Introduction to Android Programming

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Android Programming

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- The Dalvik Virtual Machine

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- Python on Android
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- A Python more complex example
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Part I - Android

- **Introduction to Android**
- **The Dalvik Virtual Machine**

Introduction to Android

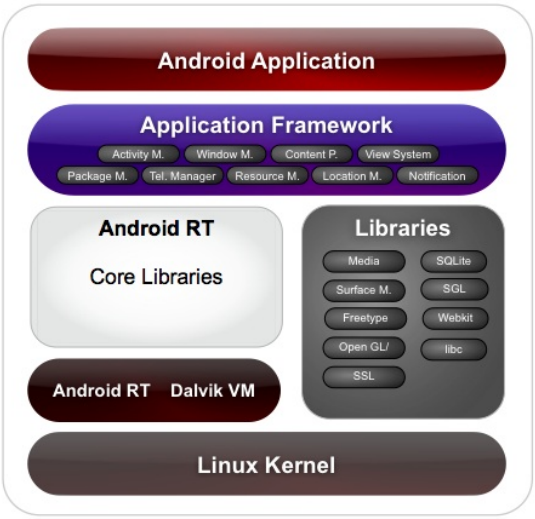
Introduction

Android is a Linux-Based OS which target-platform are mobile devices.
Nowaday, over the 60% of smartphones in the world are running Android.
It is Open Source, it has a good SDK, and it is Linux, this made developers quickly start to love Android.
Android is under ongoing development by Google, which also provides the Android SDK.
Each Android version corresponds to a specific API level, more API levels might be compatible each other.

Life, Death and Miracles

When	What
2003	Android development starts.
2005	Google buys Android Inc..
oct 2008	HTC Dream is the first Android phone to be commerced.
apr 2009	Android 1.5 "Cupcake" released, based on Kernel Linux 2.6.
oct 2011	Android 4.0 "Ice Cream Sandwich" released, based on Kernel Linux 3.0.
q1 2012	More than 800.000 Apps on the Play Store.
q3 2012	1.5 Million new device activation per day.
q1 2013	Over 600 Million total activation.

Internal Structure



Linux Kernel

The Linux Kernel provides basic functions to Android :

- Hardware Abstraction Layer
- C/C++ APIs.
- GCC.
- Memory Manager
- Scheduler

Dalvik Virtual Machine

See the following charapter for this.

Android Runtime

Android RT consist essentially of core C and Java libraries used by the DVM.

- LibC
- OpenGL ES
- Webkit
- SQLite
- ...

Application Framework

- Development libraries
- Sdk Interface
- Windows Provider
- Package Manager

The Dalvik Virtual Machine

Introduction

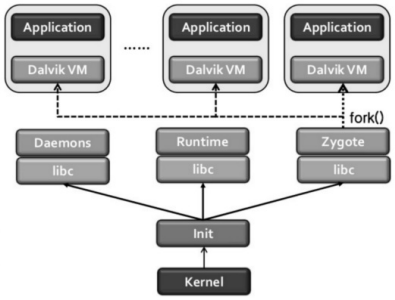
An OS offers a set of common APIs on every platform on which the system runs.
That allows to run the same kind of executable file on different platform, or OS version.
This is possible in a lot of ways, such as cross-compiling the source, or execute it on a Virtual Machine.
In Android, users application are executed trough the Dalvik Virtual Machine.

What does the DVM?

- Executes Dalvik Bytecode.
- Manages multiple instance of itself (Like the JVM does.)
- Provides a "sandbox" where applications can run *without* interact each other.
- Abstracts the problem of memory menagement to the OS.

Applications run on the DVM just like in a "sandbox".

Make it efficient



As mentioned, every application runs on a single instance of the Dalvik Virtual Machine.
Zygote is the process that make the creation of new DVM instace efficient.

1. The Boot-loader loads the kernel and start init process.
2. Starts Zygote process.
3. Initializes a Dalvik VM which preloads and pre-initializes core library classes.
4. The system keeps in an idle state the process until the execution request.
5. Once an application execution request occurs, Zygote forks itself and create new process with the pre-loaded Dalvik VM.

Not a JVM clone

- **The architecture is Register-Based (instead of Stack-Based, like the JVM).**
  Up to 2^16 avaiable registers.

