



# Multithreaded Programming Part II: Android-Specific Techniques

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## Topics in This Section

- GUI update guidelines
- Updating UI after threads complete
- Downloading images from Internet
- Updating UI with View.post
- Updating UI with AsyncTask

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## Overview

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# Issues

- **Nonresponsive GUI controls**
  - Long-running code in main thread will make GUI controls nonresponsive.
- **Threads cannot update user interface**
  - Background threads are prohibited from updating UI.

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# Nonresponsive GUI Controls

- **Problem**
  - Long-running code in main thread will make GUI controls nonresponsive.
    - For example, if a Button's onClick handler takes 5 seconds, then none of the other controls will respond for 5 seconds.
- **Solution**
  - Move time-consuming operations to background threads
    - This was the entire point of the previous lecture on the basics of multithreaded programming

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# Threads Cannot Update UI

- **Problem**

- Background threads are prohibited from updating UI.
  - E.g., background threads cannot add a new View to the display, nor can they call setText on a visible View.

- **Solutions (alternatives)**

- Wait until all threads are done, then update UI
  - When multithreading improves performance, but total wait time is small
- Have background threads use View.post to send UI-updating operations back to UI thread
  - Especially when transitioning standard threading code to Android
- Use AsyncTask to divide tasks between background and UI threads
  - Especially when developing for Android from beginning and you have a lot of incremental GUI updates.

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## Updating UI After Threads Complete

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## Updating UI All at Once

- **Scenario**

- Using threads improves performance.
- Total wait time is small, so no need to display intermediate results.

- **Approach**

- Add threads to ExecutorService task list.
- Use awaitTermination to wait until all tasks are finished (or a timeout is exceeded)
- Update UI. You are in UI thread, so this is safe/legal.

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## Example: Multi-URL Validator

- **Idea**

- Let user enter any number of URLs
- Check if they are legal by making HTTP HEAD requests and checking the server status line

- **Approach**

- Make a List of URL result holders
- For each URL, pass result holder to background thread. Background thread stores result in holder. Use inner class for background thread implementation.
- After all tasks are complete or 10 seconds have elapsed (whichever is sooner), show results in ScrollView

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## Main Activity: Setup Code

```
public class UrlCheckerActivity extends Activity {
    private LinearLayout mResultsRegion;
    private EditText mUrlsToTest;
    private int mGoodUrlColor, mForwardedUrlColor,
               mBadUrlColor;
    private Drawable mGoodUrlIcon, mForwardedUrlIcon,
                   mBadUrlIcon;
    List<UrlCheckerResult> mResultsHolder =
        new ArrayList<UrlCheckerResult>();
    private final static int HEAD_TIMEOUT = 10;
    private float mResultTextSize;
    private int mResultPaddingSize;
```

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## Main Activity: Setup Code (Continued)

```
@Override
public void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);
    setContentView(R.layout.url_checker);
    mUrlsToTest = (EditText)findViewById(R.id.urls_to_test);
    mResultsRegion = (LinearLayout)findViewById(R.id.results_region);
    Resources resources = getResources();
    mGoodUrlColor = resources.getColor(R.color.url_good);
    mForwardedUrlColor = resources.getColor(R.color.url_forwarded);
    mBadUrlColor = resources.getColor(R.color.url_bad);
    mGoodUrlIcon = resources.getDrawable(R.drawable.emo_im_happy);
    mForwardedUrlIcon = resources.getDrawable(R.drawable.emo_im_wtf);
    mBadUrlIcon = resources.getDrawable(R.drawable.emo_im_sad);
    mResultTextSize =
        resources.getDimension(R.dimen.url_checker_result_size);
    mResultPaddingSize =
        (int)resources.getDimension(R.dimen.url_checker_padding_size);
```

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## Main Activity: Button Handler (Starts Threads)

```
public void checkUrls(View clickedButton) {
    mResultsRegion.removeAllViews();
    mResultsRegion.requestLayout();
    String[] urls =
        mUrlsToTest.getText().toString().split("\\s+");
    ExecutorService taskList =
        Executors.newFixedThreadPool(50);
    for (String url: urls) {
        UrlCheckerResult resultHolder =
            new UrlCheckerResult(url);
        mResultsHolder.add(resultHolder);
        taskList.execute(new UrlTester(resultHolder));
    }
    try {
        taskList.shutdown();
        taskList.awaitTermination(HEAD_TIMEOUT,
            TimeUnit.SECONDS);
    } catch (InterruptedException e) {}
}
```

