EE712 Embedded System Design

Course Project Report, EE Department, IIT Bombay

(Course Instructor: Prof. P. C. Pandey & Prof. D. K. Sharma)

Human Fall Detection

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Abstract

In this project we developed a wearable human fall-detection system intended for the elderly. On detecting a fall, the system sends an emergency SMS using the wearer's bluetooth enabled smartphone to a caregiver. The system uses a GY-87 inertial sensor integrated with an Arduino Nano micro-controller.

1 Problem Statement

Falls are a significant source of injury for the elderly. This wearable device aims to detect a fall by detecting the change in accelerometer output, before during and immediately after a fall. It also detects the direction of the fall by combining readings from the accelerometer with gyroscope output. The combination of readings from the two sensors using a complementary filter results in more usable readings compared to just the use of the accelerometer. The HC05 bluetooth module pairs the wearable with the user's bluetooth enabled smartphone. In the event of a fall the devices sends a message to the the smartphone which is loaded with an application to convert the message into a SMS to a designated caregiver.

2 Literature Review

[1] is a comprehensive survey of recent fall detection techniques which includes wearable based detection as well as detection using ambient and vision sensors. Wearable based detection increasingly gravitate towards accelerometer based techniques due to lower costs and power efficiency of mems-based accelerometers. Accelerometer-based techniques usually consist of detecting a sudden change in the acclerator output due to the fall-event.
[2] discusses appropriate filtering techniques to estimate the vertical acceleration vector from a tri-axial accelerometer. The readings from a tri-axial accelerometer cannot be used directly as they tend to be very noisy and are also combined with the acceleration due to the earth's gravity.
[3] uses a threshold based technique combining readings from the accelerometer and gyroscope to detect the fall-event.

3 Approach

The idea is to use the I2C interface to interface a GY-87 sensor to the Arduino Nano's micro-controller. The GY-87 provides separate readings for each axes of the accelerator and gyroscope sensors. These six separate readings are combined using a complementary

filter. Our fall detection algorithm works on the output of the complementary filter, by identifying a fall when the values cross a certain preset threshold.
We then experimented with various regular movements like walking, running (slowly), climbing stairs, sitting and sleeping to find an appropriate threshold value below which a fall should not be detected. In addition to comparing the combined accelro-gyro output against the threshold, we also use declare that a fall has been detected only when the gyroscope indicates that the orientation of the device has changed by at least 60 degrees.

4 Hardware Setup

Our hardware setup consists of four major components as show in figure 1 on page 3.

GY-87 The GY-87 also known as the MPU-60X0 integrates a tri-axial accelerometer and gyroscope with on-chip ADCs to deliver digital outputs via an I2C interface to an off-chip controller. To a controller this device acts as a slave on the I2C. GY-87 also features an auxiliary I2C bus which it masters to integrate discrete sensors like magnetometers.

Arduino Nano The Arduino Nano is a board based on the ATmega328P microcontroller. The ATmega328 has 32 KB, (also with 2 KB used for the bootloader). We have chosen the Nano due to its small form factor as the device is meant to be a wearable.

HC05 The HC05 is a bluetooth to serial port module which communicates via UART. The bluetooth module communicates fall information to a bluetooth enabled smartphone

Power Supply A 9V battery is used as the power supply on the wearable.

4.1 I2C and UART Integration

The I2C is used to integrate the GY-87 with the ATmega328P. The GY-87 behaves as a slave.
The HC05 communicates with via a UART interface which is run at a baud rate of 9600 baud.

4.2 GY87 Calibration and Integration

Two experiments were conducted on the GY87 to calibrate it prior to integration.

