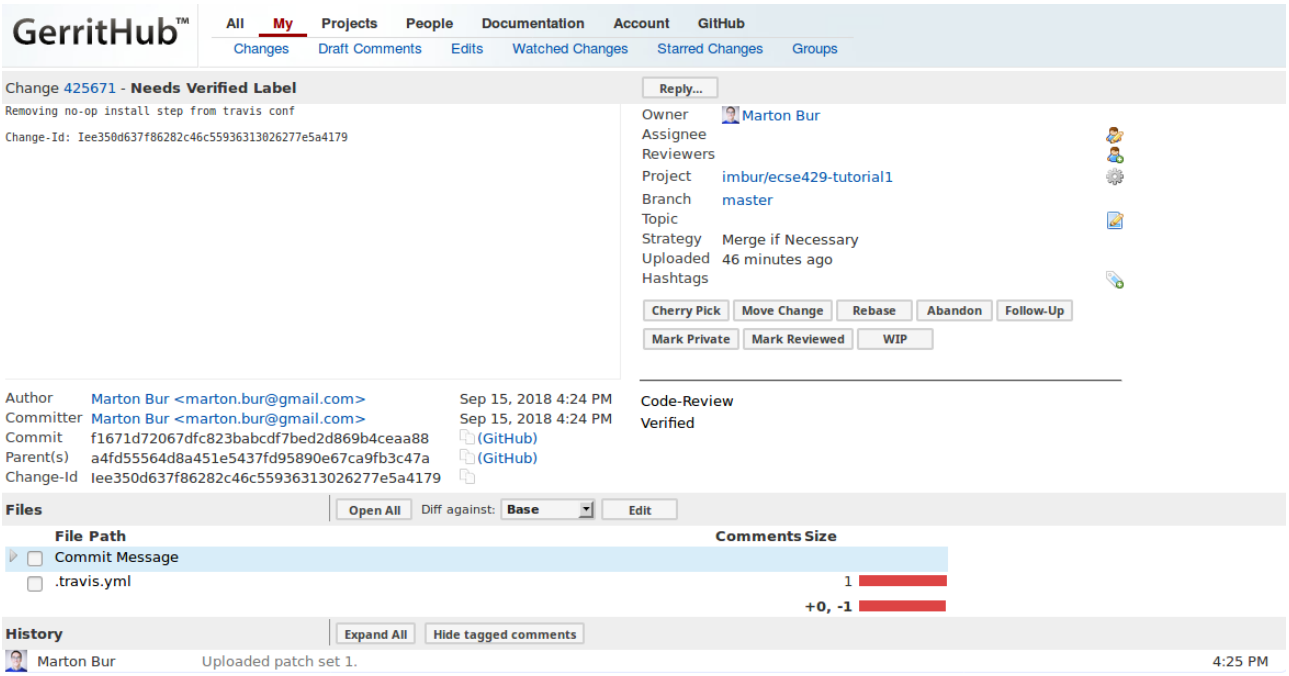
6. Navigate to your GerritHub dashboard. Observe the changes there.



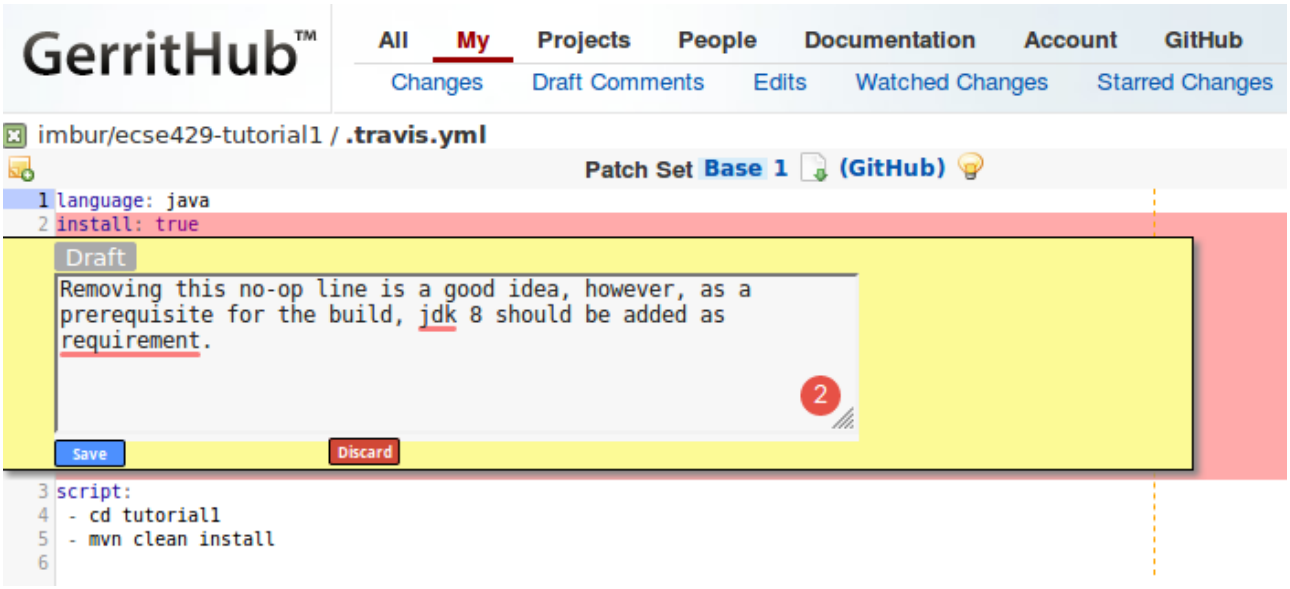
NOTE	GitHub does not sync Gerrit changes, since they are pushed to a gerrit-specific branch (`refs/for/[branchname]`).

2.2.2. Review and Manage a Change with Gerrit

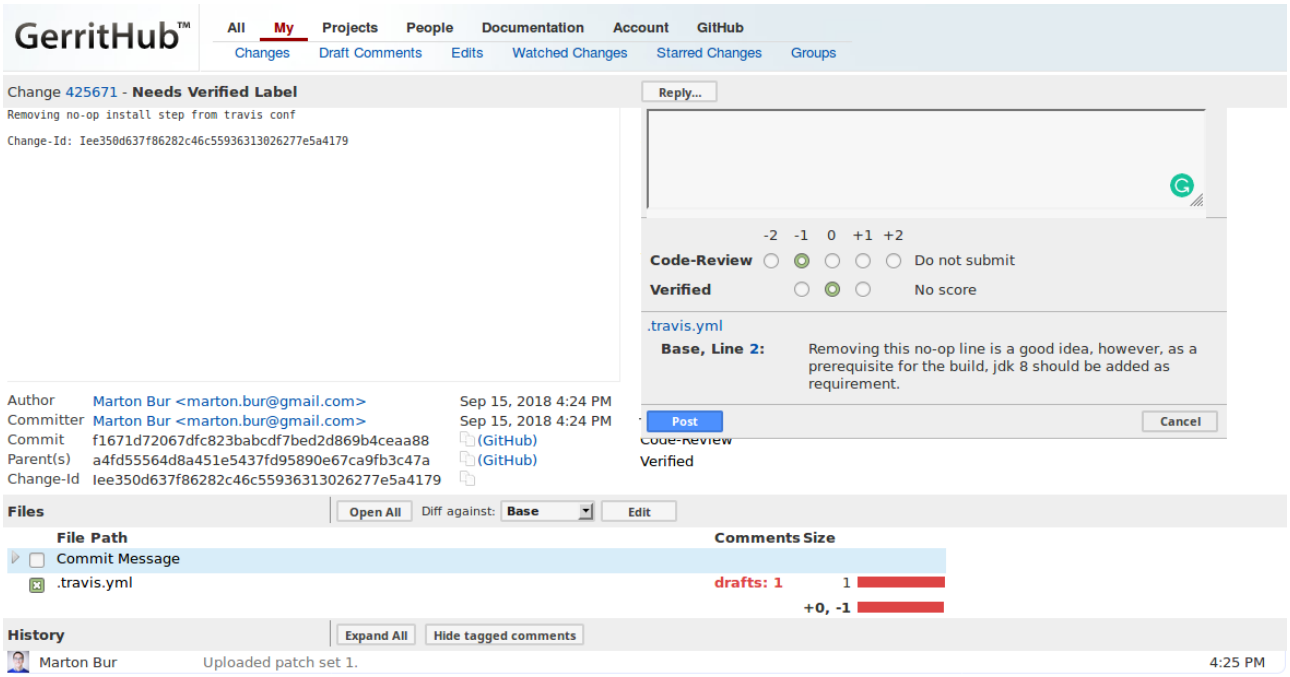
1. Click on the change and explore the options on the web interface.



2. Comment on the `.travis.yml` file within the change suggesting that JDK8 should be used with the project.



3. The comment will remain a draft up to the point until you submit your review. Click on the *Reply…* button on the overview page for the change.



4. Implement the modifications.

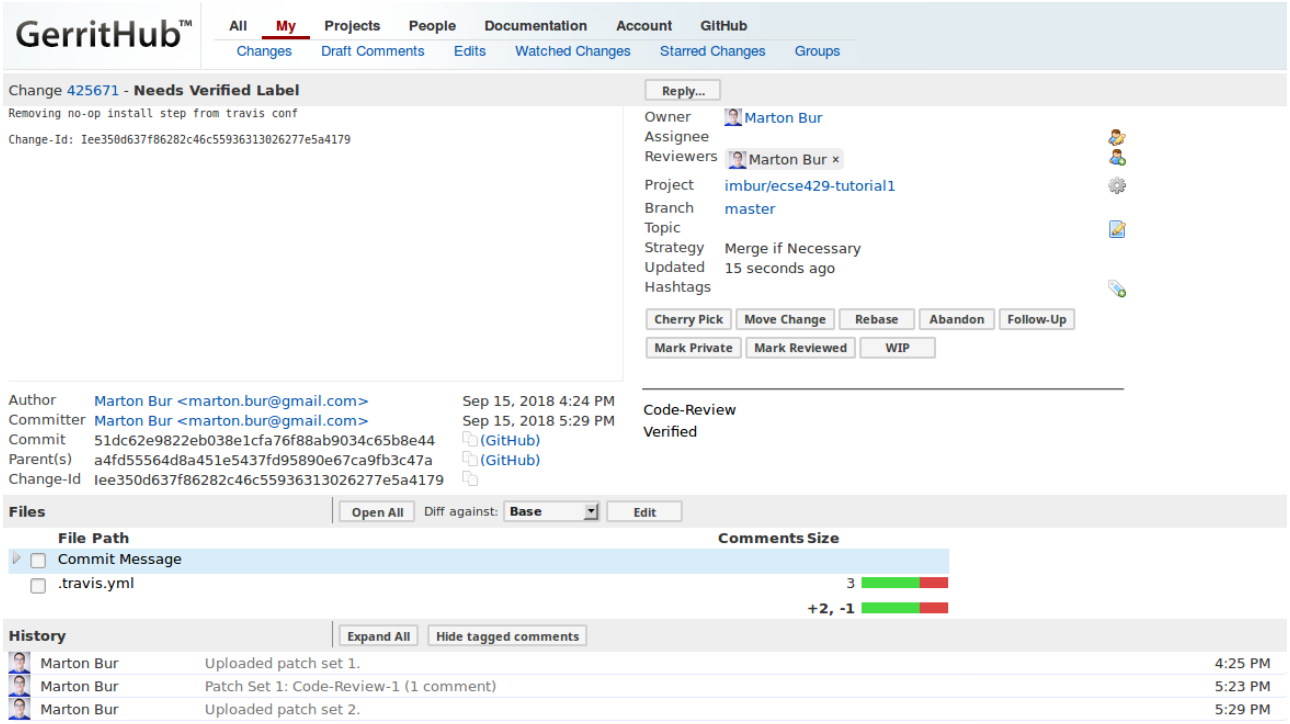
```
language: java
jdk:
 - oraclejdk8
script:
 - cd tutorial1
 - mvn clean install
```

5. Append these modifications to the change

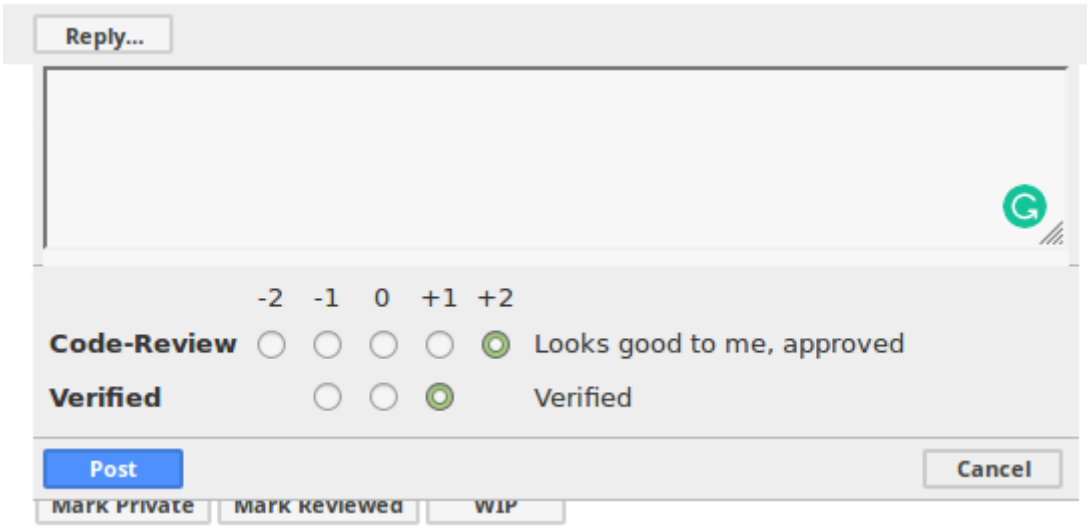
```
> git add .
> git commit --amend
> git push origin HEAD:refs/for/master
```

CAUTION	It is very important to add that in git amending a pushed commit is a history-rewriting operation, that is in most cases to be avoided. However, Gerrit follows these changes by amending a previous commit that holds the previous version of the change.

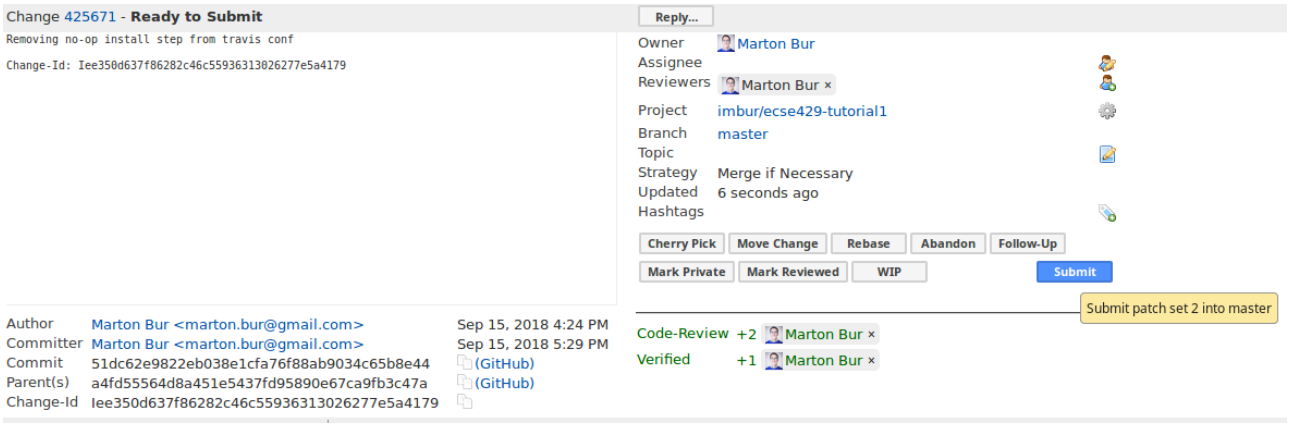
6. Observe the new patch set online.



7. Approve and verify the change.



8. Submit the changes to the `master` branch.



9. Soon the commit becomes visible in GitHub as well. Make sure to pull afterwards to update your local branches.

3. Unit Testing Frameworks

This material is included in two public tutorials:

1. AssertJ: http://www.vogella.com/tutorials/AssertJ/article.html (Sections 1-6)
2. JUnit5: http://www.vogella.com/tutorials/JUnit/article.html#junit5 (Sections 10-11)

4. Static Analysis

4.1. Prerequisites

This tutorial assumes that you have `maven` version 3.x.x installed on your computer. To create a new, default, maven project, simply type the command `mvn -B archetype:generate -DarchetypeGroupId=org.apache.maven.archetypes -DgroupId=com.mcgill.ca.tutorial3 -DartifactId=tutorial3` in the folder of your choice.

Next we will update the JUnit dependencies. Locate your `pom.xml` file that was created after the above command. The default generated `pom.xml` should look something like:

```
<project xmlns="http://maven.apache.org/POM/4.0.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://maven.apache.org/POM/4.0.0 http://maven.apache.org/maven-
v4_0_0.xsd">
  <modelVersion>4.0.0</modelVersion>
  <groupId>com.mcgill.ca</groupId>
  <artifactId>tutorial3</artifactId>
  <packaging>jar</packaging>
  <version>1.0-SNAPSHOT</version>
  <name>tutorial-3</name>
  <url>http://maven.apache.org</url>
  <dependencies>
    <dependency>
      <groupId>junit</groupId>
      <artifactId>junit</artifactId>
      <version>3.8.1</version>
      <scope>test</scope>
    </dependency>
  </dependencies>
</project>
```

Change the version number for JUnit from 3.8.1 to 4.12 and remove the `<scope>test</scope> tag`.

Change the `AppTest.java` class definition to a single empty test:

```
package com.mcgill.ca.tutorial3;

import org.junit.Test;

public class AppTest
{
    @Test
    public void emptyTest() {
    }
}
```

Finally, to make sure everything is working correctly, run the command `mvn clean install` and check that the build succeeded.

No git repository is created for this project. If you already have a repository containing this project and wish to use that one, ignore the steps having the (*Optional*) tag

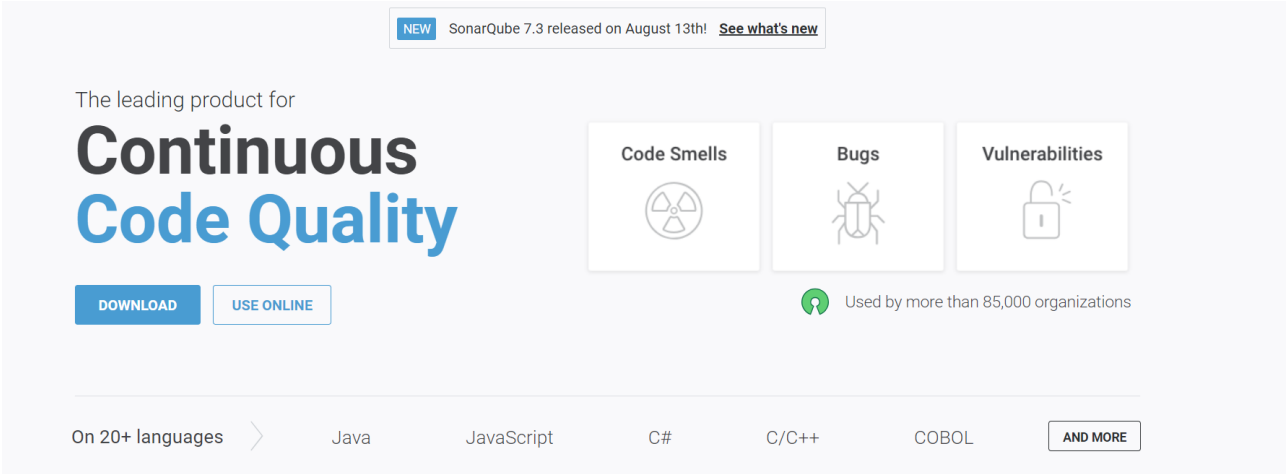
This default project will be used in the next sections.

4.2. SonarQube Static Code Analysis

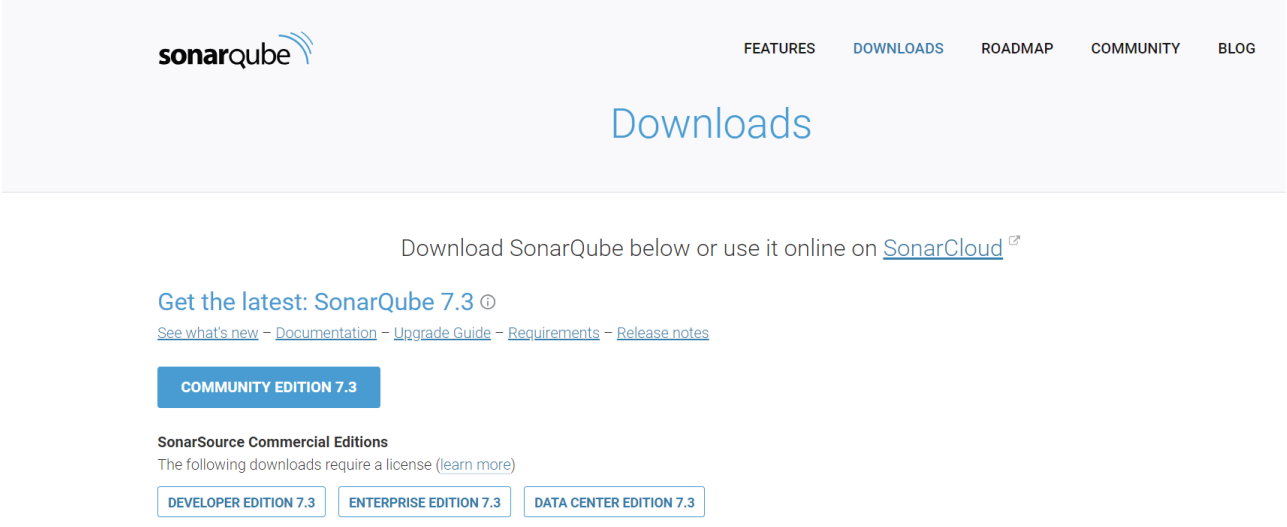
This section looks at how to use SonarQube, both integrated with Travis and as a standalone setup.

4.2.1. Offline SonarQube Installation

1. Navigate to the folder of the working copy of your repository used during the previous tutorial. If you no longer keep a working copy, clone it again.
2. Go to the SonarQube main page (https://www.sonarqube.org/) and click on the blue *Download* button.



