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探索、创新、开拓

针对可穿戴和无线设备的低功耗传感器融合算法

Low Power Sensor Fusion for Wearables and Wireless Devices

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Sensor Fusion for Wearable & Wireless Devices

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Introduction

Recent technological advances have enabled a new breed of wearable and smart devices

- Low footprint and low power microelectronic technologies
- Low power wireless communications
  - Bluetooth Low Energy

Ability to sense stimuli from the wearer or environment around them

- Movement, touch, sound, temperature, etc.
- Information gleaned from individual stimuli is limited
- Real value comes when combining stimuli to derive more complex metrics

Characteristics of Wireless Sensor Devices

Low Power

- Run off battery
- Long periods between charges

Multiple Sensors

- Inertial: Accelerometer, Gyroscope & Magnetometer
- Environmental: Temperature, Pressure & Humidity
- Health: Heart Rate

Communicate Wirelessly

- Intermittently upload data to host device
- Stream data in real-time

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Wireless Sensor Devices and their Applications

Wearables

- Smartwatches and Activity Trackers
  - Activity/Fitness Tracking
    - Step Counting, Distance Travelled, Floors Climbed, Calories Burned
    - Classification
  - Heart Rate Monitoring
  - Indoor Navigation

Wireless Controllers

- Air Mice , Game/VR Controllers, TV/Media Center Remotes
  - Motion Tracking
    - 3 DoF Orientation Tracking
    - 6 DoF Positioning/Dead Reckoning
  - Gesture Recognition

Wearable and Wireless Sensor Device Architectures

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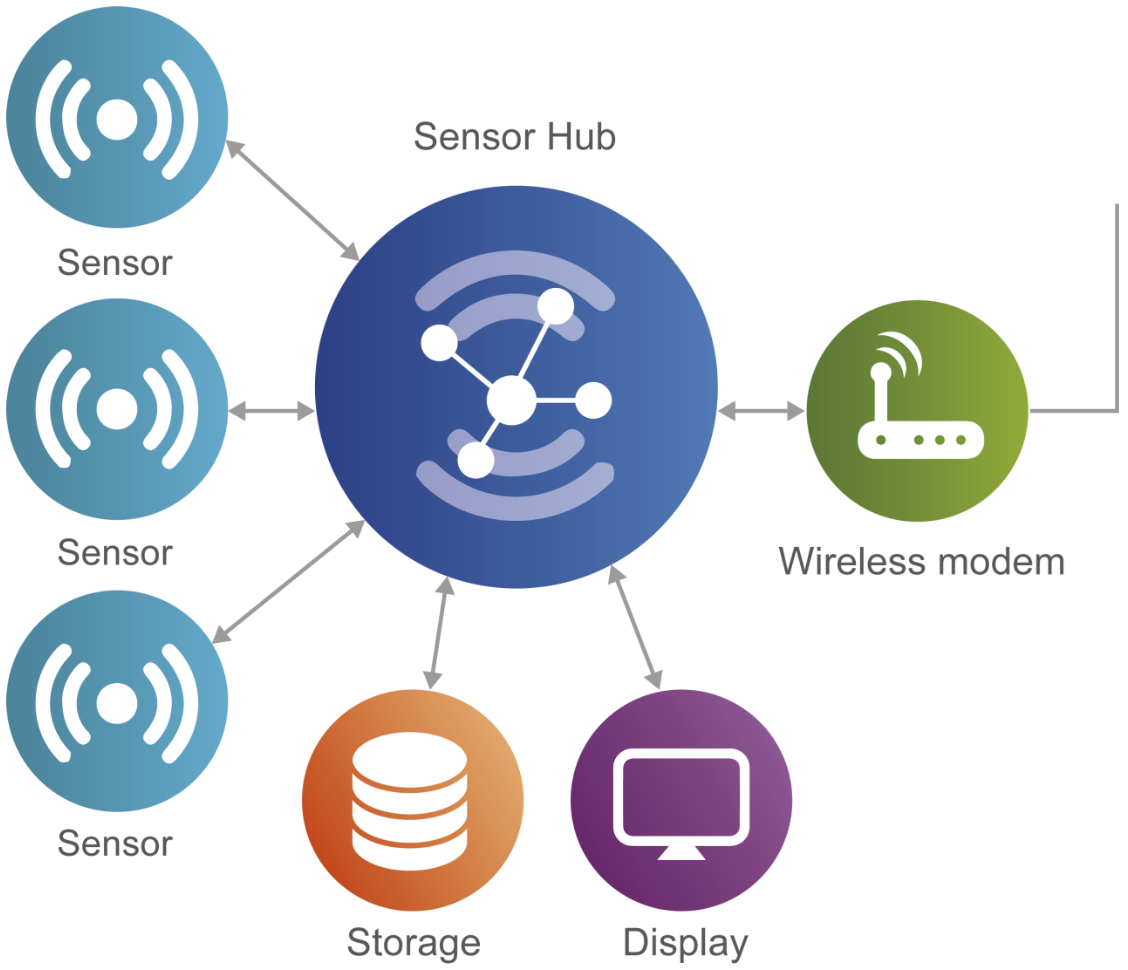
dialog SEMICONDUCTOR

