Gesture Recognition through Wi-Fi Sensing in Smart Homes

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- System Design
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  - Data Pre-processing
  - Deep Learning based Algorithm
  - Gesture Recognition
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Introduction

- With the fast growth of smart appliances and smart devices at home, Smart Homes have received increased attention and have been translating from a vision into reality
- Human gesture recognition serves a diverse range of human-centric applications in health care, smart homes and security
- Human gesture recognition aims to increase personal autonomy of elderly and impaired people by means of ambient-assisted living(AAL) to detect home accident, long term behaviour analysis, telecare

Introduction

Applications of Gesture Recognizing System:

- Monitoring of in-house exercise, human respiration and heart rates while sleeping, other human gestures
- Preserve Energy by using Wi-Fi based gesture application for switching on and off devices and automatically shift the device to deep sleep when no gesture is detected
- Fall Detection for elderly
- Security

Related Work

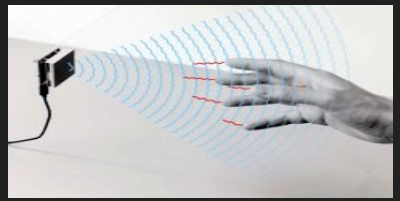
The methods for detecting human gestures can be categorized in two main approaches

1. Device-Based Approaches
2. Device-Free Approaches

Related Work

Device-based approaches:

- Wearable Devices: In this approach the gesture is detected by devices like smart watches, wired gloves etc which can be wore in day to day life
- Camera based approach: This approach uses camera to sense human gestures
- Sensor based approach: This approach uses sensors, and radars which can be trained to recognize human gestures



Related Work

Drawback of existing approach

- ➢ User needs to constantly wear a wearable-device which can be uncomfortable and an overhead
- ➢ Cameras need to be in Line of Sight(LOS) of human gesture to detect it, that may require multiple camera to increase coverage which will lead to increase cost as well as privacy issues
- ➢ To overcome, all these drawbacks we propose using a device-free technology already present in most homes and places: Wi-Fi

Related Work

Advantages of using Wi-Fi

- Easily available
- Wi-Fi signals can propagate through wall, furniture and doors, and do not require Line of Sight (LOS) thereby enabling larger detection area.
- Low cost

Principle of Wireless Sensing

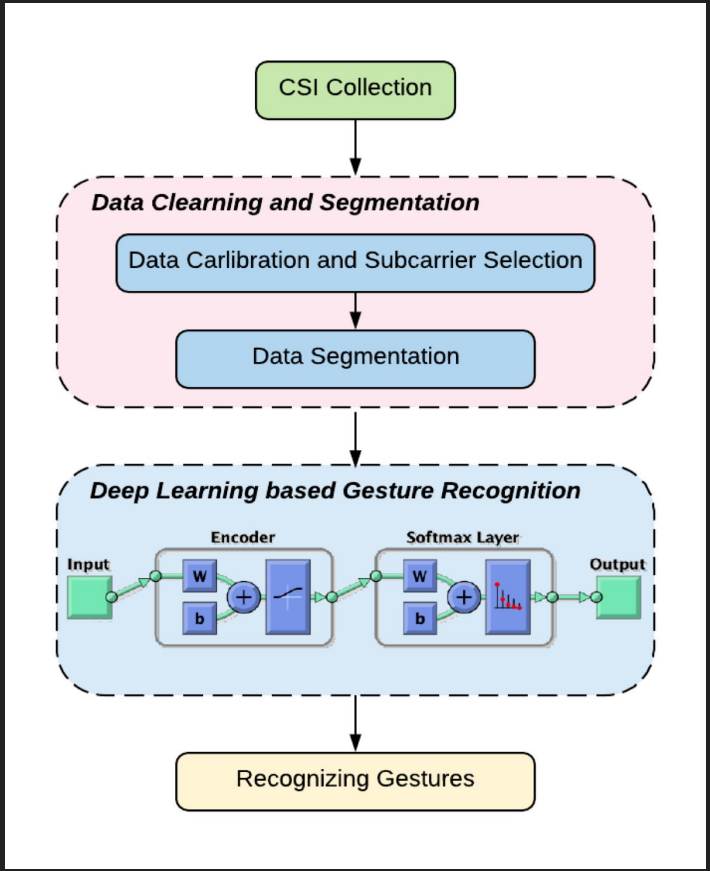
The state of channel changes due to any obstruction in the path of the signal. It can be denoted as:

