Fusing Sensors into Mobile Operating Systems & Innovative Use Cases

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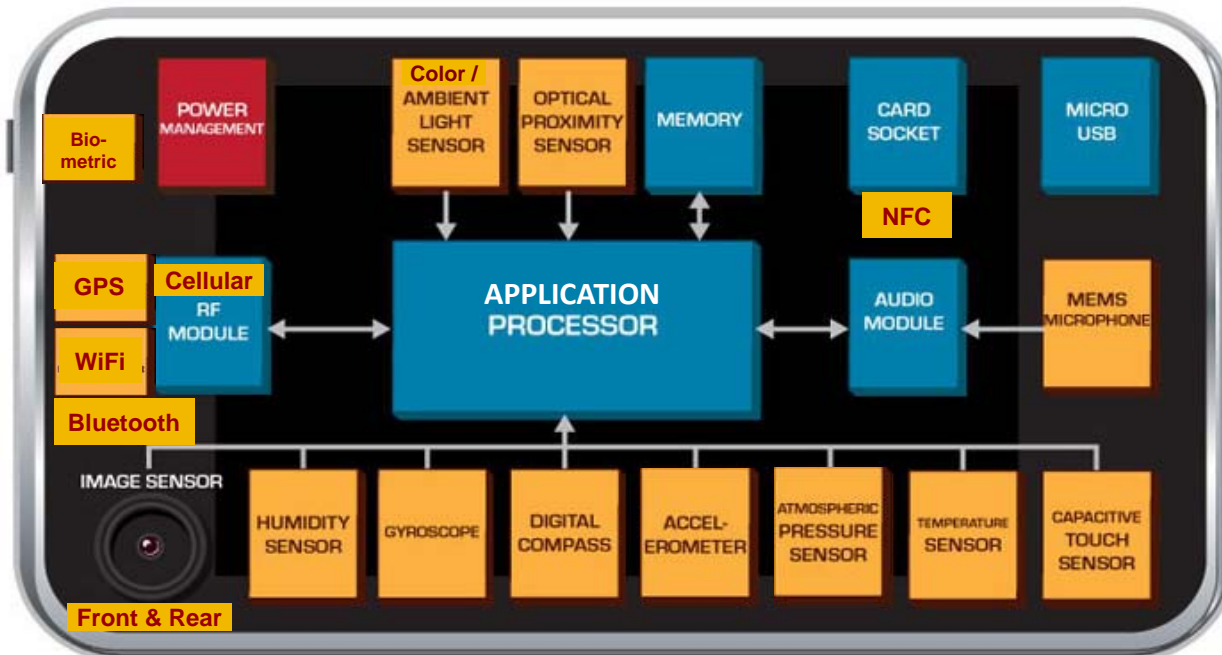# Sensors in Today's Smartphones & Tablets

How many Sensor are there?

-Low-end Smartphones

-High-end Smartphones

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Sensors in Today's Smartphones & Tablets

12 ~ 18 Sensors!

- Inertial Sensors: Gyroscope, Accelerometer, Magnetometer (e-Compass)
- Optical Sensors: Proximity, Ambient Light, RGB Color, Image Sensors (Front/Rear)
- Touch Sensors: Multi-Touch, Touchless Hover, Pressure Touch
- Environmental Sensors: Temperature, Humidity, Barometric Pressure, Gas (CO…)*
- Wireless/RF Sensors: GPS, WiFi, Cellular A-GPS, Bluetooth Low Energy, NFC
- Other Sensors: MEMS Microphones, Biometric/Fingerprint*, BioSensors*

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Mobile Sensors:
Use Cases and Applications

