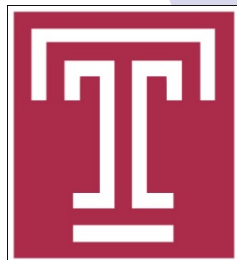# A Robust Sign Language Recognition System with Multiple Wi-Fi Devices

Jiacheng Shang

Center for Networked Computing

Dept. of Computer and Info. Sciences

Temple University

Motivation

- Wi-Fi signals are available almost everywhere

- Wi-Fi signals can monitor surrounding activities

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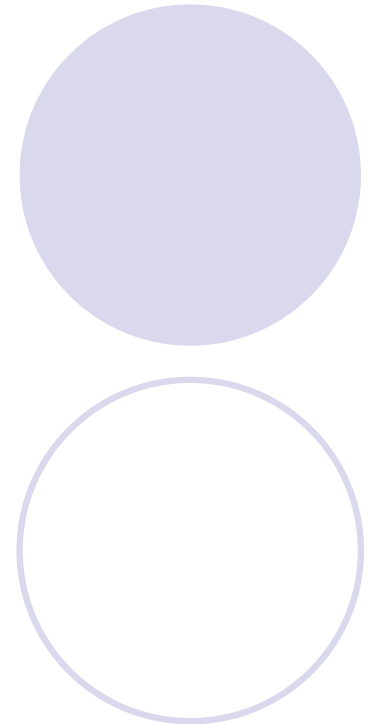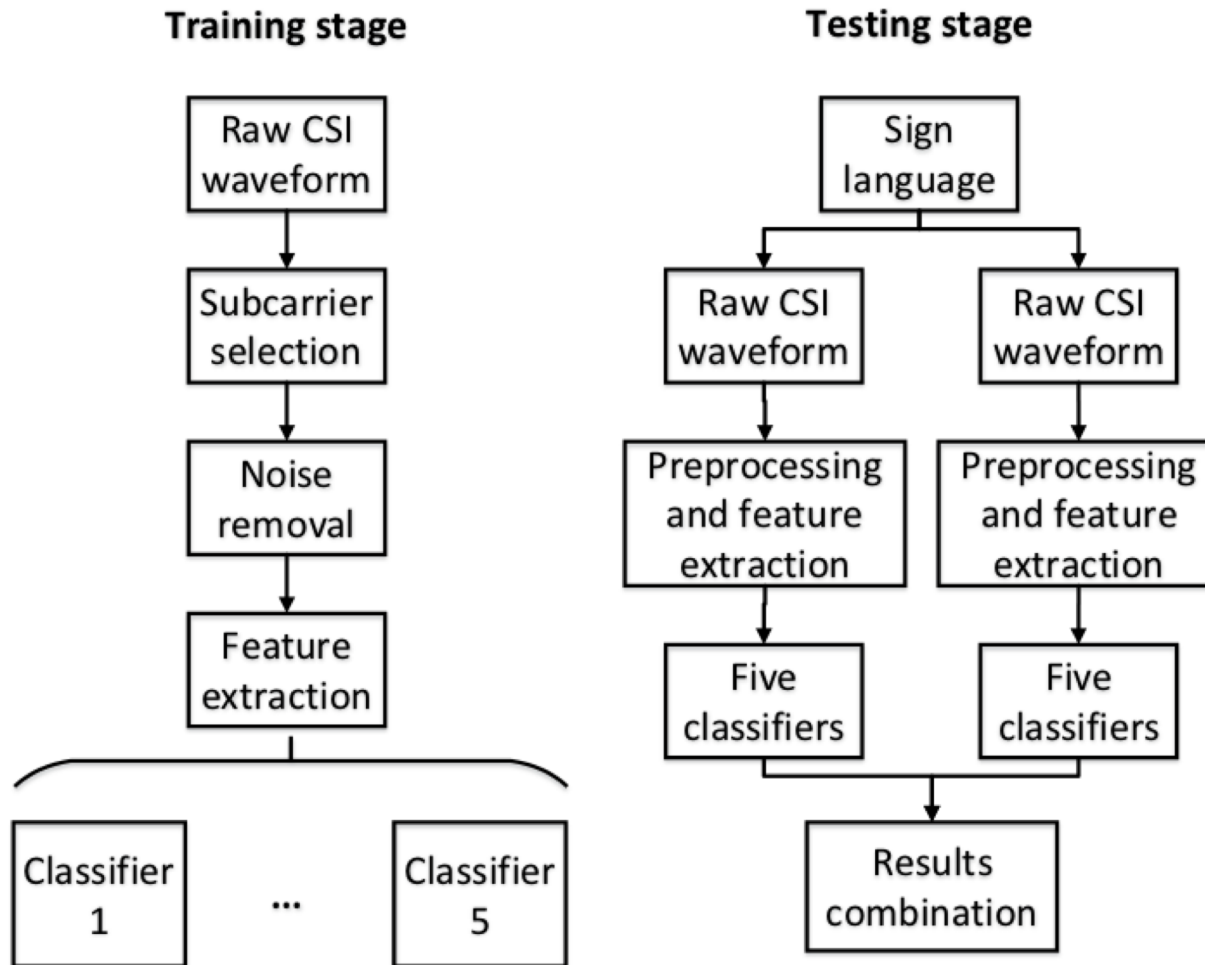
Problem Statement

