FTF | FREESCALE TECHNOLOGY FORUM POWERING INNOVATION

Application of Location Based Services - GPS Enhancement & Indoor Navigation

FTF-CSD-F0222

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Session Introduction

Location-Based Services (LBS) are taking off with augmented reality apps at the forefront. Join us to learn how we can help increase your system capability with lower power. We can help you address the challenge of location tracking with Xtrinisic sensors and the smart sensor platform. For instance, floor determination is a crucial component and the trends and challenges for next-generation pressure/altimeter systems will be presented, integration with GPS, necessary changes in map data, smart altitude algorithms for location determination. This lecture also will address challenges of sensor fusion for increased accuracy along with real-time calibration to extend resolution of 3D positioning to enable the ultimate app.

Session Objectives

After completing this training, you will be able to:

- Discuss the trends in LBS, sensors and applications
- List the sensor devices applicable for mobile sensing solutions along with their challenges and benefits
- Understand why Augmented Reality (AR) requires higher accuracy
- Discuss the sensor enablement in various OS frameworks

Agenda

- Trends: Sensor use cases, sensors, LBS, OS sensor frameworks
- Overview of the LBS system
- How do sensors fit into the LBS solution?
- What sensors are needed for LBS?
- How is *Augmented Reality* progressing?
- What are the limitations of LBS?

