WiSee: Whole-Home Gesture Recognition Using Wireless Signals

Qifan Pu, Sidhant Gupta, Shyam Gollakota, Shwetak Patel

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Wed, Oct 2, 13
in-air gestures anywhere in the home without sensors everywhere
Beyond the Keyboard and Mouse
Can we scale gesture recognition to entire home?
vision based sensing limited by line-of-sight
Thalmic Labs, Myo armband prototype, 2013
Could we do gesture recognition without addition infrastructure and user instrumentation?
WiSee leverages existing WiFi infrastructure
Whole-home coverage
From WiFi to WiSee

Circle Gesture

Kick Gesture
WiFi Signals Reflect off the Body
WiFi Signals Reflect off the Body
WiFi Signals Reflect off the Body
WiFi Signals Reflect off the Body

reflected signal
Doppler Effect
Doppler Effect

Positive frequency shift
Doppler Effect

Positive frequency shift

Negative frequency shift
Extract Doppler shift from WiFi

Classify gestures from shift

Support multiple users
Extract Doppler shift from WiFi

Classify gestures from shift

Support multiple users
at 5 GHz, a 0.5 m/s motion causes 17 Hz frequency shift
Challenge: From 20MHz to 2Hz

WiFi Signal

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Create Narrowbands at **WiFi Subchannels**
Create Narrowbands at WiFi Subchannels

TX repeats same OFDM symbol

| OFDM #1 | OFDM #1 | OFDM #1 | OFDM #1 | ... | OFDM #1 |

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Create Narrowbands at WiFi Subchannels

TX repeats same OFDM symbol

<table>
<thead>
<tr>
<th>OFDM #1</th>
<th>OFDM #1</th>
<th>OFDM #1</th>
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<th>OFDM #1</th>
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</table>
Create Narrowbands at WiFi Subchannels

TX repeats same OFDM symbol

FFT over $N$ symbols

Reduces channel bandwidth by factor of $N$
Create Narrowbands at WiFi Subchannels

TX repeats same OFDM symbol

Reduces channel bandwidth by factor of N

FFT over N symbols
Create Narrowbands at WiFi Subchannels

Random OFDM symbol

OFDM #1  OFDM #2  OFDM #3  OFDM #4  ...  OFDM #N
Create Narrowbands at WiFi Subchannels

Random OFDM symbol

Naive approach:
Receiver repeats symbol

Loses gesture timing and phase information
Channel Preserving Transformation

Random OFDM symbol

OFDM #1  OFDM #2  OFDM #3  OFDM #4  ...  OFDM #N
Channel Preserving Transformation

Random OFDM symbol

OFDM #1  OFDM #2  OFDM #3  OFDM #4  ...  OFDM #N

Decode symbols

11001011  00110101  11110000  00001111  ...  10101010

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Channel Preserving Transformation

Random OFDM symbol

Decode symbols

Re-encode equalized symbols
Channel Preserving Transformation

Random OFDM symbol

OFDM #1  OFDM #2  OFDM #3  OFDM #4  ...  OFDM #N

Decode symbols

11001011  00110101  11110000  00001111  ...  10101010

Re-encode equalized symbols

11001011  11001011  11001011  11001011  ...  11001011

Reduces to same OFDM symbols case
Channel Preserving Transformation

Random OFDM symbol

OFDM #1  OFDM #2  OFDM #3  OFDM #4  ...  OFDM #N

Decode symbols

11001011  00110101  11110000  00001111  ...  10101010

Re-encode equalized symbols

11001011  11001011  11001011  11001011  ...  11001011

Designed algorithms to generalize to bursty traffic

Reduces to same OFDM symbols case
Extract Doppler shift from WiFi

Classify gestures from shift

Support multiple users

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Gestures from Doppler Shift
Different body parts move at different speeds
Different body parts move at different speeds

Multiple Doppler shifts
Gestures from Doppler Shift

Different body parts move at different speeds

Velocity of gesture varies over time

Multiple Doppler shifts
Gestures from Doppler Shift

Different body parts move at different speeds

Velocity of gesture varies over time

Multiple Doppler shifts

Time-varying Doppler Profile
Gestures from Doppler Shift

Doppler Shift (Hz)

Time (s)

-30 -20 -10 0 10 20 30

2.5 5 7.5 10 12.5 15 17.5 20 22.5

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Gestures from Doppler Shift

Doppler Shift (Hz)

Time (s)

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Gestures from Doppler Shift
Gestures from Doppler Shift
Extract Doppler shift from WiFi

Classify gestures from shift

Support multiple users
Start Gesture
Double Tap

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Iterative algorithm that estimates MIMO channel of the user
Can gestures be classified across different people, locations and environments?
5 Participants
2 Environments (Office and Apartment)
6 Scenarios (LOS and NLOS)
9 Gestures (LOS and NLOS)
Total 900 gestures
Office Environment
Office Environment

Doppler SNR for various RX/TX placements, antennas and LOS/NLOS
6 LOS/NLOS Scenarios
6 LOS/NLOS Scenarios

WiSee Receiver

TX RX

TX RX

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6 LOS/NLOS Scenarios

[Diagram showing different scenarios of LOS/NLOS with TX and RX symbols, and a distance of 19.7 ft.]
6 LOS/NLOS Scenarios
3-4 antennas at receiver sufficient for robust gesture detection in all scenarios
Home Environment

Gesture recognition accuracy across different users and locations

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5 users, 9 gestures, 10 locations
5 users, 9 gestures, 10 locations
5 users, 9 gestures, 10 locations
5 users, 9 gestures, 10 locations
5 users, 9 gestures, 10 locations
5 users, 9 gestures, 10 locations

5 X 9 X 10 X 2 = 900 trials

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Mobicom 2013
2% gestures not detected
94% gestures classified correctly
Gesture false positive rate while 12 people shared the work space
0.13\$/hour with a 3-tap start gesture
Through The Wall Human Motion Detection


2013: See Through Walls with WiFi!, Adib et al., SIGCOMM 2013
WiSee is a novel approach for whole-home gesture recognition
WiSee is a **novel approach** for whole-home gesture recognition

Introduced algorithms to **transform WiFi** into a gesture recognition sensor
WiSee is a novel approach for whole-home gesture recognition

Introduced algorithms to transform WiFi into a gesture recognition sensor

Sidhant Gupta
http://www.sidhantgupta.com
sidhant@uw.edu