Sensor Hub

- Single µP/µC captures data from multiple sensors
- Processes data
- Communicates with host device via wireless interface
- Writes information to local storage or display
- Data Sharing Options:
  - Stream raw or processed data to host in real time across wireless interface
  - Write raw or processed to local storage for later transmission to host
  - Display locally on device



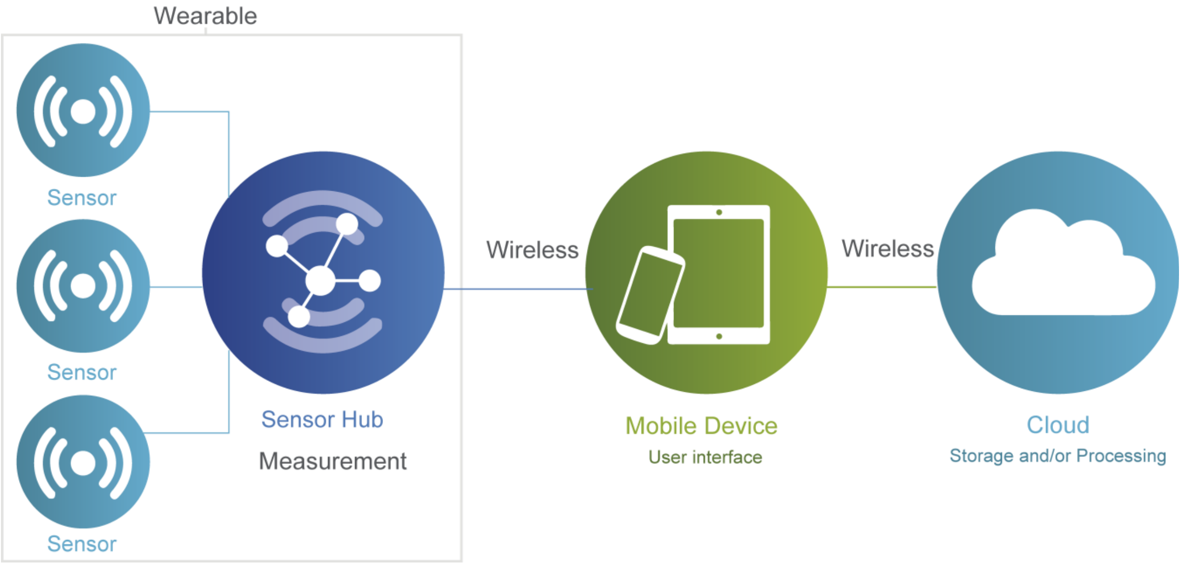
Sensor Fusion Processing Options

On Host Device or In the Cloud

- Pros:
  - Low footprint hardware architecture
  - Low cost
- Cons:
  - Generates a lot of raw sensor data to transmit/store
  - Requires high wireless bandwidth and power usage
  - Information not available to user locally on device

On Wearable Device

- Pros:
  - Allows raw data to be analyzed, combined and decimated before transmission/storage
  - Lowers required wireless bandwidth and power usage
  - Information available to user locally on device
- Cons:
  - High footprint hardware architecture
  - Higher cost



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Overview of Sensor Fusion Algorithms

