A Smart Wireless Inertial Measurement Unit System

Simplifying & Encouraging Usage of WIMU Technology

Mark Gaffney, Michael Walsh, Seán O'Connell, Binyu Wang, Brendan O'Flynn, Cian Ó Mathúna
Clarity: Centre for Sensor Web Technologies
Microsystems Centre, Tyndall National Institute
Dyke Parade, Cork, Ireland
(mark.gaffney michael.walsh sean.oconnell binyu.wang brendan.oflynn cian.omathuna)@tyndall.ie

Abstract—**Wireless Inertial Measurement Units (WIMUs) combine motion sensing, processing & communications functions in a single device. Data gathered using these sensors has the potential to be converted into high quality motion data. By outfitting a subject with multiple WIMUs full motion data can be gathered. With a potential cost of ownership several orders of magnitude less than traditional camera based motion capture, WIMU systems have potential to be crucially important in supplementing or replacing traditional motion capture and opening up entirely new application areas and potential markets particularly in the rehabilitative, sports & at-home healthcare spaces. Currently WIMUs are underutilized in these areas. A major barrier to adoption is perceived complexity. Sample rates, sensor types & dynamic sensor ranges may need to be adjusted on multiple axes for each device depending on the scenario. As such we present an advanced WIMU in conjunction with a Smart WIMU system to simplify this aspect with 3 usage modes: Manual, Intelligent and Autonomous. Attendees will be able to compare the 3 different modes and see the effects of good and bad set-ups on the quality of data gathered in real time.**

Keywords; Inertial Measurement, Ubiquitous Computing, Intelligent Embedded Sensor

I. INTRODUCTION

As part of their work on ambient & embedded smart sensor devices the Microsystems Centre at Tyndall developed the Tyndall 25mm Mote system. This tiny modular computing & sensing platform is based on stackable 25*25mm layers. A large family of layers exist allowing for functions such as radio comms, processing, chemical sensing, actuation, interfacing, battery charging & energy scavenging to name a few.

One key group of Tyndall 25mm mote family sensing layers are Inertial Measurement Unit (IMU) layers. These contain one or more sensors to detect motion or orientation i.e. Accelerometers, Gyroscopes & Magnetometers. When combined with suitable RF hardware they are termed Wireless Inertial Measurement Units (WIMUs). Such WIMU devices (once accurately calibrated) can be used to record motion data.

II. CAPTURING "GOOD DATA"

A. Sensor Range

One of the issues of using such a WIMU system for motion capture is ensuring the recording of "Good Data". The first part in achieving this is ensuring dynamic ranges of each sensing element are properly chosen. If the range is set too low then the sensor may saturate during high motion events and useful motion data such as peak values of acceleration will be lost. If the range is set too high then low motion events will not be accurately sensed or in extreme cases the motion data will be lost amongst sensor or ADC noise.

B. Sampling Rate

The second part of achieving "Good Data" is choosing a suitable sampling rate. This sampling rate must be high enough that sufficient temporal resolution is obtained to identify features of interest; however it must be low enough not to lead to other issues, such as reduced battery life & inability to store, process or otherwise handle all the data. If the sample rate is sufficiently high it may be beyond the sustainable limits of the hardware to reliably transmit or save the data. In addition certain sensors may not perform correctly at very high sampling rates. None of these outcomes are desirable as they entail potentially useful data being lost or rendered useless.

III. AIDING EXPERT USERS, ENABLING NON-EXPERT USERS

Ideally a WIMU user would be expertly knowledgeable in both the motion regime that he is studying and inertial sensing technology, giving them an intuitive knowledge of required dynamic ranges, sampling rate, appropriate device selection and settings to ensure that data of interest is likely to be recorded successfully. However this is often not the case and is likely to become even more prevalent as WIMU technology becomes widely used by consumers. Many WIMU systems allow only very limited control over the components and parameters used. To tackle this, Tyndall began development of a Smart WIMU system, improving ease of control for expert users & reducing the need for expert knowledge in many cases.

The system developed consists of a PC running a Java based GUI allowing 2 way communications with the embedded code running on the WIMU, allowing users to remotely change its operating mode as well as view data on screen. The system has 3 Modes each with different intended user scenarios:

A. Manual Mode

For the Expert User, familiar with both the inertial measurement devices as well as the motion regime of interest - Entering this mode allows the user to explicitly specify settings for each WIMU. These include the sampling rate, active sensors & dynamic range for each sensor axis. In future, options for enabling on board storage & choosing what

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percentage of recorded data will be transmitted to the base station could be added. This allows for high data sampling rate for post processing with live data streaming at a lower sampling rate enabling real-time PC side processing to flag events to be analyzed in greater detail later using the stored data. As radio transmission is a significant part of total power usage on such devices, this will also help improve battery life.