- Sign language recognition using Wi-Fi signals
    - Using commercial Wi-Fi devices (routers and laptops) to recognize sign language

- Strengths
    - Work in the dark
    - Avoid breaching user privacy
    - No need to wear sensors
    - Low cost
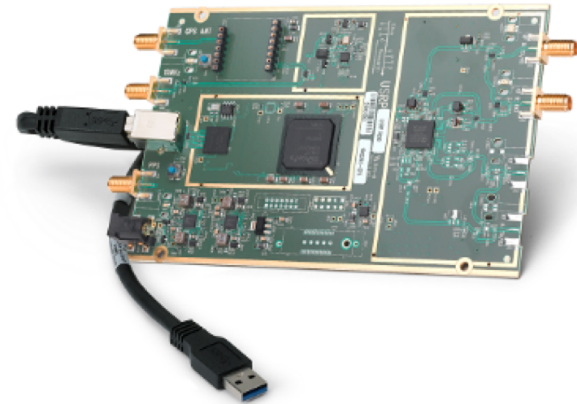
Limitations of Existing Systems

- Limitation of existing systems: make decisions on one machine
  - A mistake made using a single machine can lead to a totally wrong prediction
  - Accuracy can be easily influenced by noise
- Our approach: combine the predictions from multiple machines
  - Improve recognition performance
 - Robust to mistakes made on machines

Sign Language Recognition Pipeline

Training stage

Raw CSI waveform

↓

Subcarrier selection

↓

Noise removal

↓

Feature extraction

Classifier 1 ... Classifier 5

Testing stage

Sign language

Raw CSI waveform | Raw CSI waveform

↓

Preprocessing and feature extraction | Preprocessing and feature extraction

↓

Five classifiers | Five classifiers

↓

Results combination

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Signal Preprocessing

- Subcarrier Selection
  - Different subcarriers have different sensitivities to different human activities

