Android Workload Suite (AWS): Measure the software stack of mobile devices

Xiao-Feng Li
xiaofeng.li@gmail.com

Oct, 2011

Thanks to Greg Zhu and Ke Chen

Summary

- Android Workload Suite (AWS) is an engineering tool for Android software stack measurement
  - It uses the software stack metrics to measure the interaction scenarios
- AWS covers the major areas for Android software stack evaluation
  - The key is to map user interactions to system behavior

Agenda

- User interactions measurement
- Interaction scenarios definition
  - Case studies
- Android workloads construction
  - Case studies
- Summary
- Information

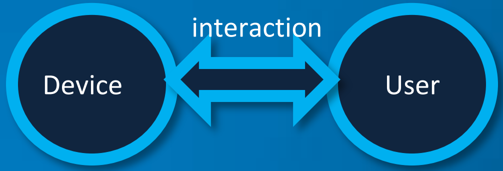
Optimize User Interaction Systematically

- What we need:
  - A well-established methodology
  - An engineering workload suite
  - An analysis/tuning toolkit
  - Sightings/requests/feedbacks from PECA/IXR, xPGs, developers, users, etc.

- (The methodology details are in another deck)
- (The UXtune toolkit details are in another deck)

User Interactions with Client Device

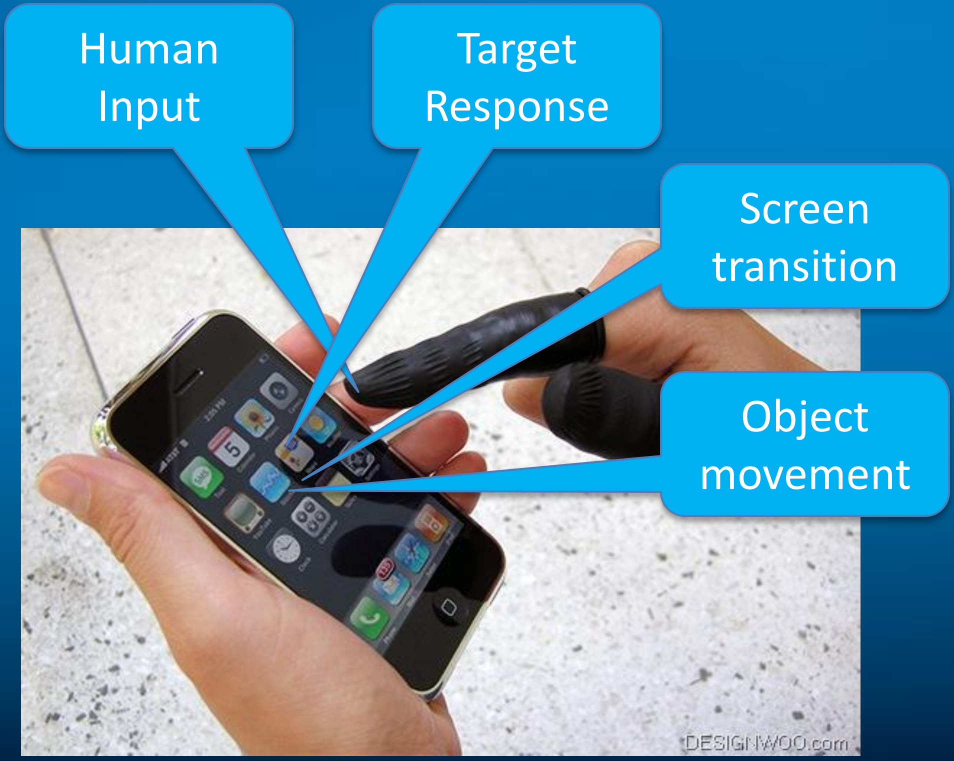
- A sequence of interactions



Device

interaction

User



Human Input

Target Response

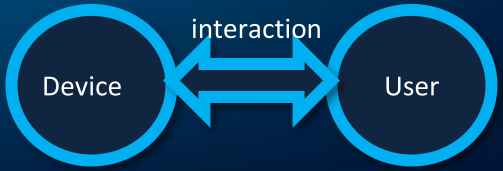
Screen transition

Object movement

- Does the input trigger the target **correctly**?
- Does the system act **responsively**?
- Does the graphics transition **smoothly**?
- Does the object move **coherently**?

Interaction Measurement Aspects

- User controls device (subject → object)
  1. Accuracy/fuzziness: Range/resolution of inputs that can trigger a correct response
  2. Coherence: Object move delay, difference in move trajectory
- Device reacts to user (object → subject)
  3. Responsiveness: Time between an input delivered to the device response, and to the action finish
  4. Smoothness: Maximal frame time, frame time variance, FPS and frame drop rate



Android Workload Suite (AWS)

- Goals
  - Reflect the representative usage of Android client devices
  - Evaluate Performance, Power and User interactions

- AWS usages
  - Drive and validate Android optimizations
  - Support comparative and competitive analysis

AWS

Suite	Workload	#Scenarios	Components
Browser			
Media			
Graphics			
Productivity			
Touch			
Sensors			
Built-in apps			
Task management			

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Understand The Representative Scenarios

- Extensive surveys
  - Feedbacks/inputs from users
  - Public documents from key players
  - Popular applications
  - Form-factor usages (Tablet vs. smart-phone)
  - User interaction life-cycles and software design

Usage Categories: Market and Built-in Apps

Business & Productivity	Office, Video conference, Payment, LBS, Security…
Information & Content	Internet access, Video, Music, Gaming, eBooks…
Communication	Phone, Contacts, SMS, MMS, E-mail, IM, Video phone…
Basic accessibility	Home screen, App launcher, Setting, Touch, Sensor…

Tablet-specific Apps Characteristics

- Larger screen size than phone
  - More realistic view experience (game, cartoon, 3D)
  - Easier or more controls through touch/sensors or virtual controllers (virtual controller, editor, handwriting)
  - Bigger space to put more contents (news, education, ebook)
  - Support more than one players (game, education)
  - PC-experience web access (browser, info portal)
  - More small utilities apps for daily use (on-screen vs. in-pocket)

Phone-specific Apps Characteristics

- Phone as handy gadget as a Swiss-knife
  - Communicator (chat through AV/text/picture)
  - Camera (barcode scanner and photo/video apps)
  - Utility (flashlight, night vision, barcode scanner)
  - Navigation (GPS, compass), music player, Phone
- Smaller size
  - Games are cartoon or lightweight-animation based
  - Relatively simple games with simple sensor controls
  - Many accelerometer-based games
    - Shake to operate (vs. gyroscope-based with Tablet)

Form Factor Consideration in Workload Design

- Some scenarios in AWS may only exist in one form factor, e.g.,
  - Status bar vs. system bar
  - Browser: switch window vs. switch tab
- Same scenario in AWS may have two design variants, e.g.,
  - The 2D game workload has more animated sprites in its tablet profile
  - Browser workload use PC web page on tablet, and _can_ use mobile web page on phone

User Scenario Categories

- User operations
  - Browsing, gaming, authoring, setting/configuring
    - Touch gestures, and sensors
  - Communications
- Loading and rendering
  - Loading:
    - Web page, eBook, image
  - Rendering:
    - Web page, HTML5, eBook, media, 2D/3D
- Task management
  - App launch, Task switch
  - Multi tasking (Parallel execution)

Primary Metrics for User Scenarios

- User operations
  - Browsing, gaming, authoring, setting, communication
  - Responsiveness, smoothness, coherency, accuracy
- Loading and rendering
  - Web/HTML5, eBook, media, image, 2D/3D
  - Responsiveness (loading time, rendering capability), smoothness, coherency, accuracy
- Task management
  - App launch, Task switch, Multi tasking
  - Responsiveness (time to launch/exit), smoothness, coherency, accuracy