- **DVM uses the Dalvik Bytecode instead of the Java one.**
  Which is far more pragmatic :

```
                      iload s0
add-int d0, s0, s1    iload s1
                      iadd
                      istore d0
```

  The DVM instruction set has 218 opcodes (JVM: 200 opcodes).
  Its use reduces by 30% fewer instructions, but 25% larger code size (bytes) compared to JVM.

- **Constant Pool**
  The dx compiler significantly reduces the size of the costant pool, by inling them directly in the bytecode.
  This permits the use of one single costant pool, unlike the JVM does.

- **It comes without exceptions handling.**

- **Null references**
  DVM does not specify a null type, the 0 value is used instead.

- **Ambiguos primitive types**
  The JVM is strongly typed, and uses different opcodes for every data-type.
  DVM does not distinguish between int/float/null, it uses aget (and aget-wide for double and long).

- **DVM is far more efficient.**
  A Register-Based architecture is up to 47% more efficient than a Stack-Based one!
  The larger code size involves only 1.07% extra real machine loads per VM instruction, which is negligible.

Part II - Android Programming

- **General lines about Android Programming**
- **Packing Application**
- **Sample Application in Java**

General lines about Android Programming

Android SDK

The Android software development kit (SDK) includes a comprehensive set of development tools.
These include a debugger, libraries, a handset emulator based on QEMU, documentation, sample code, and tutorials.
Enhancements to Android's SDK go hand in hand with the overall Android platform development.
Each Android Version has a specific set of API, named "API level".
Android applications are packaged in .apk format and stored int the /data/app folder on the Android OS.
APK package contains .dex files (executable for the dvm), resource files, etc.

Android NDK

The NDK is a toolset that allows you to implement parts of your app using native-code languages (C/C++).
This can be helpful in reusing existing code libraries written in these languages.
Most apps do not need the Android NDK.

Android Debug Bridge

The Android Debug Bridge (ADB) is a toolkit included in the Android SDK package.
It consists of both client and server-side programs that communicate each other.
The ADB is typically accessed through the command-line interface.
A typical use is to compile a source file and run it on a physical device, without the use of the android emulator.

Project Sections

The project is composed of three main directory :

- **Gen**
  This folder contains Java Library automatically generated.
  In particular, an "R.java" file, containing exadecimal values referreing to gui elements.
- **Src**
  This directory contatins the source code of the application.
  In Java it corresponds to the default source package.
- **Res**
  This directory contains all the resources used by the application.
  Its subdirectory, "drawable", contains all the graphics resource such as image and so on.
  The GUI Layout is defined in a xml file, contained in this directory.

Activity

The concept

An activity is a single, focused thing that the user can do.
Almost all activities interact with the user, so the Activity class takes care of managing graphics resources.
Every application is build around a single instance of the Activity class.
All the activity classes must have a corresponding tag in their package's manifest file.

Some Methods

- **onCreate(), onStart(), onResume(), onDestroy(), ...**
  As easy to understand, these are methods used to interact with the flow of the application lifecycle.
  Override these methods to initialize it on start or commmit modifications when exiting.

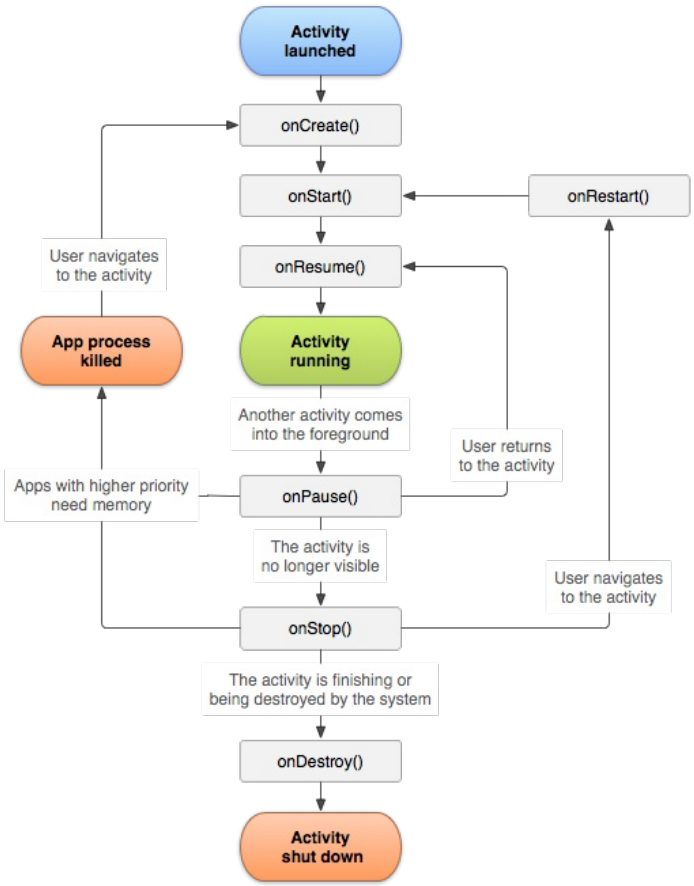
- **setContentView()** Set the activity content to an explicit view.
  This view is placed directly into the activity's view hierarchy. It can itself be a complex view hierarchy.
  Parameters :
  - view: the desired content to display.
  - params: layout parameters for the view.