Trends: Sensor Use Case Progression

Navigation
Location-Based Services

Navigation
Pedometer

Phone Camera
Image Stabilization

UI Phone++
Gesturing

UI Phone+
Pattern unlock

UI Phone
Tilt
Scroll
Portrait/Landscape

UI Gaming
Tilt
Scroll

Enhanced Mapping

Asset Tracking

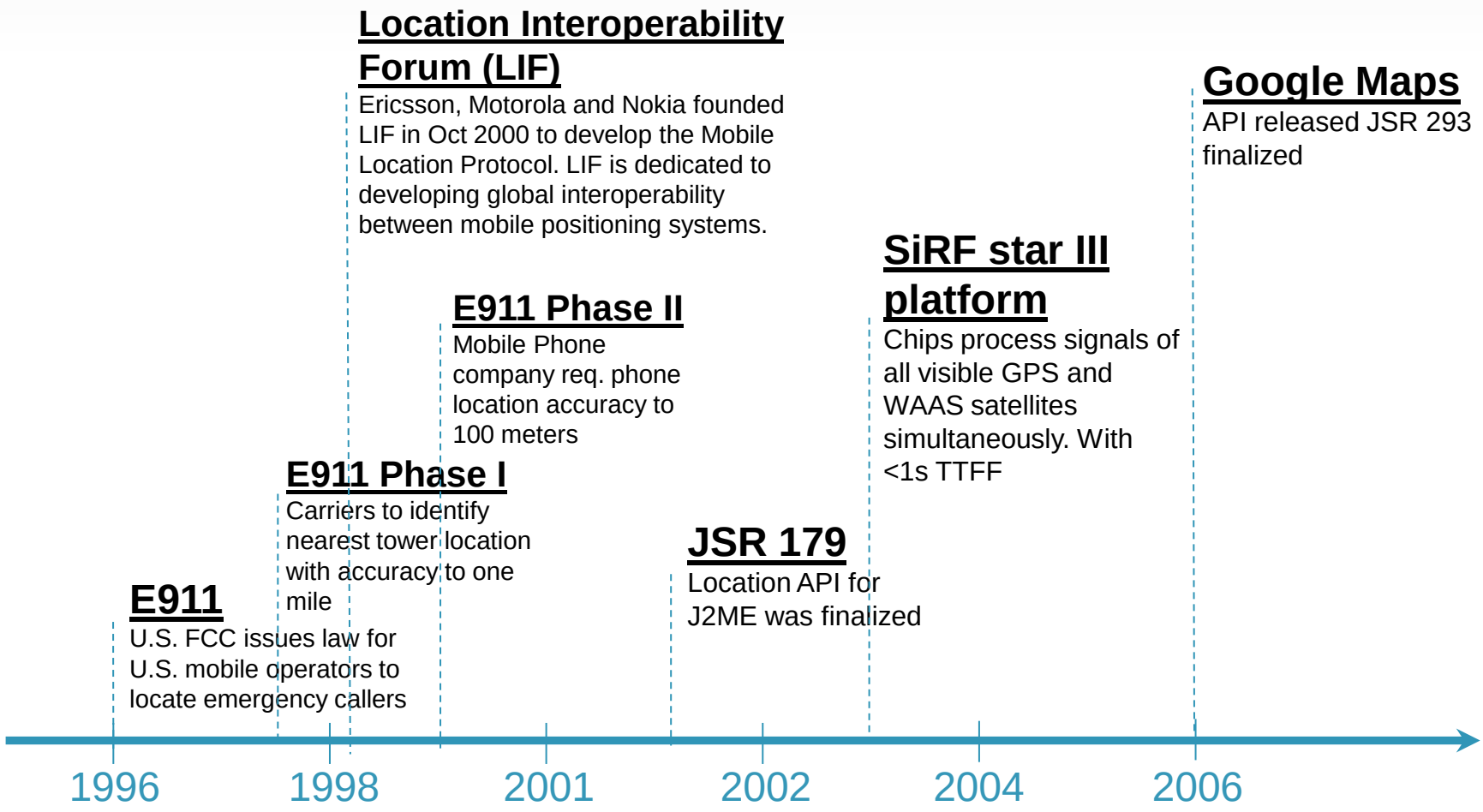
Vehicle Tracking

Local coupons

Local weather

Gaming

Trends: Location-Based Services Critical Milestones



Android API Level with Sensor Progression



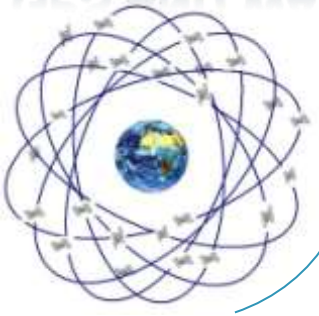




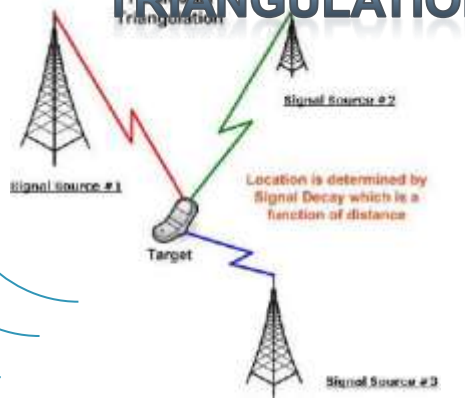
Platform Version	API Level	VERSION_CODE	Sensor Highlights
Android 4.0.3	15	ICE_CREAM_SANDWICH_MR1	
Android 4.0, 4.0.1, 4.0.2	14	ICE_CREAM_SANDWICH	
Android 3.2	13	HONEYCOMB_MR2	
Android 3.1.x	12	HONEYCOMB_MR1	API provides a way to interact across a wide range of peripherals, from robotics controllers to musical equipment, exercise bicycles, and more.
Android 3.0.x	11	HONEYCOMB	
Android 2.3.4			
Android 2.3.3	10	GINGERBREAD_MR1	Near-field communications Apps can write to tags and set up peer-to-peer connections with other NFC devices.
Android 2.3.2			
Android 2.3.1			
Android 2.3	9	GINGERBREAD	Android 2.3 adds API support for several new sensor types, including gyroscope, rotation vector, linear acceleration, gravity, and barometer sensors
Android 2.2.x	8	FROYO	
Android 2.1.x	7	ECLAIR_MR1	
Android 2.0.1	6	ECLAIR_0_1	
Android 2.0	5	ECLAIR	
Android 1.6	4	DONUT	New gestures framework provides android.location updated
Android 1.5	3	CUPCAKE	Redesigned Sensor Manager APIs
Android 1.1	2	BASE_1_1	
Android 1.0	1	BASE	

Location-Based Decisions

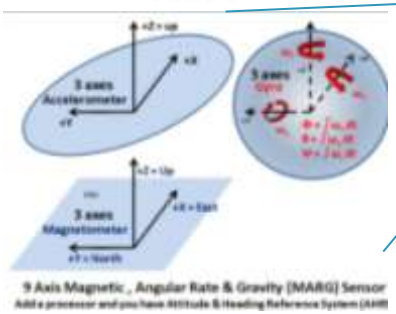
GPS AND WAAS



WIFI TRIANGULATION



IMU



NEAR FIELD COMMUNICATION

NFC

- NFC is a set of short-range wireless technologies, typically requiring a distance of 4 cm or less
- Operates at 13.56MHz on ISO/IEC 18000-3 air interface and at rates ranging from 106 kbit/s to 424 kbit/s
- Always involves an initiator and a target where the initiator actively generates an RF field that can power a passive target
- Targets can take very simple form factors such as tags, stickers, key fobs or cards that do not require batteries

In 2011 several handset vendors released more than 40 NFC-enabled handsets. According to analyst firm Berg Insight, global sales of handsets featuring Near Field Communication (NFC) increased ten-fold in 2011 to 30 million units. Growing at a compound annual growth rate (CAGR) of 87.8 percent, shipments are forecasted to reach 700 million units in 2016.

Next Generation GPS Chips

- Next generation GPS chips are claiming to enable indoor navigation with extended battery life.

- GPS chips will use locating beacons placed around buildings to allow mobile device users to use indoor maps to navigate their way through a building.

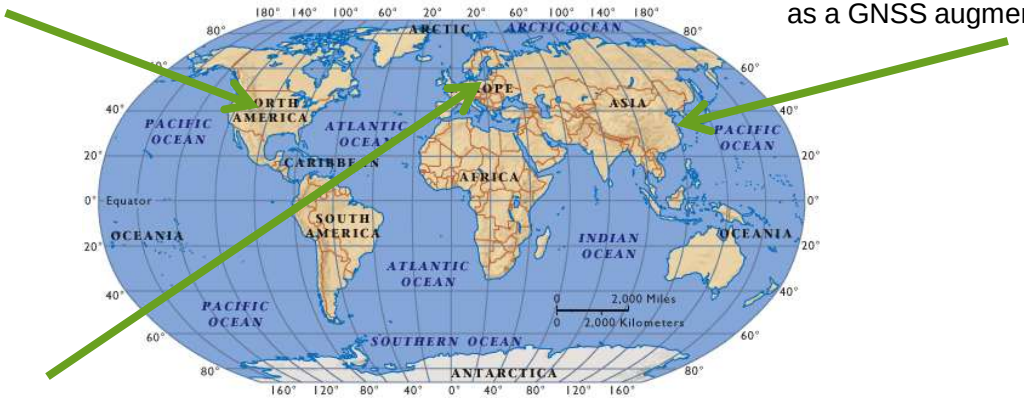
WAAS

Wide Area Augmentation System (WAAS)

WAAS uses a network of ground-based reference stations, in North America and Hawaii, to measure small variations in the GPS satellites' signals in the western hemisphere. WAAS-enabled GPS receivers use the corrections while computing their positions to improve accuracy. WAAS specification requires it to provide a position accuracy of <=7.6m (25 ft) (lateral and vertical), >95% of the time. Actual is <=1.0m laterally and <=1.5m vertically throughout most of the contiguous U.S. and Canada.

Quasi-Zenith Satellite System (QZSS)

A satellite-based augmentation system (SBAS) that can only provide limited accuracy on its own and is not currently required in its specifications to work in a stand-alone mode. As such, it is viewed as a GNSS augmentation service.



European Geostationary Navigation Overlay Service (EGNOS)

A satellite-based augmentation system (SBAS) developed by the European Space Agency, the European Commission and EUROCONTROL. It supplements the GPS, GLONASS and Galileo systems by reporting on the reliability and accuracy of the signals.

Wi-Fi Triangulation

- A phone “sniffs” for Wi-Fi networks that are within range, measures their signal strength and compares the results with a database. The device doesn't actually connect to or use any of these hotspots. It only scans them to measure the relevant factors used for the database lookup.

PROS

Good for urban areas where GPS signals don't penetrate and accuracy is of the utmost importance.

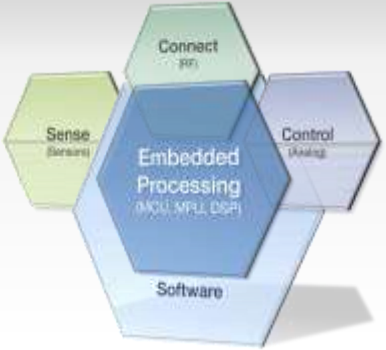
CONS

Service providers will constantly need to re-survey areas to update the catalog of WiFi hotspots

This means that a service provider must conduct periodic sweeps of an area to maintain the catalog of WiFi hotspots in the database.