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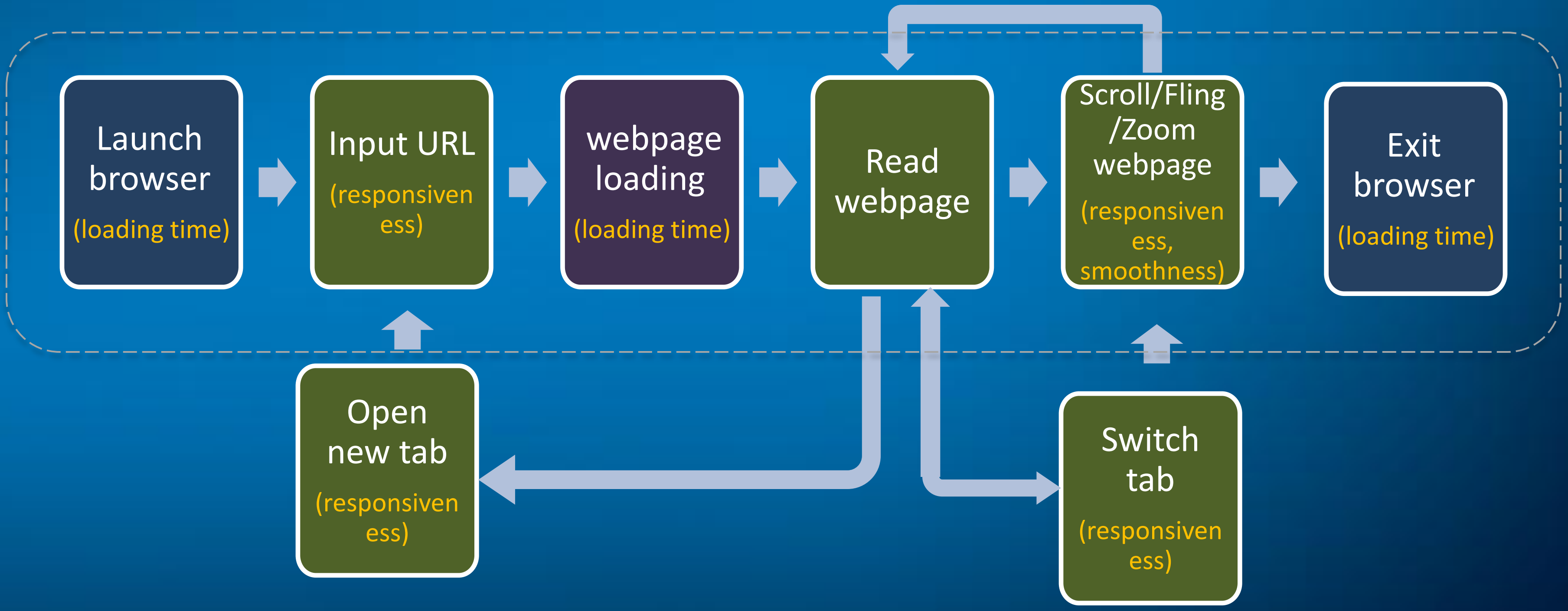
Example of Interaction Lifecycle - Browser

Scenarios on critical path are selected



Launch browser (loading time)

Input URL (responsiveness)

webpage loading (loading time)

Read webpage

Scroll/Fling /Zoom webpage (responsiveness, smoothness)

Exit browser (loading time)

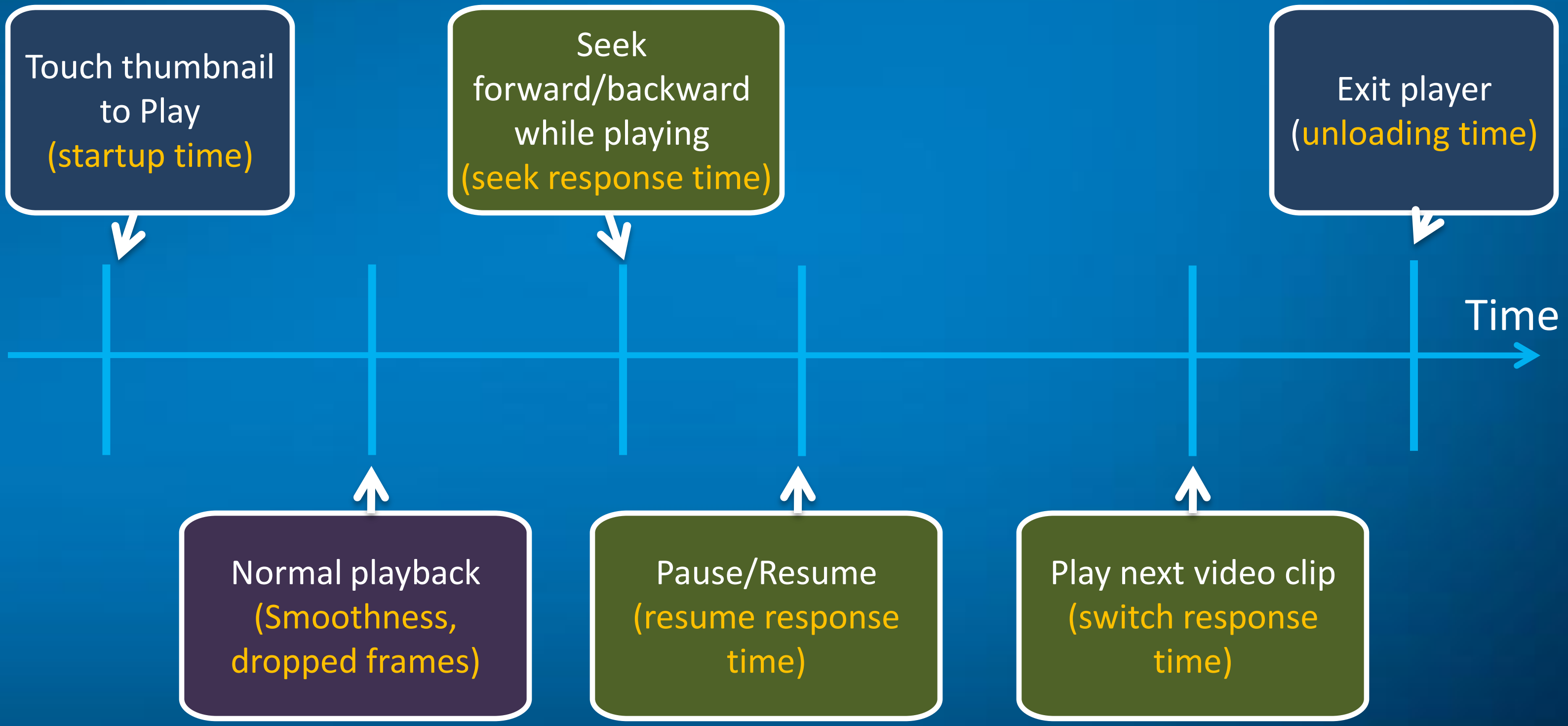
Open new tab (responsiveness)

Switch tab (responsiveness)

User interaction lifecycle is composed with three types of scenarios:

🟩 User operations 🟪 Loading and rendering 🟦 Task management

Example of Interaction Lifecycle - Video Player



Touch thumbnail to Play (startup time)

Seek forward/backward while playing (seek response time)

Exit player (unloading time)

Time

Normal playback (Smoothness, dropped frames)

Pause/Resume (resume response time)

Play next video clip (switch response time)

