Java ExecutorService: Application to PrimeChecker App

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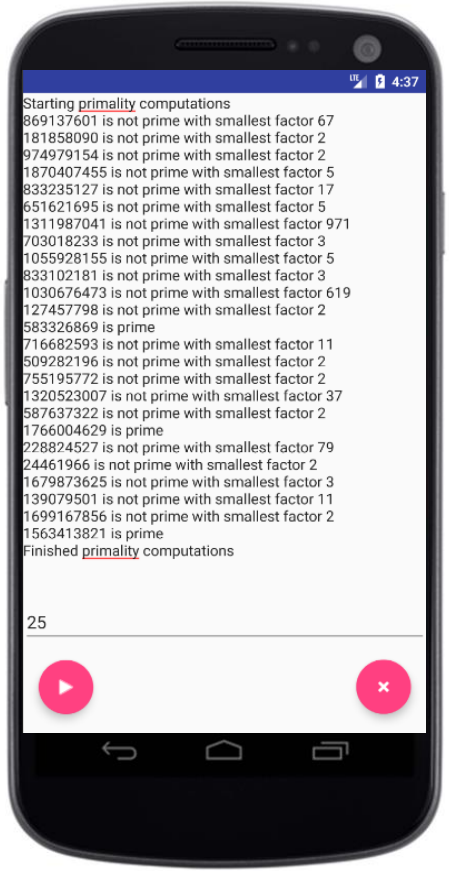
Learning Objectives in this Part of the Lesson

- Recognize the powerful features defined in the Java ExecutorService interface
- Understand other interfaces related to ExecutorService
- Know the key methods provided by ExecutorService
- Be aware of how ThreadPoolExecutor implements ExecutorService
- Learn how to program the PrimeChecker app using ExecutorService



Overview of the PrimeChecker App

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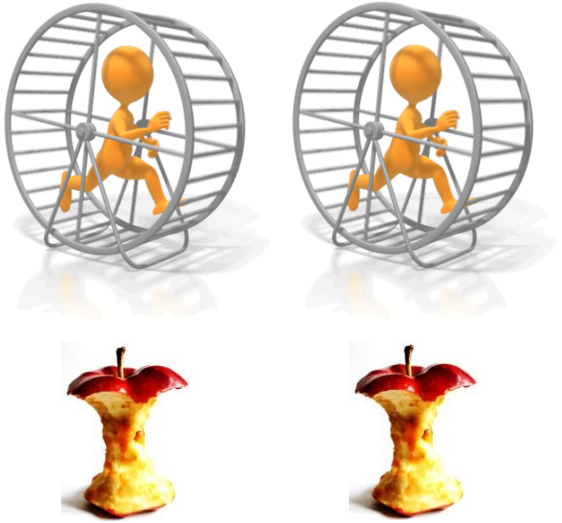
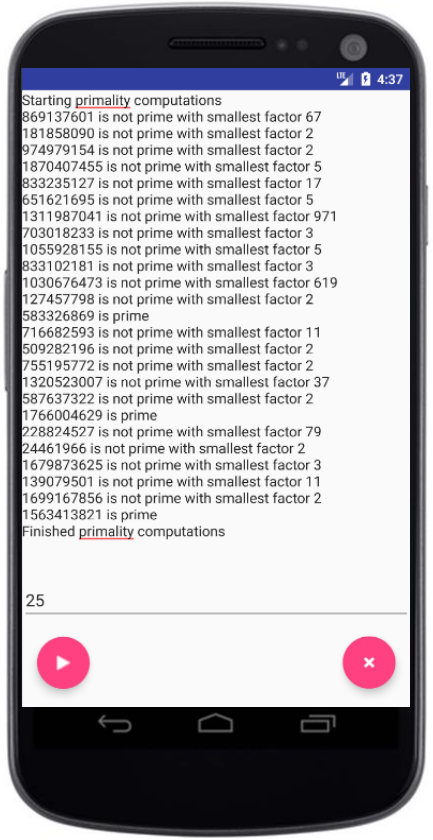
- This "embarrassingly parallel" & compute-bound app uses the Java ExecutorService to check if *N* random #'s are prime

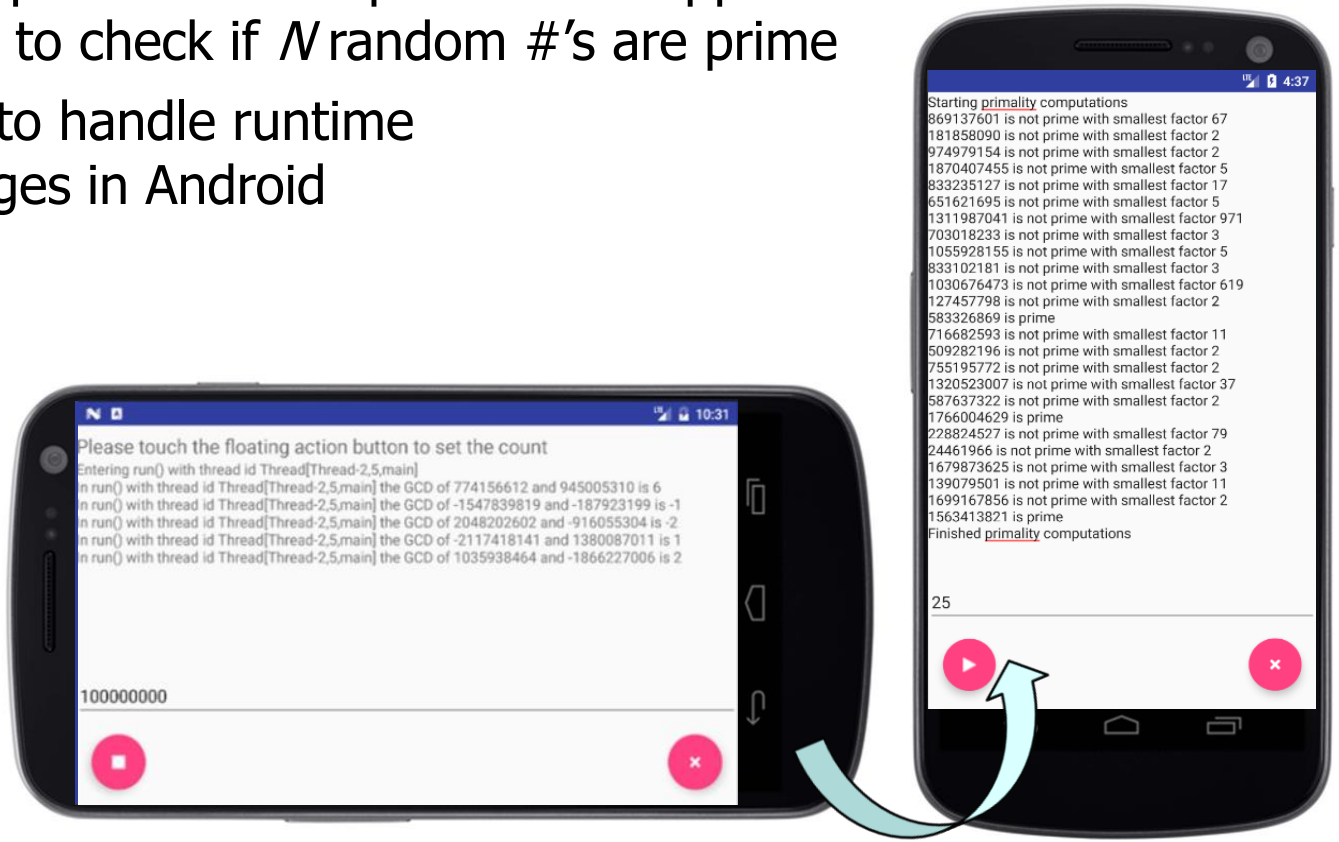




See github.com/douglascraigschmidt/POSA/tree/master/ex/M4/Primes/PrimeExecutorService

Overview of the PrimeChecker App

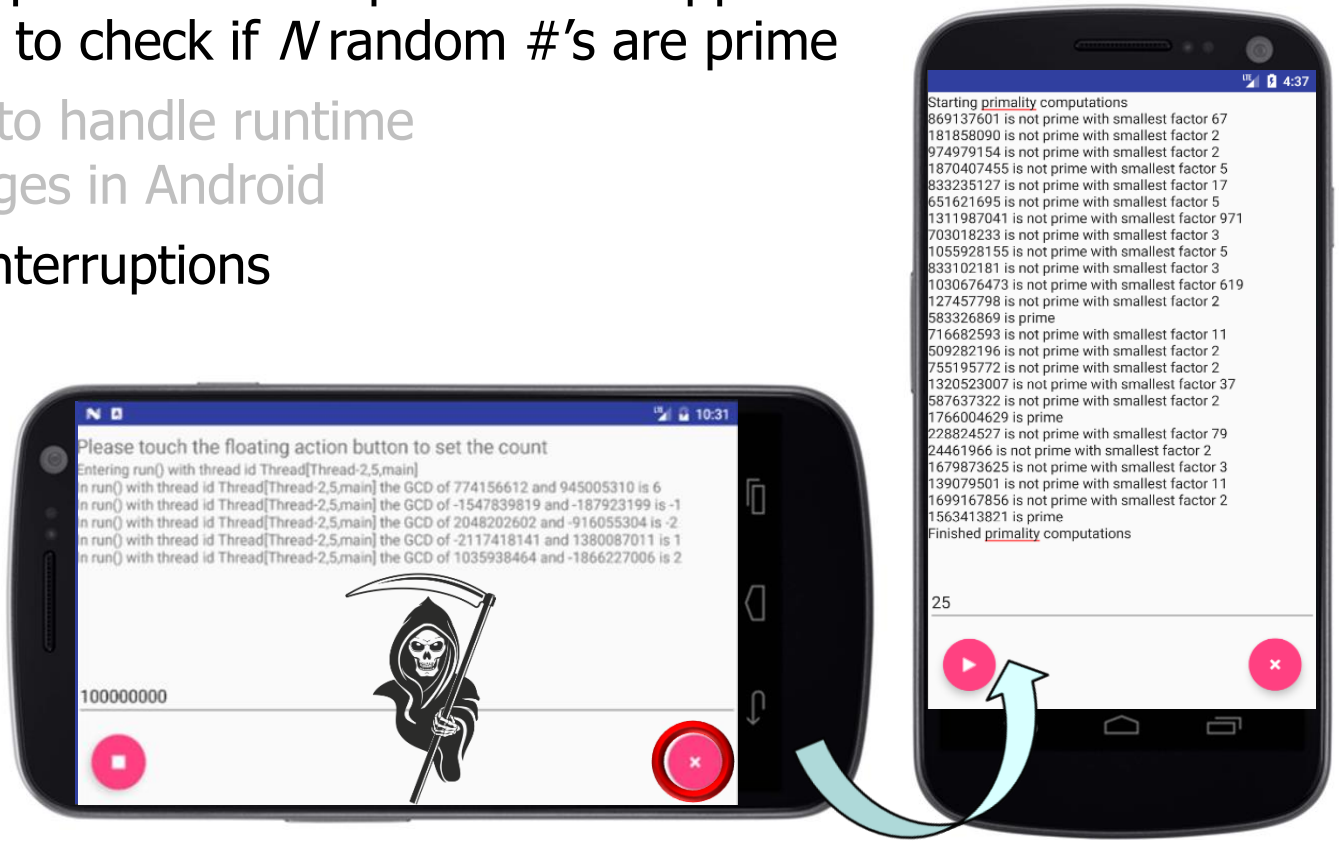
- This "embarrassingly parallel" & compute-bound app uses the Java ExecutorService to check if *N* random #'s are prime
  - It also shows how to handle runtime configuration changes in Android