$$Y = H*X + N_0$$

- Y = Signal Received
- H = CSI
- X = Transmitted Signal
- N_0 = Environmental Noise

System Design

1. Data Collection
2. Data Pre-processing
3. Deep Learning based Algorithm for Gesture Recognition
4. Recognizing Gestures

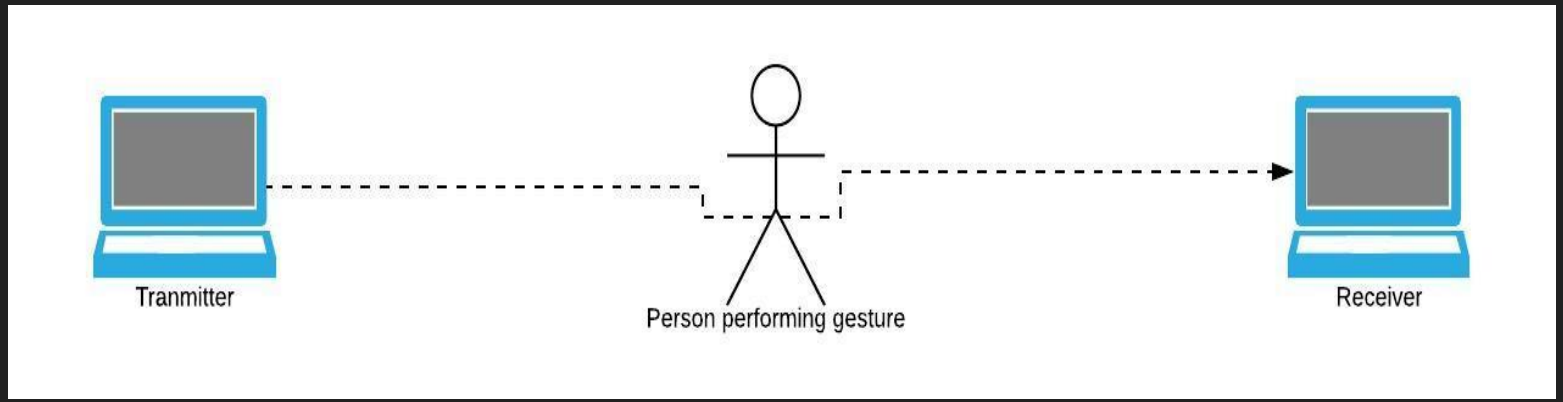


Data Collection

- Data is collected using Channel State Information(CSI)
- In wireless communication, channel state information(CSI) simply represents the property of a communication link between the transmitter and the receiver
- The CSI describes how signal propagates from the transmitter to the receiver and represents the combined effect of scattering, fading and power decay with distance