Sensors
for
Location Based Services
GPS Enhancement & Indoor
Navigation

Sensors Play in LBS



Sensors in Tablets and Smartphones

Accelerometers

An accelerometer measures the difference between acceleration and gravity.

Benefits

- Can be used to sense orientation WRT gravity vector when stationary (linear acceleration = 0)
- Measures linear acceleration, can be used to sense motion/no-motion and freefall

Limitations

- Cannot separate gravity from linear acceleration
- Cannot determine heading as it is insensitive to rotation about the gravity vector

Magnetometers

A magnetometer measures the local magnetic field, which consists of earth's field plus interference from various sources

Benefits

- Provides magnetic heading, which can be translated to geographic heading if coarse position is known (via GPS, cell tower)

Limitations

- Magnetic inclination reduces performance at higher (lower) Northerly (Southerly) latitudes
- Sensitive to magnetic interference and magnetic anomalies
- Insensitive to rotation about the geomagnetic field vector

Gyroscopes

A gyroscope measures rotation rate using the Coriolis effect.

Benefits

- Insensitive to magnetic fields and linear acceleration
- Gyro data is smooth, with no large spike during linear motion/acceleration

Limitations

- Significant zero-rate offset and zero-rate drift over time
- Outputs need to continuously integrated to maintain orientation
- Noise and drift lead to errors that grow rapidly with time
- High current consumption due to the mechanical work needed to oscillate the sense mass at resonance (needed to sense the Coriolis force)

Accelerometer + Magnetometer

Fused Data

- Accelerometer plus magnetometer can provide device orientation and magnetic heading. A magnetometer also can be used as a “virtual” gyro in certain situations (magnetically clean and stable environment).

- Major weakness of this sensor pair is its sensitivity to linear acceleration, which leads to errors in both orientation and heading.

Accelerometer + Gyroscopes

Fused Data

- Accelerometer can help to stabilize the drift in the gyroscope output data.
- Rotation and linear acceleration can be separated.

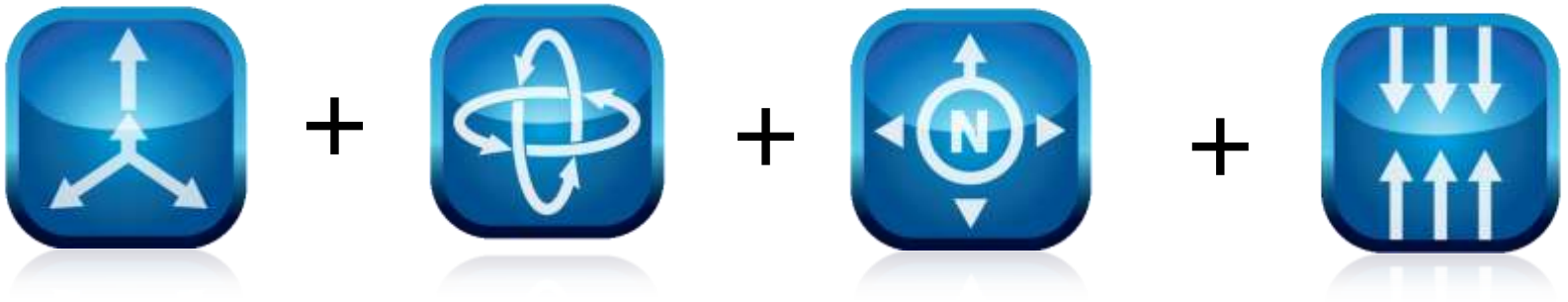
- Major weakness of this pair is the lack of an absolute heading reference

Accelerometer + Gyroscope + Magnetometer

Fused Data

- This combination of sensors can overcome the inherent limitations of each of the previous sensor pairings as their error sources (deficiencies) complement each other.

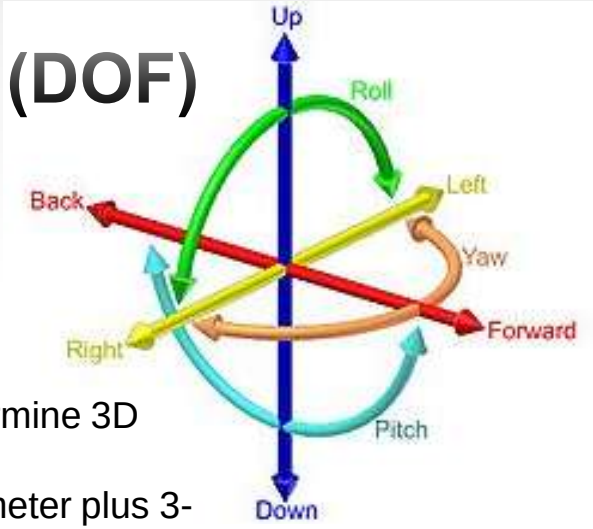
Accelerometer + Gyroscope + Magnetometer + Pressure



Fused Data

- This combination of sensors further improves on the previous pair with the addition of elevation. This is essential for use within buildings to sense the floor you are on. The pressure sensor also can be used to enable weather prediction.

Sensor Terms: Degrees of Freedom (DOF)



3 DOF:

- linear motion or rotation (but not both)
- 3-axis accelerometer OR 3-axis magnetometer OR 3-axis gyroscope

6 DOF:

- Ability for distinction between rotation and linear acceleration to determine 3D position
- 3-axis accelerometer plus 3-axis magnetometer OR 3-axis accelerometer plus 3-axis gyroscope

9 DOF:

- Ability to discriminate between rotation and linear acceleration and heading. Sensor fusion allows for the limitations inherent in each sensor to be overcome as the error sources for each sensor are complementary
- 3-axis accelerometer plus 3-axis magnetometer plus 3-axis gyroscope