Key Mobile Use Cases & Applications

- **Single Sensor Use Cases**
  - *Compass Apps*
  - *Tilt Sensing*
  - *Multi-Touch, Touchless Hover*
  - *Ambient Light/Color or Proximity Sensing*
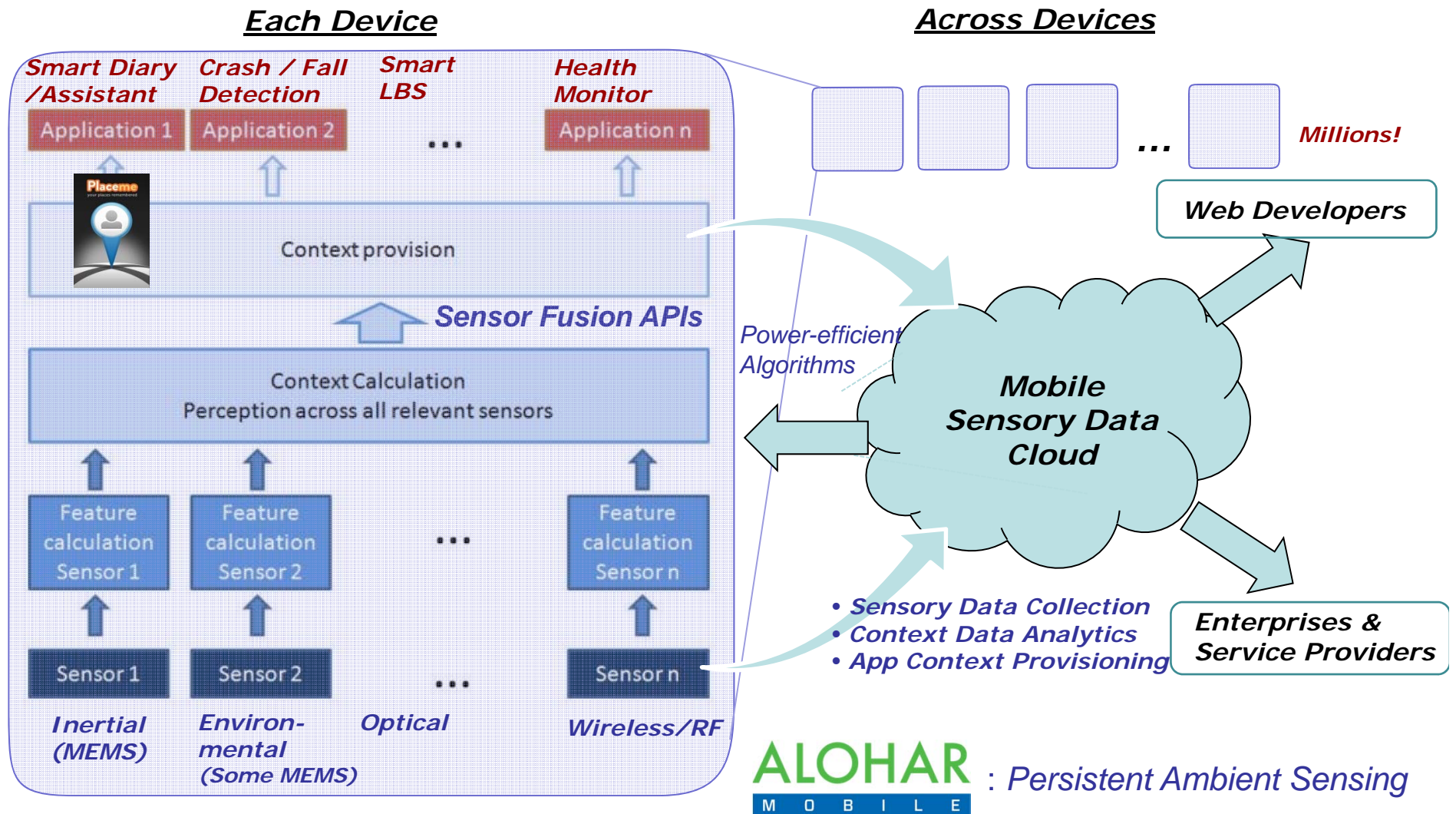 - *Ambient Temperature & Humidity Sensing…*

Innovative User Experiences enabled by Multiple Sensors Fusion!