See developer.android.com/guide/topics/resources/runtime-changes.html

Overview of the PrimeChecker App

- This "embarrassingly parallel" & compute-bound app uses the Java ExecutorService to check if *N* random #'s are prime
  - It also shows how to handle runtime configuration changes in Android
  - As well as thread interruptions

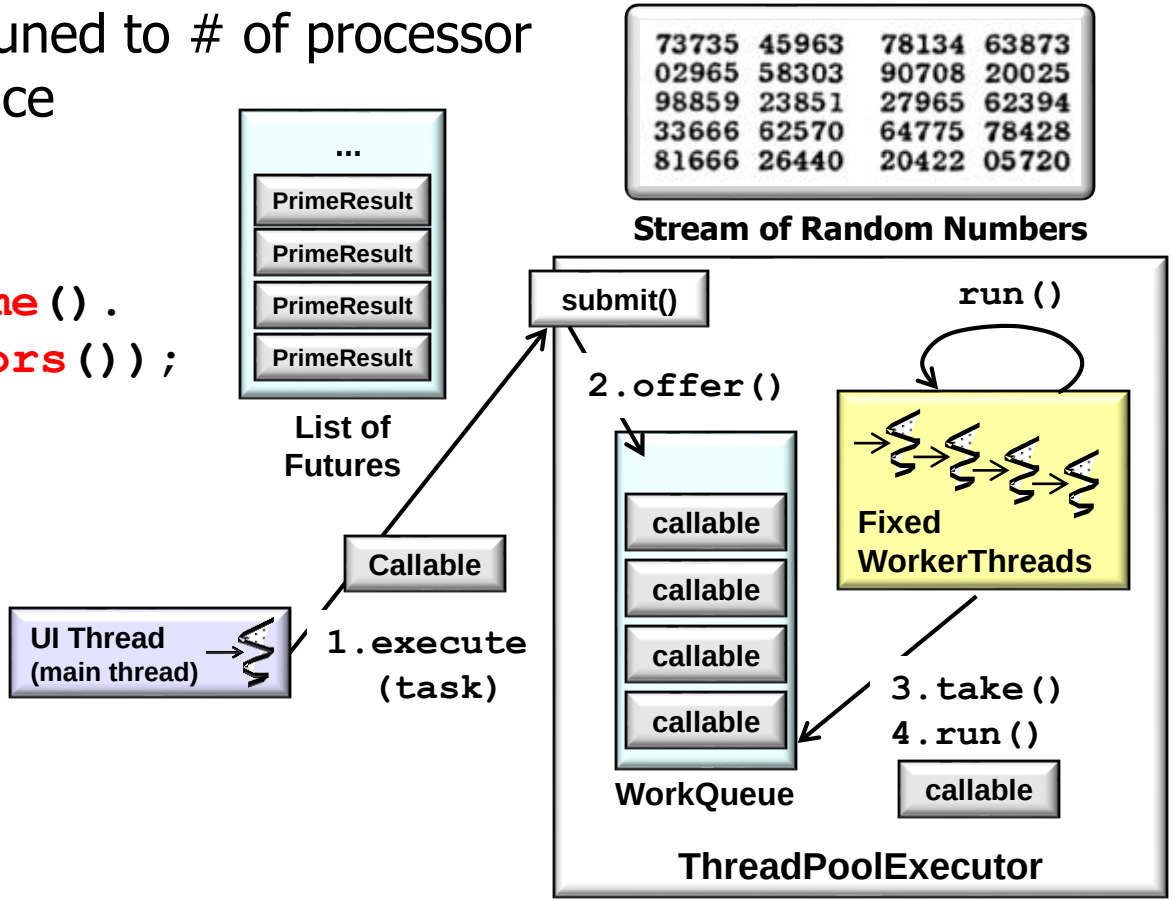


See docs.oracle.com/javase/tutorial/essential/concurrency/interrupt.html

Overview of the PrimeChecker App

- A fixed-size thread pool is tuned to # of processor cores in the computing device

```
mExecutor = Executors
   .newFixedThreadPool
       (Runtime.getRuntime().
        availableProcessors());
```



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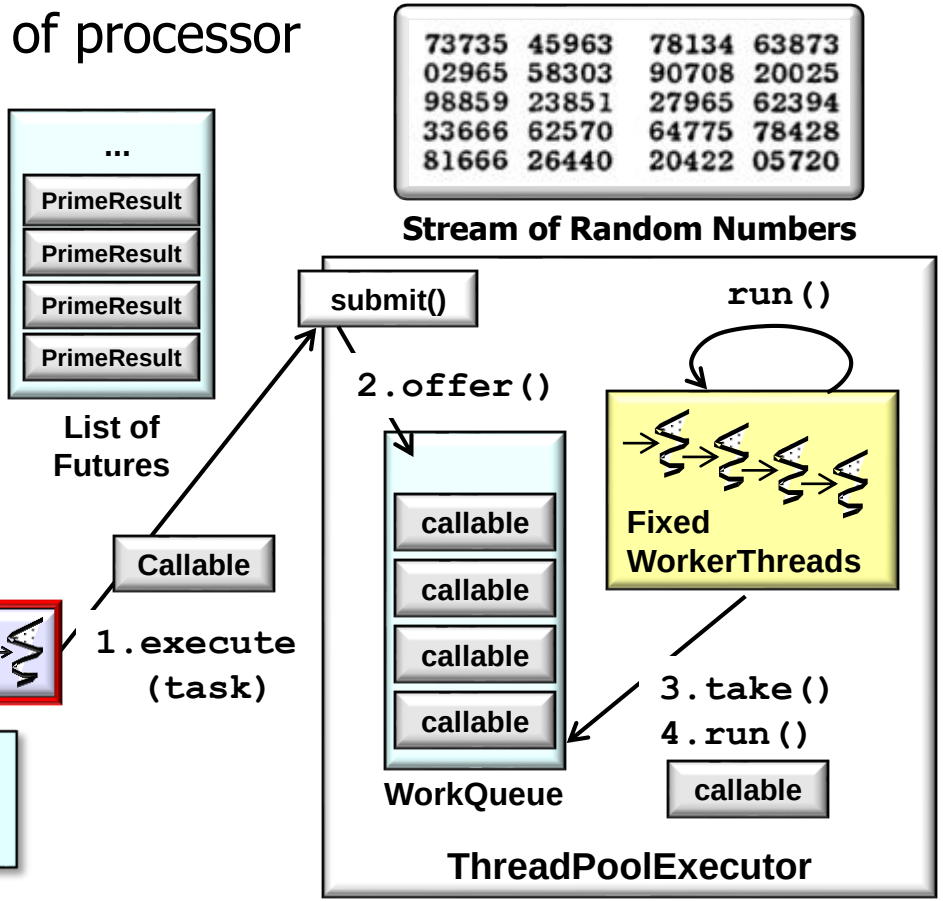

The UI thread generates random #'s that are processed via the thread pool

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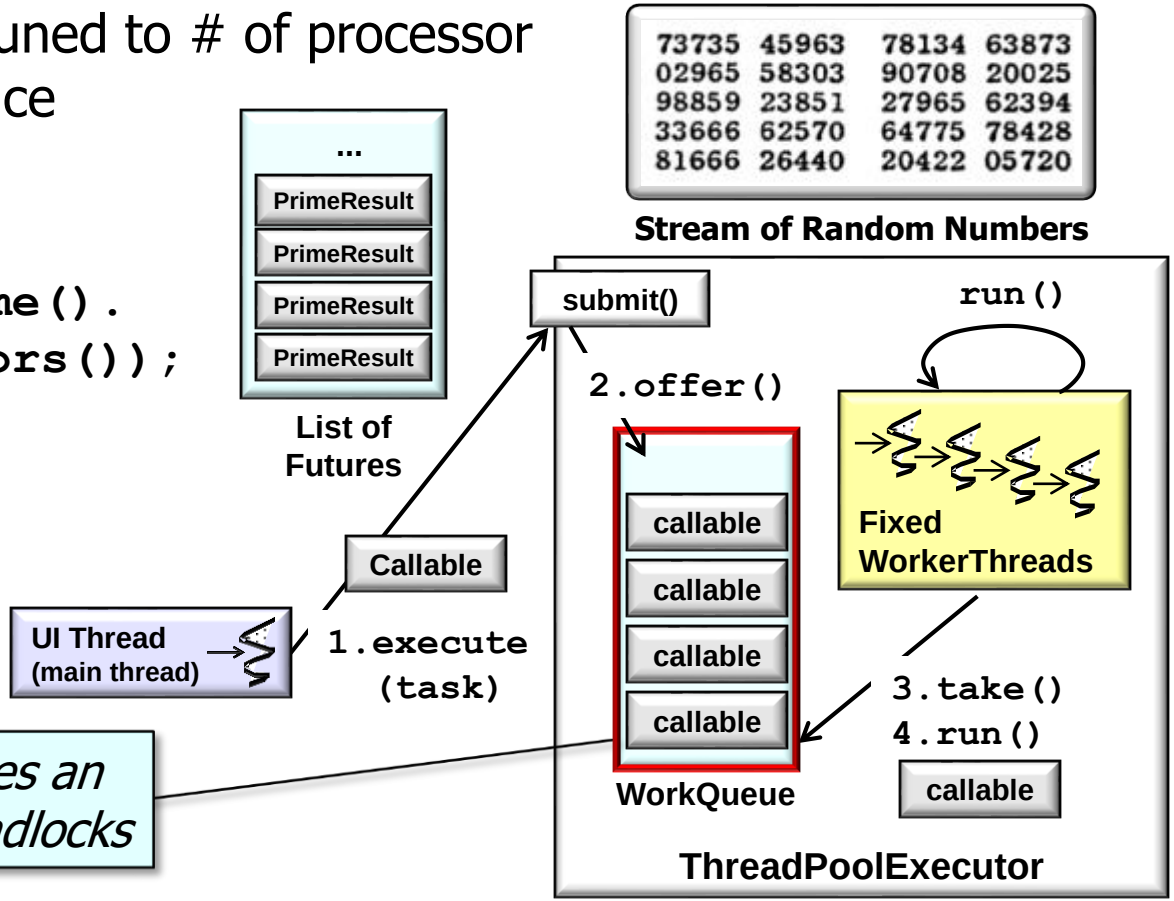


This fixed-size thread pool uses an unbounded queue to avoid deadlocks

See asznajder.github.io/thread-pool-induced-deadlocks

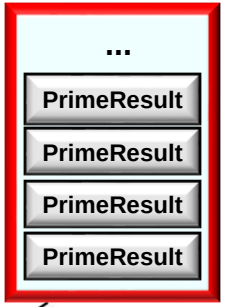
Overview of the PrimeChecker App

- A fixed-size thread pool is tuned to # of processor cores in the computing device