🟩 User operations 🟪 Loading and rendering 🟦 Task management

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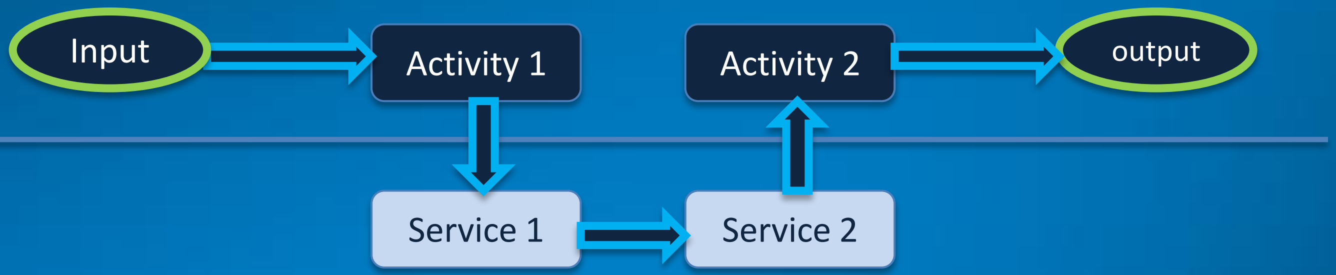
Interaction Measurement Criteria

- Measure the critical path of user interactions in software stack
- Criteria
  - Perceivable (PECA/IXR has the UX perceptual model)
  - Measureable (by different teams)
  - Repeatable (in multiple measurements)
  - Comparable (between different measured systems)
  - Reasonable (about the causality)
  - Verifiable (for an optimization)
  - Automatable (largely unattended, not strictly)

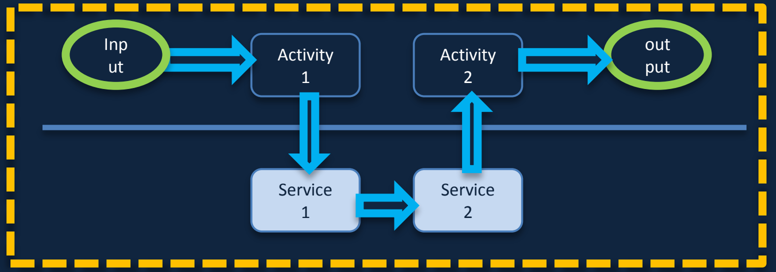
Workloads Construction

- Key is to map user interactions to system behavior
  - Purpose is to assist software optimization instead of simulating user behavior
- Kinds of workloads
  - Standalone workload: Run as full workload and give results
  - Micro workload: Stress certain execution paths of the stack
  - Measurement tool: Allow manual operation and get metrics
  - Scenario driver of built-in app: only give inputs and extract metrics

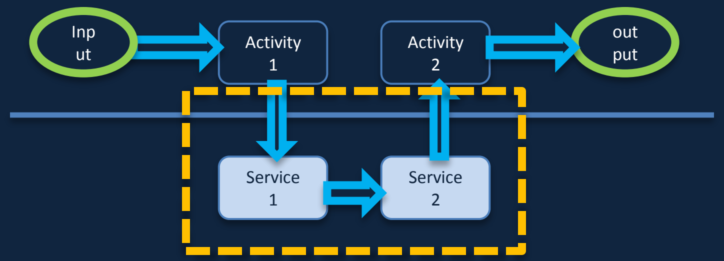
Kinds of Workloads



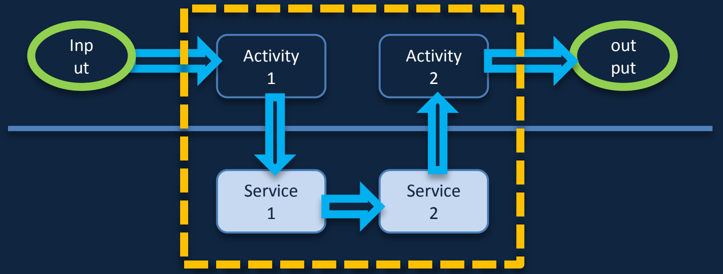
1. Standalone workload



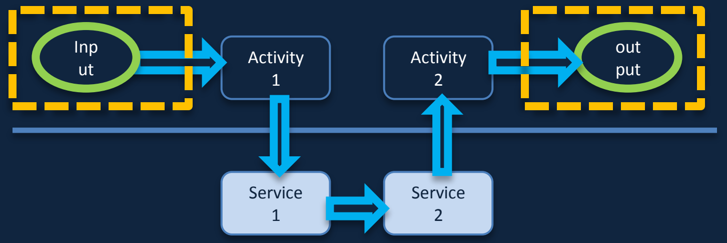
2. Micro workload



3. Measurement tool



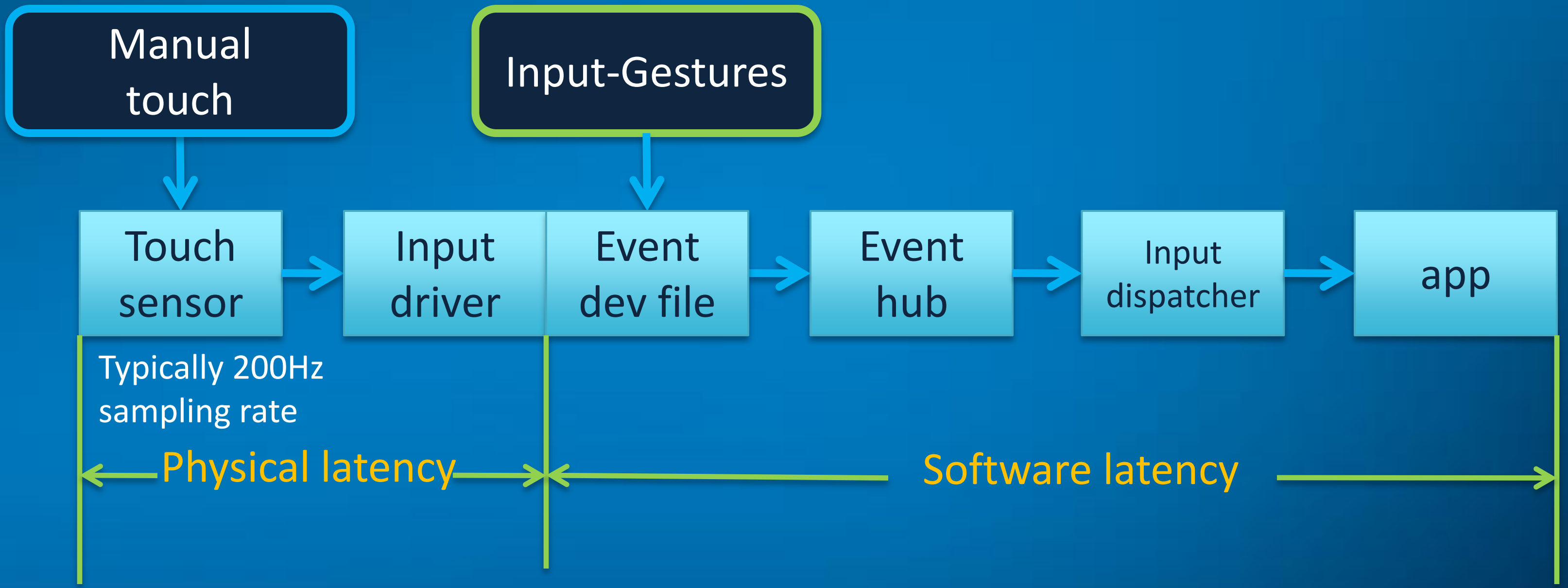
4. Scenario driver



Challenges in Workload Construction

- How to measure response time of user inputs?
- How to measure smoothness?
- How to measure drag coherence?
- How to make the results repeatable?
- How to make the workload comparable across platforms?
- Etc.

