Magnetic Induction Approach for Human Activity Recognition

Andy Chen | 24chenay@gmail.com | ACME Lab
Troy High School, Class of 2024
USC Viterbi Department of Electrical and Computer Engineering, SHINE 2023

SHINE
Summer High School Intensive in Next-Generation Engineering

Introduction

Human Activity Recognition (HAR) is becoming more and more useful in recent years to enable point-of-care testing and diagnosis. It can detect any simple and complex actions in real-time, allowing computer systems to assist users with their tasks and to improve the quality of life in areas such as senior care, rehabilitation, daily life-logging, personal fitness, and assistance for people with cognitive disorders. We used a wearable magnetic induction (MI) based approach to achieve this goal because it requires low power.

Magnetic Field Modality

The ACME Lab is interested in a broad range of biomedical applications, focusing on designing ultra energy-efficient wearable and ingestible integrated circuit (IC) sensors, using the magnetic field modality as a way for sensing. Fig. 1 shows an IC developed in the lab to localize smart ingestible pills inside the body using magnetic fields within sub-mm precision for capsule endoscopy applications.

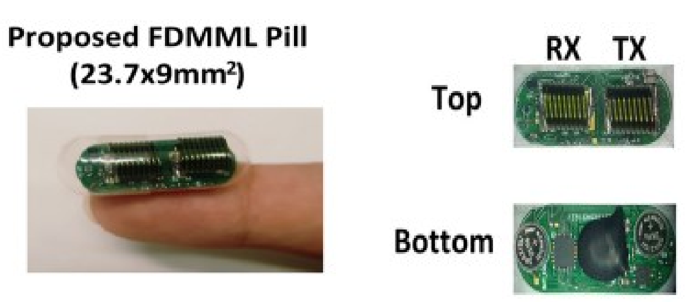

Fig. 1. Pill with a magnetic localization scheme based on frequency-division multiplexing for capsule endoscopy applications [1].

Motion tracking can be achieved by sensing the magnetic link strength (represented by the mutual inductance) between the receiver and transmitter coils, which is a function of the separating distance and the coils orientation and alignment.

In order to sense the magnetic field, the operating frequency for sensing is important and should be lower than 30MHz, because beyond this frequency, the human body is not anymore transparent to the magnetic fields and causes scattering effects that lead to tracking errors in the motion data.

Methodology

Coil-based MI Human Model

MATLAB is used to model the receiver and transmitters coils distributed across the limbs as shown in Fig. 2. in order to generate synthetic magnetic induction motion data.

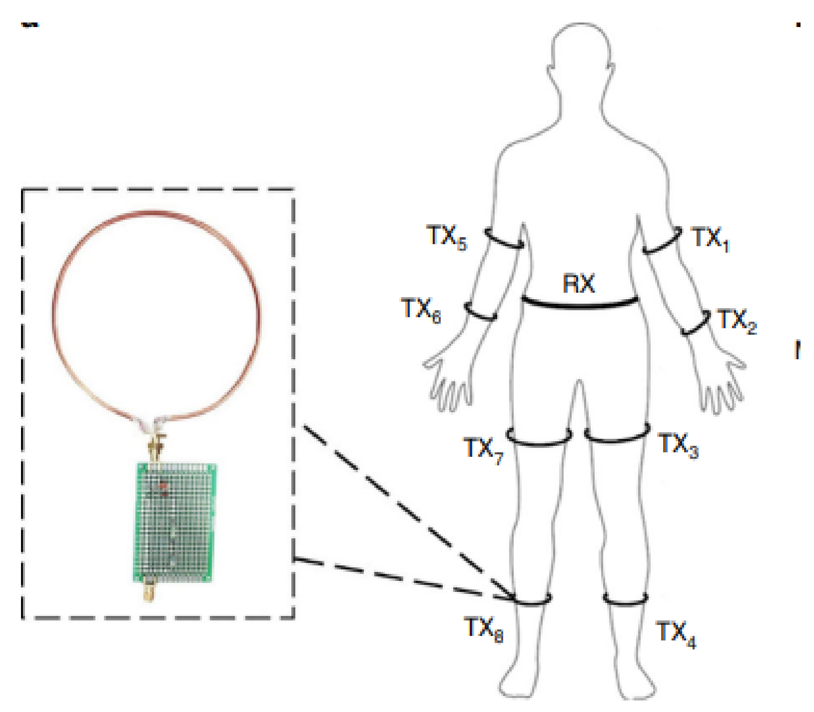

Fig. 2. Magnetic Induction (MI)-based human body model with coil-based sensors distributed across the limbs [2].