3. Click on the blue *Community Edition 7.3* button

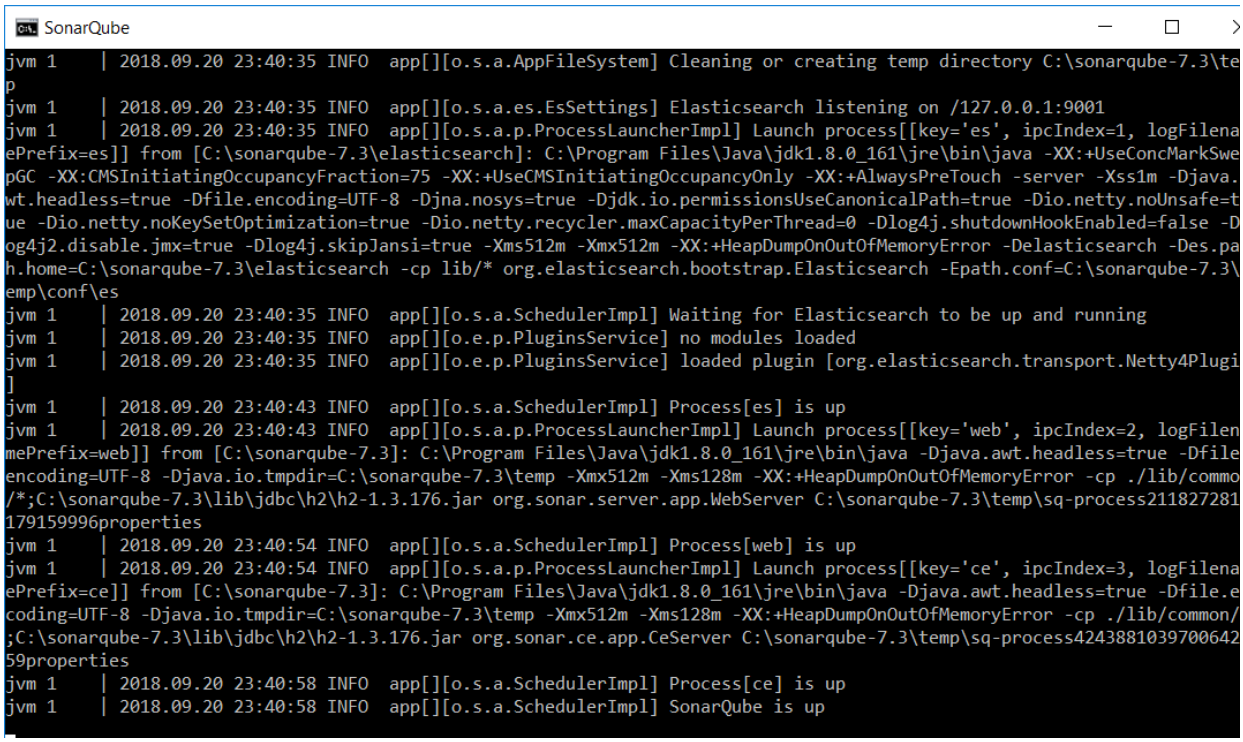


4. Extract the sonarqube-7.3.zip to the location of your choice.
   For this tutorial, we unzipped it in C:\
5. Start the SonarQube Server.
   Assuming you are in the root folder of the sonarqube directory, that is `C:\sonarqube-7.3` this example, you run either:
   `.\bin\[OS]\StartSonar.bat` for windows or `./bin/[OS]/sonar.sh console` for linux or mac

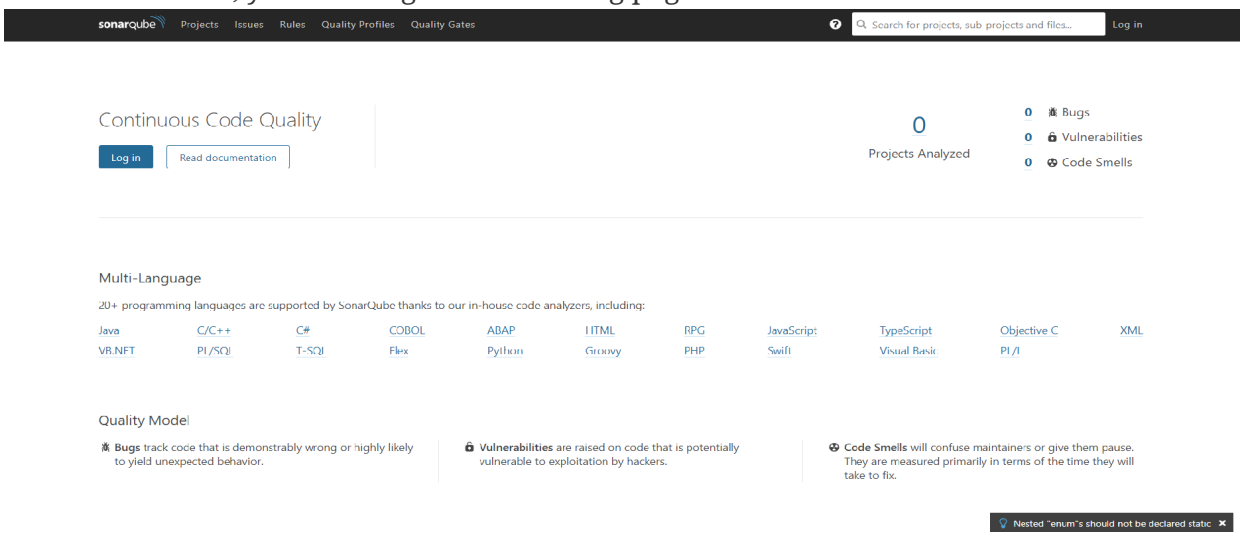
environments.
The OSs that are included are:

- windows-x86-32
- windows-x86-64
- macosx-universal-64
- linux-x86-32
- linux-x86-64

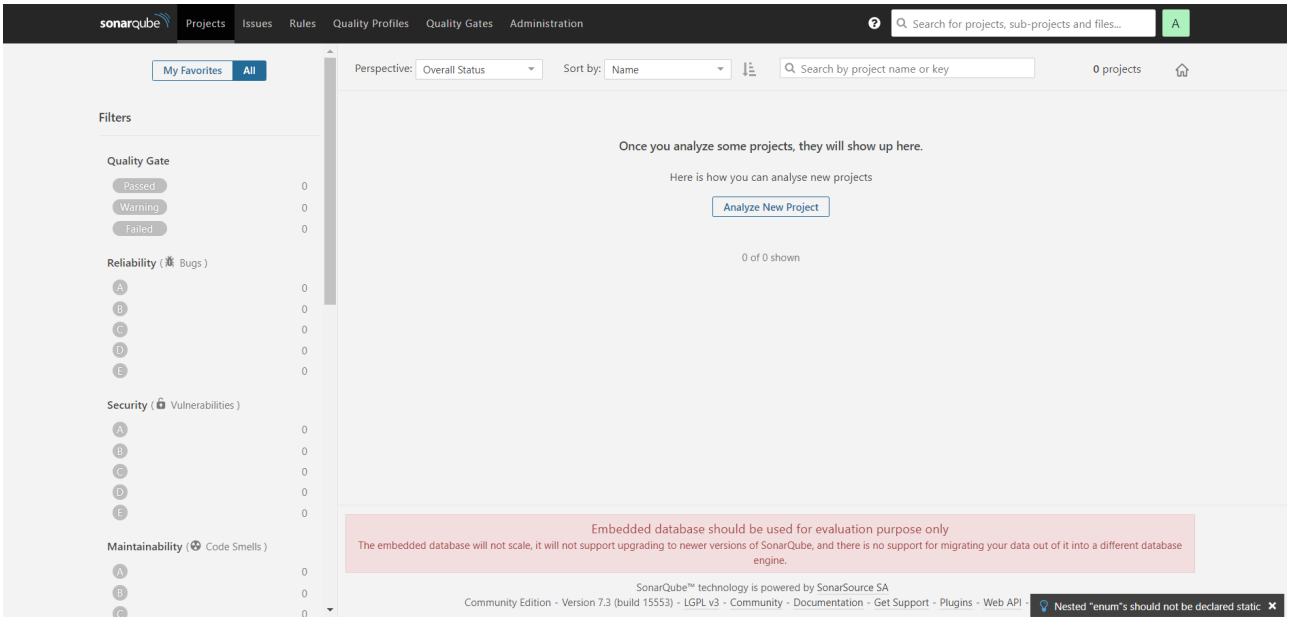
  In this example, we have a Windows machine, so we use `.\bin\windows-x86-64\StartSonar.bat` as a command. The server should boot and when it is finally ready, you should get an output similar to this



  SonarQube created a default webserver at localhost:9000. If you type the latter in your Internet browser, you should get the following page



6. Log in the server
   The default account created for your page is admin:admin



7. Create Basic Code Smells in the Project
   Locate the file `App.java` in your maven project and change the class definition to the following:

```
package ca.mcgill.ecse429;

public class App
{
    private int x;

    public static void main( String[] args )
    {
        String s = null;
        System.out.println(s.length());
    }

}
```

8 Edit the `pom.xml`
Add the Sonar Maven plugin and its configuration to the project (e.g., after the `</dependencies>` closing tag)

```
...
<build>
    <plugins>
        <plugin>
            <groupId>org.sonarsource.scanner.maven</groupId>
            <artifactId>sonar-maven-plugin</artifactId>
            <version>3.5.0.1254</version>
        </plugin>
    </plugins>
</build>

<profiles>
    <profile>
        <id>sonar</id>
        <activation>
            <activeByDefault>true</activeByDefault>
        </activation>
        <properties>
        <!-- Optional URL to server. Default value is http://localhost:9000 -->
            <sonar.host.url>
                http://localhost:9000
            </sonar.host.url>
        </properties>
    </profile>
</profiles>
...
```

+

NOTE For gradle 2.1 and above, add the following snippet to the build script:

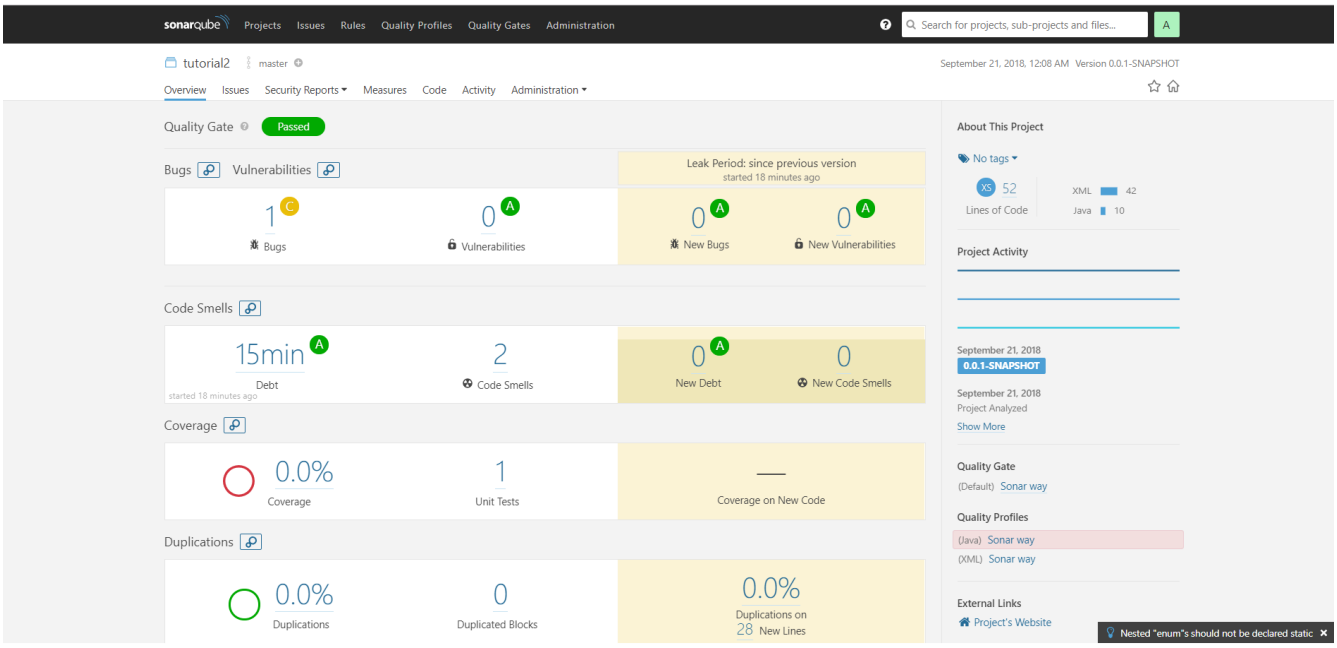
```
plugins {
  id "org.sonarqube" version "2.6.2"
}
```

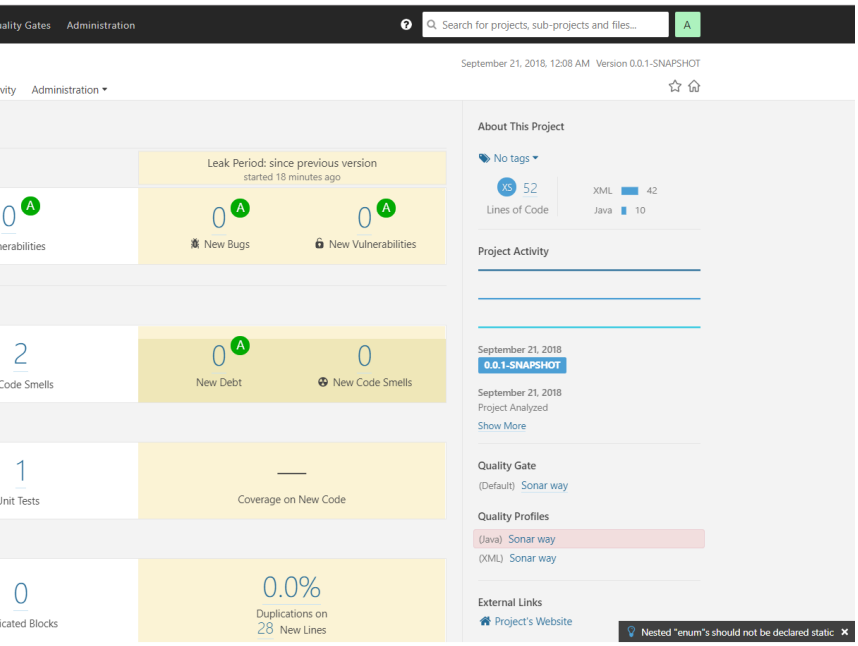
+ Then, you can run analysis using `gradle sonarqube`

9 Build the Project
In another terminal, run the command `mvn clean install sonar:sonar` at the root of the project folder
You should get an output similar to this:

```
[INFO] Sensor XML Sensor [xml]
[INFO] Sensor XML Sensor [xml] (done) | time=77ms
[INFO] Sensor Zero Coverage Sensor
[INFO] Sensor Zero Coverage Sensor (done) | time=11ms
[INFO] Sensor Java CPD Block Indexer
[INFO] Sensor Java CPD Block Indexer (done) | time=13ms
[INFO] SCM provider for this project is: git
[INFO] 3 files to be analyzed
[INFO] 0/3 files analyzed
[WARNING] Missing blame information for the following files:
[WARNING]   * pom.xml
[WARNING]   * src/main/java/mcgill/ecse429/tutorial2/App.java
[WARNING]   * src/test/java/mcgill/ecse429/tutorial2/AppTest.java
[WARNING] This may lead to missing/broken features in SonarQube
[INFO] 1 file had no CPD blocks
[INFO] Calculating CPD for 0 files
[INFO] CPD calculation finished
[INFO] Analysis report generated in 70ms, dir size=34 KB
[INFO] Analysis reports compressed in 16ms, zip size=12 KB
[INFO] Analysis report uploaded in 21ms
[INFO] ANALYSIS SUCCESSFUL, you can browse http://localhost:9000/dashboard?id=mcgill.ecse429%3Atutorial2
[INFO] Note that you will be able to access the updated dashboard once the server has processed the submitted analysis r
eport
[INFO] More about the report processing at http://localhost:9000/api/ce/task?id=AWX6UG4FKQha6VudJpJT
[INFO] Task total time: 4.301 s
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time: 7.815 s
[INFO] Finished at: 2018-09-21T00:08:19-04:00
```

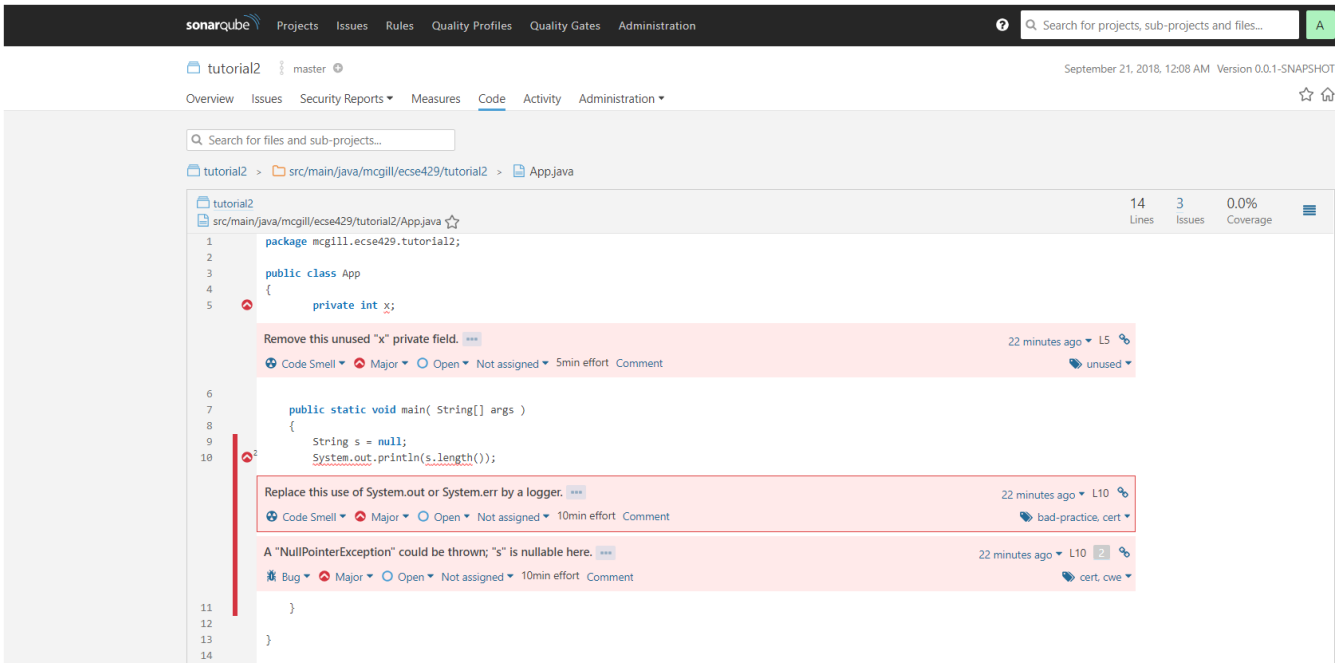
If we visit the link in the terminal output (it follows the format of http://localhost:9000/dashboard?id=<INSERT_PROJECT_NAME>), we are brought to a page similar to this:





10 Investigate the Error Causes:

Click on *Code* in the toolbar above. Then select the package containing the `App.java` class from the list and click on `App.java` and click on the red icons on the left of your code.



Adding Code Coverage

1. Edit the `pom.xml` and add a new `profile` somewhere between the `<profiles>` tags

```
<profile>
<id>sonar-coverage</id>
<activation>
<activeByDefault>true</activeByDefault>
</activation>
<build>
<pluginManagement>
  <plugins>
    <plugin>
      <groupId>org.jacoco</groupId>
      <artifactId>jacoco-maven-plugin</artifactId>
      <version>0.7.8</version>
    </plugin>
  </plugins>
</pluginManagement>
<plugins>
  <plugin>
    <groupId>org.jacoco</groupId>
    <artifactId>jacoco-maven-plugin</artifactId>
    <configuration>
      <append>true</append>
    </configuration>
    <executions>
      <execution>
    <id>agent-for-ut</id>
    <goals>
      <goal>prepare-agent</goal>
    </goals>
      </execution>
      <execution>
    <id>jacoco-site</id>
    <phase>verify</phase>
    <goals>
      <goal>report</goal>
    </goals>
      </execution>
    </executions>
  </plugin>
  </plugins>
  </build>
</profile>
```

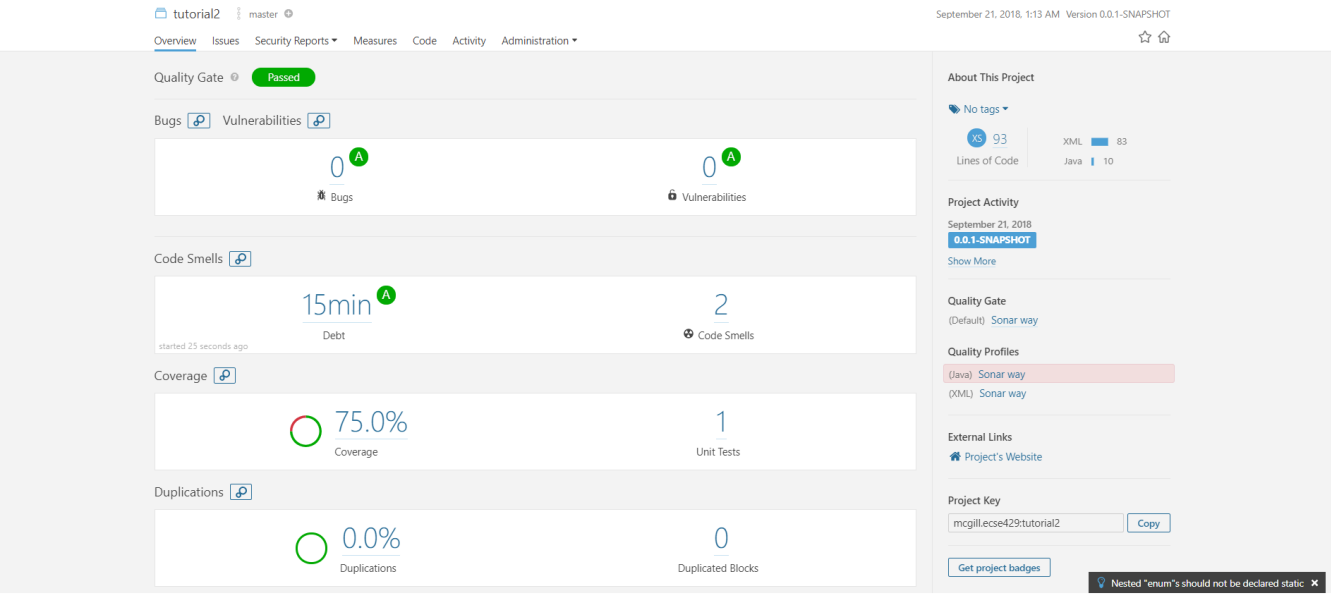
2. Write a Dummy Test

In `AppTest.java`, substitute `emptyTest` with the following:

```
@Test
public void mainTest() {
    App.main(null);
}
```

3 Run the command `mvn clean install sonar:sonar` once again

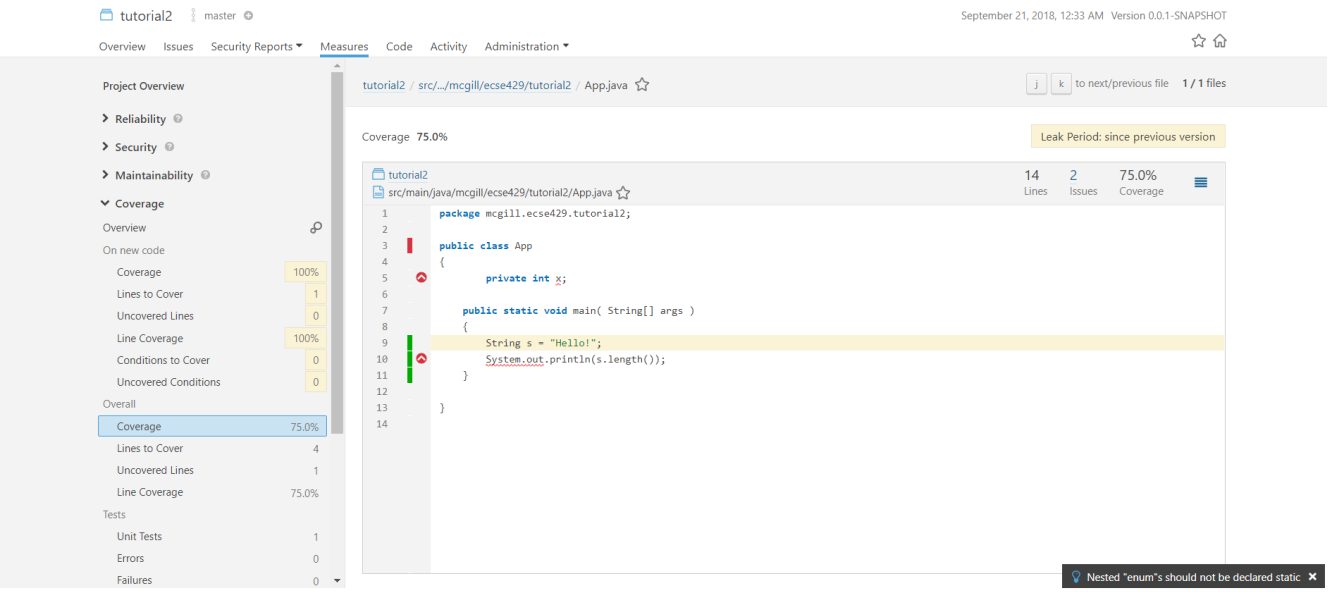
4 Use the outputted URL to inspect the changes in SonarQube



5 Click on the `75%` of the `Code Coverage` Section

6 Click on the `App.java` file in the list

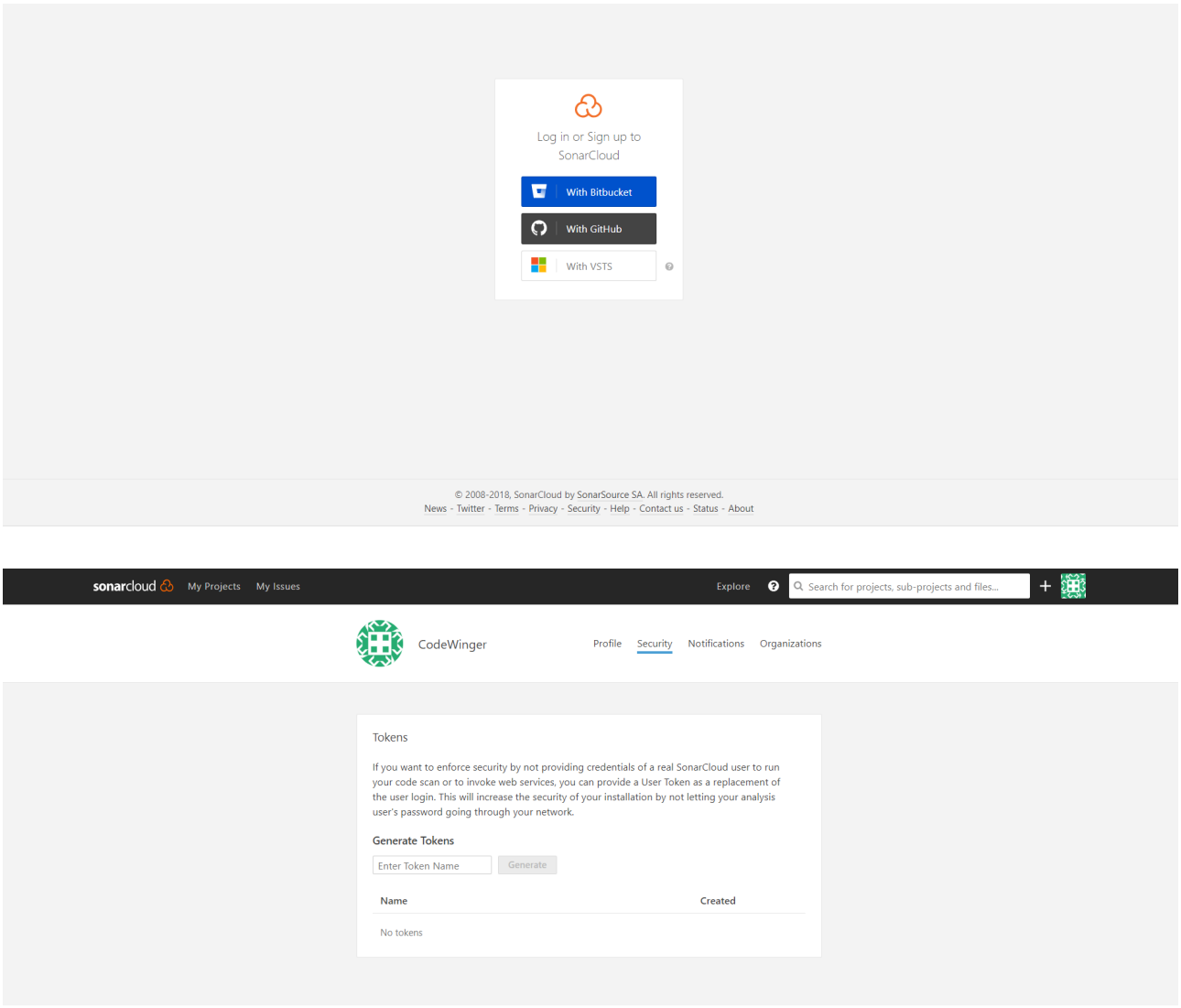
7 Look to the left of the red error icons. We now see which lines were tested by the unit tests.