10 DOF:

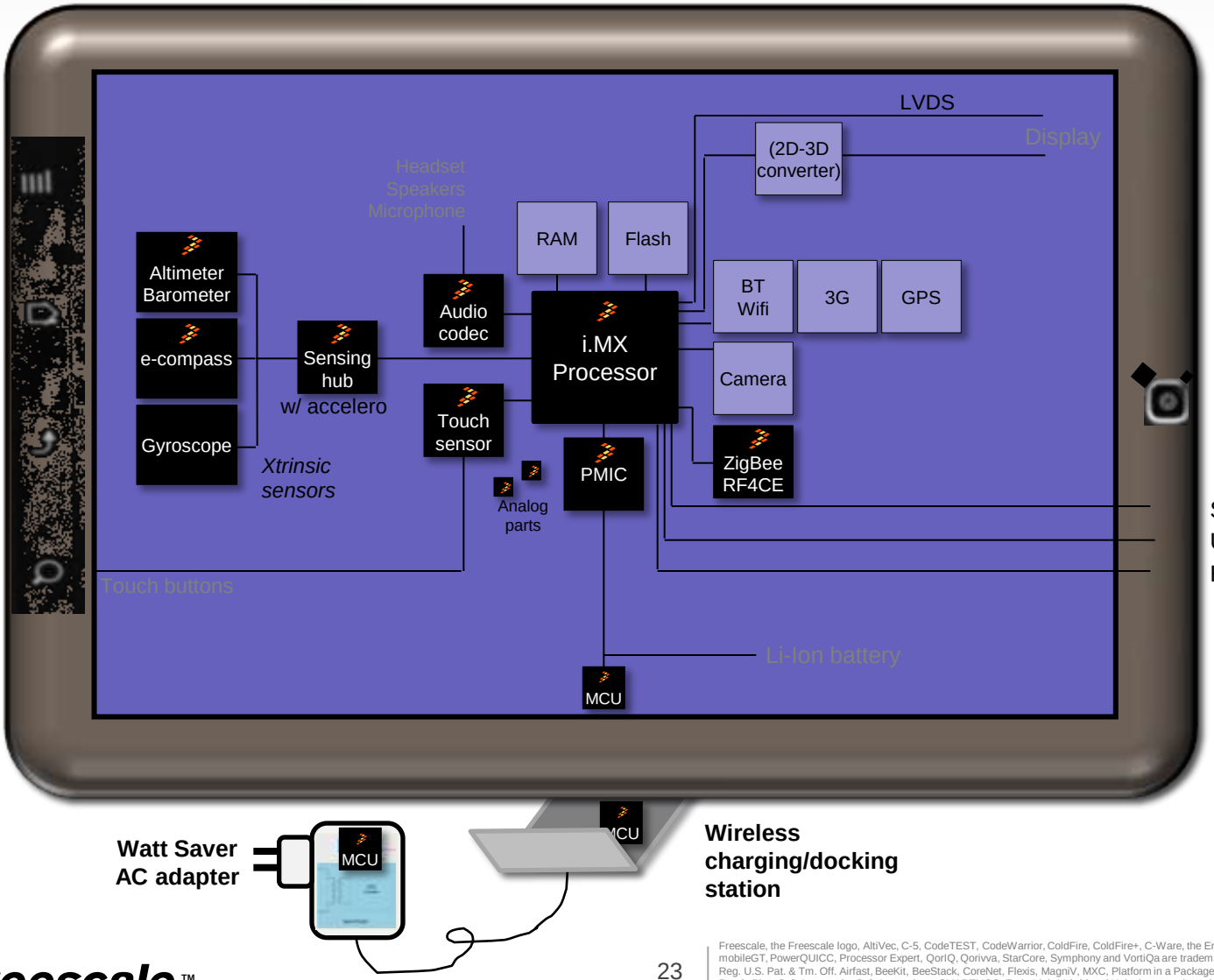
- 3-axis accelerometer plus 3-axis magnetometer plus 3-axis gyroscope plus a pressure sensor

Dead Reckoning:

- The process of estimating one's current position based upon a previously determined position and advancing that position based upon known or estimated speeds over elapsed time.
- A disadvantage of dead reckoning is that since new positions are calculated solely from previous positions, the errors of the process are cumulative, so the error in the position fix grows with time.

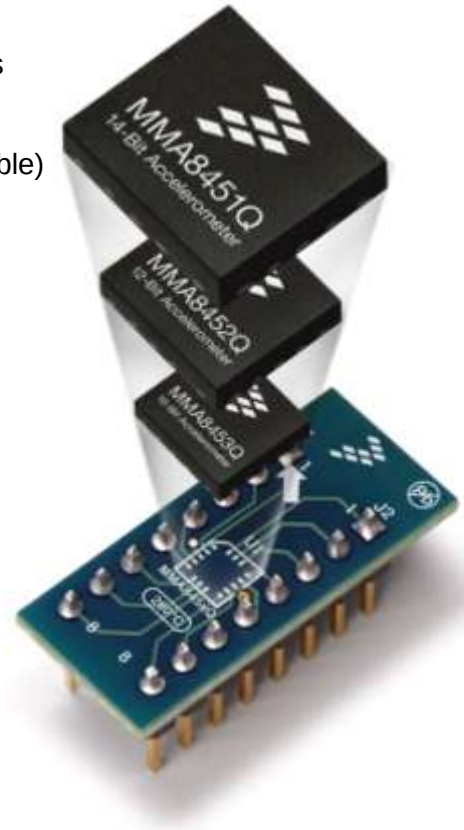
Freescale: SABRE Platform For Smart Mobile Devices

Example: Tablet **= Freescale solution**



MMA8x5x 3-Axis Xtrinsic Accelerometers

- **Features Options Dependent on Product Version**
  - 1.95V to 3.6V supply voltage
  - ±2g/±4g/±8g dynamically selectable full-scale
  - Output data rates (ODR's) from 800Hz to 1.563Hz
  - 99µg/sqrt(Hz) noise density
  - 14/12/10 bit digital output
  - I²C digital interface (operates at up to 2.25MHz with 4.6kOhm pull-up resistors) and up to 4.75MHz with 1kOhm pull-ups)
  - 2 programmable interrupt pins for 7 interrupt sources
  - Embedded orientation (portrait/landscape) with hysteresis
  - Embedded automatic ODR change for auto-wake-up and return-to-sleep to reduce current consumption
  - Embedded 32 sample FIFO for 14 and 8 bit data (selectable)
  - Embedded high pass filter
  - Up to 0.02º resolution at 1.56Hz (Hi Res mode)
  - 4 oversampling modes: low power, low noise+low power, high resolution, normal modes
  - Low noise and low power operating mode (limited to 4g range)
  - Embedded self test
- **Best In Class Specs**
  - Zero-g level offset accuracy
  - Board mount offset shift
  - Output noise
  - Sensitivity Accuracy
  - Offset temperature coefficients
  - Power consumption