Motion Data

Motion capture data from the Berkeley Multimodal Human Action Database (MHAD) was used in this work, which covers a wide range of activities performed by different subjects, e.g., jumping in place, jumping jacks, throwing, waving hands, clapping hands, sit down, stand up, etc. Fig. 3 shows plot of the motion data for the activity of waving both hands at different instants.

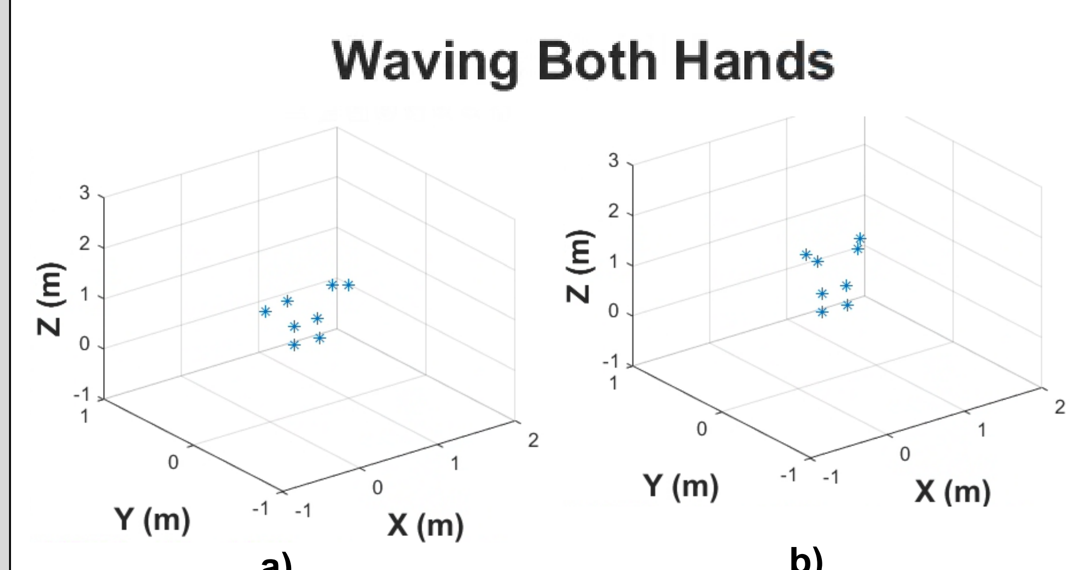

Fig. 3. Plot of the motion data from the Human Model
a) Initial position of coils on the human model in still-position
b) Final position of Human in stretched position

Results

Synthetic MI Data

The MI MATLAB code is used to calculate the output received power of a lumped circuit model of the MI link. The code is also configured such that each coil can act as a receiver or as a transmitter. Fig. 4 shows the time-series patterns of the received power from all the seven transmitters for two types of activities, bending and clapping hands.

