IS-ACTIVE

Inertial Sensing System for Advanced Chronic Condition Monitoring and Risk Prevention

WP3 – Platforms

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1. Overview

This document briefly describes the software developed for sensor interfacing, calibration and filtering, which is part of the wireless sensor node platform developed and used in the IS-ACTIVE project for experimentation and evaluation. The resulting software modules are available as prototypes programmed in the ProMove hardware platform. For details on the ProMove hardware platform, please see deliverable D3.1 – Hardware platform and software packages for wireless networking.

2. General software architecture

The ProMove platform allows for a proper division of tasks between the two microcontrollers on board: one microcontroller is dedicated to sensor interfacing and data processing, while the other microcontroller has the responsibility of wireless networking. The two microcontrollers communicate with each other via a high-speed bus, in order to synchronize data sampling with data communication and to indicate specific actions, such as requests for reconfiguration. The general software architecture and main building blocks (sensing drivers, data processing modules and wireless networking) are depicted in Figure 1.

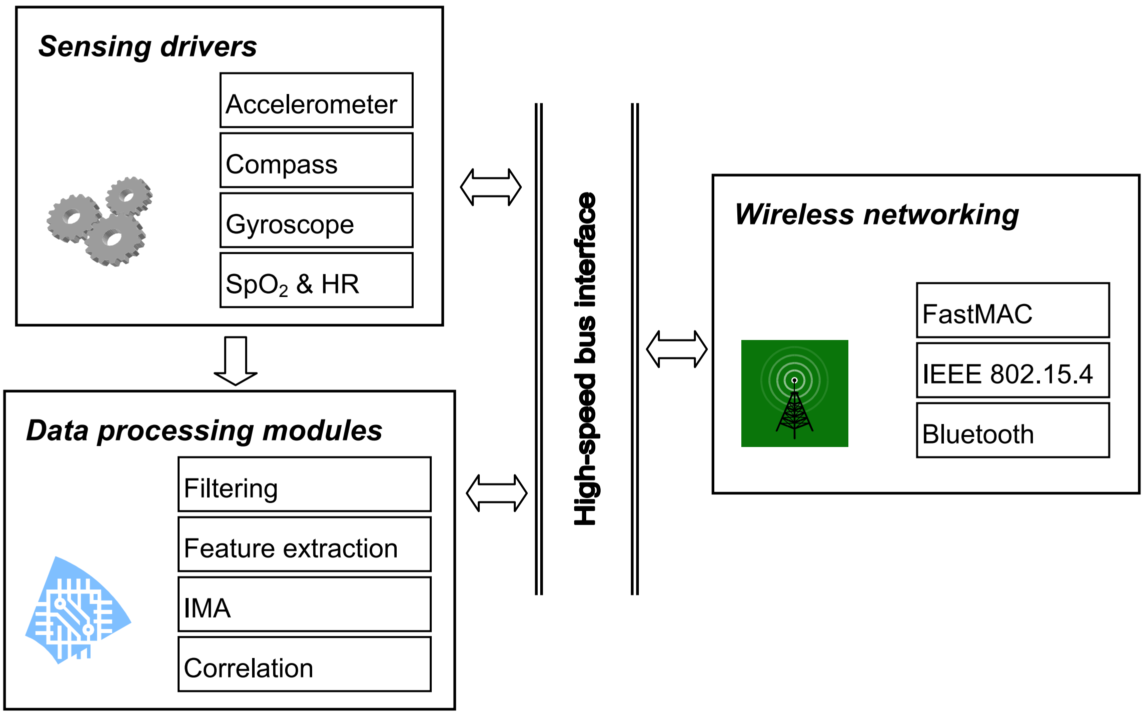

Figure 1 - General software architecture

3. Sensor interfacing

The sensor interfacing is done through dedicated drivers per each sensor type. The following drivers have been implemented:

- Accelerometer: three-axial digital acceleration information.
- Compass: three-axial digital magnetic field intensity (digital compass) information.
- Gyroscope: three-axial analog (converted to digital via internal ADC) turn rate information.
- Internal temperature: for internal microcontroller monitoring, not used by user applications.
- Oxygen saturation and heart rate: the interface to third-party SpO_2 & heart rate sensors (Nonin Medical) is available and is used for risk prevention along the IS-ACTIVE use cases.

The sensor drivers are executed as real-time separate tasks in the multi-tasking kernel, which ensures a very reliable sampling and efficient usage of the resources on-board.

