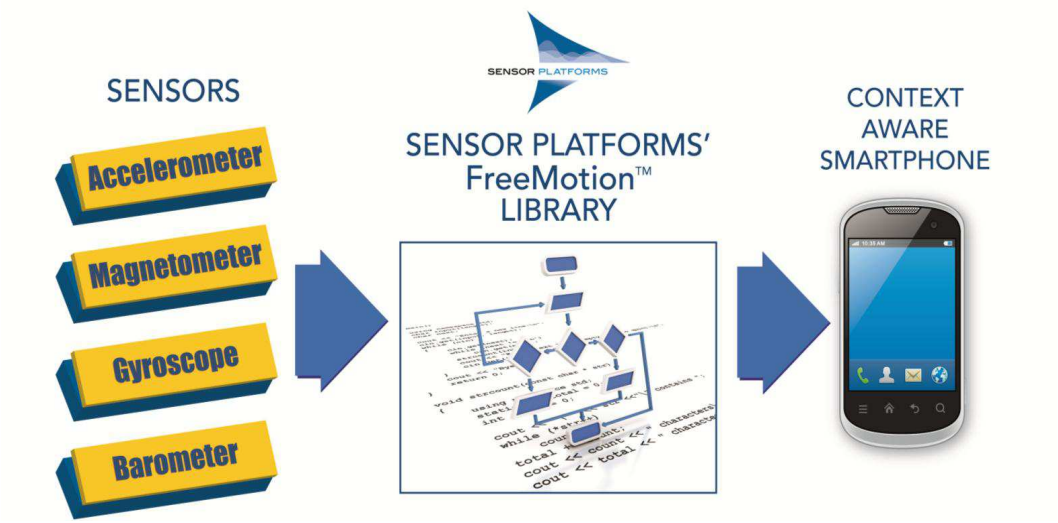


HOT CHIPS

SENSOR PLATFORMS

Sensor Fusion

Mobile Platform Challenges and Future Directions

Jim Steele

VP of Engineering, Sensor Platforms, Inc.

How Many Sensors are in a Smartphone?

- **Light**
- **Proximity**
- **2 cameras**
- **3 microphones (ultrasound)**
- **Touch**
- **Position**
  - GPS
  - WiFi (fingerprint)
  - Cellular (tri-lateration)
  - NFC, Bluetooth (beacons)
- **Accelerometer**
- **Magnetometer**
- **Gyroscope**
- **Pressure**
- **Temperature**
- **Humidity**