- **onActivityResult()** Let's suppose an application needs the user to select a contact from the contect list.
  Calling another application is as simple as this :

```
startActivityForResult(
    new Intent( Intent.ACTION_PICK,
        new Uri( "content://contacts" )
    ),
    PICK_CONTACT_REQUEST
);
```

  Override onAcitvityResult() let you use the result of the called application, by using an Intent object.

Lifecycle Diagram



Manifest

In software packaging, it is common to list the contents of a distribution in a manifest file.
In java this kind of file is used to specify information used when packing in a jar file :

- store hashes of stored files for signature validation.
  This aspect will be deepened in the next charapter, "Packing Applications".
- sealing jar files (i.e. ensure that only classes from this jar file are loaded in the packages defined in this jar file).
- store version/product/producer information to be readable at runtime

This file also contains information about the permission of the application.
The ability to start a particular Activity can be enforced when it is declared in its manifest's <activity> tag.
Other applications will need to declare a corresponding <uses-permission> element in their own manifest to be able to start that activity.

Layout

A layout defines the visual structure for a user interface, such as the UI for an activity or app widget. You can declare a layout in two ways:

- Declare UI elements in XML.
  Android provides a straightforward XML vocabulary that corresponds to the View classes, such as those for widgets and layouts.
- Instantiate layout elements at runtime.
  Your application can create View and ViewGroup objects (and manipulate their properties) programmatically.

The Android framework allows you to use either or both of these methods for declaring and managing your application's UI.
For example, you could declare your application's default layouts, screen elements, and their properties in a XML file,
and then modify the state of those object in yout code, at run time.

Packing an Application

Introduction

"To compile" a programm means translate it in an other language (e.g. C to x86 assembly, Java to Java Bytecode).
When compiling an application for Android, our target-language is the Dalvik Bytecode.
The compiled program is stored in a file *.dex.

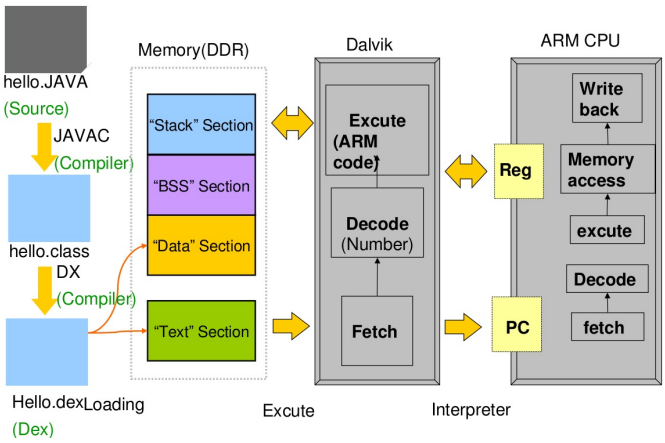
Structure of a DEX file

- **Header**
- **Constant Pool**
  - References to other classes
  - Method names
  - Numerical constants
- **Classes definition**
  - Access flags
  - Class names
- **Data**
  - Method code
  - Info related to methods
  - Variables

Building an APK file

Application Package File (APK) is the file format used to distribute and install application on Android.
Any program, to run on Android, needs to be packed in an apk file.
The apk files contains the application code, the dex file, and all the resources needed.
Those information are stored in a special JAR file (using ZIP), with ".apk" as file extensions.
The application can be compiled using the ADT plugin.
After this, the apk needs to be signed, using Jarsigner, and aligned, using Zipalign.

