

Overview of Asynchrony & Asynchronous Operations

Douglas C. Schmidt

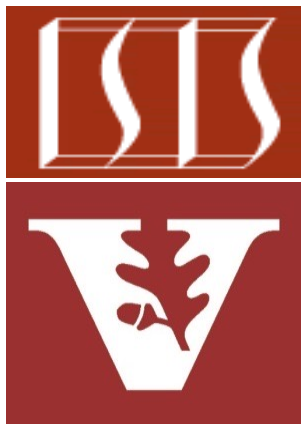
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Learning Objectives in this Part of the Lesson

- Understand what synchrony & synchronous operations are
- Motivate the need for Java Future & CompletableFuture mechanisms by understanding the pros & cons of synchrony
- Understand what asynchrony & asynchronous operations are



See [en.wikipedia.org/wiki/Asynchrony_\(computer_programming\)](https://en.wikipedia.org/wiki/Asynchrony_(computer_programming))

Overview of Asynchrony & Asynchronous Operations

Overview of Asynchrony & Asynchronous Operations

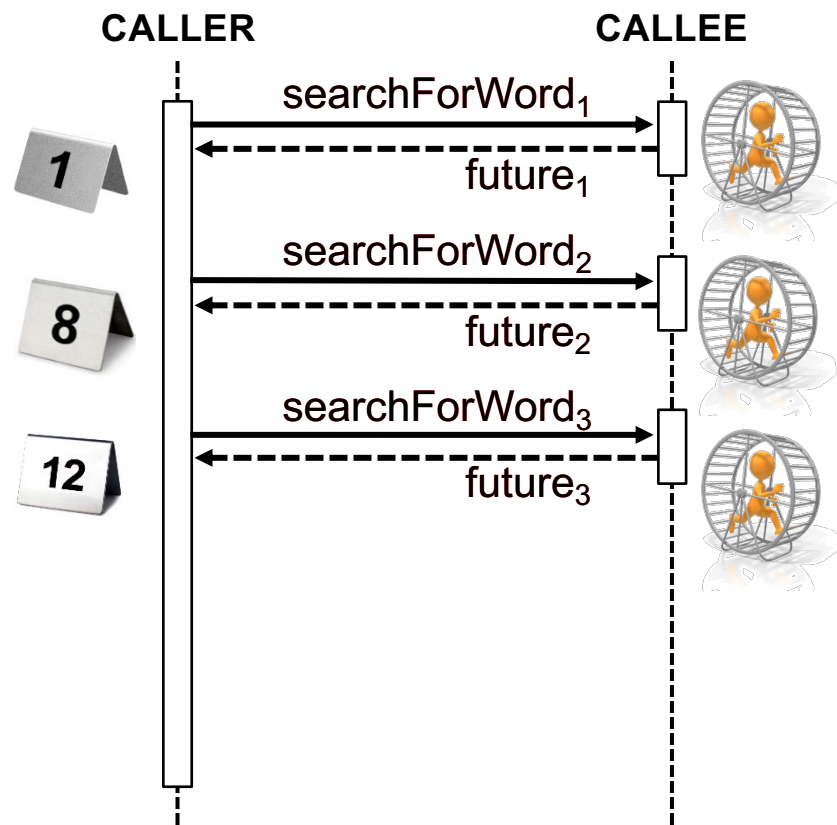
- Asynchrony is a means of concurrent programming where caller does not block waiting for callee to complete



See [en.wikipedia.org/wiki/Asynchrony_\(computer_programming\)](https://en.wikipedia.org/wiki/Asynchrony_(computer_programming))