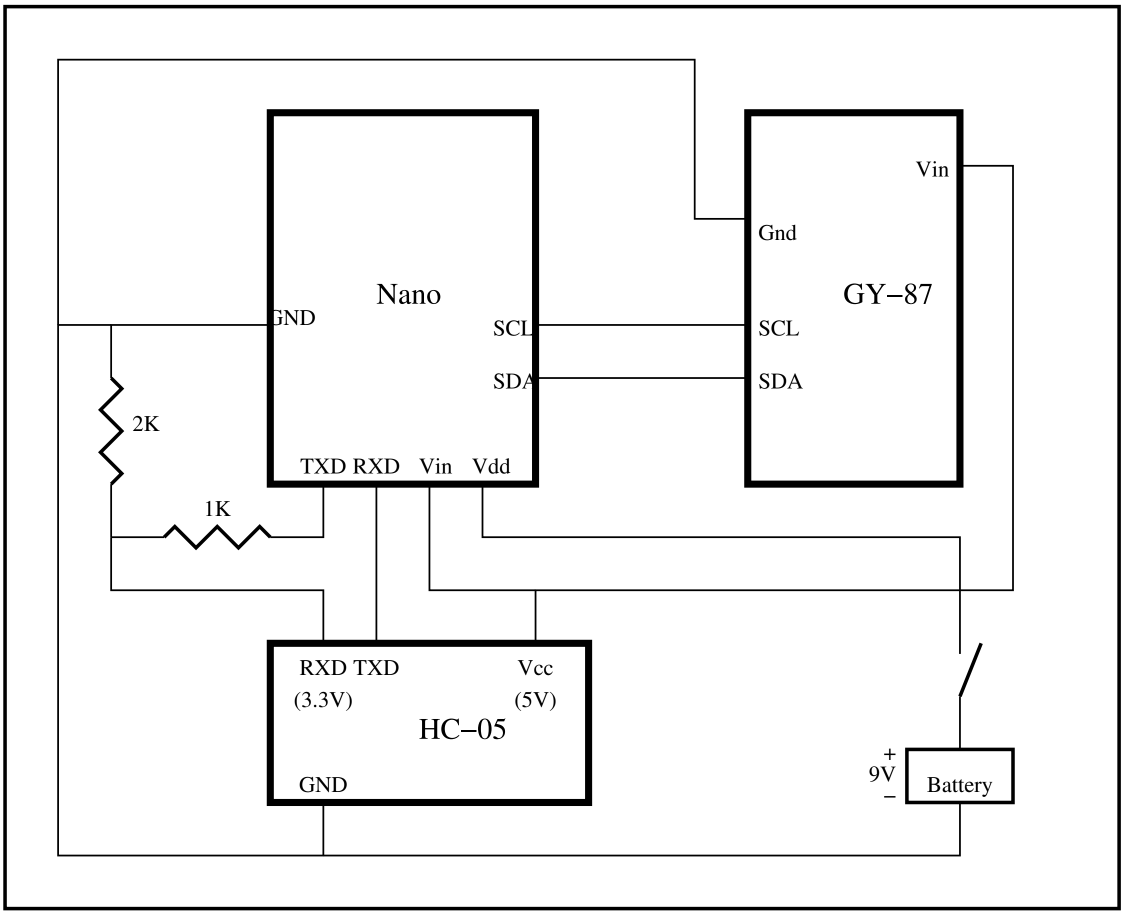

Figure 1: Block Diagram

4.2.1 Cube-mounted Measurements

The GY-87 was mounted along the face of a thermocol cube. The cube itself was placed on the surface of a flat table. The readings along the axis aligned to the earth's gravitation field were verified to be as close to $\pm g$. This experiment was repeated aligning each axis with g.

4.2.2 Pendulum-mounted Measurements

We attached the GY-87 to the arm of a pendulum and swung it, while measuring the accelerometer output. As expected the output recorded its lowest value at the point of the furthest swing, and was maximum near its rest position.