19

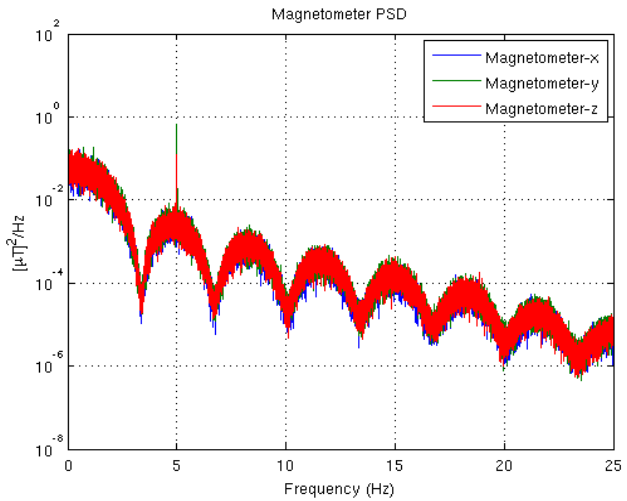
Mobile Sensor Challenges

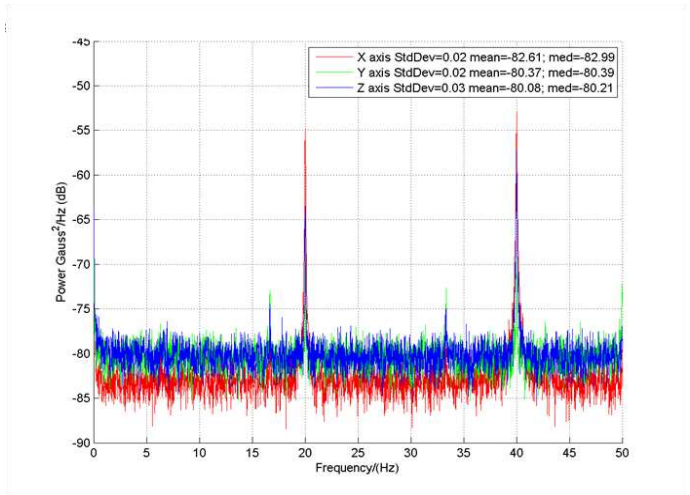
~90° compass error in the first Ice Cream Sandwich smartphone

- **Underlying problems:**
- **Some sensor components lack repeatability**
- **RF and other PCB noise interaction with mag sensor**
- **Non-standard availability (no gyro, pressure, 2nd camera, …)**
- **Non-standard capability (resolution, update rate, …)**
- **Not fully specified (non-uniform gain, skew)**

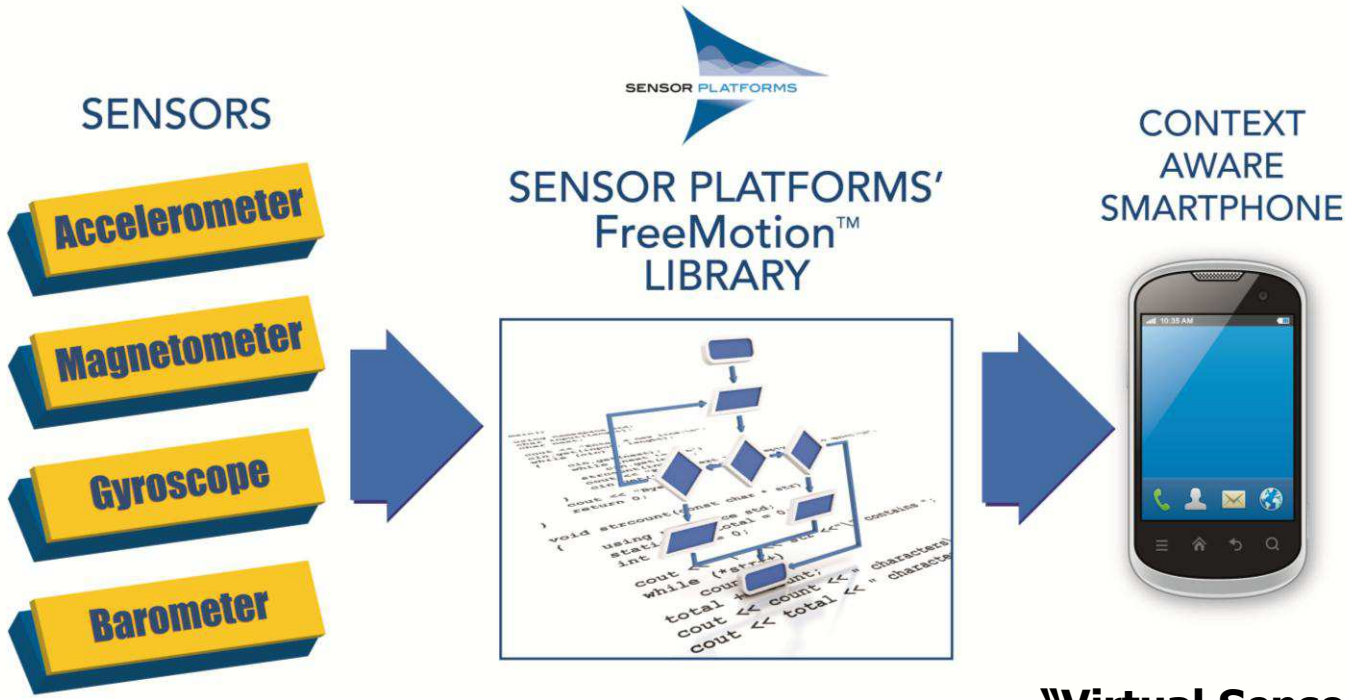
User Experience Across Platforms

- **Heavy engineering burden to maintain consistency across system variations**
  - Hard and soft iron contents
  - Component selection for optimal price/performance
  - Different application processors (sensor hubs)
  - Different mobile OS
- **Validation efforts diffused over multiple platforms**