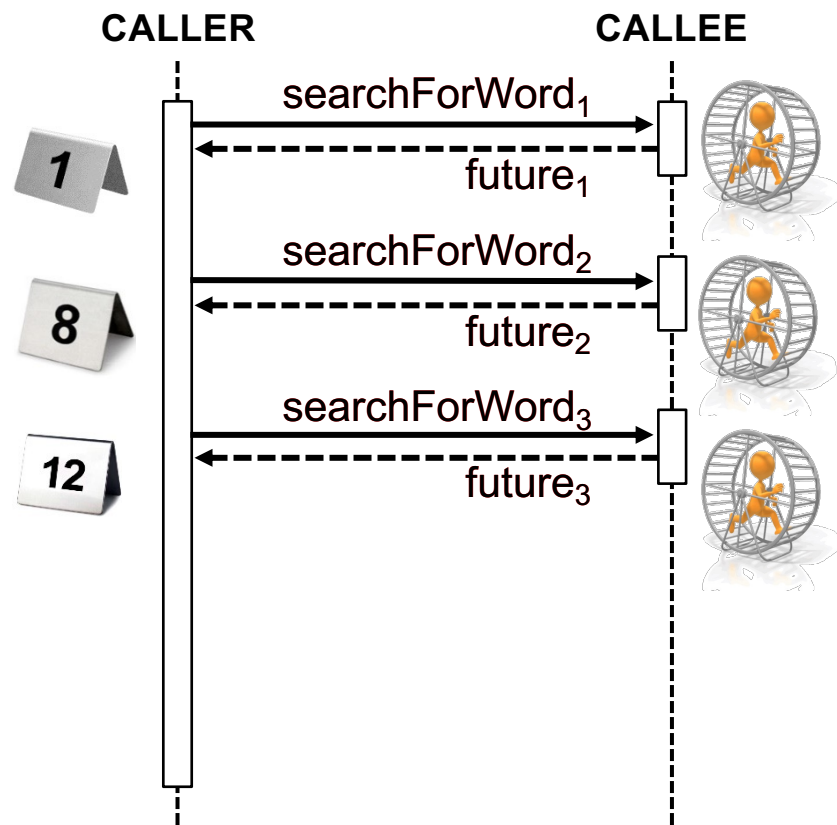
Overview of Asynchrony & Asynchronous Operations

- Asynchrony is a means of concurrent programming where caller does not block waiting for callee to complete
- An async call immediately returns a future & while the computation runs “in the background” concurrently



Overview of Asynchrony & Asynchronous Operations

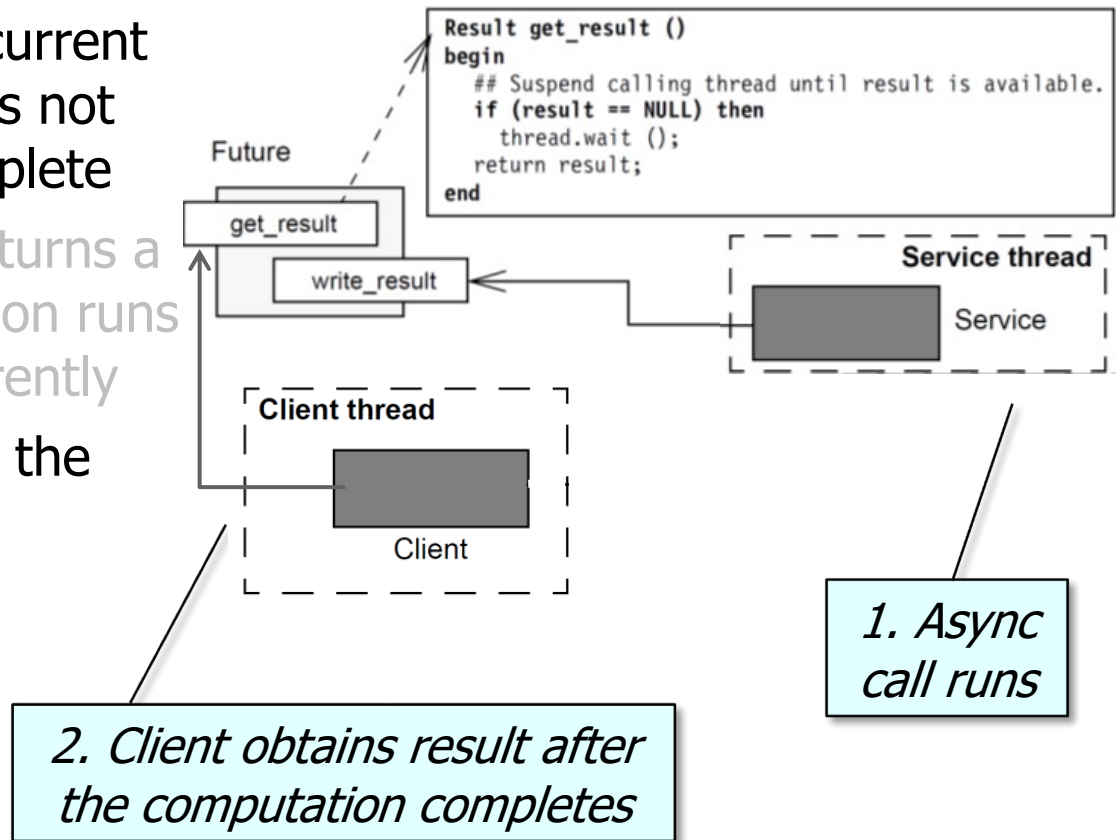
- Asynchrony is a means of concurrent programming where caller does not block waiting for callee to complete
- An async call immediately returns a future & while the computation runs “in the background” concurrently
- i.e., independent of the flow of control for the callee’s thread