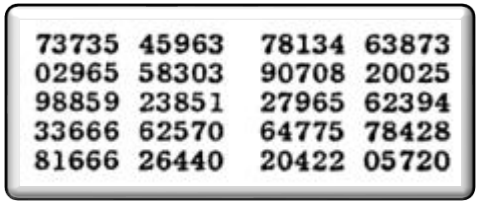
```
mExecutor = Executors
   .newFixedThreadPool
      (Runtime.getRuntime().
       availableProcessors());

...mThread = new Thread(...);

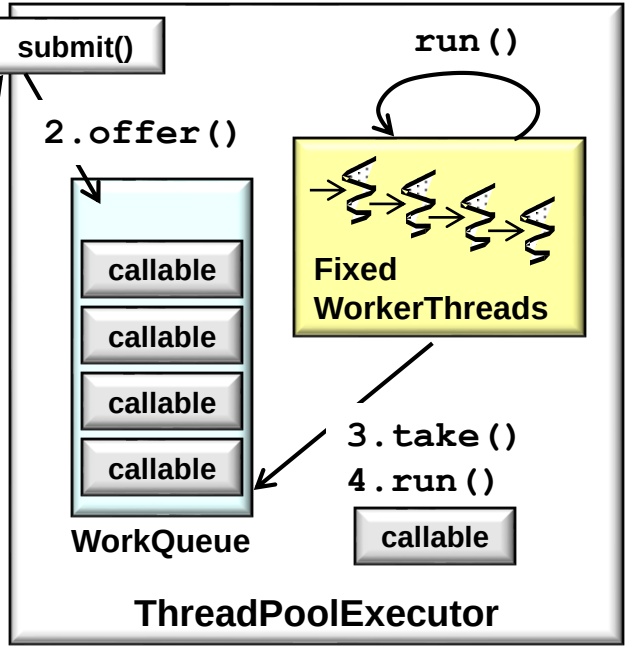
...mThread.start();
```



List of Futures



Stream of Random Numbers



Callable

UI Thread (main thread)

1.submit (task)

Start a 2nd thread to wait for the completion of all futures in the list of futures

Background Thread

This background thread ensures no blocking occurs in the UI thread

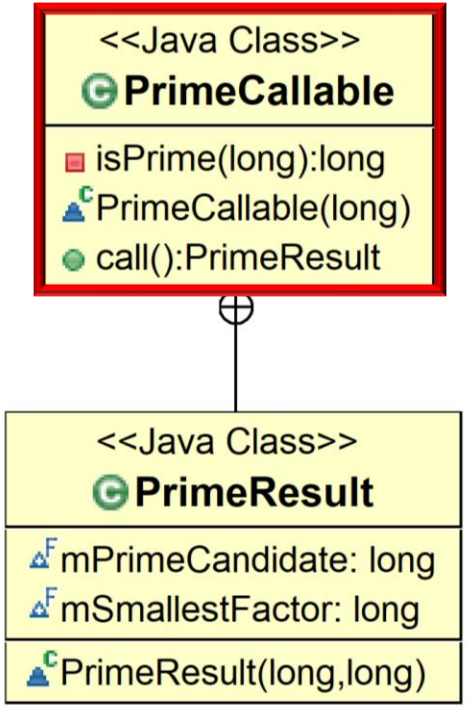
Overview of the PrimeChecker App

- PrimeCallable defines a two-way means of determining whether a # is prime

```
class PrimeCallable
      implements Callable<PrimeResult> {
  long mPrimeCandidate;
  ...

  PrimeCallable(Long primeCandidate)
  { mPrimeCandidate = primeCandidate; }

  PrimeResult call() {
    return new PrimeResult
      (mPrimeCandidate,
       isPrime(mPrimeCandidate));
  } ...
```



See src/main/java/vandy/mooc/prime/activities/PrimeCallable.java

Overview of the PrimeChecker App

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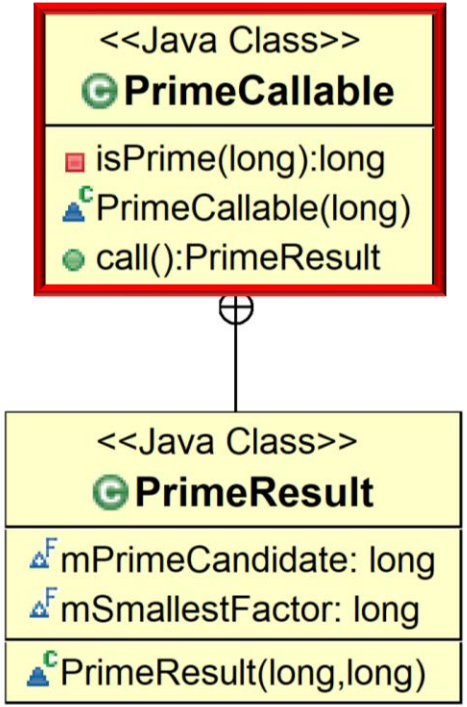
```

Implements Callable



See docs.oracle.com/javase/8/docs/api/java/util/concurrent/Callable.html

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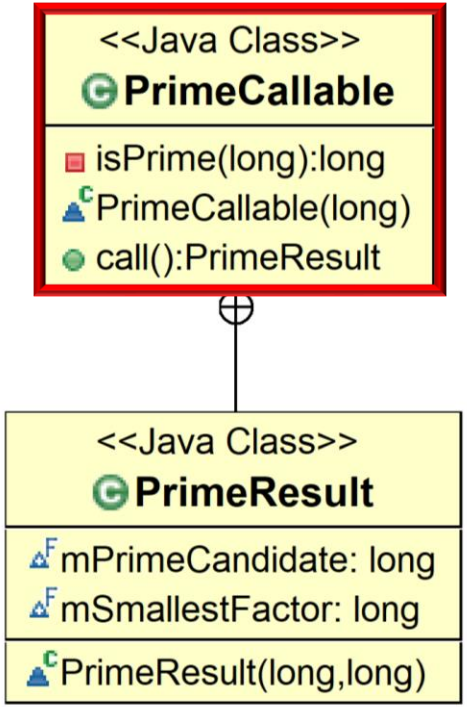
```

Constructor stores prime # candidate in a field



See *"Java Executor: Application to PrimeChecker App"*

Overview of the PrimeChecker App

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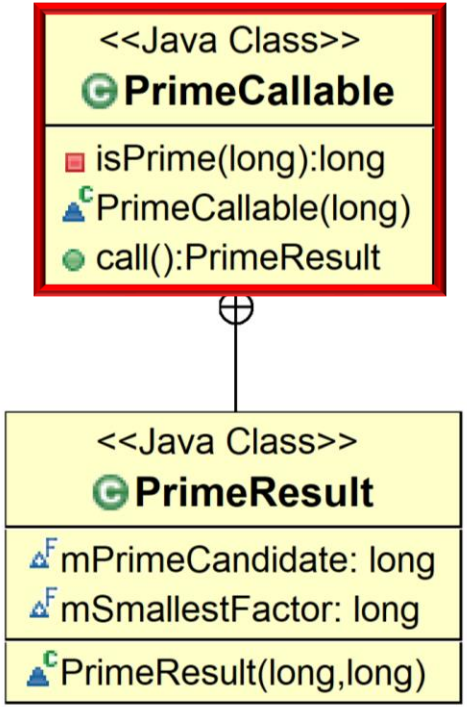

call() hook method invokes isPrime() in a pool thread

Interruptible isPrime() based on "*Java Executor: Application to PrimeChecker App*"

Overview of the PrimeChecker App

- PrimeCallable defines a two-way means of determining whether a # is prime

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class PrimeCallable
      implements Callable<PrimeResult> {
  long mPrimeCandidate;
  ...
```

PrimeResult is a tuple that matches the prime # candidate with the result of checking primality

```
  PrimeResult call() {
    return new PrimeResult
      (mPrimeCandidate,
       isPrime(mPrimeCandidate));
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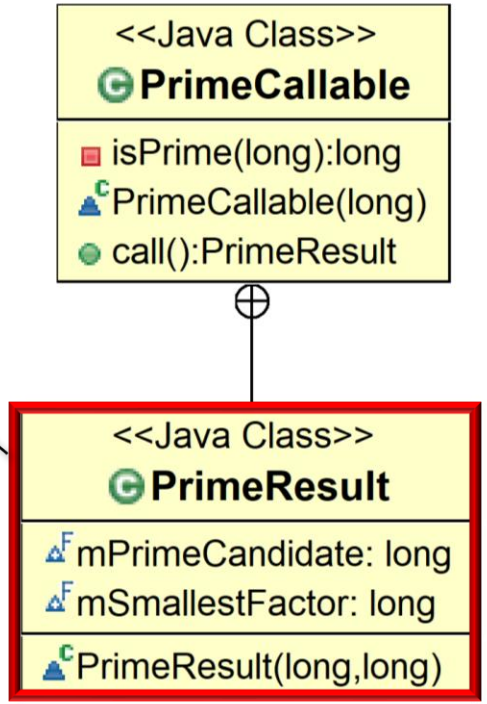
```



These two-way semantics eliminate the need for a dependency on MainActivity!

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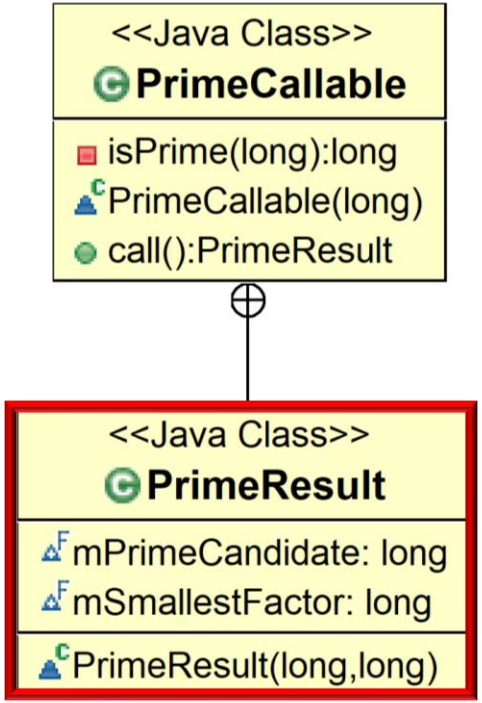


These two-way call semantics eliminate the need for any dependency on MainActivity!

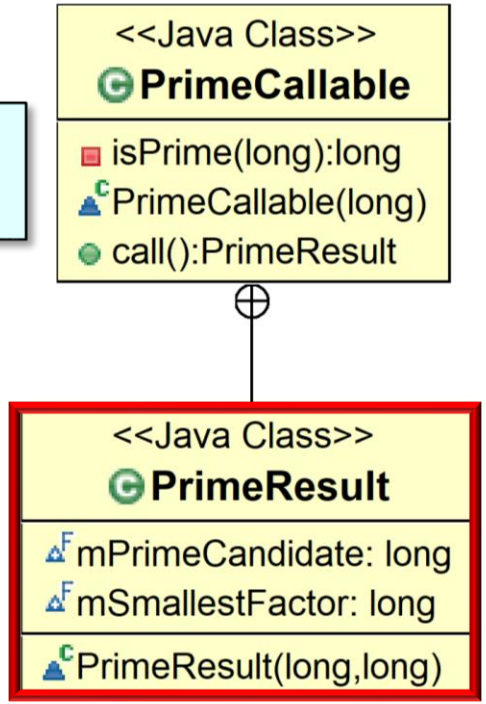
Overview of the PrimeChecker App

- PrimeCallable defines a two-way means of determining whether a # is prime

```
class PrimeCallable
      implements Callable<PrimeResult> {
  ...

