Context-oriented Programming for Mobile Devices: JCop on Android

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Outline

Context of mobile applications

- Location
- Battery status
- Network availability and bandwidth
- Airplane mode, Silent mode

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- Network availability and bandwidth
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- Date and Time
- User language and preferences
- Mobile device (screen resolution, processor speed, ...)
- etc.

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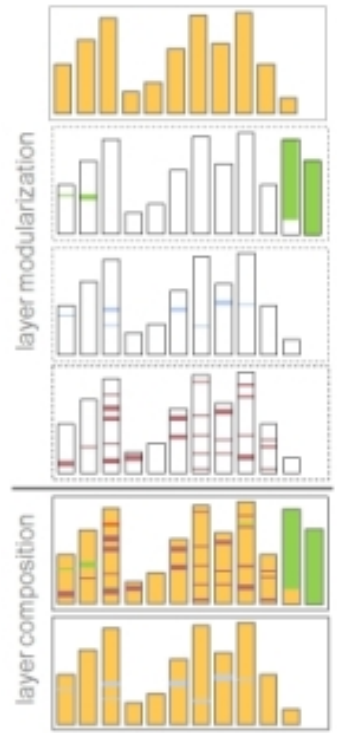
$\Rightarrow$ Let's explore how to provide COP for Android!

JCop[1]

- COP extension to Java



[1] Malte Appeltauer et al. "Event-specific software composition in context-oriented programming". In: *Proceedings of the 9th International Conference on Software Composition*. Lecture Notes in Computer Science. Malaga, Spain: Springer-Verlag, 2010, pp. 50–65. ISBN: 3-642-14045-9, 978-3-642-14045-7.

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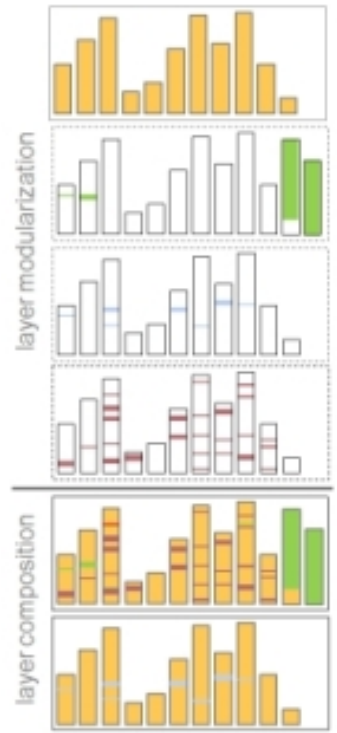

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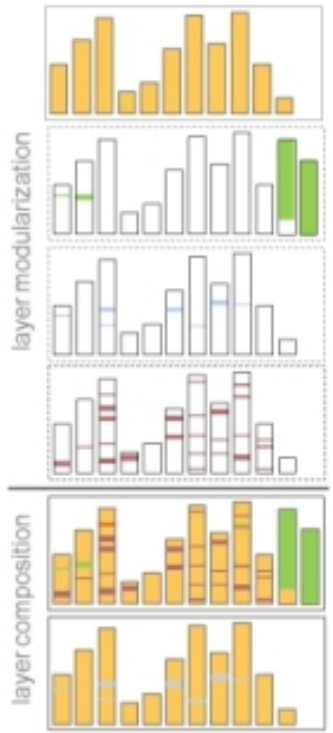

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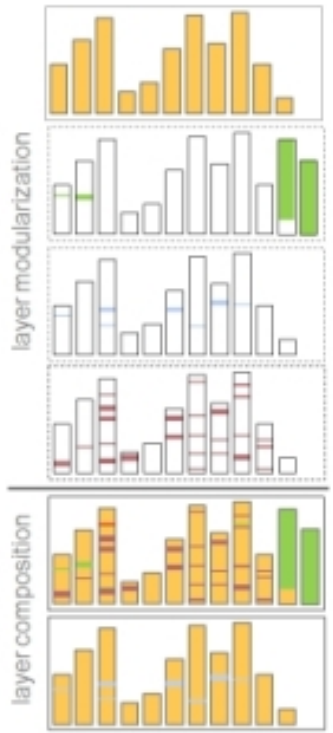
- COP extension to Java
- Behavioral variations as partial methods in layers
- Layer activation/deactivation
  - either explicit (using **`with`**)
  - or declarative (using a context object and pointcuts)



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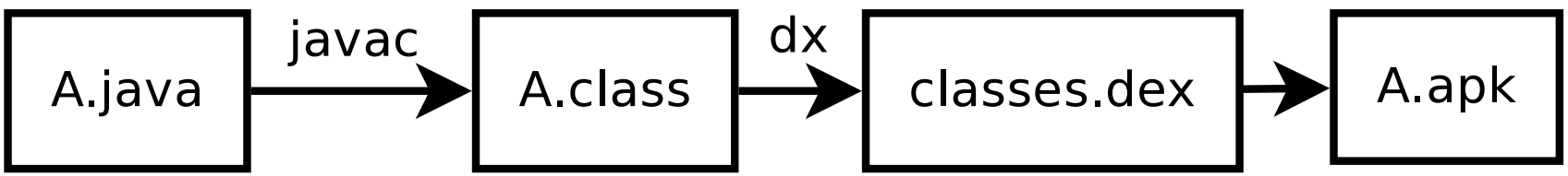
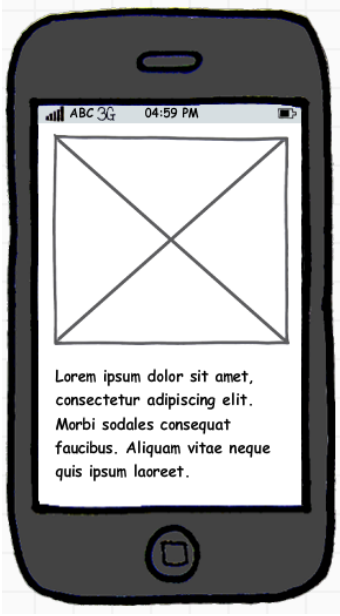
Android[2] overview

- Linux-based open source software stack for mobile devices
- Java as intended language for application developers
  - besides Scala, JRuby and native C libraries
- Application code needs to subclass and implement certain Android classes to fit in the framework



[2] Android is a trademark of Google Inc.

