Human Fall Detection Using Inertial Sensors

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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.

PCP's student's mtech thesis used a LPF to filter the accelerometer readings with a cut-off frequency of Hz.

[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:

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 Block Diagram

4.2 I2C and UART Integration

The I2C is used to integrate the GY-87 with the ATmega328P. The GY-87 behaves as a slave.

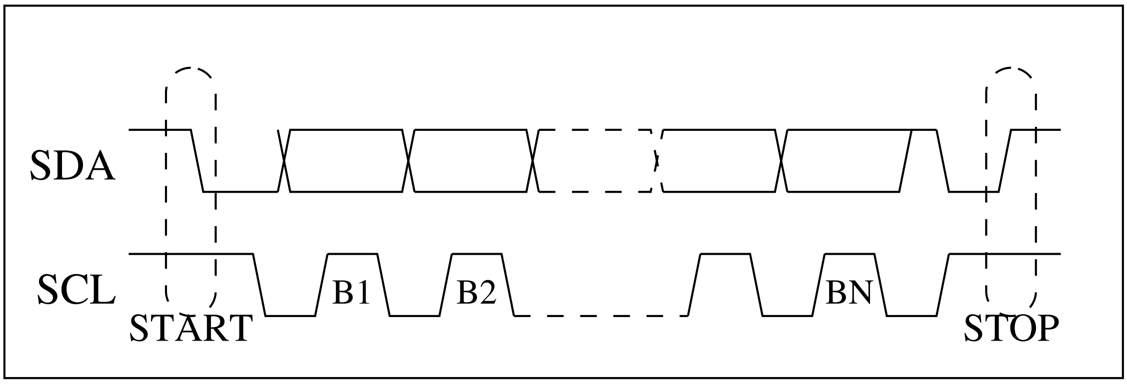

Figure 1: I2C Data Transfer

The HC05 communicates with via a UART interface which is run at a baud rate of 9600 baud.

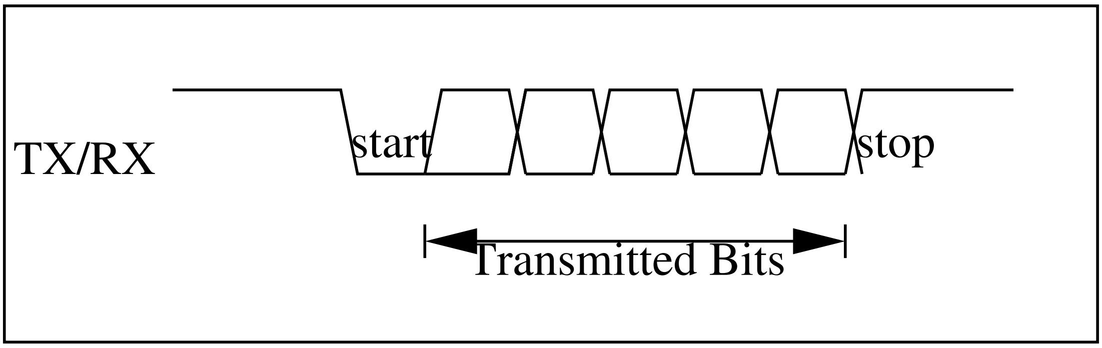

Figure 2: UART Data Transfer

4.3 GY87 Calibration and Integration

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

4.3.1 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

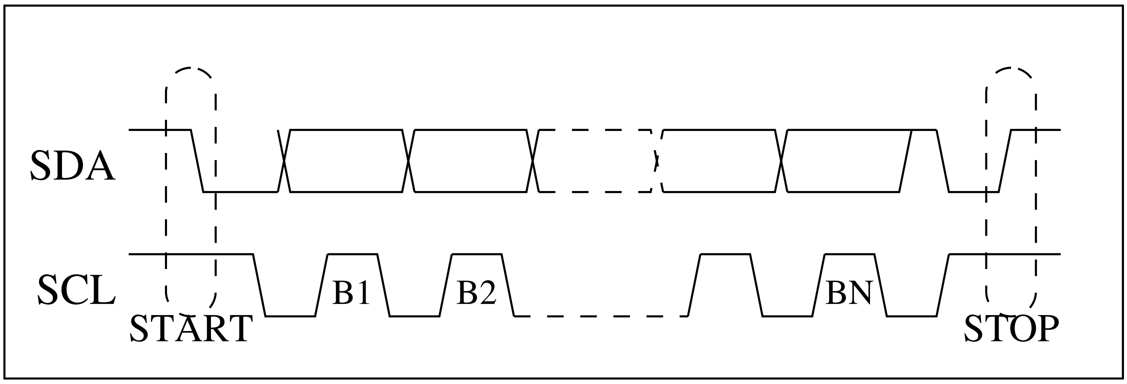

Figure 3: Plot: Walking

field were verified to be as close to $\pm g$. This experiment was repeated aligning each axis with g. The following readings were recorded:

Alignment Axis	A_x	A_y	A_z
X-Axis	−9.8	0.0	0.0
Y-Axis	0.0	−9.8	0.0
Z-Axis	0.0	0.0	−9.8

4.4 Power Supply

How long do we expect a rechargable 9V cell to last? What is the current drawn under normal usage?