  long isPrime(long n) {
    if (n > 3)
      for (long factor = 2;
           factor <= n / 2; ++factor)
        if (Thread.interrupted()) break;
        else if (n / factor * factor == n)
           return factor;
    return 0L;
  }
  ...
```

Returns 0 if n is prime or smallest factor if it's not



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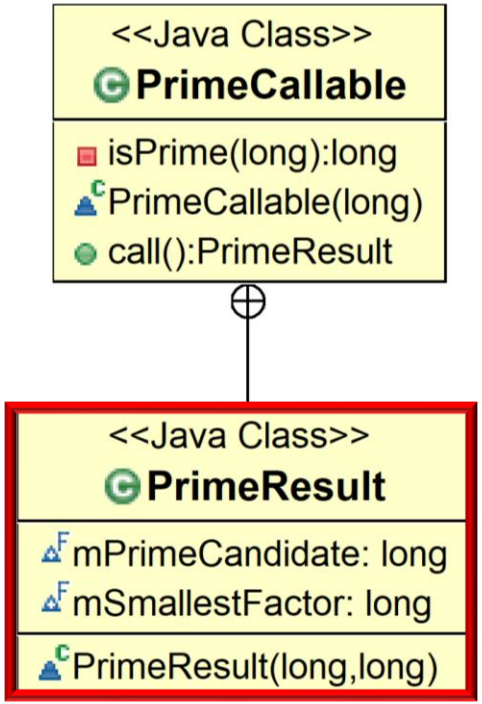
        if (Thread.interrupted()) break;
        else if (n / factor * factor == n)
           return factor;
    return 0L;
  }
  ...
```

isPrime() repeatedly checks to see if it's been interrupted

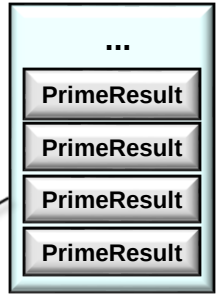


See lesson on "*Managing the Java Thread Lifecycle*"

Overview of the PrimeChecker App

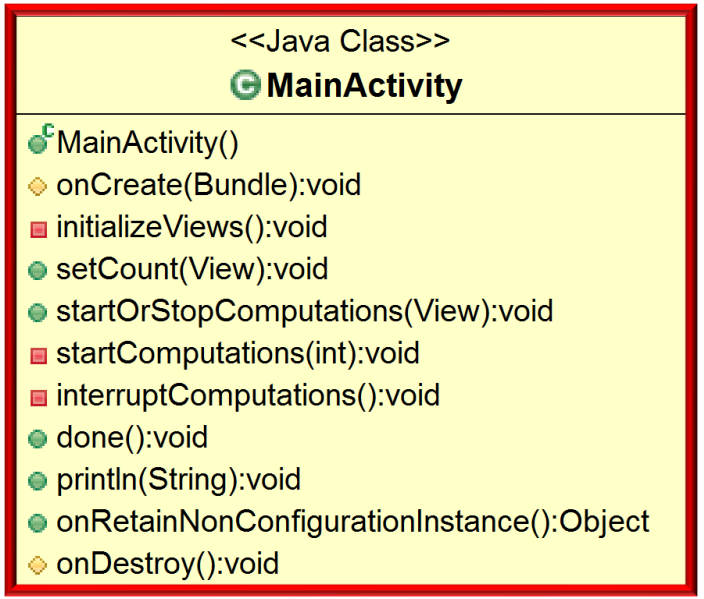
- MainActivity creates a list of futures that store results of concurrently checking primality of "count" random #'s within a range

```
List<Future<PrimeResult>>
   futures = ...
```



List of Futures

This list of futures is initialized via a Java sequential stream

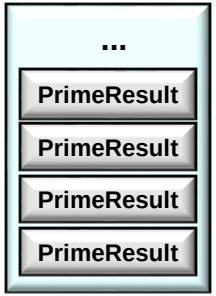


See src/main/java/vandy/mooc/prime/activities/MainActivity.java

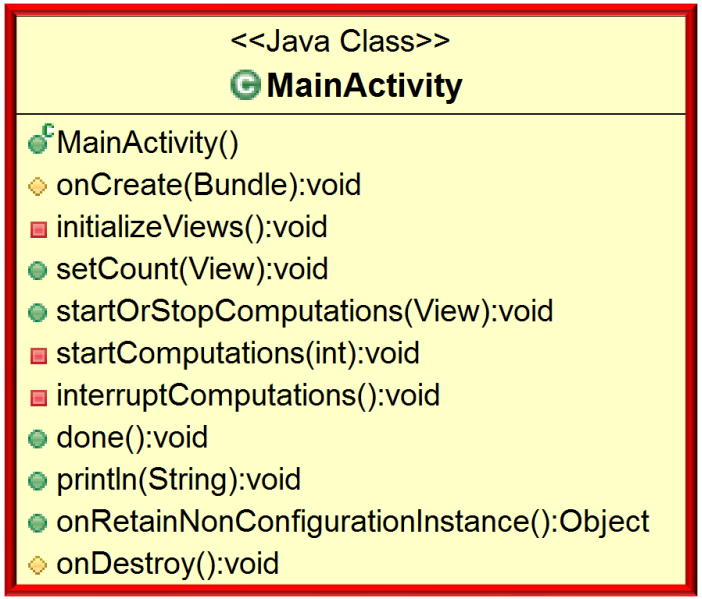
Overview of the PrimeChecker App

- MainActivity creates a list of futures that store results of concurrently checking primality of "count" random #'s within a range

```
List<Future<PrimeResult>>
   futures = new Random()
      .longs(count,
             sMAX_VALUE - count,
             sMAX_VALUE)
```



List of Futures



Generates "count" random #'s ranging from sMAX_VALUE – count & sMAX_VALUE

Overview of the PrimeChecker App

- MainActivity creates a list of futures that store results of concurrently checking primality of "count" random #'s within a range

```
List<Future<PrimeResult>>
   futures = new Random()
      .longs(count,
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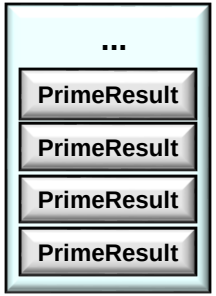
             sMAX_VALUE)

      .mapToObj(PrimeCallable::new)
```



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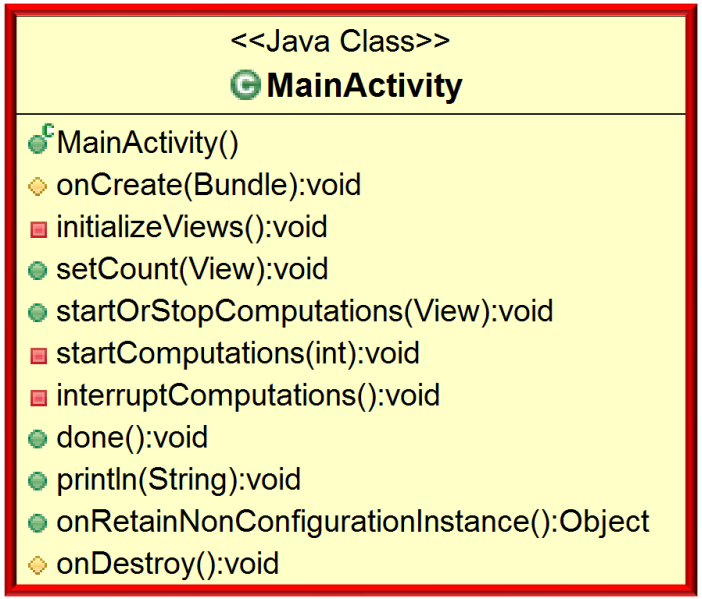

This constructor reference converts random #'s into PrimeCallables

See docs.oracle.com/javase/tutorial/java/javaOO/methodreferences.html

Overview of the PrimeChecker App

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List<Future<PrimeResult>>
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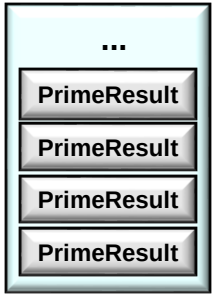
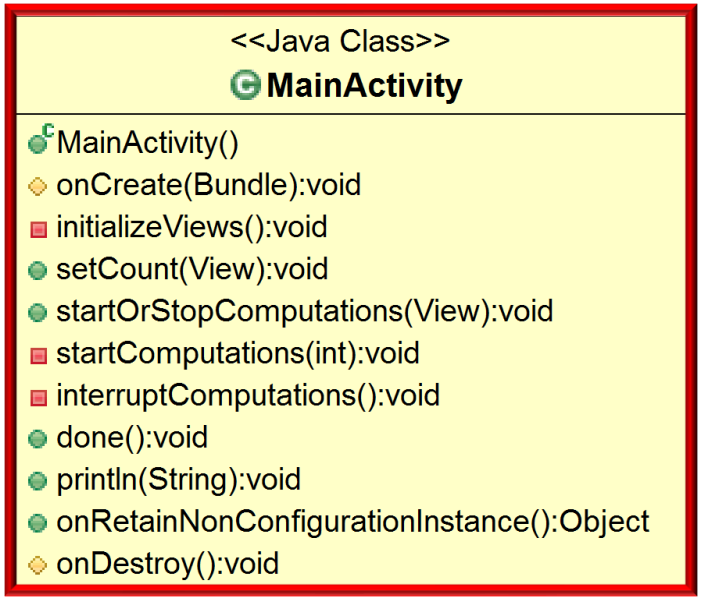
      .mapToObj(PrimeCallable::new)

      .map(mRetainedState.mExecutorService::submit)
```



List of Futures



Submit a two-way task for execution & return a future representing pending task results

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ExecutorService.html#submit

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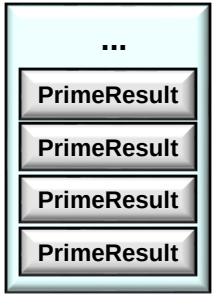
      .map(mRetainedState.mExecutorService::submit)

      .collect(toList());
```



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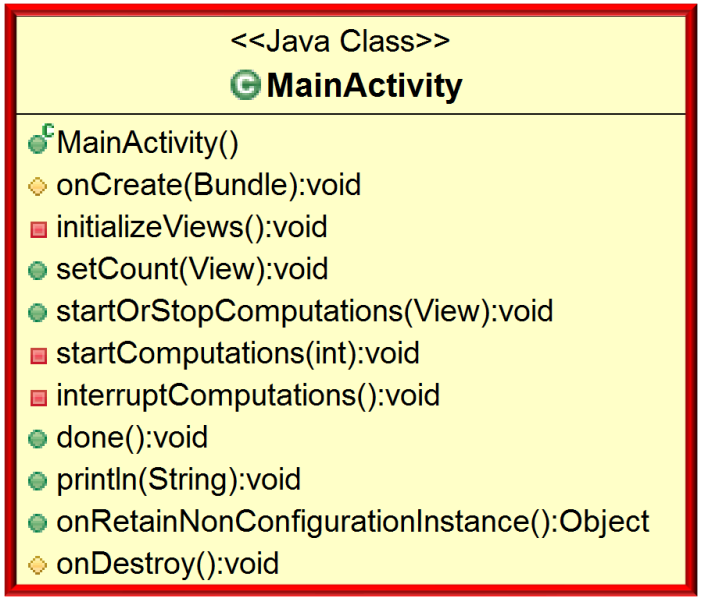