3x3mm Digital Accelerometers

MMA8451Q
14 bit digital output
Full feature set

MMA8452Q
12 bit digital output
No FIFO, fixed PL at 30/60 trip points

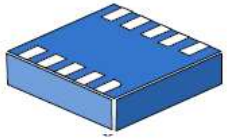
2x2mm Digital Accelerometers

MMA8652FC
160µg/sqrtHz noise
12 bit digital output
Full feature set

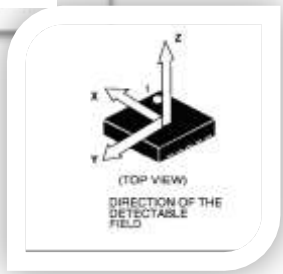
MMA8653FC
160µg/sqrtHz noise
10 bit digital output
No FIFO, No HPF, fixed PL at 30/60 trip points

freescale™

MAG3110 – 3 Axis Magnetometer



2x2x0.85mm
DFN-10



Features

- 1.95V to 3.6V supply voltage
- Orientation independent high accuracy compass function
- Typical resolution of 0.1µTesla
- Output data rates (ODR's) from 2.5Hz to 80Hz
- Maximum field of ±10G (±1000 uT)
- Multiple oversampling options to control the power vs. noise trade-off
- Current consumption down to 24uA at 1.25Hz
- Standby mode current consumption 2µA typical
- I²C digital interface
- Internally temperature compensation
- Extended operating temperature range of -40°C to +85°C

Xtrinsic FXOS8700CQ
6DOF (3-axis Accelerometer, 3-axis Magnetometer)

- **Differentiating Points**
  - Low noise accelerometer and magnetometer
  - Advanced embedded functionality to lower power consumption and increase response time
  - 32 sample accelerometer FIFO with burst read capability
- **Product Features**
  - 1.95V to 3.6V supply voltage, I/O 1.6V – 3.6V
  - ±2g/±4g/±8g accelerometer, and wide ±15 Gauss (±1500µT) magnetometer full-scale ranges
  - Output data rates (ODR's) from 1.563Hz to 800Hz for each sensor
  - Up to 400Hz ODR in hybrid mode with both sensors active
  - 14-bit accelerometer data, 16 bit magnetometer data
  - Low offset drift: 0.1mg/ºC (accelerometer) and 0.2µT/ºC (magnetometer)
  - 4 channel motion detection- FF, pulse, transient, HPF, tap
  - Vector magnitude detection function for both magnetometer and accelerometer
- **Typical Applications**
  - Electronic compass
  - Enhanced user interface

Package

- 3 x 3 x 1.2mm QFN

Timing

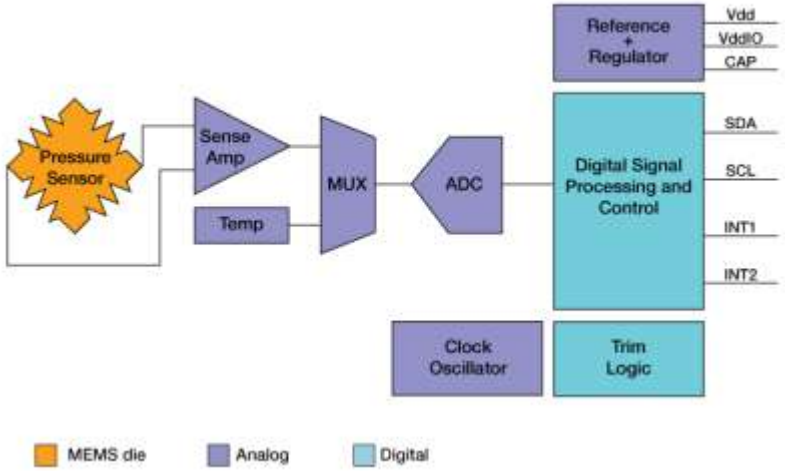
- Alpha samples – Now
- Alpha Dev Tool – Now
- Dev Tool orderable – Sept'12
- Production – Q3'12

MPL3115A2 – Pressure Sensor

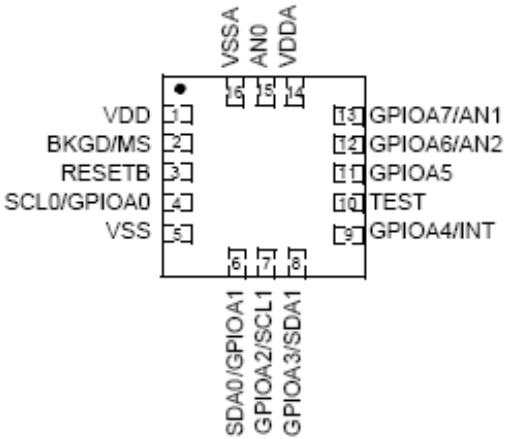
Features

- 1.95V to 3.6V supply voltage
- 50 to 110 kPa calibrated pressure range
- Direct reading and output compensated pressure
- 20-bit ADC for pressure measurement
- Direct altitude output option(with 3.1cm resolution)
- 12-bit temperature measurement
- Pressure resolution of 0.0625Pa
- FIFO and interrupts (to warn of pressure alarm windows)
- I2C interface (operates at up to 400 kHz)