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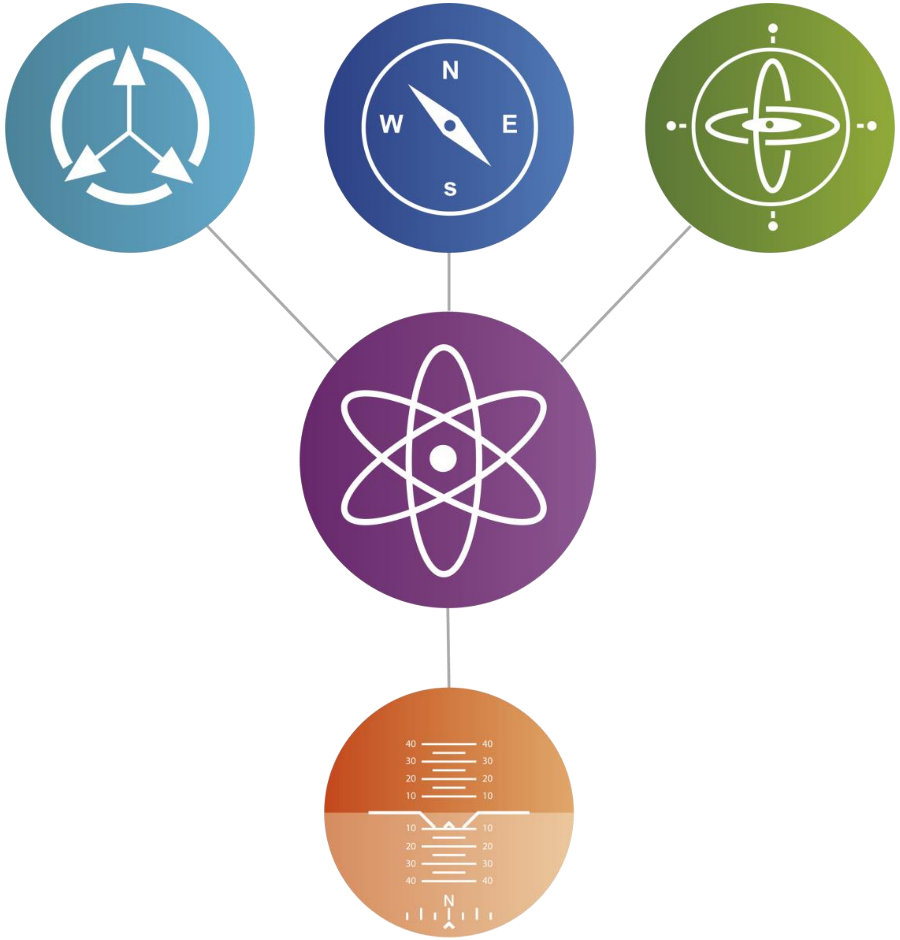
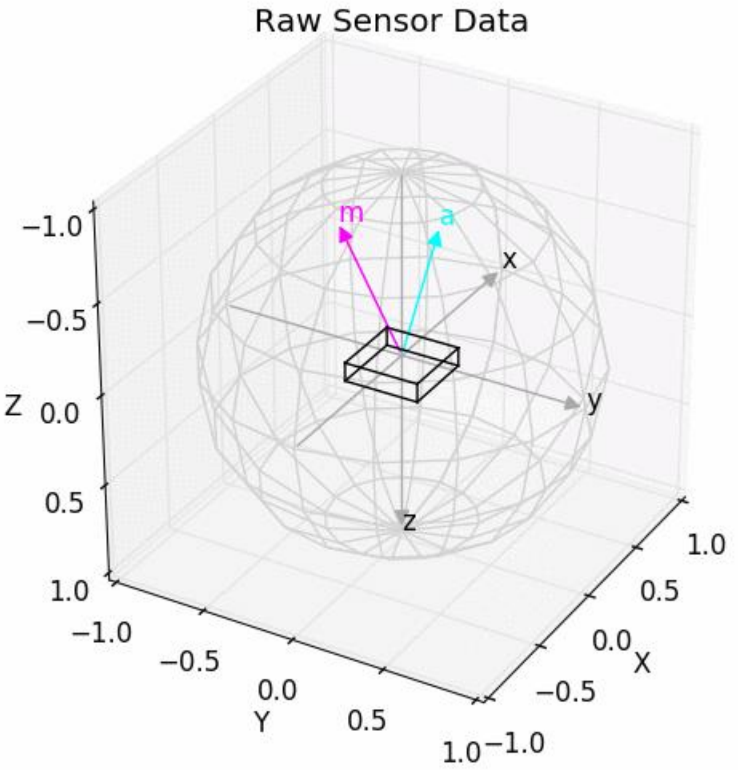
Sensor Fusion Algorithms

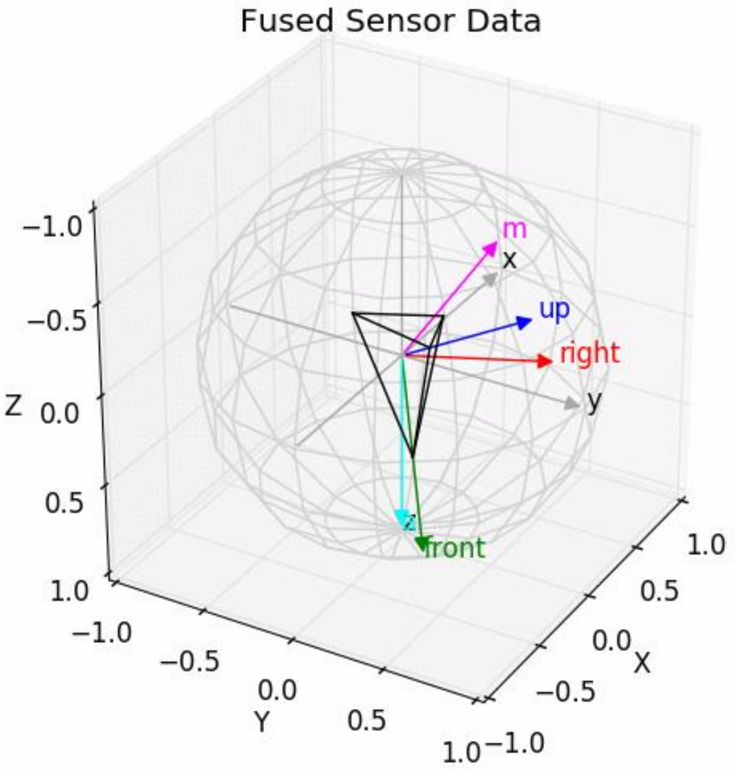
Attitude and Heading Reference System (AHRS)

- Fuses data from multiple sensors:
  - Gyroscope: Detects rotation (no absolute orientation reference)
  - Accelerometer: Detects acceleration/gravity (tilt reference)
  - Magnetometer: Detects direction of geomagnetic field (heading reference)
- Combining this information we can work out and track the absolute orientation and movement



Raw vs. Fused Sensor Data





- Data from each individual sensor plotted independently (in relative frame of reference)
- Difficult to make sense of what is going on
- Data from individual sensors combined to plot orientation (in absolute frame of reference)
- Much better overall idea of what is going on