4.2.2. SonarQube Integrated With Travis

1. Register your Github Account in this link (https://sonarcloud.io/sessions/new?

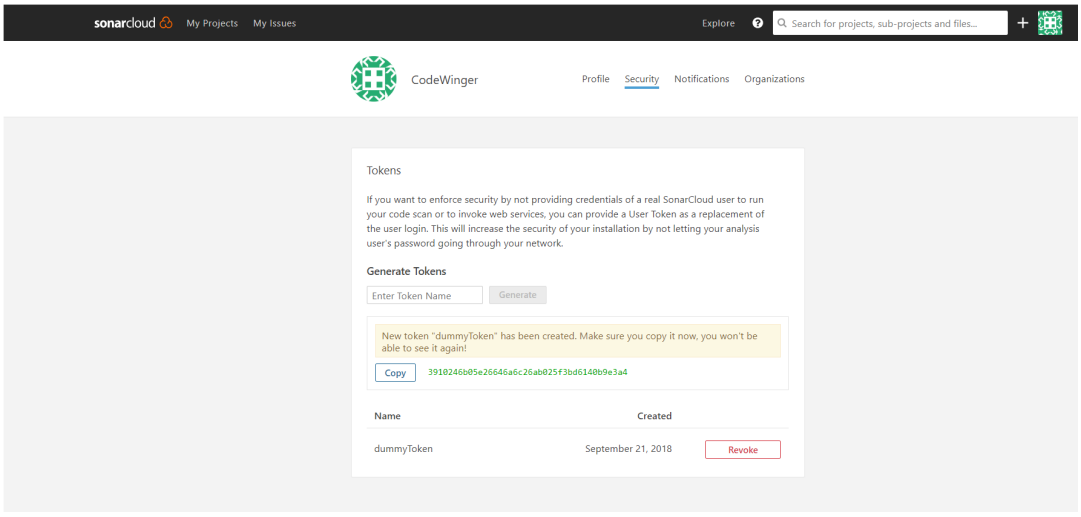
return_to=%2Faccount%2Fsecurity)



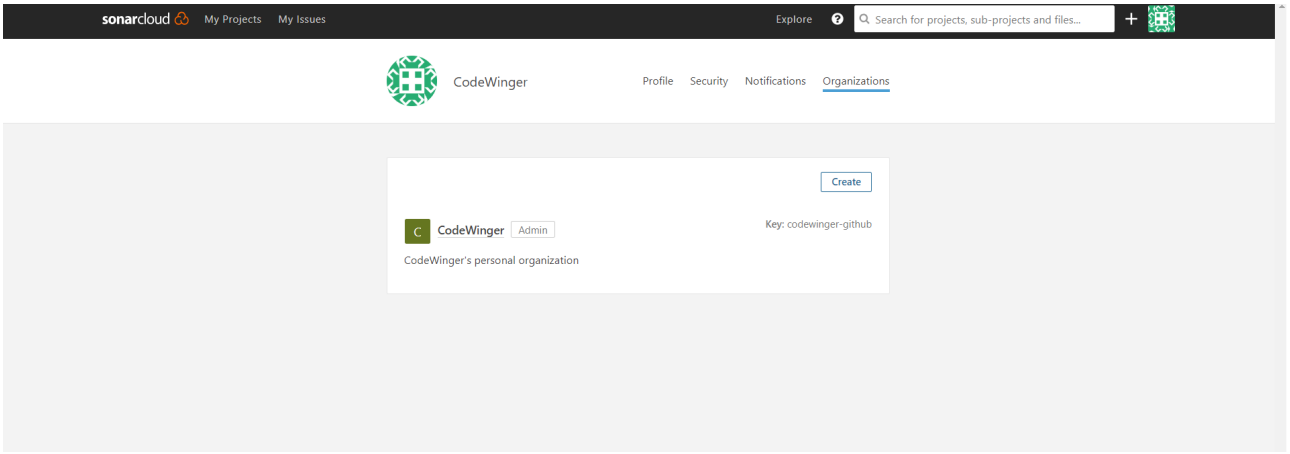
2. Add a security token of your choice and store in a file of your choice

NOTE

It is important to copy it somewhere; you will not be able to see it again afterwards



3. Click on your picture in the top right-hand side of the toolbar, next to the search bar, then on the button *My Organizations*



4. Jot down the key given by SonarCloud.io under the *Create* button
5. Add a `.travis.yml` file to the project's directory

```
language: java
sudo: false
install: true

addons:
  sonarcloud:
    organization: "[YOUR ORGANIZATION KEY]"
    token:
      secure: "[YOUR GENERATED TOKEN]"


jdk:
  - oraclejdk8

script:
  - mvn clean org.jacoco:jacoco-maven-plugin:prepare-agent package sonar:sonar

cache:
  directories:
    - '$HOME/.m2/repository'
    - '$HOME/.sonar/cache'
```

For this example, the `addons` section would look like

```
addons:
  sonarcloud:
    organization: "codewinger-github"
    token:
      secure: "3910246b05e26646a6c26ab025f3bd6140b9e3a4"
```

6 Create a new local repository with the command `git init` (*Optional*)

7 Create a new upstream repository on GitHub (*Optional*)

After creating the repository, from the command line enter the commands:

```
git remote add origin https://github.com/[YOUR GITHUB ID]/[YOUR REPO NAME].git
```

In my case, the above would look like:

```
git remote add origin https://github.com/CodeWinger/tutorial3.git
```

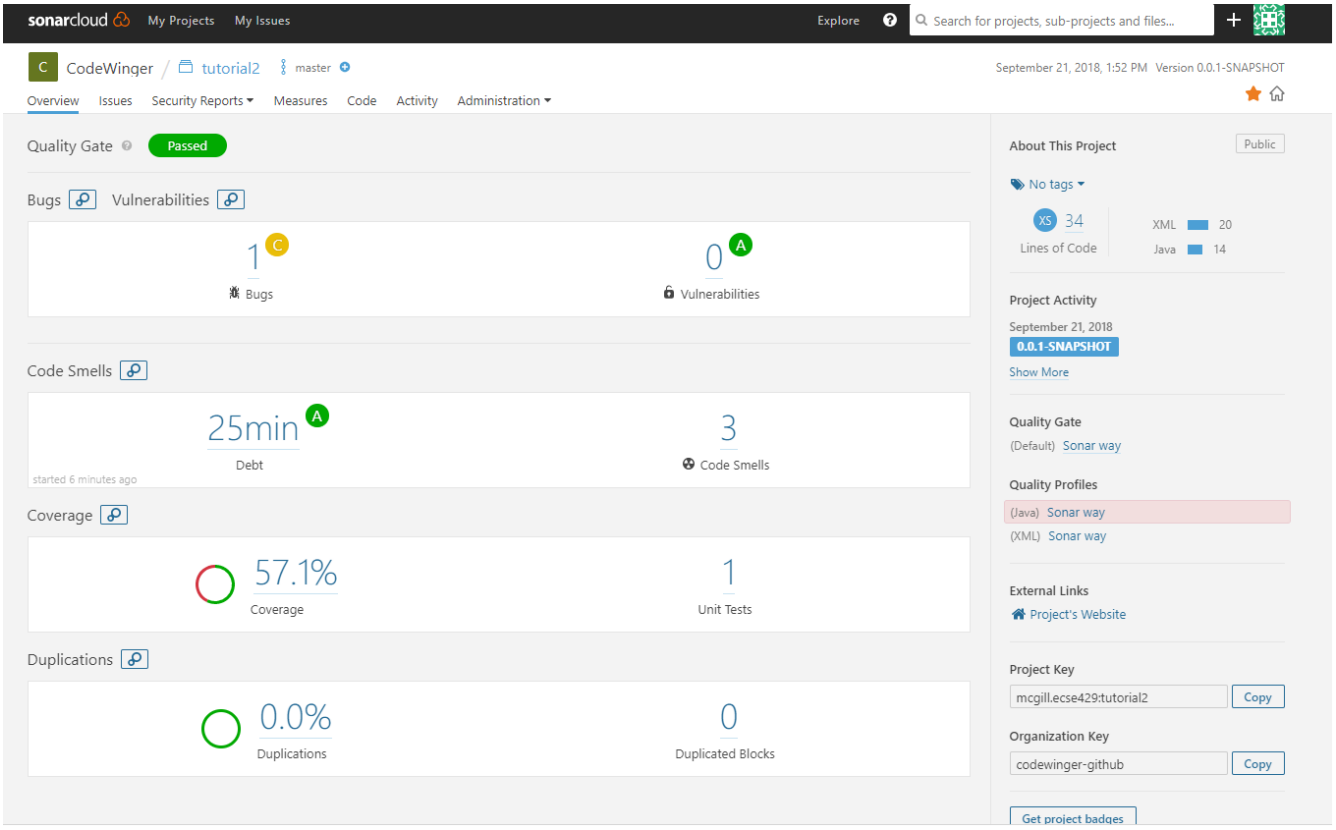
8 Add a `.gitignore` file (*Optional*)

```
# Compiled class file
*.class

# Log file
*.log

# BlueJ files
*.ctxt

# Mobile Tools for Java (J2ME)
.mtj.tmp/

# Package Files #
*.jar
*.war
*.nar
*.ear
*.zip
*.tar.gz
*.rar

# virtual machine crash logs, see
http://www.java.com/en/download/help/error_hotspot.xml
hs_err_pid*
```

9 Push your work from the `master` branch to GitHub with the command `git add . && git commit -m "SonarCloud Integration" & git push origin master:master --set-upstream`
We need to first analyze the `main` branch before we can analyze new branches along with their differences with the `master` branch Your output should look something like this:

```
[INFO] Sensor XML Sensor [xml] (done) | time=133ms
[INFO] Sensor Zero Coverage Sensor
[INFO] Sensor Zero Coverage Sensor (done) | time=13ms
[INFO] Sensor JavaSecuritySensor [security]
[INFO] UCFGs: 2, excluded: 2, source entrypoints: 0
[INFO] No UCFGs have been included for analysis.
[INFO] Sensor JavaSecuritySensor [security] (done) | time=80ms
[INFO] Sensor CSharpSecuritySensor [security]
[INFO] UCFGs: 0, excluded: 0, source entrypoints: 0
[INFO] No UCFGs have been included for analysis.
[INFO] Sensor CSharpSecuritySensor [security] (done) | time=0ms
[INFO] Sensor Java CPD Block Indexer
[INFO] Sensor Java CPD Block Indexer (done) | time=16ms
[INFO] SCM provider for this project is: git
[INFO] 3 files to be analyzed
[INFO] 3/3 files analyzed
[INFO] 1 file had no CPD blocks
[INFO] Calculating CPD for 0 files
[INFO] CPD calculation finished
[INFO] Analysis report generated in 150ms, dir size=63 KB
[INFO] Analysis reports compressed in 14ms, zip size=23 KB
[INFO] Analysis report uploaded in 1122ms
[INFO] ANALYSIS SUCCESSFUL, you can browse https://sonarcloud.io/dashboard?id=mcgill.ecse429%3Atutorial2
[INFO] Note that you will be able to access the updated dashboard once the server has processed the submitted analysis report
[INFO] More about the report processing at https://sonarcloud.io/api/ce/task?id=AWX9QxmLHR8j8dJrX_Iy
[INFO] Task total time: 13.329 s
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time: 54.065 s
[INFO] Finished at: 2018-09-21T17:52:37Z
[INFO] Final Memory: 74M/914M
[INFO] ------------------------------------------------------------------------
```

10 Copy the outputted URL (https://sonarcloud.io/dashboard?id=mcgill.ecse429%3Atutorial2, in this case) and paste it in your Internet browser.



11 From the `master` branch, create and checkout a new branch `git branch sonarqube-travis-integration && git checkout sonarqube-travis-integration`

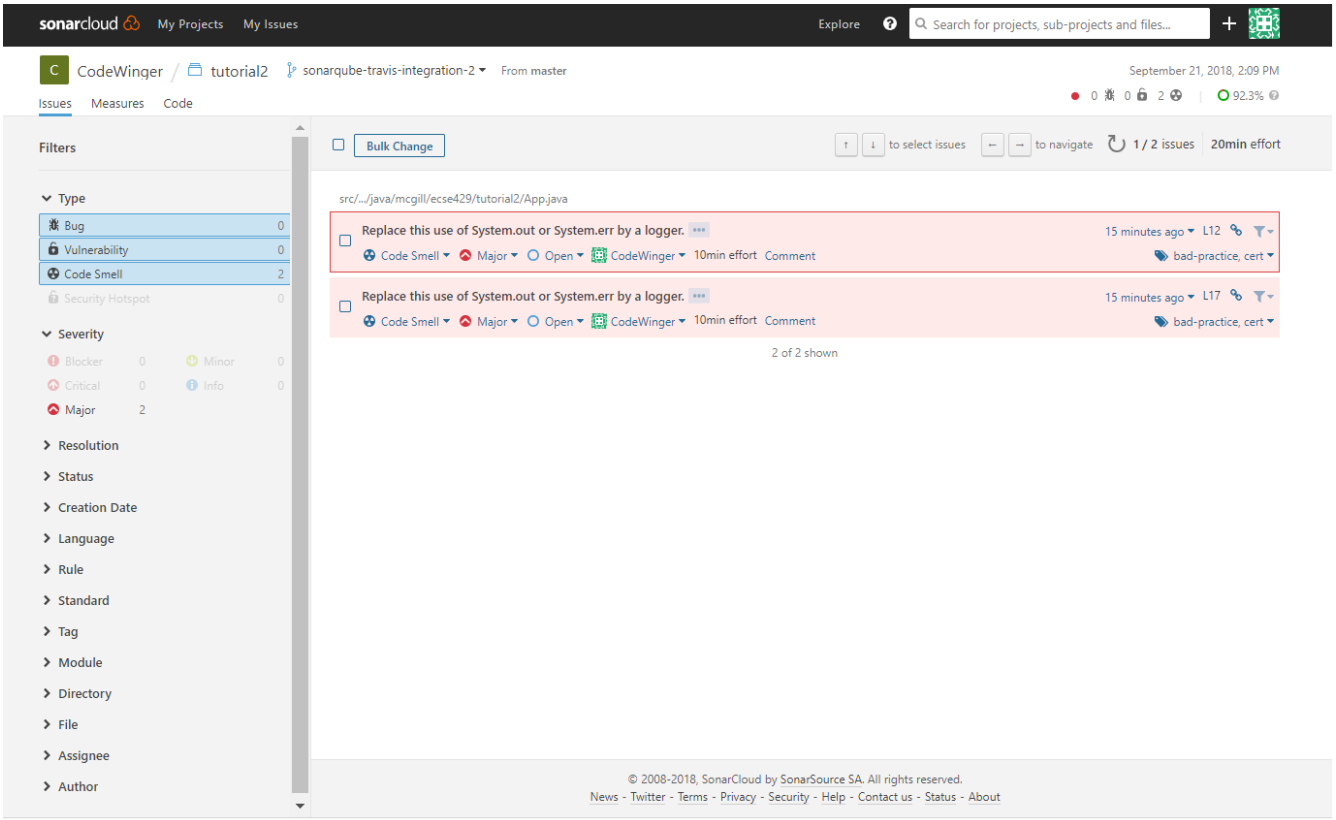
12 Modify `App.java's class definition:

```
public class App
{
    public static void main( String[] args )
    {
        if (args == null || args.length == 0) {
            System.out.println("no input");
            return;
        }

        for (String argument : args) {
            System.out.println(argument);
        }
    }
}
```

13 Modify `AppTest.java's class definition:

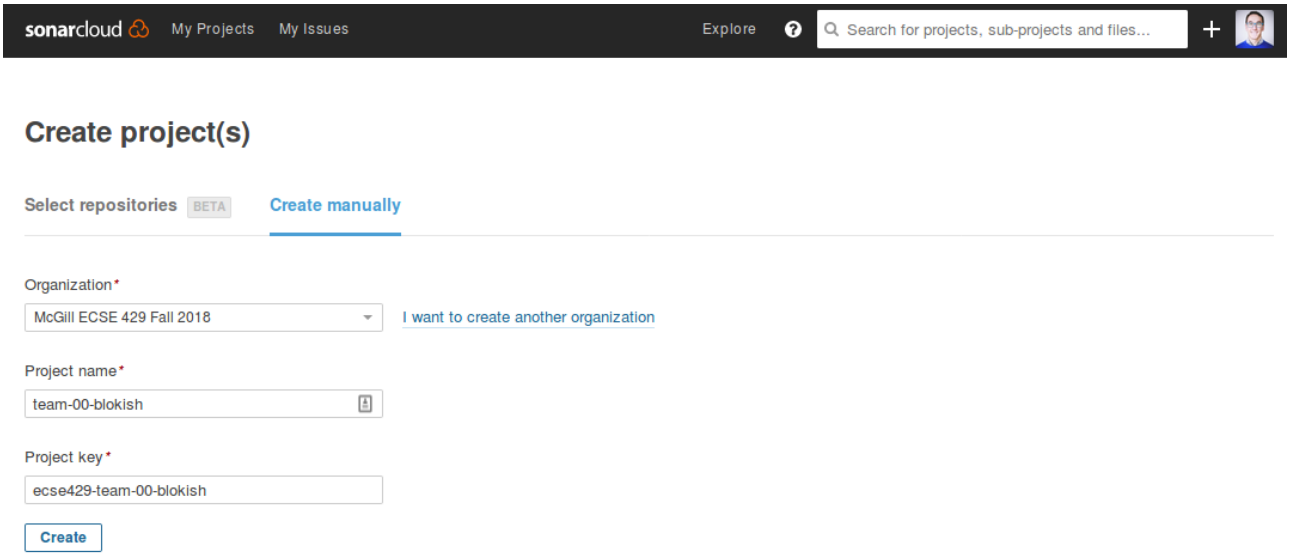
```
import org.junit.Test;

public class AppTest
{
    @Test
    public void testMainMethodForNull() {
        App.main(null);
    }

    @Test
    public void testMainMethodForEmptyArray() {
        App.main(new String[0]);
    }

    @Test
    public void testMainMethodForNonEmptyArray() {
        String[] args = {"Hello", "World"};
        App.main(args);
    }
}
```

14 Push your work on the branch and check the output in SonarCloud.io (`git add . && git commit -m "SonarCloud Integration" & git push -u origin sonarqube-travis-integration`

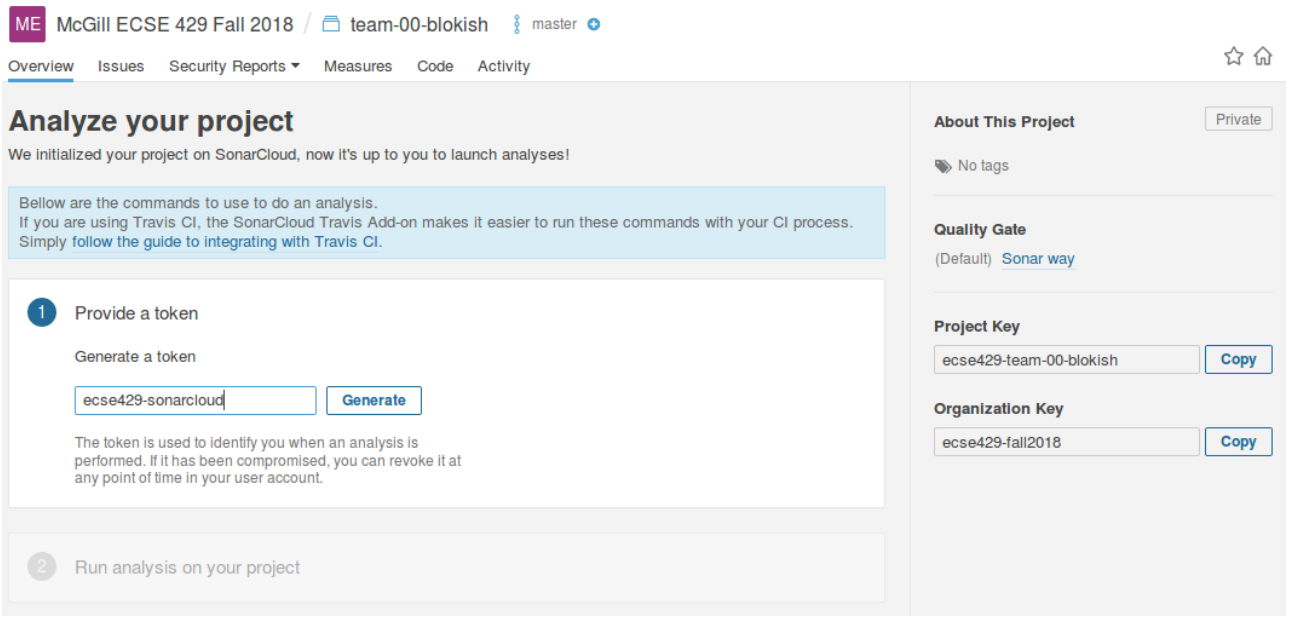


4.3. SonarCloud integration for Project deliverable

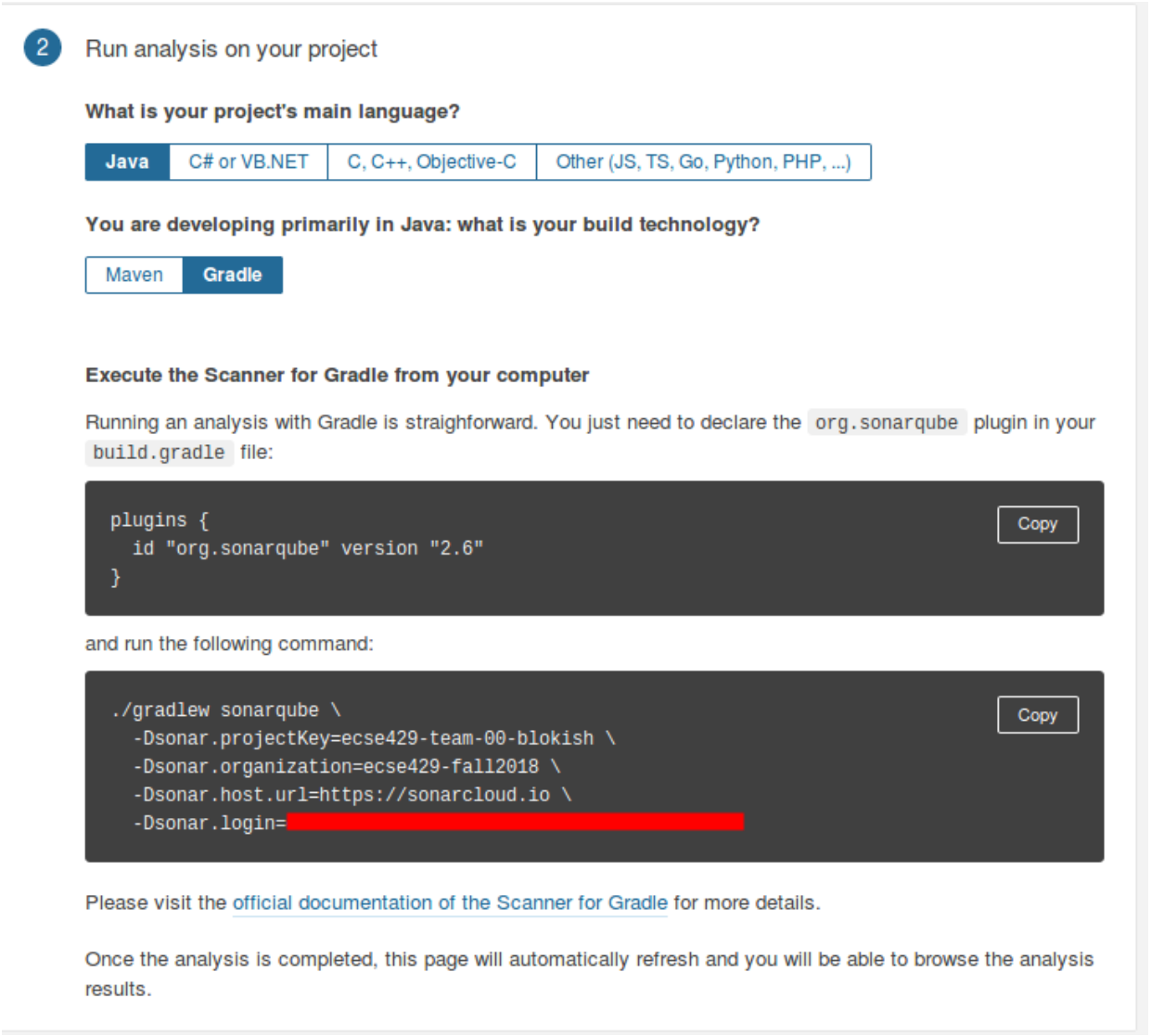
1. One team member is registered to SonarCloud organization McGill ECSE429 Fall2018. Follow the steps with that team member's SonarCloud account.
2. Create a SonarCloud project *under the organization* (and not under your user). Name it `team-NO-blokish`, where `NO` is the placeholder for the two digit team number. Assign a unique project key to it afterwards as shown below.



