CAreDroid: Adaptation Framework for Android Context-Aware Applications

Salma Elmalaki
Lucas Wanner
Mani Srivastava

Networked & Embedded Systems Laboratory
Computing … From Isolation to Awareness
eCompass

Magnetometers

Sense

Touch Sensors

Accelerometers

Altimeter / Pressure
Sense

Understand
"Turn screen brightness down"

It's a little darker now.

Settings

Adapt

Emergency

Understand
Challenges

1. Automatically adapt to the environmental change at runtime.
2. Adaptation should be burden-free for the user.
3. Overhead of reading the environmental context should be small.
What is Context-awareness?

- **ContextOS**: A Context Aware Operating System for Mobile Devices ([GreenCom’13])
- **ErdOS**: Achieving Energy Savings in Mobile ([MobiArch’11])
- **ContextOS**: A Context Aware Operating System for Mobile Devices ([GreenCom’13])
- **SymPhoney**: A Coordinated Sensing Flow Execution Engine for Concurrent Mobile Sensing Applications ([SenSys’12])
- **ACE**: Exploiting Correlation for Energy-Efficient and Continuous Context Sensing ([MobiSys’12])
- **Range**: The Latency Accuracy and Battery LAB Abstraction: Programmer Productivity and Energy Efficiency for Continuous Mobile Context Sensing ([OOPSLA’13])
- **Balancing Energy, Latency and Accuracy for Mobile Sensor Applications**

The processes of sense, understand, and adapt are cyclic and integral to context-awareness.
Adaptation Realization

Program

f()

f1()

f2()

f3()

fn()

Context-Aware System

Location

Temperature

Activity

Connectivity

Battery Status

Function Adaptation
Adaptation Realization

Function Adaptation

Program

f()
f1()
f2()
f3()
fn()
Adaptation Realization

Program

f()

f1()

f2()

f3()

fn()

Context-Aware System

Location

Temperature

Activity

Connectivity

Battery Status

Function Adaptation
CAreDroid
Architecture

Usability  Performance
CAreDroid Architecture
CAreDroid Architecture

Sensitivity Config File → app → Context Sensors

Sensitive function registration & config parsing → Adaptation Engine

Application Layer

System Layer
CAreDroid Architecture

Application Layer

System Layer

Context Sensors

Temperature  Energy  Connectivity  …
Sensitivity Configuration File

Method
  <MethodName>AdjustCameraPowerAware</MethodName>
  <priority>1</priority>
  <tag>cameraAdjust</tag>

  <itemName>BatteryCapacity</itemName>
  <vstart>0</vstart>
  <vend>25</vend>

  <mobility>run, walk, still</mobility>
  <wifi>on, off</wifi>

Method
  <MethodName>AdjustCameraWhileRunning</MethodName>
  <tag>cameraAdjust</tag>

  <itemName>BatteryCapacity</itemName>
  <vstart>20</vstart>
  <vend>100</vend>

  <mobility>run</mobility>
  <wifi>on, off</wifi>
Function Registration

- The sensitive function registration part is responsible for:
  - understanding the ranges of operations of each method
  - integrate it in the Android run-time system
Function Registration & Config. Parsing

Normal Android flow

CAreDroid flow

Development time

Sensitive function registration & config parsing

Application Layer

System Layer

Temperature

Energy

Connectivity

Context Sensors

Context Monitoring

Adaptation Engine

Sensitive function registration & config parsing

Temperature

Energy

Connectivity

Context Sensors
Function Registration & Config. Parsing

Development time

Normal Android flow

Compilation and packaging time

CAreDroid flow

Sensitivity Config File

Sensitivity Config File

.java

.class

.dex

.apk

Temperature

Energy

Connectivity

Application Layer

System Layer

Adaptation Engine

Context Monitoring

Context Sensors
Function Registration & Config. Parsing

Normal Android flow

Development time

Compilation and packaging time

Installation time

CAreDroid flow
Function Registration & Config. Parsing

<table>
<thead>
<tr>
<th>B-Range</th>
<th>ORI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 → 100</td>
<td>1</td>
</tr>
<tr>
<td>20 → 30</td>
<td>2</td>
</tr>
<tr>
<td>10 → 20</td>
<td>3</td>
</tr>
<tr>
<td>30 → 100</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S-Range</th>
<th>ORI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 → 2</td>
<td>1</td>
</tr>
<tr>
<td>1 → 4</td>
<td>2</td>
</tr>
<tr>
<td>2 → 3</td>
<td>3</td>
</tr>
<tr>
<td>0 → 3</td>
<td>4</td>
</tr>
</tbody>
</table>

Compilation and packaging time

Normal Android Flow

CAreDroid Flow

Normal Android Flow

Installation time

intercept

Replacement Map

Table of Range Identifiers

Extended .odex
1. **Battery state**: capacity, temperature, voltage
2. **Connectivity state**: WiFi connection status, WiFi link quality, RSSI received signal strength indication
3. **Location**: GPS location
4. **Mobility**: run, walk, still

- Bypassing the **HAL layer** and the associated **sensor managers**.
- Snooping on the interface between the HAL and the low-level device drivers through the sysfs virtual file system.
Adaptation Engine

