Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
**Corresponding author: venvannuth@gmail.com*

Oral No.
OR-SD13-049

Human Detection with WiFi CSI

Presented by: Mr.Ven vannuth

Under Supervision of:
Prof. Hidekazu Yanagimoto, Prof. Kiyota Hashimoto

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Table Of Content

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
**Corresponding author: venvannuth@gmail.com*

Oral No.
OR-SD13-049

Introduction

Background

In recent years, the advancement of wireless communication technologies has opened new avenues for various applications beyond traditional data transmission. One such application is using WiFi Channel State Information (CSI) for human activity recognition. CSI provides detailed information about the signal propagation environment, making it possible to detect and classify human movements with high accuracy.

Human Detection with WiFi CSI

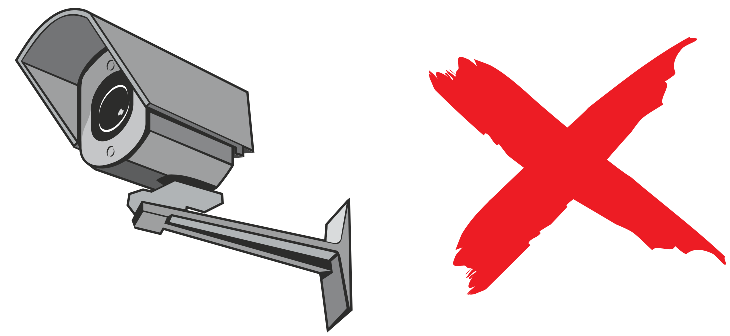
Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Oral No.
OR-SD13-049

Introduction

Statement of Problem

- Traditional methods of human activity detection often rely on cameras or wearable sensors, which can be intrusive and raise privacy concerns.
- These methods require significant infrastructure and maintenance. Our research addresses these challenges by utilizing WiFi CSI data, a non-intrusive and cost-effective alternative.



Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

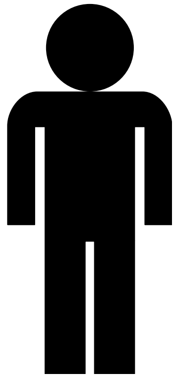
Oral No.
OR-SD13-049

Introduction

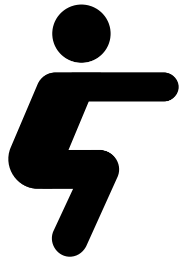
Objective

The objectives of this research are:

- Develop an effective method for detecting and classifying human activities, specifically standing and squatting, using WiFi CSI data. By employing signal processing techniques and machine learning algorithms, we aim to demonstrate that WiFi CSI can be a reliable tool for human activity recognition in various environments



Standing



Squatting

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina , Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Introduction

What is CSI ?

Channel State Information (CSI) is a critical metric in wireless communication, representing the channel properties of a WiFi signal between the transmitter and receiver.

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina , Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Introduction

What is CSI ?

The transmitted signal does not reach the receiver without any changes.

- After reflecting off objects in the communication environment, it arrives at the receiver with some delays.
- Assuming that the transmitted signal has reached the receiver via M different paths, it can be modeled as follows.

$$h(t;\tau) = \sum_{i=0}^{M-1} a_i e^{j\phi_i} \delta(t-\tau_i)$$

- $h(t;\tau)$: Impulse response function of the channel.
- $\sum_{i=0}^{M-1}$: Summation over all multipath components, from $i=0$ to $i=M-1$.
- a_i: Amplitude of the i-th multipath component. This reflects the strength of the signal for that path.
- $e^{j\phi_i}$: Phase shift of the i-th multipath component. The j here is the imaginary unit, indicating that this part of the signal is in the complex plane.
- $\delta(t-\tau_i)$: Dirac delta function, which indicates that the signal arrives at the receiver with a time delay of τ_i for the i-th path.

