CEN 590
Offline Data Collection for e-Lab Prototype

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I. Abstract

This report describes the implementation of micro SD FAT File System for the E-Lab prototype board 4.1 in order to log raw data from the ICM-20948 accelerometer and Bend Lab sensor. The major constraints in order to satisfy this objective are: (a) Power consumption (b) Data transfer rate via the data communication buses and write operations. The data collected from the sensor can be used for solving a wide range of pattern recognition problems.The one that is studied in this report is stride length and step length while walking(gait analysis).

II. Introduction

Ad-hoc wireless sensing is being deployed in many Internet of Things devices in order to achieve efficient and portable data collection in low-power based systems. In our project, we are using Bluetooth Low Energy (BLE) sensing in order to track human movements with the utilisation of accelerometers and BendLab sensors. One major difficulty that we face is irregularities in data transfer to the main application that could lead to loss of high amounts of data. Another difficulty is achieving the maximum data transfer (in microseconds), which also leads to greater power consumption as BLE needs to be in active mode always. Real-time data logging using an on-board SD card can lead to improvements in sample collection as well as reduce overall stress on the BLE functionality.

III. Related Works

There have been several low-power sensing devices that incorporate SD working in cohesion with sensors. One such work is shown in [1]. Here, the authors explain how storage of data facilitates non data streaming applications and ensures no loss of data while the device is mobile or during network outages. As SD cards are inexpensive in recent years, they offer a viable low cost alternative sending all sensed data over the radio to a base station, once the wireless communication is turned on.

IV. Experimental Evaluation

A. Set-up

The software for the TI-CC26x2 chip is developed on the Code composer studio(V9) with the TI SDK version 3.10.11.The on-board SD card communicates with the E-Lab board using the SPI in synchronous mode at 3.3V and consumes over 80mA during a read/write cycle [2] . In

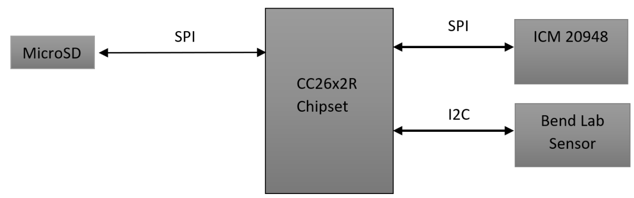

Fig. 1: Basic block design of the e-Lab sensor board 4.1, The Ti CC

synchronous mode, SD communicates with the chip using 3 pins: MISO(Master in, Slave out), MOSI(Master out, Slave in) and SCLK(SPI clock).Initially, this module was implemented as part of the SDK multirole sample project. An issue encountered here was that the SD card wasn't powering on as BLE was consuming high power due to the fact that it is active at all times.For experimental purposes, SD Raw sample project was used that did not implement any wireless sensing. A FAT file system has been implemented over this example that supports creation of .txt/.bin files. This is because file sifting becomes easier as it follows a structure of a table that depend on parameters sch as partition boot table, allocation table and cluster size to keep track of large data sets.

The sensors active currently are the ICM-20498 accelerometer via the SPI bus and the Bend Lab sensor via the I2C bus. The accelerometer sensor measures the amount of acceleration and angular velocity on the three axes.The Bend Lab sensor gives information on the amount of bend angle in a single or double axes.

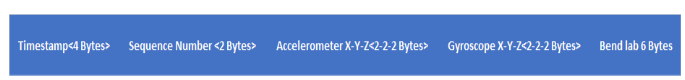

Fig. 2: Packet format for transfer

B. Evaluation Metrics and Observation

A major challenge was to implement the two functionalities(SD and accelerometer) on a single SPI bus, at a bit rate of 4Mbps.In order to tackle this, Slave Select(SS) enabled multiplexing for the two operations. Whenever a specific slave has to be activated, it needs to be enabled and disabled subsequently after usage is completed. If at any point of time, both the SS are set to active low together, neither of them would be able to use the SPI transfer mode. In order to implement both functionalities simultaneously, separate SPI buses would need to be configured.

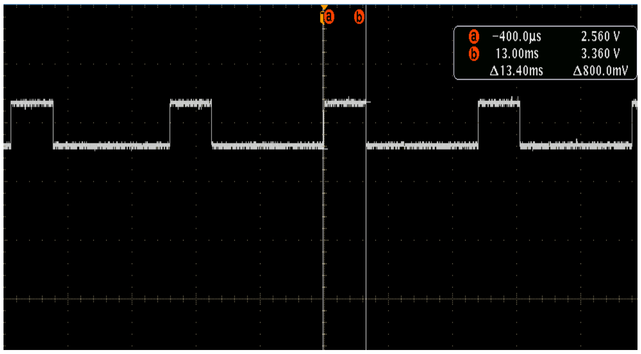

Fig. 3: SPI bitrate + read/write operations

C. Time synchronization problem

For the sensor data collection for gait analysis, a prototype board along with the SD card needs to be connected to the front and back leg of the user. The boards on each leg that collect data from the sensors need to be brought into a same time scale. In the offline mode, a real-time time synchronization is not possible as there is no communication between the boards nor a central collecting node as in the case of an online system. So the synchronization is done by bending the front and back leg together, and this synchronization point can be identified at the post processing stage.

V. RESULTS

Fig 3. illustrates the packet format for data transfer. It contains the timestamp, sensor data from the ICM-20498 and Bend Lab sensor. Based on the experiments conducted, with SPI Bit rate = 4Mbps, Fig.3 illustrates the time taken for transfer of 100 packets into the SD.The total time taken is 13.4ms.This time takes into consideration the following:

- Time taken for SPI transfer
- Write operation into SD
- Overhead

The sensor data is logged to the SD card at a transfer rate of 4Mbps, the size of a single packet as shown in figure 2 is 24 Bytes. Hundred packets are collated and logged to the SD card. The data transfer time for 19200 bits (100*24h*8) at a transmission rate of 4Mbps is 4.8ms. Taking the additional overhead time to be negligible the time for writing 19200 bits to the SD card is 8.6ms (13.4 - 4.8). According to the microSD specifications, expected current usage for the SD is in the range of 20-100mA. The observed current obtained in our device is 25-30mA.In order to average out the current usage, a higher number of packets can be written into the SD at a time, instead of just 100 packets.

This also explains the reason BLE module and SD module are not able to run together. BLE independently running consumes 15mA, whereas SD consumes 30mA.

VI. FUTURE WORK

In order to build a completely efficient prototype, there is a need to integrate the SD with BLE in the future work. This can be done by working around the ON time periods for each of these functionalities. While BLE is working, SD needs to enter sleep mode/low-power mode and vice-versa. For this, it would also be useful to collate higher amounts of data at a time.

VII. CONCLUSION

The main contribution of the work has been to create a software code base for offline data collection working on e-Lab prototype 4.1 to back-up data in cases when wireless sensing is not an option due to connection loss or complete absence of BLE. The sensor data is sampled at a rate of 4KHz for ICM 20948 and the Bend lab is sampled at a rate of 100Hz. The Bend lab sampling rate is low because the filter coefficient in the post processing of the bend lab data is designed for a sampling rate of 100Hz.

REFERENCES

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[2] E. S. Lee, J. V. Jeyakumar, B. Balaji, R. P. Wilson, and M. Srivastava, "Aquamote: Ultra low power sensor tag for animal localization and fine motion tracking," in *Proceedings of the 15th ACM Conference on Embedded Network Sensor Systems*, ser. SenSys '17. New York, NY, USA: ACM, 2017, pp. 71:1–71:2.