See en.wikipedia.org/wiki/Control_flow

Overview of Asynchrony & Asynchronous Operations

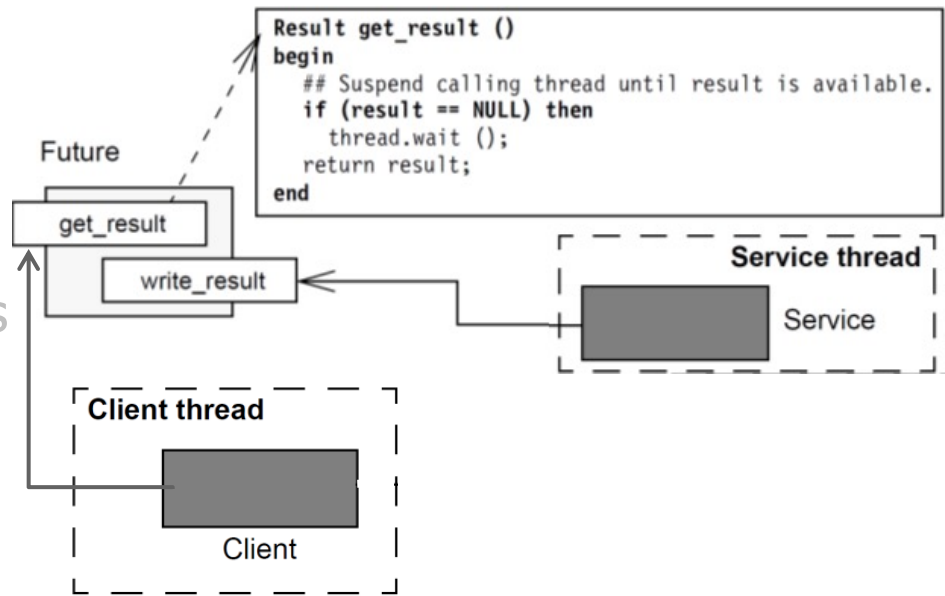
- Asynchrony is a means of concurrent programming where caller does not block waiting for callee to complete
- An async call immediately returns a future & while the computation runs "in the background" concurrently
- The future is triggered when the computation completes



See upcoming lessons on "Overview of Java Futures"

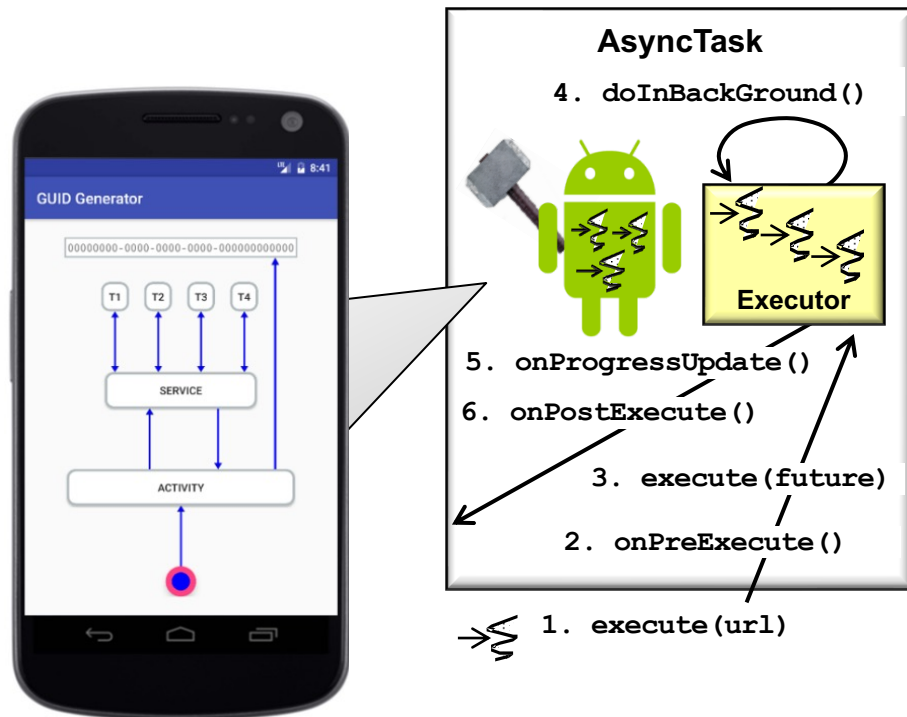
Overview of Asynchrony & Asynchronous Operations