4.3 Power Supply

During development the assembly was powered using the micro-usb connection to the Arduino-Nano. Once we assembled the device as a wearable, we were using a 9V cell with

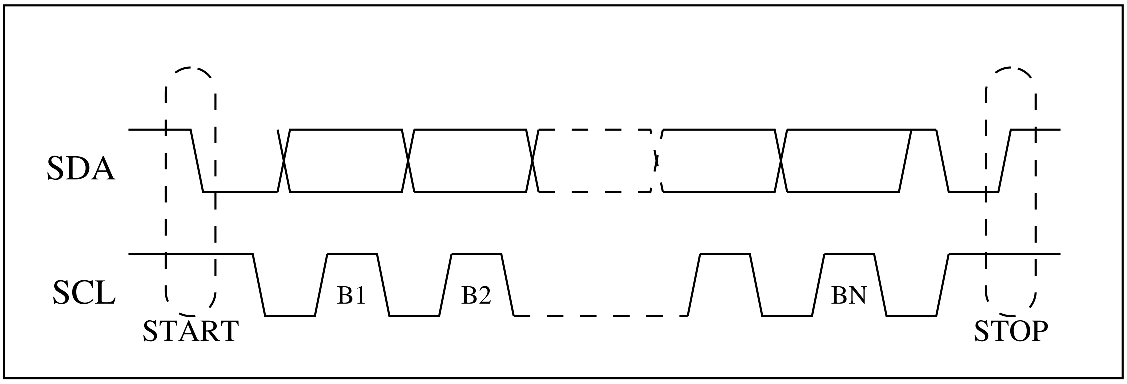

Figure 2: I2C Data Transfer

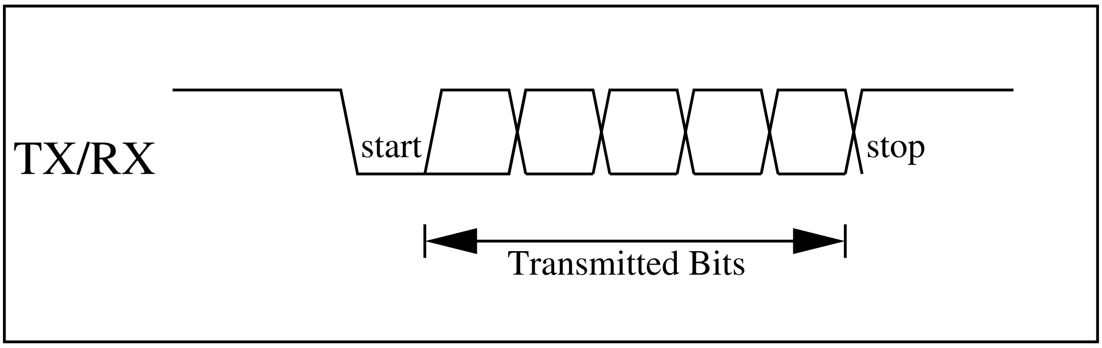

Figure 3: UART Data Transfer

a capacity of 400 mAH to power the device. The following table lists the different devices and their peak current consumption:

Device	Current Drawn (mA)
Arduino Nano	2.4
GY-87 Sensors	3.9
LEDs (4)	16.0
HC-05	30.0
Total	52.3

The device can draw a peak current of 52.3 mA. At this consumption, a 9V cell will last for about 7.50 hours.

5 Software

The figure 4 on page 5 describes the processing which occurs with the accelerometer and gyroscope sensor readings from the GY-87. The input from the two sensors are received as a set of six, 16-bit values, one for each axis of each sensor.

The accelerometer values are taken through a LPF, while the gyroscope values are taken through a HPF. These filtered values are then combined using a complementary filter which essentially does a weighted sum of the sensor values.