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Introduction

Fourier Transform and CSI Measurement

$$H(f) = \sum_{i=0}^{M-1} a_i e^{j\phi_i} e^{-j2\pi f t_i}$$

Here, $H(f)$ represents the measured Channel State Information (CSI) in the frequency domain.

M is the number of multipath components (signals taking different paths from transmitter to receiver).

a_i represents the amplitude of the i-th multipath component.

ϕ_i is the phase shift of the i-th multipath component.

t_i is the time delay for the i-th multipath component.

j is the imaginary unit.

INSTITUTE OF TECHNOLOGY OF CAMBODIA
RESEARCH AND INNOVATION CENTER

THE 13TH SCIENTIFIC DAY
June 6-7, 2024
Phnom Penh, Cambodia

RESEARCH AND INNOVATION CENTER

Human Detection with WiFi CSI

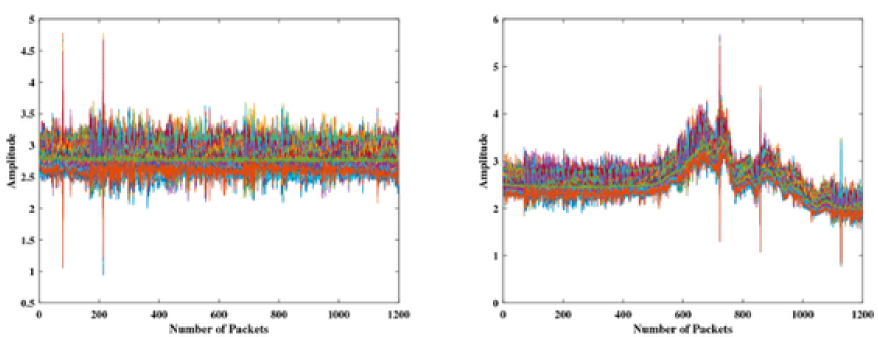
Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina , Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Oral No.
OR-SD13-049

WiFi Signal (CSI) VS Camera

WiFI Signal (CSI)

- Does not capture visual images, more privacy .
- Presence and movements detection based on signals.
- Generally low cost.
- Cover large area, scalable



(a) (b)

Camera

- Visual capture may be invasive to privacy
- Subject to lighting condition
- Software and hardware cost factor
- Less scalable as it can be costly to cover large area

Human Detection with WiFi CSI

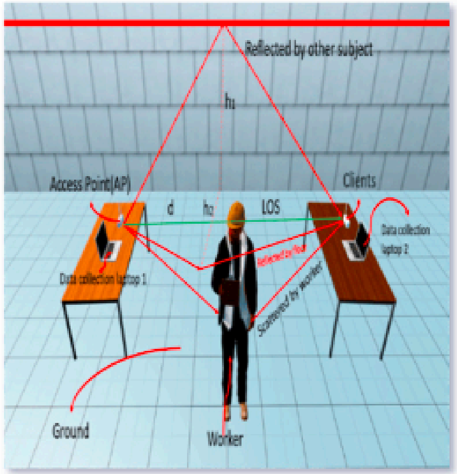
Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Oral No.
OR-SD13-049

Experiment Conduction

Flowchart

Collection of CSI Data



Data Preprocessing

- Raw CSI Data
- Noise Cleaning
- PCA

Classifier

- Decision Tree
- Logistic Regression
- Random Forest
- SVM
- Gradient Boosting Decision Tree