3. Generate an access token for the project.



4. On the next page, you will be shown two snippets:
   - one is to be added to the `build.gradle` file
   - the other one is the command you can use out-of-the box to build and analyze on SonarCloud



4.4. Infer Static Analyzer

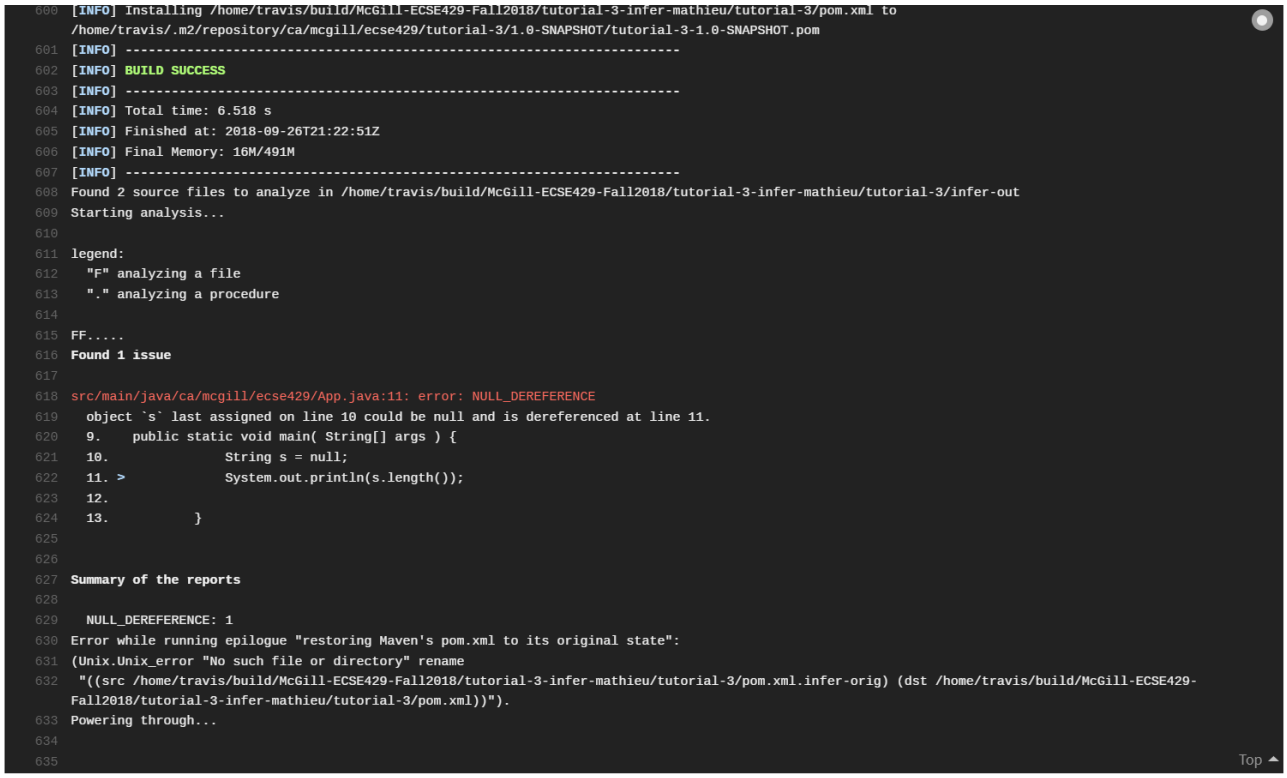
1. Create and checkout a new branch from master (`git branch infer && git checkout infer`)
2. Edit the .travis.yml file:

```
dist: trusty
sudo: required
language: java
jdk: oraclejdk7

script:
 - #TODO: get infer archive and extract it
 - #TODO: add infer executable to the path
 - #TODO: invoke infer with your project
```

3. Introduce a null warning In the default file `App.java`, change the main method to the following:

```
public static void main( String[] args ) {
    String s = null;
    System.out.println(s.length());
}
```

4. Commit and push the 2 modified files (`commit add . && git commit -m "Added Infer Static Analyzer" && git push -u origin infer`)
5. Go to https://travis-ci.com/ to see your build processes. It should look something similar to this:



5. Test Generation and Code Coverage

5.1. EvoSuite Installation and Initial Project Setup

NOTE	For this session, we are reusing a sligthly modified version of the example project available here.

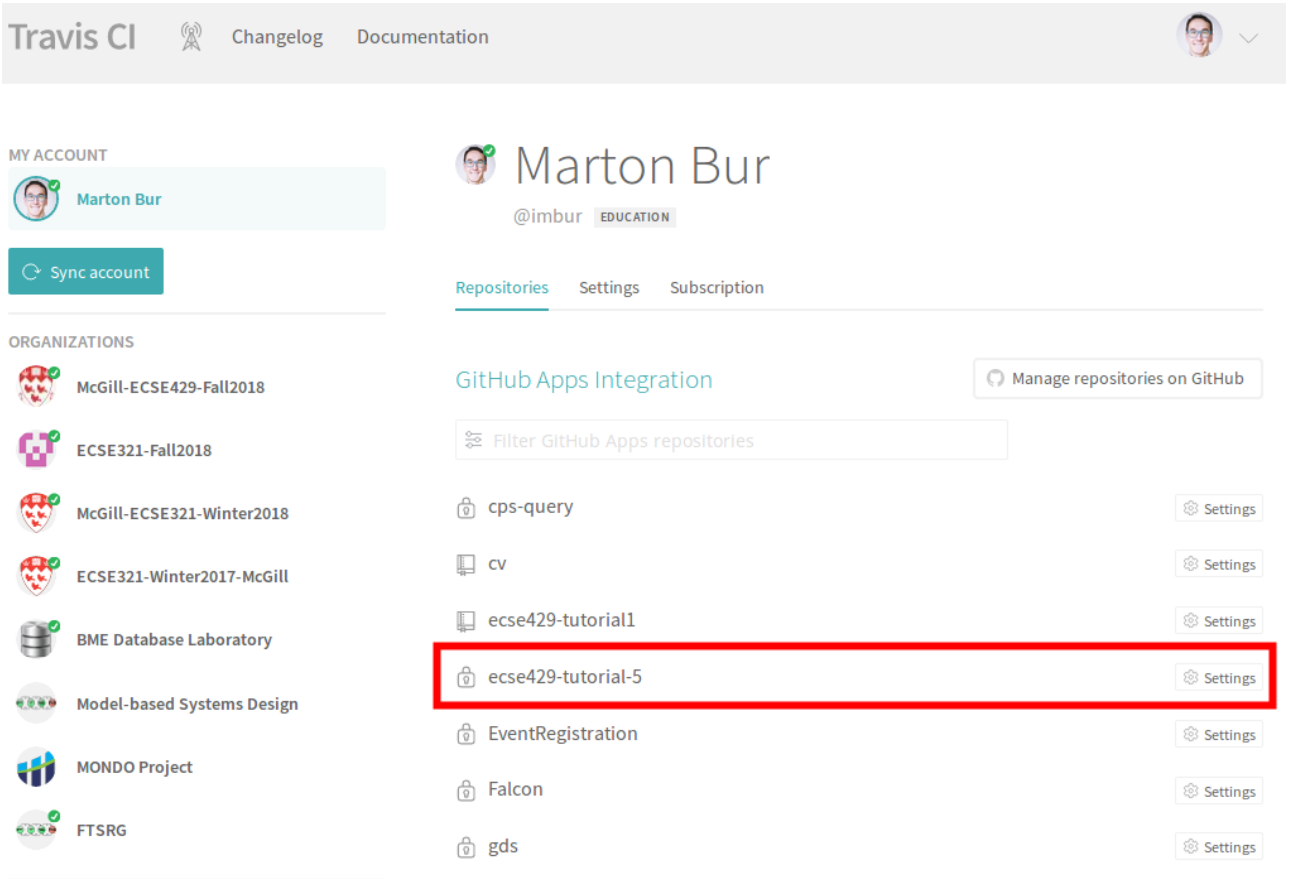
1. Download EvoSuite Commandline tool from http://www.evosuite.org/downloads/

IMPORTANT	EvoSuite is not compatible yet with Java 9 and above.

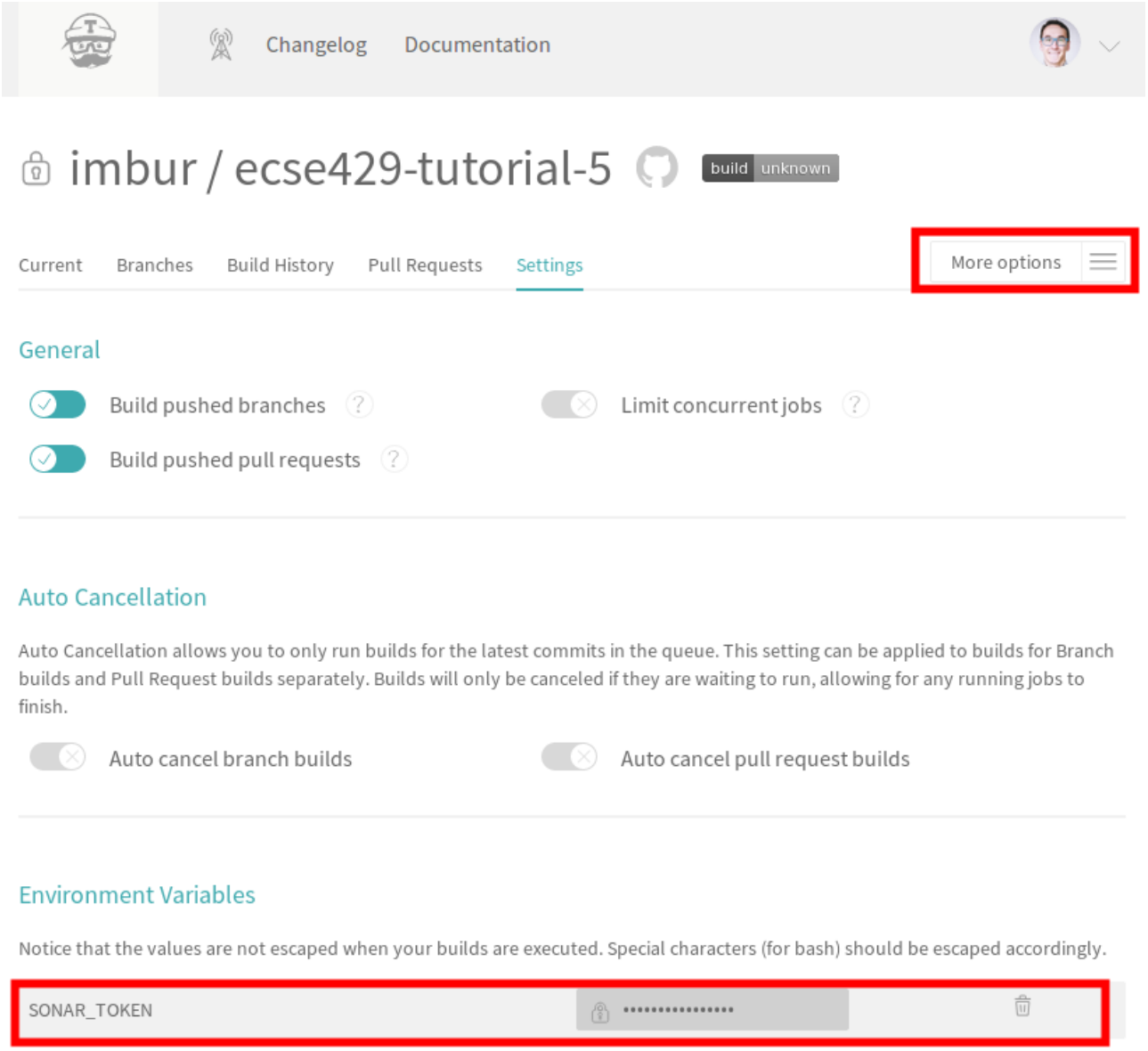
2. Fork the ecse429-tutorial-5 repository **under your GitHub user**.

IMPORTANT	After creating your fork, it is important to apply the steps below to your own fork (and not on the organization's repository).

3. Go to https://travis-ci.com/account/repositories and make sure you see the fork on Travis. If not, synchronize with GitHub.



4. Click on *Settings* with the cogs icon next to the repository's name. Under *More options* > *Settings* Set the value of the `SONAR_TOKEN` environment variable (the value is the token obtained from sonarcloud.io earlier) for **your fork's** build.



5. Clone your fork of the repository to your computer.
6. Replace **both** `project.key` and `project.name` properties in `.travis.yml` with `ecse429-tutorial-5-YOUR_GITHUB_USERNAME`. Commit and push your changes afterwards and see your project automatically built on Travis-CI and analyzed on SonarCloud.

5.2. Generating Tests using EvoSuite

NOTE

In the following steps, we assume that the `EVOSUITE` environment variable points to the evosuite.jar executable, and the program can be started by issuing `java -jar $EVOSUITE`. For Windows: in the default Windows command line tool this would be `java -jar %EVOSUITE%`, while also make sure that the firewall settings allow EvoSuite to run.

1. Navigate to the folder where your working copy of your tutorial 5 repository is located.
2. Explore the project sources.
3. Build the project locally using `./gradlew build` to generate classfiles.
4. You can run the app with `./gradlew run`.

5. Go to the folder `simple/` and generate tests for the class `SimpleStaticSut`

```
java -jar $EVOSUITE -class
com.github.cseppento.gradle.evosuite.testprojects.simple.SimpleStaticSut -projectCP
build/classes/java/main/ -Duse_separate_classloader=false
```

6. Explore the switches for EvoSuite with `java -jar $EVOSUITE -help`! Also observe the output of `java -jar $EVOSUITE -listParameters`!
7. Go to (or stay in) the folder `simple/` and generate tests for the class `SimpleObjectSut` with Branch coverage and also print the all test goals as well as the missed goals.

```
java -jar $EVOSUITE -class
com.github.cseppento.gradle.evosuite.testprojects.simple.SimpleObjectSut -projectCP
build/classes/java/main/ -Duse_separate_classloader=false -criterion BRANCH
-Dprint_goals=true -Dprint_missed_goals
```

8. Try other settings according to EvoSuite documentation to generate tests for the `SimpleObjectSut` class!

5.3. Adding the Generated Tests to the Build

1. Tests are generated under `simple/evosuite-tests`. We need to add them to the build.
2. First, add EvoSuite runtime to project dependencies to `simple/simple-deps.gradle`: `implementation 'org.evosuite:evosuite-standalone-runtime:1.0.6'`
3. Modify the test sources list in `simple/simple-app.gradle` by adding the following lines to the end of the file:

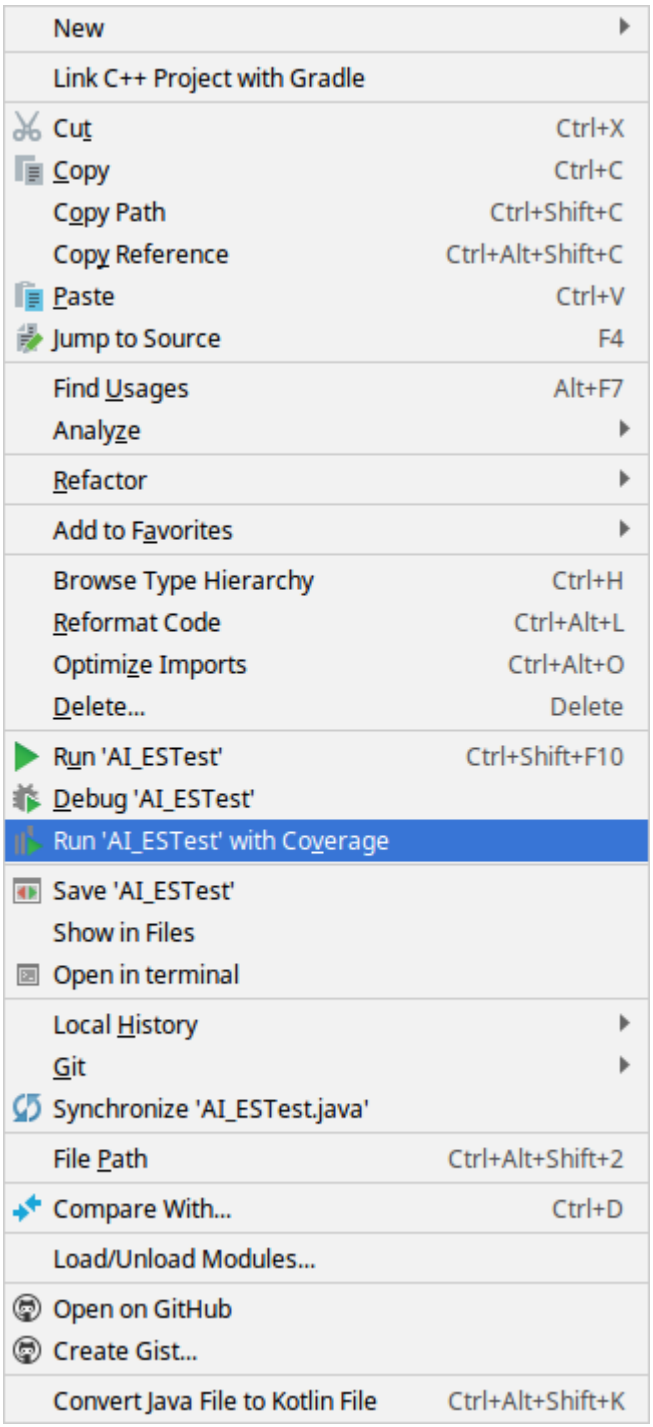
```
sourceSets {
    test {
        java {
            srcDirs = ['./src/test/java' ,'./evosuite-tests']
        }
    }
}
```

4. Commit your tests and make sure they are executed by Gradle.

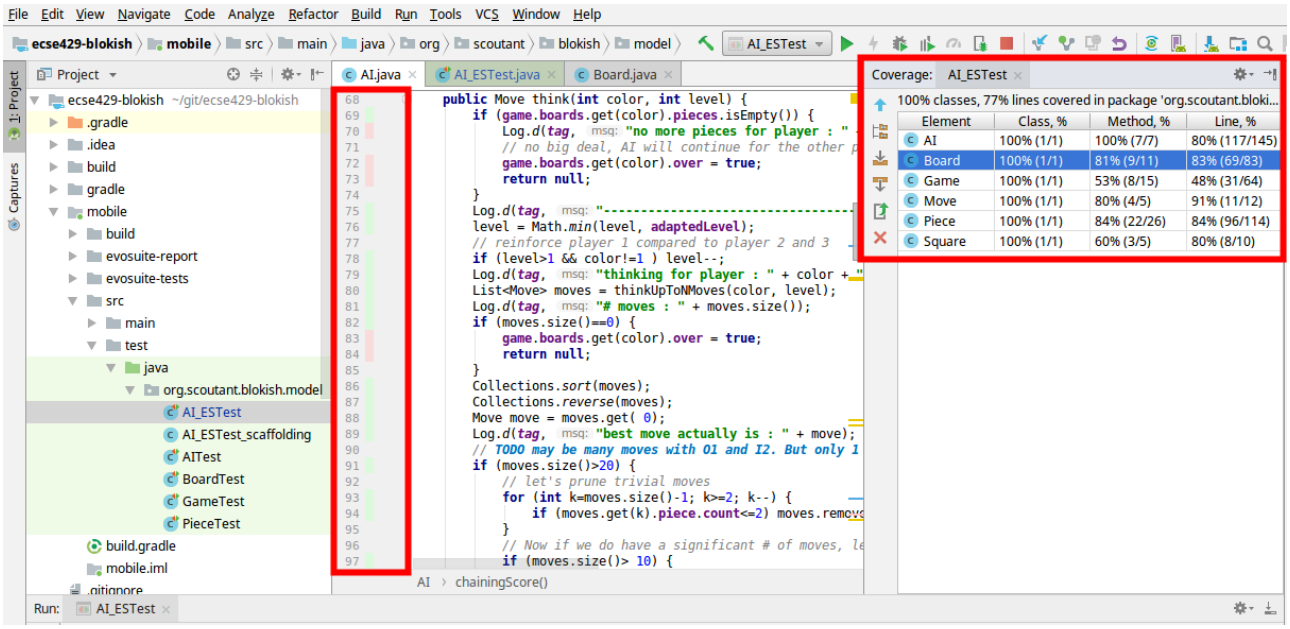
NOTE	You might encounter build failure if you have `use_separate_classloader=false` set in EvoSuite test cases. If this is the case, switch it back to `use_separate_classloader=true`.

5.4. Measuring Code Coverage with Android Studio

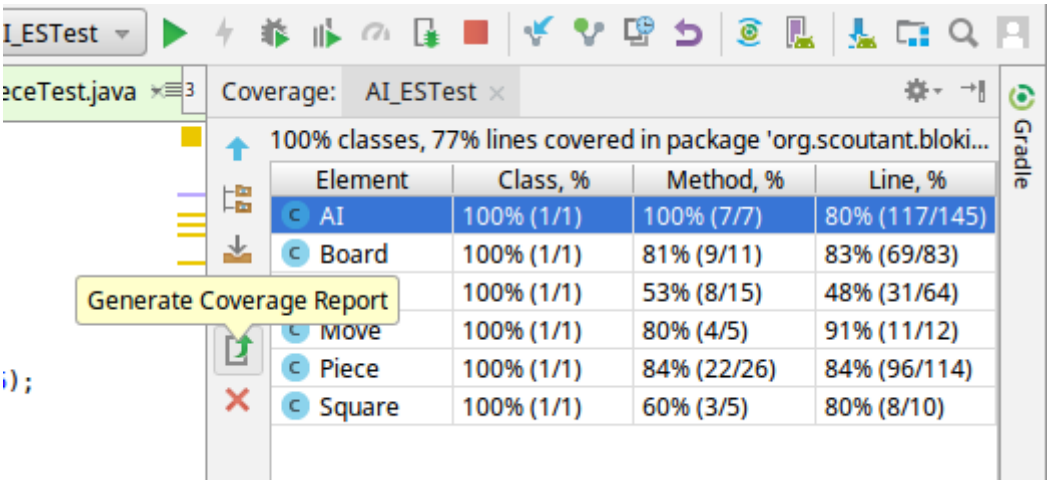
1. Select a single test class or multiple tests classes, then open the right click menu to run them with coverage



2. Android Studio will show the coverage report after running the test. It also highlights which lines were executed by at least one of the test cases



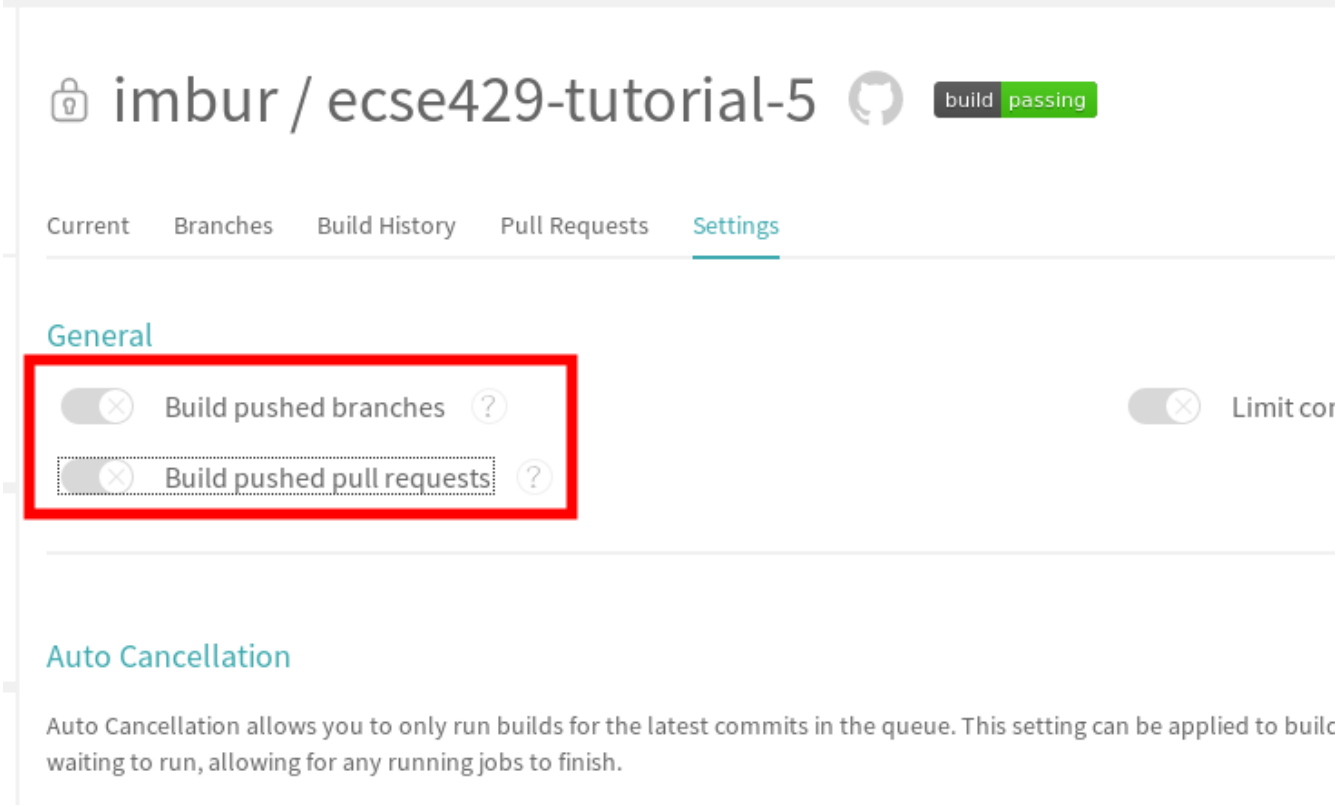
3. You can also export and view coverage results using the button shown below



