Smartphone-Enabled Mobile Measurements

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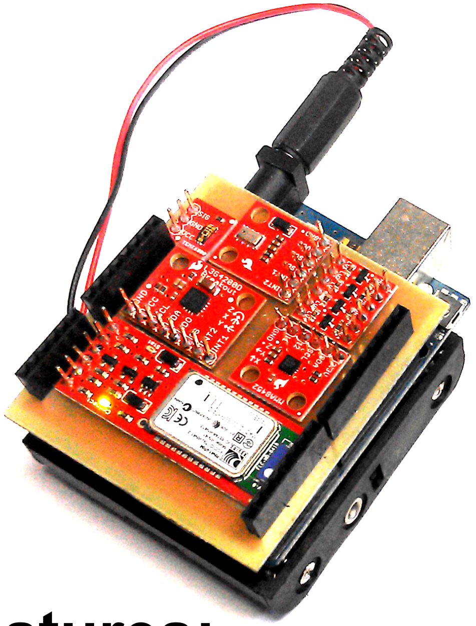
Overview

Project Goal:

Develop an embedded sensor platform controlled, queried and recorded from a smartphone application



Sensor Measurements:

Acceleration
Rotational Rate
Altitude/Pressure
Temperature
Ambient Light

Features:

250 Hz Sample rate
Low cost: $185
Integratable MCU

Systems Architecture

Logging Platform:

