Wilmage: Fine-grained Human Imaging from Commodity WiFi

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Abstract

Privacy-preserving wireless-based human imaging technologies attract much attention in academia and industry. They can serve in surveillance, security inspection, and health monitoring, while preventing the privacy leakage from current camera-based surveillance system. However, previous solutions either requires dedicated hardware or costly infrastructure deployment, which hurts their practicality. In this paper, we propose Wilmage, a low-cost, instantly-deployed sensing system that can capture a fine-grained human image and infer his contour using ubiquitous WiFi. Wilmage is free of pre-training or placing any marker on a user's body. Wilmage consists of two technical components. First, a lightweight multipath resolution algorithm exploit the spatial and temporal correlation of WiFi packets to address the multipath and extract reflected signals from a human body. Second, an imaging algorithm infers the contour of a human from WiFi reflections. We prototype Wilmage using offthe-shelf WiFi chips and conduct experiments in several typical indoor settings. The results show that Wilmage can recover a representative human figure and use it to identify the user precisely.

Full Text

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Figures

Figure 1

Phase changes are different in antennas when a signal arrives at an antenna array.

$$\begin{bmatrix} \text{csi}_{1,1} & \dots & \text{csi}_{1,30}, \text{csi}_{2,1} & \dots & \text{csi}_{2,30}, \text{csi}_{3,1} & \dots & \text{csi}_{3,30} \end{bmatrix}$$

↓

$$\begin{bmatrix} \text{csi}_{1,1} & \text{csi}_{1,2} & \dots & \text{csi}_{1,15} & \text{csi}_{2,1} & \text{csi}_{2,2} & \dots & \text{csi}_{2,15} \\ \text{csi}_{1,2} & \text{csi}_{1,3} & \dots & \text{csi}_{1,16} & \text{csi}_{2,2} & \text{csi}_{2,3} & \dots & \text{csi}_{2,16} \\ \vdots & \vdots & \dots & \vdots & \vdots & \vdots & \dots & \vdots \\ \text{csi}_{1,16} & \text{csi}_{1,17} & \dots & \text{csi}_{1,17} & \text{csi}_{2,16} & \text{csi}_{2,17} & \dots & \text{csi}_{2,30} \\ \text{csi}_{2,1} & \text{csi}_{2,2} & \dots & \text{csi}_{2,16} & \text{csi}_{3,1} & \text{csi}_{3,2} & \dots & \text{csi}_{3,15} \\ \vdots & \vdots & \dots & \vdots & \vdots & \vdots & \dots & \vdots \\ \text{csi}_{2,16} & \text{csi}_{2,17} & \dots & \text{csi}_{2,30} & \text{csi}_{3,15} & \text{csi}_{3,17} & \dots & \text{csi}_{3,30} \end{bmatrix}$$

Figure 2

This figure illustrates construction of the smoothed CSI matrix. The new CSI matrix is “fat” enough to distinguish the signal space and the noise space.

Figure 3

System Overview of WilImage

(a) Phase before and after the preprocessing

(b) Amplitude before and after the preprocessing

Figure 4

CSI Preprocessing.

Figure 5

An illustration of AoA calibration.

Figure 6

An illustration of the contour detection.

(a) AoA error in the corridor

(b) AoA error in the office

Figure 7

AoA accuracies in different environments.

(a) Contour error in the corridor

(b) Contour error in the office

Figure 8

Contour extraction accuracies in different environments.

Figure 9

Width detection results of different human bodies.

(a) Average width error of heads.

(b) Average width error of torsos .

(c) Average width error of legs.

Figure 10

Impacts of the CSI series length.

Figure 11

Heat-maps and contours obtained by Wilmage.

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