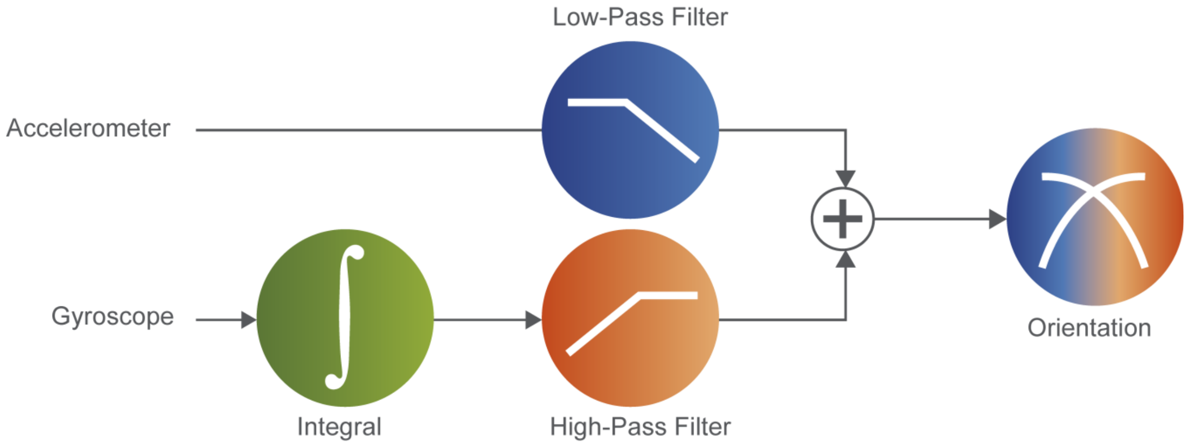
Sensor Fusion Algorithms

Complementary Filtering

– Combines data from multiple sensors:
  - High-pass filtered gyroscope data
    - Tracks rapid rotations
  - Low-pass filtered accelerometer & magnetometer data
    - Tilt and heading references
– Susceptible to sensor distortions

Kalman Filtering

– Models expected behavior
– Compensates for inconsistencies between sensors
– More complex and computationally demanding



SmartFusion™ Library

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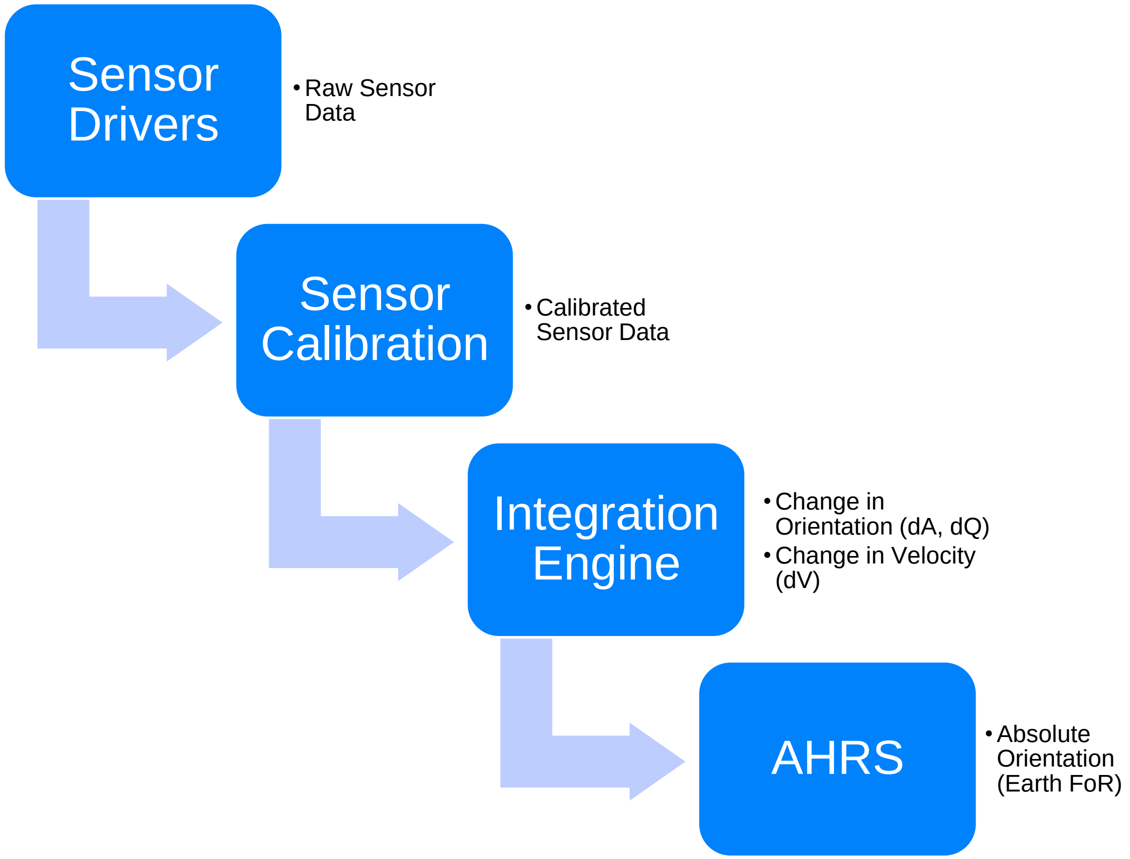
SmartFusion™ Library