Motorola Moto X

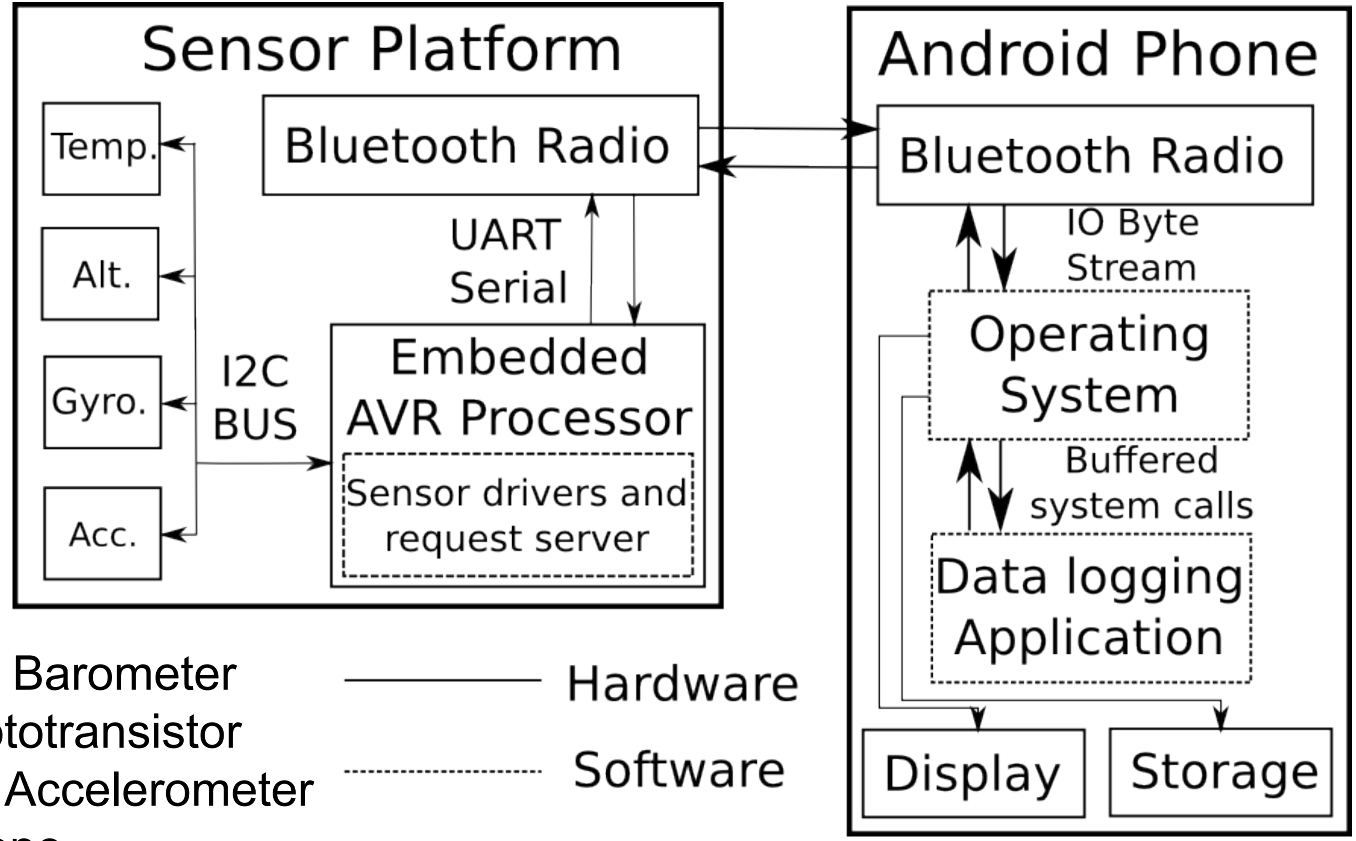
running Android 4.4

Sensor Platform:

AVR microcontroller and Arduino board compatible sensor shield powered by an AA battery pack

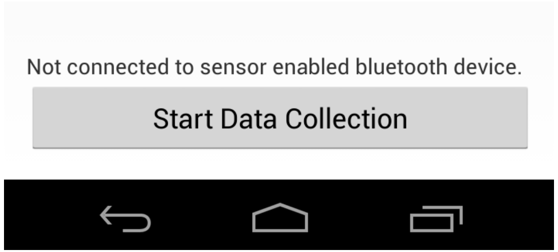
Sensor Hardware:

Freescale MPL3115A2 Barometer
Vishay TEMT6000 Phototransistor
Freescale MMA8452Q Accelerometer
ST L3G4200D Gyroscope

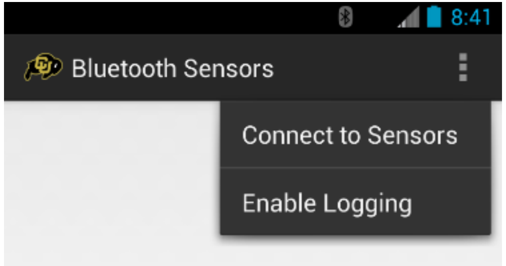


Android User Interface

- Simultaneous logging and display
- Defaults to lower power mode with logging disabled and slower sampling
- Clear control interface buttons and error handling messages
- Exception based error handling deals with unexpected radio states and can help guide the user to a solution.



Error messaging

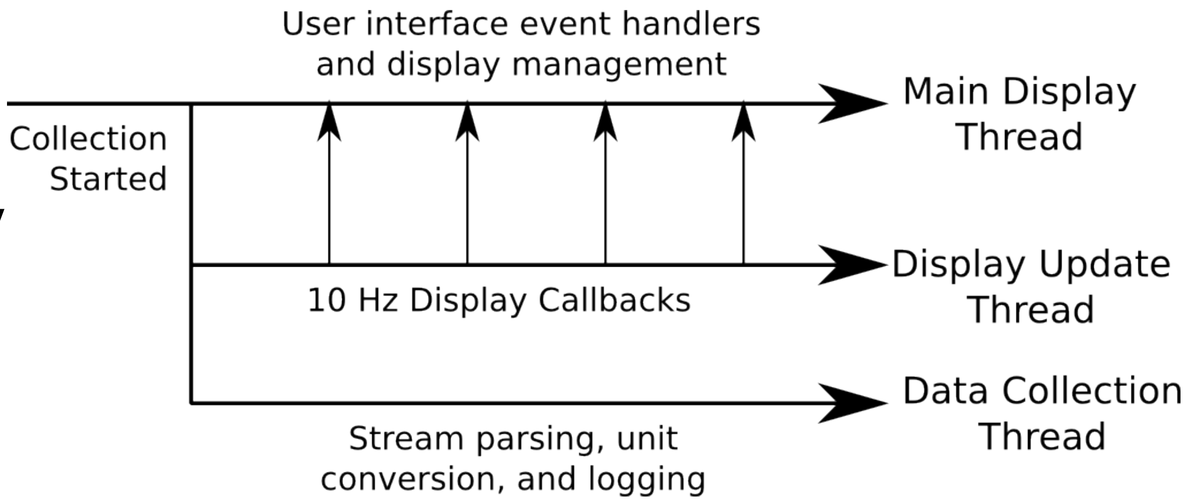


State Controls

Sampling Interface

Android Threading Methods

Multithreading:
Allows sensor data processing and display synchronisation to be handled by the operating system scheduler



This approach solves several problems:

1. Minimizing report latency and consistent display refreshing
2. Allows user interface to be responsive regardless of load
3. Reduces complexity of error handling and state changes