30 subcarriers

TX   RX
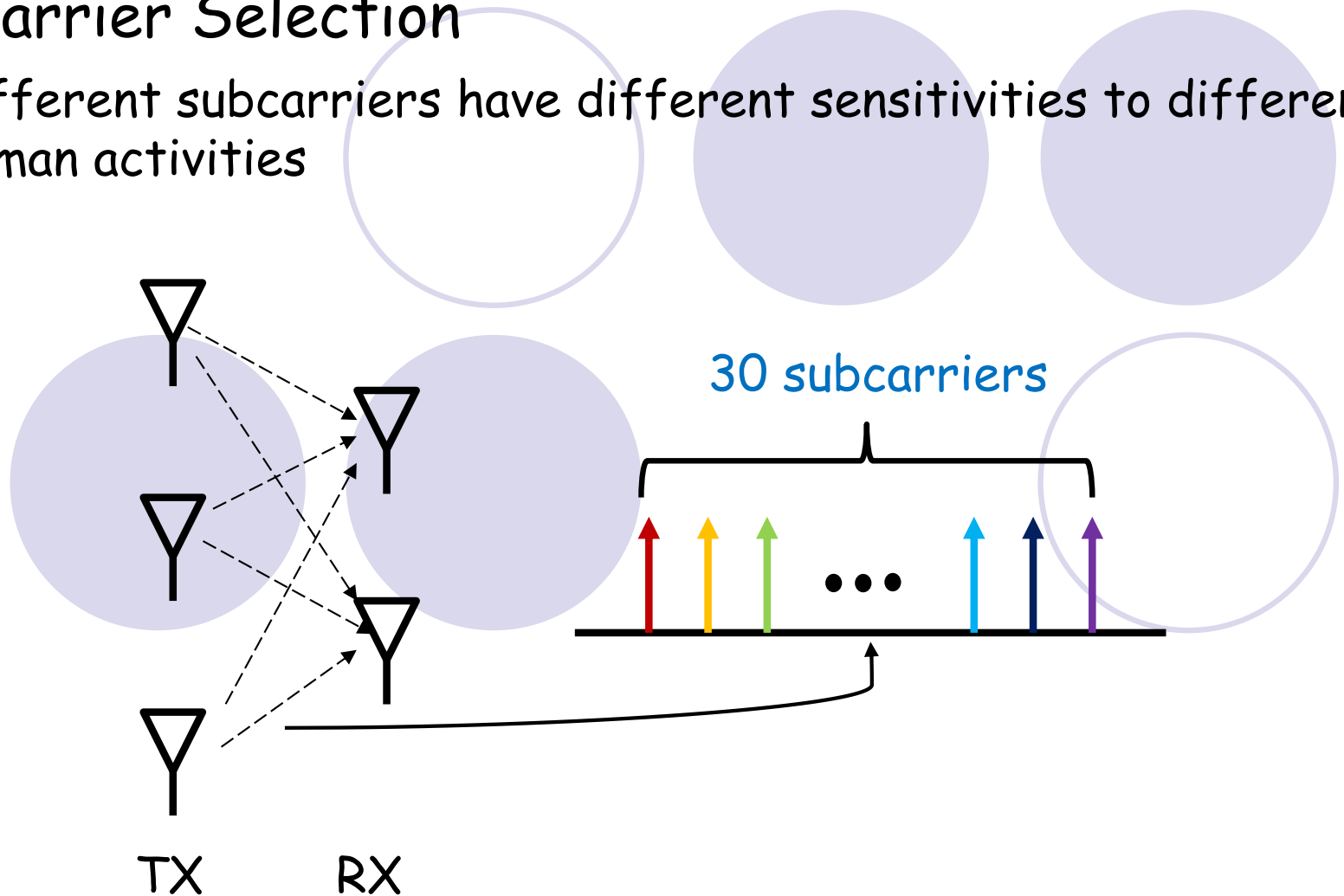
Signal Preprocessing

- Noise removal
  - Smoothing: remove outliers
  - Low-pass filter: remove high frequency noise
 - The average amplitude and average median absolute deviation are chosen as the features
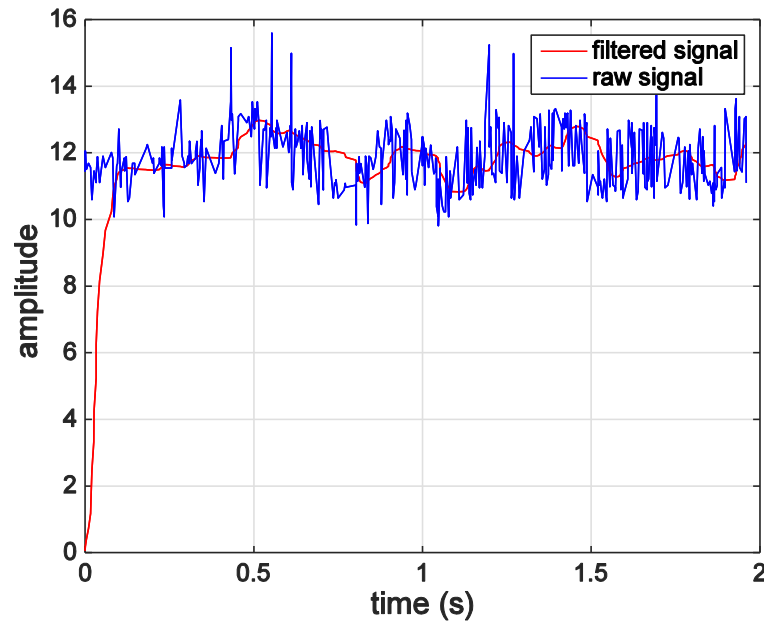
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Sign Language Recognition