ARM Cortex-M0 ANSI C Library

Includes toolbox of functionality:

- Calibration of MEMS sensor data to compensate for distortions
- Processing, integration and decimation of data from various types of sensor
- Fusion of data from 3D inertial and magnetic sensors

Provided free of charge for designs using Dialog Semiconductor SmartBond™ Bluetooth Low Energy SoCs



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SmartFusion™ Library – Sensor Calibration

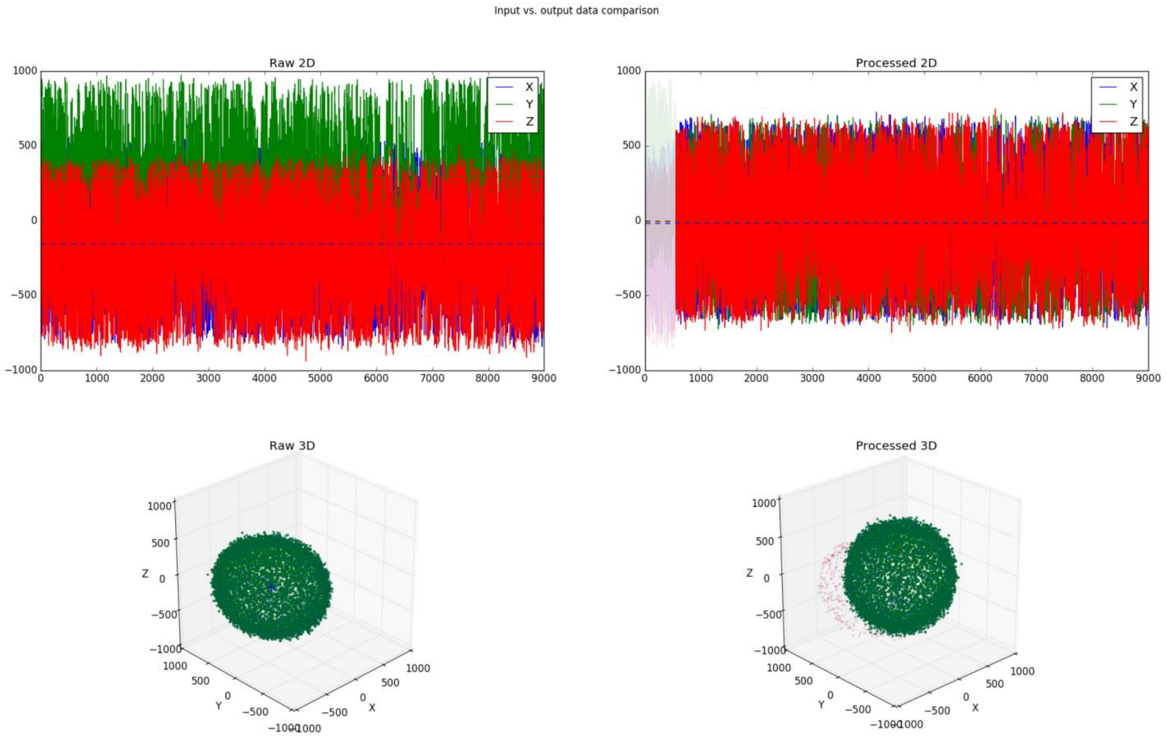
Static Calibration Routines

- Application of externally derived calibration coefficients
- Applies 3x3 matrix and offset:

$$\begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix} = \begin{bmatrix} m_{xx} & m_{xy} & m_{xz} \\ m_{yx} & m_{yy} & m_{yz} \\ m_{zx} & m_{zy} & m_{zz} \end{bmatrix} \begin{bmatrix} u_x \\ u_y \\ u_z \end{bmatrix} + \begin{bmatrix} o_x \\ o_y \\ o_z \end{bmatrix}$$

Automatic Calibration

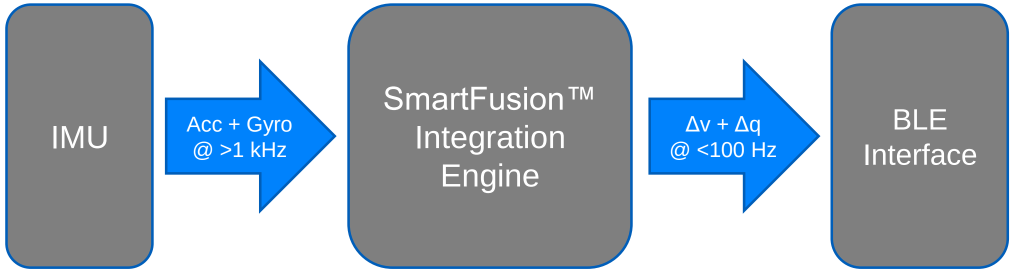
- Calculates and compensates for offset, scaling and spherical distortions at runtime
- Hard and soft-iron magnetometer distortions
- Gyro drift compensation and noise gating