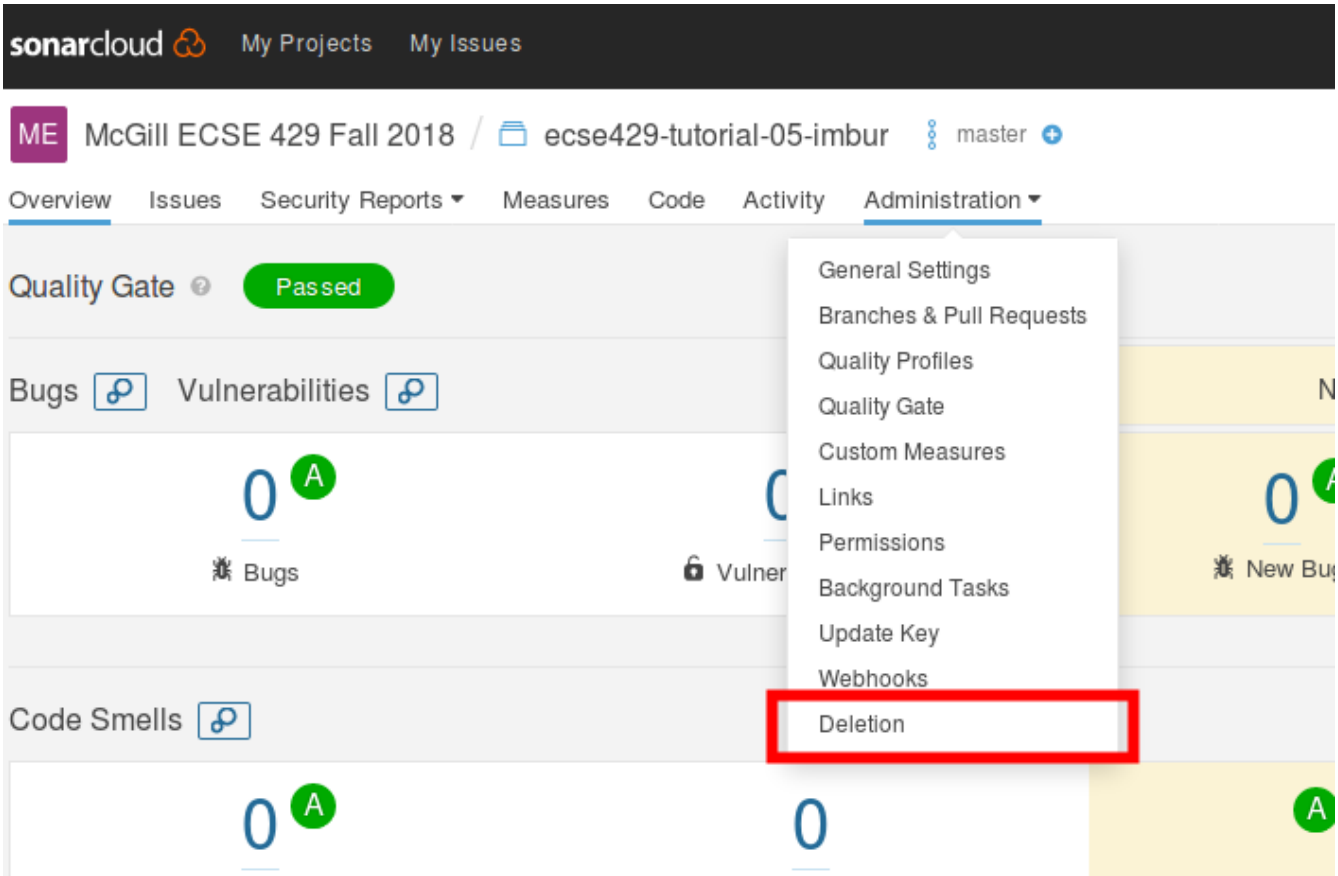
5.5. Cleaning Up the Project

IMPORTANT: At the end of the tutorial, turn off the build on Travis-CI and delete the project in SonarCloud as shown below, so that this demo project is not taking up the allowed line count on SonarCloud

Travis:



SonarCloud:



6. Mutation Testing

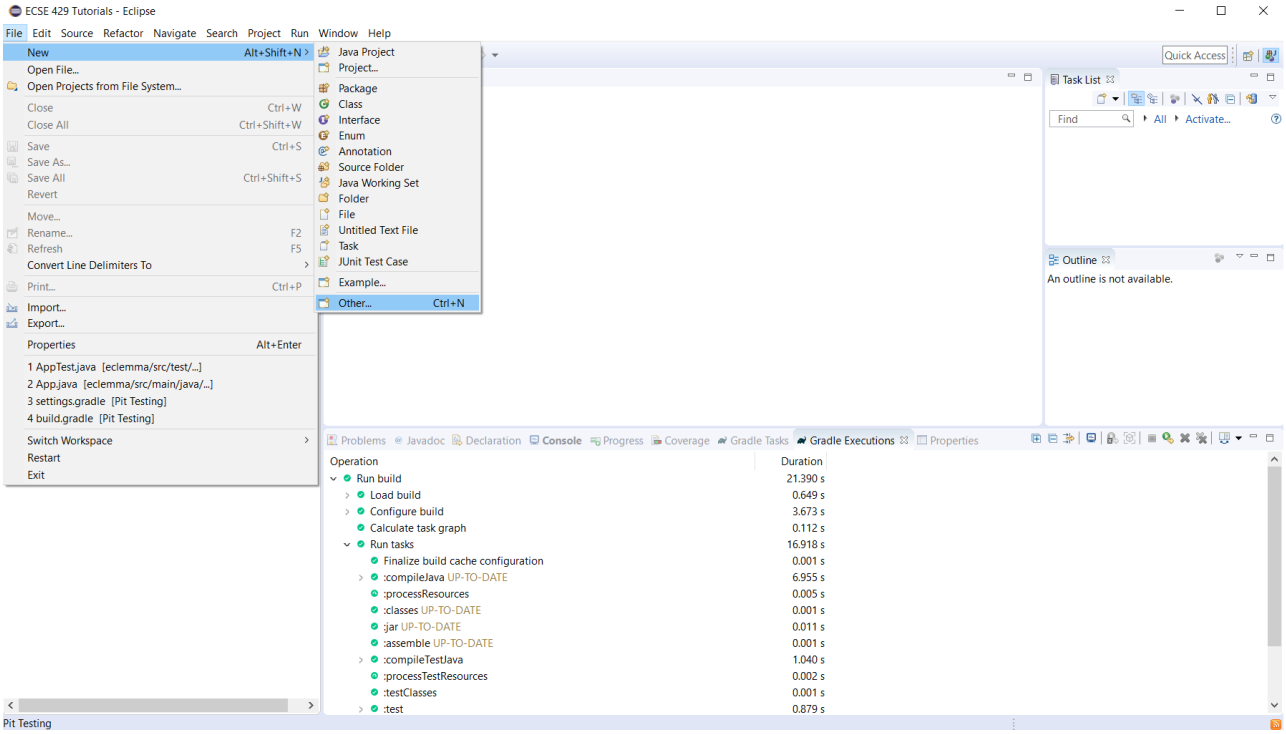
6.1. Mutation Testing Using PIT

This tutorial covers the basics of using PIT (link:http://pitest.org/), both as part of a build using Gradle and using an Eclipse plugin.

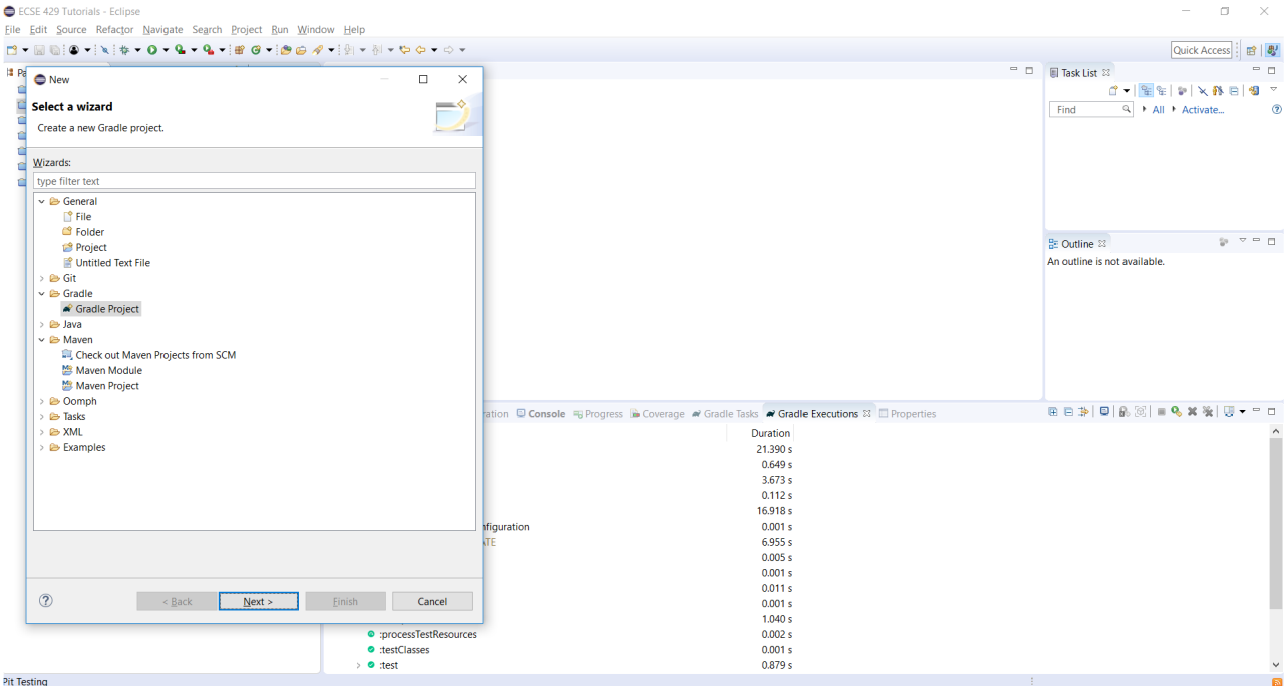
NOTE

For this tutorial, we assume that you the Gradle Eclipse plugin installed on your computer.
We will create a Gradle project from scratch and be testing the method from the fourth question of your first assignment *returnAverage(int[], int, int, int)* .

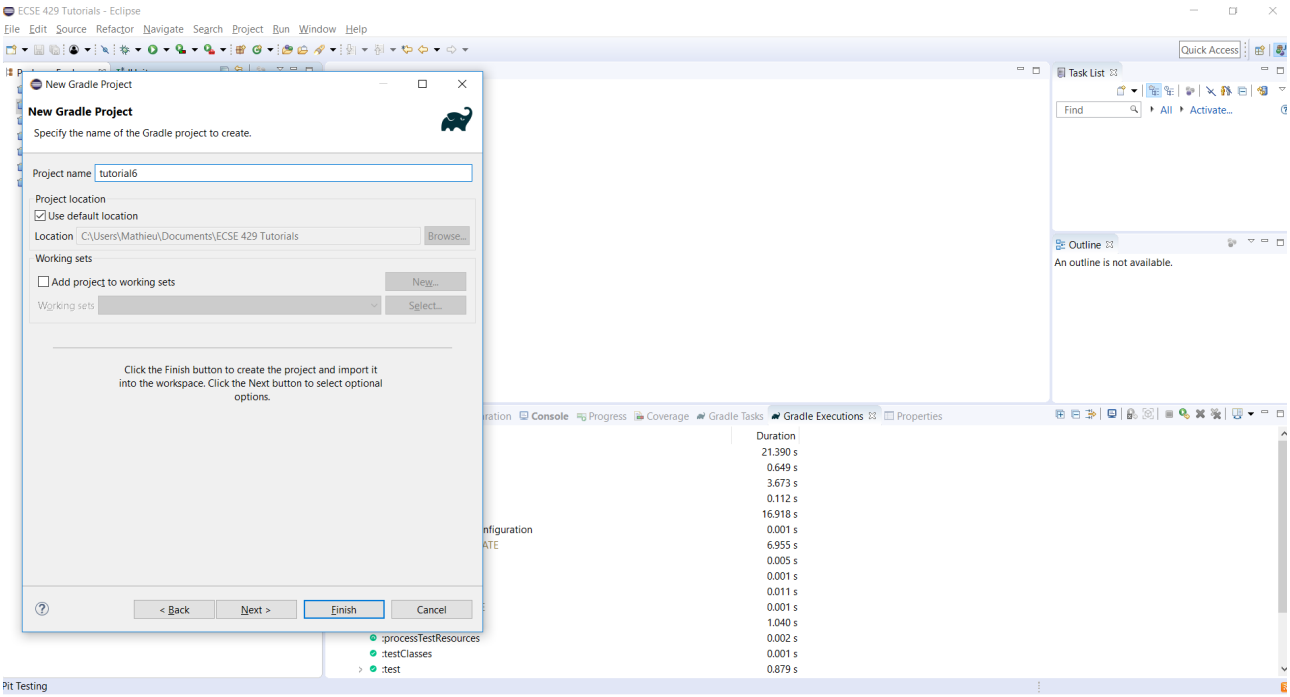
1. Create a new Gradle project in Eclipse by clicking on *File* > *New* > *Other*



2. Under *Gradle*, choose Gradle Project

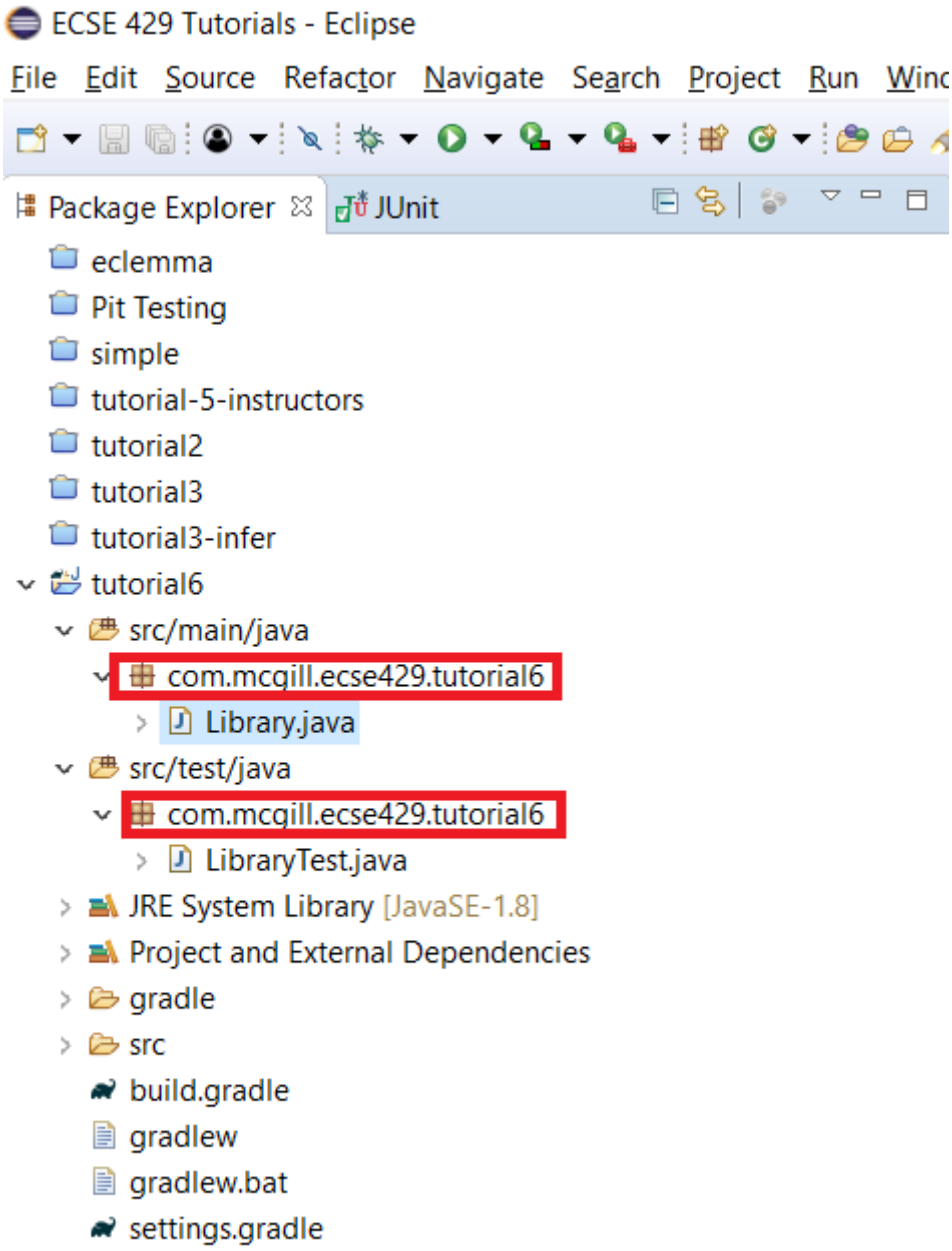


3. Click on *Next*, *Next*, then name your project *tutorial6*, click on *Finish*



NOTE The project may take some time to be created.

4. Create a new package instead of the default ones for both the source and test folders (e.g `com.mcgill.ecse429.tutorial6`) and move the default generated classes (`Library` and `LibraryTest`) to this package.



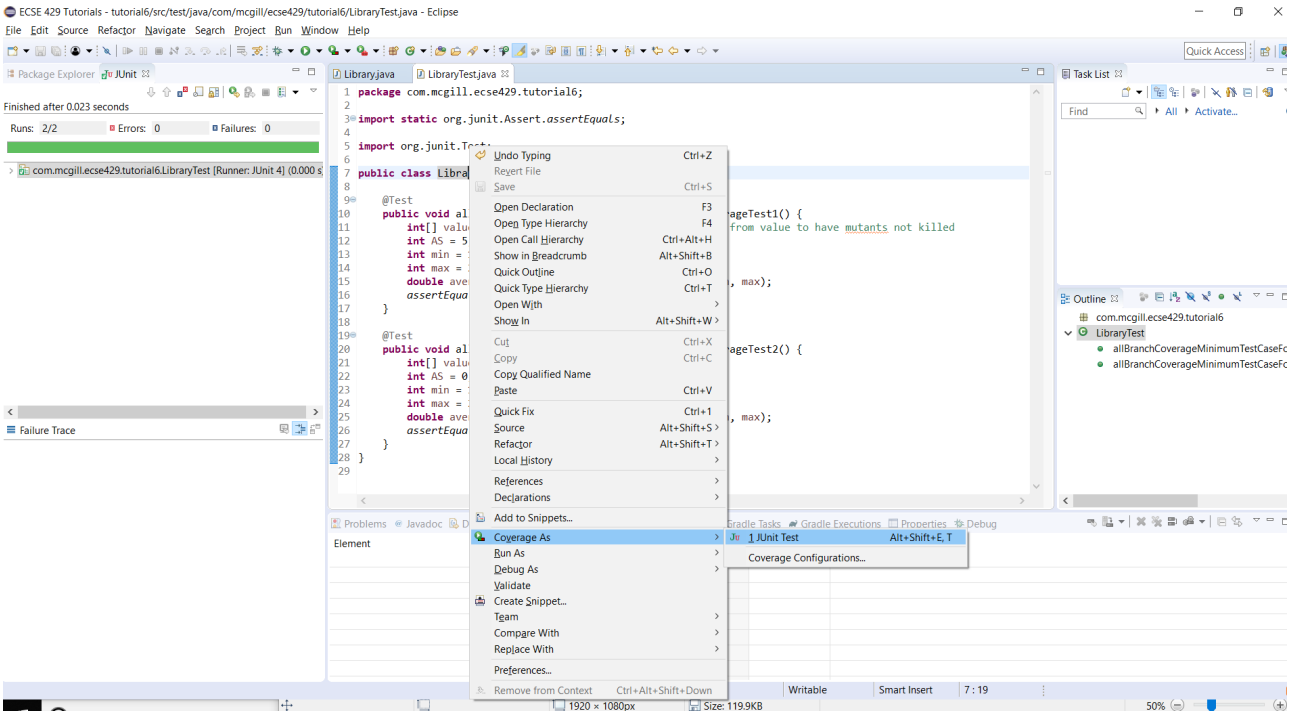
5. Change the code in the `Library` class

```
package com.mcgill.ecse429.tutorial6;

public class Library {

    public static double returnAverage(int value[], int arraySize, int MIN, int
MAX) {
        int index, ti, tv, sum;
        double average;
        index = 0;
        ti = 0;
        tv = 0;
        sum = 0;
        while (ti < arraySize && value[index] != -999) {
            ti++;
            if (value[index] >= MIN && value[index] <= MAX) {
                tv++;
                sum += value[index];
            }
            index++;
        }
        if (tv > 0)
            average = (double) sum / tv;
        else
            average = (double) -999;
        return average;
    }
}
```

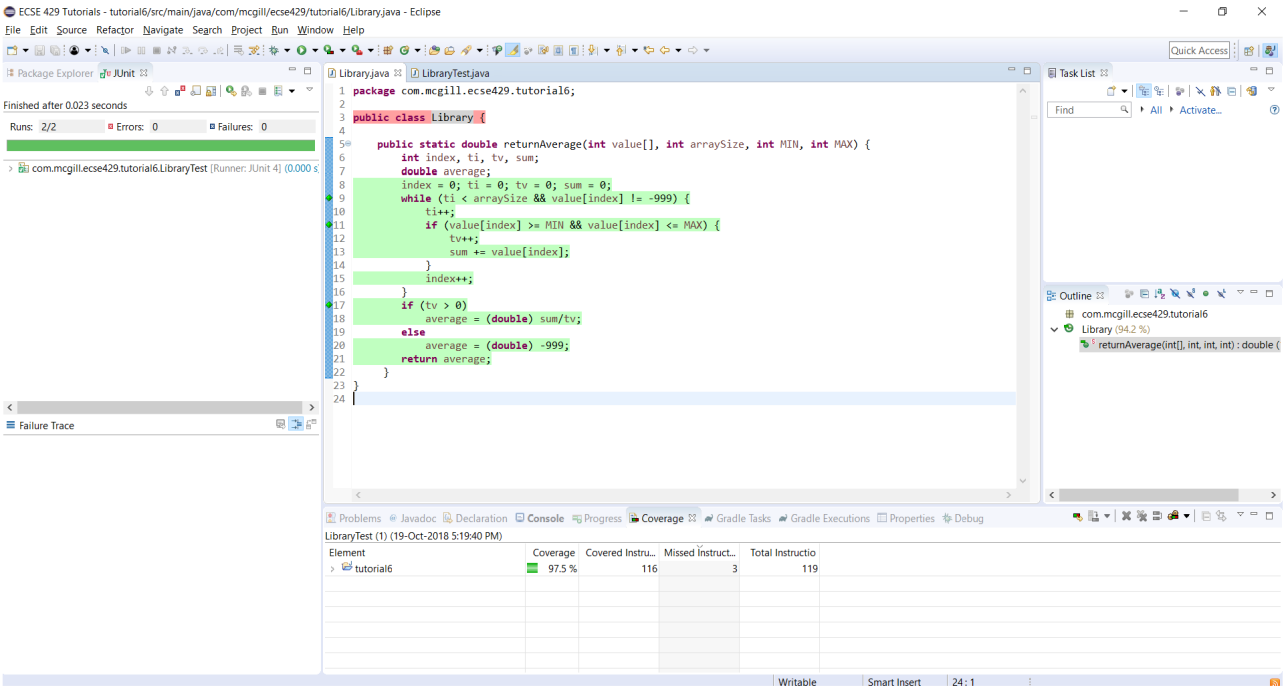
6. Change the code in the `LibraryTest` class

```
package com.mcgill.ecse429.tutorial6;

import static org.junit.Assert.assertEquals;

import org.junit.Test;

public class LibraryTest {

    @Test
    public void allBranchCoverageMinimumTestCaseForReturnAverageTest1() {
        int[] value = {5, 25, 15, -999};
        int AS = 4;
        int min = 10;
        int max = 20;
        double average = Library.returnAverage(value, AS, min, max);
        assertEquals(15, average, 0.1);
    }

    @Test
    public void allBranchCoverageMinimumTestCaseForReturnAverageTest2() {
        int[] value = {};
        int AS = 0;
        int min = 10;
        int max = 20;
        double average = Library.returnAverage(value, AS, min, max);
        assertEquals(-999.0, average, 0.1);
    }
}
```

7. Run the Test in coverage mode using Eclemma.



8. Verify that we have 100% branch coverage.



6.2. Using Gradle with PIT testing

1. Modify the `build.gradle` file to include the pitest plugin

```
apply plugin: 'java'
apply plugin: 'java-library'

sourceCompatibility = JavaVersion.VERSION_1_8

buildscript {
    repositories {
        jcenter()
    }
    dependencies {
        classpath 'info.solidsoft.gradle.pitest:gradle-pitest-plugin:1.3.0'
    }
}

repositories {
    jcenter()
}

dependencies {
    testCompile "junit:junit:4.12"

    compile "args4j:args4j:2.0.21"
    compile "org.codehaus.groovy:groovy-all:2.3.7"
}

apply plugin: 'info.solidsoft.pitest'

pitest {
    targetClasses = ["com.mcgill.ecse429.tutorial6*"]
    timestampedReports = true
}
```

2. Navigate to the project folder and run the command `gradle build pitest` (you can also use the Gradle wrapper script)

3. In your projects root folder, open the file `./build/reports/pitests/{TIMESTAMP}/index.html`, then navigate to the report for the `Library` class

Library.java

```
1   package com.mcgill.ecse429.tutorial6;
2
3   public class Library {
4
5           public static double returnAverage(int value[], int arraySize, int MIN, int MAX) {
6           int index, ti, tv, sum;
7           double average;
8           index = 0; ti = 0; tv = 0; sum = 0;
9  3        while (ti < arraySize && value[index] != -999) {
10 1                ti++;
11 4                if (value[index] >= MIN && value[index] <= MAX) {
12 1                        tv++;
13 1                        sum += value[index];
14                  }
15 1                index++;
16          }
17 2        if (tv > 0)
18 1                average = (double) sum/tv;
19          else
20                  average = (double) -999;
21 1        return average;
22           }
23  }
```

Mutations

```
    1. changed conditional boundary → SURVIVED
9   2. negated conditional → KILLED
    3. negated conditional → KILLED
10  1. Changed increment from 1 to -1 → SURVIVED
    1. changed conditional boundary → SURVIVED
11  2. changed conditional boundary → SURVIVED
    3. negated conditional → KILLED
    4. negated conditional → KILLED
12  1. Changed increment from 1 to -1 → KILLED
13  1. Replaced integer addition with subtraction → KILLED
15  1. Changed increment from 1 to -1 → KILLED
    1. changed conditional boundary → KILLED
17  2. negated conditional → KILLED
18  1. Replaced double division with multiplication → SURVIVED
21  1. replaced return of double value with -(x + 1) for com/mcgill/ecse429/tutorial6/Library::returnAverage → KILLED
```

Active mutators

- INCREMENTS_MUTATOR
- VOID_METHOD_CALL_MUTATOR
- RETURN_VALS_MUTATOR
- MATH_MUTATOR
- NEGATE_CONDITIONALS_MUTATOR
- INVERT_NEGS_MUTATOR
- CONDITIONALS_BOUNDARY_MUTATOR

Tests examined

- com.mcgill.ecse429.tutorial6.LibraryTest.allBranchCoverageMinimumTestCaseForReturnAverageTest1(com.mcgill.ecse429.tutorial6.LibraryTest) (7 ms)

NOTE	You may have a different output as the one shown. This is normal as the types and number of mutants may vary each run.