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## Main Activity: Button Handler (After Threads Complete)

```
for(UrlCheckerResult resultHolder: mResultsHolder) {
    UrlChecker result = resultHolder.getUrlResult();
    if (result == null) {
        result =
            new UrlChecker(resultHolder.getUrlString(),
                HEAD_TIMEOUT);
    }
    TextView displayedResult = new TextView(this);
    displayedResult.setTextColor(chooseColor(result));
    displayedResult.setTextSize(mResultTextSize);
    displayedResult.setText(result.toString());
    displayedResult.setCompoundDrawablesWithIntrinsicBounds
        (chooseIcon(result), null, null, null);
    displayedResult.setCompoundDrawablePadding
        (mResultPaddingSize);
    mResultsRegion.addView(displayedResult);
}
}
```

It would have been illegal to do this in the background thread, because it changes the visible UI. Creating the TextView would have been legal, but adding it to the vertical LinearLayout inside the ScrollView (as done here) would have been illegal.

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## Main Activity: Runnable Inner Class

```
private class UrlTester implements Runnable {
    private UrlCheckerResult mResultHolder;

    public UrlTester(UrlCheckerResult resultHolder) {
        mResultHolder = resultHolder;
    }

    public void run() {
        UrlChecker result =
            new UrlChecker(mResultHolder.getUrlString());
        mResultHolder.setUrlResult(result);
    }
}
```

The run method does not update the UI directly. Instead, it updates a data structure that will later be read and then used to update the UI (code that does this was shown on previous slide).

The UrlChecker class does the actual network calls. Since different servers can respond at different speeds, calling UrlChecker in a background thread can substantially improve performance.

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## Main Activity: Helper Methods

```
private int chooseColor(UrlChecker urlResult) {
    if (urlResult.isGood()) {
        return(mGoodUrlColor);
    } else if (urlResult.isForwarded()) {
        return(mForwardedUrlColor);
    } else {
        return(mBadUrlColor);
    }
}

private Drawable chooseIcon(UrlChecker urlResult) {
    if (urlResult.isGood()) {
        return(mGoodUrlIcon);
    } else if (urlResult.isForwarded()) {
        return(mForwardedUrlIcon);
    } else {
        return(mBadUrlIcon);
    }
}
```

I use different text colors and different icons depending on whether the URL is good, forwarded, or bad.

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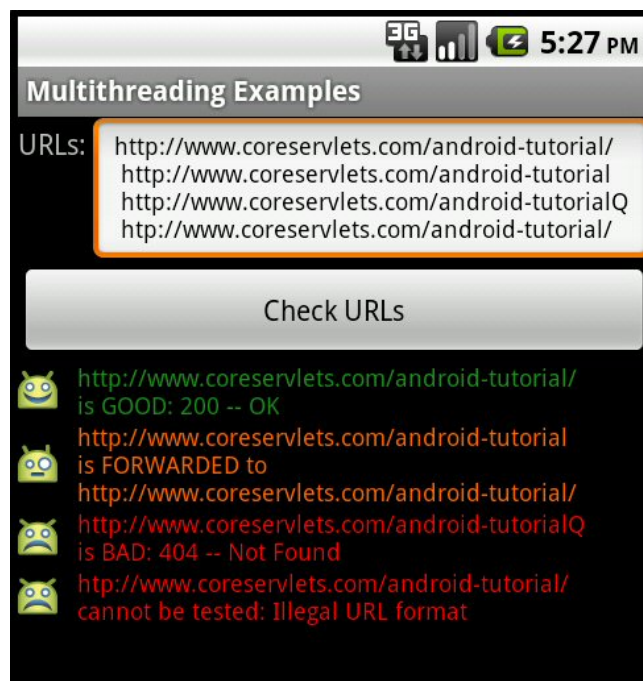


# Main Helper Classes

- **UrlChecker**
  - Makes a HEAD request and parses status line. If status code is 301 or 302, looks up Location header.
    - Most of the code shown in earlier lecture on Networking
- **UrlCheckerResult**
  - Stores a URL and the associated UrlChecker result.
    - The timeout could be exceeded before the results are found, in which case the UrlChecker is null. In that scenario, we display a message that shows the URL and says that no result was found within the allotted time.