Challenge1: Response Time Measurement

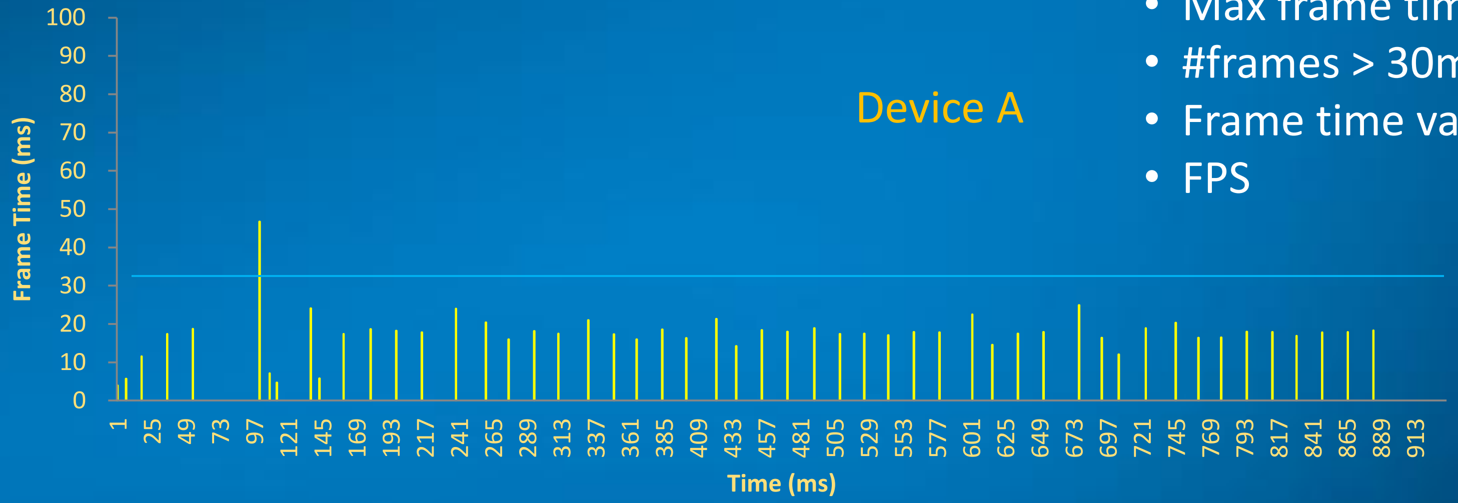


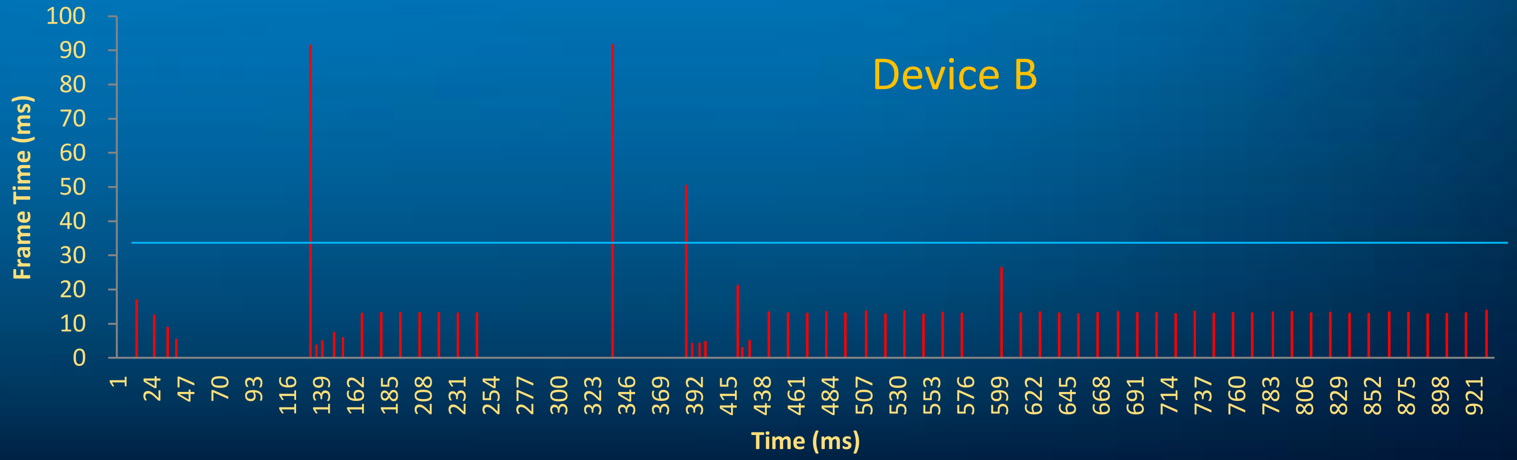
- Software latency is our optimization focus
  - Software latency is around x100ms
  - Touch sampling rate is typically 200HZ (5ms interval)

Challenge2: Smoothness Measurement

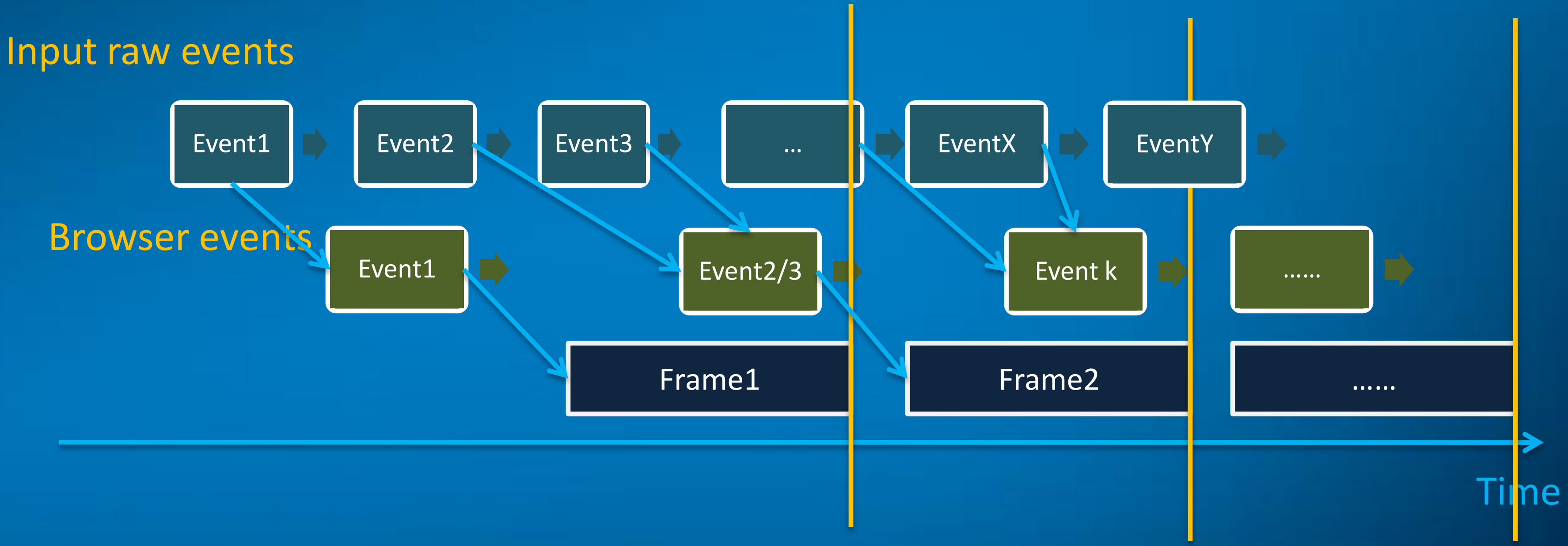
Notice the followings:

- Max frame time
- #frames > 30ms
- Frame time variance
- FPS





Challenge3: Drag Coherence Measurement



Distances[k] = {Touch[i].pos – Draw[k].pos |
Touch[i].t<=Draw[k+1].t AND Touch[i].t>Draw[k].t}