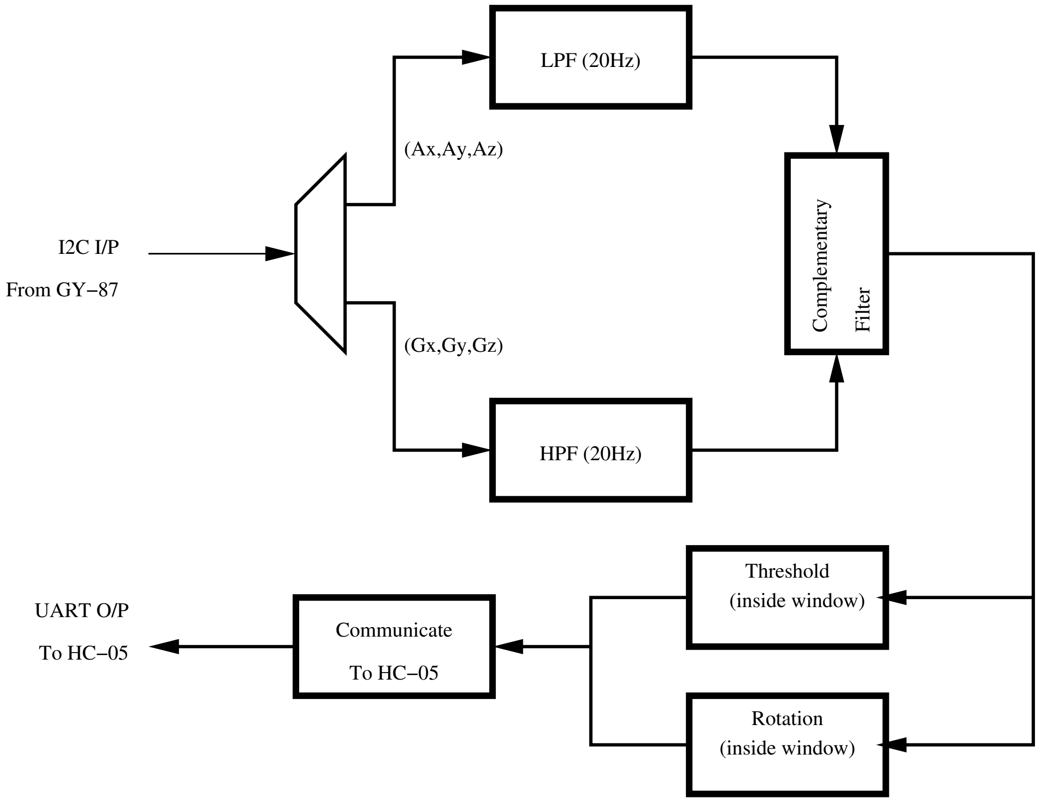

Figure 4: Software Flow

6 Test Procedure and Results

We tested the device both with normal movements, such as walking, sitting, jumping and sleeping. The tests also included transitions between these movements as the transition points were more interesting from our application's point-of-view. The following are plots of everyday actions like jogging, walking, sitting, sleeping.

In all these plots, the blue plot indicates filtered accelero output. The red and green plots indicate roll and pitch.

In the walk test, the wearer walked at a normal pace during this test. The plot is on figure 5 on page 6.

The sit-stand test was conducted when the wearer sat into a short chair from a standing position and stood up again. The plot is on figure 6 on page 6.

The jump test was conducted when the wearer was jumping in place. This action most