SmartFusion™ Library – Sensor Fusion

Integration Engine

- Integrates multiple samples of high rate sensor data over given period
- Decimates quantity of sensor data - Minimizes wireless bandwidth requirements and power consumption
- No loss of accuracy - Tracks movements more precisely and minimizes drift



Attitude and Heading Reference System (AHRS)

- Novel computationally efficient algorithm
- Utilizes quaternion geometry
- Avoids numerical issues (gimbal lock)
- Low latency
- Supports different sensor combinations in various 3, 6 & 9 DoF configurations

Mode	Degrees of Freedom	Gyroscope	Accelerometer	Magnetometer	Supported
Gyroscope Only (G)	3	✓	×	×	✓
Gyroscope + Accelerometer (GA)	6	✓	✓	×	✓
Gyroscope + Magnetometer (GM)	6	✓	×	✓	×
Accelerometer + Magnetometer (AM)	6	×	✓	✓	✓
Gyroscope + Accelerometer + Magnetometer (GAM)	9	✓	✓	✓	✓

SmartFusion™ Library – Software Integration

Simple/Flexible API

- Modular
  - Use and combine only set of components suitable for application
  - Each module has it's own instance/parameter structure and set of functions
- Tunable
  - Module parameters allow algorithms to be tuned according to specific hardware characteristics and application requirements

```
typedef struct cal_instance_str {
    cal_mode mode;      /**< Calibration mode */
    cal_params params;  /**< Calibration parameters */
} cal_instance;

void cal_init(cal_instance *instance);

void cal_process(cal_instance *instance);
```

Lifecyle

1. Instantiate module instance structure
2. Initialize module
   a) Set pointers to input/output data
   b) Set module parameters
   c) Call 'init' function (if it exists)
3. Process Data
   a) Update input data
   b) Call 'update'/'process' function

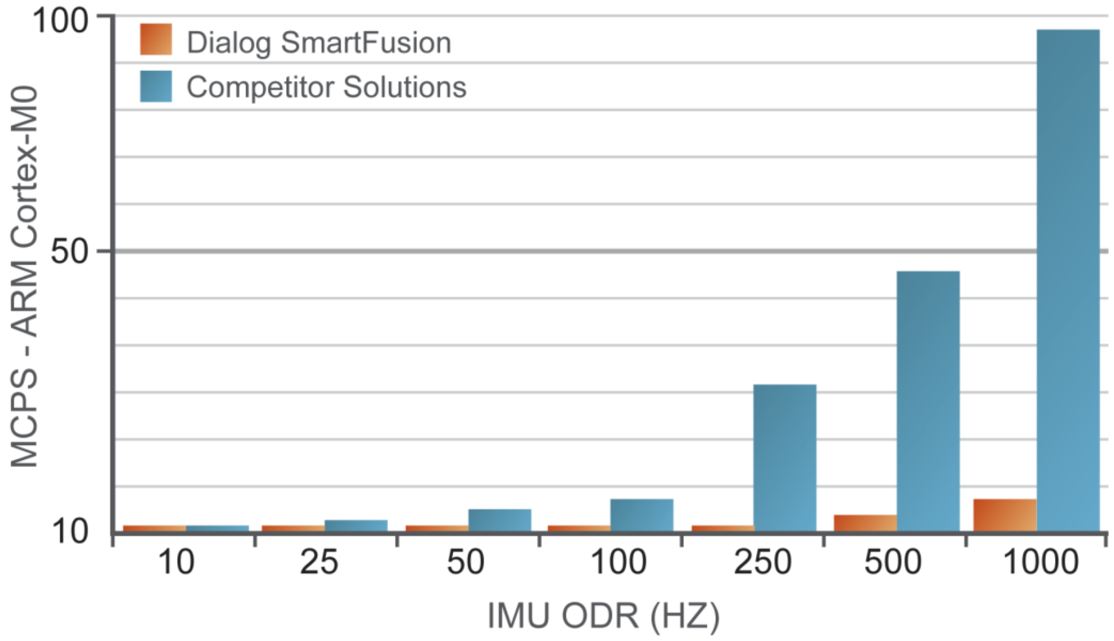
```
typedef struct {
    SmartFusionAHRS_controls controls;
    vect *g_vec_ptr;  /**< Pointer to the gyroscope vector */
    vect *m_vec_ptr;  /**< Pointer to the magnetometer vector */
    vect *a_vec_ptr;  /**< Pointer to the accelerometer vector */
    fix  g_scale;     /**< Gyroscope scaling factor */
    fix  beta_a;      /**< Parameter controlling relative weight of
                           accelerometer data */
    fix  beta_m;      /**< Parameter controlling relative weight of
                           magnetometer data */
    quat q;           /**< Current estimate of the orientation */
} SmartFusionAHRS_param;

void SmartFusionAHRS_update(SmartFusionAHRS_param *p);
```

The SmartFusion™ Advantage

The SmartFusion™ Advantage

ARM Cortex-M0 C Library

- Designed from scratch to be as efficient as possible:
  - Smart and efficient algorithms
  - Optimized fixed point implementation (does not use floating point emulation)
  - No dependencies on external runtime libraries
- Low latency/high data rate
- Flexible/Scalable
- Processing requirements: <0.5 MCPS @ 100 Hz ODR
- Memory requirements: 5 kB
- Low Cost
  - Eliminates software licensing costs
  - Able to run on the least complex and lowest cost h/w platforms available