B. Intelligent Mode

For the Skilled User, familiar with the motion regime involved but perhaps not certain of the WIMU settings required - Entering this mode allows users to specify a recording time then perform a representative sample set of motions and actions within this time. These are then analyzed on the PC to automatically determine the best range for each sensing axis. In future the algorithm will also allow for automatic determination of suitable sampling rate for the user's needs.

C. Autonomous Mode

For the Unskilled User or one unfamiliar with the motion regime - Once this mode is chosen no further user interaction is required. The WIMUs can be immediately used and on-board motion regime analysis algorithms change the dynamic range of the sensors "on-the-fly" in response to changes in the levels of activity seen. There is, as expected, a tradeoff between autonomous operation and battery lifetime. This is as a result of the inherent increase in onboard computation while the device is in Autonomous Mode. However the benefits in usability are expected to outweigh the inconvenience of reduced battery life. In future versions it is possible that multiple range sensors will be continuously sampled with only the ranges deemed most useful being committed to storage.

IV. REALTIME GRAPHICAL USER INTERFACE

The user interface is implemented in Java to allow for future cross platform compatibility and portability to other devices like smart phones. It initially presents the user with a connection dialog to set-up communications with an individual WIMU device. Once a connection has been established the user can request the WIMU's current settings, specify settings using the Manual Mode controls, or switch to one of the other two operating modes "Intelligent" or "Autonomous". There is also the option to see live graphs of sensor output in a separate tab.

Manual Mode controls feature a slider to set sampling rate, radio buttons to enable various sensor type combinations such as Accelerometer, Gyro or Magnetometer only & one to enable all sensor types. A pair of drop down menus allows the user to choose the sensitivity or range of each of the sensor types e.g. "Accelerometer" "+-2g". At each step the user can simply click "update" to transfer new settings to the WIMU. The effects can then be previewed on the "Graphing" tab.

Intelligent Mode allows users to specify a time in seconds for the WIMU to record data, beginning once the "Capture" button is pressed. During this period, the WIMU will sample 3 axes for each sensor type at max sample rate & dynamic range. By analyzing the captured data for peaks detected on each channel it can identify the lowest settings for dynamic range for each sensor axes required to gather the sample data without saturation. It presents the analysis results to the user with the option to "Update" the WIMU via a single button click. Assuming this sample of motion data is representative of the in-service motion regime; this should give WIMU settings very close to the ideal. Once committed the effects of using these settings can then be previewed on the "Graphing" Tab.

In Autonomous Mode, a variant of the intelligent analysis algorithm is run on the WIMU itself. There is no GUI for this option merely a button labeled "Autonomous". When the motion levels for an individual sensor pass preset thresholds the WIMU adjusts the dynamic range, increasing or decreasing the sensing range to prevent data loss by saturation or fine detail loss respectively.

Regardless of Mode, all data is currently streamed live to the PC via a USB base-station, before being suitably annotated and saved in a human readable format.

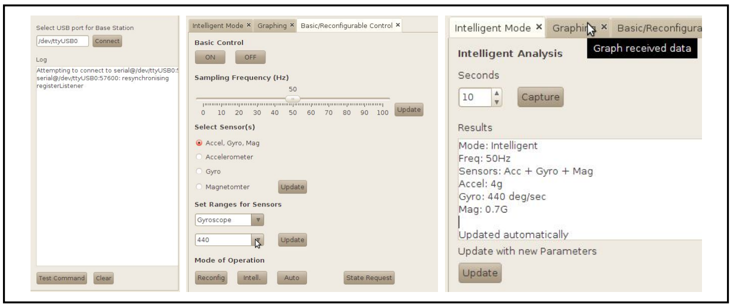

Figure 1. Java GUI: (Left) Initial Connection Dialog, (Centre) Manual Mode Controls, (Right) Intelligent Mode with Post Analysis Results

V. CONCLUSION

In this demo an intelligent computer interface and accompanying Smart WIMU system that reduces the barrier to entry for inertial measurement technology has been presented. The complete system allows for experts to make rapid changes to detailed settings, as well as allowing non-experts to use the system's built in intelligence to allow for user friendly set-up. This allows the creation of a nearly generic WIMU solution, equally suitable for fall detection in a home setting or seizure monitoring for bed-bound hospital patients as it is for providing subtle inputs to a computer or recording detailed performance metrics for coaching professional athletes. As a consequence, the cost and difficulty of gathering human motion data will be greatly reduced, which we believe will greatly increase WIMU use in everyday life.

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