Weekly Reports
Project in Embedded Control

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Last Updated
November 30, 2016

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1  Week 47

We tested and evaluated different packaging options to get a prototype of a wireless device. A mobile power source is currently missing.

We updated the code on the microcontroller and implemented a state machine. Currently we have problems with loading the calibration data on startup. It would be nice if this works since the calibration phase is quite long. We also look into the motion interrupts of the BNO055 to start the measurements on the detection of movements.

We did also research on the $\alpha\beta\gamma$ filter. Here we are not sure how to use these filters. It seems they all rely on position measurements which are not available to us. Our current understanding is that a position is estimated by using/integrating the current velocity and acceleration. The difference between the measured and estimated position $r$ is then used to get the new states:

- The position is updated using $r$ and $\alpha$
- The velocity is updated using $r$ and $\beta$
- The acceleration is updated using $r$ and $\gamma$

2  Week 46

During this week we focused on making the microcontroller get reliable measurements and import them on the computer.

Each time the BNO-055 sensor is powered on, calibration has to be done on the chip. To save time from calibrating each time, a function has been implemented to save or load the previous calibration values on the chip.

An interrupt timer has been set up to get the data from the sensor every 100Hz, to achieve the maximum accuracy in the data.

The data are been transmitted to the computer using a bluetooth chip. After that they can be saved and then we can process them in Matlab. Integration of the data to Matlab has been achieved and some preliminary processing to analyze them is available but we have to work more in this part.

Data transfer using DMA to optimize the data transfer has not been implement yet.

3  Week 45

This week we mainly read literature and wrote a preliminary version of the related work-section in the final report.

Additionally we made us familiar with the sensor, its configuration and calibration and its startup sequence. The connection between the sensor and the microcontroller is working and a preliminary serial connection from the microcontroller to the host is available. We plan to use the host during the development and test phase for making the necessary computations.

For the next week we plan to implement the algorithm to obtain position data from the linear acceleration and the absolute orientation of the device (which is given using quaternions). How to use a Kalman filter without a concrete model beside usual kinematics?

We also plan to optimize the data transfer by using DMA and to set up interrupt handlers which enable the device to go into and wake up from a power save mode.

When the first tests are working we need to think about replacing the power source (currently USB) by batteries to obtain a mobile system.

4  Week 44

We read several papers on quantification of tremor caused by the Parkinson Disease. We focused on papers which evaluate inertial measurement units such as accelerometers and gyroscopes because we plan to use such a unit in our project. The papers were obtained by searching PubMed, IEEE, Googling and following the references.

Most papers agree in their method to analyze the data obtained by the sensors and analyze the frequency content. Voluntary motion corresponds to frequencies up to 3 Hz. The relevant frequency range of tremor is — depending on the type of tremor — 3 Hz to 12 Hz.

To map the measured data to the MDS-UPDRS (Movement Disorder society updated the Unified Parkinson’s Disease Rating Scale in 2007) the power spectral density close to the tremor-peak-frequency is considered. It is logarithmically correlated to the UPDRS value.

Several papers focus on algorithms/methods that recognize if the tremor is treated (using medication/deep brain stimulation) or not. Other papers focus on developing real-time monitoring and prediction of tremor. This might be used to develop gloves providing stimuli which suppress tremor.
In our project we plan to track the position of the arm and use this data to quantify the tremor. We therefor read some papers about position tracking using accelerometer, gyroscope and magnetometer data. Most papers deal with the fusion of these data to remove drift and bias from the acceleration data, the position is then obtained by double integrating the acceleration. In an experiment with similar distances and a similar time-frame to the arm movement the tracked position was quite accurate (The errors were smaller than 2 cm in each direction, the travel distance was $\approx 40$ cm).

Since the BNO055 provides fused, drift free data the quality of the estimated position might be of acceptable accuracy. In order to improve the position estimation a model of the intended, voluntary movement might be used to design a Kalman filter. We also read a paper which focuses on the estimation of the non-voluntary movement and it seems to work quite accurate. Maybe these two approaches can be combined to get a good estimation of the position.

We also continued to write a computer program which collects the sensor data. Computer to USART module to Bluetooth module (HC-05) to Bluetooth module to Computer is working under linux. STM32 to Bluetooth (HC-05) is working. STM32 to BNO055 is working. Now we need to write a program that saves the data from a com port to a file.

Here is our formulation for what we think this project is about. To see if filtering out the voluntarily motion using a mathematical model of an arm and prior knowledge about the motion is better than filtering out voluntary motion using a high-pass filter.

Is the current way of quantification not good enough? Most papers seem to agree than measuring frequency is giving an accurate quantification.

In the end, how will we be able to prove if our solution is better or worse than just filtering by frequency?

Where should we look for mathematical models for arms and motions?

Should we try to measure position data or look at angles and velocities?

5 Week 43

During the first week we discussed the different project proposals and decided to work on the tremor project. The goal of this project is to develop a system which quantifies tremor of patients suffering from diseases like Parkinson. The system should be able to track the movement of the hand which performs a predefined movement like ”pick up a phone from the table and move it to the ear”. The motion consists of a fast part — the tremor — which overlays the movement from the table to the ear.

The movement tracking is done by using sensors which are normally available on smart phones today. This includes gyroscopes (which measures the angular velocity of the device around its axes), accelerometers (which measure the acceleration applied to the device) and magnetometers. We watched a video about sensor fusion 1 which gives a short introduction in how these sensors work and how they can be used. It also discusses briefly the difficulties regarding position tracking 2.

We plan to gather sensor data using a specialized chip, the BNO-055 from Bosch. It includes sensors and sensor fusion in a single package. A microcontroller of the STM32F103 family is used to read out the sensor data. The data is then processed either on the chip itself or it is transferred to another device using Bluetooth. Currently we are setting up the environment and the communication between the BNO-055 and the microcontroller.

In order to plan further we would like to discuss how the tremor can be quantified. Is it enough to analyze acceleration data or will it be necessary to track the position of the device. A conference paper we read 3 used only the acceleration data which might be sufficient.

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1 See the Google-Tech-Talk at https://www.youtube.com/watch?v=C7JQ7Rpm2zk
2 See minutes 23–29.
3 https://www.researchgate.net/publication/266080900_A_Smartphone_Application_for_Parkinson_Tremor_Detection