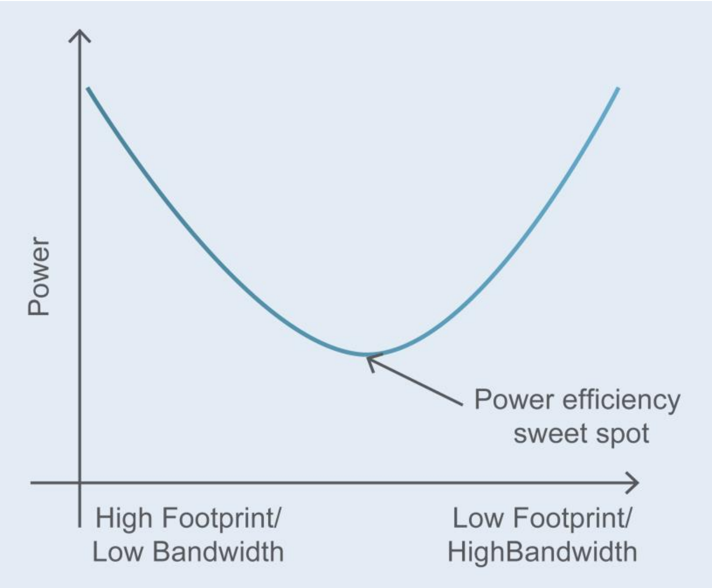
The SmartFusion™ Advantage

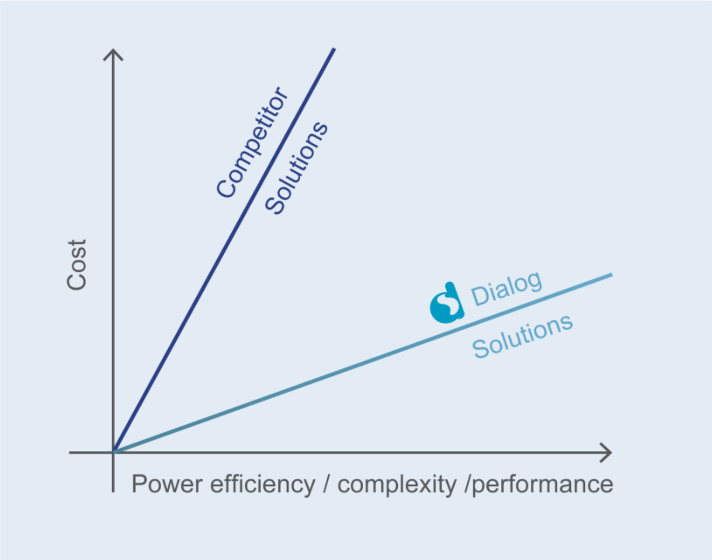
Novel approach combines the best characteristics of other approaches:

- High accuracy/performance
- Low bandwidth
- Low footprint
- Hits power efficiency sweet spot

When combined with SmartBond™ Bluetooth Low Energy SoCs

- Enables the most power efficient and low cost sensor fusion solutions on the market
- DA14583 IoT Sensor uses just 1.7 mA!





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SmartFusion™ Hardware Platforms & Development Kits

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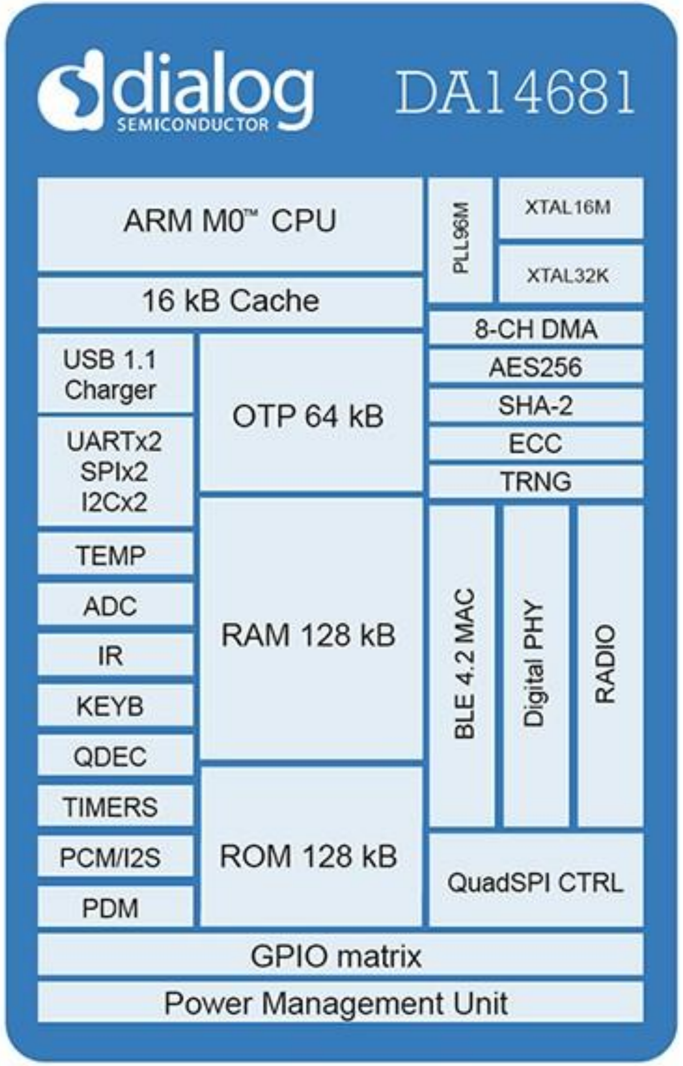
SmartFusion™ Hardware Platforms