Sensor Fusion Algorithms Solve Challenges



What can be measured
-acceleration
-magnetic field
-angular rate
-pressure

"Virtual Sensors"

What developers want
-quaternion
-gravity
-linear acceleration
-tilt

Examples of Sensor Fusion

- **10-axis sensor fusion and background calibration**
  - Industry standard foundation for sensors
  - No user-intervention to keep sensors calibrated
  - Adjusts to changes in environment
- **Sensor data can be interpreted using algorithms**
  - Magnetometer → Compass (avoid magnetic anomalies)
  - Pressure → Altitude (avoid pressure anomalies)
  - Throttle the gyroscope (keep highest power sensor off until needed)
- **Combine multiple sensors to improve sensing**
  - Pressure + GPS = faster GPS fix
  - Camera + Sensor Fusion = Augmented Reality
  - inElevator sensor?

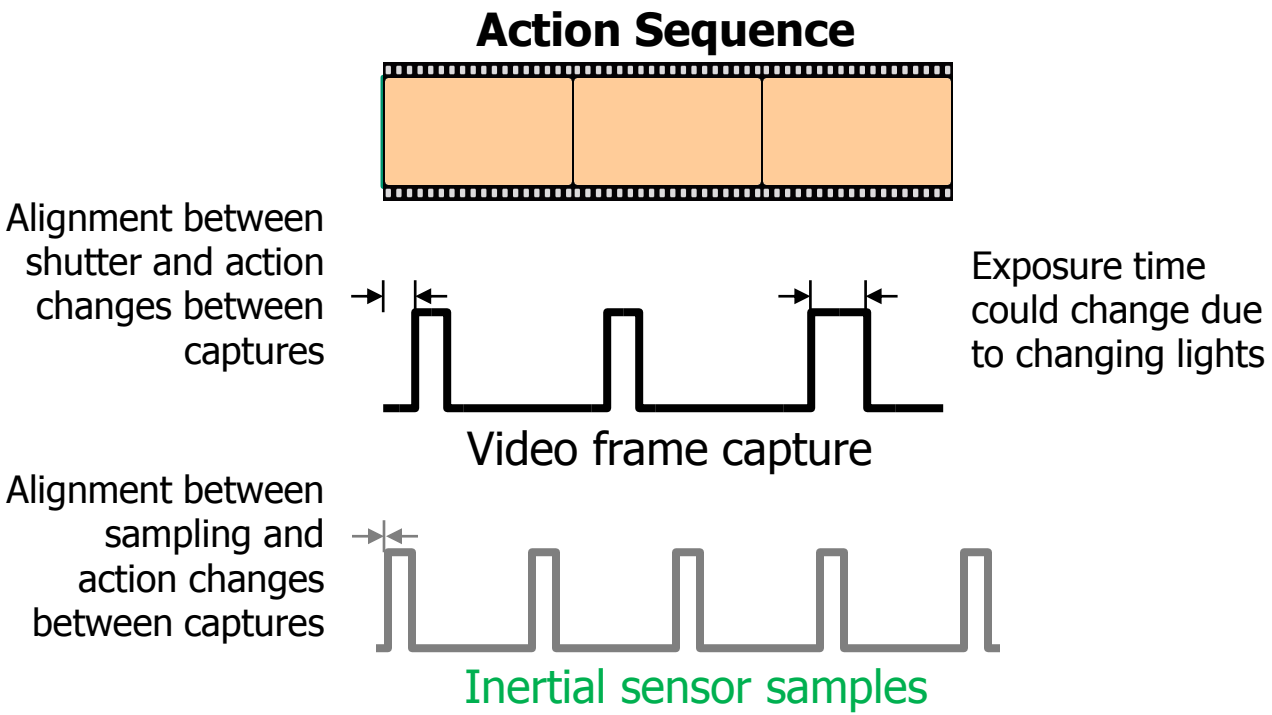
Comparison of Mobile OS Sensor Support

Sensor	iOS 5	Android	Win8
Accel/Mag/Gyro	✓	✓	✓
Pressure/Humidity	x	✓	x
Quaternion	CMAttitude	ROTATION_VECTOR	Orientation
Euler Angles	CMAttitude	ORIENTATION (depr.)	Inclinometer
Dynamic Acceleration	userAcceleration	LINEAR_ACCELERATION	Shake
Gravity in body frame	gravity	GRAVITY	Tilt
Tilt-compensated Compass	x	x	Compass
In Elevator	x	x	x

Virtual Sensors, e.g.

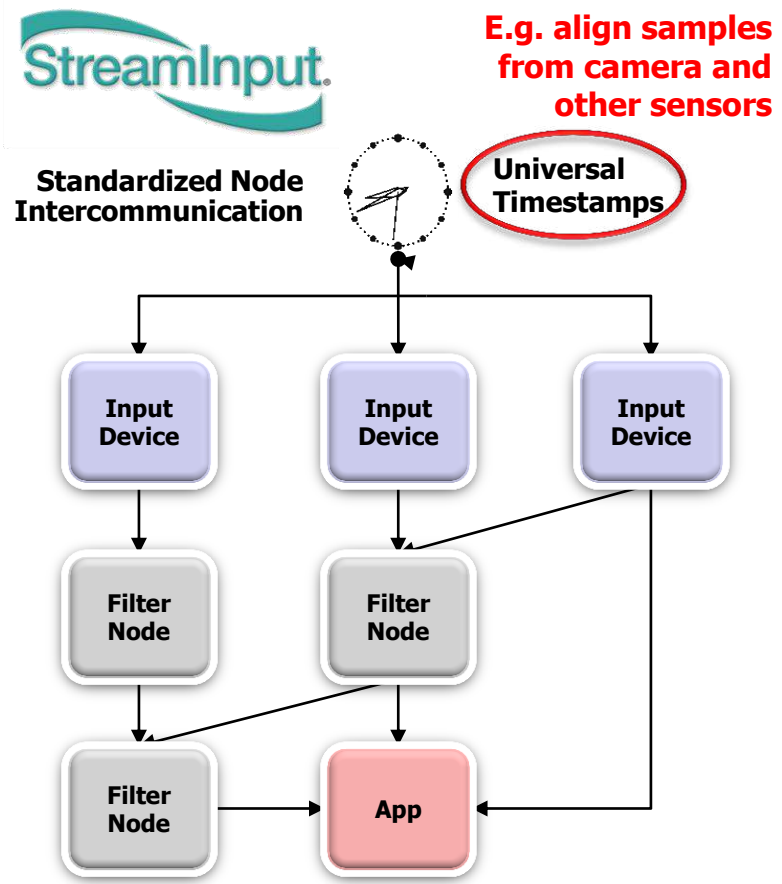
Need Unified Timestamp between Sensors

- **Sensors work on different time bases that drift**
- **Not all sensors support the same sampling rate**