- On a single machine
  - In order to support 5 gestures, we need to train 5 classifiers based on One vs. All (OVA)

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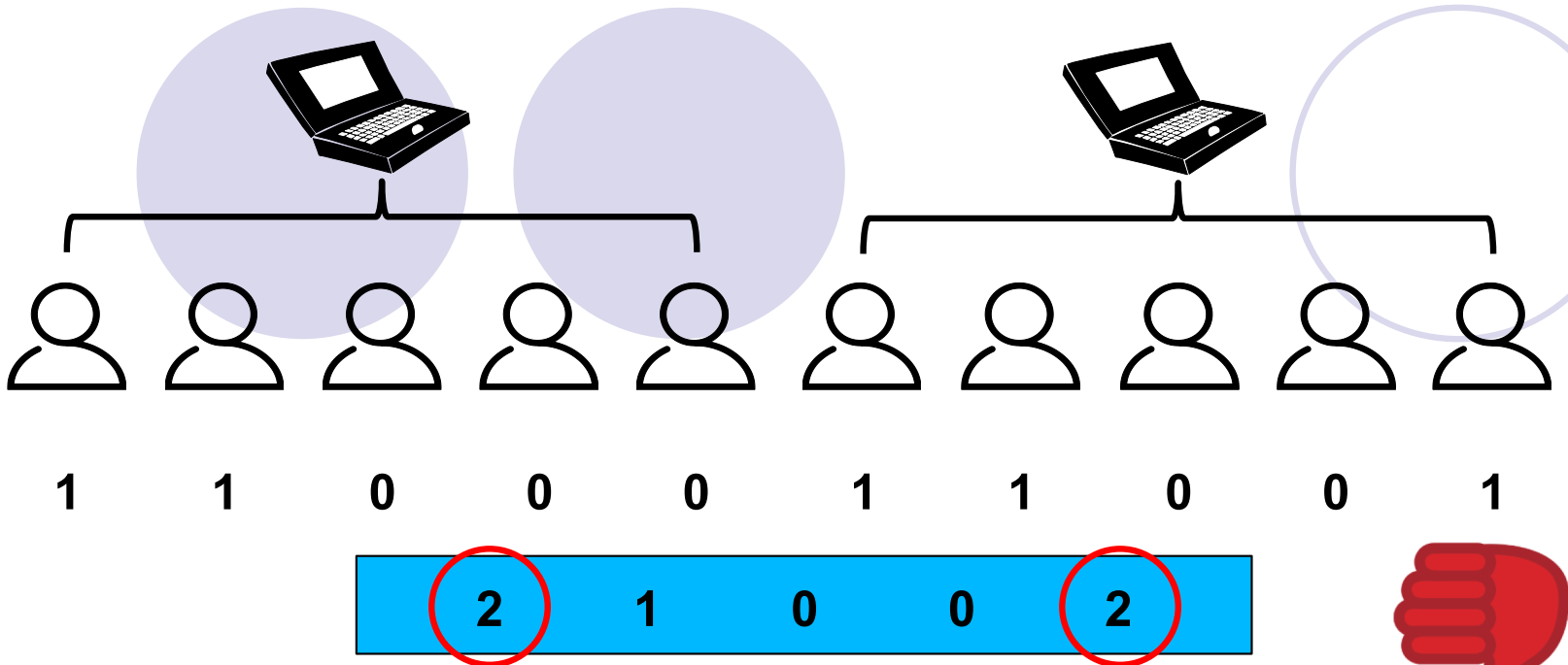# Sign Language Recognition