- Asynchrony is a means of concurrent programming where caller does not block waiting for callee to complete
 - An async call immediately returns a future & while the computation runs “in the background” concurrently
 - The future is triggered when the computation completes
 - The client may or may not block awaiting the results, depending on various factors



Overview of Asynchrony & Asynchronous Operations

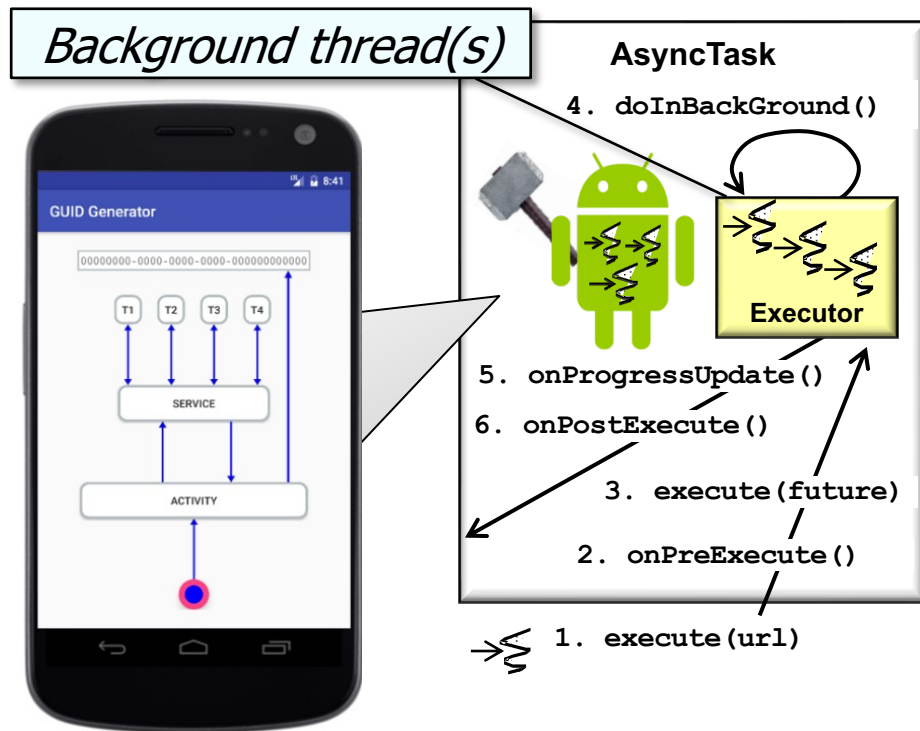
- e.g., Android's AsyncTask framework performs background operations & publishes results on the user-interface (UI) thread without having to manipulate threads and/or handlers



See developer.android.com/reference/android/os/AsyncTask

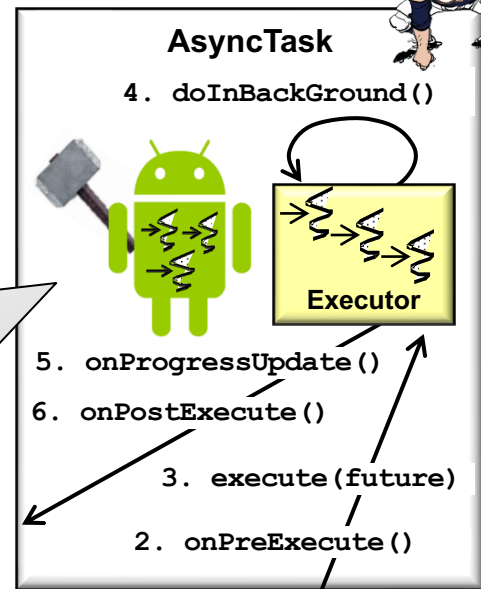
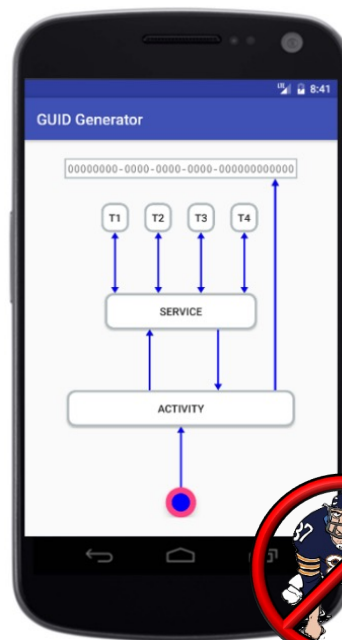
Overview of Asynchrony & Asynchronous Operations