It is where the **method replacement** happens at runtime.
Adaptation Engine

Normal Android flow

invoke-virtual-quick

Dalvik Interpreter

Class ID, Method ID

Class Virtual Table

Execute method

Pointer to method byte code

Application Layer

System Layer

Temperature
Energy
Connectivity

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Context Sensors

Temperature
Energy
Connectivity

Adaptation Engine

Copyright (c) 2015
Adaptation Engine

Normal Android flow

invoke-virtual-quick

Dalvik Interpreter

Class ID, Method ID

Class Virtual Table

Execute method

Pointer to method byte code
Adaptation Engine

Normal Android flow

invoke-virtual-quick

Dalvik Interpreter

CAreDroid Dalvik Interpreter Extension

Class ID, Method ID

intercept

Class Virtual Table

Class ID, Replaced Method ID

Execute method

Pointer to method byte code

Current Context

CAreDroid flow

 Replace Map

Table of Range Identifiers

Operation Range Identifiers

CAreDroid Decision Graph

Replacement Cache update cache

cache miss

cache hit

Temperature Energy Connectivity

Application Layer

System Layer

Context Sensors

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Application Layer

System Layer

Context Sensors

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Sensitive Cards File
Adaptation Engine

invoke-virtual-quick

Normal Android flow

Dalvik Interpreter

Class ID, Method ID

intercept

Class Virtual Table

CAreDroid Dalvik Interpreter Extension

Class ID

Operation Range Identifiers

Replacement Map

Table of Range Identifiers

Current Context

CAreDroid Decision Graph

Class ID, Replaced Method ID

Execute method

Pointer to method byte code
Normal Android flow

invoke-virtual-quick

Dalvik Interpreter

Class ID, Method ID

intercept

Class Virtual Table

CAreDroid Dalvik Interpreter Extension

Table of Range Identifiers

Replacement Map

CAreDroid Decision Graph

Execute method

Pointer to method byte code

Class ID, Replaced Method ID

Current Context

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

System Layer

Temperature

Energy

Connectivity

System Layer

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Adaptation Engine

Application Layer

Sensitivity Config File

Sensitive function registration & config parsing

Adaptation Engine
Adaptation Engine

invoke-virtual-quick

Normal Android flow

CAreDroid flow

invoke-virtual-quick

Class ID, Method ID

intercept

Class Virtual Table

CAreDroid Decision Graph

Table of Range Identifiers

Replacement Map

Current Context

Execute method

Pointer to method byte code

Class ID, Replaced Method ID

Application Layer

Temperature

Energy

Connectivity

System Layer

Context Sensors

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

Temperature

Energy

Connectivity

Temperature

Energy

Connectivity

Application Layer

System Layer

Adaptation Engine

Context Monitoring

Sensitive function registration & config parsing

CAreDroid flow

Normal Android flow
Adaptation Engine

Class Virtual Table

Best Fit policy
Must Fit policy

Execute method

Pointer to method byte code

Class ID, Replaced Method ID

CAreDroid Decision Graph

M1 | M2 | M3 | M4 | M5
---|----|----|----|----
1  | 2  | 3  | 4  | 5  
2  | 3  | 4  | 1  | 2  
1  | 4  | 2  | 3  | 4  
1  | 2  | 3  | 4  | 5  
2  | 2  | 1  | 3  | 3  
4  | 3  | 2  | 1  | 2  
2  | 3  | 3  | 1  | 2  
1  | 4  | 3  | 2  | 3  

Application Layer
- Sensitive function registration & config parsing
- Adaptation Engine
- Context Monitoring
  - Temperature
  - Energy
  - Connectivity

System Layer
- Sensitive function registration & config parsing
- Context Monitoring