4. Sensor calibration

All sensors benefit from precise on-chip factory calibration. This guarantees a reliable performance for daily usage activities/applications. For specific applications that require maximum accuracy, such as exercise coaching, we implemented additional calibration procedures for:

- *Accelerometer calibration based on static acceleration matching*. The central idea of this method is that the accelerometer measures only the gravitational acceleration when it is stationary. Measuring this constant acceleration at equally distributed stationary sensor orientations provides enough information to calibrate the sensor for scale, offset and cross-axis influence. In practice, this means that the sensor is placed in a series of discrete orientations while recording the sensor output in each situation. The desired calibration parameters are determined from the obtained sensor measurements by solving a nonlinear Least Squares (LS) problem. This problem describes that for all obtained measurements the magnitude of the calibrated acceleration measurements must equal a constant gravitational acceleration. Similar versions of this method are described in various recent publications such as [1] or [2].
- *Compass calibration based on three-dimensional scanning of the surrounding magnetic field*. The fixed distortion of the magnetic field can be determined systematically and applied to subsequent readings to eliminate the effect of ferrous metals in the surroundings. Three scale factors and three offset values can be determined to calibrate the compass by three-dimensional scanning of the surrounding magnetic field. More details on the procedure can be found in [3] and [4].
- *Gyroscope calibration based on zero-offset adaptation*. The zero-offset of the gyroscope can be determined while the sensor is in static position and subtracted from each subsequent reading.

5. **Data processing**

The data processing is organized in separate modules that can be plugged in or out depending on the specific application and usage of the system. The main modules developed for the IS-ACTIVE usage scenarios relate to the following:

- Feature extraction, containing submodules for:
    - Time window feature segmentation.
    - Mean acceleration magnitude extraction.
    - Compass rotation angle extraction.
- IMA, calculating the level of physical activity with a given time granularity level, based on the algorithm proposed by Bouten [5].
- Receiving user commands - the user can send commands to the user interface by tapping the sensor node, without the need of additional hardware.
- Determining automatic user – object associations and thus enabling seamless interaction of the user with the instrumented environment (e.g. for assisted exercises as defined by the IS-ACTIVE scenarios) [7].
- Filtering is used in various steps of the data processing:
    - *Computation of the IMA value*: a high-pass filter is used to remove the gravity component of the accelerometer signal [6].
    - *Receiving user commands via tap detection*: A tap causes high-frequency vibration, which is picked up as a high frequency acceleration pulse by the accelerometer. The actual tap instances are detected by high-pass filtering the signal with a cut-off frequency of 35 Hz, then rectifying the signal and finally low-pass filtering the result to obtain a signal that correlates with the amount of high-frequency vibration. The actual tap detection uses thresholds to mark the onset and end of a tap [6].

6. **High-speed bus interfacing**

As shown in Figure 1, the connection between the sensor interfacing and data processing, on the one hand, and the wireless networking, on the other hand, is based on a high-speed bus interface. A dedicated real-time protocol governs the access to the bus, handshaking mechanisms, signaling and interrupt handling. The protocol implements a Dynamic Bit Field specification for efficient and yet flexible data transfer between the two microcontrollers. In this way, we can easily additional sensor drivers or data processing modules that require new data types to be exchanged on the bus.

7. **Configuration**

The wireless sensor network can be wirelessly reconfigured from a central point. Provided that the high-speed bus interface is bidirectional, it allows not only raw or processed data to be communicated via the wireless network, but also to wirelessly receive (re)configuration commands.

The currently implemented commands relate to the following:

- Retrieve current configuration.

- Reset to default configuration.
- Set radio settings – transmission power level, frequency channel, gain mode, higher-level protocol settings.
- Set global settings – enable/disable, global sampling rate, trigger source.
- Individual sensor settings:
    - Accelerometer – enable/disable, sampling rate, measurement range, offset and scale values.
    - Compass – enable/disable, sampling rate, measurement range, offset and scale values.
    - Gyroscope – enable/disable, sampling rate, measurement range, offset values.
    - Oxygen saturation and heart beat – enable/disable, sampling rate.
- IMA settings – enable/disable, sampling interval, no. of IMA values per data packet.
- Correlation settings – enable/disable, window size, window overlap, correlation history, minimum history.
- Real-time clock settings – enable/disable, sampling rate.
- On-board logging settings – autostart at boot-up, logging type, samples per frame.

8. Conclusions

The software packages described in this document provide a compact, yet flexible functionality to the developers for building the user-level applications of IS-ACTIVE. All efforts have been made for a good separation of tasks among the three levels of operation: low-level sensor interfacing, data processing and connection to the wireless network. The tasks are properly divided between the two microcontrollers on-board, ensuring thus a balanced loading of the resources. Easy plug-in of software modules at all the previously enumerated levels is possible due to a flexible data interfacing protocol.

9. References

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