5 Software

Algorithm. Flow diagram: sampling, lpf, hpf, complementary.

6 Investigations

7 Test Procedure

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 something, something and something-else for each movement.
Wearer walked at a normal pace during this test.
This test was conducted when the wearer sat into a short chair from a standing position and stood up again.

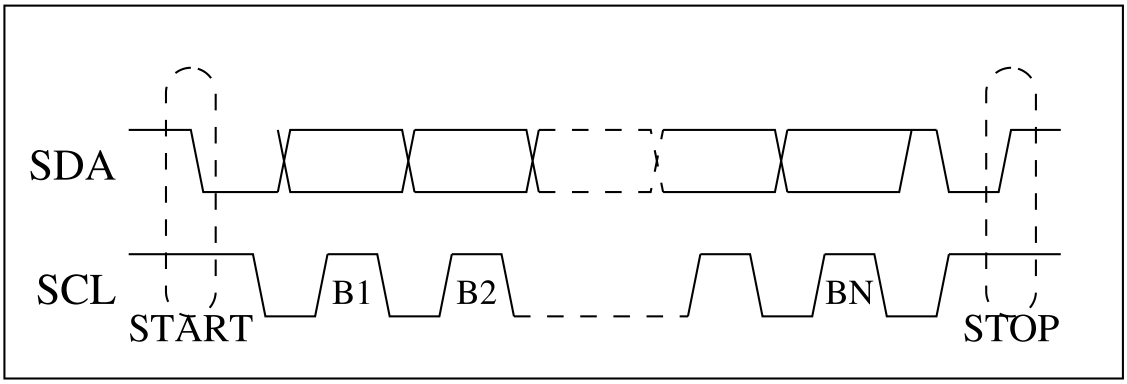

Figure 4: Plot: Sitting-Standing

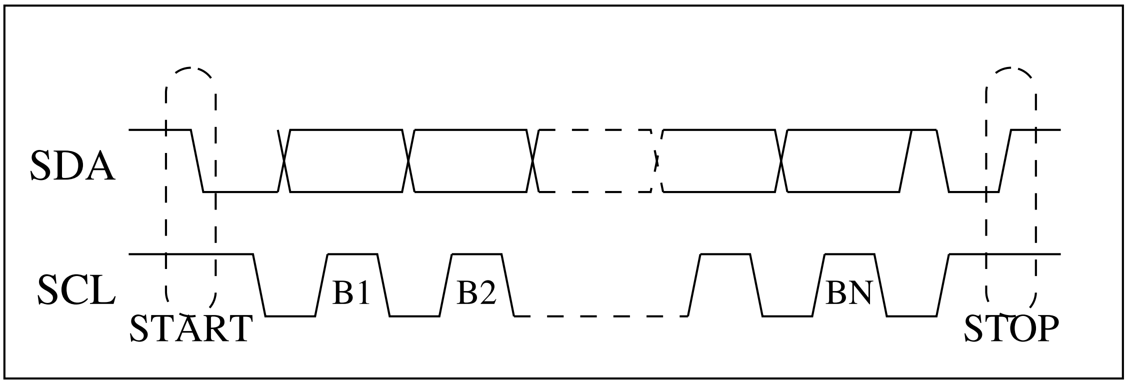

Figure 5: Plot: Jumping

This test was conducted when the wearer was jumping in place. This action most closely resembles a fall, and the test was conducted to ensure our thresholding was correct.
This test was conducted when the wearer was lying down and suddenly got up.

8 Test Results

with plots and tables (appendices, if necessary).

9 Conclusion

suggestions for further improvement.

References

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

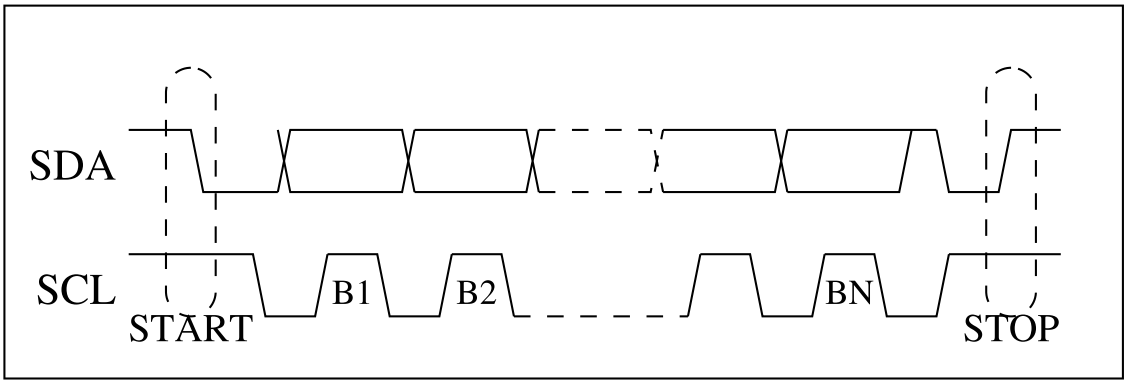

Figure 6: Plot: Sleeping-Waking

[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 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.