# Multithreading

## Overview

In this lab, you will refactor an existing application so that it performs time-consuming tasks on background threads.

## Source modules

Student module: StudentMultithreading

Solution module: SolutionMultithreading

## Roadmap

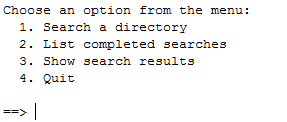
There are 3 exercises in this lab, of which the last exercise is "if time permits". Here is a brief summary of the tasks you will perform in each exercise; more detailed instructions follow later:

1. Introduce multithreading into the application
2. Ensure thread safety
3. Wait for threads to terminate gracefully

## Familiarization with the application

Open the student module, and expand the student.multithreading package. The package contains a single class named Main, which runs entirely in a single thread.

Run the application. You are presented with a menu of options, as follows:



At the prompt, type 1 and press ENTER. You will be asked to enter a directory name - enter a directory name that doesn’t contain too many files! The application then performs a recursive search for all the files and sub-directories in the specified directory. It performs this search on the main application thread, so the application is blocked until the search is complete.

When the search finally completes, the application displays the main menu again. If you choose option 2, you should see your directory name listed (because the application has completed the search for that directory). To see the results of that search, choose option 3; the application will display all the files and sub-directories that it found in your directory (recursively).

Try another search (i.e. choose option 1 again). This time enter the name of a directory that contains a large number of files and/or sub-directories. This search might take a long time to complete, and the application is blocked until the search has finished.

When you’re comfortable with how the application works, take a look at the code in the Main class. There are lots of comments in the code, so you should be able to follow the logic fairly easily. If there’s anything you don’t understand, feel free to ask the instructor.

## Exercise 1: Introduce multithreading into the application

The application is unacceptable because it forces the user to wait until a search finishes before the user can do anything else. A better approach would be to use multithreading

To run code in a separate thread, you must define a class that implements the Runnable interface. So, add a new class named DirectorySearcher and implement it as follows:

* The class must implement the Runnable interface (obviously).
* The class needs some instance variables so it can “remember” what it’s meant to be doing. We suggest the following instance variables:
  + A String instance variable called directoryName, which remembers the name of the directory to search.
  + A List<File> instance variable called thisResult, to accumulate all the files and sub-directories for this search. Create an empty list initially.
  + A Map<String, List<File>> instance variable called allResults, which will hold the results of all searches completed so far (this will be passed in from the main code – see the constructor info below…)
* Write a constructor. The constructor requires two parameters, which will be passed in from the main application code:
  + The name of the directory to search.
  + The map into which the thread can store its results on completion of this search.
* Copy the searchDirectory() method from the Main class into the DirectorySearcher class (because the search operation will now be performed in your background thread class). Refactor the method as follows:
  + It doesn’t need to be static any more (it was only declared static originally because all the methods in the Main class were static for simplicity).
  + It doesn’t need a List<String> parameter (the DirectorySearcher class can use the thisResult instance variable instead).
* Write a run() method to perform the work for this thread. Implement it as follows:
  + Invoke searchDirectory(), passing in a File object to represent the directory to search.
  + After searchDirectory() has completed, insert the result into the map of all results (similar to the existing code in the Main class’s doSearch() method).
* In the Main class, refactor doSearch() to perform the search in a background thread (i.e. create a DirectorySearcher object and start it in a separate thread).

Run the application again. Now, when you do a search, the search should take place in a background thread. This means you can kick off multiple searches simultaneously ☺.

## Exercise 2: Ensure thread safety

The application isn’t thread-safe at the moment, because multiple threads might insert results into the allResults map simultaneously. As currently implemented, the application uses a HashMap, which is a non-thread-safe collection class.

It’s extremely important to ensure thread safety in your applications. There are various ways to achieve thread safety in this situation… the simplest approach is to use a thread-safe map class, e.g. ConcurrentHashMap. Refactor the Main class to do this.

You probably won’t observe any differences when you run the application, but at least you won’t get any nasty thread concurrency surprises later on either!

## Exercise 3 (If time permits): Wait for threads to terminate gracefully

Improve the application so that it allows all running threads to complete first when the application shuts down. Hints:

* Keep a list of all threads you create in the application.
* When the user quits the application, loop through the thread list and invoke join() to wait for the thread to finish. Optionally, specify a timeout on each join() operation (to avoid potentially having to wait a very long time for a thread to finish!)