- e.g., Android's AsyncTask framework performs background operations & publishes results on the user-interface (UI) thread without having to manipulate threads and/or handlers
- AsyncTask executes long-duration operations asynchronously in one or more background threads



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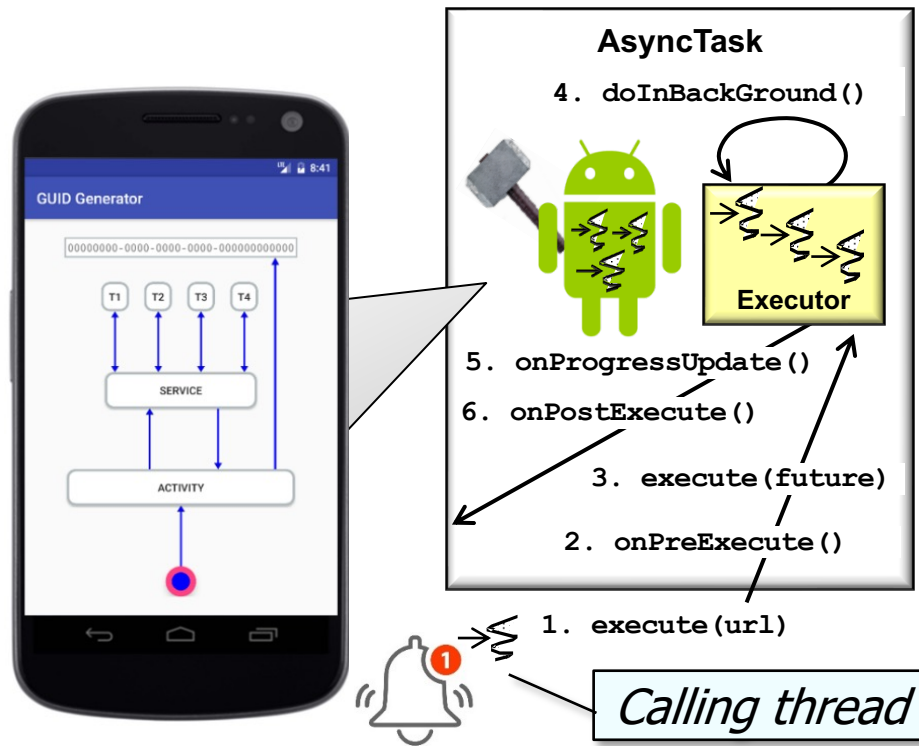
- e.g., Android's AsyncTask framework performs background operations & publishes results on the user-interface (UI) thread without having to manipulate threads and/or handlers
- AsyncTask executes long-duration operations asynchronously in one or more background threads
- Blocking operations in background threads don't block the caller (e.g., UI) thread



Calling thread

Overview of Asynchrony & Asynchronous Operations

- e.g., Android's AsyncTask framework performs background operations & publishes results on the user-interface (UI) thread without having to manipulate threads and/or handlers
- AsyncTask executes long-duration operations asynchronously in one or more background threads
- Blocking operations in background threads don't block the caller (e.g., UI) thread
- The caller (UI) thread can be notified upon completion, failure, or progress of the async task



AsyncTask shields client code from details of programming futures

End of Overview of Asynchrony & Asynchronous Operations

Understanding the Pros & Cons of Asynchrony

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The Pros of Asynchrony

The Pros of Asynchrony

- Pros of asynchronous operations



The Pros of Asynchrony

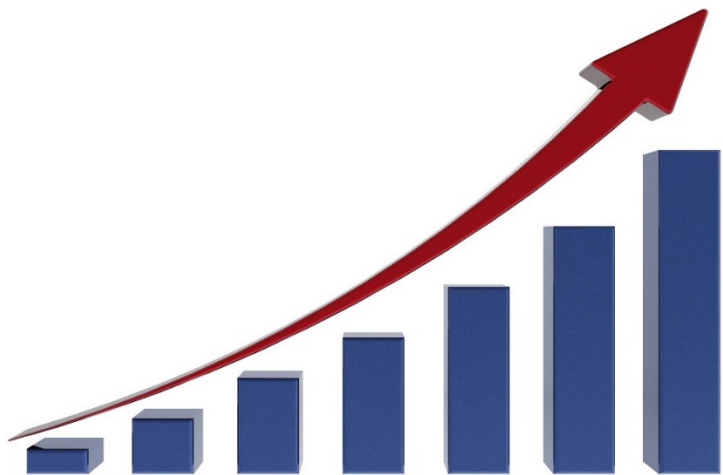
- Pros of asynchronous operations
 - Responsiveness
 - A calling thread needn't block waiting for the async request to complete