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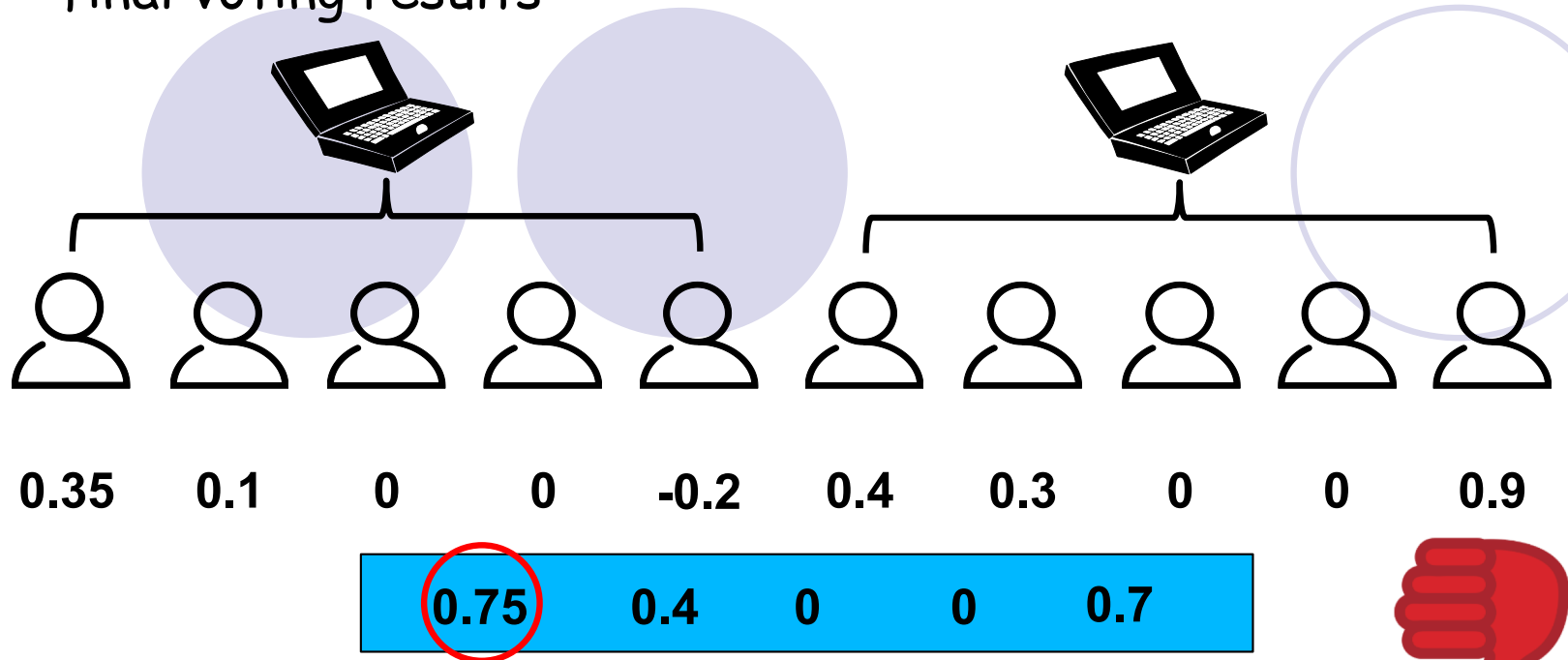