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# Results



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# Downloading Web Images

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## Displaying a Network Image

- **Idea**

- The decodeStream method of BitmapFactory can take an InputStream and produce a Bitmap. You can put a Bitmap into an ImageView

- **Approach**

- Get an HttpURLConnection (as explained in second networking lecture)
- Get the input stream with connection.getInputStream()
- Pass the stream to BitmapFactory.decodeStream and store result in Bitmap
- Get a reference to an ImageView and pass new Bitmap to setImageBitmap

## BitmapUtils: Getting a Bitmap

```
public class BitmapUtils {
    public static Bitmap bitmapFromUrl(String urlString)
        throws MalformedURLException, IOException {
        URL url = new URL(urlString);
        HttpURLConnection urlConnection =
            (HttpURLConnection)url.openConnection();
        InputStream in = urlConnection.getInputStream();
        Bitmap bitmapImage = BitmapFactory.decodeStream(in);
        urlConnection.disconnect();
        return(bitmapImage);
    }
}
```

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## Making a View for an Image

- **Idea**
  - Given an address, try to load a Bitmap from it. If successful, make an ImageView showing the Bitmap. If unsuccessful, make a TextView showing information on the error.
- **Approach**
  - Call BitmapUtils.bitmapFromUrl.
    - If no Exception, instantiate ImageView and pass Bitmap to setImageBitmap.
    - If Exception, instantiate TextView and store an error message in it.

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# BitmapUtils: Getting a View for an Image

```
public static View viewForImage(String urlString, Context context) {
    Bitmap bitmapImage = null;
    String errorMessage = "";
    try {
        bitmapImage = BitmapUtils.bitmapFromUrl(urlString);
    } catch (MalformedURLException mue) {
        errorMessage = String.format("Malformed URL %s", urlString);
    } catch (IOException ioe) {
        errorMessage = String.format("Error downloading image: %s",
            ioe.getMessage());
    }
    if (bitmapImage != null) {
        ImageView displayedImage = new ImageView(context);
        displayedImage.setImageBitmap(bitmapImage);
        displayedImage.setPadding(5, 5, 5, 5);
        return(displayedImage);
    } else {
        TextView displayedMessage = new TextView(context);
        displayedMessage.setText(errorMessage);
        return(displayedMessage);
    }
}
```

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# Example: Unthreaded Image Viewer

- **Idea**
  - Let user enter URL of an image to be displayed
  - Either show that image, or show error message
- **Approach**
  - Read the address from EditText, pass to BitmapUtils.viewForImage
  - Add resultant View to the layout

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# Activity

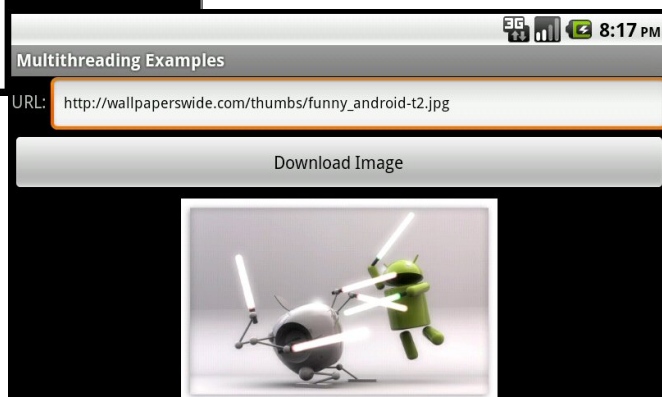
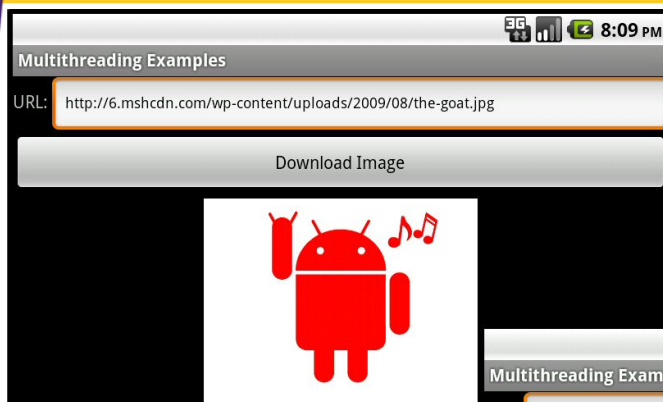
```
public class SimpleImageDownloaderActivity extends Activity {
    private LinearLayout mMainWindow;
    private EditText mImageToDownload;
    private View mViewForImage;

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.simple_image_downloader);
        mMainWindow = (LinearLayout) findViewById(R.id.main_window);
        mImageToDownload =
            (EditText) findViewById(R.id.image_to_download);
    }

    public void downloadImage(View clickedButton) {
        if (mViewForImage != null) {
            mMainWindow.removeView(mViewForImage);
        }
        String imageUrl = mImageToDownload.getText().toString();
        mViewForImage = BitmapUtils.viewForImage(imageUrl, this);
        mMainWindow.addView(mViewForImage);
    }
}
```