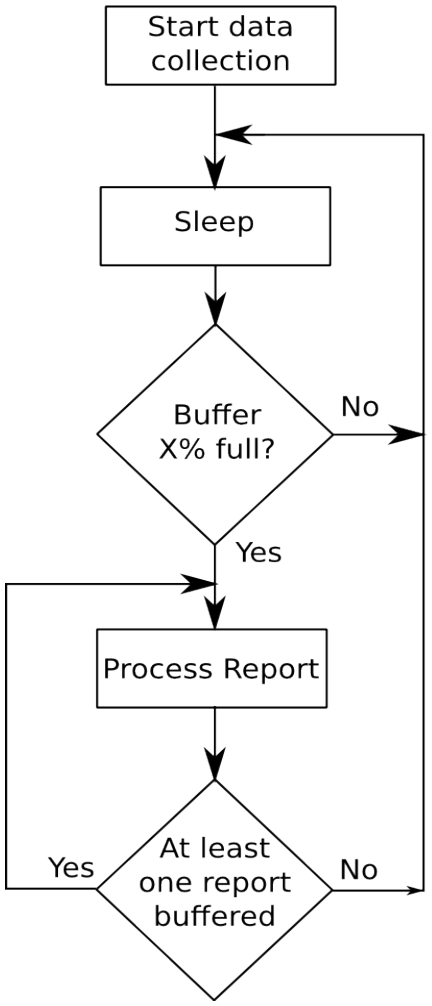
Android Input/Output Methods

Buffered I/O Benefits:

- Reduced context switching overhead: Fewer system calls are required to read the stream
- Fast and efficient memory access: Large chunks of each memory page can be cached and processed quickly

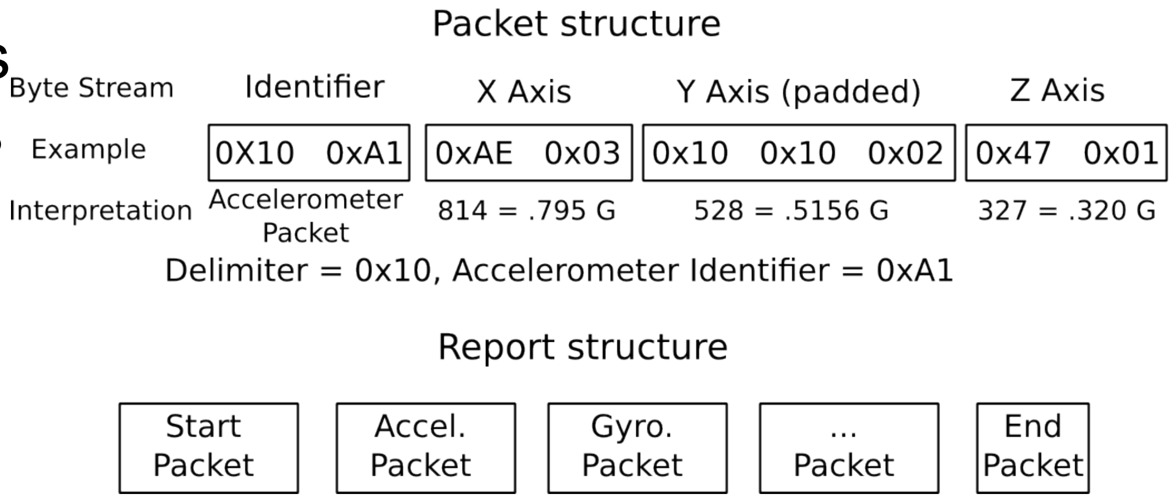
Tuning:

- Single parameter for management of buffer overflow and report processing latency
- Buffer size set to maximize sampling with system memory and processing resources



Networking Methods

- Bluetooth Radio has no QOS guarantees
- Packets structure allows checking for lost bytes, enabling streaming reports
- Report Structure simplifies correction routine after a corrupted packet