Collect results into a list of futures to PrimeResults

See docs.oracle.com/javase/8/docs/api/java/util/stream/Stream.html#collect

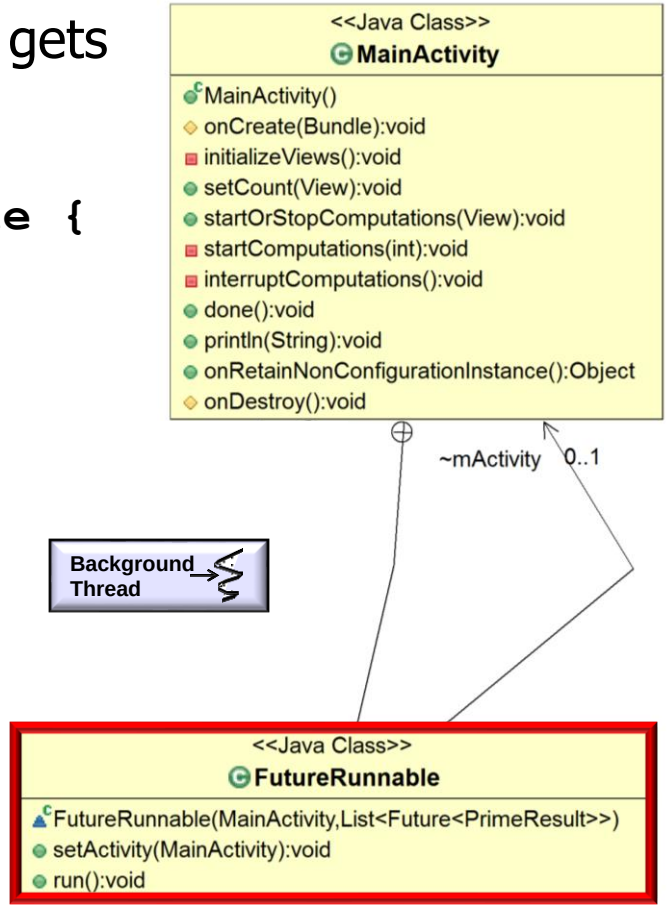
Overview of the PrimeChecker App

- FutureRunnable runs in a background thread & gets the results of all futures as they complete

```
...
class FutureRunnable implements Runnable {
  List<Future<PrimeResult>>
    mFutures;


  MainActivity mActivity;
  ...

  FutureRunnable(MainActivity a,
          List<Future<PrimeResult>> f)
  { mActivity = a; mFutures = f; }
  ...
```



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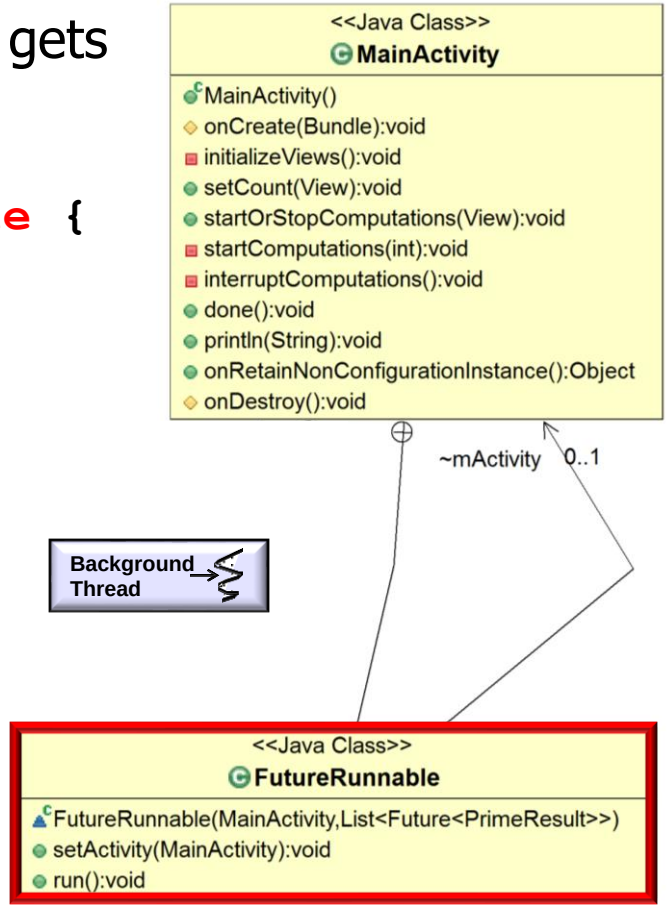

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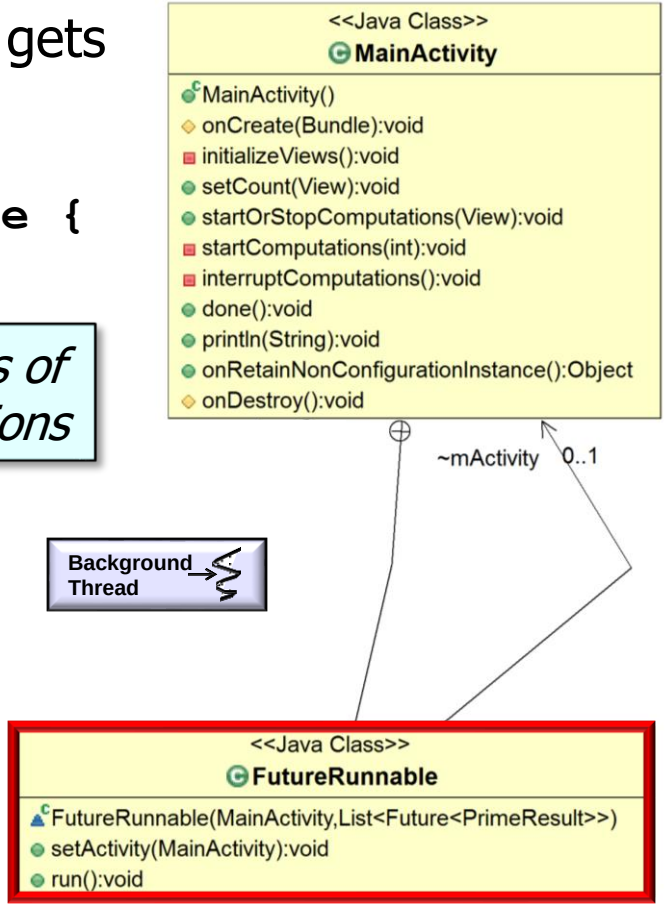
List of futures to results of PrimeCallable computations



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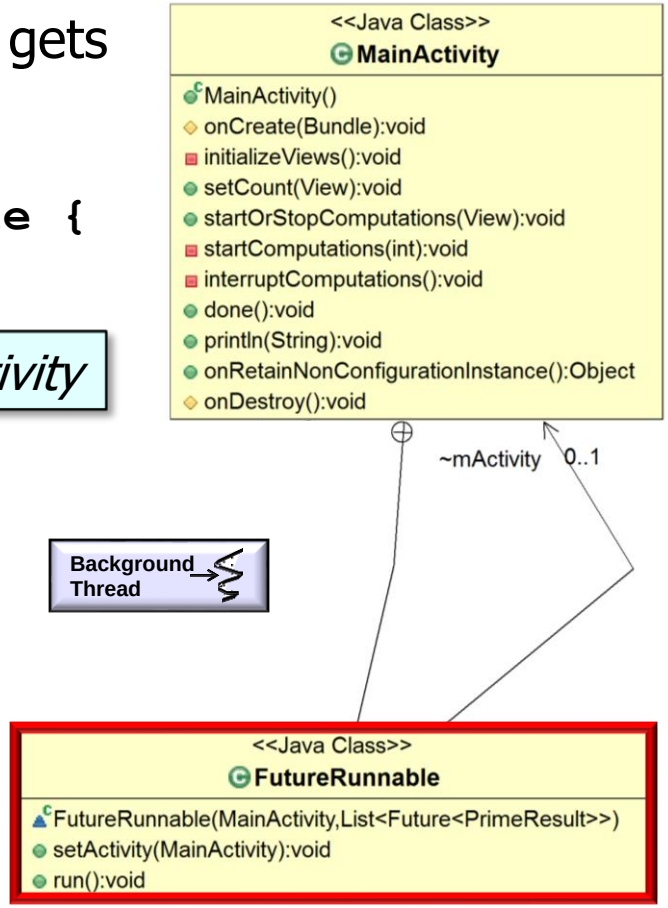
Reference back to enclosing activity



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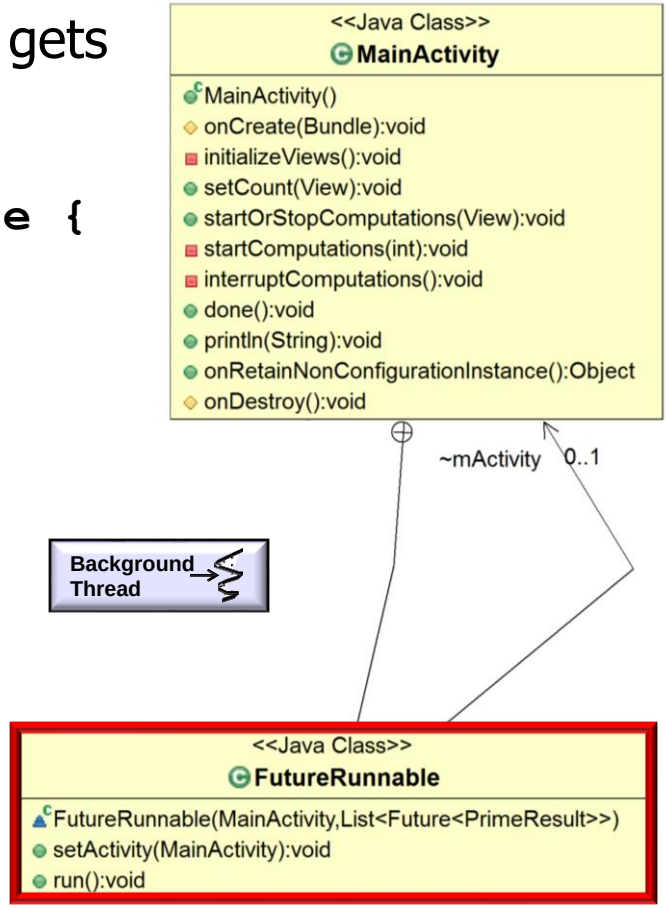
Constructor initializes the fields



Overview of the PrimeChecker App

- FutureRunnable runs in a background thread & gets the results of all futures as they complete

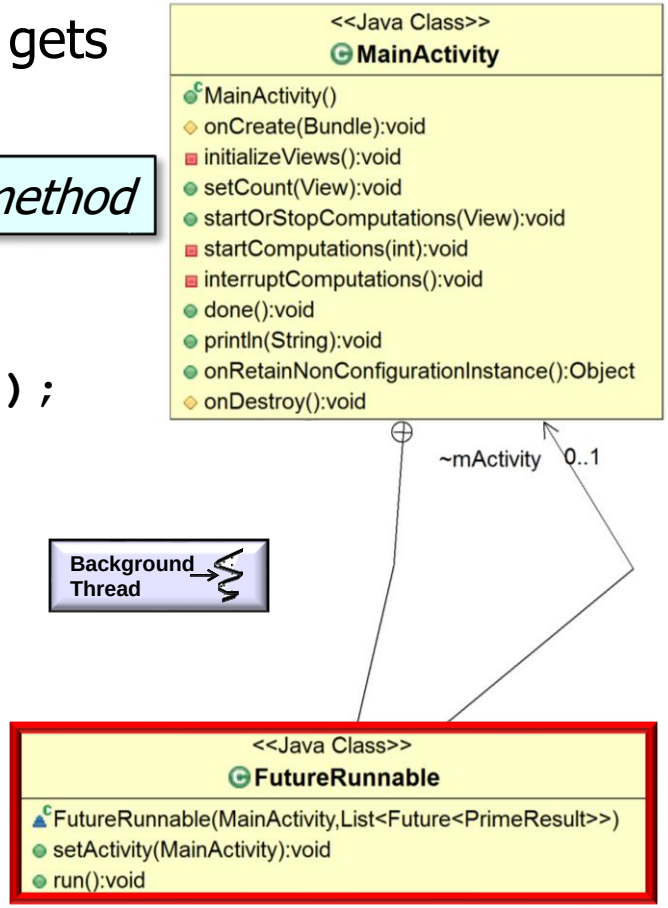
```
...
public void run() {
  mFutures.forEach(future -> {
    PrimeCallable.PrimeResult pr =
      rethrowSupplier(future::get).get();

    if (pr.mSmallestFactor != 0)
      ...
    else ...});



  mActivity.done(); ...
```