- **Mobile Sensor Fusion Use Cases & Apps (in App Stores)**
  - *Gesture UI Control (**Motion**, Proximity) – Sensor Music Player, Gesture authentication, etc.*
  - *Remote Control App (**Motion**, Multi-Touch, RF) – NeguSoft UControl, Samsung Remote, etc.*
  - *Augmented Reality (**Inertial**, GPS, Image) – Wikitude, Layar, etc.*
  - *Exercise Apps: SitUp, PushUp, PullUp, Pedometer, etc. (**Motion**, Proximity, GPS)*
  - *Sensors Games: Alien Attack (AR **Motion**), A.Squadron & ZombieGate (**9-axis Motion**), etc.…*
  - *Indoor Navigation and Positioning (**Inertial, Pressure**, WiFi): SenionLab, Meridian, etc.*
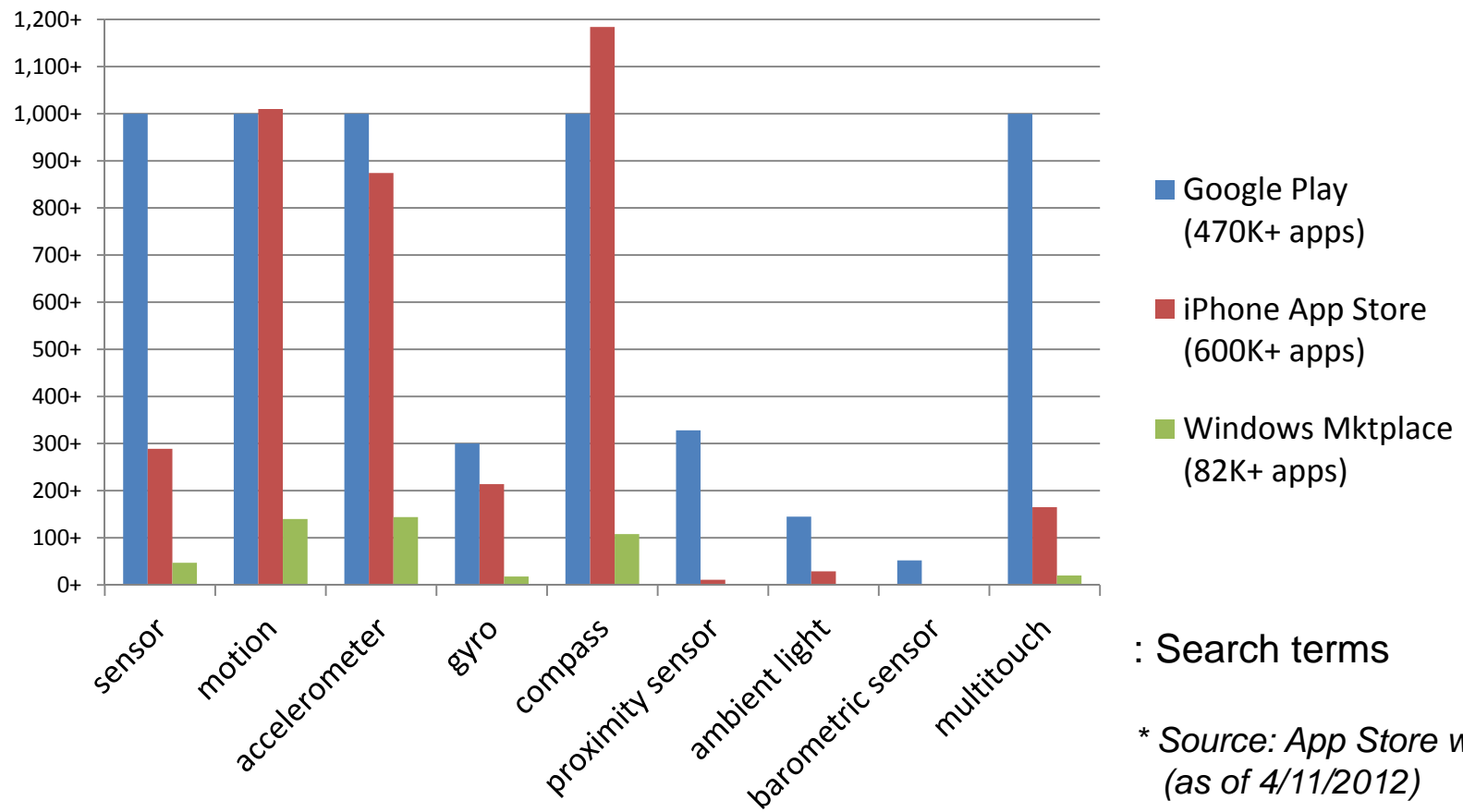 - *Context-Aware Mobile Services (**ALL Sensors!**): Address Sense, Smart Assistant, etc. …*