See en.wikipedia.org/wiki/Asynchronous_method_invocation

The Pros of Asynchrony

- Pros of asynchronous operations
 - Responsiveness
 - Elasticity
 - Multiple requests can run scalably & concurrently on multiple cores



See [en.wikipedia.org/wiki/Elasticity_\(cloud_computing\)](https://en.wikipedia.org/wiki/Elasticity_(cloud_computing))

The Pros of Asynchrony

- Pros of asynchronous operations
 - Responsiveness
 - Elasticity
 - Multiple requests can run scalably & concurrently on multiple cores
 - Able to better leverage parallelism available in multi-core systems



The Pros of Asynchrony

- Pros of asynchronous operations
 - Responsiveness
 - Elasticity
 - Multiple requests can run scalably & concurrently on multiple cores
 - Able to better leverage parallelism available in multi-core systems
 - Elasticity is particularly useful to auto-scale computations in cloud environments



The Cons of Asynchrony

The Cons of Asynchrony

- Cons of asynchronous operations



The Cons of Asynchrony

- Cons of asynchronous operations
 - Unpredictability
 - Response times may not unpredictable due to non-determinism of async operations



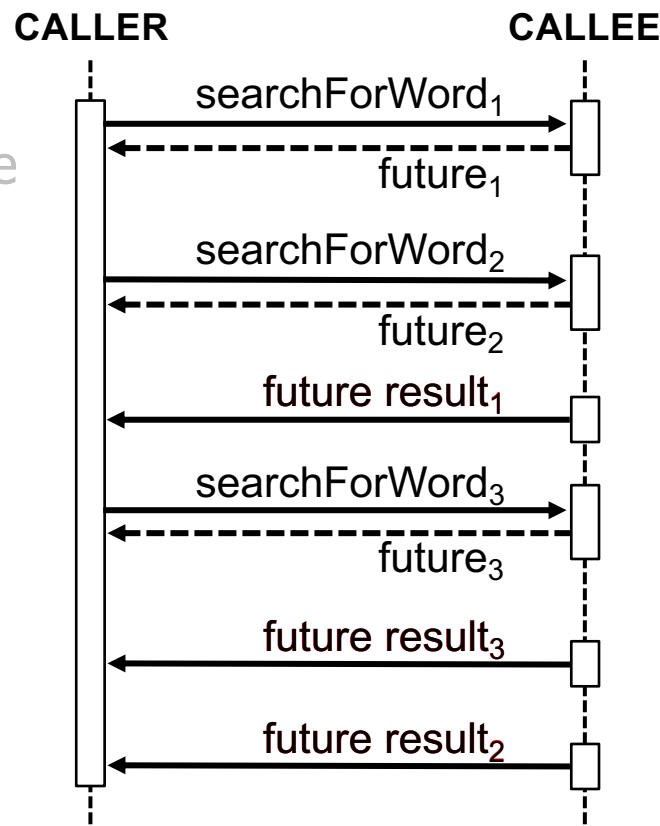
Non-determinism is a general problem with concurrency & not just asynchrony

See en.wikipedia.org/wiki/Nondeterministic_algorithm

The Cons of Asynchrony

- Cons of asynchronous operations
 - Unpredictability
 - Response times may not be unpredictable due to non-determinism of async operations
 - Results can occur in a different order than the original calls were made

OUT OF ORDER



Additional time & effort may be required if results must be ordered somehow

The Cons of Asynchrony

- Cons of asynchronous operations
 - Unpredictability
 - Complicated programming & debugging



The Cons of Asynchrony

- Cons of asynchronous operations
 - Unpredictability
 - Complicated programming & debugging
 - The patterns & best-practices of asynchronous programming are not well understood



Parallel and Asynchronous Programming in Java 8

Java 8 offered a boon to parallel and asynchronous programming. Let's check out the lessons Java learned from JavaScript and how JDK 8 changed the game.



by Lisa Steendam · May, 11, 18 · Java Zone · Tutorial

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Parallel code, which is code that runs on more than one thread, was once the nightmare of many an experienced developer, but Java 8 brought a lot of changes that should make this performance-boosting trick a lot more manageable.

CompletableFuture

`CompletableFuture` implements both the `Future` and the `CompletionStage` interface. `Future` already existed pre-Java8, but it wasn't very developer-friendly by itself. You could only get the result of the asynchronous computation by using the `.get()` method, which blocked the rest (making the async part pretty pointless most of the time) and you needed to implement each possible scenario manually. Adding the `CompletionStage` interface was the breakthrough that made asynchronous programming in Java workable.