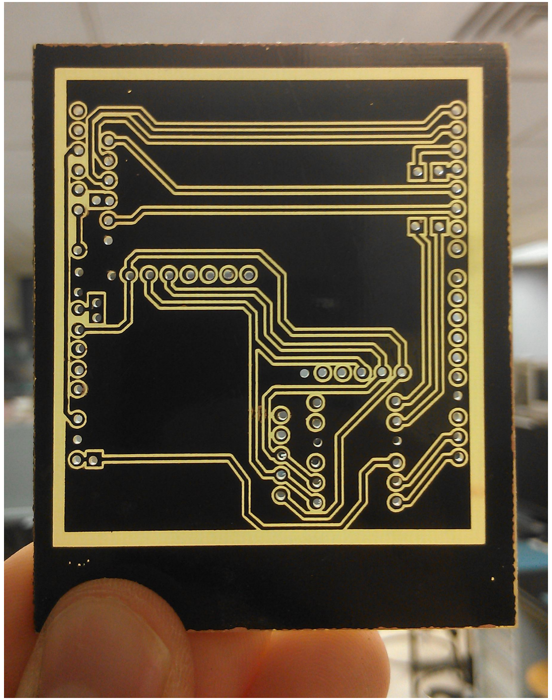


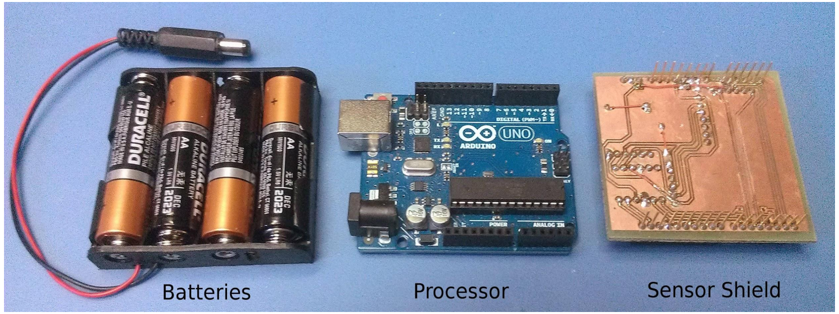
An single delimiter indicates a packet type while two delimiters indicates a payload byte that is identical to the delimiter itself

Sensor Board Construction

Sensor system constructed with ITLL facilities and breakout modules for educational purposes

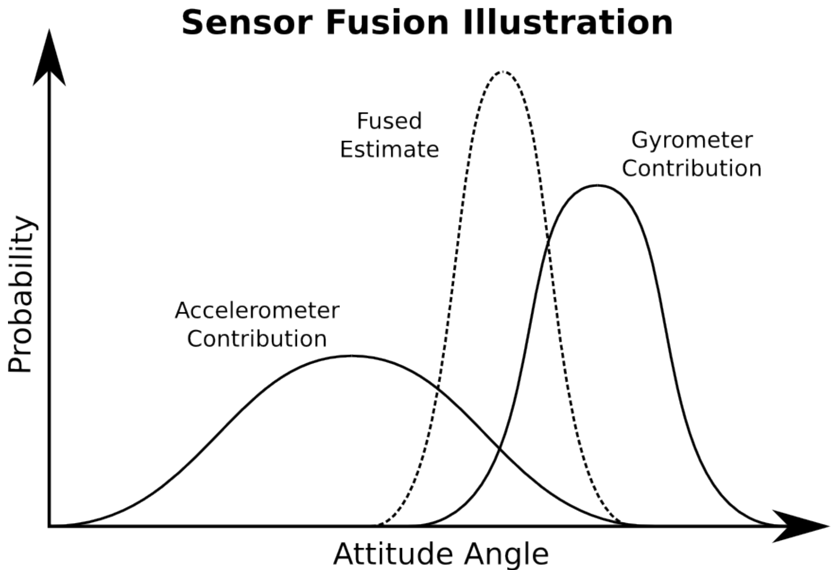
- Laser cut and chemically etched PCB
- Arduino compatible sensor shield and software interface
- Exposed pins for interrupt line switching and digital signal sniffing





Sensor Fusion

- Change in linear distance can be estimated by double integrating acceleration with respect to time
- Gravity must be subtracted from the total acceleration and the result transformed into the earth's reference frame
- The gyro is integrated to keep track of changes in attitude when the acceleration vector is greater than the gravity vector
- Information from both sensors can be fused to provide an estimate with smaller uncertainty