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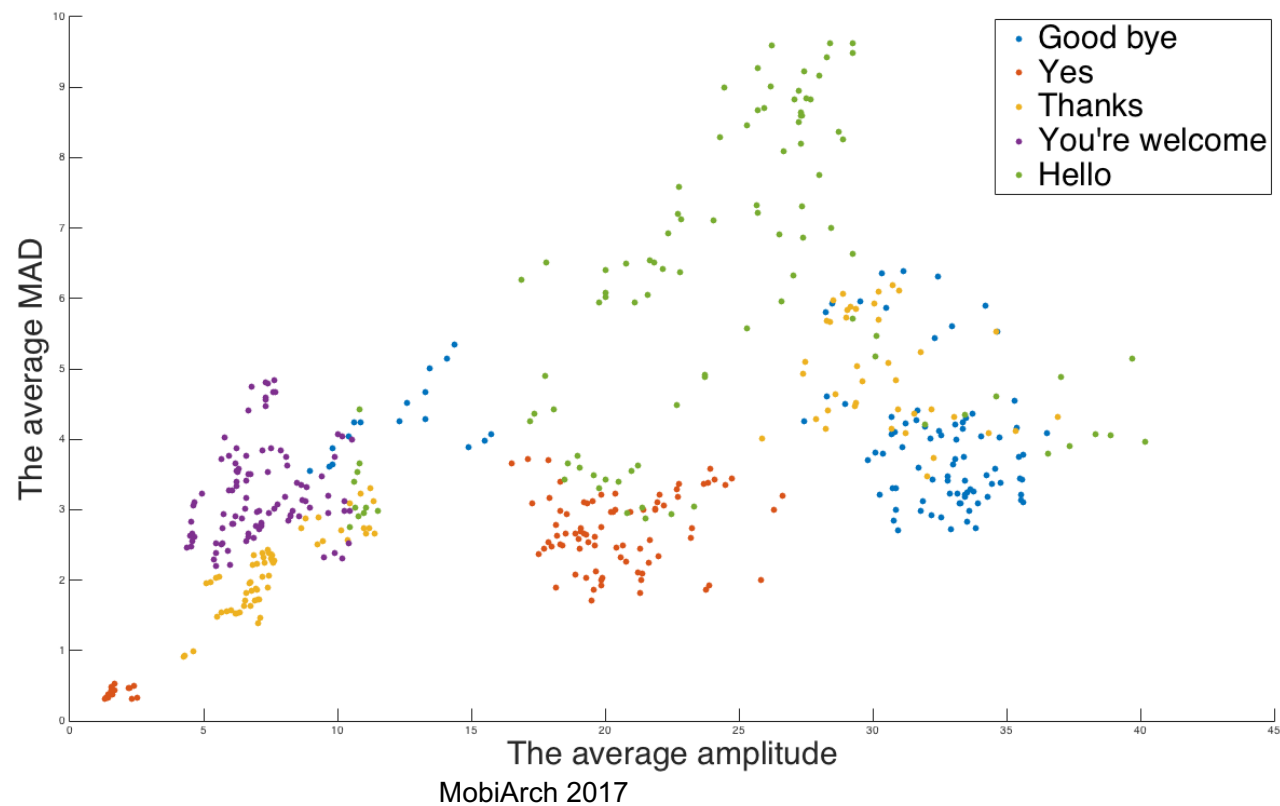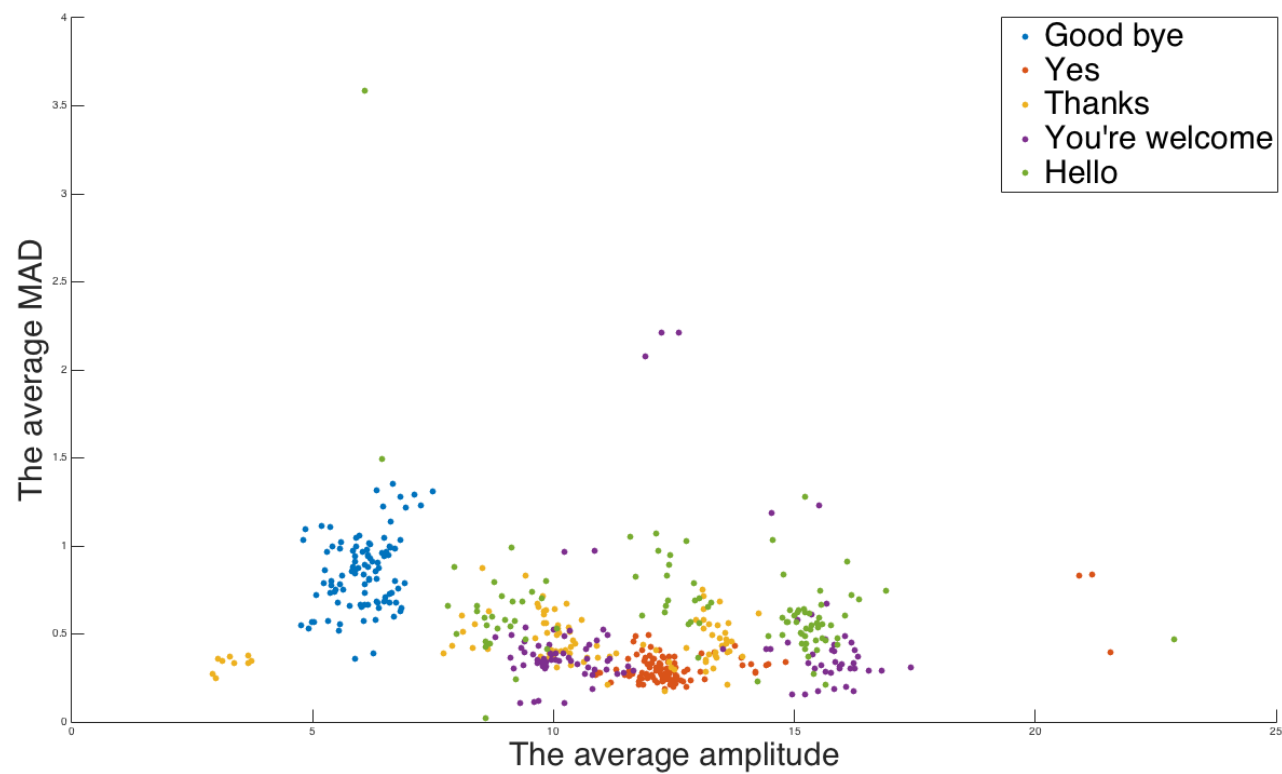
Sign Language Recognition