Humen Detection

- Standing
- squatting

INSTITUTE OF TECHNOLOGY OF CAMBODIA
RESEARCH AND INNOVATION CENTER

THE 13TH SCIENTIFIC DAY
June 6-7, 2024
Phnom Penh, Cambodia

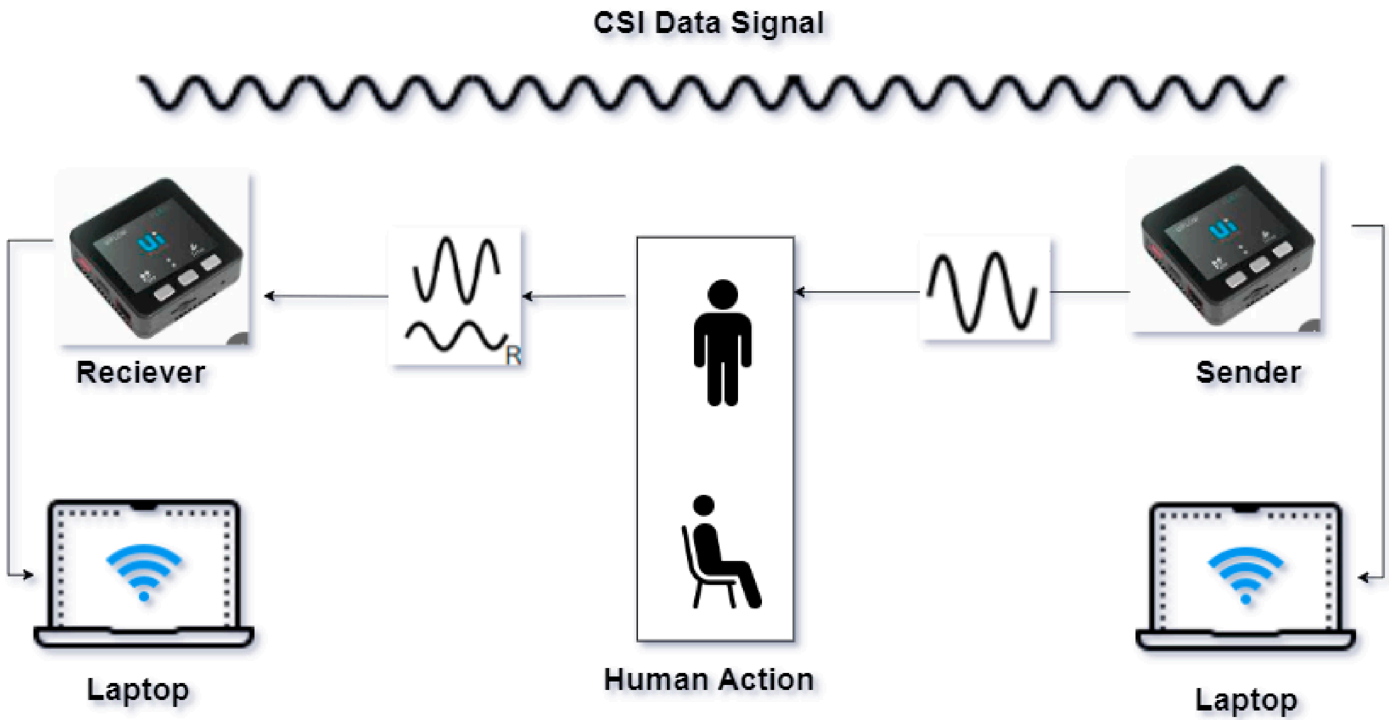
Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Oral No.
OR-SD13-049

Experiment Conduction

Data Collection



Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Oral No.
OR-SD13-049

Experiment Conduction

Data Structure

```
2023-11-11 17:19:40.180126,CSI_DATA,0,1a:00:00:00:00:00,-66,11,1,0,1,1,1,0,0,0,1,-97,0,11,2,9739,0,44,0,384
```

Timestamp: 2023-11-11 17:19:40.180126

DataType: CSI_DATA

Channel Number: 0

MAC Address: 1a:00:00:00:00:00

-66,11,1,0,1,1,1,0,0,0,1:

- RSSI (Received Signal Strength Indicator): -66
- Antenna Index: 11
- Number of Spatial Streams: 1
- Bandwidth: 0
- Number of Subcarriers: 1