Runtime through the Dalvik Virtual Machine

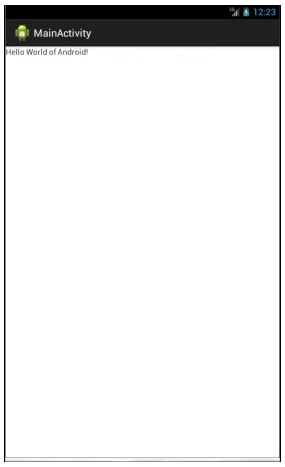


A compiled program is loaded by the DVM and unpacked.
Application memory is divided in various sections (like the 8086 segments).

- Stack Section
- Data Section
- BSS Section
  (A special Part of the data segment, for statically-allocated variables.)
- Text Section (A special segment for strings treatment

A sample Application

Hello World!




```
package com.curzel.sample.helloword;

import android.app.Activity;
import android.os.Bundle;
import android.widget.TextView;

public class MainActivity extends Activity {

 @Override
 protected void onCreate( Bundle savedInstanceState ) {
  super.onCreate( savedInstanceState );
  TextView text = new TextView( this );
  text.setText( "Hello World of Android!" );
  setContentView( text );
 }
}
```

The Bundle class

A bundle is generally used for passing data between various Activities of android.
The following code will start up an activity and pass to it some values.

```
Intent intent = new
Intent( getApplicationContext(), SecondActivity.class );
intent.putExtra( "myKey", someValues );
startActivity( intent );
```

Then, in the second activity, you can use the bundle just like an HashMap.

```
Bundle extras = intent.getExtras();
Object someValues = extras.get( "myKey" );
```

Part III - The Role of Java

- **Java and ARM**

Java and ARM

Java, over time, has become one of the most widely used programming languages.
J2ME is a runtime and a collection of APIs for software development dedicated to devices with limited resources.
The portability of Java, and all the benefits gained from using J2ME, had led Java soon to become a de-facto development standart for mobile devices.

On the other side, the main problem of ARM architecture is the limited computational power.
A solution that has been found was to make cpu natively execute Java Bytecode.
The following is an overview about technologies used in ARM Architectures to treat instructions.

Jazelle

Jazelle DBX (Direct Bytecode eXecution) allows some ARM processors to natively execute Java bytecode.
The target of this tecnology is to facilitate the execution on Java ME programs on mobile devices.
The BXJ (Branch and eXchange to Java) instruction attempts to switch to Jazelle state.
If allowed and successful, sets the 'J' bit in the CPSR; otherwise, it "falls through" and acts as a standard BX (Branch) instruction.

Thumb

To improve compiled code-density since 1994 arm processors have featured Thumb instruction set, which have their own state.
When in this state, the processor executes the Thumb instruction set, a compact 16-bit encoding for a subset of the ARM instruction set.
Most of the Thumb instructions are directly mapped to normal ARM instructions.

Thumb2

Both ARM and Thumb instructions sets were exdended.
A stated aim for Thumb-2 was to achieve code density similar to Thumb with performance similar to the ARM instruction set on 32-bit memory.
As you can see below, the same source code can so be compiled as ARM or Thumb2 code.
Recall that the Thumb MOV instruction has no bits to encode "EQ" or "NE", as MOVEQ and MOVNE are ARM instruction.

code	pseudo-code	ARM meaning	Thumb2 meaning
`CMP r0, r1`	--	comparison	comparison
`ITE EQ`	if r0 == r1	--	starts an If-Then-Else block
`MOVEQ r0, r2`	then r0 = r2	conditional	"Then" block
`MOVNE r0, r3`	else r0 = r3	conditional	"Else" block

ThumbEE

ThumbEE, also known as Jazelle RCT (Runtime Compilation Target), was announced in 2005.
It added a fourth processor mode, and made small changes to the Thumb-2 extended Thumb instruction set.
These changes make JIT compilers able to output smaller compiled code without impacting performance.
ThumbEE is a target for languages such as Java, C#, Perl, and Python, which all uses JIT compilers.

