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WiAudina: Multimodal Gait Sensing Using Wi-Fi Signal and Acoustic Information

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Abstract. Wi-Fi sensing, which can identify human's action, number of that, and individuals using Wi-Fi signals, is a method that can be introduced easily. The reason for this is possible to operate low cost and protect privacy. However, with only Wi-Fi signal sensing, there are few problems of decreased identification accuracy due to difference in the location of device and in silhouette. Therefore, in this paper, we propose WiAudina to achieve robust identification for environmental changes using Wi-Fi signals with acoustic information from footsteps. In this proposed method, then changing clothing, an average improves about 10% of identification accuracy compared to only Wi-Fi signals or only acoustic information.

Keywords. Wi-Fi sensing, multimodal

1. Introduction

Wi-Fi sensing is a technology that enables the prediction of human identification, position, and number by acquiring Channel State Information (CSI).
That makes it possible to acquire amplitude and phase information at each frequency as CSI from Wi-Fi signals. The unique patterns of CSI are made by the different body movements by individuals, and observing these that is able to sense.

There are two advantages of using Wi-Fi sensing. Firstly, this sensing method is not used a camera, it does not capture the faces or private rooms, which makes it possible to protect privacy. Secondly, it can be used with commodity access point (AP), making it possible to operate at low cost [1].

However, identification accuracy decreases due to changes the sensing location or changes the clothing of the person. This is because changing shape and number of surrounding objects, and the silhouette of the person. The CSI pattern significantly changes before and after different the environmental, making it difficult to correctly identify the person [2].

Therefore, in this paper, we aim to use acoustic information from footsteps as an additional modality to CSI, to perform person identification in cases of different clothing by making use of the two modalities complementarity [3].

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The rest of the paper is as follows. Section 2 explains related works. Section 3 describes the design of our proposed method. Section 4 describes the experimental environment for data acquisition. Section 5 shows validation of our proposed method using the acquired data and Section 6 concludes this paper.

2. Related Work

In this paper, we conducted data collection, experimental environment settings, and data processing based on the related work shown below.

In this study by Lang Deng et al. [4], a system called GaitFi is proposed, which is a person identification system based on gait using CSI and video. That achieves a person identification accuracy of 94.2% by performing feature fusion after extracting features for each modality. The accuracy of identification using fused feature is higher than using either CSI or video alone for prediction.

Similarly, to verify robustness against presence or absence of brightness, identification accuracy of this method is higher than other methods.

A study by Wang et al. [5], a system called WifiU is sensing method using only CSI. WifiU performs person identification using walking data from 50 individuals in a room of 7 m square, achieving accuracy of 79.28%, 89.52, and 93.05% for top 1, 2, and 3.

This system can achieve approximately 92% accuracy in identification until the distance between devices exceeds14m. However, the distance is about 6m when actually use for gait identification, so it can be operated without any problems.

A study by Hori et al. [6], a system is proposed that only use sound of footstep in front of a microphone placed 5cm above the floor. The acquired sounds are divided into each step and converted using identification is performed using convolutional neural network (CNN), achieving high accuracy.

3. System Design

In this section, we describe the structure of our system.

3.1. Overall Structure

We describe the overall structure of our proposed system, WiAudina (Wi-Fi and Audio Identification of Gait).

WiAudina is a multimodal gait sensing system that combines two modalities: CSI and acoustic information. The structure of our system is shown in Figure 1.

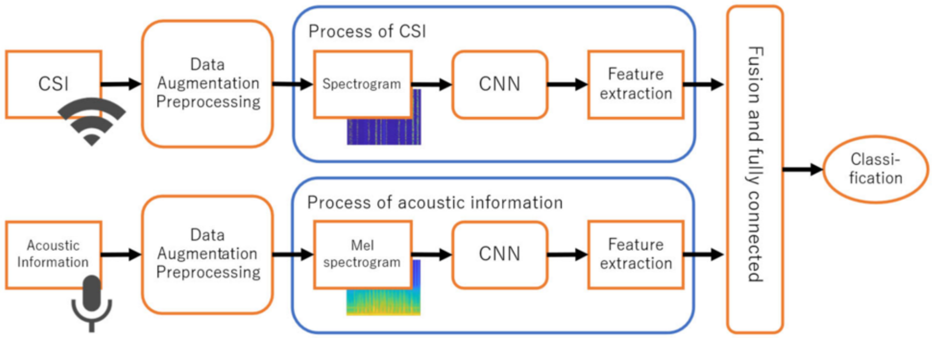

Figure 1. Structure of WiAudina.