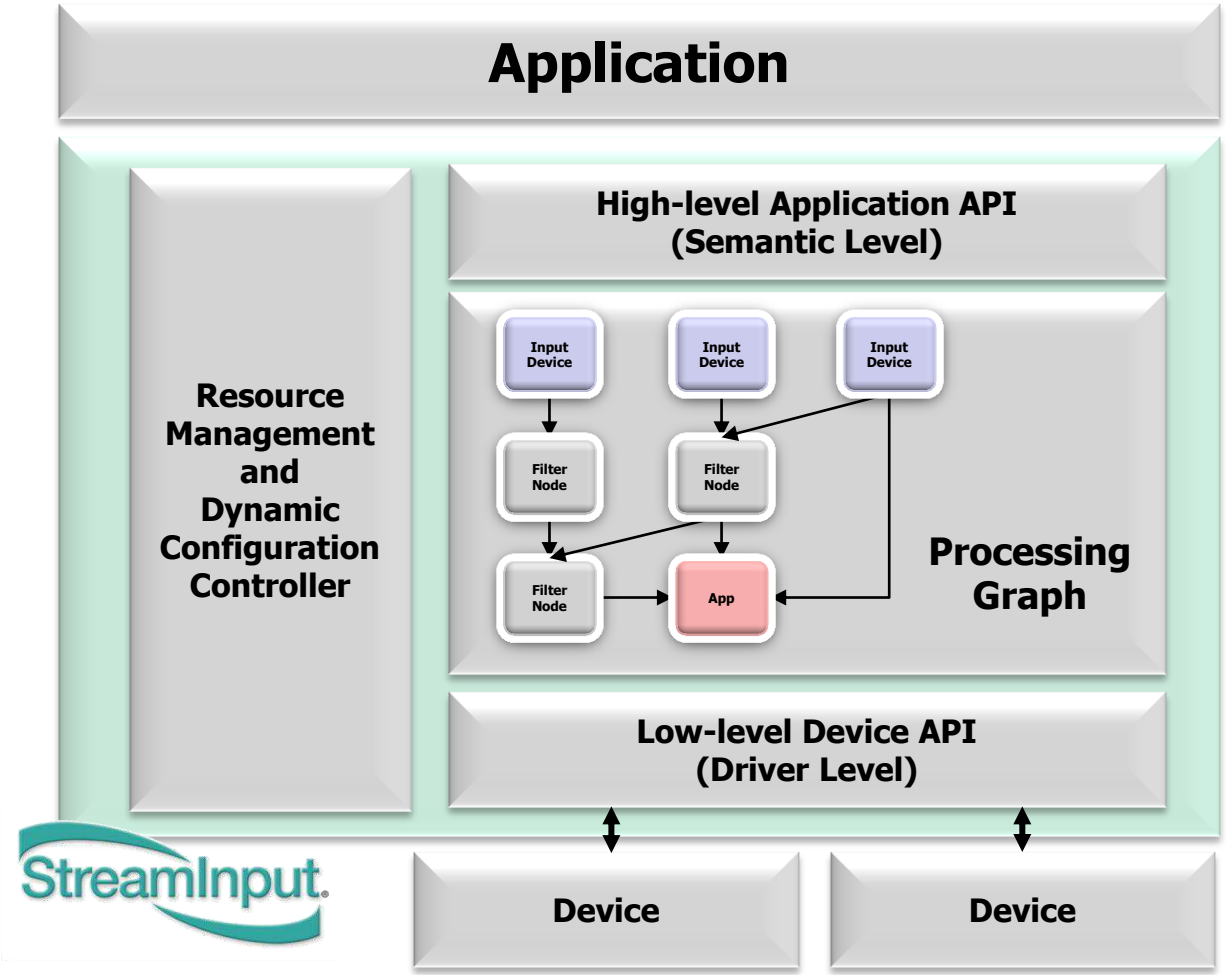


StreamInput Concepts

- **Standardized Application-defined filtering and conversion**
  - Can create virtual input devices
- **Sensor Hardware Vendor Agility for OEMs**
  - Allows standardized interface for hardware accelerated features
- **Extensibility to any sensor type**
  - Can define new node data types, state and methods
- **Sensor Synchronization**
  - Universal time stamp on every sample



StreamInput Architecture



1. Setup Processing Graph (or use pre-supplied graph), request and receive semantic sensor stream through High-level API
2. Optionally, dynamically configure sensor processing through Low-level API – can tune power vs. performance

Implementable over existing OS input APIs to simplify adoption

Sensor Platforms

- We create algorithms for sensors

- More information at our blog: www.sensorplatforms.com
- jsteele@sensorplatforms.com