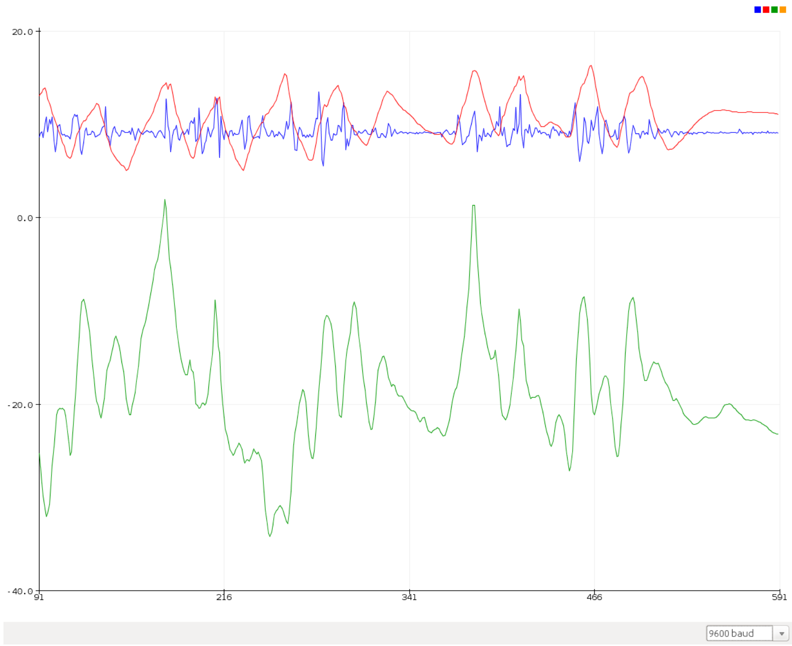

Figure 5: Walking

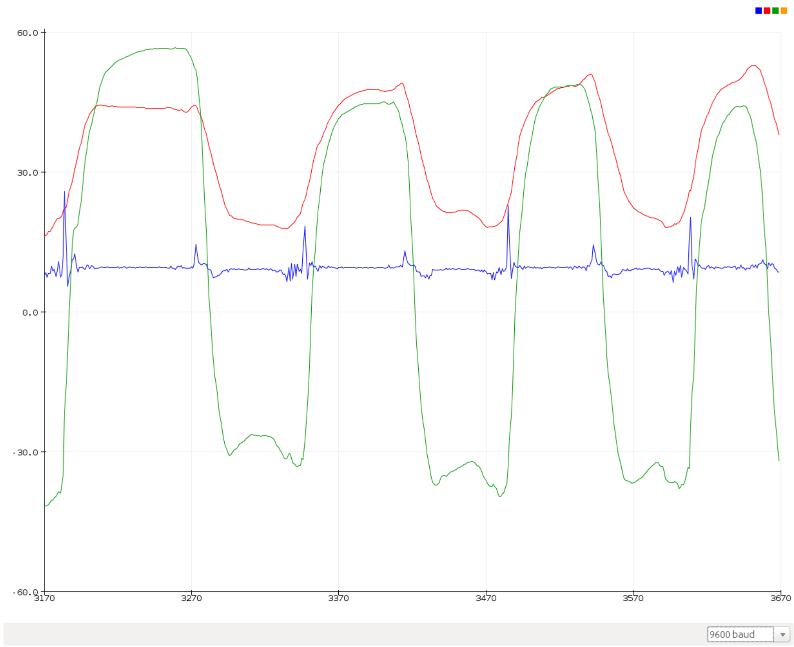

Figure 6: Sitting-Standing

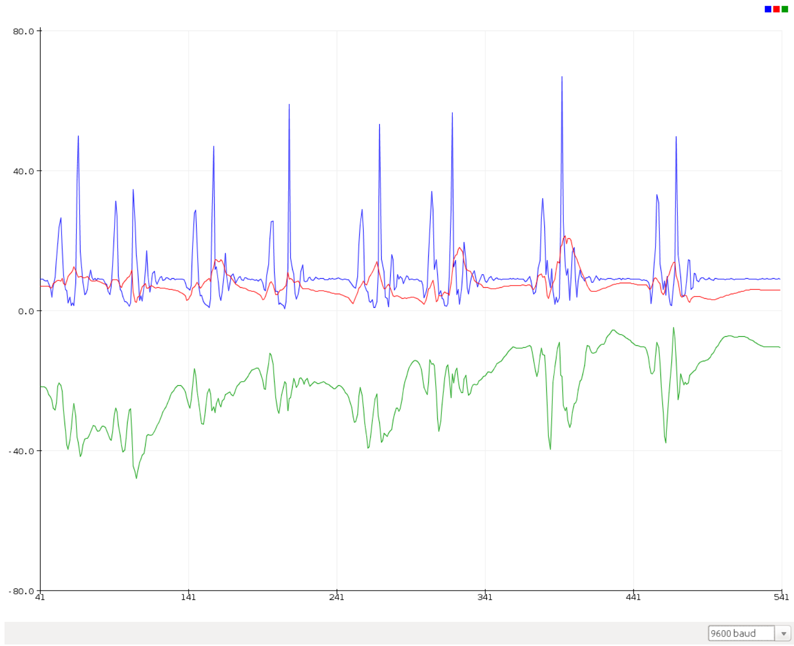

Figure 7: Jumping

closely resembles a fall, and the test was conducted to ensure our thresholding was correct. The plot is on figure 7 on page 7.
The sleep-and-walk test was conducted when the wearer was lying down and suddenly got up. The plot is on figure 8 on page 8.

7 Conclusion

We have implemented a device which detects if the wearer has had a fall, and classifies the fall direction – front, back, right or left. This information is communicated via Bluetooth to the wearer's smartphone.
A limitation of this device is that orientation of the device has to be fixed with respect to the wearer. A future improvement could be for the device to automatically