Example application: Astronomy Picture of the Day




```
class Main extends Activity {
  void onCreate(..) {
    super.onCreate(savedInstanceState);
    setContentView(R.layout.main);
    new DownloadEntryTask().execute(this);
  }
}
class DownloadEntryTask extends AsyncTask {
  Entry doInBackground(..) {
    client = AndroidHttpClient.newInstance()
    Entry e = loadEntry();
    loadPicture(e);
  }
}
```

Basic Android concepts

Activity

- include graphical user interface
- usually starting point of an application
- cannot execute blocking calls

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No network available

- Current implementation would fail silently
- Traditional implementation would have to use conditional statements

Challenges for a JCop-Android Integration

- Thread control done by Android and separated into GUI and blocking threads
- Framework approach based on callbacks
- Technical limitations
  - No custom classloaders
  - No dynamic code generation
  - No bytecode manipulation
- `dx` tool makes certain assumptions
  - private method calls and constructors will never use the virtual method table
  - certain class flags are not used

Static contexts

Problem:

- Callbacks make control flow-based `with` context activation difficult
- Explicit context activation hard due to lack of control over thread creation
- Most context-dependent behavior in mobile applications driven by external events and information from the environment like sensor data

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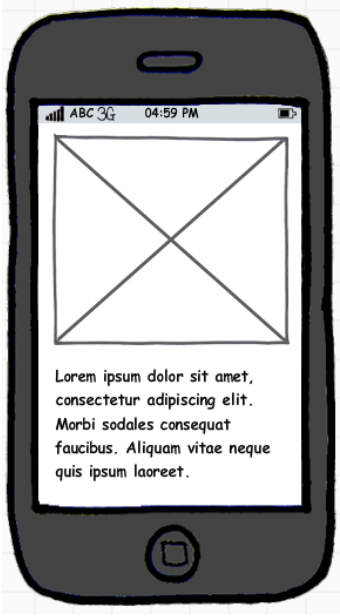
Our proposed solution:

- Language extension to change context activation
- **`static`** context is assumed to be always active
- Declarative layer activation by using **`when`** statements and pointcuts

Example application with JCop




```
Entry e = loadEntry(main);
loadPicture(e, main);

public layer OfflineEntry {
 public Entry DownloadEntryTask
                .loadEntry(Context ctx) {
  return new Entry("No network available");
 }
}

public static context NetworkContext {
 when (!Network.connected()) {
  with (OfflineEntry);
 }
}
```

Demo

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Evaluation

- COP successfully applied to the example application
- JCop processes the bytecode of the application ⇒ works on Android 2.3 and later
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  - But evaluated whether overhead is *feasible*
  - Compared runtime performance for simple code snippit with three different implementation strategies

Results of the performance evaluation

Approach	Runtime
No context-dependency	2901ms
Conditional `if` branching	2959ms
JCop on Android	3450ms

Table: Measured runtime performance[3]

- JCop adds additional overhead for layer management
- Implementation on Android not significantly different
- Measured runtime performance still within reasonable limits

[3] Virtual Android 2.3.1 device inside the Android Emulator on an Intel Core Duo processor with 1.66 GHz running a Linux 2.6.35 kernel

Future Work

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- Evaluate effects of COP on code quality and modularization by using code metrics
  - e.g. lines of code, cyclomatic complexity or class cohesion
- Adding additional, more complex, types of context variables like GPS location or user preferences

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- Successfully used JCop to implement an Android application
- JCop's pointcuts and `static` contexts useful for modifying behavior without relying on the application's control flow
- Initial results for performance evaluation look reasonable
- Applying COP to mobile applications seems promising
- Further research possible for location-based applications

Appendix: Static behavior adaptation

- Repeated execution of one method
- Statically changed after 1000 invocations

```
for (i = 0; i < 1000; i++) {
  countFromZero();
}
for (i = 0; i < 1000; i++) {
  countFromOne();
}
```

- Average measured runtime: 2901ms

Appendix: Conditional behavior adaptation

- Repeated execution controlled by an **if** statement

```
boolean state = false;
for (int i = 0; i < 2000; i++) {
  if (i == 1000) {
    state = true;
  }
  if (state) {
    countFromOne();
  } else {
    countFromZero();
  }
}
```

- Average measured runtime: 2959ms

Appendix: Behavior adaptation by JCop on Android

- Variations in the repeated execution by using JCop

```
GlobalState.setActive(false);
for (int i = 0; i < 2000; i++) {
  if (i == 1000) { GlobalState.setActive(true); }
  countZero();
}
public layer CountLayer {
  public int Main.countZero() {
    Main.CountOne();
}}
public static context CountContext {
  when (GlobalState.isActive()) {
    with (CountLayer);
}}
```

- Average measured runtime: 3450ms