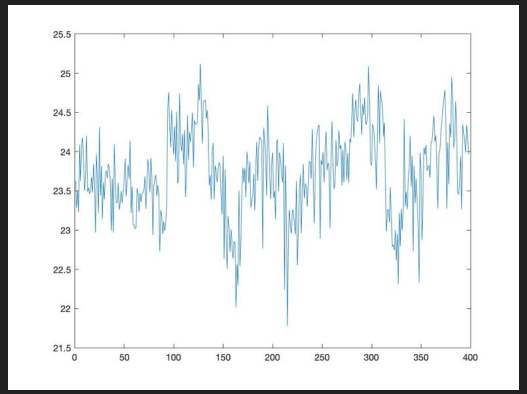
Data Collection

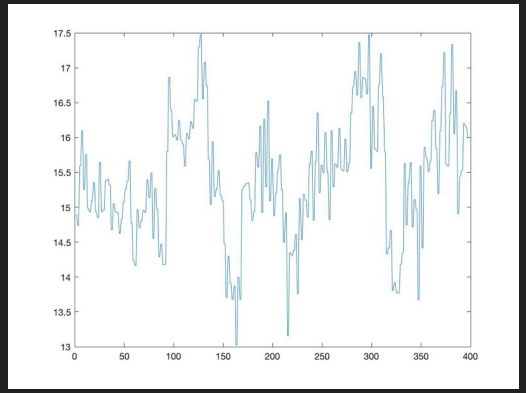
- Here is an example of how the data is collected using CSI



Data Pre-Processing

- The raw CSI data contains high frequency noise, outliers, and artifacts
- We have used wavelet based denoising to remove the noise
- Here is the example of a signal before and after denoising



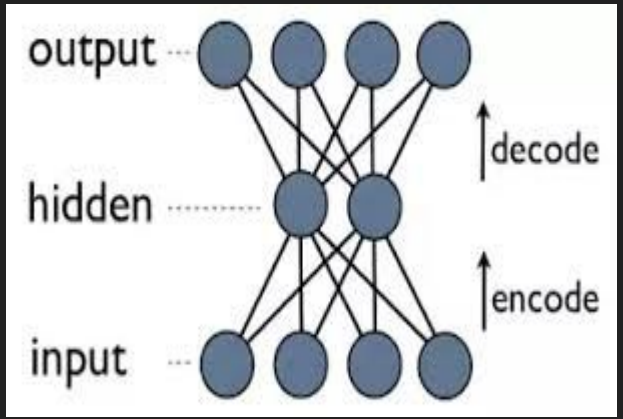


Data Pre-Processing

- The filtered data becomes smooth after the high frequency noise reduction
- This approach of removing the noise preserves the high frequency features in the signal
- The Intel 5300 NIC reports CSI for 30 groups of subcarriers
- We experimented with different combinations of subcarriers to get the best possible accuracy and stable CSI measurement, and have choose to use data of all 30 subcarriers

Deep Learning based Gesture Recognition

- We have used an artificial neural network called Autoencoder for developing the deep learning algorithm for recognizing human gestures
- An autoencoder is trained in unsupervised fashion to replicate it's input at its output.
- The autoencoder learns a compressed representation of the input in the hidden layer

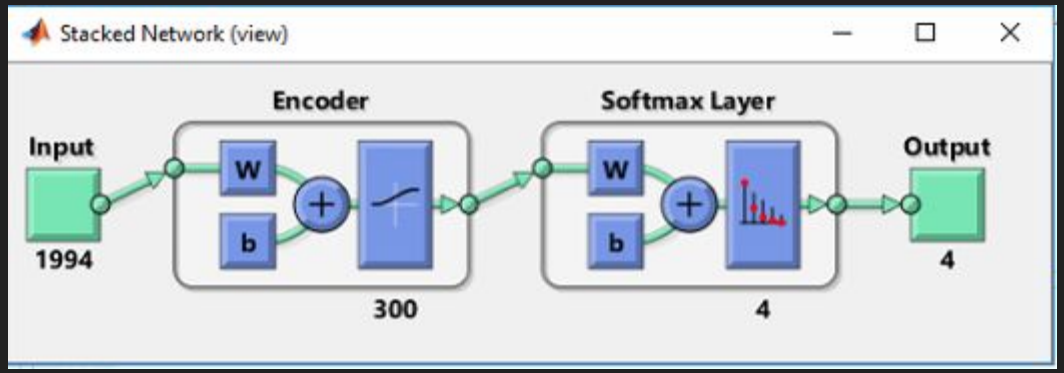


Deep Learning based Gesture Recognition

- Then we use this features extracted from the hidden layer of the autoencoder to train the softmax layer in a supervised fashion using labels for the training data.
- Softmax Regression is a generalization of logistic regression that can be use for multi-class classification