The preprocessed CSI and acoustic information are used as inputs to the CNN in the form of color spectrograms, and feature vectors are extracted from both. Next, the two feature vectors are fused and classified.

3.2. Processing the CSI and acoustic information

When the AP is constantly running, the frequency at which the amplitude of the CSI that can be obtained increases significantly changes over time. [7]

We attempt to extract only the impact of people on the CSI by separately acquiring the CSI when people are not walking, calculating the average amplitude from there, and taking the difference with the obtained CSI.

Both CSI and acoustic information use data augmentation, adding noise that follows a normal distribution with a mean of 0 and a standard deviation equal to the maximum amplitude.

4. Experiment

In this section we show a result of an experiment to evaluate our system. 15 subjects of this experiment walk between the two APs as shown in the figure, wearing and not wearing a jacket, Figure 2, 3 and 4 shows a location of this experiment and presence or absence of a jacket.

During the walk, we acquire CSI and acoustic information. Each data length is 10 second.

Table 1 shows the number of experimental data. The set of CSI and acoustic data is indicated as 1.

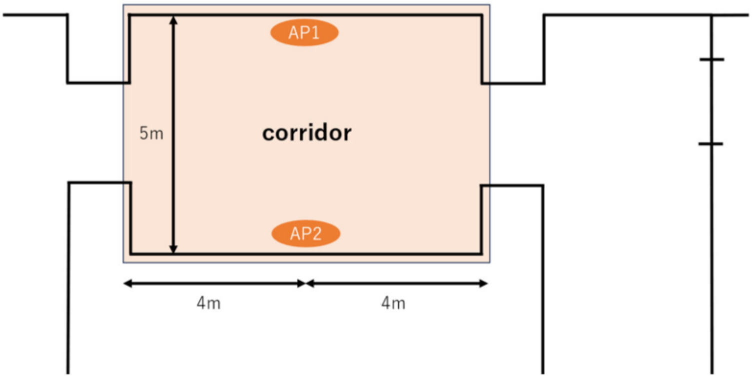

Figure 2. Top view of experimental environment.

Figure 3. Image of experimental environment.

Figure 4. Difference of presence or absence of a jacket.

Table 1. Number of the data each subject.

Subjects (label)	Wearing	Not wearing	Sum
A	50	25	75
B	50	25	75
C	50	25	75
D	49	24	74
E	47	23	70
F	50	25	75
G	50	25	75
H	50	25	75
I	50	25	75
J	50	25	75
K	48	25	73
L	47	25	72
M	47	25	71
N	46	22	68
O	44	22	66
Total	728	366	1094

5. Evaluation

We verify the following two points as evaluation: Whether WiAudina has usefulness, whether there is a change in accuracy due to presence or absence the jacket.

For this purpose, classification by the model verify as follows:

- Verification A (Ver A): Leaning and testing verify with wearing jacket data.
- Verification B (Ver B): Learning and testing verify with wearing jacket data and with not wearing jacket data. In addition, each verification is conducted with three types: only CSI, only acoustic information, and WiAudina. All learning and testing are repeated more 20 times.

Table 2 is shown the accuracy of each verification.

Table 2. The accuracy of each verification.

	Ver A	Ver B
Only CSI	93.30%	85.46%
Only acoustic information	94.19%	88.66%
WiAudina	**96.42%**	**97.88%**

Regarding the usefulness of WiAudina, in both Var A and B, the accuracy of WiAudina is higher than that of only CSI and only acoustic information.

Regarding the change in accuracy depending on presence or absence of a jacket from Var A to B. it is shown the accuracy decreases when classification using single modality. However, WiAudina did not decrease in accuracy.

Therefore, it indicates that WiAudina has usefulness, in addition WiAudina enables sensing that is less affected by changes in clothing.

6. Conclusion

In this paper, we investigated method to mitigate the decrease in accuracy due to changes in clothing in sensing using CSI. By comparing the accuracy of single modality and the proposed method WiAudina, using gait data with and without jacket from 15 subjects. We found that WiAudina achieved accuracy approximately 10% higher than single modality identification when clothing changes occurred.

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