Mosaic: Cross-platform User-interaction Record and Replay for the Fragmented Android Ecosystem

Matthew Halpern, Yuhao Zhu, Ramesh Peri*, Vijay Janapa Reddi
Department of Electrical and Computer Engineering, UT Austin
*Intel Corporation

ISPASS - March 31st, 2015
Building Better Computer Systems
Run faster

Building Better Computer Systems
Building Better Computer Systems

Run faster

Last longer
Building **Better** Computer Systems

- Run **faster**
- Last **longer**
- Be **reliable**
Building Better Computer Systems

- Run faster
- Be cooler
- Less buggy
- More debuggable
- Be reliable
- More fair
- Last longer
- More secure
- Be reliable
Building “Better” Computer Systems
How Do We Know We Are Building “Better” Computer Systems?
How Do We Know We Are Building “Better” Computer Systems?

We compare them.
Quantitative Performance Comparisons
Quantitative Performance Comparisons

System 1

System 2
Quantitative Performance Comparisons

Program

System 1

System 2
Quantitative Performance Comparisons

Program -> System 1

System 1 — Inputs — System 2

System 2
Quantitative Performance Comparisons

Program

System 1

Inputs

System 2

Data

Data
Quantitative Performance Comparisons

Program

System 1

Inputs

System 2

Comparison & Analysis

Insight

Data
### SPEC CPU 2006

```
$ runspec --config <PLATFORM>.cfg --reportable int
Running (#1) 400.perlbench ref base mar21a.native32 default
Running (#1) 401.bzip2 ref base mar21a.native32 default
Running (#1) 403.gcc ref base mar21a.native32 default
Running (#1) 429.mcf ref base mar21a.native32 default
Running (#1) 445.gobmk ref base mar21a.native32 default
Running (#1) 456.hmmer ref base mar21a.native32 default
Running (#1) 458.sjeng ref base mar21a.native32 default
Running (#1) 462.libquantum ref base mar21a.native32 default
Running (#1) 464.h264ref ref base mar21a.native32 default
Running (#1) 471.omnetpp ref base mar21a.native32 default
Running (#1) 473.astar ref base mar21a.native32 default
Running (#1) 483.xalancbmk ref base mar21a.native32 default
Running (#1) 999.specrand ref base mar21a.native32 default
```
SPEC CPU 2006

- Representative
- Repeatable
- Cross-Platform
SPEC CPU 2006

- Representative
- Repeatable
- Cross-Platform

$ runspec --config <PLATFORM>.cfg --reportable int
Running (#1) 400.perlbench ref base mar21a.native32 default
Running (#1) 401.bzip2 ref base mar21a.native32 default
Running (#1) 403.gcc ref base mar21a.native32 default
Running (#1) 429.mcf ref base mar21a.native32 default
Running (#1) 445.gobmk ref base mar21a.native32 default
Running (#1) 456.hmmer ref base mar21a.native32 default
Running (#1) 458.sjeng ref base mar21a.native32 default
Running (#1) 462.libquantum ref base mar21a.native32 default
Running (#1) 464.h264ref ref base mar21a.native32 default
Running (#1) 471.omnetpp ref base mar21a.native32 default
Running (#1) 473.astar ref base mar21a.native32 default
Running (#1) 483.xalancbmk ref base mar21a.native32 default
Running (#1) 999.specrand ref base mar21a.native32 default
SPEC CPU 2006

✓ Representative

• Repeatable

• Cross-Platform
SPEC CPU 2006

✓ Representative
✓ Repeatable
• Cross-Platform
SPEC CPU 2006
✓ Representative
✓ Repeatable
✓ Cross-Platform
SPEC CPU 2006

$ runspec --config <PLATFORM>.cfg --reportable int
Running (#1) 400.perlbench ref base mar21a.native32 default
Running (#1) 401.bzip2 ref base mar21a.native32 default
Running (#1) 403.gcc ref base mar21a.native32 default
Running (#1) 429.mcf ref base mar21a.native32 default
Running (#1) 445.gobmk ref base mar21a.native32 default
Running (#1) 456.hmmer ref base mar21a.native32 default
Running (#1) 458.sjeng ref base mar21a.native32 default
Running (#1) 462.libquantum ref base mar21a.native32 default
Running (#1) 464.h264ref ref base mar21a.native32 default
Running (#1) 471.omnetpp ref base mar21a.native32 default
Running (#1) 473.astar ref base mar21a.native32 default
Running (#1) 483.xalancbmk ref base mar21a.native32 default
Running (#1) 999.specrand ref base mar21a.native32 default
SPEC CPU 2006