`CompletionStage` is a promise, namely the promise that the computation will eventually be done. It contains a bunch of methods that let you attach callbacks that will be executed on that completion. Now we can handle the result without blocking.

There are two main methods that let you start the asynchronous part of your code: `supplyAsync` if you want to do something with the result of the method, and `runAsync` if you don't.

See dzone.com/articles/parallel-and-asynchronous-programming-in-java-8

The Cons of Asynchrony

- Cons of asynchronous operations
 - Unpredictability
 - Complicated programming & debugging
 - The patterns & best-practices of asynchronous programming are not well understood
 - Async programming is tricky without proper abstractions

```
function register()
{
  if (!empty($_POST)) {
    $msg = '';
    if ($_POST['user_name']) {
      if ($_POST['user_password_new']) {
        if ($_POST['user_password_new'] == $_POST['user_password_confirm']) {
          if (strlen($_POST['user_password_new']) > 5) {
            if (strlen($_POST['user_name']) < 45 && strlen($_POST['user_name']) > 1) {
              if (preg_match('/^[a-z\d]{2,64}$/i', $_POST['user_name'])) {
                $user = read_user($_POST['user_name']);
                if (!isset($user['user_name'])) {
                  if ($_POST['user_email']) {
                    if (strlen($_POST['user_email']) < 65) {
                      if (filter_var($_POST['user_email'], FILTER_VALIDATE_EMAIL)) {
                        create_user();
                        $_SESSION['msg'] = 'You are now registered so please login!';
                        header('location: ' . $_SERVER['PHP_SELF']);
                        exit();
                      } else $msg = 'You must provide a valid email address';
                    } else $msg = 'Email must be less than 64 characters';
                  } else $msg = 'Email cannot be empty';
                } else $msg = 'Username already exists';
              } else $msg = 'Username must be only a-z, A-Z, 0-9';
            } else $msg = 'Username must be between 2 and 64 characters';
          } else $msg = 'Password must be at least 6 characters';
        } else $msg = 'Passwords do not match';
      } else $msg = 'Empty Password';
    } else $msg = 'Empty Username';
    $_SESSION['msg'] = $msg;
  }
  return register_form();
}
```



icompile.eladkarako.com

See dzone.com/articles/callback-hell

The Cons of Asynchrony

- Cons of asynchronous operations
 - Unpredictability
 - Complicated programming & debugging
 - The patterns & best-practices of asynchronous programming are not well understood
 - Errors can be hard to track due to unpredictability



See www.jetbrains.com/help/idea/tutorial-java-debugging-deep-dive.html

The Cons of Asynchrony

- Cons of asynchronous operations
 - Unpredictability
 - Complicated programming & debugging
 - The patterns & best-practices of asynchronous programming are not well understood
 - Errors can be hard to track due to unpredictability

Again, non-determinism is a general problem with concurrency & not just with asynchrony



Weighing the Pros & Cons of Asynchrony

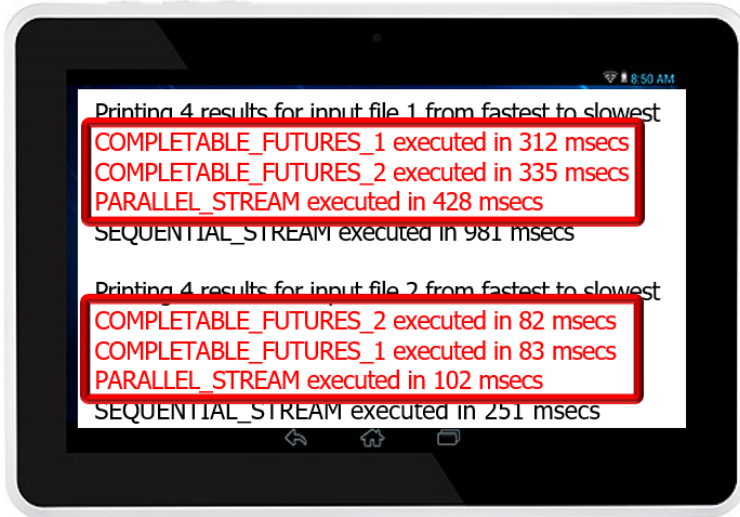
Weighing the Pros & Cons of Asynchrony

- Two things are necessary for the pros of asynchrony to outweigh the cons



Weighing the Pros & Cons of Asynchrony

- Two things are necessary for the pros of asynchrony to outweigh the cons
- Performance should improve to offset the increased complexity of programming & debugging