AArch64e

Every use of the ThumbEE instruction set have been deprecated at the and of 2011, as AArch64 have enstabilished.
AArch64 is a 64-bit architecture, main news are :

- New instruction set, A64
  - 31 general-purpose 64-bit registers
  - Instructions are still 32 bits long and mostly the same as A32
  - Most instructions can take 32-bit or 64-bit arguments
  - Addresses assumed to be 64-bit
- Advanced SIMD (NEON) enhanced
  - Has 32x128-bit registers (up from 16), also accessible via VFPv4
  - Supports double-precision floating point
  - Fully IEEE 754 compliant
  - AES encrypt/decrypt and SHA-1/SHA-2 hashing instructions also use these registers
- A new exception system
  - Fewer banked registers and modes

Kernel Linux 3.7 included pathes to support AArch64e.

Part IV - Python as an alternative to Java

- **Python on Android**
- **Languages comparison**
- **Java vs Python in Android context**
- **Sample Application using Python-Kivy**
- **A Python more complex example**
- **Conclusion**

Python on Android

Python is a multi-paradigm programming language, initially developed by Guido Van Rossum, in 1989.
In analogy with Java, is both compiled and interpreted, note that compilation could also come at runtime
Python source files (*.py) are compiled in bytecode, which is executed by an interpreter.
It is often used as a scripting language, but is also used in a wide range of non-scripting contexts.
Using third-party tools it can also be packaged into standalone executables.

In Pills

- Emphasize the readability
- Concise Syntax
- Multi-Paradigm
- Duck Typing
- No modifier, but Decorators
- Completely Cross-Platform

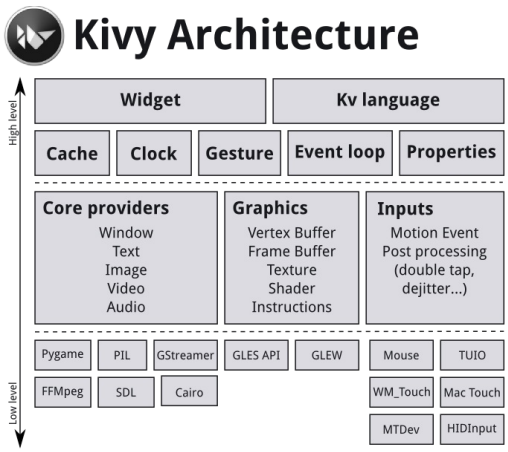
SL4A

As mentioned, Python runs on an interpreter.
This allows to develop multiplatform code, just like Java.
The Scripting Layer for Android (SL4A) allows to run various script directly on Android devices.
Supported languages includes Python, Perl, Ruby, Lua, JavaScript and so on...
SL4A is designed for developers and is still alpha quality software.

Python for Android

Python for android is a project to create your own Python distribution.
The software allows you to include all the modules you want and use them to compile and apk.

Kivy



Kivy is a cross-platform Python framework for rapid development of application.
Using python-for-android technology to create a python distribution that includes kivy
allows you to run the same application code on any Android device.
All without modify a single line of code.
This is possible because the framework itself is written in pure python.
As many other frameworks do, kivy provides a set of classes for building the GUI,
but also to manage internal process and touch input.
However, Kivy comes with a further kind of approach.
Both GUI layout and widgets can be described using the Kv Language.
This technology is cross between UIML (Layout definition) and XML (Structure definition). The second approach makes kivy easily extensible.

Java and Python comparison

Lets now compare Python and Java without a specific context.

Consider a function to traverse a data structure (a tree, for instance) to find objects that match certain criteria.
The matching function is generic: It traverses the structure and calls a caller-supplied matching function to match two objects.
It makes sense to have the tree class supply the matching logic (which hides the details of efficiently traversing the tree),
while allowing the caller to specify the matching function.

```
//Java implementation, using an interface.
import java.util.Collection;
import java.util.ArrayList;

public interface Matcher {
    boolean matches(T o);
}

public class MyTree {
    // details omitted

    Collection matches(Matcher matcher) {
        Collection result = new ArrayList();

        for ( element : this.treeElements ) {
            if ( matcher.matches(element) ) {
                result.add(element);
            }
        }
        return result;
    }
}

MyTree keywords = new MyTree();

//get all keywords starting with 'a'.
Collection matches = keywords.matches (
    new Matcher() {
        public boolean matches( String s ) {
            return s.startsWith("a");
        }
    }
);
```

```
#Same thing in Python
class MyTree() :

    # details omitted

    def matches( self, matches ):
        return [el for el in self.__tree_elements if matches(el)]

keywords = MyTree()

# Code that fills the tree goes here
# Now, get all keywords starting with 'a'.
matches = keywords.matches( lambda el: el.startswith('a') )
```