$ runspec --config <PLATFORM>.cfg --reportable int
Running (#1) 400.perlbench ref base mar21a.native32 default
Running (#1) 401.bzip2 ref base mar21a.native32 default
Running (#1) 403.gcc ref base mar21a.native32 default
Running (#1) 429.mcf ref base mar21a.native32 default
Running (#1) 445.gobmk ref base mar21a.native32 default
Running (#1) 456.hmmer ref base mar21a.native32 default
Running (#1) 458.sjeng ref base mar21a.native32 default
Running (#1) 462.libquantum ref base mar21a.native32 default
Running (#1) 464.h264ref ref base mar21a.native32 default
Running (#1) 471.omnetpp ref base mar21a.native32 default
Running (#1) 473.astar ref base mar21a.native32 default
Running (#1) 483.xalancbmk ref base mar21a.native32 default
Running (#1) 999.specrand ref base mar21a.native32 default
Mobile Applications Require Interactivity
Mobile Applications Require Interactivity
Mobile Applications

- Representative
- Repeatable
- Cross-Platform
Mobile Applications

- Representative
- Repeatable
- Cross-Platform
Mobile Applications

X Representative

- Repeatable
- Cross-Platform
Mobile Applications

- X Representative
- Repeatable
- Cross-Platform
Mobile Applications

× Representative
× Repeatable
• Cross-Platform

Yuhaoo

Ramesh

Vijay
Mobile Applications

- Representative
- Repeatable
- Cross-Platform
Mobile Applications

× Representative
× Repeatable
× Cross-Platform
Mobile Applications

- Representative
- Repeatable
- Cross-Platform
The Cross-Platform Requirement

Samsung Galaxy S5

Asus Nexus 7
The Cross-Platform Requirement
The Cross-Platform Requirement
The Cross-Platform Requirement
The Cross-Platform Requirement
The Cross-Platform Requirement
The Cross-Platform Requirement

(557, 655)

(1522, 582)
The Cross-Platform Requirement

(557, 655)

1200

3000

(1522, 582)
The Cross-Platform Requirement

(557, 655)

(1522, 582)

1080

1200

1920

3000

18
The Cross-Platform Requirement

Samsung Galaxy S5

Asus Nexus 7
The Cross-Platform Requirement

Samsung Galaxy S5

1080 x 1920

Touchscreen

Asus Nexus 7

3000 x 1200
The Cross-Platform Requirement

Samsung Galaxy S5
- 1080 x 1920
- Smartphone

Asus Nexus 7
- 3000 x 1200
- Tablet
The Cross-Platform Requirement

Samsung Galaxy S5

- 1080 x 1920
- Smartphone
- Android 4.4.2

Asus Nexus 7

- 3000 x 1200
- Tablet
- Android 4.1

Touchscreen

Form Factor
The Cross-Platform Requirement

**Samsung Galaxy S5**
- 1080 x 1920
- Smartphone
- Android 4.4.2
- Touchscreen
- Form Factor
- OS Version

**Asus Nexus 7**
- 3000 x 1200
- Tablet
- Android 4.1
“The Fragmentation Problem”
“The Fragmentation Problem”
Form Factors x Displays x Processors x OS’s x UI’s x Drivers
Interactive Mobile Applications

Inputs

Data

Comparison & Analysis

Insight

Data
Interactive Mobile Applications

User Interactivity

Comparison & Analysis

Insight

Data

Data
Portable user interactivity that is **device agnostic**.
Portable user interactivity that is **device agnostic**.

Representative user interactivity is **device specific**.
Portable user interactivity that is **device agnostic**.

Representative user interactivity is **device specific**.
Portable user interactivity that is device agnostic.