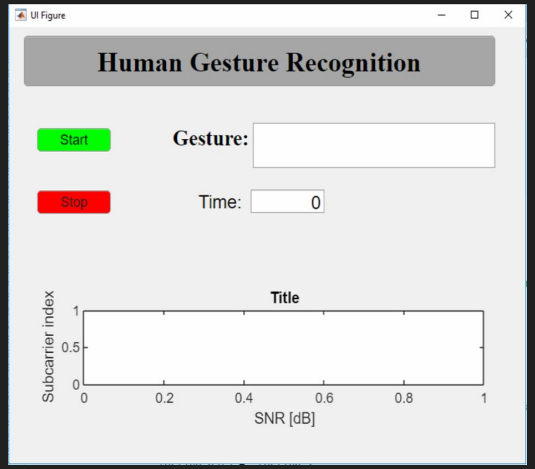
Deep Learning based Gesture Recognition

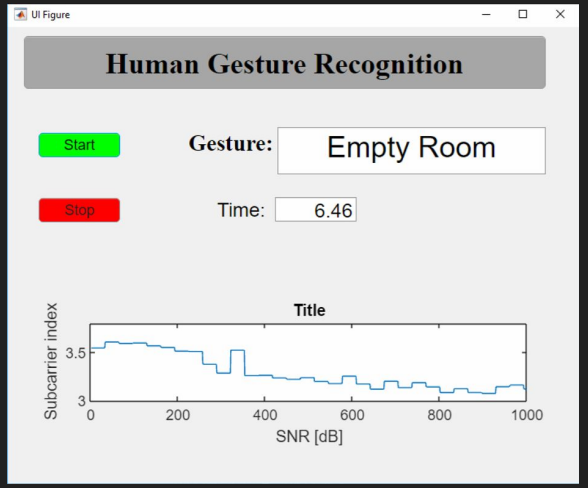
- The output of autoencoder and softmax regression is stacked to form a stacked neural network
- We can used this stacked network to compute the results on testing data to obtain accuracy by plotting a confusion matrix



Real-Time Monitoring UI

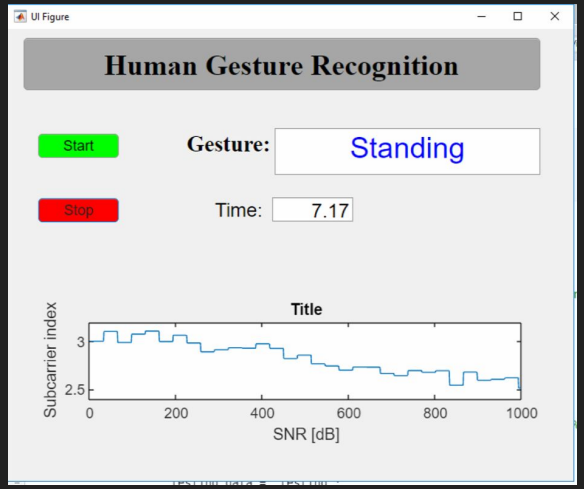
- We have used Matlab App Designer to build a UI for displaying real-time human gestures