4. Look at the reports and get familiar with it.
   We can see the code coverage, the location where the mutations took place, the mutations themselves, the types of mutators and the test suite used to assess mutation score.

5. From the ouput above, we update the test cases
   The test cases are not killing all mutants due to not checking `value[index] == MIN` and `value[index] == MAX` conditions in the boundary. A similar problem occurs for `ti == arraySize` in the while loop. `LibraryTest.java` now contains:

```
package com.mcgill.ecse429.tutorial6;

import static org.junit.Assert.assertEquals;

import org.junit.Test;

public class LibraryTest {

    @Test
    public void allBranchCoverageMinimumTestCaseForReturnAverageTest1() {
        int[] value = {5, 25, 10, 20, -999};
        int AS = 5;
        int min = 10;
        int max = 20;
        double average = Library.returnAverage(value, AS, min, max);
        assertEquals(15, average, 0.1);
    }

    @Test
    public void allBranchCoverageMinimumTestCaseForReturnAverageTest2() {
        int[] value = {};
        int AS = 0;
        int min = 10;
        int max = 20;
        double average = Library.returnAverage(value, AS, min, max);
        assertEquals(-999.0, average, 0.1);
    }

}
```

6. Rerun pit mutation with `gradle build pitest` and reopen the outputted report `index.html`

Library.java

```
1   package com.mcgill.ecse429.tutorial6;
2
3   public class Library {
4
5           public static double returnAverage(int value[], int arraySize, int MIN, int MAX) {
6           int index, ti, tv, sum;
7           double average;
8           index = 0; ti = 0; tv = 0; sum = 0;
9  3        while (ti < arraySize && value[index] != -999) {
10 1                ti++;
11 4                if (value[index] >= MIN && value[index] <= MAX) {
12 1                        tv++;
13 1                        sum += value[index];
14                  }
15 1                index++;
16          }
17 2        if (tv > 0)
18 1                average = (double) sum/tv;
19          else
20                  average = (double) -999;
21 1        return average;
22           }
23  }
```

Mutations

```
    1. changed conditional boundary → KILLED
9   2. negated conditional → KILLED
    3. negated conditional → KILLED
10  1. Changed increment from 1 to -1 → SURVIVED
    1. changed conditional boundary → KILLED
11  2. changed conditional boundary → KILLED
    3. negated conditional → KILLED
    4. negated conditional → KILLED
12  1. Changed increment from 1 to -1 → KILLED
13  1. Replaced integer addition with subtraction → KILLED
15  1. Changed increment from 1 to -1 → KILLED
    1. changed conditional boundary → KILLED
17  2. negated conditional → KILLED
18  1. Replaced double division with multiplication → KILLED
21  1. replaced return of double value with -(x + 1) for com/mcgill/ecse429/tutorial6/Library::returnAverage → KILLED
```

Active mutators

- INCREMENTS_MUTATOR
- VOID_METHOD_CALL_MUTATOR
- RETURN_VALS_MUTATOR
- MATH_MUTATOR
- NEGATE_CONDITIONALS_MUTATOR
- INVERT_NEGS_MUTATOR
- CONDITIONALS_BOUNDARY_MUTATOR

Tests examined

- com.mcgill.ecse429.tutorial6.LibraryTest.allBranchCoverageMinimumTestCaseForReturnAverageTest1(com.mcgill.ecse429.tutorial6.LibraryTest) (7 ms)
- com.mcgill.ecse429.tutorial6.LibraryTest.mutationTestCaseForReturnAverageTest1(com.mcgill.ecse429.tutorial6.LibraryTest) (0 ms)
- com.mcgill.ecse429.tutorial6.LibraryTest.allBranchCoverageMinimumTestCaseForReturnAverageTest2(com.mcgill.ecse429.tutorial6.LibraryTest) (1 ms)

7. After the second run, we see that the line `ti++;` inside the while loop is useless and a code smell!

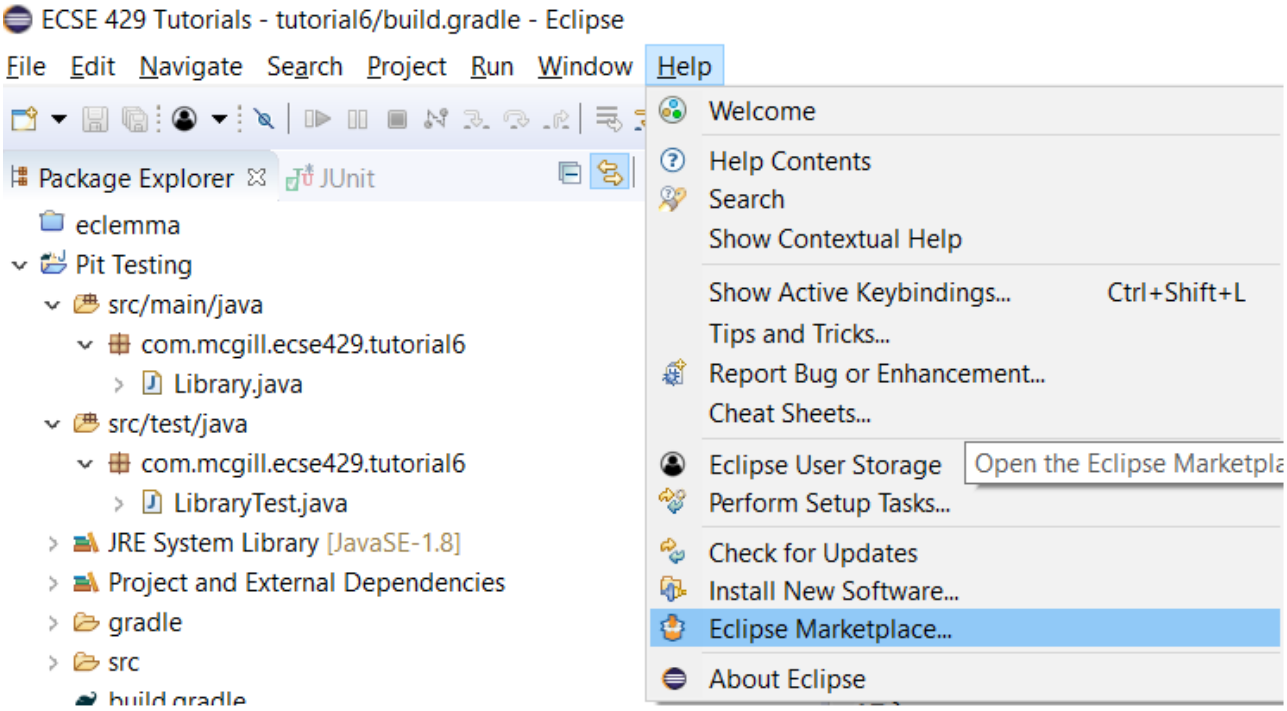
6.3. Configuring PIT testing

1. To understand the different mutants, you can go here.
2. You can customize the plugin in the `builde.gradle` file using all the parameters for the command line.
   Reference: http://pitest.org/quickstart/commandline/
3. For example, we can specify the mutators we want in `build.gradle`:

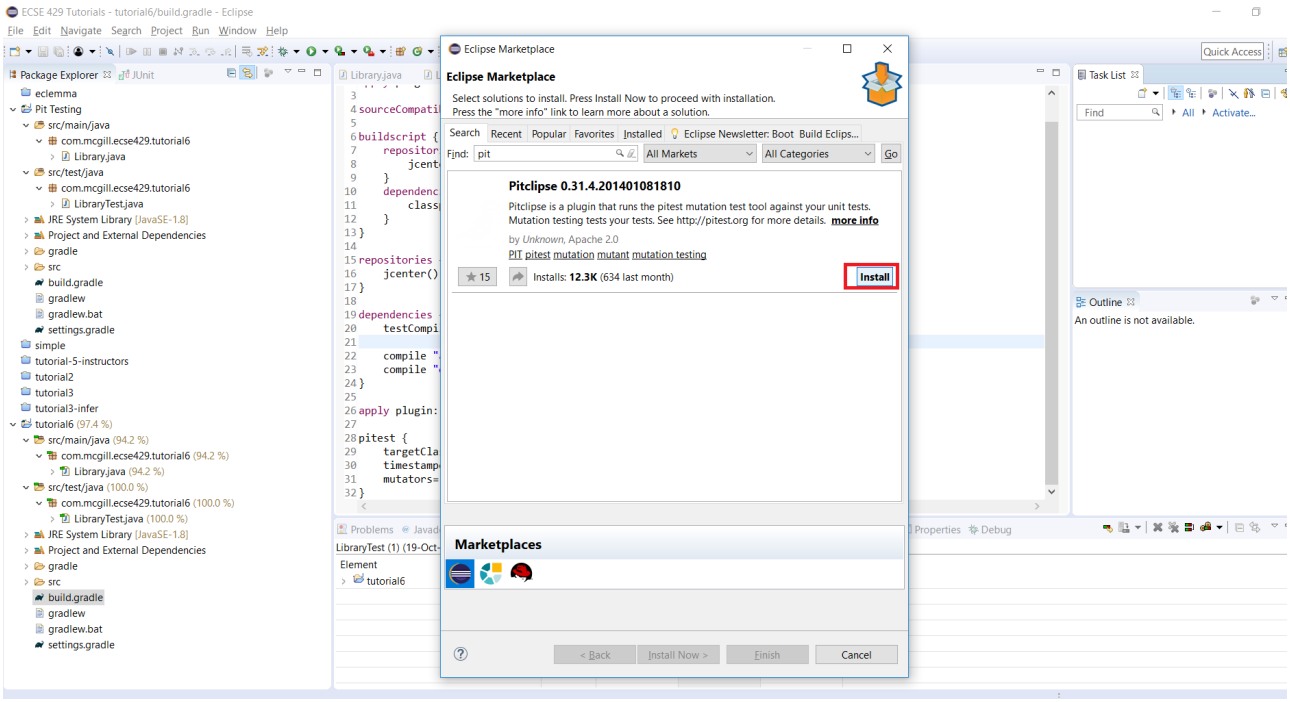
```
...
pitest {
    targetClasses = ["com.mcgill.ecse429.tutorial6*"]
    timestampedReports = true
    mutators=['NEGATE_CONDITIONALS','CONDITIONALS_BOUNDARY']
}
...
```

6.4. Using PIT in Eclipse

1. Go to *Help* > *Eclipse Marketplace*

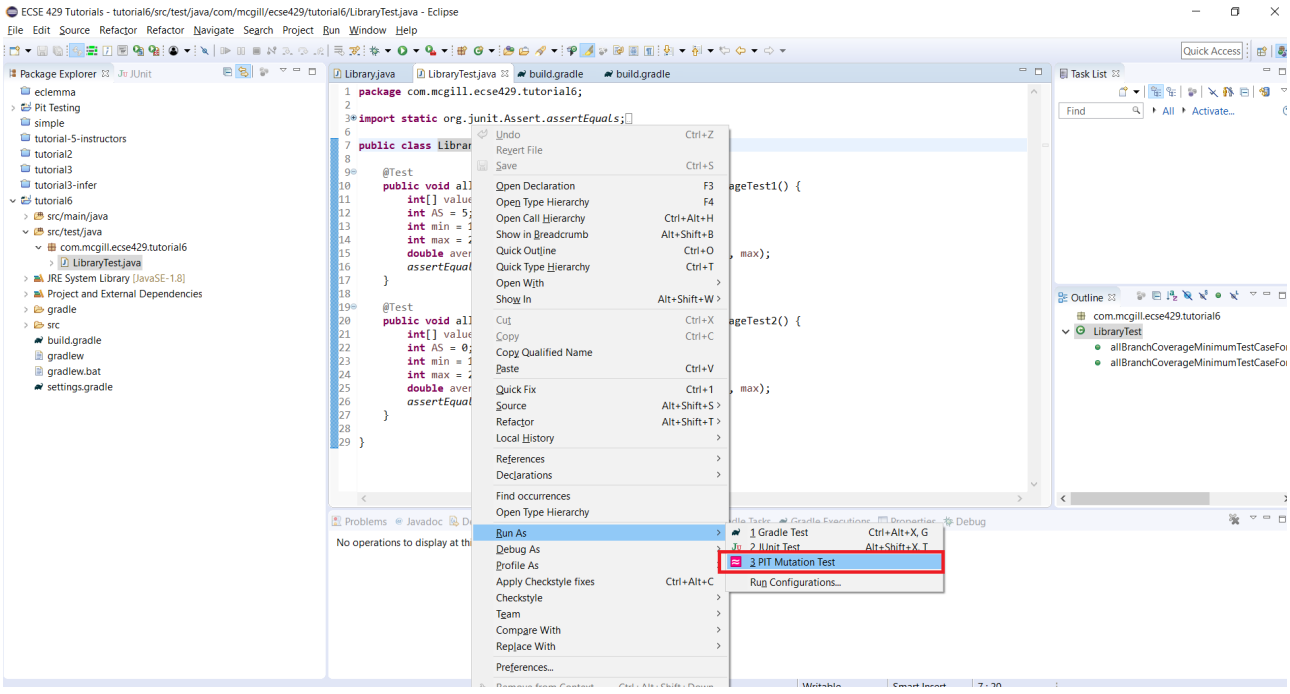


2. Type *pit* in the search box and find *Pitclipse*

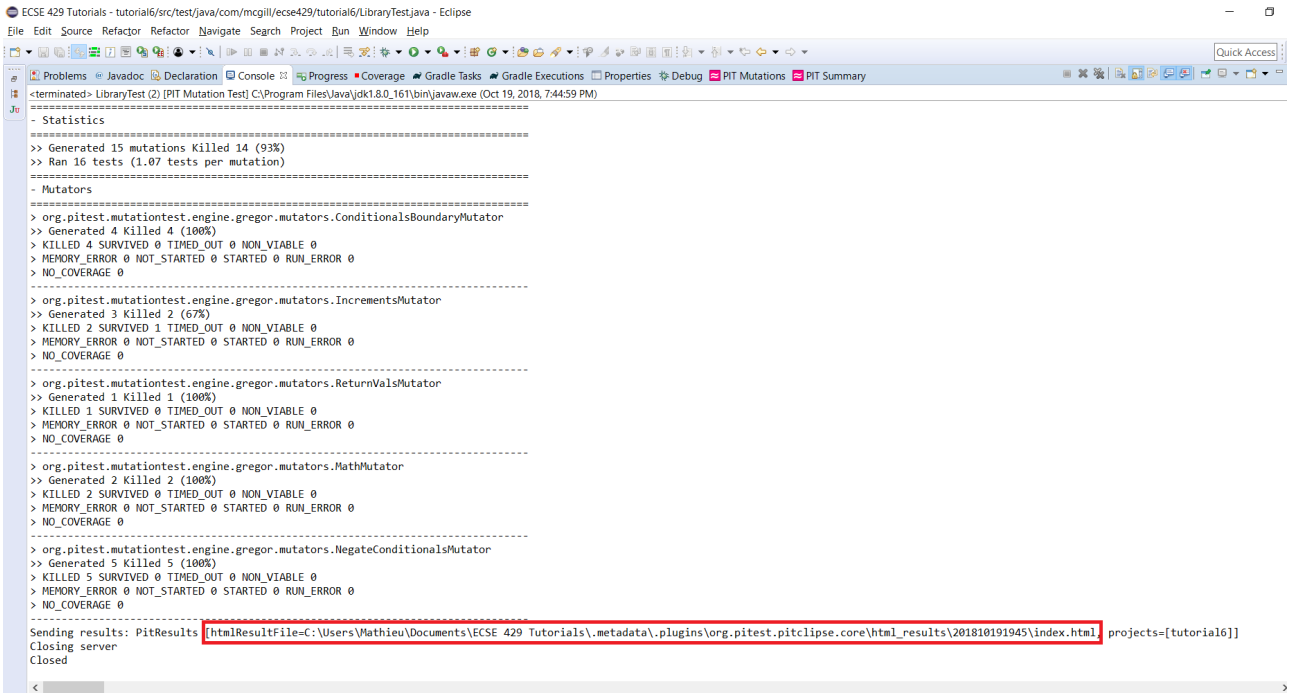


3. Restart your Eclipse after the installation is successful
4. You can now executet the tests in `LibraryTest` class by selecting *Pit Mutation Test* from the available run configurations.

> **NOTE** If you get a `NullPointerException` for the first run, try re-running it.



5. Check the output in the console for where the report is generated.



NOTE	The output of the report should be identical to the one we generated with the Gradle plugin

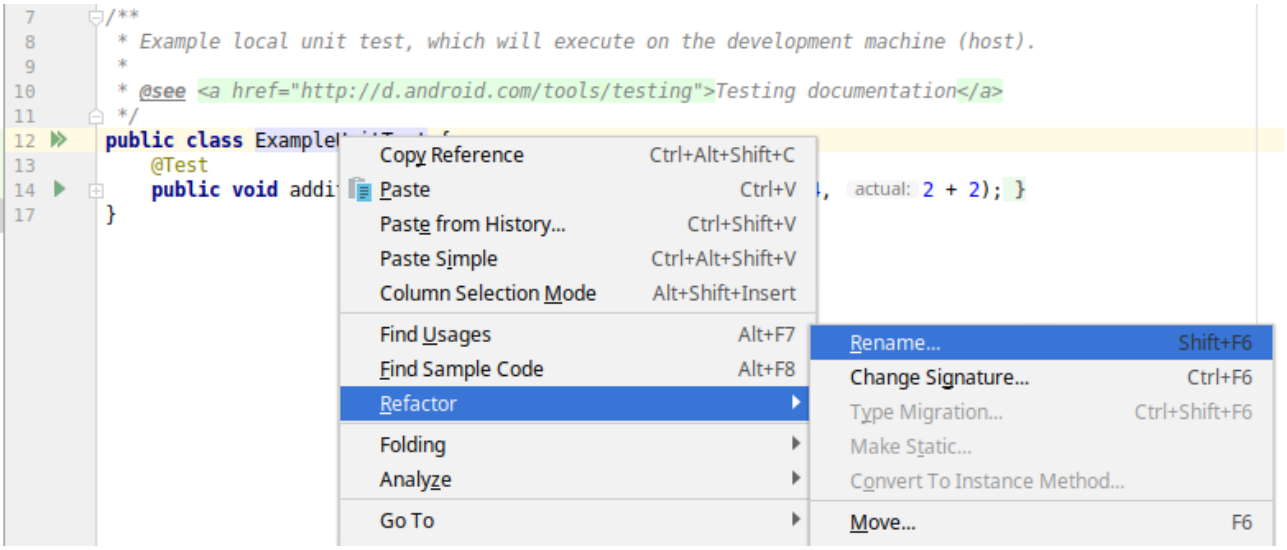
7. Integration Testing

7.1. Testing Using Mocks

1. Clone (or fork and clone the fork of) the initial project from this link and import it to Android Studio.
2. Open the project with Android Studio and verify that it builds fine from the IDE (or by running the corresponding Gradle wrapper).
3. Explore the (not too complex) application sources. Start the app and try its features as well.
4. Add the Mockito gradle dependency in `app/build.gradle` for compiling test sources: `testImplementation 'org.mockito:mockito-core:2.23.0'`
5. In the same `build.gradle` file, add to the `android` task

```
testOptions {
        unitTests.returnDefaultValues = true
}
```

6. Locate the `ExampleUnitTest.java` and refactor the class' name to `IntegrationTest`.



7. Add the following code to the class:

```
package ca.mcgill.ecse321.eventregistration;

import com.loopj.android.http.AsyncHttpClient;
import com.loopj.android.http.BlackholeHttpResponseHandler;
import com.loopj.android.http.RequestParams;

import org.junit.Before;
import org.junit.Test;
import org.mockito.Mock;
import org.mockito.Mockito;

public class IntegrationTest {

    @Mock
    AsyncHttpClient httpClient;

    HttpUtils httpUtils;

    @Before
    public void setUp(){
        httpUtils = new HttpUtils(httpClient);
    }

    @Test
    public void testHttpPostCalled() {
        String url = "participants/";
        RequestParams params = new RequestParams();
        BlackholeHttpResponseHandler handler = new BlackholeHttpResponseHandler();

        // Call the SUT
        httpUtils.post(url, params, handler);

        // Verify interactions
        Mockito.verify(httpClient).post(HttpUtils.getBaseUrl() + url, params,
handler);
    }
}
```

8. Run the test as JUnit test (failure is expected). Try understanding the error message!
9. Add the following annotation to the test class.

```
// ... other imports
import org.junit.runner.RunWith;
import org.mockito.junit.MockitoJUnitRunner;

@RunWith(MockitoJUnitRunner.class)
public class IntegrationTest {
    // ...
}
```

7.2. Local UI Tests

1. Add the following to the module's `build.gradle` file within the `android` task

```
android {
    testOptions {
        unitTests {
            includeAndroidResources = true
        }
    }
    // ... other settings
}
```

2. In this same Gradle file, add/verify dependencies

```
testImplementation 'junit:junit:4.12'
testImplementation 'org.mockito:mockito-core:2.23.0'
testImplementation 'org.robolectric:robolectric:4.0'
```

3. Create a new test class `LocalUITest` within the `src/test/java` directory in package `ca.mcgill.ecse321.eventregistration`

```
package ca.mcgill.ecse321.eventregistration;

import com.loopj.android.http.AsyncHttpClient;
import com.loopj.android.http.RequestParams;
import com.loopj.android.http.ResponseHandlerInterface;

import org.junit.Rule;
import org.junit.Test;
import org.junit.runner.RunWith;
import org.mockito.Mock;
import org.mockito.Mockito;
import org.mockito.junit.MockitoJUnit;
import org.mockito.junit.MockitoRule;
import org.robolectric.Robolectric;
import org.robolectric.RobolectricTestRunner;

@RunWith(RobolectricTestRunner.class)
public class LocalUITest {

    @Rule
    public MockitoRule mockitoRule = MockitoJUnit.rule();

    @Mock
    public AsyncHttpClient httpClient;

    @Test
    public void aTest() {
        MainActivity mainActivity = Robolectric.setupActivity(MainActivity.class);
        mainActivity.setHttpUtils(new HttpUtils(httpClient));
        mainActivity.addParticipant(null);

Mockito.verify(httpClient).post(Mockito.anyString(),Mockito.<RequestParams>any(),Mo
ckito.<ResponseHandlerInterface>any());
    }

}
```

4. Run it as a local test.

7.3. Android Instrumentation Tests

With Android, we have previously created **Local tests** that that run on your local machine only. In this tutorial we show how you can create **Instrumented tests**, unit tests that run on an Android device or emulator. See more about the difference between local and instrumentation tests at: https://developer.android.com/training/testing/unit-testing/.

7.3.1. Project dependencies and setup

This section takes configurations from the Android documentation. You can follow the steps below by reusing the example project from the first step of the previous section.

1. Add the used libraries to `<module-name>/src/main./AndroidManifest.xml` **within** the `<application>···</application>` tags

```
<uses-library android:name="android.test.base"
    android:required="false" />
<uses-library android:name="android.test.runner"
    android:required="false" />
<uses-library android:name="android.test.mock"
    android:required="false" />
```

The next few steps will update the module's `build.gradle` file (`<module-name>/build.gradle` file).