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# Results



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# Updating UI with View.post

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## View.post

- **Scenario**

- Total wait time might be large, so you want to show intermediate results
- You have a lot of normal threading code but you occasionally need to update UI.

- **Approach**

- When background thread has result that should affect UI, create a Runnable and pass to post

```
public void run() {                // Background thread
    doStuffButDontUpdateUI();
    someView.post(new Runnable() {
        public void run() { updateUI(); });
    }
}
```

# Example: Multithreaded Image Viewer (Version 1)

- **Idea**

- Let user enter URLs of images to be displayed
- Download and display them inside a scrolling horizontal LinearLayout

- **Approach**

- Download images and associate them with ImageView, as shown in the previous subsection. If there was an error, create a TextView saying so.
- Create a Runnable that will add the resultant View to the LinearLayout
- Pass that Runnable to the post method of the LinearLayout

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## Main Activity: Setup Code

```
public class ImageDownloader1Activity extends Activity {
    protected LinearLayout mResultsRegion;
    protected EditText mImagesToDownload;

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.image_downloader);
        mImagesToDownload =
            (EditText) findViewById(R.id.images_to_download);
        mResultsRegion =
            (LinearLayout) findViewById(R.id.results_region);
    }
}
```

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## Main Activity: Button Handler

```
public void downloadImages(View clickedButton) {
    mResultsRegion.removeAllViews();
    mResultsRegion.requestLayout();
    String[] images =
        mImagesToDownload.getText().toString().split("\\s+");
    addImages(images);
}

protected void addImages(String[] images) {
    ExecutorService taskList =
        Executors.newFixedThreadPool(50);
    for (String image: images) {
        taskList.execute(new ImageDownloader(image));
    }
}
```

The event handler is split into two methods because the next example will extend this class and override `addImages`, but will keep the inherited version of `downloadImages` unchanged.

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## Main Activity: Runnable Inner Class (For Background)

```
private class ImageDownloader implements Runnable {
    private String mImageUrl;

    public ImageDownloader(String imageUrl) {
        mImageUrl = imageUrl;
    }

    public void run() {
        View viewToAdd =
            BitmapUtils.viewForImage(mImageUrl,
                                    ImageDownloader1Activity.this);
        mResultsRegion.post(new ViewAdder(viewToAdd));
    }
}
```

This is the task that the `ExecutorService` executes. It calls `viewForImage`, a time-consuming task that loads an image from the network and associates it with an `ImageView` (or a `TextView` if there was an error). The `View` is then sent to the main UI thread by putting it in a `Runnable` and passing the `Runnable` to the `post` method of a `View` that is in the main Activity.

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# Main Activity: Runnable Inner Class (For UI Thread)

```
private class ViewAdder implements Runnable {  
    private View mViewToAdd;  
  
    public ViewAdder(View viewToAdd) {  
        mViewToAdd = viewToAdd;  
    }  
  
    public void run() {  
        mResultsRegion.addView(mViewToAdd);  
    }  
}
```

This changes the UI, so could not have been done in the background.