Runnable hook method



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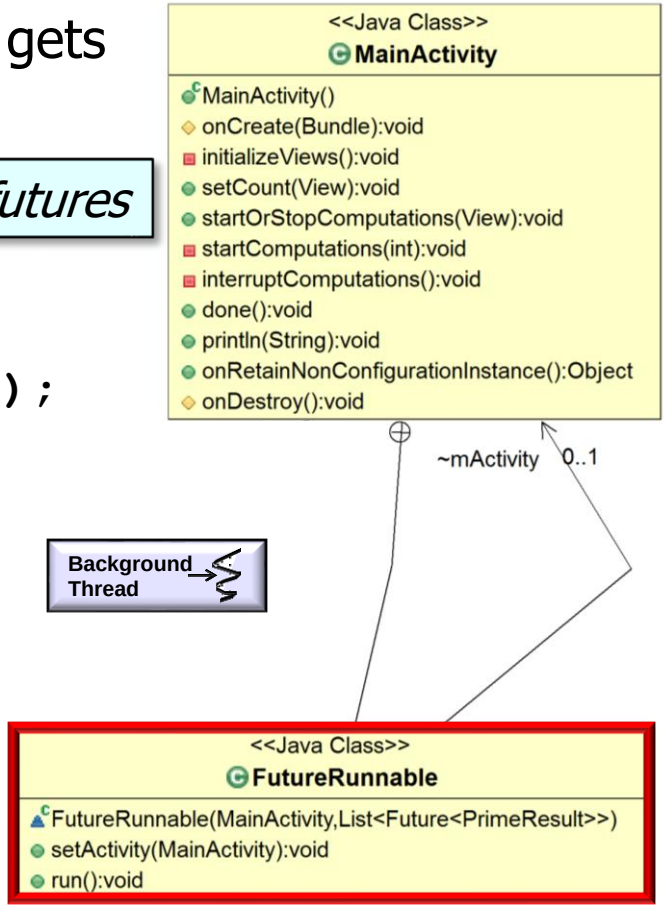
  mActivity.done(); ...
```

Iterate thru all futures



Overview of the PrimeChecker App

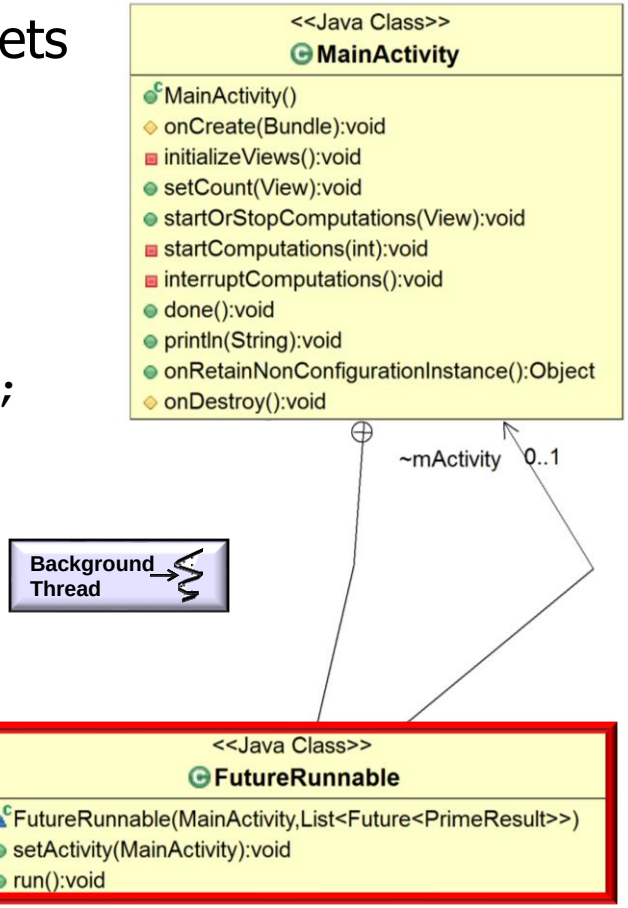
- FutureRunnable runs in a background thread & gets the results of all futures as they complete

```
...
public void run() {
  mFutures.forEach(future -> {
    PrimeCallable.PrimeResult pr =
      rethrowSupplier(future::get).get();

    if (pr.mSmallestFactor != 0)
      ...
    else ...});
```

future::get blocks if async processing associated with future hasn't completed

```
  mActivity.done(); ...
```



This is an example of the "synchronous future" processing model

Overview of the PrimeChecker App

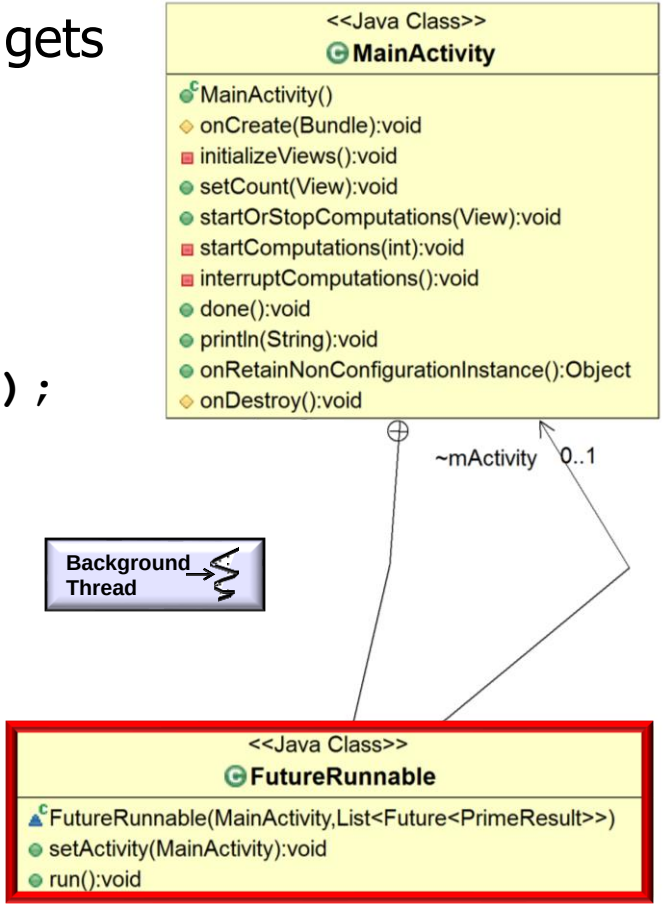
- FutureRunnable runs in a background thread & gets the results of all futures as they complete

```
...
public void run() {
  mFutures.forEach(future -> {
    PrimeCallable.PrimeResult pr =
      rethrowSupplier(future::get).get();

    if (pr.mSmallestFactor != 0)
      ...
    else ...});

  mActivity.done(); ...
```

Convert checked exception to a runtime exception



See stackoverflow.com/a/27644392/3312330

Overview of the PrimeChecker App

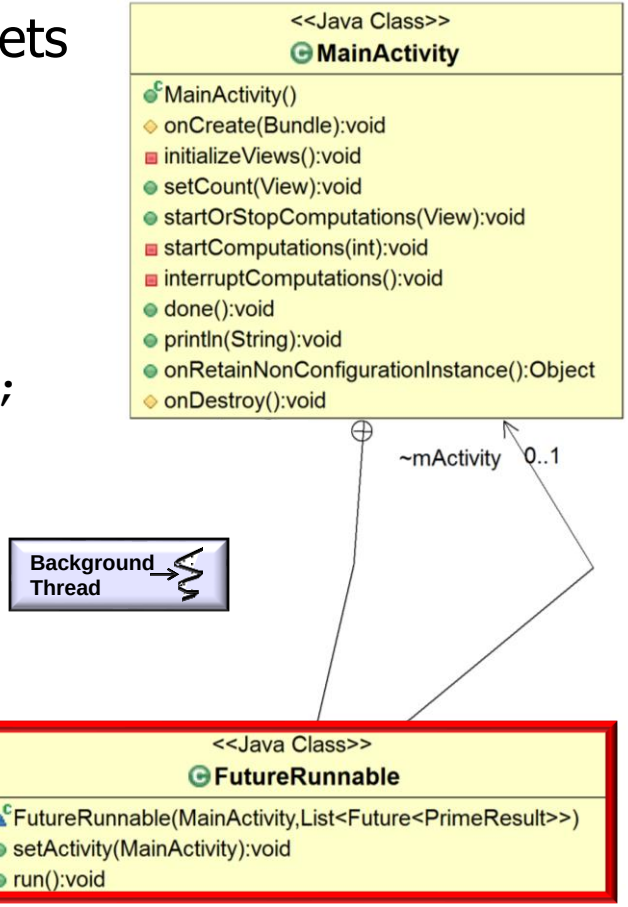
- FutureRunnable runs in a background thread & gets the results of all futures as they complete

```
...
public void run() {
  mFutures.forEach(future -> {
    PrimeCallable.PrimeResult pr =
      rethrowSupplier(future::get).get();

    if (pr.mSmallestFactor != 0)
      ...
    else ...});

  mActivity.done(); ...
```

Get the result from the supplier



See docs.oracle.com/javase/8/docs/api/java/util/function/Supplier.html#get

Overview of the PrimeChecker App

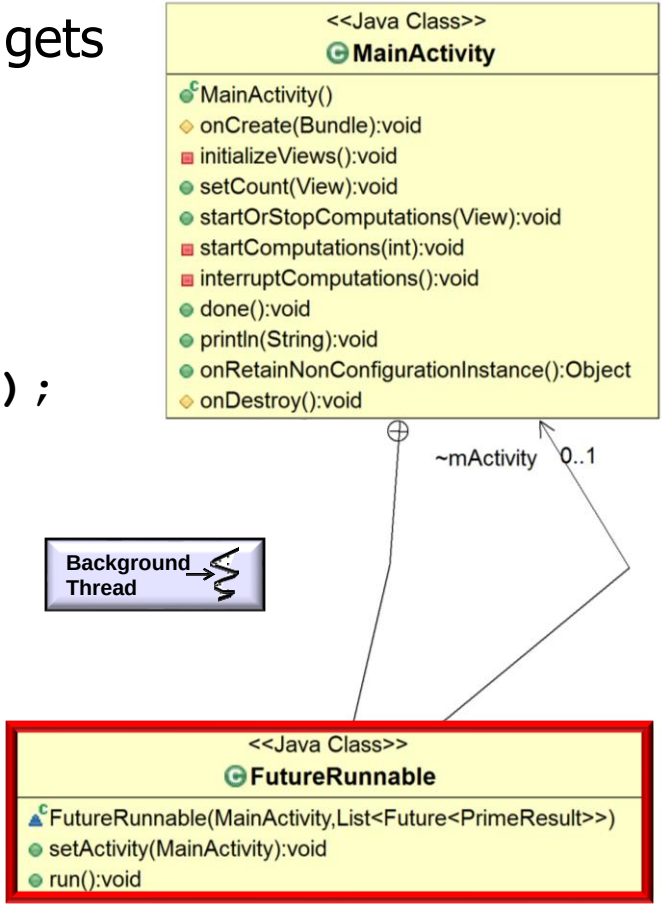
- FutureRunnable runs in a background thread & gets the results of all futures as they complete