Representative user interactivity is device specific.
Mosaic Makes Interactivity Portable
Mosaic Makes Interactivity Portable

Record
Mosaic Makes Interactivity Portable

Record

Replay
Mosaic Makes Interactivity Portable

✓ Off-the-shelf Mobile Devices
Mosaic Makes Interactivity Portable

✓ Off-the-shelf Mobile Devices
✓ Mainstream Mobile Applications
Mosaic Makes Interactivity Portable
✓ Off-the-shelf Mobile Devices
✓ Mainstream Mobile Applications
✓ Low Overhead
Mosaic Makes Interactivity Portable

✓ Off-the-shelf Mobile Devices
✓ Mainstream Mobile Applications
✓ Low Overhead

Record

Source

Touchscreen Events

Target

Touchscreen Events

Replay
Touchscreen Events
Touchscreen Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Value</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact point 1 found</td>
<td></td>
<td>X-position is at X0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y-position is at Y0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pressure is N</td>
</tr>
<tr>
<td>Interaction has ended</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact point 1 is gone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction has ended</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td></td>
</tr>
</tbody>
</table>
Touchscreen Events

Contact point 1 found
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
Touchscreen Events

Contact point 1 found
X-position is at $X_0$
Y-position is at $Y_0$
Pressure is $N$
Interaction has ended

Interaction has ended
Contact point 1 is gone
Interaction has ended
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Contact point 1 is gone
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Contact point 1 is gone
Interaction has ended
Touchscreen Events

Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Contact point 1 is gone
Interaction has ended
# Touchscreen Events

<table>
<thead>
<tr>
<th>Event Code</th>
<th>Event Value</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS_MT_TRACKING_ID</td>
<td>1</td>
<td>Contact point 1 found</td>
</tr>
<tr>
<td>ABS_MT_POSITION_X</td>
<td>X0</td>
<td>X-position is at X0</td>
</tr>
<tr>
<td>ABS_MT_POSITION_Y</td>
<td>Y0</td>
<td>Y-position is at Y0</td>
</tr>
<tr>
<td>ABS_MT_PRESSURE</td>
<td>N</td>
<td>Pressure is N</td>
</tr>
<tr>
<td>SYN_REPORT</td>
<td>NULL</td>
<td>Interaction has ended</td>
</tr>
<tr>
<td>ABS_MT_POSITION_X</td>
<td>X1</td>
<td>X-position is at X1</td>
</tr>
<tr>
<td>ABS_MT_POSITION_Y</td>
<td>Y1</td>
<td>Y-position is at Y1</td>
</tr>
<tr>
<td>SYN_REPORT</td>
<td>NULL</td>
<td>Interaction has ended</td>
</tr>
<tr>
<td>ABS_MT_TRACKING_ID</td>
<td>-1</td>
<td>Contact point 1 is gone</td>
</tr>
<tr>
<td>SYN_REPORT</td>
<td>NULL</td>
<td>Interaction has ended</td>
</tr>
</tbody>
</table>
## Touchscreen Events

<table>
<thead>
<tr>
<th>Event Code</th>
<th>Event Value</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS_MT_TRACKING_ID</td>
<td>1</td>
<td>Contact point 1 found</td>
</tr>
<tr>
<td>ABS_MT_POSITION_X</td>
<td>X0</td>
<td>X-position is at X0</td>
</tr>
<tr>
<td>ABS_MT_POSITION_Y</td>
<td>Y0</td>
<td>Y-position is at Y0</td>
</tr>
<tr>
<td>ABS_MT_PRESSURE</td>
<td>N</td>
<td>Pressure is N</td>
</tr>
<tr>
<td>SYN_REPORT</td>
<td>NULL</td>
<td>Interaction has ended</td>
</tr>
<tr>
<td>ABS_MT_POSITION_X</td>
<td>X1</td>
<td>X-position is at X1</td>
</tr>
<tr>
<td>ABS_MT_POSITION_Y</td>
<td>Y1</td>
<td>Y-position is at Y1</td>
</tr>
<tr>
<td>SYN_REPORT</td>
<td>NULL</td>
<td>Interaction has ended</td>
</tr>
<tr>
<td>ABS_MT_TRACKING_ID</td>
<td>-1</td>
<td>Contact point 1 is gone</td>
</tr>
<tr>
<td>SYN_REPORT</td>
<td>NULL</td>
<td>Interaction has ended</td>
</tr>
</tbody>
</table>
Touchscreen Event Differences
Touchscreen Event Differences
Touchscreen Event Differences