Printing 4 results for input file 1 from fastest to slowest

COMPLETABLE_FUTURES_1	executed in 312 msecs
COMPLETABLE_FUTURES_2	executed in 335 msecs
PARALLEL_STREAM	executed in 428 msecs
SEQUENTIAL_STREAM	executed in 981 msecs

Printing 4 results for input file 2 from fastest to slowest

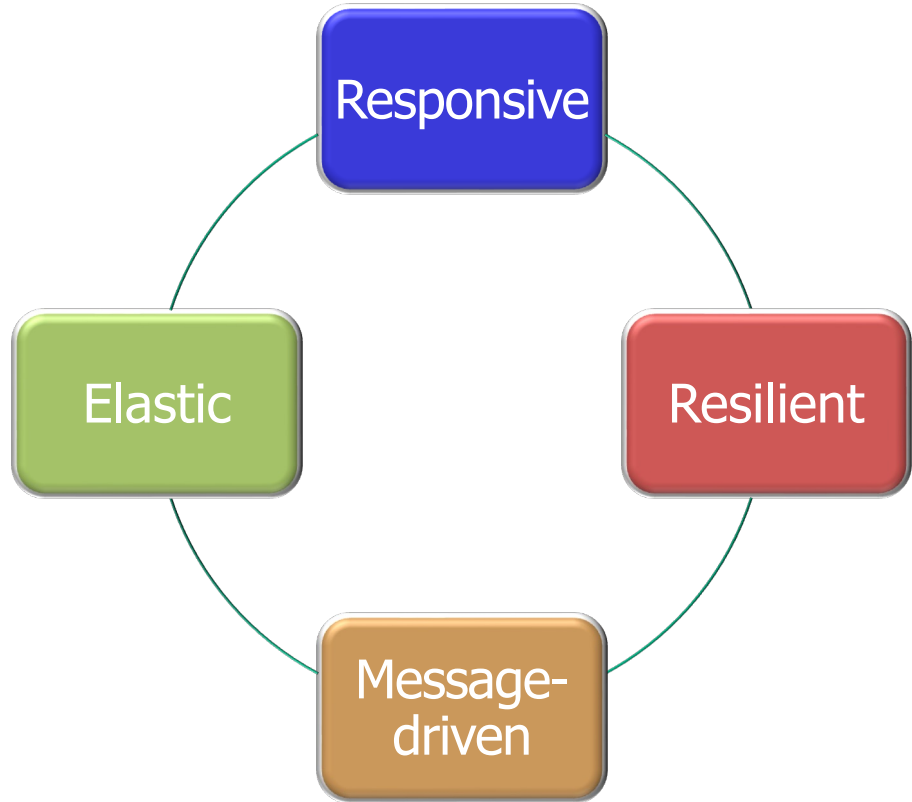
COMPLETABLE_FUTURES_2	executed in 82 msecs
COMPLETABLE_FUTURES_1	executed in 83 msecs
PARALLEL_STREAM	executed in 102 msecs
SEQUENTIAL_STREAM	executed in 251 msecs



See upcoming lesson on "Java Completable Futures ImageStreamGang Example"

Weighing the Pros & Cons of Asynchrony

- Two things are necessary for the pros of asynchrony to outweigh the cons
 - Performance should improve to offset the increased complexity of programming & debugging
- An asynchronous programming model should reflect the key principles of the reactive paradigm



See earlier lesson on "*Overview of Reactive Programming*"

Weighing the Pros & Cons of Asynchrony

- Java's completable futures framework provides an asynchronous concurrent programming model that performs well & supports the reactive paradigm

Class `CompletableFuture<T>`

```
java.lang.Object  
    java.util.concurrent.CompletableFuture<T>
```

All Implemented Interfaces:

```
CompletionStage<T>, Future<T>
```

```
public class CompletableFuture<T>  
    extends Object  
    implements Future<T>, CompletionStage<T>
```

A `Future` that may be explicitly completed (setting its value and status), and may be used as a `CompletionStage`, supporting dependent functions and actions that trigger upon its completion.

When two or more threads attempt to `complete`, `completeExceptionally`, or `cancel` a `CompletableFuture`, only one of them succeeds.

In addition to these and related methods for directly manipulating status and results, `CompletableFuture` implements interface `CompletionStage` with the following policies:

Weighing the Pros & Cons of Asynchrony

- Java's completable futures framework provides an asynchronous concurrent programming model that performs well & supports the reactive paradigm
- However, reactive streams frameworks are even better suited to supporting the reactive programming paradigm



Project
Reactor

End of Understanding the Pros & Cons of Asynchrony