calibrate its current orientation with respect to a preset reference. This would allow the wearer greater flexibility in device placement.

References

[1] M. Mubashir, L. Shao, and L. Seed, "A survey on fall detection: Principles and approaches," *Neurocomputing*, vol. 100, pp. 144–152, 2013.

[2] A. K. Bourke, K. O'Donovan, A. Clifford, G. Olaighin, and J. Nelson, "Optimum gravity vector and vertical acceleration estimation using a tri-axial accelerometer for

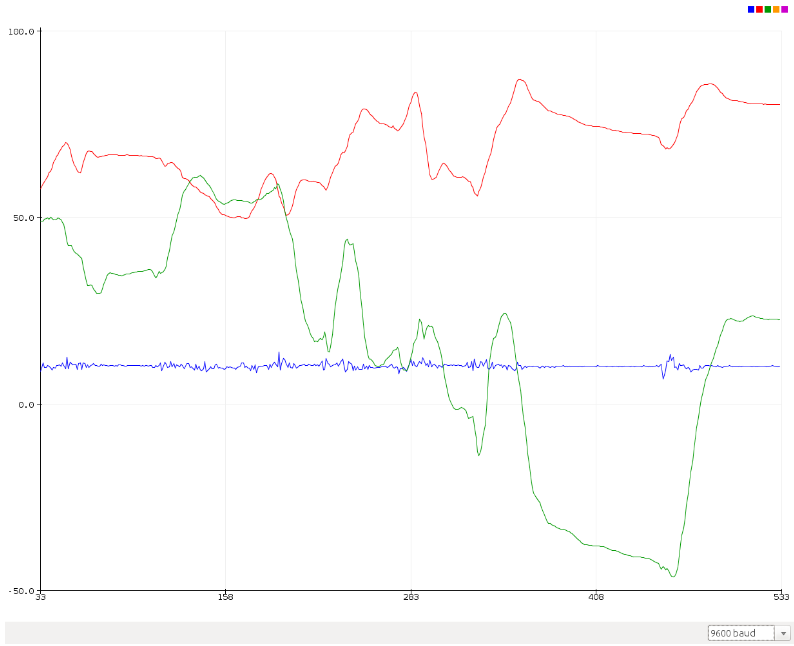

Figure 8: Sleeping-Waking

falls and normal activities," *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, pp. 7896–7899, 2011.

[3] F. Wu, H. Zhao, Y. Zhao, and H. Zhong, "Development of a Wearable-Sensor-Based Fall Detection System," *International Journal of Telemedicine and Applications*, vol. 2015, pp. 1–11, 2015.