Sensor Fusion: Key to Context-Aware UX Future

Each Device

Across Devices

Smart Diary /Assistant | Crash / Fall Detection | Smart LBS | Health Monitor

Application 1 | Application 2 | ... | Application n

Placeme
your places remembered

Context provision

Sensor Fusion APIs

Context Calculation
Perception across all relevant sensors

Feature calculation Sensor 1 | Feature calculation Sensor 2 | ... | Feature calculation Sensor n

Sensor 1 | Sensor 2 | ... | Sensor n

Inertial (MEMS) | Environ-mental (Some MEMS) | Optical | Wireless/RF

... **Millions!**

Web Developers

Power-efficient Algorithms

Mobile Sensory Data Cloud

- **Sensory Data Collection**
- **Context Data Analytics**
- **App Context Provisioning**

Enterprises & Service Providers

ALOHAR MOBILE : *Persistent Ambient Sensing*

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Reality Check: Mobile Apps that use Sensors Today

- Most popular Sensor Apps still **<0.5% Share** of Entire App Stores!

[Sensor Apps by App Store]

Legend:
- Google Play (470K+ apps)
- iPhone App Store (600K+ apps)
- Windows Mktplace (82K+ apps)

X-axis categories: sensor, motion, accelerometer, gyro, compass, proximity sensor, ambient light, barometric sensor, multitouch

: Search terms

Source: App Store websites (as of 4/11/2012)

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So, what's holding back the Sensors Apps?

- **Lack of Education of App Developers on Sensors capabilities**
  - Some sensors are complex beasts for average developers to embrace
  - Need creative juice to figure out how to differentiate UX using sensors

- **Fragmentation causing UX Inconsistencies**
  - OS versions with varying Sensors support
  - OEM Devices with varying Sensors integration (that Apps developers don't access)
  - Sensors with varying feature definitions (axis conventions, etc.) and performance

- **Evolution of Native OS Sensors Support (a Moving Target)**
  - New sensor types added
  - New "virtual" sensors added (e.g., auto-rotation, gravity, linear accel, etc.)
  - Modified APIs or dropped features (Android Orientation -> Rotation Vector, etc.)
  - Lacking OS support for proprietary extensions

- **Lack of Industry Standard Sensor specifications**
  - Unspecified or vague performance targets
  - Sometimes overly restrictive

Too Difficult for Developers!