ABS_MT_TRACKING_ID
ABS_MTPOSITION_X
ABS_MTPOSITION_Y
ABS_MTPRESSURE
SYN_REPORT

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MTPOSITION_X
ABS_MTPOSITION_Y
ABS_MTTOUCH_MAJOR
ABS_MTTOUCH_MINOR
SYN_REPORT
Touchscreen Event Differences

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
SYN_REPORT

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
SYN_REPORT
Touchscreen Event Differences

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
SYN_REPORT
ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
SYN_REPORT
ABS_MT_TRACKING_ID
BTN_TOUCH
SYN_REPORT
ABS_MT_TRACKING_ID
BTN_TOUCH
# Touchscreen Event Differences

<table>
<thead>
<tr>
<th>ABS_MT_TRACKING_ID</th>
<th>ABS_MT_TRACKING_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTN_TOUCH</td>
<td>BTN_TOUCH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ABS_MT_POSITION_X</th>
<th>ABS_MT_POSITION_X</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS_MT_POSITION_Y</td>
<td>ABS_MT_POSITION_Y</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ABS_MT_PRESSURE</th>
<th>ABS_MT_PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYN_REPORT</td>
<td>SYN_REPORT</td>
</tr>
<tr>
<td>ABS_MT_POSITION_X</td>
<td>ABS_MT_POSITION_X</td>
</tr>
<tr>
<td>ABS_MT_POSITION_Y</td>
<td>ABS_MT_POSITION_Y</td>
</tr>
<tr>
<td>SYN_REPORT</td>
<td>SYN_REPORT</td>
</tr>
<tr>
<td>ABS_MT_TRACKING_ID</td>
<td>ABS_MT_TRACKING_ID</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYN_REPORT</th>
<th>SYN_REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTN_TOUCH</td>
<td>BTN_TOUCH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYN_REPORT</th>
<th>SYN_REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTN TOUCH</td>
<td>BTN TOUCH</td>
</tr>
</tbody>
</table>
How Mosaic Makes Interactivity Portable

Record
Source
Touchscreen Events

MOSAIC

Target
Touchscreen Events

Replay
Touchscreen Driver

Source
Touchscreen Events

Target
Touchscreen Events
Touchscreen Driver

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
Touchscreen Driver

Virtualized Interactivity

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT

BTN_TOUCH
ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
Touchscreen Driver

Virtualized Interactivity

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT

Press XYX YXY

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
Virtualized Interactivity

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT

Press XYX YXY

BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
Touchscreen Driver

Virtualized Interactivity

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT

Press XXY YXY

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
Touchscreen Driver

Virtualized Interactivity

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT

Press XYX YXY

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
**Touchscreen Driver**

**Virtualized Interactivity**

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT

Press XYX YXY

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
Touchscreen Driver

Virtualized Interactivity

ABS_MT_TRACKING_ID
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_PRESSURE
SYN_REPORT
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
SYN_REPORT

Press XYX YXY
Move XYX YXY

BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
SYN_REPORT
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
SYN_REPORT
Virtualized Interactivity

ABS_MT_TRACKING_ID  Press XYX YXY  ABS_MT_TRACKING_ID  BTN_TOUCH
ABS_MT_POSITION_X  ABS_MT_POSITION_X  ABS_MT_POSITION_X
ABS_MT_POSITION_Y  ABS_MT_POSITION_Y  ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR
ABS_MT_PRESSURE
SYN_REPORT
ABS_MT_POSITION_X  Move XYX YXY  ABS_MT_POSITION_X
ABS_MT_POSITION_Y  ABS_MT_POSITION_Y
SYN_REPORT
ABS_MT_TRACKING_ID  Release  ABS_MT_TRACKING_ID
SYN_REPORT
SYN_REPORT
SYN_REPORT
Virtualizing Interactions
Virtualizing Interactions

• Timing
• Type
• Location
Virtualizing Interactions

- **Timing**
- **Type**
- **Location**

```
time finger <N> <interaction> [[x] [y]]
```
Virtualizing Interactions