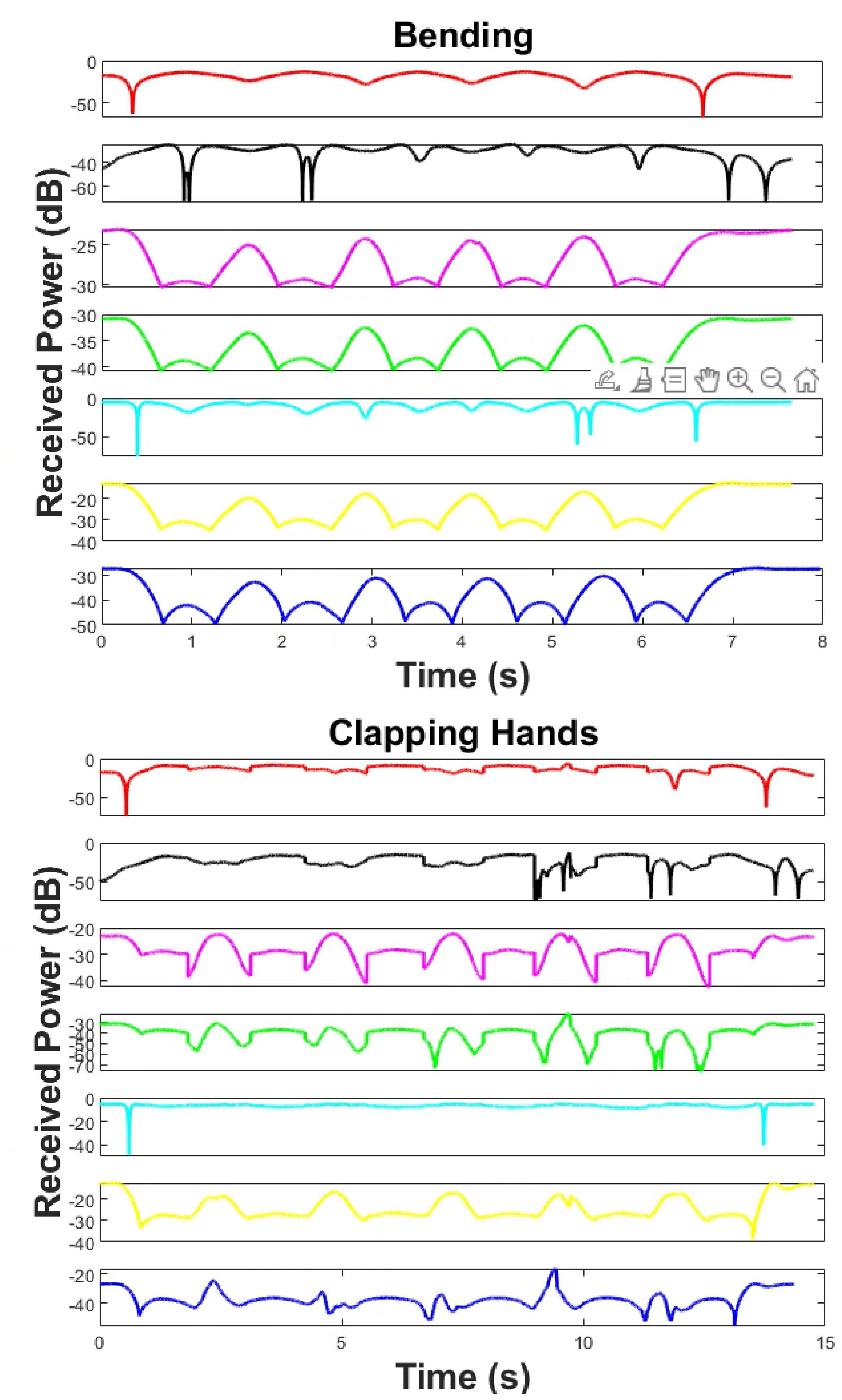

Fig. 4. The received power from the transmitters sensed by the receiver are generated using the proposed MI model and the human motion data captured for different activities in the MHAD Dataset

Future Work

The synthetic MI received power will be used as input to the machine learning regression model in order to track the motion of the body for different activities. A deep long short-term memory (LSTM) recurrent neural network (RNN) could be a very accurate candidate model for predicting these motion activities.

Learning Outcomes

Throughout SHINE, I learned fundamentals of electromagnetics, magnetic induction, coil-based sensors, and its properties. I also learned a new programming language, MATLAB, and used it to synthetize magnetic-induction based signals, as well as for data post-processing in order to meet the project goals.

Acknowledgements

I would like to thank Monica Lopez for organizing SHINE, Prof. Constantine Sideris for the opportunity to work in his lab, and my mentor Michella Rustom for her guidance.

Citations

[1] M. Rustom and C. Sideris, “Wireless frequency-division multiplexed 3D magnetic localization for low power sub-mm precision capsule endoscopy,” in Proc. IEEE CICC, Apr. 2022,
[2] N. Golestani and M. Moghaddam, “Human activity recognition using magnetic induction-based motion signals and deep recurrent neural networks,” Nat. Commun., vol. 11, no. 1, p. 1551, 2020.