```
...
public void run() {
  mFutures.forEach(future -> {
    PrimeCallable.PrimeResult pr =
      rethrowSupplier(future::get).get();

    if (pr.mSmallestFactor != 0)
      ...
    else ...});

  mActivity.done(); ...
```

Process each result & produce output



Overview of the PrimeChecker App

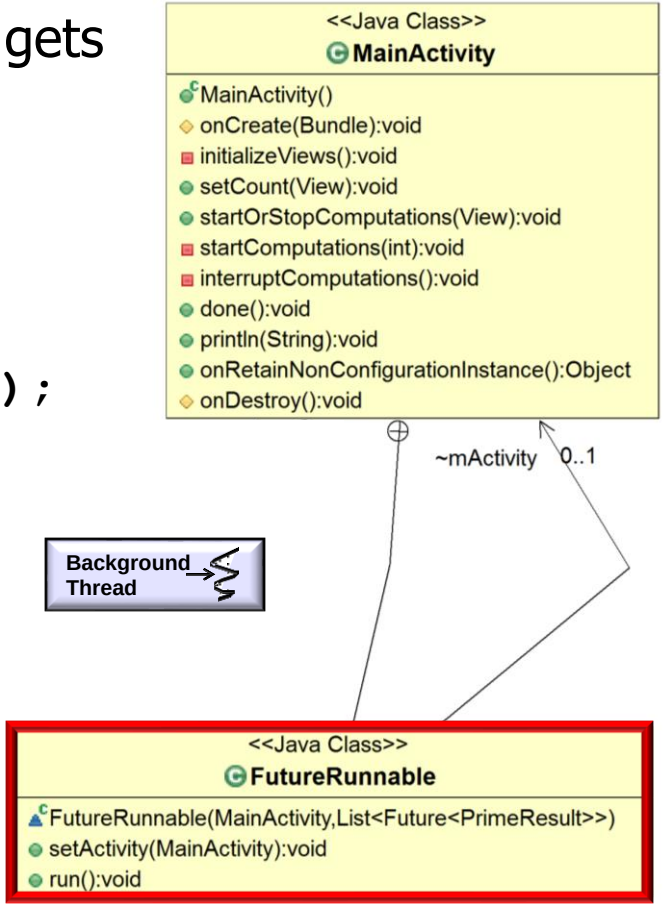
- FutureRunnable runs in a background thread & gets the results of all futures as they complete

```
...
public void run() {
  mFutures.forEach(future -> {
    PrimeCallable.PrimeResult pr =
      rethrowSupplier(future::get).get();

    if (pr.mSmallestFactor != 0)
      ...
    else ...});
```

Inform MainActivity that we're all done

```
  mActivity.done(); ...
```



Overview of the PrimeChecker App

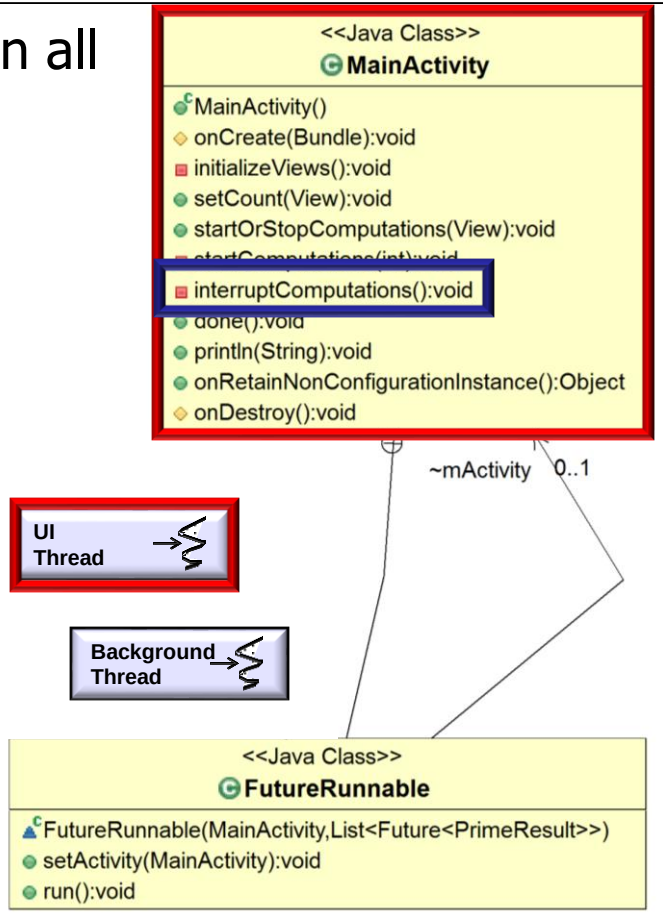
- The interruptComputations() method shuts down all the concurrent computations via the UI thread

```
void interruptComputations() {
  mRetainedState.mExecutorService
                  .shutdownNow();



  mRetainedState.mThread.interrupt();
  ...


  mRetainedState
    .mExecutorService.awaitTermination
      (500, TimeUnit.MILLISECONDS);
```



Overview of the PrimeChecker App

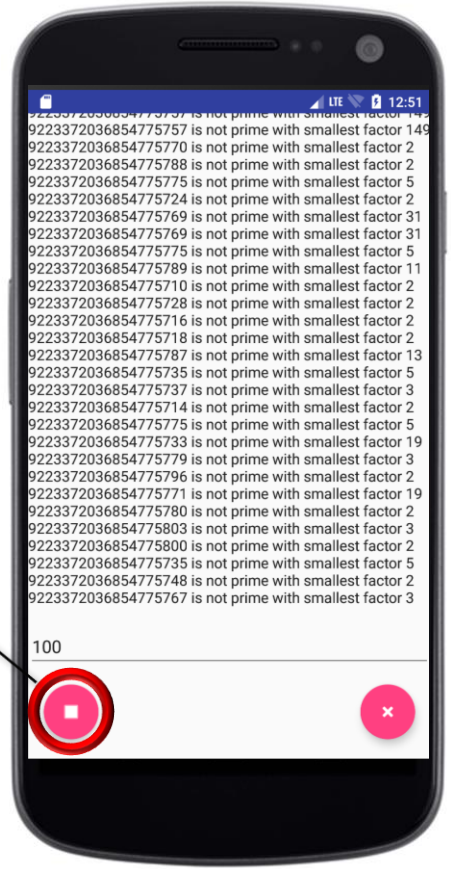
- The interruptComputations() method shuts down all the concurrent computations via the UI thread

```
void interruptComputations() {
  mRetainedState.mExecutorService
                .shutdownNow();
```

Called when user presses the cancel button

```
  mRetainedState.mThread.interrupt();
  ...

  mRetainedState
    .mExecutorService.awaitTermination
      (500, TimeUnit.MILLISECONDS);
```



Overview of the PrimeChecker App

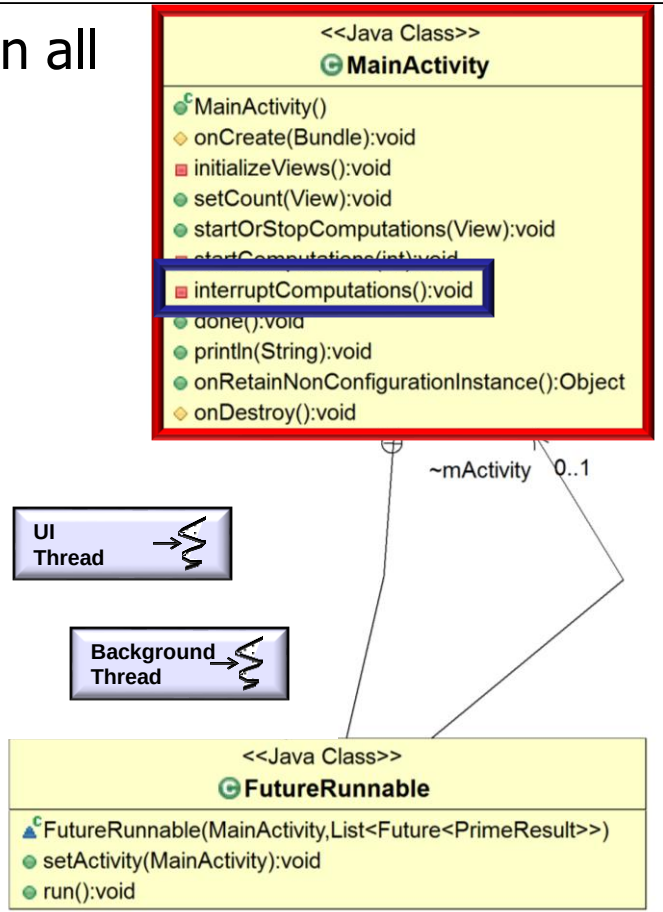
- The interruptComputations() method shuts down all the concurrent computations via the UI thread

```
void interruptComputations() {
  mRetainedState.mExecutorService
                    .shutdownNow();
```

Abruptly shutdown the executor service, which interrupts all threads running tasks

```
  mRetainedState.mThread.interrupt();
  ...

  mRetainedState
    .mExecutorService.awaitTermination
      (500, TimeUnit.MILLISECONDS);
```



See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ExecutorService.html#shutdownNow

Overview of the PrimeChecker App

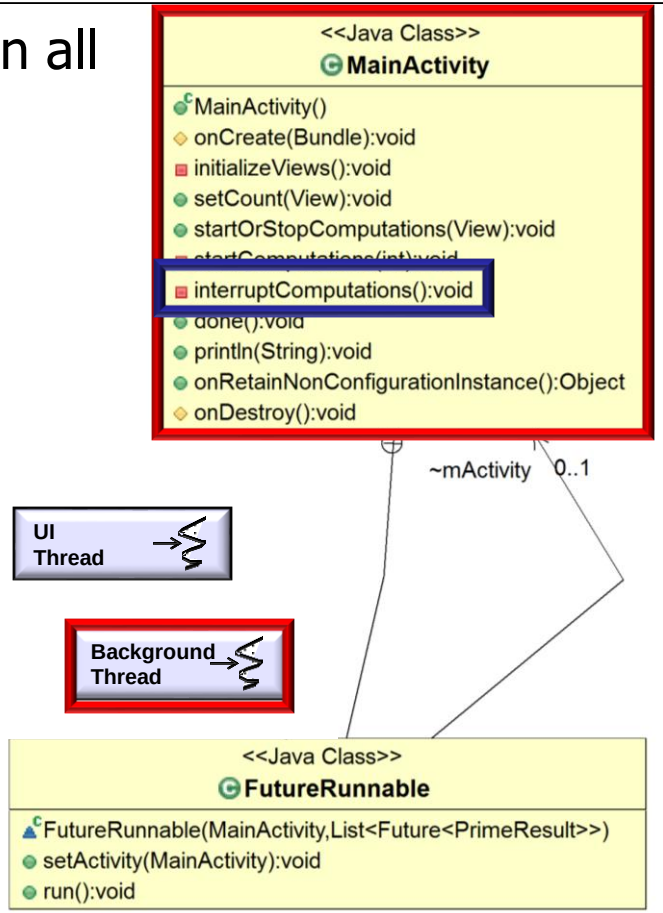
- The interruptComputations() method shuts down all the concurrent computations via the UI thread

```
void interruptComputations() {
  mRetainedState.mExecutorService
                  .shutdownNow();


  mRetainedState.mThread.interrupt();
  ...