MPL3115A2 Pressure Sensor Block Diagram



MMA955xL – Sensor Hub with accelerometer



Features

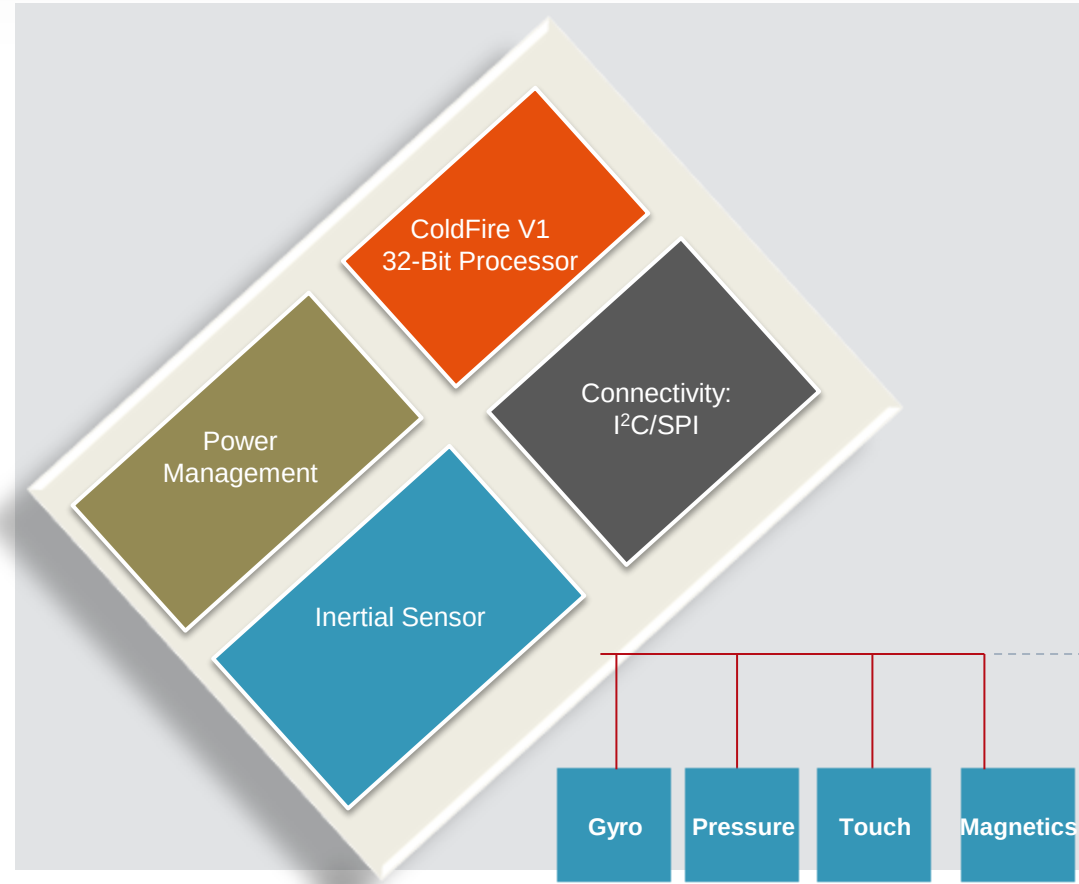
- +/-2g, 4g, 8g configurable dynamic ranges available
- Configurable 8-, 10-, 12-, 14-bit resolution
- Configurable sample rate from 0.24 to 1953 Hz
- 1.71 – 1.89V for AVdd and DVdd or single supply
- 2 µA standby current (I2C active)
- 20 µA operating current at 14-bit, 1 samples/s
- < 150 µA operating current at 14-bit, 64 samples/s
- Internal low power oscillator
- Slave I2C and SPI
- Master I2C
- 32-bit CPU core with multiply and accumulate block (MAC)
- Full software enablement with sensor algorithm libraries and development tools
- Downloadable software upgrades
  - 3x3x1mm LGA package
- -40°C to 85°C operating temperature range

Freescale's Xtrinsic eCompass Software

- Tilt compensation
- Soft iron and hard iron calibration
- Standard ANSI C source code
- Flash footprint 15 KB (approximate)
- RAM requirements 5 KB (approximate)
- Available in several formats free of charge:
  - 4-element model recommended for minimal soft iron distortion and limitation to processor RAM
  - 7-element model recommended for customers with typical soft iron interference

Available at: www.freescale.com/eCompass

Performance, Fusion & Application Content
Xtrinsic Differentiation Example – MMA9550L