Coherency = Max({Max(Distances[k]) | k=0,…,N})

Challenge4: Repeatable Results

- Use Input-Gesture tool to generate standard touch gestures for inputs
- Ensure the generated gestures are comparable across different platforms

Events of same gesture on Device X

```
1000000000 3 48 1
1000000010 3 53 3284
1000000020 3 54 2747
1000000030 0 2 0
1000000040 0 0 0
1000005000 3 48 1
1000005010 3 53 3284
1000005020 3 54 2735
```

Events of same gesture on Device Y

```
1000000000 3 48 1
1000000010 3 53 1810
1000000020 3 54 1515
1000000030 0 2 0
1000000040 0 0 0
1000005000 3 48 1
1000005010 3 53 1810
1000005020 3 54 1508
```

Challenge5: Comparable Across Platforms

- For example, browser workloads
  - Different platforms may have different built-in browsers
- Depending on the measurement purpose
  - If for rendering engine comparison, use standard contents (web pages or Javascripts)
  - If for app operation comparison, use “scenario driver” generated by input-Gestures
  - If for framework comparison, build a “standalone browser” and install to target platforms

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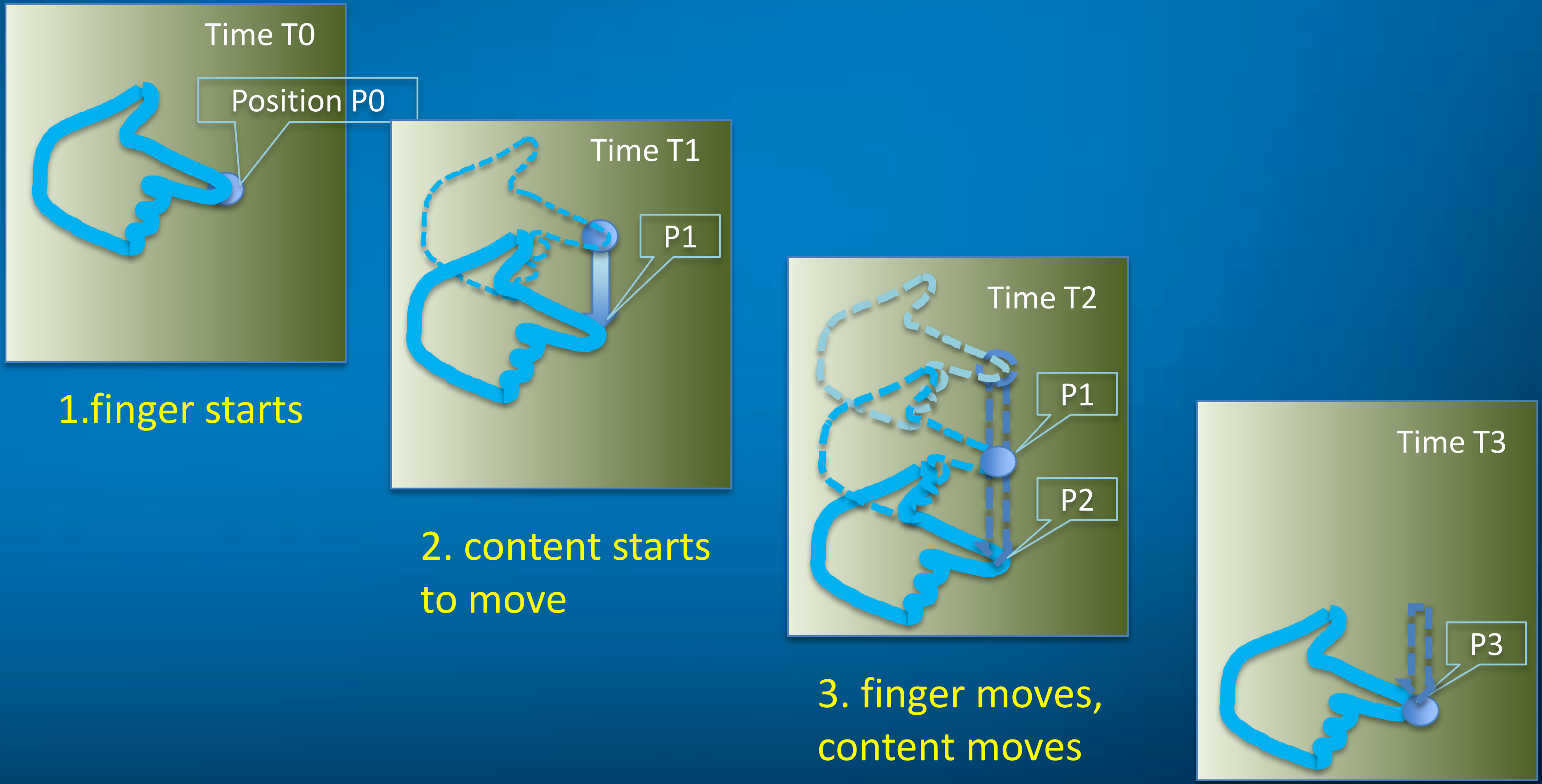
Workload Construction Case Studies