Java and Python on Android

Accessing Java classes in Python

Both the SDK and the NDK are written in Java and C++.
The usage of Java classes in a Python program is allowed using Jython, a Python interpreter written in Java.
An other option is using Pyjnius, which is what Python-For-Android does :

```
from jnius import autoclass

Stack = autoclass('java.util.Stack')
stack = Stack()
stack.push('hello')
stack.push('world')

print stack.pop() # --> 'world'
print stack.pop() # --> 'hello'
```

Python-For-Android internally mix Cython, JNI (Java Native Interface) and Pyjnius.
The cost in terms of efficiency is minimal, and provides a more flexible interface.

While Pyjnius sounds to have no limitation, Kivy does not officially supports the whole SDK.
Basic Hardware Interface such as GPS or Bluetooth API are currently not avaiable in Kivy.

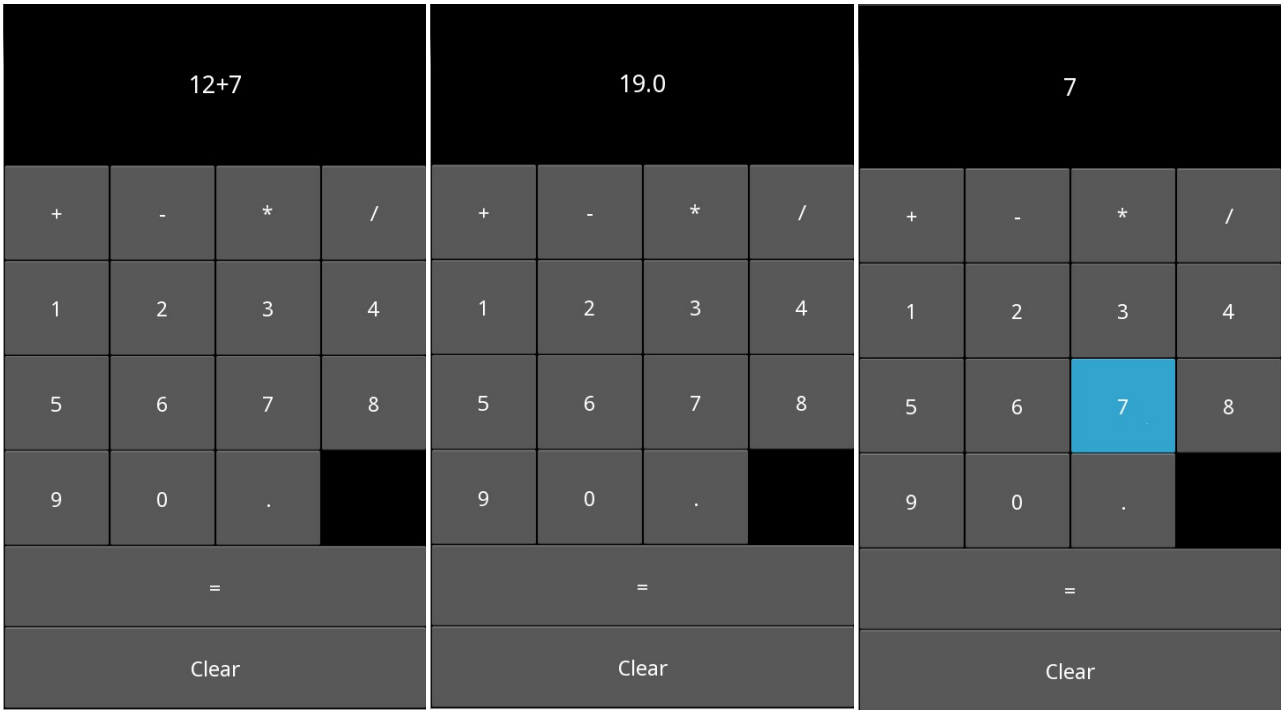
Table of concepts

How do you...	Java	Python
...define a job for the DVM?	Using the **Activity** class.	Using the **App** class. • onCreate(Bundle) -> build() • onPause(Bundle) -> on_pause() • and so on...
...interact with an other application?	Using a **Bundle** object.	Actually, there is no way of doing this.
...handle touch events?	**Overriding** the onTouchEvent method.	**Overriding** respectively : • on_touch_down • on_touch_move • on_touch_up You also can grab a certain touch to a Widget.
...handle multi-touch events?	Using the touch-event unique **id**.	
...make 2D drawing?	You need to extend the View class and override **the onDraw(Canvas c)** method.	Every Widget object as a canvas property, which you can treat in different ways : • Using **Kv-Language**, expecially for static things, in comfortable a separeted file. • Using the Python **with** statement. • Or using it as a python variable (not so widely used).
...extend a widget?	By **extending** the Widget class and **overriding** the onDraw() method.	You have to extend a class, like in Java, then you will modify the canvas property as mentioned before.
...make 3D drawing?	Of course, you will need to pass through OpenGL ES, which APIs are provided by the Application Framework. In both languages however you will not have the same set of API you will have on a desktop app.	
	Just use the classes of the OpenGL package in the NDK. While it not differs a lot from JOGL or Java3D, you will have a different set of APIs.	Kivy have its own OpenGL wrapper, which offers common APIs on every platform. 3D drawing is currently in a "beta" phase. However, it does not have the same set of API of PyOpenGL.