Mobile Sensors:
Fusing into Mobile Operating Systems

Sensors Comparison across Mobile OS Platforms

- *Native OS Sensor API Support*

Sensor API	Android 4.0 (Oct. 2011)	Android 2.3 (Dec. 2010)	Android 2.2 (May 2010)	Win Phone 7.5 (Sept. 2011)	iOS 5 (Oct. 2011)	iOS 4 (June 2010)
LINEAR_ACCELERATION	Yes[3]	Yes[3]	No	Yes	Yes	Yes
ORIENTATION	Yes[1]	Yes	Yes	Yes	Yes	Yes
ROTATION VECTOR /QUATERNION	Yes[3]	Yes[3]	No	Yes[3]	Yes[3]	Yes[3]
GRAVITY	Yes[3]	Yes	No	Yes	Yes	Yes
ACCELEROMETER	Yes	Yes	Yes	Yes	Yes	Yes
GYROSCOPE	Yes	Yes	No	Yes	Yes	Yes
MAGNETIC FIELD	Yes	Yes	No	Yes	Yes	No
PROXIMITY	Yes	Yes	Yes	No	Yes	Yes
AMBIENT LIGHT	Yes	Yes	Yes	No	Yes	Yes
PRESSURE	Yes[2]	Yes[2]	No	No	No	No
AMBIENT TEMPERATURE	Yes[2]	No	No	No	No	No
RELATIVE HUMIDITY	Yes[2]	No	No	No	No	No
MULTI-TOUCH	Yes	Yes	Yes	Yes	Yes	Yes
CAMERA (FRONT / REAR)	Yes	Yes	Yes	Yes	Yes	Yes

1. Deprecated. 2. Newly added. 3. Requires Gyro.

* Source: OSV websites & interviews (Apr. 2012)
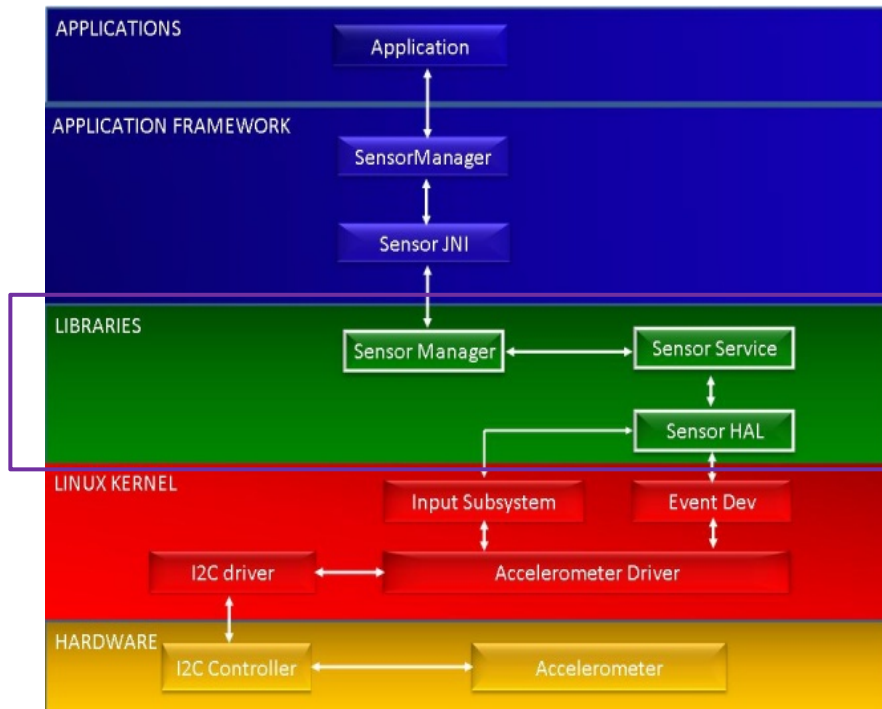
▢ : Also available as Software Sensors

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Sensor Fusion Implementations: Android Case