- Browser scroll scenario

Browser Scroll Scenario



1.finger starts

2. content starts to move

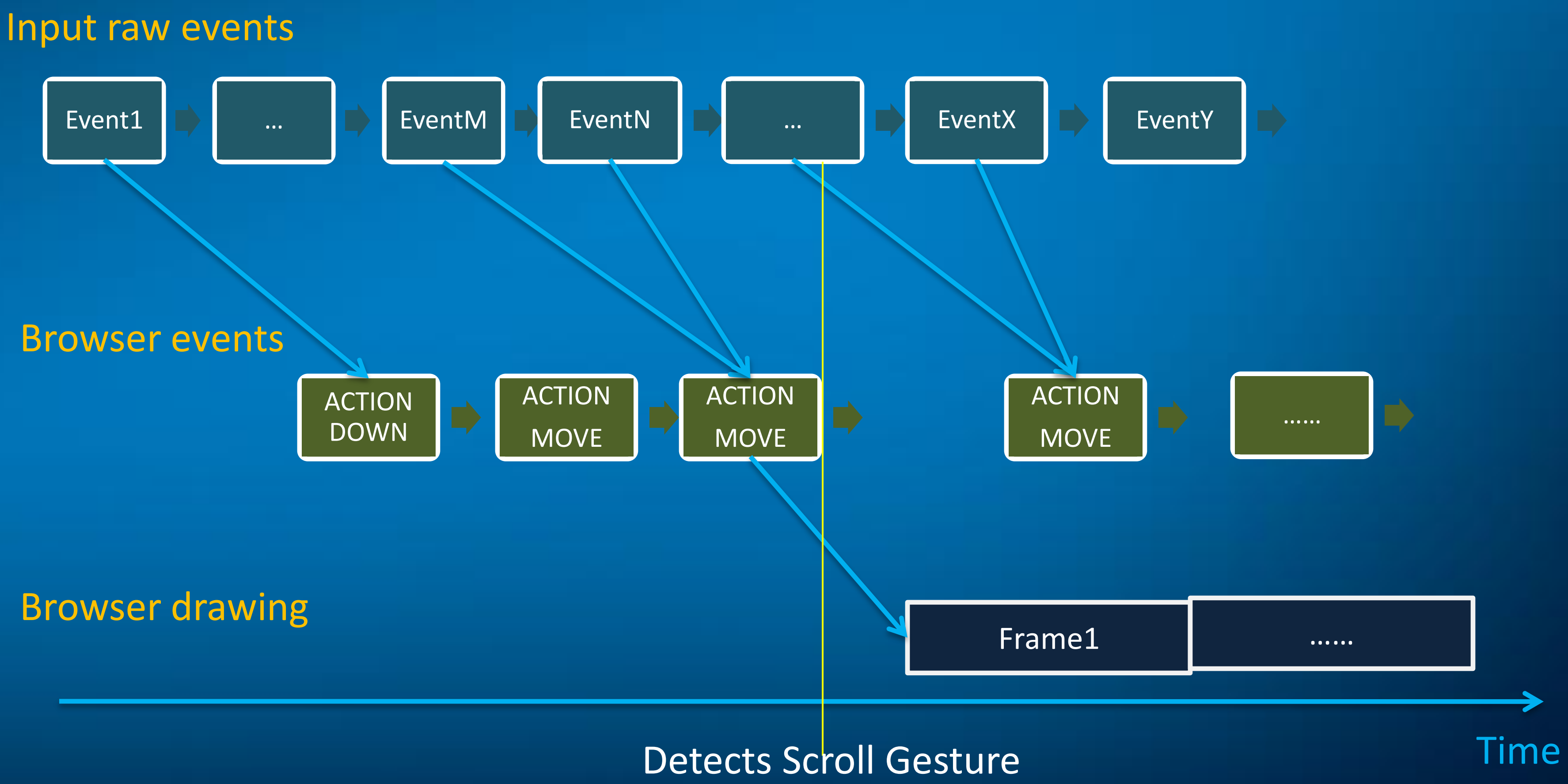
3. finger moves, content moves

4. finger releases

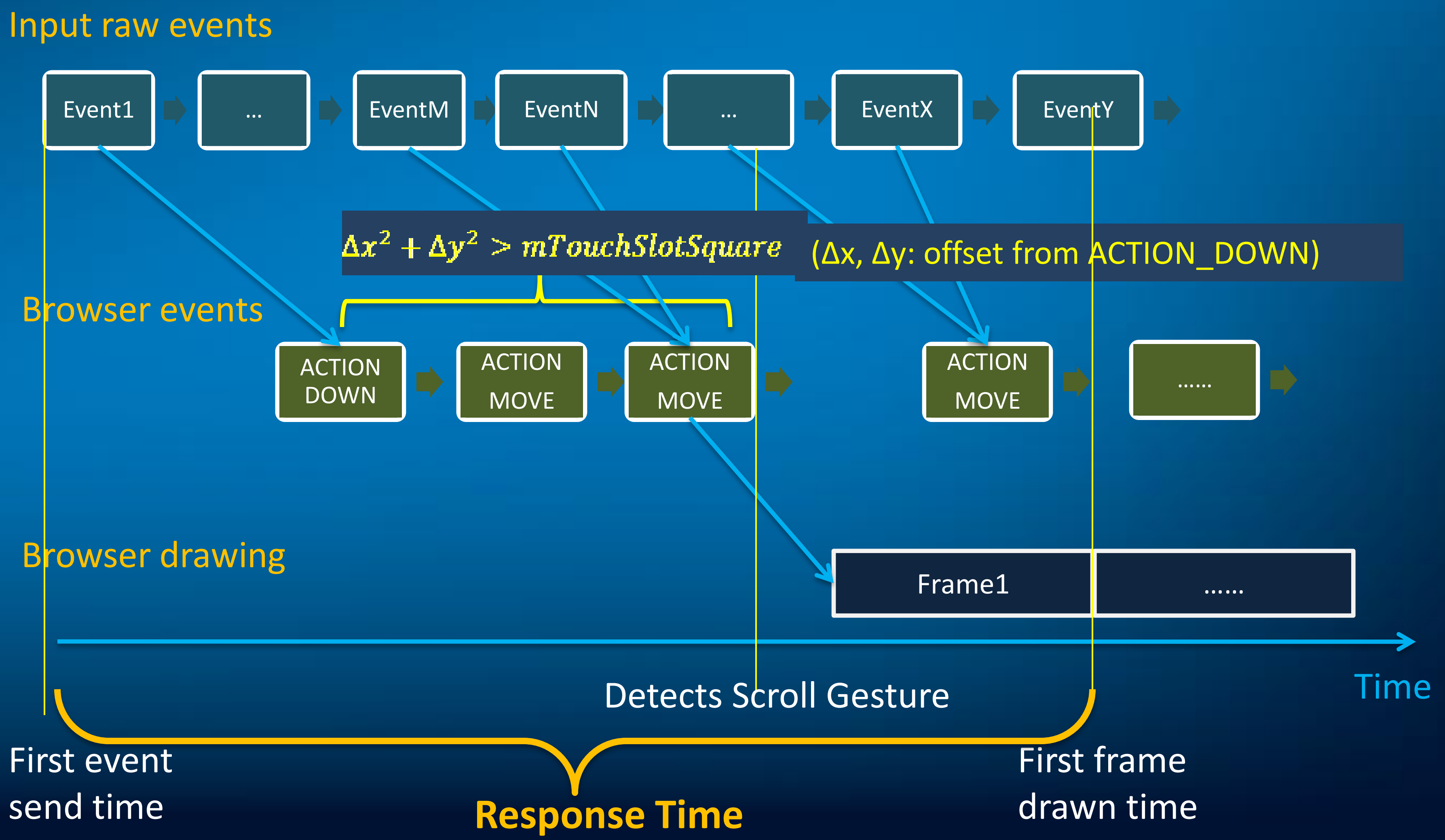
Measurement for Scroll

- Response time
  - How fast the content start to follow the finger
- Drag lag distance
  - How far the content movement lags behind finger
- Smoothness
  - How smooth the browser animates the scroll