A Python-Kivy basic Application

```
# -*- coding: utf-8 -*-

from kivy.app import App
from kivy.uix.boxlayout import BoxLayout
from kivy.uix.button import Button
from kivy.uix.gridlayout import GridLayout
from kivy.uix.label import Label
import re

class SimpleCalc( BoxLayout ) :

    def __init__( self, **kargs ) :
        BoxLayout.__init__( self, orientation="vertical" )
        #For layout reason, I put this function in the bottom of the page!
        self.build_window()

    def update( self, instance ) :
        self.lblDisplay.text += instance.text

    def clear( self, instance ) :
        self.lblDisplay.text = ""

    def calc( self, instance ) :
        self.lblDisplay.text = str( eval(self.lblDisplay.text) )

class SimpleCalcApp( App ) :

    title = 'Simple Calc'

    def build( self ) :
        return SimpleCalc()

    def on_pause( self ) :
         return True

if __name__ in [ "__android__", "__main__" ] :
    SimpleCalcApp().run()
```

Screenshots



And here are the missing functions

```
#Build a set of bottons and add them to the given layout.
def names_to_buttons( names, op, targetLayout ) :
    for name in names :
        b = Button( text=str(name), font_size=24 )
        b.bind( on_press=op )
        targetLayout.add_widget( b )

#Build all the widget of the window
def build_window( self ) :

    #Kivy's Label supports unicode texts and bbcode for text makeup!!
    self.lblDisplay = Label( text="", \
                             size_hint=(1, 0.3), \
                             font_size=28
                           )

    #A container for the buttons
    buttons = GridLayout( cols=4, size_hint=(1, 0.7) )

    #Generating labels for the buttons
    names = [ "+", "-", "*", "/" ] + list( range( 1, 10 ) )+["0", "."]

    #Generating the buttons
    names_to_buttons( names, self.update, buttons )

    #A button to commit operations
    btnCalc = Button( text="=", size_hint=(1, 0.15), font_size=24  )
    btnCalc.bind( on_press=self.calc )

    #A button to clear all
    btnClear = Button( text="Clear", size_hint=(1, 0.15), font_size=24  )
    btnClear.bind( on_press=self.clear )

    #Adding all this widget to the main one
    self.add_widget( self.lblDisplay )
    self.add_widget( buttons )
    self.add_widget( btnCalc )
    self.add_widget( btnClear )
```