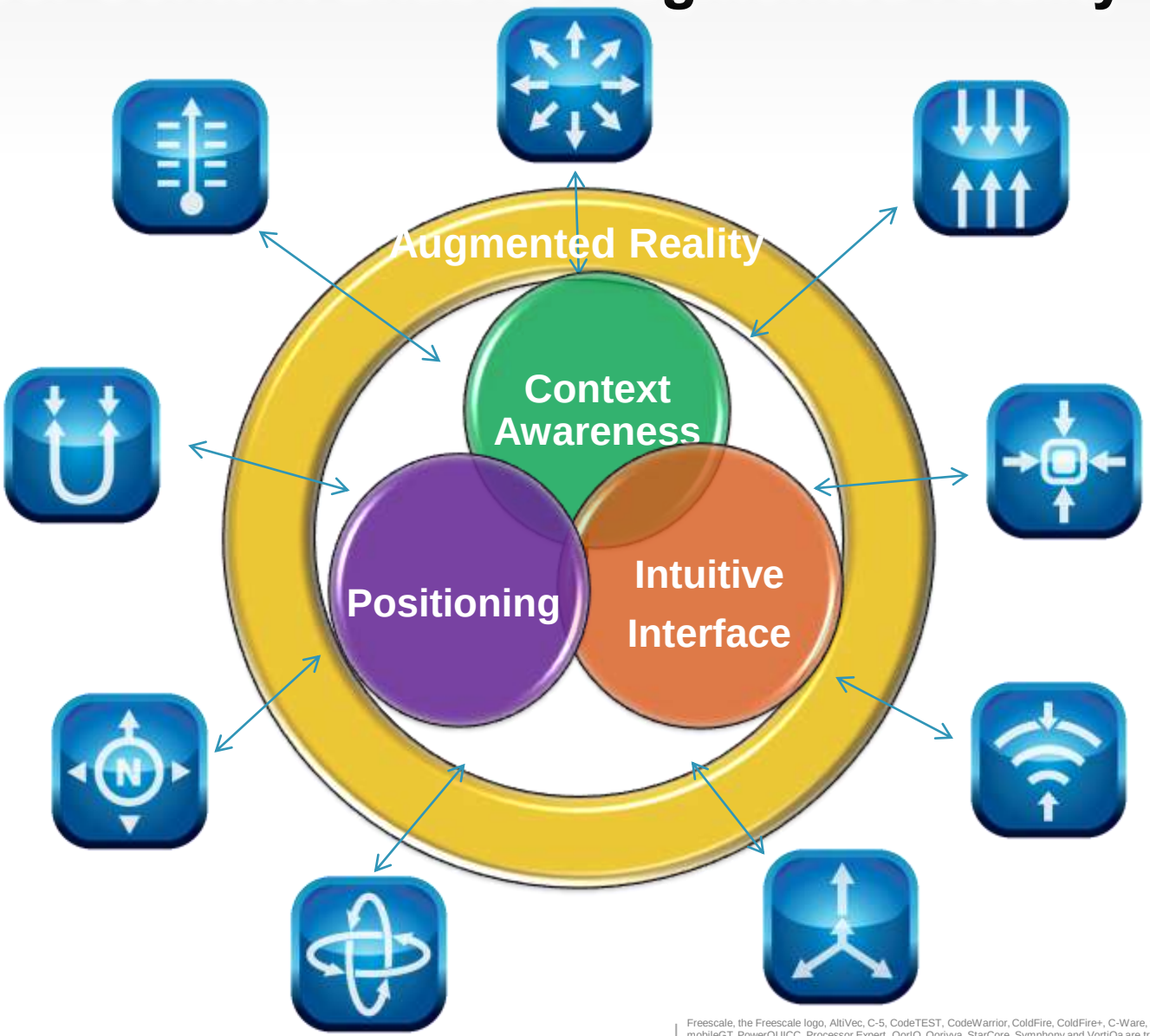


Compass

Gestures

Pedometer
(third party)

Sensor Content Enables Augmented Reality



…he Path to Augmented Reality…
…Evolving to Interactive Environment

Intuitive User Interface

Augmented Reality

Home Control:
Energy
Security
Multimedia

Medical
Health Monitoring

Pro-active
Communication:
Mood
Preferences

Location-Based Services

Smart Advertisement with ROI

Augmented Reality Top Apps for 2012

SpotCrime uses augmented reality to give you an idea of how dangerous the local area is. Using different icons and colors, SpotCrime shows you specific crimes that have occurred in your immediate region. This app is probably useful for house hunting. Other free AR apps also have crime layers, but SpotCrime offers a more comprehensive database and crime-area scouring system.

Junaio is another cool augmented reality browser with tons of options. It includes layers for Wikipedia, amenities, tweets, eBay classifieds and Foursquare venues. The app also has a handy built-in bar-code and QR scanner.

Theodolite is an electronic viewfinder for hikers and other active sportspeople. It serves as a compass, GPS tool, zoom camera, rangefinder, and two-axis inclinometer. For advanced users, the app also has an A-B calculator for height, distance, heading position, triangulation and relative angles.

Peaks is a simple augmented reality app that lets you point to any mountain (major or minor) and get information about it. The app will tell you the peak's altitude and how far away it is. When you go outside, the app also lets you take photos, both with and without the overlaid info.

freescale™

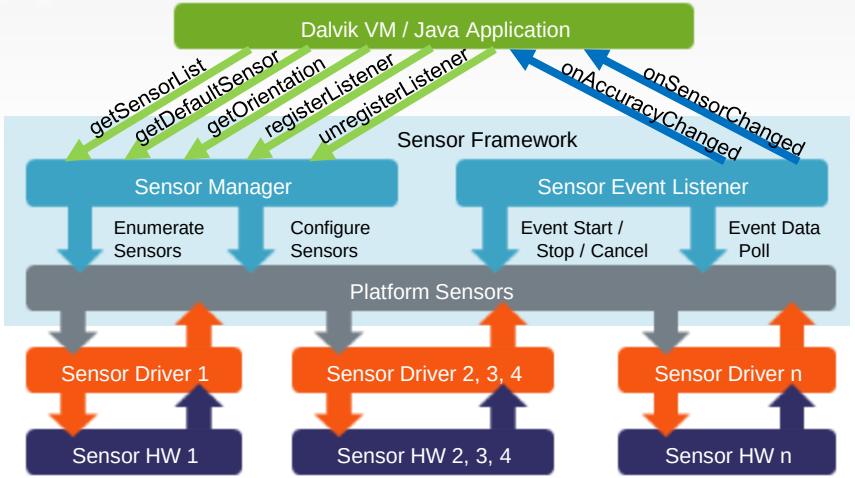
Android Sensor Driver Support

- Freescale provides a series of software drivers for use in consumer and industry applications. Android™, Linux and other operating systems are supported.

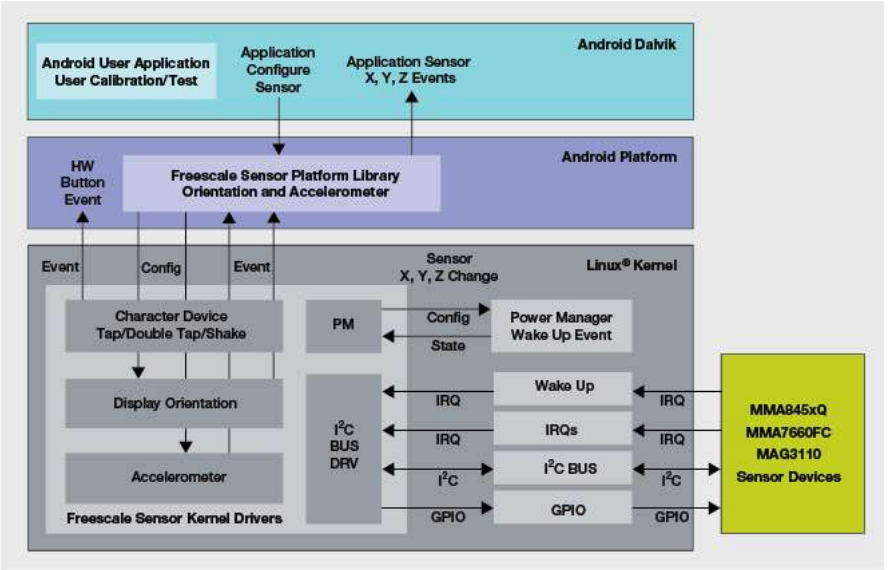
- Using a layered approach with the right selection of components to interface into the platform software stack results in a more complete and ready solution. Designers can directly integrate Freescale sensor drivers into their solutions or easily modify their code based on our reference code.