Software Stack Internals in Scroll

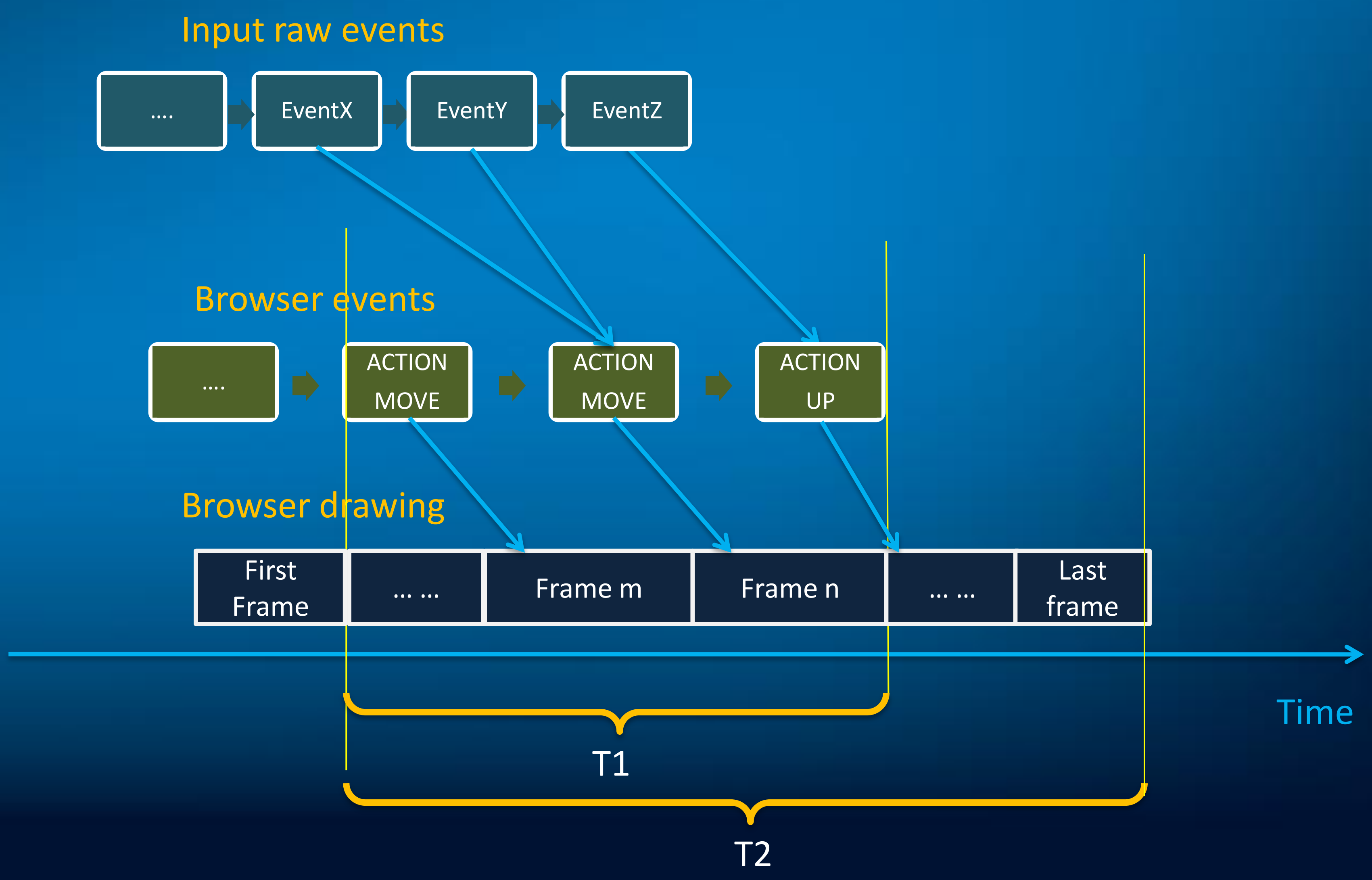


Response Time Measurement

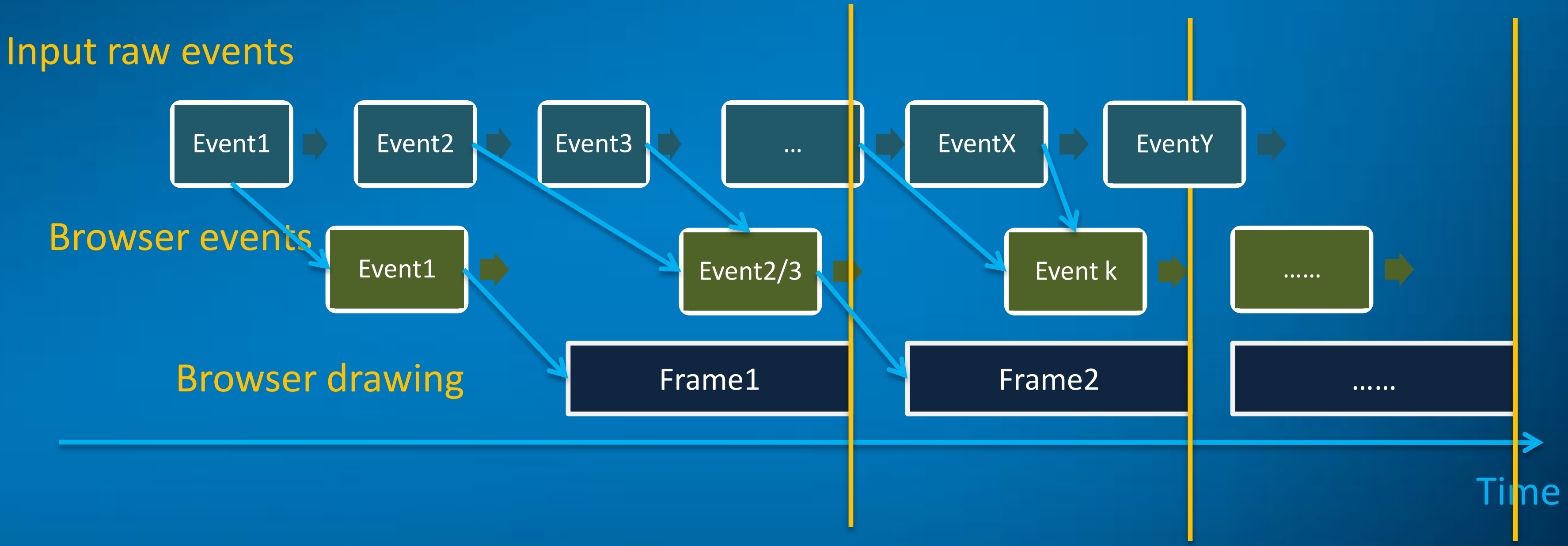


$\Delta x^2 + \Delta y^2 > mTouchSlotSquare$ (Δx, Δy: offset from ACTION_DOWN)

Smoothness Measurement



Drag Lag Measurement



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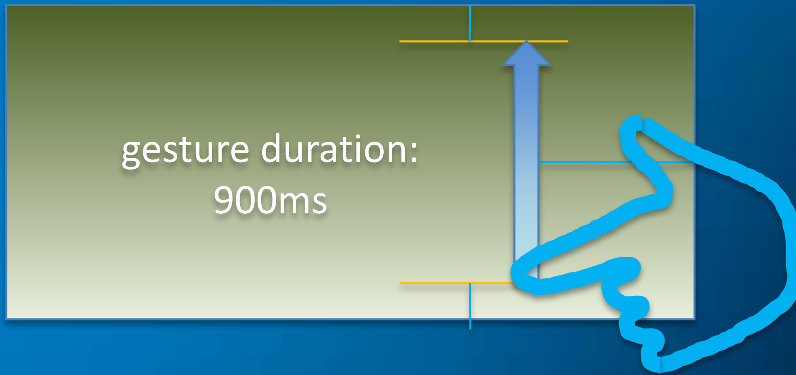
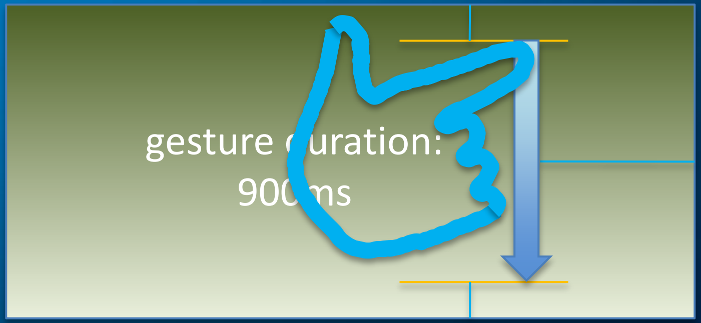
Touch[i].t<=Draw[k+1].t AND Touch[i].t>Draw[k].t}

Coherency = Max({Max(Distances[k]) | k=0,…,N})