Adaptation Engine
- Temperature
- Energy
- Connectivity

Best Fit policy
Must Fit policy
Adaptation Engine

invoke-virtual-quick

Normal Android flow

Dalvik Interpreter

Class ID, Method ID

intercept

Class Virtual Table

CAreDroid Dalvik Interpreter Extension

Operation Range Identifiers

Replacement Map

Table of Range Identifiers

CAreDroid Decision Graph

Current Context

CAreDroid flow

Execute method

Pointer to method byte code

Class ID, Replaced Method ID

App

Context Sensors

Temperature

Energy

Connectivity

Application Layer

System Layer

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Adaptation Engine

invoke-virtual-quick

Normal Android flow

Dalvik Interpreter

Class ID, Method ID

intercept

Class Virtual Table

CAreDroid Dalvik Interpreter Extension

Operation Range Identifiers

Replacement Map

Table of Range Identifiers

CAreDroid Decision Graph

Current Context

Copyright (c) 2015

CAreDroid flow

App

Context Sensors

Temperature

Energy

Connectivity

Application Layer

System Layer

Sensitive function registration & config parsing

Adaptation Engine

Context Monitoring

Temperature

Energy

Connectivity

Adaptation Engine

invoke-virtual-quick

Normal Android flow

Dalvik Interpreter

Class ID, Method ID

intercept

Class Virtual Table

CAreDroid Dalvik Interpreter Extension

Operation Range Identifiers

Replacement Map

Table of Range Identifiers

CAreDroid Decision Graph

Current Context

Copyright (c) 2015
Adaptation Engine

invoke-virtual-quick

Normal Android flow

Dalvik Interpreter → Class Virtual Table

CAreDroid Dalvik Interpreter Extension → Resolution Cache

Class ID, Method ID → Cache hit/miss

Class ID, Replaced Method ID → Resolution Cache

Current Context

Execute method

Pointer to method byte code

CAreDroid Decision Graph

Class ID, Replaced Method ID

update cache

cache hit/miss

Operation Range Identifiers

Table of Range Identifiers

Replacement Map

invoke-virtual-quick

Class ID, Method ID

intercept
Evaluation

1. Push context monitoring and adaptation to runtime system
2. At least 2x fewer lines of code
3. At least 10× more efficient in execution time
Context-aware Camera

Still position
Context-aware Camera

Still position

Walking (non-context aware)
Context-aware Camera

Still position

Walking (non-context aware)

Walking (With CAreDroid)
## Analysis - Significant Line of Code (SLOC)

<table>
<thead>
<tr>
<th>Platform</th>
<th>SLOC</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-context aware (Base)</td>
<td>277</td>
<td>-</td>
</tr>
<tr>
<td>Context-aware (Pure Java)</td>
<td>782</td>
<td>182%</td>
</tr>
<tr>
<td>CAreDroid</td>
<td>277 + 133&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48%</td>
</tr>
</tbody>
</table>

<sup>a</sup>XML Configuration file
Analysis of CAreDroid

1. Analyze the effect of cache in the adaptation engine
2. Examine the overhead of context-monitoring module
3. The difference in energy and execution time between pure Java implementation using Android APIs and CAreDroid
Testbed and testing environment

• Nexus 4

• Android 4.2 - API 17

• Overhead of system image is 4.6%
### Analysis—Execution time

#### CPU time (ms)

<table>
<thead>
<tr>
<th>Platform</th>
<th>Method time</th>
<th>Decision Tree</th>
<th>Context Monitoring (parallel thread)</th>
<th>Total</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>without cache</td>
<td>with cache</td>
<td></td>
<td>without cache</td>
</tr>
<tr>
<td>Non-context aware (Base)</td>
<td>f1</td>
<td>8.322</td>
<td>-</td>
<td>8.322</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>f2</td>
<td>16.372</td>
<td>-</td>
<td>16.372</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>f3</td>
<td>13.375</td>
<td>-</td>
<td>13.375</td>
<td>-</td>
</tr>
<tr>
<td>Context aware (Pure Java)</td>
<td>f1</td>
<td>8.322</td>
<td>0.227</td>
<td>5.093</td>
<td>13.642</td>
</tr>
<tr>
<td></td>
<td>f2</td>
<td>16.372</td>
<td>0.776</td>
<td>5.093</td>
<td>25.471</td>
</tr>
<tr>
<td></td>
<td>f3</td>
<td>13.375</td>
<td>0.351</td>
<td>5.093</td>
<td>18.819</td>
</tr>
<tr>
<td>CAreDroid (Must Fit)</td>
<td>f1</td>
<td>8.322</td>
<td>0.183</td>
<td>0.336</td>
<td>8.841</td>
</tr>
<tr>
<td></td>
<td>f2</td>
<td>16.372</td>
<td>0.335</td>
<td>0.336</td>
<td>17.543</td>
</tr>
<tr>
<td></td>
<td>f3</td>
<td>13.375</td>
<td>0.198</td>
<td>0.336</td>
<td>13.909</td>
</tr>
<tr>
<td>CAreDroid (Best Fit)</td>
<td>f1</td>
<td>8.322</td>
<td>0.183</td>
<td>0.336</td>
<td>8.841</td>
</tr>
<tr>
<td></td>
<td>f2</td>
<td>16.372</td>
<td>0.732</td>
<td>0.336</td>
<td>17.635</td>
</tr>
<tr>
<td></td>
<td>f3</td>
<td>13.375</td>
<td>0.489</td>
<td>0.336</td>
<td>14.213</td>
</tr>
</tbody>
</table>

Average of 10 executions with variance 0.5% ~ 1%
Analysis — Energy

1. CAreDroid consumes only 6.73% more energy compared with the non-context aware implementation and
2. CAreDroid gives 69.33% energy saving compared to the pure Java implementation.
3. Measurements are taken every 5 seconds. Average is shown with variance < 1%
Future Work

1. Migrate to new versions of Android that are based on ART instead of Dalvik (Kitkat and Lollipop).

2. Add support for more abstract contexts, for example, stress, smoking, fitness, ... etc

3. The adaptation can be privacy-aware.

4. Time of the day is another axis that can be used to enhancing the adaptation support
Thank you!

http://www.seas.ucla.edu/~salma/
Keeping the developer/user in the loop

• Make the user *not* fully obfuscated

  • Why this adaptation takes place?

  • Special CAreDroid API - "read_operating_point()"