  mRetainedState
    .mExecutorService.awaitTermination
      (500, TimeUnit.MILLISECONDS);
```

Interrupt the background thread



See docs.oracle.com/javase/8/docs/api/java/lang/Thread.html#interrupt

Overview of the PrimeChecker App

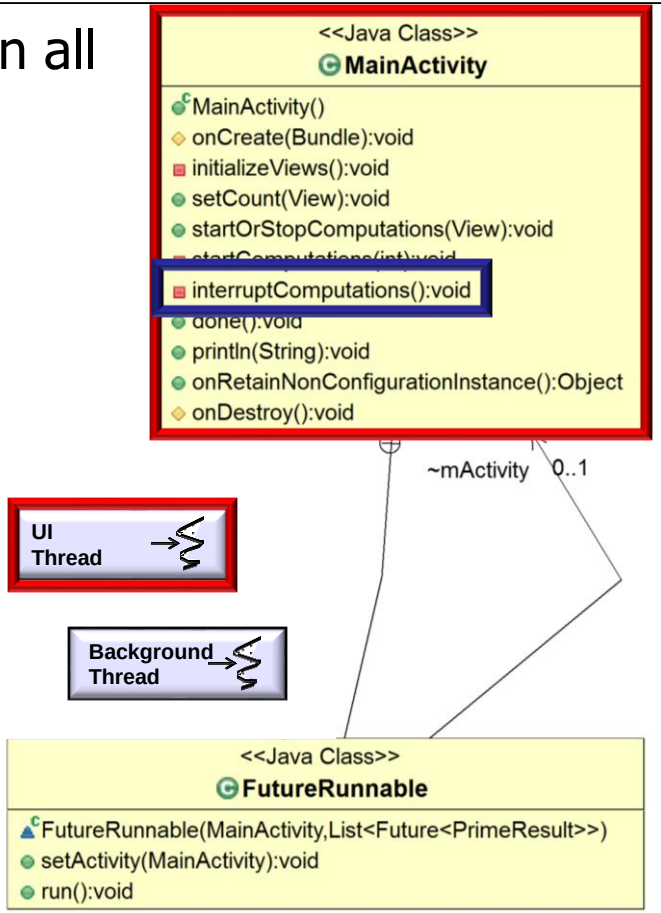
- The interruptComputations() method shuts down all the concurrent computations via the UI thread

```
void interruptComputations() {
  mRetainedState.mExecutorService
                  .shutdownNow();


  mRetainedState.mThread.interrupt();
  ...
```

Block until all tasks have completed execution

```
  mRetainedState
    .mExecutorService.awaitTermination
      (500, TimeUnit.MILLISECONDS);
```



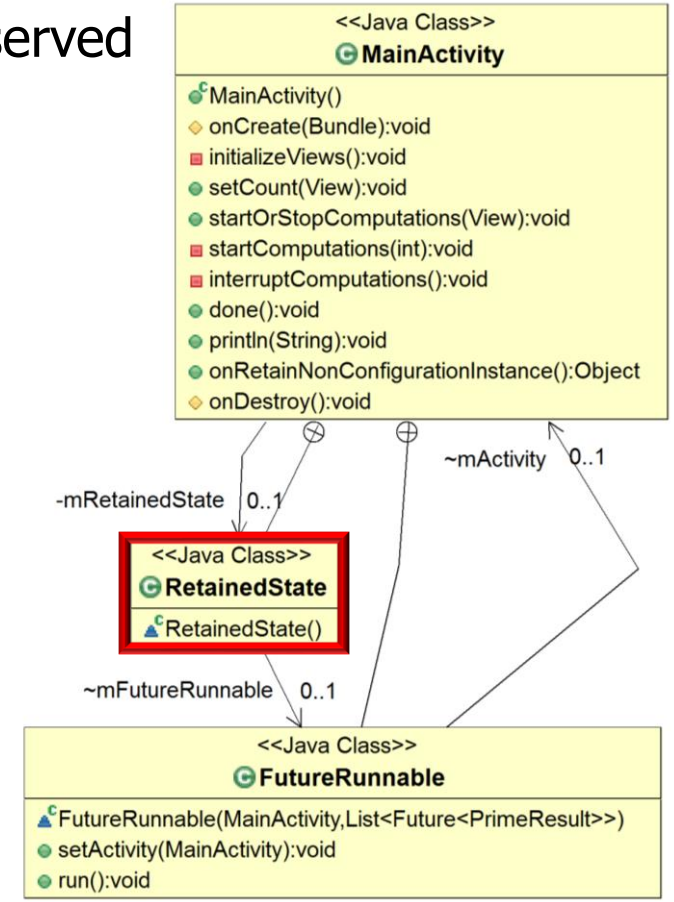
See docs.orade.com/javase/8/docs/api/java/util/concurrent/ExecutorService.html#awaitTermination

Overview of the PrimeChecker App

- RetainedState contains fields that must be preserved across Android runtime configuration changes

```
class RetainedState {
   ExecutorService mExecutorService;
   FutureRunnable mFutureRunnable;
   Thread mThread;
}
```

These fields store concurrency-related objects



Overview of the PrimeChecker App

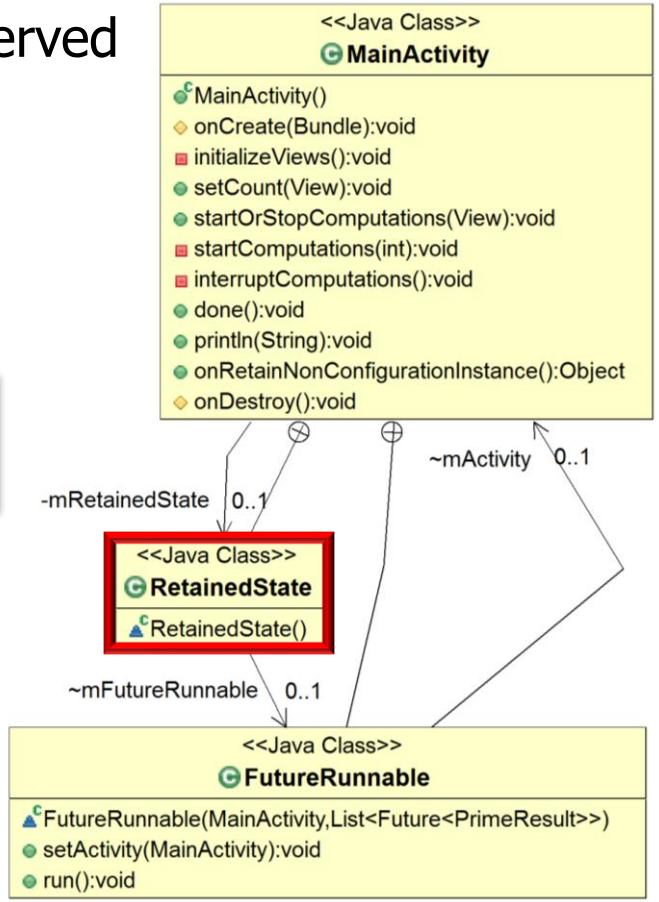
- RetainedState contains fields that must be preserved across Android runtime configuration changes

```
...
mRetainedState.mFutureRunnable =
   new FutureRunnable(this, futures);
```

FutureRunnable is stored in a field so its state can be updated during a runtime configuration change

```
mRetainedState.mThread =
   new Thread(mRetainedState
              .mFutureRunnable);

mRetainedState.mThread.start();
```



See developer.android.com/guide/topics/resources/runtime-changes.html

Overview of the PrimeChecker App

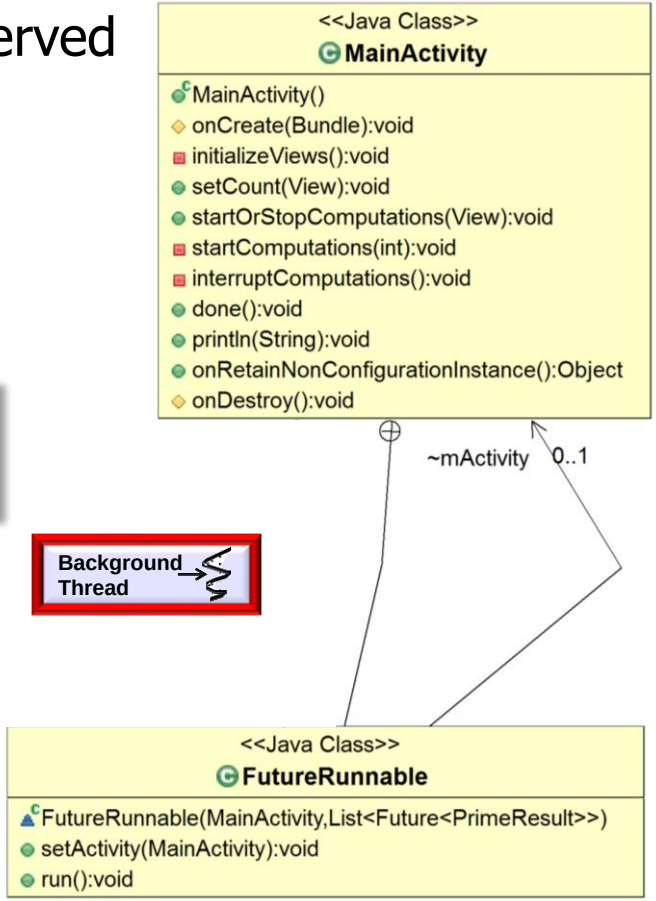
- RetainedState contains fields that must be preserved across Android runtime configuration changes

```
...
mRetainedState.mFutureRunnable =
   new FutureRunnable(this, futures);
```

A background thread is started to wait for all future results to avoid blocking the UI thread

```
mRetainedState.mThread =
   new Thread(mRetainedState
              .mFutureRunnable);

mRetainedState.mThread.start();
```



See developer.android.com/training/articles/perf-anr.html

Overview of the PrimeChecker App

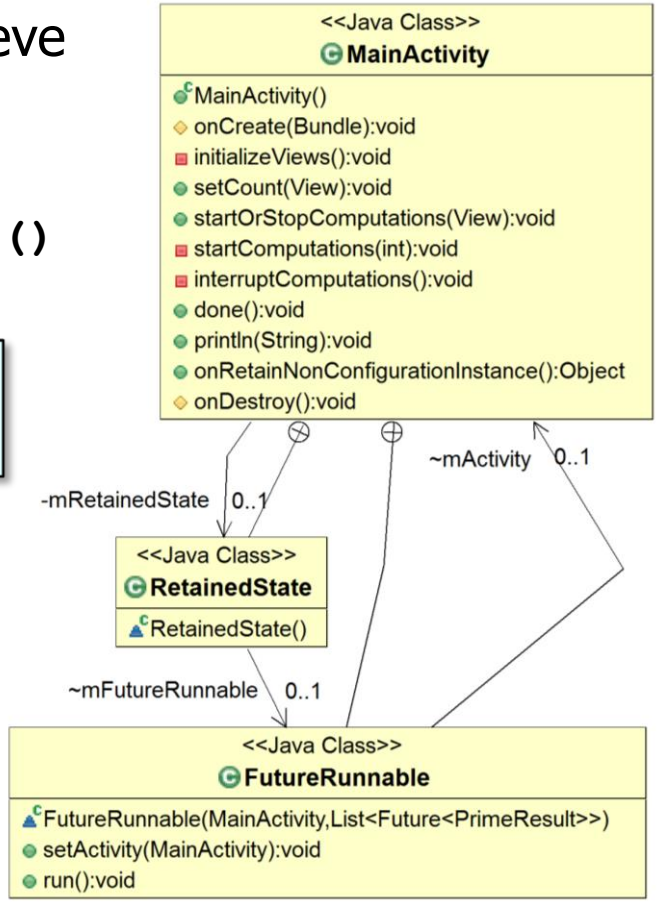
- Android provides hook methods to store & retrieve app state across runtime configuration changes

```
...
Object onRetainNonConfigurationInstance()
{ return mRetainedState; }
...

void onCreate(...) {
  mRetainedState = (RetainedState)
   getLastNonConfigurationInstance();

 if (mRetainedState != null) {
   ...
```

Retained state is loaded/stored via Android hook methods



See developer.android.com/reference/android/app/Activity.html#onRetainNonConfigurationInstance()

End of Java Executor Service: Application to PrimeChecker App