Results Repeatability

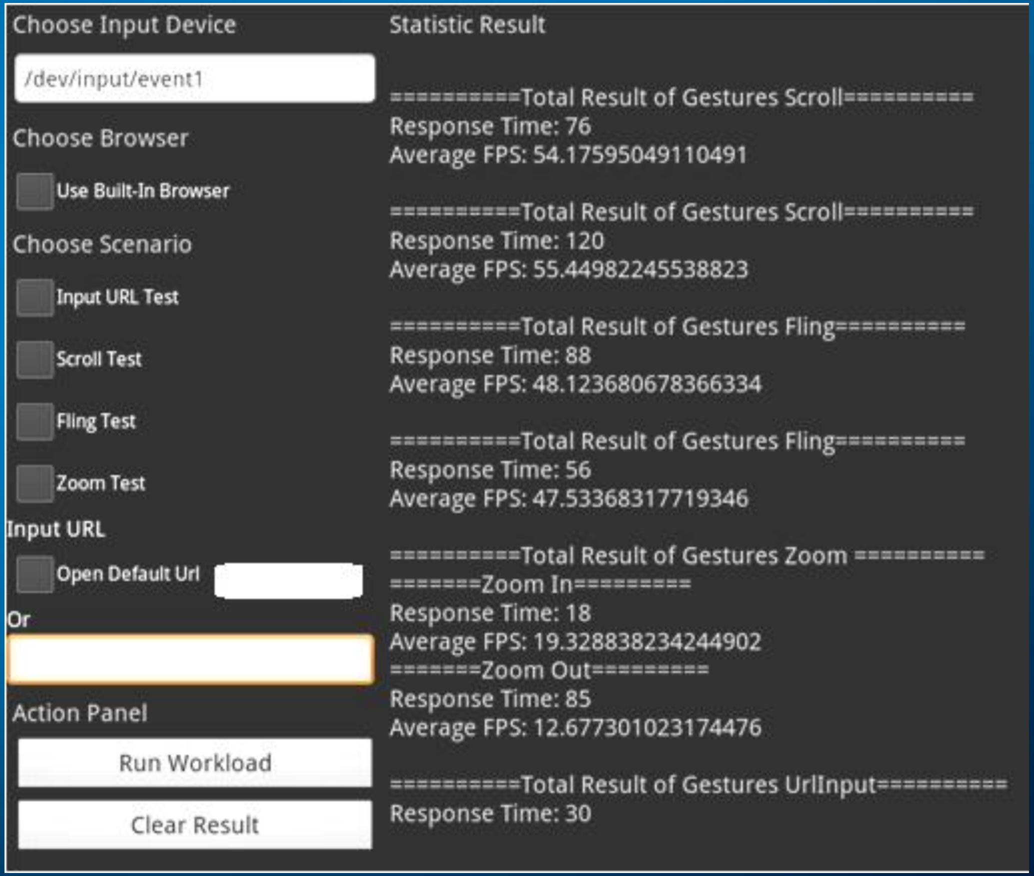
- Standard scroll gesture set generated by the Input-Gestures tool
  - Scroll up 20 times, down 20 times
  - Events are transformed for different devices





Workload Usage

- Support built-in and self-built browser
- Support scenario selection
- Support user input webpage address

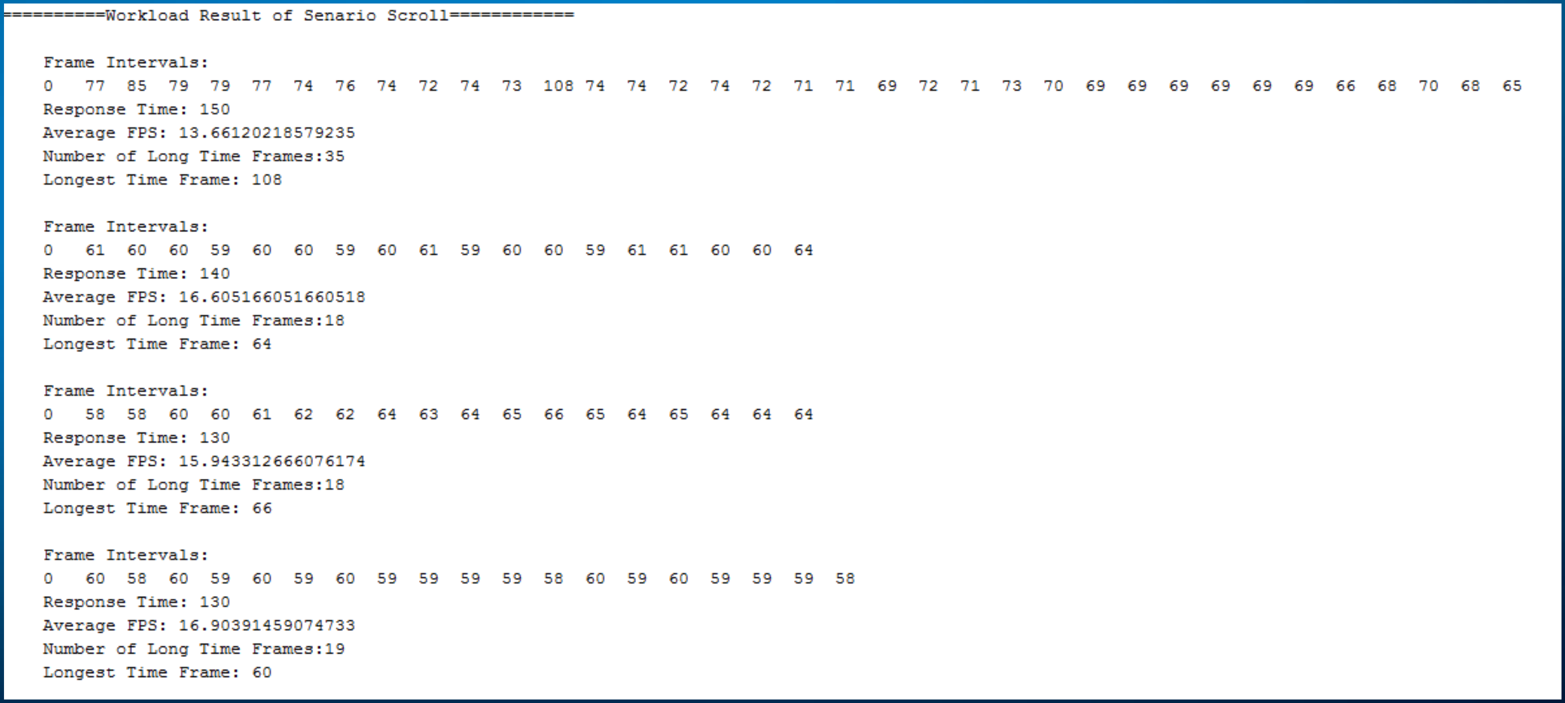


Choose Input Device: /dev/input/event1

```
==========Total Result of Gestures Scroll==========
Response Time: 76
Average FPS: 54.17595049110491

==========Total Result of Gestures Scroll==========
Response Time: 120
Average FPS: 55.44982245538823

==========Total Result of Gestures Fling==========
Response Time: 88
Average FPS: 48.123680678366334

==========Total Result of Gestures Fling==========
Response Time: 56
Average FPS: 47.53368317719346

==========Total Result of Gestures Zoom ==========
=======Zoom In=========
Response Time: 18
Average FPS: 19.328838234244902
=======Zoom Out=========
Response Time: 85
Average FPS: 12.677301023174476

==========Total Result of Gestures UrlInput==========
Response Time: 30
```

Detailed Results Archive

- Result Files - /data/local/tmp/XXX_result.txt
  - Record data of each gesture
    - Frame interval, maximum LTF, #LTFs



```
==========Workload Result of Senario Scroll============

   Frame Intervals:
   0   77  85  79  79  77  74  76  74  72  74  73  108 74  74  72  74  72  71  71  69  72  71  73  70  69  69  69  69  69  69  66  68  70  68  65
   Response Time: 150
   Average FPS: 13.66120218579235
   Number of Long Time Frames:35
   Longest Time Frame: 108

   Frame Intervals:
   0   61  60  60  59  60  60  59  60  61  59  60  60  59  61  61  60  60  64
   Response Time: 140
   Average FPS: 16.605166051660518
   Number of Long Time Frames:18
   Longest Time Frame: 64

   Frame Intervals:
   0   58  58  60  60  61  62  62  64  63  64  65  66  65  64  65  64  64  64
   Response Time: 130
   Average FPS: 15.943312666076174
   Number of Long Time Frames:18
   Longest Time Frame: 66

   Frame Intervals:
   0   60  58  60  59  60  59  60  59  59  59  59  58  60  59  60  59  59  59  58
   Response Time: 130
   Average FPS: 16.90391459074733
   Number of Long Time Frames:19
   Longest Time Frame: 60
```

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