CSI Data: -97,0,11,2,9739,0,44,0,384

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina , Hidekazu Yanagimoto , Kiyota Hashimoto
*Corresponding author: venvannuth@gmail.com

Experiment Conduction

Convert CSI Data to Amplitude

- CSI values are complex numbers, they provides comprehensive information but may be difficult to interpret to interpret directly.
- Converting it to amplitude simplifies the data and can boost interpretability
- we convert the complex number to an amplitude as following.

$$a = \sqrt{Re[H(f)]^2 + Im[H(f)]^2}$$

Where:

- ***a*** represent amplitude of CSI
- $Re[H(f)]$ is the real part of the complex CSI.
- $Im[H(f)]$ is the imaginary part of the complex CSI.

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hahimoto
*Corresponding author: venvannuth@gmail.com

Oral No.
OR-SD13-049

Experiment Conduction

Data Pre-processing

The Data pre-processing step include:

- **Clean Noise Data:** The first couple seconds of the data are removed as this is when we start and prepare to monitor the signal transmission
- **PCA:** The data distribution is reduced to a lower dimensions .
- Divide data into training set and testing set.

Data after Clean

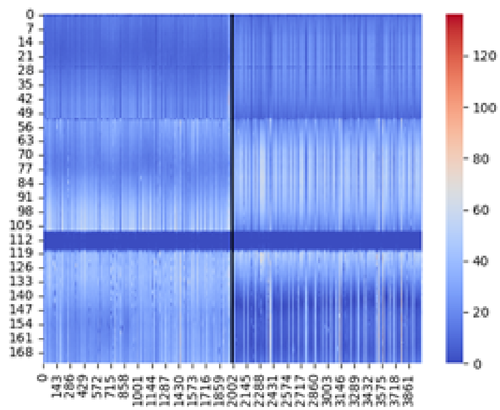


Fig.3. Heatmap of CSI amplitude for standing and squatting.

PCA

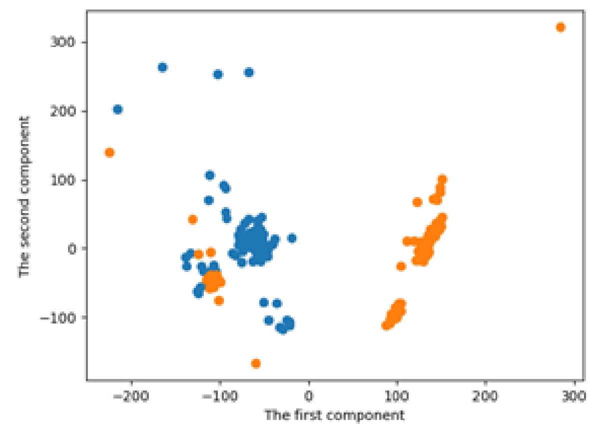


Fig. 4. The data distribution reduced to lower dimensions with PCA.

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hahimoto
*Corresponding author: venvannuth@gmail.com

Result and Discussion

Table 1. Prediction accuracy for test data.

Method	Accuracy
Decision Tree	0.978
Logistic Regression	0.991
Random Forest	0.997
Support Vector Machine	0.994
Gradient Boosting Decision Tree	0.997

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hahimoto
*Corresponding author: venvannuth@gmail.com

Conclusion

we constructed a CSI measurement system using M5Stack and proposed a system for estimating human posture without any cameras. The estimation accuracy achieve was over 99%. This means that a human detection system can be build using CSI and machine learning.

Future Work

In the future we hope to develop a systems that detect not only human posture but also movements and crowd counting which can be used for various application such as in elderly caring. Moreover, we will explore other machine learning such as deep learning, to further improve estimation accuracy.

Human Detection with WiFi CSI

Ven Vannuth, Keo Vonmonyroth , Ek Vongpanharith , Sean Vengngy , Chhon Chaina ,
Hidekazu Yanagimoto , Kiyota Hahimoto
*Corresponding author: venvannuth@gmail.com