- 4 Levels: App Processors, Sensor Hub (Co-MPU), Sensors (w/ MPU), Linux Kernel

Software (Virtual) Sensors

- ✓ *Device/Sensor-agnostic Integration*
- ✓ *Common Sensor fusion libraries*
- – *Native OS API: Power inefficient*
- – *Native OS API: Accuracy & Performance poor*
- ✓ *3rd Party API: Accuracy & Performance improved*
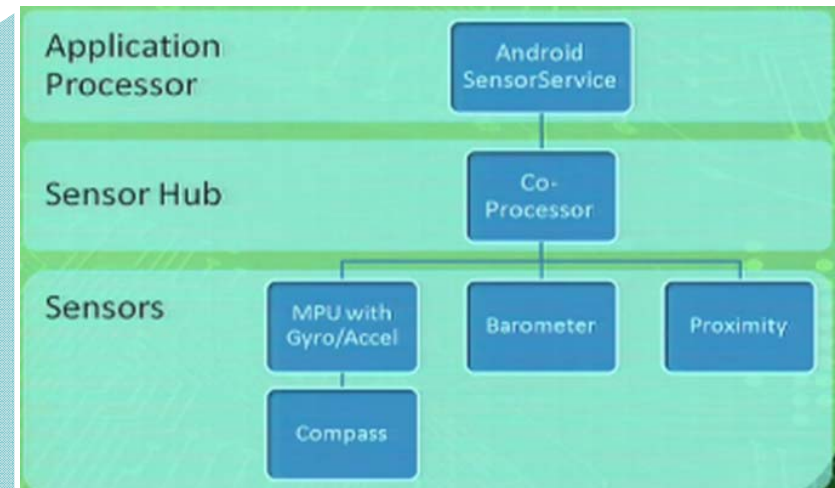
Hardware Sensors + Software Integration

- – *Device/Sensor specific Integration (Fragmented)*
- – *Proprietary Sensor fusion libraries*
- – *A/P level: Power hungry* ✓ *Sensor level: Low-pwr*
- ✓ *Sensor Vendor API: Accuracy & Performance best*
- ✓ *3rd Party API: Accuracy & Performance optimized*

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MEMS Motion Sensor Fusion Software Providers

- Sensor Silicon-specific (IMU + Software & API)

- Sensor Silicon-agnostic (Software & API)

Sensor Fusion System Integration Challenges

- **18+** Sensor types
- **18+** Mainstream Sensor vendors
- **30+** Sensor product lines
- **3+** Mobile OS requirements sets
- **35+** OEM device makers
- **5+** Third-party software libraries

- *Algorithm tuning for each sensor*
- *Sensor mechanical design and placement considerations*
- *Sensor calibration requirements*
- *Sensor driver integration*
- *Sensor fusion library integration*

Fragmentation

Scalable

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A Way Forward: *Standardization*

- **Opportunities for Standardization**
  - Sensor Data sheet contents
  - Sensor Calibration and Fusion Library APIs
  - Sensor Self-test and Reporting methods
  - Sensor Configuration (e.g. axis conventions)
  - Sensors Features & Performance standards for native Mobile OS support

- **Recommendations**
  - Standardize basic Sensor functions to enable rapid bringup and test
    - Combat Fragmentation concerns from diversifying Sensor & OEM vendors
  - Ease addition of proprietary enhancements on top of standard features
    - Sensors: Support product *differentiations in addition* to standard requirements
    - Mobile OS: Support *extensible common APIs* for *improving set of functions*
  - Accelerate innovations and future roadmaps with UX & Use Cases in mind

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"MEMS for All of Us" – Mobile Summary

- **Sensor Innovations** continue to enable **smarter Mobile Devices**
  - *12 ~ 18 sensors in today's smartphones, 5 fueled by MEMS*

- Exciting **Mobile UX Transformation** ahead leveraging **Sensor Fusion**
  - *Mobile Sensor Fusion innovations started / led by MEMS Motion sensors*
  - *Developers need education*

- As native support of HW Sensors advance across Mobile OS'es, simpler & better performing *extensions* of **Virtual / Fused Sensor APIs** become crucial

- Mobile Ecosystem (esp. MEMS) needs **concerted Standardization** efforts to effectively scale!
  - *Highly fragmented across Sensors, OS & Device Implementations*
  - *Developers need standardized API support*

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Thank You!

Q&A

[Invitation to Connect]

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