- Xtrinsic sensor drivers provide a platform for building a mobile device planned for the Android Compatibility Test Suite (CTS).

  http://www.freescale.com/SensorDrivers



Xtrinsic Sensor Drivers for Android™



Sensor Framework Issues and Solutions

- **Asynchronous data samples**
  - If each sensor is sampled asynchronously then there will be time differences between the samples during which there may have been orientation changes in the device. This adds ‘noise’ to data fusion algorithms.
- **Irregular sampling period within the Android framework**
  - Sample period changes depending on how many other tasks are running on the processor. Requested sample rate is only a guide. Irregular sample periods can disrupt frequency dependent algorithms.
- **Slow sampling rates**
  - Sample rates may be limited, preventing functions that require higher bandwidth such as tap detection from working properly.
- **Solutions**
  - Ensure synchronous sampling of sensors, ideally by placing them in the same device or under the real-time control of a dedicated MCU.
  - External buffering of samples in the sensor can help avoid missed data (FIFOs).
  - Data ready interrupts from the sensor may enable buffering in the device driver.

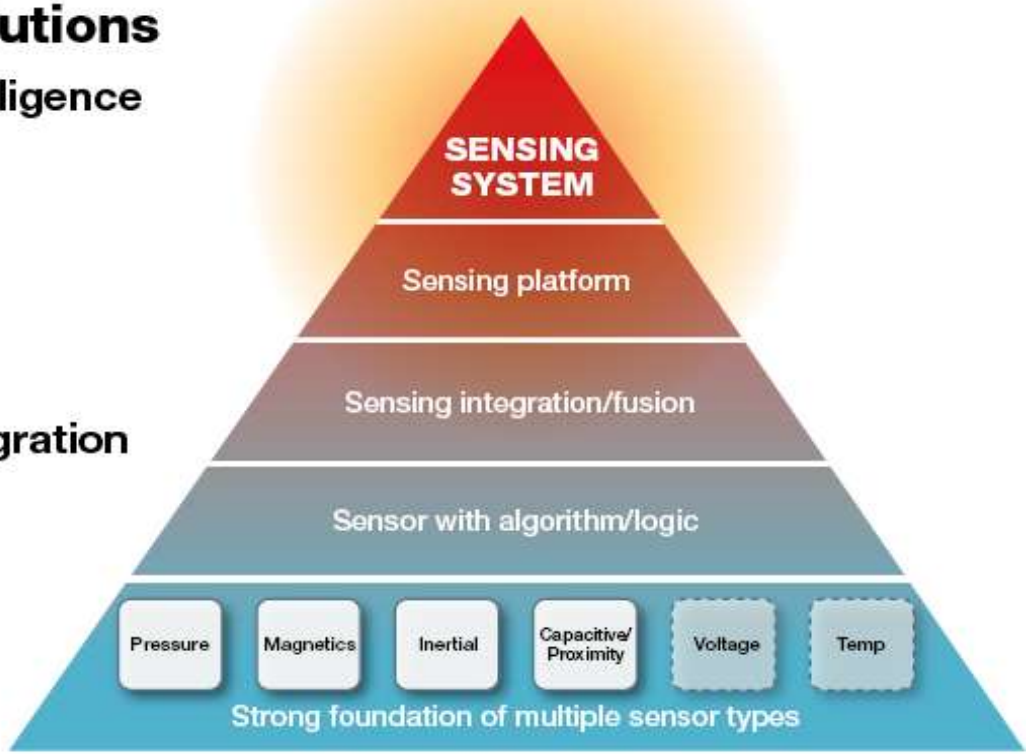
Summary: Freescale's Era of Xtrinsic Sensing

INTELLIGENT CONTEXTUAL SENSING—*more than translating a signal*

Freescale Xtrinsic sensing solutions offer increased levels of modular integration combined with multiple sensor inputs, logic and other building blocks to bring greater value and decision making to the overall sensing solution.

Xtrinsic Sensing Solutions

- **Increasing levels of intelligence**
  - Decision making
  - Software enablement
  - Programmability
  - Applications
  - Third-party software
- **Increasing levels of integration**
  - Multiple sensor types
  - Connectivity
  - Power management
  - Logic
  - Actuation



Additional Resources

Sensors

- www.freescale.com/sensors
- http://www.freescale.com/sensingplatform
- http://www.freescale.com/sensordata
- www.freescale.com/mems

Sensor Products

- www.freescale.com/xyz
- www.freescale.com/magnetic
- www.freescale.com/pressure
- http://www.freescale.com/sensortoolbox

Blogs: Smart Sensors

- http://blogs.freescale.com/2011/06/06/location-based-services-sensors-go-beyond-the-navigation/?tid=NL_2311
- http://blogs.freescale.com/author/michaelestanley/
- What in the world is contextual sensing?
- Evolving intelligence with sensors
- Magnetic sensor makes electronic compass design easy

Xtrinsic Sensor Classes at FTF

Tuesday

12:45 pm - FTF-ENT-F0137: Lunch and Learn: Xtrinsic Sensor Fusion, Part 1: Terms, Trends, Challenges and Advantages

2:00 pm - FTF-ENT-F0226: Xtrinsic Sensor Fusion, Part 2: Alignment to Sensor Framework for Windows 8, Android and Other Operating Systems

5:15 pm - FTF-CSD-F0225: Xtrinsic Sensing: Introduction, Part 1

Wednesday

10:30 am - FTF-CSD-F0224: Xtrinsic Sensing, Part 4: Applications for Pressure Sensors in Home Appliances and Health Care Solutions

12:45 pm - FTF-ENT-F0123: Lunch and Learn: Augmented Reality: New Applications and the Role of Hardware

12:45 pm - FTF-ENT-F0138: Lunch and Learn: Xtrinsic Sensor Fusion, Part 4: Designing eCompass Solutions

2:00 pm - FTF-IND-F0223: Xtrinsic Sensing, Part 2: Applications for Industrial Automation

4:15 pm - FTF-SEG-F0221: Xtrinsic Sensing, Part 3: Application of Tamper Detection for Smart Metering

5:15 pm - FTF-CSD-F0222: Xtrinsic Sensing, Part 5: Application of Location Based Services: GPS Enhancement and Indoor Navigation

Thursday

9:30 am - FTF-ENT-F0067: Hands-on Workshop: Implementing Xtrinsic Touch Sensing (Reserved Seating Required)

9:30 am - FTF-ENT-F0091: Hands-on Workshop: Xtrinsic Sensor Fusion, Part 3: Start Programming with the Xtrinsic Sensor Platform (Reserved Seat Required)

Presenter

Michelle Kelsey

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Sensor & Actuator Solutions Division

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Facebook.com/Freescale
Tag yourself in photos
and upload your own!

Tweeting?
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