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# Results

The screenshot shows an Android application titled "Multithreading Examples". At the top right, there are status icons for 3G, signal strength, battery, and the time 8:22 PM. Below the title, there is a text input field containing four URLs: <http://coreservlets.com/images/CSAJSP-Book1Ed.jpg>, <http://coreservlets.com/images/CSAJSP-Bulgarian.jpg>, <http://coreservlets.com/images/CSAJSP-Chinese.jpg>, and <http://coreservlets.com/images/CSAJSP-Spanish.jpg>. Below the URLs is a large button labeled "Download Images". Underneath the button, four book covers are displayed in a row. From left to right: 1. "СЪРВАЕТИ и JAVASERVER PAGES" by Marty Hall, published by Sina. 2. "core SERVLETS and JAVASERVER PAGES" by Marty Hall, published by Sina. 3. "Servlet与JSP 核心技术" by Marty Hall, published by Sina. 4. "SERVLETS y JAVASERVER PAGES" by Marty Hall, published by Sina.

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# Updating UI with AsyncTask

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## AsyncTask

- **Scenario**

- Total wait time might be large, so you want to show intermediate results
- You are designing code from the beginning to divide the work between GUI and non-GUI code

- **Approach**

- Use AsyncTask with `doInBackground` & `onPostExecute`

```
private class MixedTask extends AsyncTask<...> {
    public SomeType doInBackground(...) {
        doNonGuiStuff();
        return(valueForUiThread);
    }
    public void onPostExecute(SomeType valueForUiThread) {
        doGuiStuffWith(valueForUiThread);
    }
}
```

# AsyncTask: Quick Example

- **Task itself**

```
private class ImageDownloadTask extends AsyncTask<String, Void, View> {  
    public View doInBackground(String... urls) {  
        return(BitmapUtils.viewForImage(urls[0], MainActivity.this));  
    }  
  
    public void onPostExecute(View viewToAdd) {  
        mResultsRegion.addView(viewToAdd);  
    }  
}
```

- **Invoking task**

```
String imageAddress = "http://...";  
ImageDownloadTask task = new ImageDownloadTask();  
task.execute(imageAddress);
```

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# AsyncTask Details: Constructor

- **Class is genericized with three arguments**

- AsyncTask<ParamType, ProgressType, ResultType>

- **Interpretation**

- ParamType

- This is the type you pass to execute, which in turn is the type that is send to doInBackground. Both methods use varargs, so you can send any number of params.

- ProgressType

- This is the type that you pass to publishProgress, which in turn is passed to onProgressUpdate (which is called in UI thread). Use Void if you do not need to display intermediate progress.

- ResultType

- This is the type that you should return from doInBackground, which in turn is passed to onPostExecute (which is called in UI thread).

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# AsyncTask Details: doInBackground

- **Idea**

- This is the code that gets executed in the background. It *cannot* update the UI.
- It takes as arguments whatever was passed to execute
- It returns a result that will be later passed to `onPostExecute` in the UI thread.

- **Code**

```
private class SomeTask extends AsyncTask<Type1, Void, Type2> {  
    public Type2 doInBackground(Type1... params) {  
        return(doNonUiStuffWith(params));  
    } ...  
}  
...  
new SomeTask().execute(type1VarA, type1VarB);
```

The ... in the `doInBackground` declaration is actually part of the Java syntax, indicating varargs.

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# AsyncTask Details: onPostExecute

- **Idea**

- This is the code that gets executed by the UI thread. It *can* update the UI.
- It takes as an argument whatever was returned by `doInBackground`

- **Code**

```
private class SomeTask extends AsyncTask<Type1, Void, Type2> {  
    public Type2 doInBackground(Type1... params) {  
        return(doNonUiStuffWith(params));  
    }  
    public void onPostExecute(Type2 result) { doUiStuff(result); }  
}  
...  
new SomeTask().execute(type1VarA, type1VarB);
```

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## AsyncTask Details: Other Methods

- **onPreExecute**
  - Invoked by the UI thread before `doInBackground` starts
- **publishProgress**
  - Sends an intermediate update value to `onProgressUpdate`. You call this from code that is in `doInBackground`. The type is the middle value of the class declaration.
- **onProgressUpdate**
  - Invoked by the UI thread. Takes as input whatever was passed to `publishProgress`.
- **Note**
  - All of these methods can be omitted.