1. Speficy the used libraries within the `android` task as well.

```
android {
    // ... other settings
    useLibrary 'android.test.runner'
    useLibrary 'android.test.base'
    useLibrary 'android.test.mock'
    // ... other settings
}
```

2. Add the following instrumentation testing dependencies.

```
dependencies {
    // ... other dependencies
    // Core library
    androidTestImplementation 'androidx.test:core:1.0.0'
    // AndroidJUnitRunner and JUnit Rules
    androidTestImplementation 'androidx.test:runner:1.1.0'
    androidTestImplementation 'androidx.test:rules:1.1.0'
    // Assertions
    androidTestImplementation 'androidx.test.ext:junit:1.0.0'
    androidTestImplementation 'androidx.test.ext:truth:1.0.0'
    androidTestImplementation 'com.google.truth:truth:0.42'
    // Espresso dependencies
    androidTestImplementation 'androidx.test.espresso:espresso-core:3.1.0'
    androidTestImplementation 'androidx.test.espresso:espresso-contrib:3.1.0'
    androidTestImplementation 'androidx.test.espresso:espresso-intents:3.1.0'
    androidTestImplementation 'androidx.test.espresso:espresso-accessibility:3.1.0'
    androidTestImplementation 'androidx.test.espresso:espresso-web:3.1.0'
    // Add these for applications having significant library dependencies
    androidTestImplementation 'com.google.dexmaker:dexmaker:1.2'
    // Android-specific Mockito
    androidTestImplementation 'com.google.dexmaker:dexmaker-mockito:1.2:'
}
```

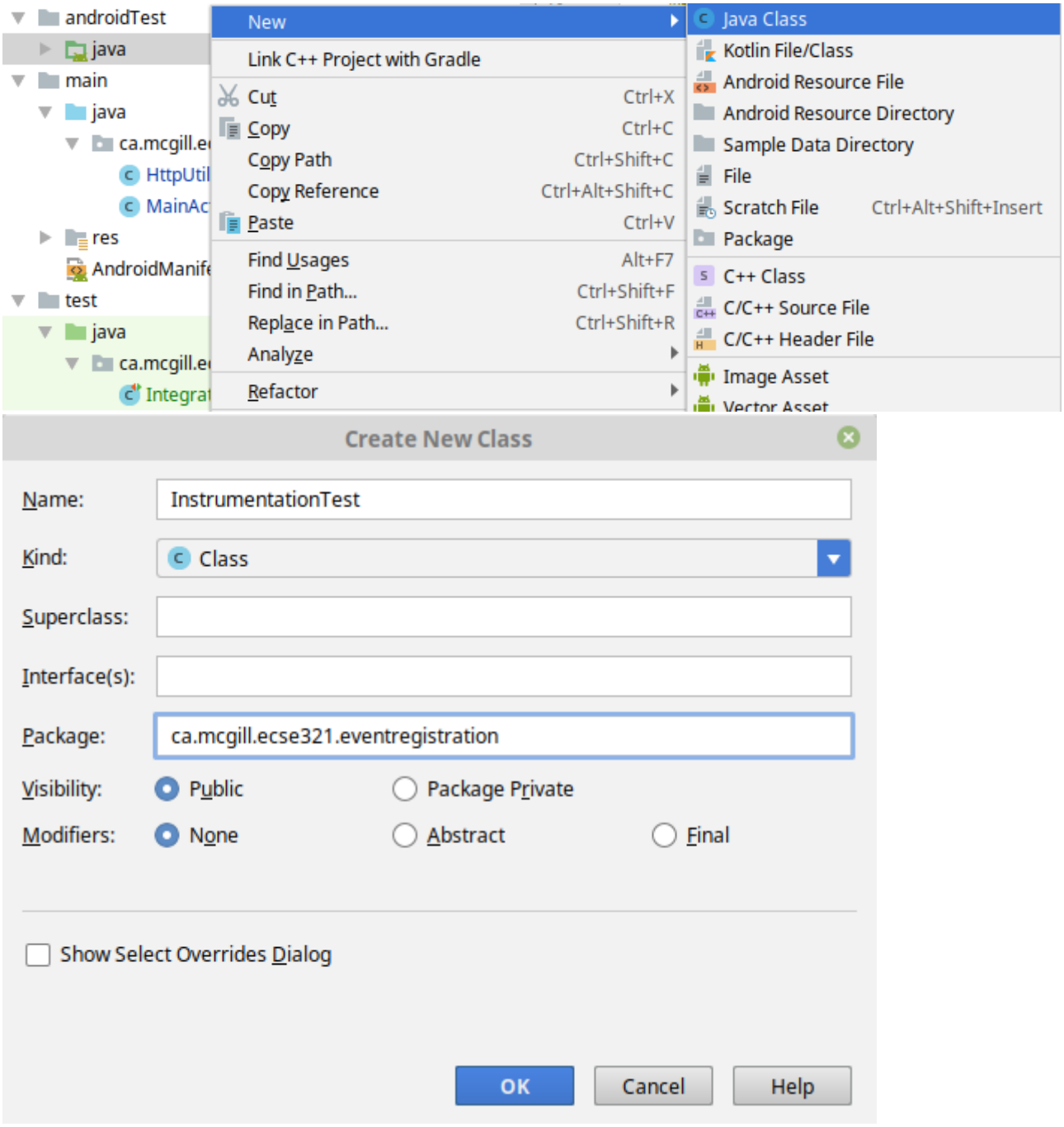
NOTE	For instrumentation tests only Mockito 1.9.x can be used currently (via the dexmaker dependency).

3. Update the `android` task as shown below. You may need to download the new SDK version.

```
android {
    compileSdkVersion 28
    // ...
    defaultConfig {
        minSdkVersion 18
        targetSdkVersion 28
        testInstrumentationRunner "androidx.test.runner.AndroidJUnitRunner"
    }
    // ...
```

7.3.2. Creating an instrumentation test

1. Create the `<module-name>/src/androidTest/java` folder structure. This is the default location where the framework will look for instrumentation tests.
2. Create a new test class `InstrumentationTest` under the same package name as the package name of the main activity.



3. Add the imports and annotations as follows

```
package ca.mcgill.ecse321.eventregistration;

import android.widget.Button;
import android.widget.ListView;

import com.loopj.android.http.AsyncHttpClient;
import com.loopj.android.http.JsonHttpResponseHandler;
import com.loopj.android.http.RequestParams;
import com.loopj.android.http.ResponseHandlerInterface;

import org.json.JSONArray;
import org.json.JSONException;
import org.json.JSONObject;
import org.junit.Rule;
import org.junit.Test;
import org.junit.runner.RunWith;
import org.mockito.Mock;
import org.mockito.Mockito;
import org.mockito.invocation.InvocationOnMock;
import org.mockito.runners.MockitoJUnitRunner;
import org.mockito.stubbing.Answer;

import androidx.test.filters.SmallTest;
import androidx.test.rule.ActivityTestRule;

import static com.google.common.truth.Truth.assertThat;

@RunWith(MockitoJUnitRunner.class)
@SmallTest
public class InstrumentationTest {

}
```

NOTE If you are not planning on using Mockito with instrumentation tests, you can replace the `@RunWith(MockitoJUnitRunner.class)` annotation with `@RunWith(AndroidJUnit4.class)`.

4. Within this class, create a private class that passes the JSON answer for a HTTP request via the handler (JSON Handler) extracted from the method call

```
private class ParticipantsAnswer implements Answer<JSONArray> {
    @Override
    public Object answer(InvocationOnMock invocation) throws JSONException {
        Object[] arguments = invocation.getArguments();
        JsonHttpResponseHandler h = (JsonHttpResponseHandler) arguments[2];
        h.onSuccess(200,null,new JSONArray()
                .put(new JSONObject().put("name", "P1"))
                .put(new JSONObject().put("name", "P2"))
                .put(new JSONObject().put("name", "P3")));
        return null;
    }
}
```

5. Add fields to the `InstrumentationTest` class

```
@Mock
AsyncHttpClient httpClient;

@Rule
public ActivityTestRule<MainActivity> activityTestRule = new
ActivityTestRule<>(MainActivity.class);
```

6. Add the implementation to the test case

```
@Test
public void aTest() throws Throwable {
    final MainActivity mainActivity = activityTestRule.getActivity();
    mainActivity.setHttpUtils(new HttpUtils(httpClient));


Mockito.when(httpClient.get(Mockito.anyString(),Mockito.<RequestParams>anyObject(),
Mockito.<ResponseHandlerInterface>anyObject())).thenAnswer(new
ParticipantsAnswer());

    final ListView participantList =
mainActivity.findViewById(R.id.participant_list);
    final int numberOfParticipants = participantList.getAdapter().getCount();

    assertThat(numberOfParticipants).isEqualTo(0);

    Button button = (Button) mainActivity.findViewById(R.id.button);
    button.performClick();

    int numberOfParticipants2 = participantList.getAdapter().getCount();
    assertThat(numberOfParticipants2).isEqualTo(3);
}
```

7. After right clicking on the class you can run the instrumentation test. Select the virtual device to run the tests on.
8. The tests failed. Try understanding the error message!
9. Fix the tests by including the last part of the test in `runOnUiThread()`

```
activityTestRule.runOnUiThread(new Runnable() {
    @Override
    public void run() {
        Button button = (Button) mainActivity.findViewById(R.id.button);
        button.performClick();
        int numberOfParticipants2 = participantList.getAdapter().getCount();
        assertThat(numberOfParticipants2).isEqualTo(3);
    }
});
```

10. Finally, exploit the *Fluent API* of Mockito and clean up your code. Import all static methods with `static import`!

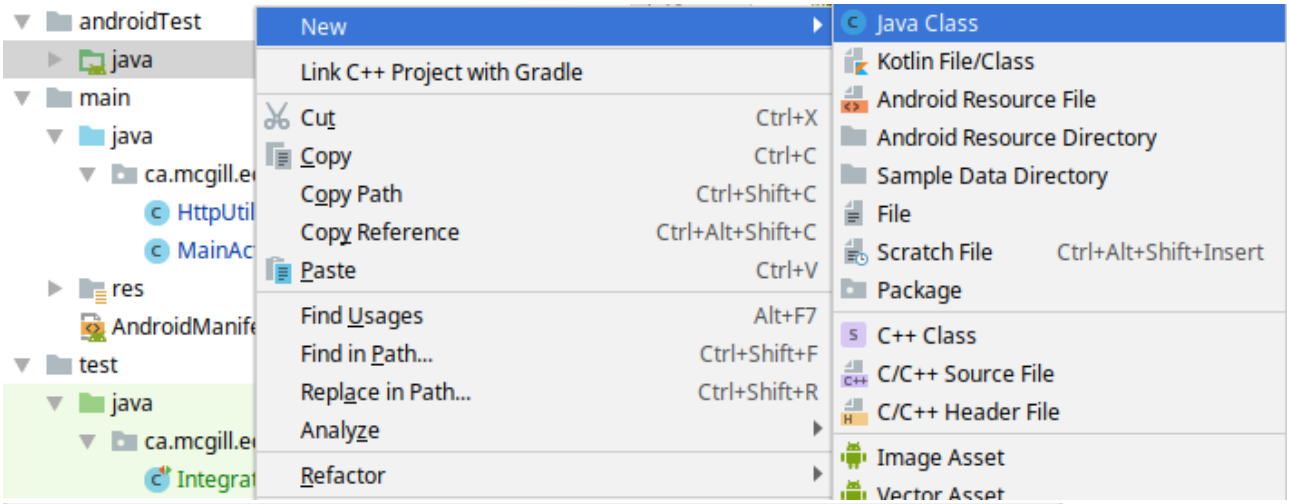
8. Android User Interface Tests

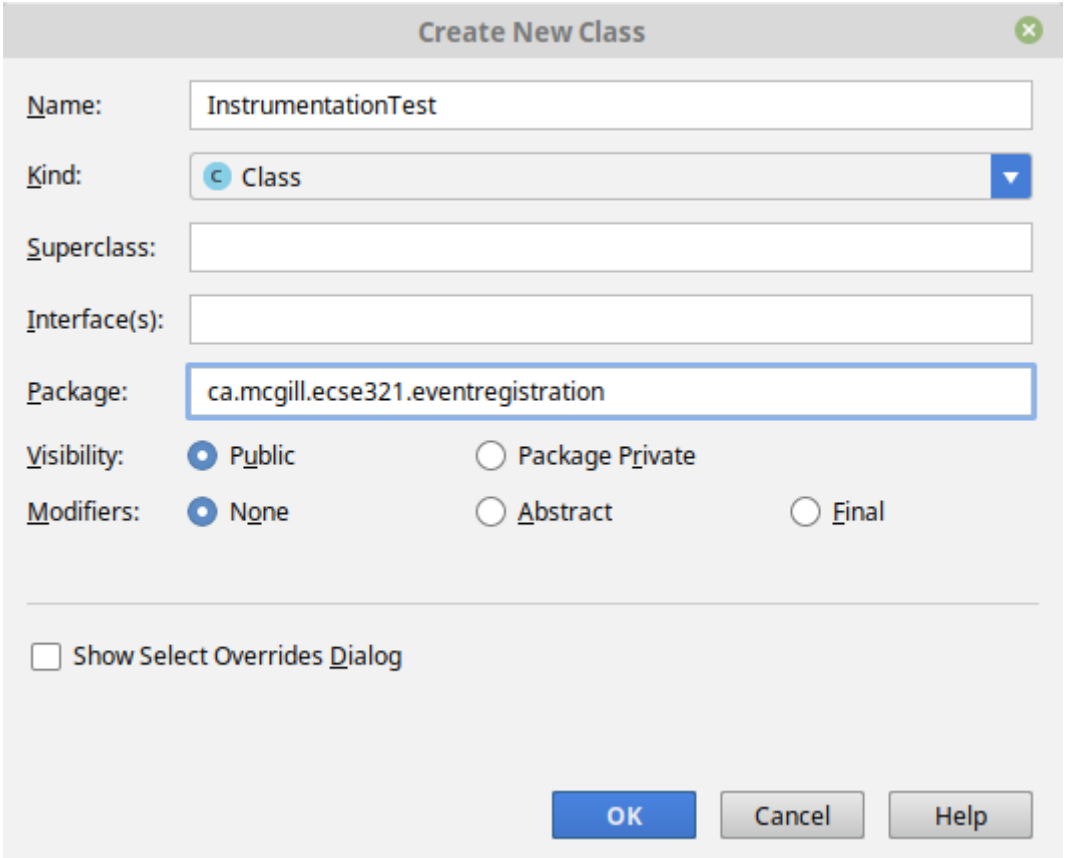
This tutorial shows how you can create UI tests using instrumentation testing with the Robotium framework.

1. Clone the initial Android project from here and import it to Android Studio.
2. Add the following dependency to the `app` module

```
dependencies {
  // ... other dependencies
   implementation 'com.jayway.android.robotium:robotium-solo:5.2.1'
}
```

3. Create the `<module-name>/src/androidTest/java` folder structure.
4. Create a new test class `RobotiumTest` under the same package name as the package name of the main activity. (In the figure the class name does not match.)





5. Add the initial implementation of the Robotium test class

```
package ca.mcgill.ecse321.eventregistration;

import android.test.ActivityInstrumentationTestCase2;
import android.widget.EditText;

import com.robotium.solo.Solo;

public class RobotiumTest extends ActivityInstrumentationTestCase2<MainActivity> {
    private Solo solo;

    private static final String LAUNCHER_ACTIVITY_FULL_CLASSNAME =
"ca.mcgill.ecse321.eventregistration.MainActivity";

    private static Class<?> launcherActivityClass;

    static {
        try {
            launcherActivityClass =
Class.forName(LAUNCHER_ACTIVITY_FULL_CLASSNAME);
        } catch (ClassNotFoundException e) {
            throw new RuntimeException(e);
        }
    }

    @SuppressWarnings("unchecked")
    public RobotiumTest() throws ClassNotFoundException {
        super((Class<MainActivity>) launcherActivityClass);
    }

    private String participantName;
    private String testParticipantName = "TestParticipant";

    @Override
    public void setUp() throws Exception {
        super.setUp();
        solo = new Solo(getInstrumentation());

        int uniqueId = 1586; // Ensure uniqueness of name
        participantName = "Participant" + uniqueId;
        getActivity();
    }

    @Override
    public void tearDown() throws Exception {
        solo.finishOpenedActivities();
        super.tearDown();
    }
}
```

6. Add a test case to see if registration succeeds

```
public void testRegisterSucceeds() throws InterruptedException {
    solo.waitForActivity("MainActivity", 2000);

    EditText editText = solo.getEditText("Who?");
    solo.enterText(editText,participantName);
    solo.clickOnText(solo.getString(R.string.newparticipant_button));

    boolean errorTextFound = solo.waitForText("exception", 1, 5000);
    assertFalse(errorTextFound);
}
```

7. Create a participant named *TestParticipant* by issuing a POST request to https://eventregistration-backend-123.herokuapp.com/participants/TestParticipant

```
# Add a participant called TestParticipant to the database
curl -X POST https://eventregistration-backend-
123.herokuapp.com/participants/TestParticipant

# Make sure participant was added by issuing a get request
curl GET https://eventregistration-backend-123.herokuapp.com/participants/
```

8. Add a test case to see if registration fails if the participant is already in the database

```
public void testRegisterFails() throws InterruptedException {
    solo.waitForActivity("MainActivity", 2000);

    EditText editText = solo.getEditText("Who?");
    solo.enterText(editText,testParticipantName);
    solo.clickOnText(solo.getString(R.string.newparticipant_button));

    boolean errorTextFound = solo.waitForText("exception", 1, 5000);
    assertTrue(errorTextFound);
}
```

9. Add a test case to see if the list of participant contains the existing participant "TestParticipant"

```
 public void testListRefreshes() {
    solo.clickOnText(solo.getString(R.string.refresh_participant_list));

    boolean textFound = solo.waitForText(testParticipantName, 1, 5000, true);

    assertTrue(textFound);
}
```

10. Start the Robotium Instrumentation Test on seleted device

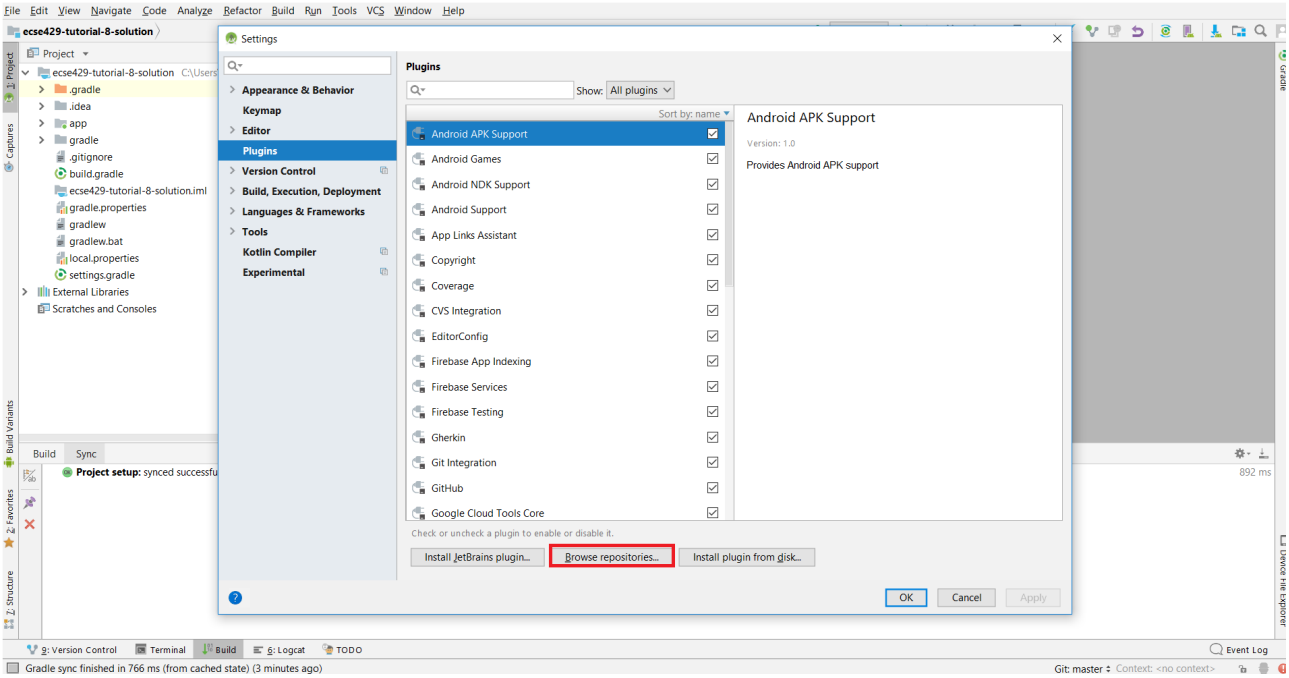
8.1. Running Android Emulator on Travis-CI

Instrumentation tests require a runtime Android. This means Travis needs to run one instance during the build to successfully execute tests. You can use the following example configuration for getting started on how to run an emulator on Travis-CI: https://gist.github.com/harmittaa/7d3c51041ffd0e54cda9807e95593309

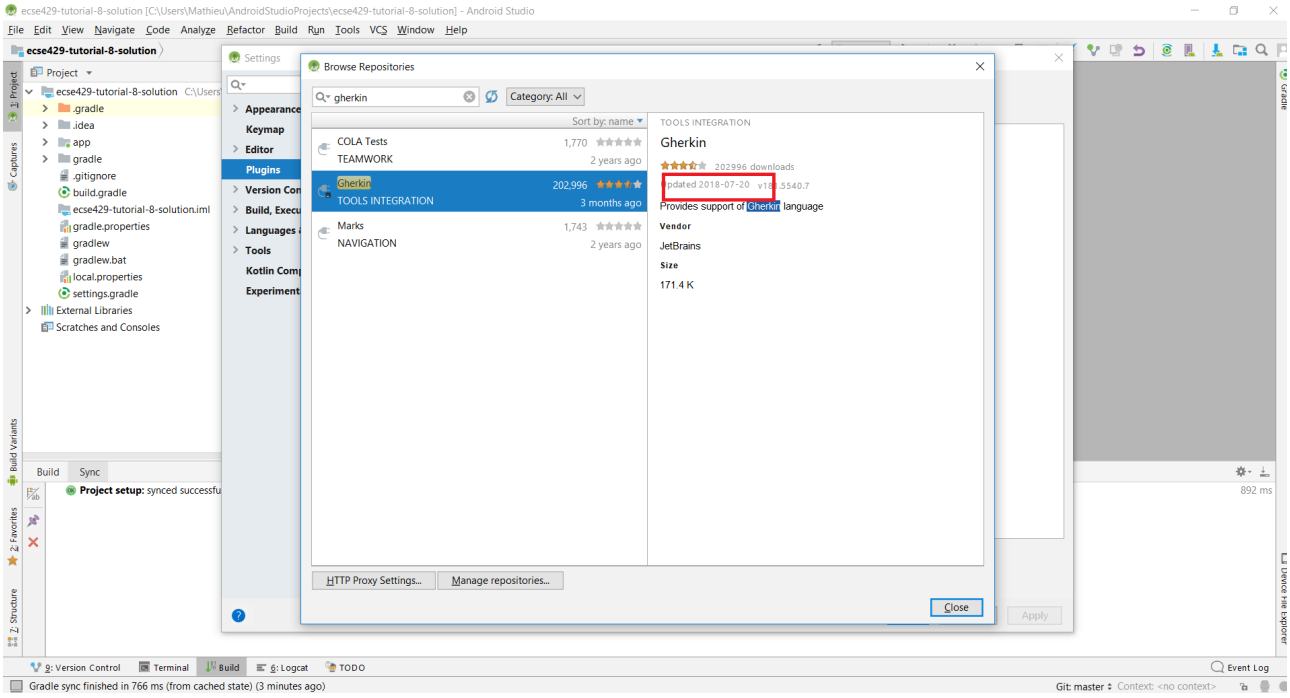
9. Acceptance Testing

This tutorial shows how you can write acceptance test using the Cucumber tool in a Behaviour-Driven Development approach.