Calibration and Filtering

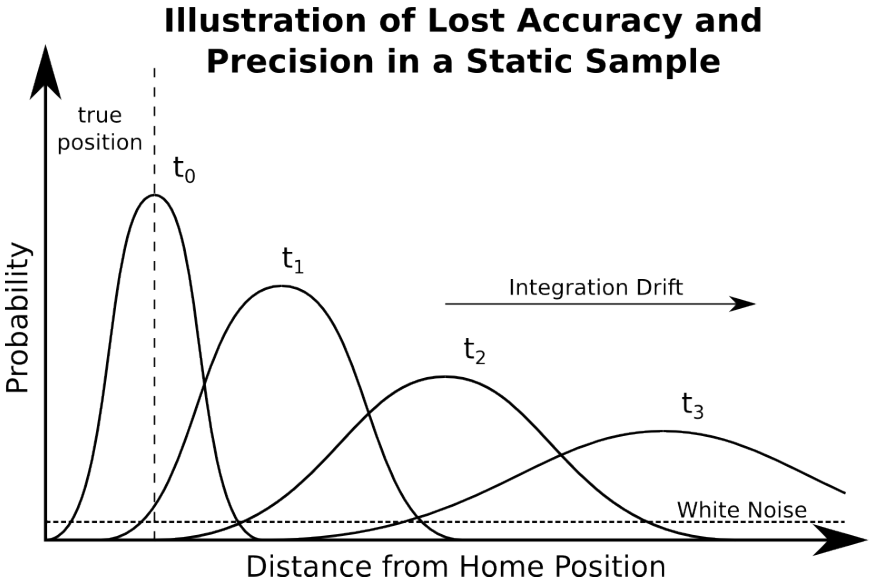
Calibration Parameters

- Accelerometer and gyrometer reference frame alignment
- Accelerometer and gyrometer scale correction
- Accelerometer offset bias

Filtering Methods

- Kalman filtering optimally removes sensor noise from the position estimate
- Quaternion attitude representation prevents gimbal lock
- Runge-Kutta integration minimizes numerical integration error

Effective calibration and filtering are required to prevent integration drift

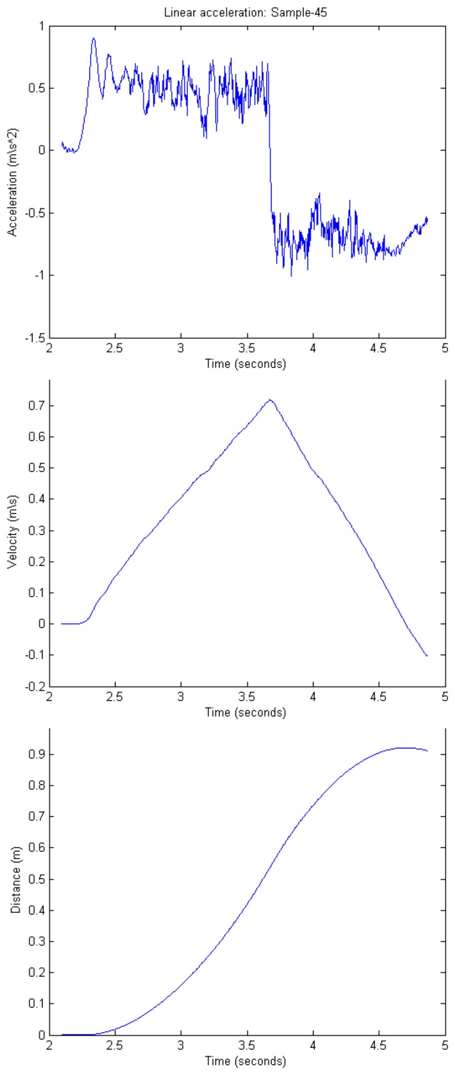


Linear Testing

Test: Estimate of linear distance traveled under step acceleration with simpsons method at various filter cutoff rates and sampling frequencies.

Results:

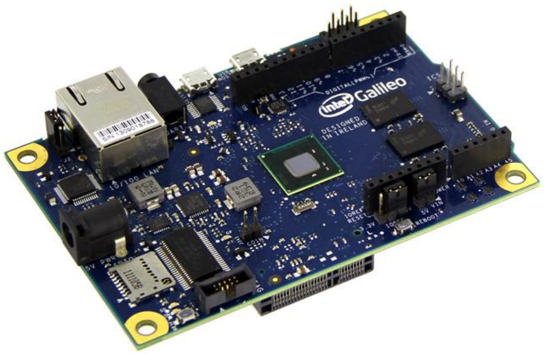
- Low pass filtering does not increase mean estimate accuracy
- Increased sampling speed increases mean estimate precision
- Bias offsets dominates the error if the sensors are not carefully calibrated



Applications

Systems Integration

- Multitasked with other processes
- Real time motion analysis
- Live networked reporting
- Control system operation
- Example: Intel Galileo development board running a Linux OS



Embedded Sensors

- Wearable electronics
- Robot attitude
- Vehicle motion
- Slip detection