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## Example: Multithreaded Image Viewer (Version 2)

- **Idea**
  - Let user enter URLs of images to be displayed
  - Download and display them inside a scrolling horizontal `LinearLayout`
- **Approach**
  - Extend previous example. Make an `AsyncTask`
  - `doInBackground`
    - Download images and associate them with `ImageView`, as shown in the previous subsection. If there was an error, create a `TextView` saying so. Return that `View`.
  - `onPostExecute`
    - Add the `View` to the `LinearLayout`

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# Activity

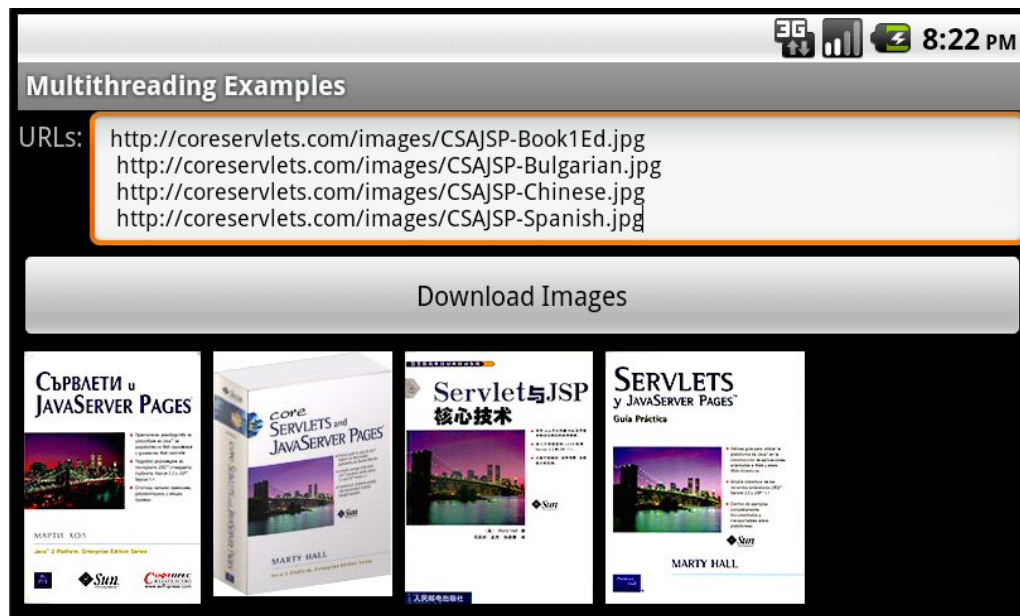
```
public class ImageDownloader2Activity extends ImageDownloader1Activity {
    @Override
    protected void addImages(String[] images) {
        for (String image: images) {
            ImageDownloadTask task = new ImageDownloadTask();
            task.execute(image);
        }
    }

    private class ImageDownloadTask extends AsyncTask<String, Void, View> {
        @Override
        public View doInBackground(String... urls) {
            return (BitmapUtils.viewForImage(urls[0],
                ImageDownloader2Activity.this));
        }

        @Override
        public void onPostExecute(View viewToAdd) {
            mResultsRegion.addView(viewToAdd);
        }
    }
}
```

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# Results



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## Wrap-Up

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## More Reading

- **JavaDoc**
  - AsyncTask
    - <http://developer.android.com/reference/android/os/AsyncTask.html>
- **Tutorial: Processes and Threads**
  - <http://developer.android.com/guide/topics/fundamentals/processes-and-threads.html>
- **Chapters**
  - Threads, Services, Receivers, and Alerts
    - From *The Android Developer's Cookbook* by Steele & To
  - Dealing with Threads
    - From *The Busy Coder's Guide to Android Development* by Mark Murphy (<http://commonsware.com/Android/>)

# Summary

- **Update UI after all threads done**
  - One update per group of tasks
    - Use `taskList.awaitTermination`
- **Update UI incrementally with post**
  - Potentially several updates per task
    - Main thread does non-GUI stuff. Sends values for UI thread via `someView.post(someRunnable)`
- **Update UI incrementally with AsyncTask**
  - One update per task, but several updates per group of tasks
    - `doInBackground`
      - Does non-GUI stuff. Returns value for UI thread.
    - `doPostExecute`
      - Does GUI stuff. Uses value from `doInBackground`
- **Loading images from network**
  - Use `HttpURLConnection` & `BitmapFactory.decodeStream`

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## Questions?

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