✓ Timing

- Type
- Location

time finger <N> <interaction> [[x] [y]]
Virtualizing Interactions

✓ Timing

- Type

- Location

time finger <N> <interaction> [[x] [y]]
Virtualizing Interactions

✓ Timing • Type • Location

time finger <N> <interaction> [[[x] [y]]]

Press
Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]

Press

Move
Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]

Press
Move
Release
Virtualizing Interactions

✓ Timing

- Type
- Location

time finger <N> <interaction> [[x] [y]]
Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[[x] [y]]]

Press
Virtualizing Interactions

✓ Timing

- Type
- Location

time finger <N> <interaction> [[x] [y]]

Press
Move
Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]

Press

Move

Release
Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]
Virtualizing Interactions

✓ Timing

• Type

• Location

\[ \text{time finger } <N> \ <interaction> \ [ [x] \ [y] ] \]

Press (0%, 0%)

Move

Release (100%, 100%)
How Mosaic Solves The Portability Paradox

* Modifications to emulator needed - see paper for details
Inputs

ARM Cortex-A7

ARM Cortex-A15

Data

Comparison & Analysis

Insight

Data

Program
Program

Inputs

Data

Comparison & Analysis

Insight
Program

Inputs

Comparison & Analysis

Insight

Data

Data
Identifying Microarchitectural Bottlenecks
Identifying Microarchitectural Bottlenecks

![Bar chart showing instructions per cycle for A7 and A15 processors]

- Processor A7: Instructions per Cycle = 0.35
- Processor A15: Instructions per Cycle = 1.0
Identifying Microarchitectural Bottlenecks

Instructions per Cycle

Processor

A7
A15

Miss Rate (%)

Processor

A7
A15

L1 I-Cache
L1 D-Cache
L2 Cache
Branches
Mosaic Assumptions and Requirements
Mosaic Assumptions and Requirements

• Linear UI Scaling
Mosaic Assumptions and Requirements

• Linear UI Scaling
Mosaic Assumptions and Requirements

- Linear UI Scaling
- Repeatable Application Behavior
Mosaic Assumptions and Requirements

• Linear UI Scaling

• Repeatable Application Behavior
Mosaic Assumptions and Requirements

- Linear UI Scaling
- Repeatable Application Behavior
- “Imperceptible” Performance
Mosaic Assumptions and Requirements

Many Applications Meet These Requirements

- Adobe Reader*
- Bubble Bee
- Clash of Lords 2
- Diamond Digger Saga
- Google Play Newsstand
- Legend of Master Online
- Firefox
- Slots - House Of Fun
- Tycoon Mania
- Angry Birds*
- Bubble Blaze
- Clean Master
- Dolphin Browser
- Hill Climb Racing*
- Messenger
- Photo Grid
- Solitaire
- Video Poker
- Big Fish Casino
- Bubble Witch Saga 2
- Coin Dozer
- Five Nights at Freddys
- iHeartRadio
- Minion Rush
- Piano Tiles
- Spider-Man
- Walmart
- Bingo Fever - World Trip
- Chase
- Destiny
- Flashlight*
- Instagram
- MonsterWarlord
- Slotomania
- Steel Avengers
- WatchESPN
- Bingo - Secret Cities
- Chrome*
- DH 2014
- Flipagram
- Jump Ninja
- News & Weather
- Slots Fever
- Temple Run 2*
- YouTube*

Evaluated across several different Android-based platforms

Mobile Devices

Dev Boards

Emulators*

with less than 1% performance and 6 kB memory overheads
Conclusion

- **Mobile device fragmentation** is not only a developer issue, but also complicates mobile systems research.
Conclusion

- Mobile device fragmentation is not only a developer issue, but also complicates mobile systems research.

- We developed a novel user-interaction virtualization technique to overcome device fragmentation.
Conclusion

- **Mobile device fragmentation** is not only a developer issue, but also complicates mobile systems research.

- We developed a **novel user-interaction virtualization technique** to overcome device fragmentation.
Conclusion

- **Mobile device fragmentation** is not only a developer issue, but also complicates mobile systems research.

- We developed a **novel user-interaction virtualization technique** to overcome device fragmentation.

- **Mosaic** enables cross-platform **performance comparisons** that incorporate representative and repeatable user interactivity.
You can checkout Mosaic soon @ https://github.com/matthalph/mosaic