Dialog Semiconductor SmartBond™ Bluetooth Low Energy SoCs:

- DA1458x – World's smallest, lowest power and most integrated Bluetooth Low Energy SoC
  - Beacons & Proximity, Health & Fitness, HID, Smart Home
- DA1468x - Highest integration, flexibility and security
  - Wearables, Virtual Reality, Smart Home, Apple HomeKit, HID, Other rechargeable devices



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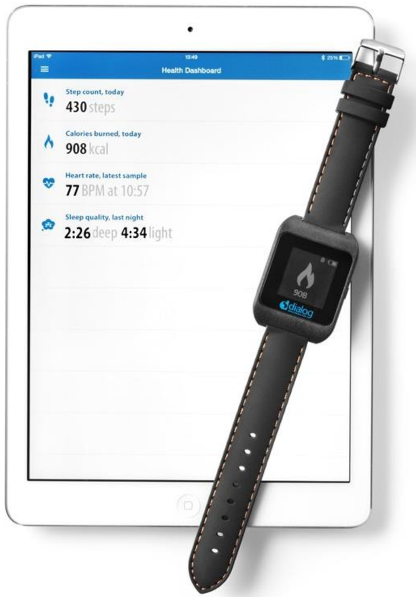
SmartFusion™ Development Kits

DA14583 IoT Sensor Development Kit

- Bosch BMI160: 6-axis inertial measurement unit
- Bosch BMM150: 3-axis geomagnetic field sensor
- Bosch BME280: Integrated environmental unit (pressure, temperature and humidity)

DA14681 Wearable Development Kit

- Activity Tracking (using same set of sensors as above)
- Heart Rate Monitor
- Capacitive touch sensor
- NFC
- Haptic motor

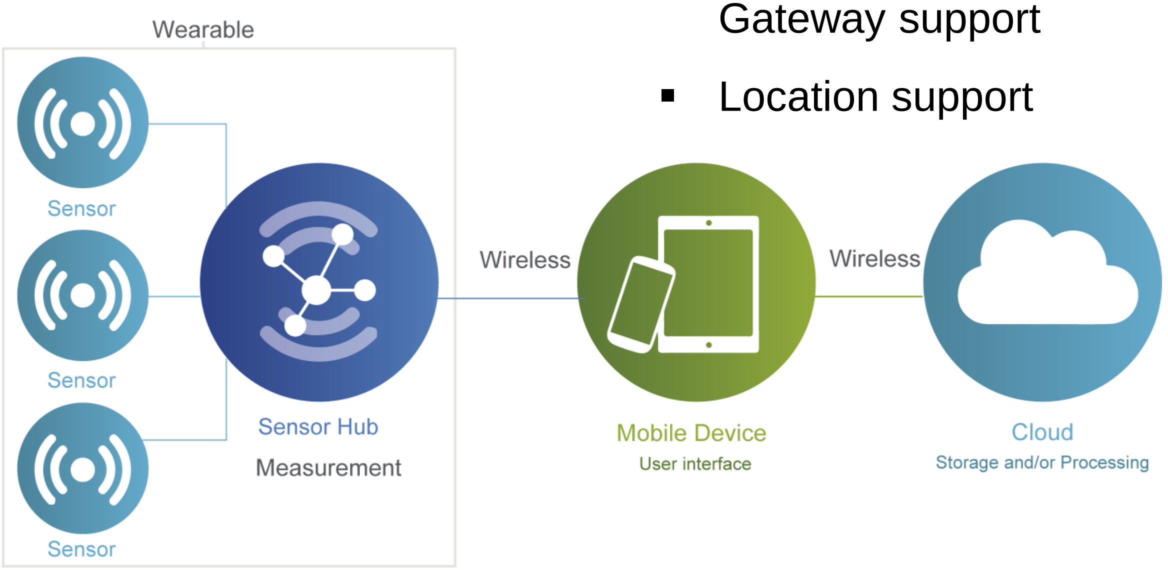


SmartFusion™ Development Kits

DA14585 15DOF IoT Sensor Development Kit

- 6-axis inertial measurement unit
  - TDK Invensense ICM42605 (mounted)
  - Bosch BMI160 supported
- 3-axis geomagnetic field sensor
  - AKM AK09915C (mounted)
  - Bosch BMM150 supported
- Integrated environmental unit
  - Bosch BME680 (mounted to measure temperature, humidity, pressure, gas)
- Light, Sound
  - VCNL4010 Proximity IR & ALS Sensor
  - SPK038HT4H digital microphone

- Alexa Voice Command Sensor reading and actuator control
- IFTTT Support
- Smartphone or Raspberry Pi Cloud Gateway support
- Location support



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谢谢

Thank you!