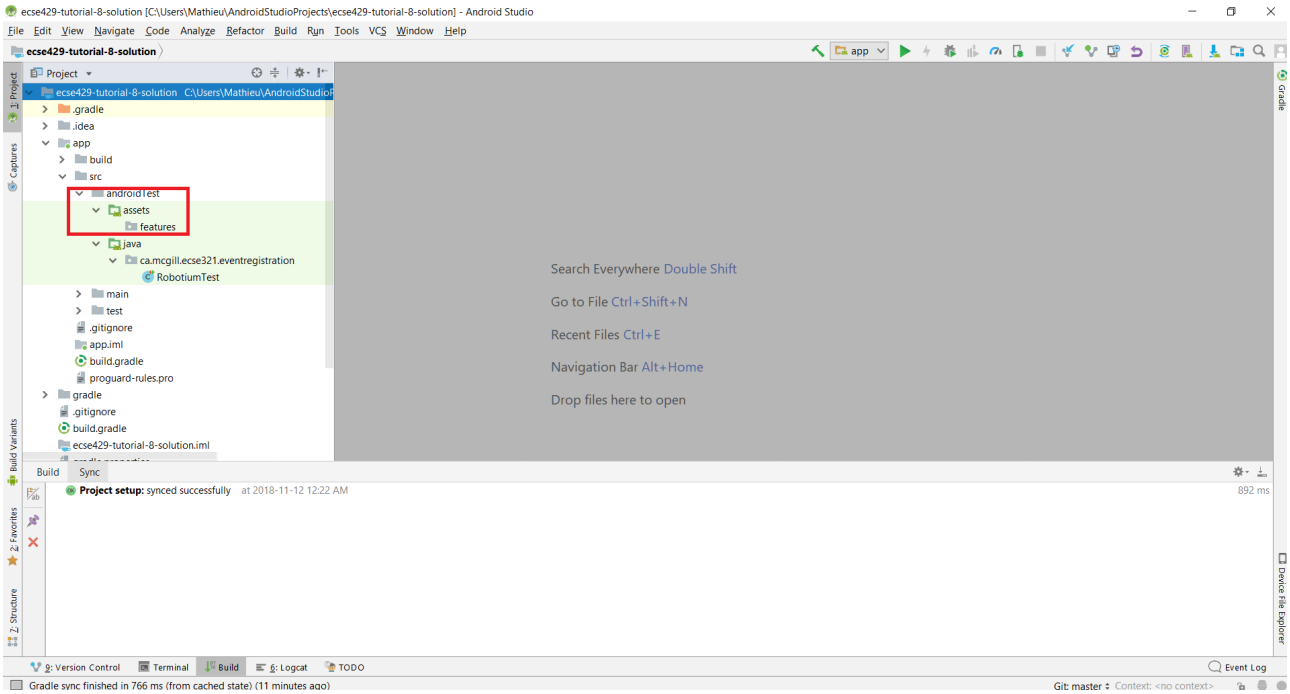
1. Clone the initial Android project from here and import it to Android Studio
2. Install the Gherkin plugin for Android Studio
   Click on *File* > *Settings* > *Plugins* > *Browse Repositories*



3. Type *Gherkin* in search box, install it and restard Android Studio.



4. Under `androidTest` folder, create a new folder structure `androidTest/assets/features`



5. Add a new file called `addParticipant.feature` in the features folder

```
Feature: Add a participant
  Add a test participant to the main activity

  Scenario Outline: Add new participant to the main activity
    Given I have a MainActivity
    When I input username <username> in text field 'Who?'
    And I press 'Add Participant' button
    When I click on the 'Refresh Participant List' button
    Then I should see <see> in the list

    Examples:
      | username          | see               |
      | some_random_guy_1 | some_random_guy_1 |
      | some_random_guy_2 | some_random_guy_2 |
      | some_random_guy_3 | some_random_guy_3 |
```

6. Add the following lines to the app's `build.gradle` file within the `android` tags

```
android {
    // ...
    defaultConfig {
        // ...
        testInstrumentationRunner
"ca.mcgill.ecse321.eventregistration.test.Instrumentation"
        // ...
    }
    // ...

    sourceSets {
        androidTest {
            assets {
                assets.srcDirs = ['src/androidTest/assets']
            }
            java {
                java.srcDirs = ['src/androidTest/java']
            }
        }
    }
    // ...

    compileOptions {
        // ...
        sourceCompatibility = '1.8'
        targetCompatibility = '1.8'
        // ...
    }
}
```

7. Add the following lines in `dependencies` section

```
dependencies {
    // ...

    //Runner
    androidTestImplementation( 'com.android.support.test:runner:0.4.1' ){
        exclude module: 'junit'
    }
    androidTestImplementation 'io.cucumber:cucumber-junit:3.0.2'
    androidTestImplementation group: 'io.cucumber', name: 'cucumber-android',
version: '3.0.2'
    androidTestImplementation 'io.cucumber:cucumber-picocontainer:3.0.2'
    androidTestImplementation group: 'io.cucumber', name: 'cucumber-jvm', version:
'3.0.2', ext: 'pom'
    androidTestImplementation 'io.cucumber:cucumber-core:3.0.2'
    androidTestImplementation 'io.cucumber:cucumber-jvm-deps:1.0.6'
    // ...
}
```

NOTE For convenience, below is the full specification of the `app.gradle` file

```
apply plugin: 'com.android.application'

android {
    compileSdkVersion 28
    defaultConfig {
        applicationId "ca.mcgill.ecse321.eventregistration"
        minSdkVersion 18
        targetSdkVersion 28
        versionCode 1
        versionName "1.0"
        testInstrumentationRunner
"ca.mcgill.ecse321.eventregistration.test.Instrumentation"
    }
    buildTypes {
        release {
            minifyEnabled false
            proguardFiles getDefaultProguardFile('proguard-android.txt'),
'proguard-rules.pro'
        }
    }
    useLibrary 'android.test.runner'
    useLibrary 'android.test.base'
    useLibrary 'android.test.mock'

    sourceSets {
        androidTest {
            assets {
                assets.srcDirs = ['src/androidTest/assets']
            }
```

```
            java {
                java.srcDirs = ['src/androidTest/java']
            }
        }
    }
    compileOptions {
        sourceCompatibility = '1.8'
        targetCompatibility = '1.8'
    }
}

dependencies {
    implementation fileTree(dir: 'libs', include: ['*.jar'])
    implementation 'com.android.support:appcompat-v7:28.0.0'
    implementation 'com.android.support.constraint:constraint-layout:1.1.3'
    implementation 'com.android.support:design:28.0.0'
    testImplementation 'junit:junit:4.12'

    implementation 'com.loopj.android:android-async-http:1.4.9'

    implementation 'com.jayway.android.robotium:robotium-solo:5.2.1'

    //Runner
    androidTestImplementation( 'com.android.support.test:runner:0.4.1' ){
        exclude module: 'junit'
    }

    androidTestImplementation 'io.cucumber:cucumber-junit:3.0.2'
    androidTestImplementation group: 'io.cucumber', name: 'cucumber-android',
version: '3.0.2'
    androidTestImplementation 'io.cucumber:cucumber-picocontainer:3.0.2'
    androidTestImplementation group: 'io.cucumber', name: 'cucumber-jvm', version:
'3.0.2', ext: 'pom'
    androidTestImplementation 'io.cucumber:cucumber-core:3.0.2'
    androidTestImplementation 'io.cucumber:cucumber-jvm-deps:1.0.6'
}
```

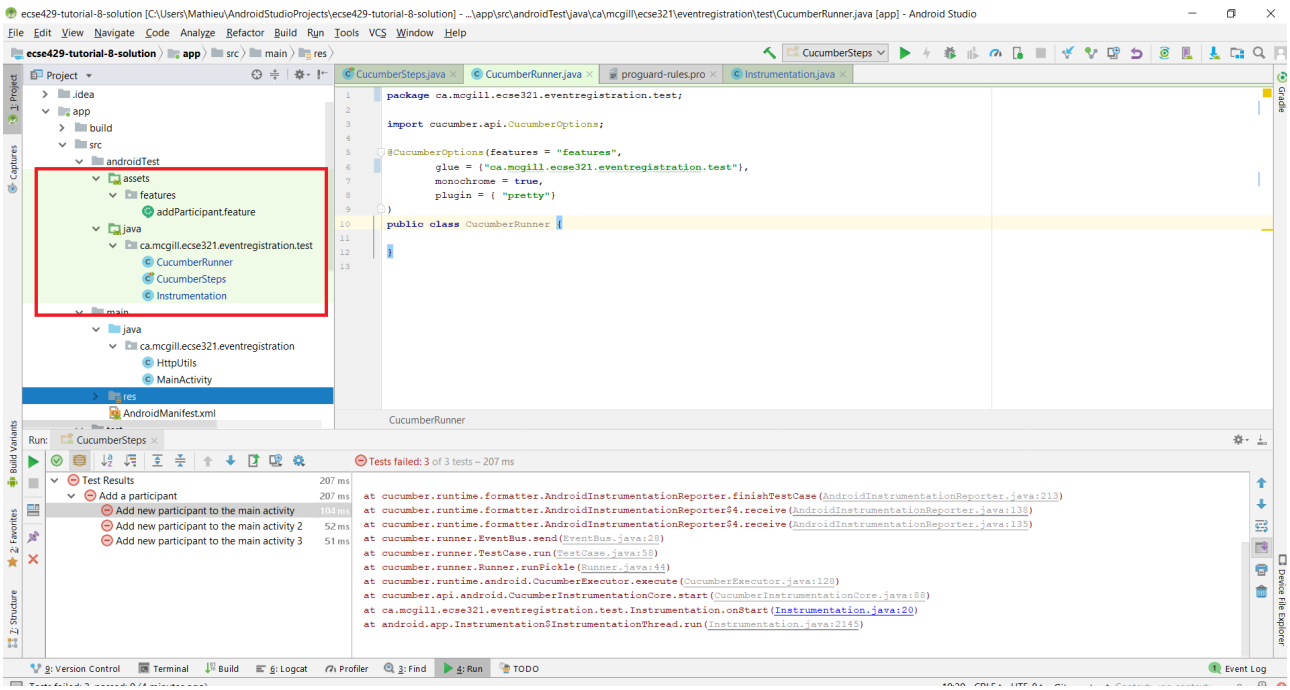
8. Sync after making the changes to the `app.gradle` file
9. Delete the current implementation of `RobotiumTest` in the `java` folder
10. Refactor or create a new package named `ca.mcgill.ecse321.eventregistration.test` under `androidTest/java`
11. Create a new class named `Instrumentation` in the `ca.mcgill.ecse321.eventregistration.test` package with the following code

```
package ca.mcgill.ecse321.eventregistration.test;

import android.os.Bundle;

import cucumber.api.android.CucumberInstrumentationCore;
import android.support.test.runner.AndroidJUnitRunner;

public class Instrumentation extends AndroidJUnitRunner {
    private final CucumberInstrumentationCore instrumentationCore = new
CucumberInstrumentationCore(this);

    @Override
    public void onCreate(Bundle arguments) {
        super.onCreate(arguments);
        instrumentationCore.create(arguments);
    }

    @Override
    public void onStart() {
        waitForIdleSync();
        instrumentationCore.start();
    }
}
```

12. Create a new class named `CucumberRunner` in the `ca.mcgill.ecse321.eventregistration.test` package with the following code

```
package ca.mcgill.ecse321.eventregistration.test;

import cucumber.api.CucumberOptions;

@CucumberOptions(features = "features",
        glue = {"ca.mcgill.ecse321.eventregistration.test"},
        monochrome = true,
        plugin = { "pretty"}
)
public class CucumberRunner {
}
```

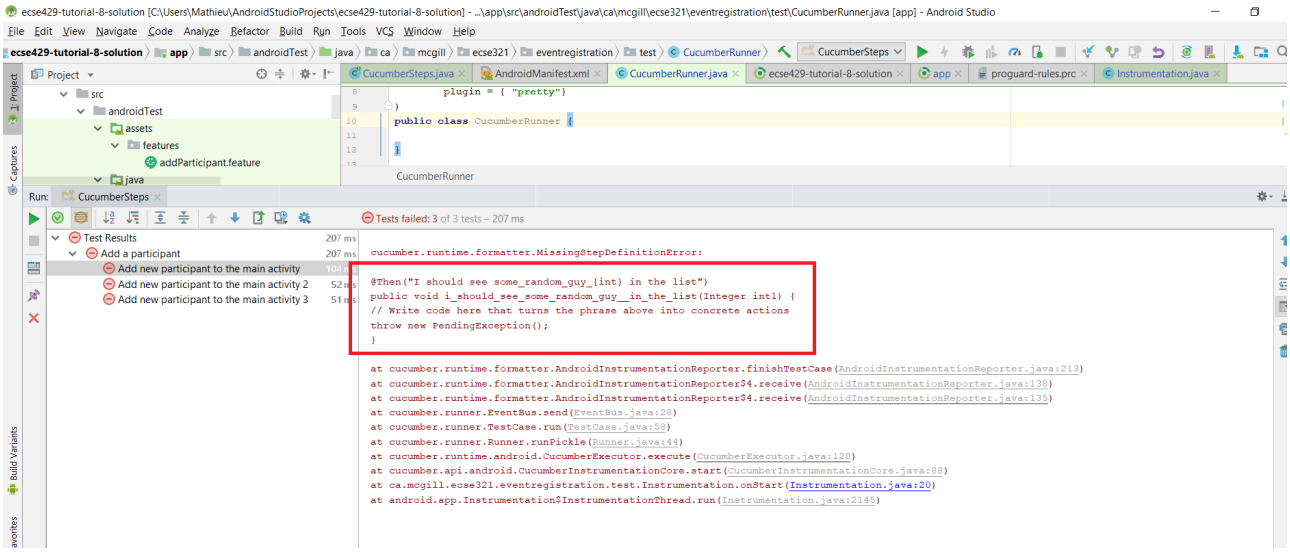
13. Create a new class `CucumberSteps` again in the `` `ca.mcgill.ecse321.eventregistration.test ``. Your file structure should look like



14. Add initializing code to `CucumberSteps`

```
package ca.mcgill.ecse321.eventregistration.test;

import android.test.ActivityInstrumentationTestCase2;

import com.robotium.solo.Solo;

import ca.mcgill.ecse321.eventregistration.MainActivity;

public class CucumberSteps extends ActivityInstrumentationTestCase2<MainActivity> {
    private Solo solo;

    private static final String LAUNCHER_ACTIVITY_FULL_CLASSNAME =
"ca.mcgill.ecse321.eventregistration.MainActivity";
    private static Class<?> launcherActivityClass;

    static {
        try {
            launcherActivityClass =
Class.forName(LAUNCHER_ACTIVITY_FULL_CLASSNAME);
        } catch (ClassNotFoundException e) {
            throw new RuntimeException(e);
        }
    }

    public CucumberSteps() throws ClassNotFoundException {
        super((Class<MainActivity>) launcherActivityClass);
    }

    @Override
    public void setUp() throws Exception {
        super.setUp();
    }

    @Override
    public void tearDown() throws Exception {
        solo.finishOpenedActivities();
        getActivity().finish();
        super.tearDown();
    }
}
```

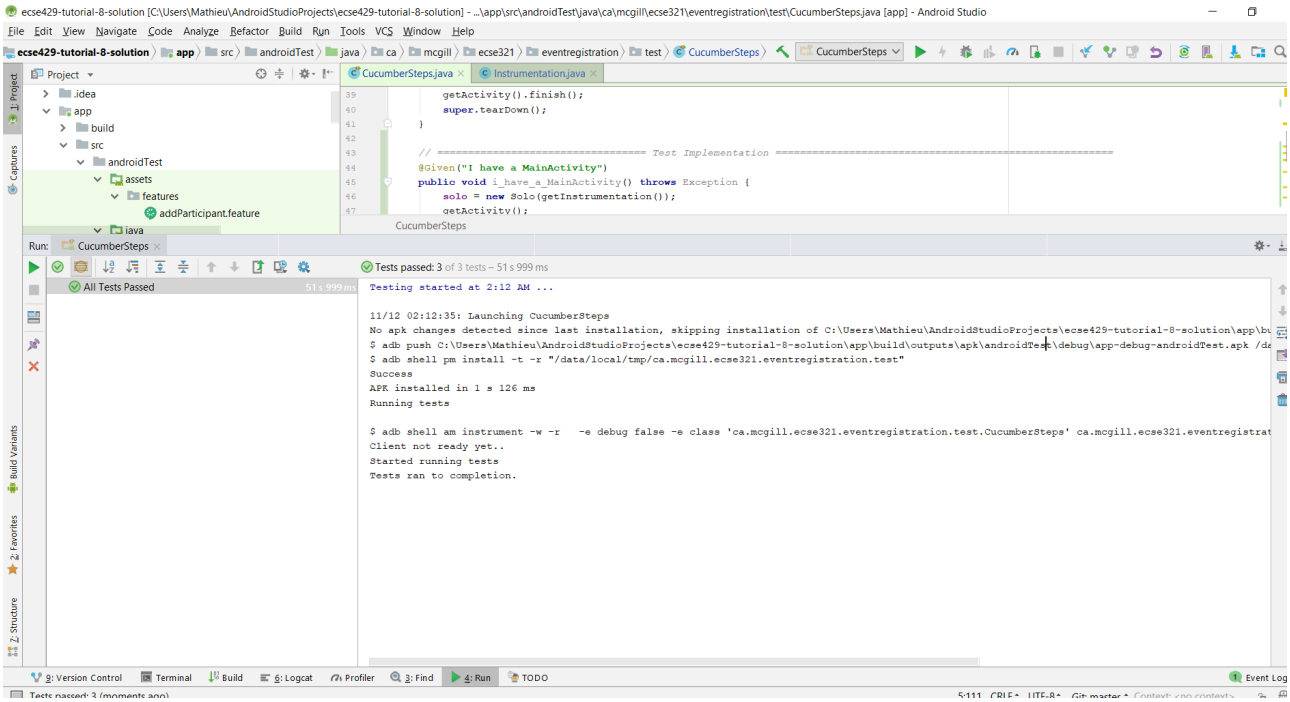
15. Run the tests under `CucumberSteps`. Take a look at the logs for the test failures



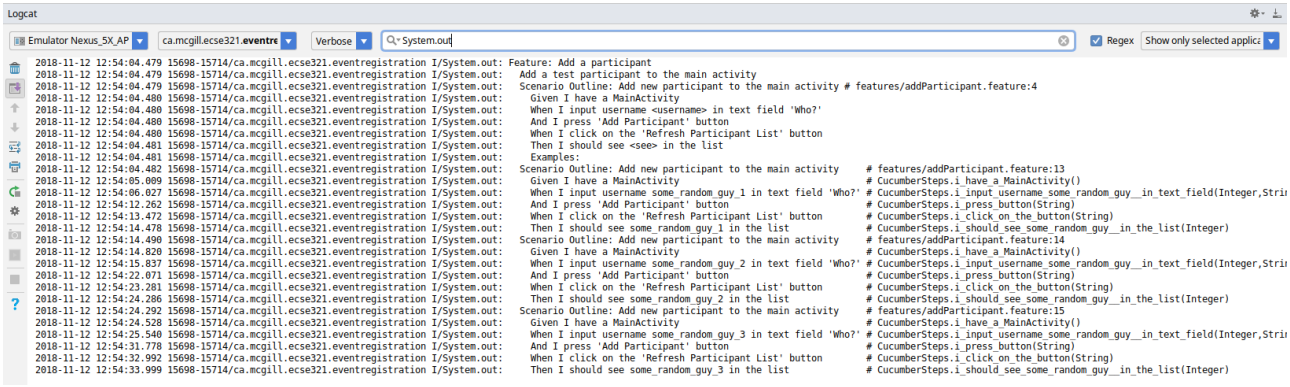
16. Add the following code to `CucumberSteps` to finish writing the tests

```
// ================================= Test Implementation
=========================================================
@Given("I have a MainActivity")
public void i_have_a_MainActivity() throws Exception {
    solo = new Solo(getInstrumentation());
    getActivity();
}

@When("I input username some_random_guy_{int} in text field {string}")
public void i_input_username_some_random_guy__in_text_field(Integer int1, String
string) {
    solo.waitForActivity("MainActivity", 2000);

    String username = "some_random_guy" + int1;

    EditText editText = solo.getEditText(string);
    solo.enterText(editText, username);
}

@When("I press {string} button")
public void i_press_button(String buttonName) {
    solo.waitForActivity("MainActivity", 2000);

    //click on button
    solo.clickOnText(buttonName);

    //make sure no error has been made
    boolean errorTextFound = solo.waitForText("exception", 1, 5000);
    assertFalse(errorTextFound);
}

@When("I click on the {string} button")
public void i_click_on_the_button(String buttonName) {
    solo.waitForActivity("MainActivity", 2000);

    //click on button
    solo.clickOnText(buttonName);
}

@Then("I should see some_random_guy_{int} in the list")
public void i_should_see_some_random_guy__in_the_list(Integer int1) {
    solo.waitForActivity("MainActivity", 2000);

    String expectedAddedParticipant = "some_random_guy" + int1;

    boolean textFound = solo.waitForText(expectedAddedParticipant, 1, 5000, true);
    assertTrue(textFound);
}
```

17. Finally, rerun the tests under `CucumberSteps`



18. Under the *Logcat* tab you can filter the view to see the output of Cucumber



10. Model-based Testing

10.1. GraphWalker

For reference, the main documentation for GraphWalker is accessible at http://graphwalker.github.io/.

10.2. Setting up GraphWalker

1. Download the Latest stable standalone CLI (3.4.2) jar file from here.
2. We assume that the `GRAPHWALKER` environment variable points to the jarfile (e.g., it points to `/home/user/graphwalker-cli-3.4.2.jar`). See its help by running

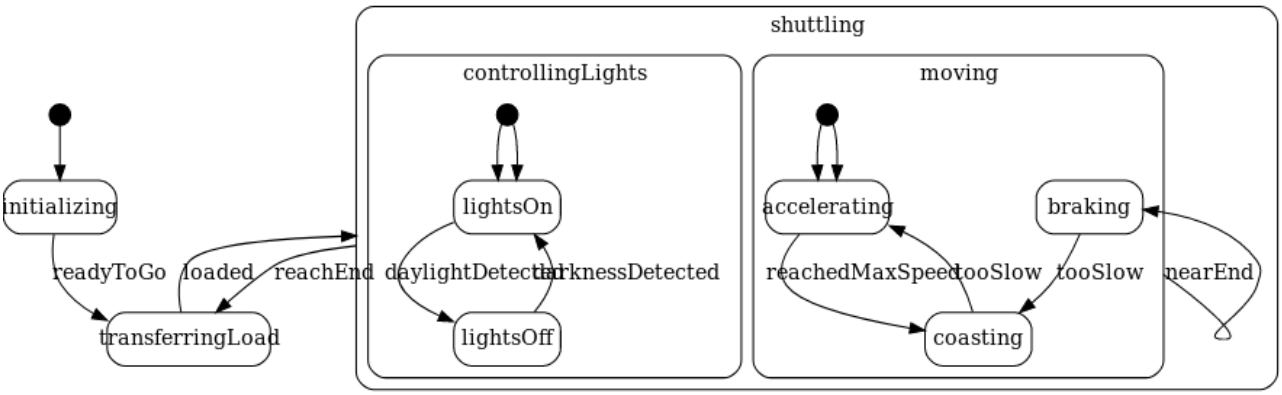
```
java -jar $GRAPHWALKER --help
```

10.3. Creating a test model

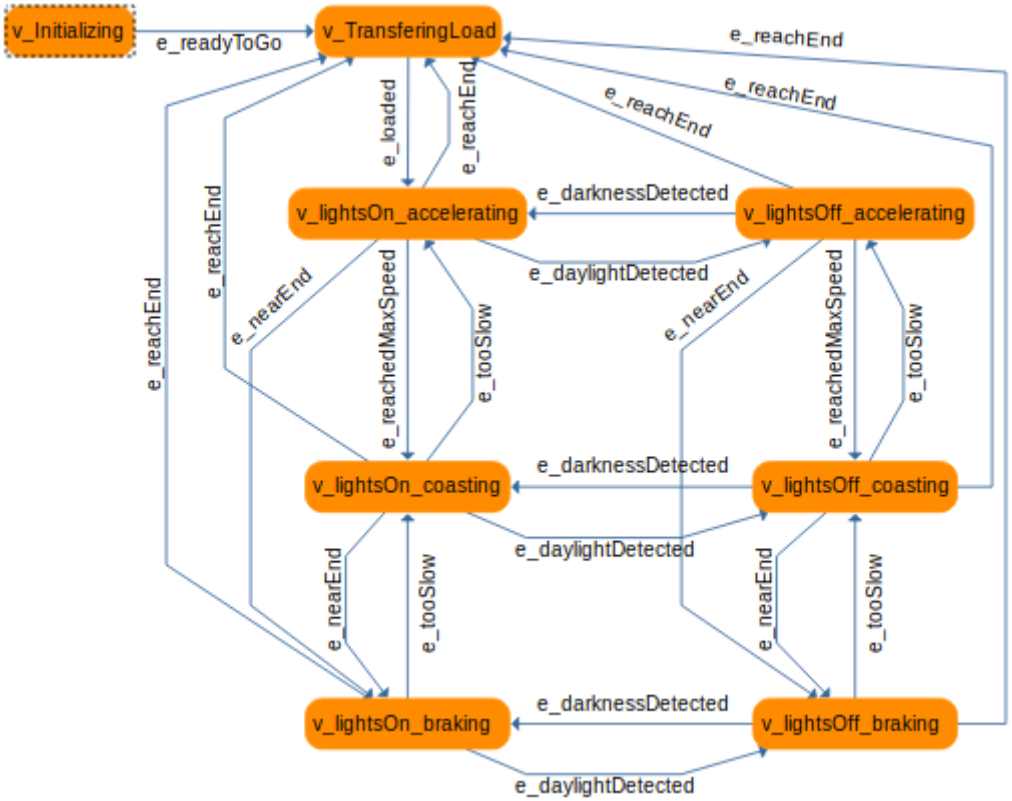
We are going to create a test model using the online UMPLE tool.

1. Go to https://cruise.eecs.uottawa.ca/umpleonline/
2. Insert the following example state machine code describing the possible states of a shuttler and insert it into the text editor (example taken from here)

```
class TrackShuttler {
  sm {
    initializing {
      readyToGo -> transferringLoad;
    }
    transferringLoad {
      loaded -> shuttling;
    }
    shuttling {
      reachEnd -> transferringLoad;
      moving {
        nearEnd -> braking;
        accelerating {
          reachedMaxSpeed -> coasting;
        }
        coasting {
          tooSlow -> accelerating;
        }
        braking {
          tooSlow -> coasting;
        }
      }
      ||
      controllingLights {
        lightsOn {
          daylightDetected -> lightsOff;
        }
        lightsOff {
          darknessDetected -> lightsOn;
        }
      }
    }
  }
}
```



3. Take a look what code is generated by the tool based on the statechart!
4. Using the yEd tool, create the flattened version of the state machine



NOTE You can download the resulting graphml from here

10.4. Test generation

1. Use the GraphWalker tool to generate a test sequence based on your criteria. For example, to generate *full vertex coverage* by applying a *random walk* strategy, use

```
java -jar $GRAPHWALKER offline --model shuttler.graphml
"random(vertex_coverage(100))" --start-element v_Initializing
```

Output:

```
{"currentElementName":"v_Initializing"}
{"currentElementName":"e_readyToGo"}
{"currentElementName":"v_TransferingLoad"}
{"currentElementName":"e_loaded"}
{"currentElementName":"v_lightsOn_accelerating"}
{"currentElementName":"e_daylightDetected"}
{"currentElementName":"v_lightsOff_accelerating"}
{"currentElementName":"e_reachEnd"}
{"currentElementName":"v_TransferingLoad"}
{"currentElementName":"e_loaded"}
{"currentElementName":"v_lightsOn_accelerating"}
{"currentElementName":"e_nearEnd"}
{"currentElementName":"v_lightsOn_braking"}
{"currentElementName":"e_daylightDetected"}
{"currentElementName":"v_lightsOff_braking"}
{"currentElementName":"e_tooSlow"}
{"currentElementName":"v_lightsOff_coasting"}
{"currentElementName":"e_tooSlow"}
{"currentElementName":"v_lightsOff_accelerating"}
{"currentElementName":"e_reachEnd"}
{"currentElementName":"v_TransferingLoad"}
{"currentElementName":"e_loaded"}
{"currentElementName":"v_lightsOn_accelerating"}
{"currentElementName":"e_daylightDetected"}
{"currentElementName":"v_lightsOff_accelerating"}
{"currentElementName":"e_darknessDetected"}
{"currentElementName":"v_lightsOn_accelerating"}
{"currentElementName":"e_reachedMaxSpeed"}
{"currentElementName":"v_lightsOn_coasting"}
```

TIP Use the jq tool to prettify the output of the test generator. Pipe the results:

```
GRAPHWALKER_COMMAND | jq -r .currentElementName
```

2. Experiment with other setting, such as creating a test case from one node to another node with A* traversal! See more here.
3. Other useful MBT resources