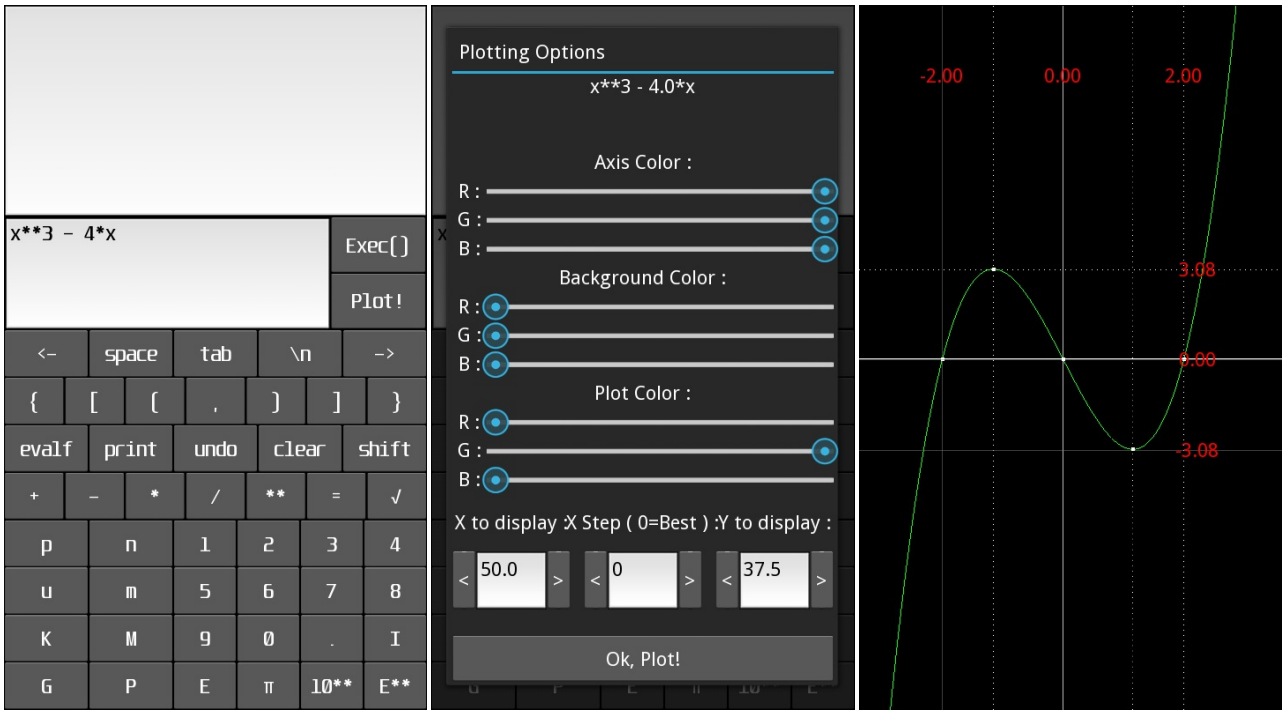
A Python more complex example

This is a programmable scientific calculator, written in pure python using kivy and sympy.
The program does no more than sending some input code to an istance of the python interpreter running a custom version of sympy.
Just this thing is the main point, it allows you to run python script in the calculator.
The gui is designed to run in portrait mode on android, but it is fully cross platform.
The program is also able to plot some graphics.

This source is also avaiable on... **Play Store** and **Github**

- **Keys Layout**
- **Some custom widget**
  - **Python side**
  - **Kv-Language Side**
- **The input Interpreter**
- **The Plotter Widget**
  - **Python Side**
  - **Kv-Language Side**

Screenshots



Conclusion

<table>
<tr><th>Parameter</th><th>Java</th><th>Python</th></tr>
<tr><td>Startup time</td><td>Irrilevant.</td><td>It depends from the content of the Python distribution.
Heavy libraries, such as sympy, could take time for be unpacked!</td></tr>
<tr><td>Efficiency</td><td colspan="2">Both the languages are compiled in Dalvik Bytecode.
The question then becomes delicate.
As Java is the "official language" for Android programming, it suppose to be more efficient.</td></tr>
<tr><td rowspan="2">Hardware acceleration</td><td colspan="2">Android 1.0 - OpenGL ES 1.0 support.
Android 2.2 - OpenGL ES 2.0 support.
Android 3.0 - Hardware-Accelerated 2D drawing.
Android 4.1 - Project Butter (Hardware Acceleration and Triple-Buffer for the GUI)</td></tr>
<tr><td>Native support through the Android SDK.</td><td>Support through pyjnius and Kiby wrappers.</td></tr>
<tr><td>Source compability</td><td>In a certain range of Android API levels.</td><td>Without changing a single line of code :
Android 2.3 and newer
Window Vista and newer
Mac OS X
Various Linux distributions</td></tr>
<tr><td>Support</td><td>Java is a de-facto standar of development, both for desktop and mobile application.
Almost everything a programmer needs has yet be done.</td><td>Kivy is yet stable but begins just in these days to be used.
That means there is a poor support for most things.</td></tr>
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