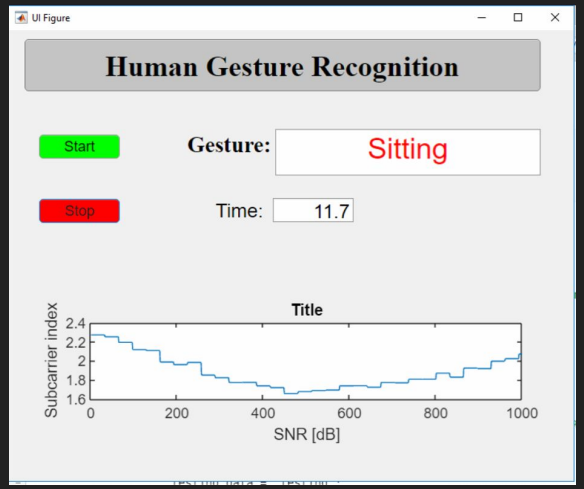


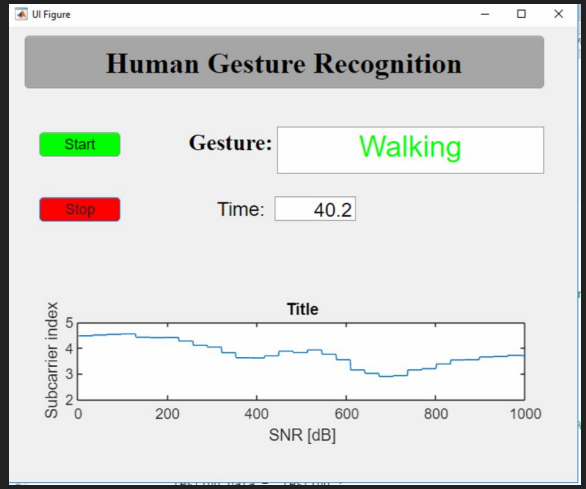


Real-Time Monitoring UI

- This system can detect gestures for standing, sitting, walking and empty room (no gesture)







Experimental Setup and Results

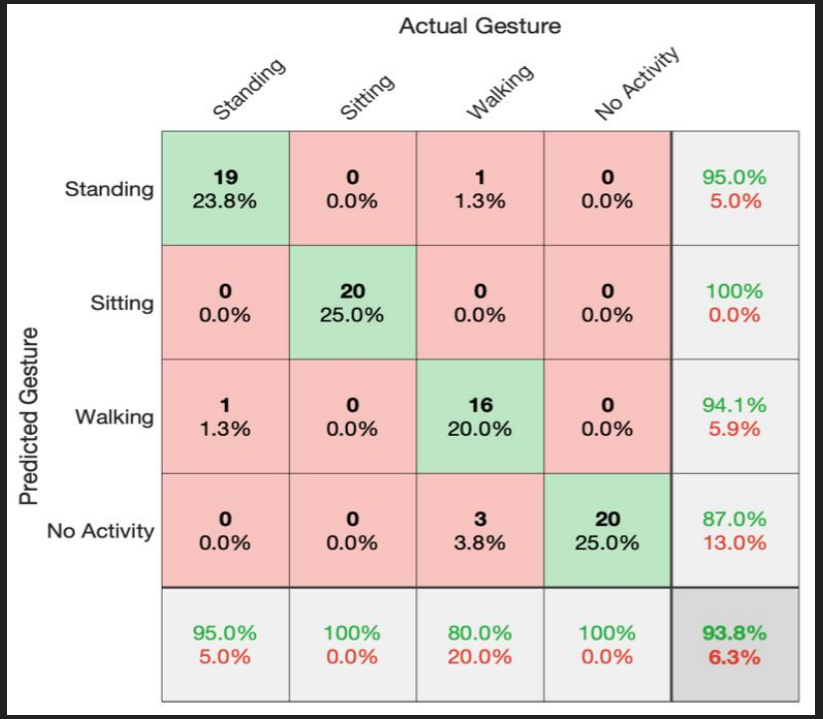
- We collected the data at NISE Lab at SFSU
- The data was collected for an individual for sitting, standing, walking and empty room (no gesture)




Experimental Setup and Results

Data Samples:

- Walking: 200
- Standing: 200
- Sitting: 200
- No gesture (Empty Room): 200



Conclusion

- Gesture Recognition through Wi-Fi can serve a wide range of applications and usher in new ear of contactless sensing
- As most places today have Wi-Fi it can eliminate the problems like over-head, Line of Sight and privacy
- We used CSI to collect Wi-Fi signals that captured human gestures and then pre-processed it by performing denoising
- This pre-processed data is then used to train our deep learning algorithm to identify four gestures: sitting, standing, walking and empty room(no gesture)
- Since Wi-Fi based gesture recognition is relative new area of research, there were some limitations but we achieved a very good accuracy of 93.8%

Thank You