- Combine the predictions
  - Combine predictions based on majority voting
  - Assume that one instance is labeled as fifth label

1   1   0   0   0   1   1   0   0   1

2   1   0   0   2

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Sign Language Recognition

- Combine the predictions
  - Combine predictions based on weighted majority voting
  - Assume that one instance is labeled as fifth label
  - Bad player: players who have low weights and may influence the final voting results

| 0.35 | 0.1 | 0 | 0 | -0.2 | 0.4 | 0.3 | 0 | 0 | 0.9 |

| 0.75 | 0.4 | 0 | 0 | 0.7 |

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Sign Language Recognition

- Combine the predictions
  - Combine predictions based on weighted (score) majority voting
  - Assume that one instance is labeled as fifth label
  - Remove players whose weights are lower than a threshold T

| 0.35 | 0.1 | 0 | 0 | -0.2 | 0.4 | 0.3 | 0 | 0 | 0.9 |

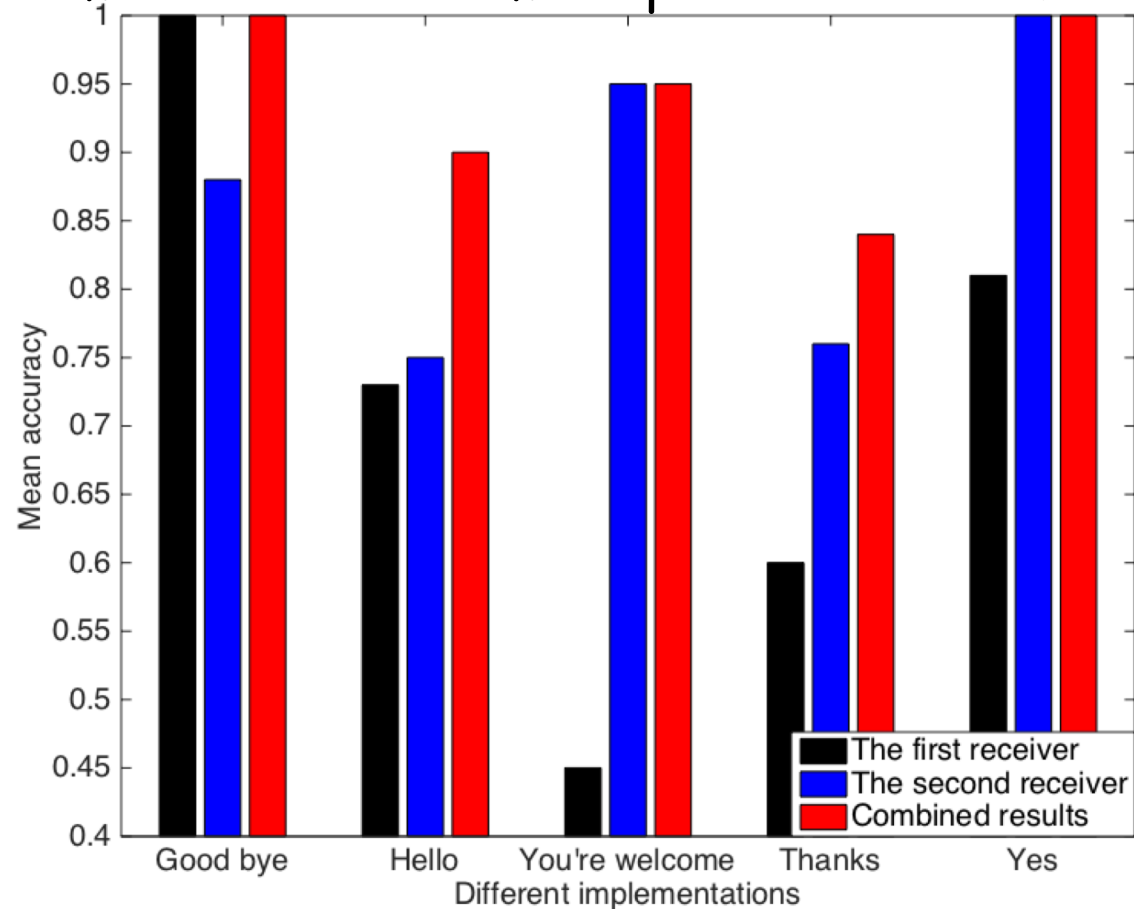| 0.75 | 0.4 | 0 | 0 | 0.9 |

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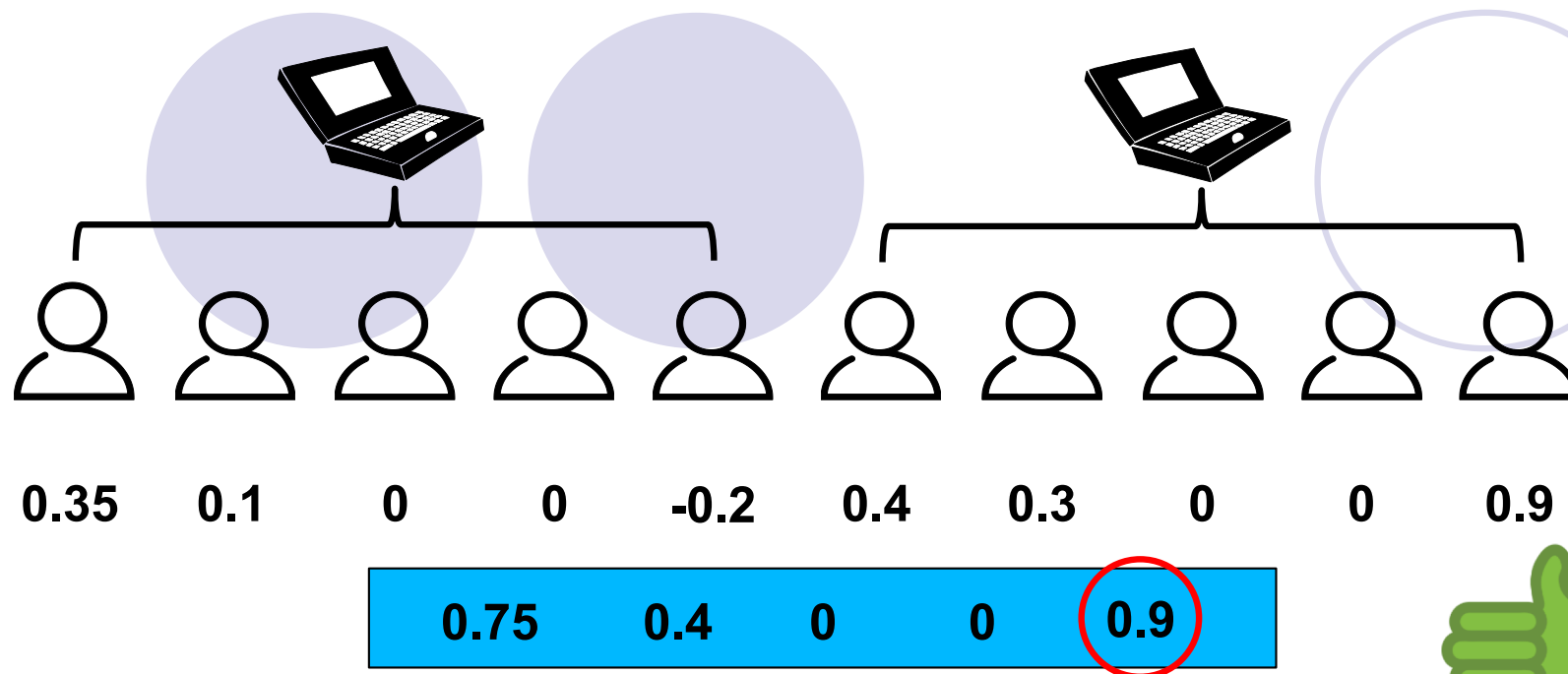
Evaluation

- Commercial hardware with no modification
  - Transmitter: TP-Link TL-WR1043ND Wi-Fi router
  - Receiver: Lenovo X100e laptop with Intel 5300 NIC
  - Downloading a large file from an FTP server within the same local network area

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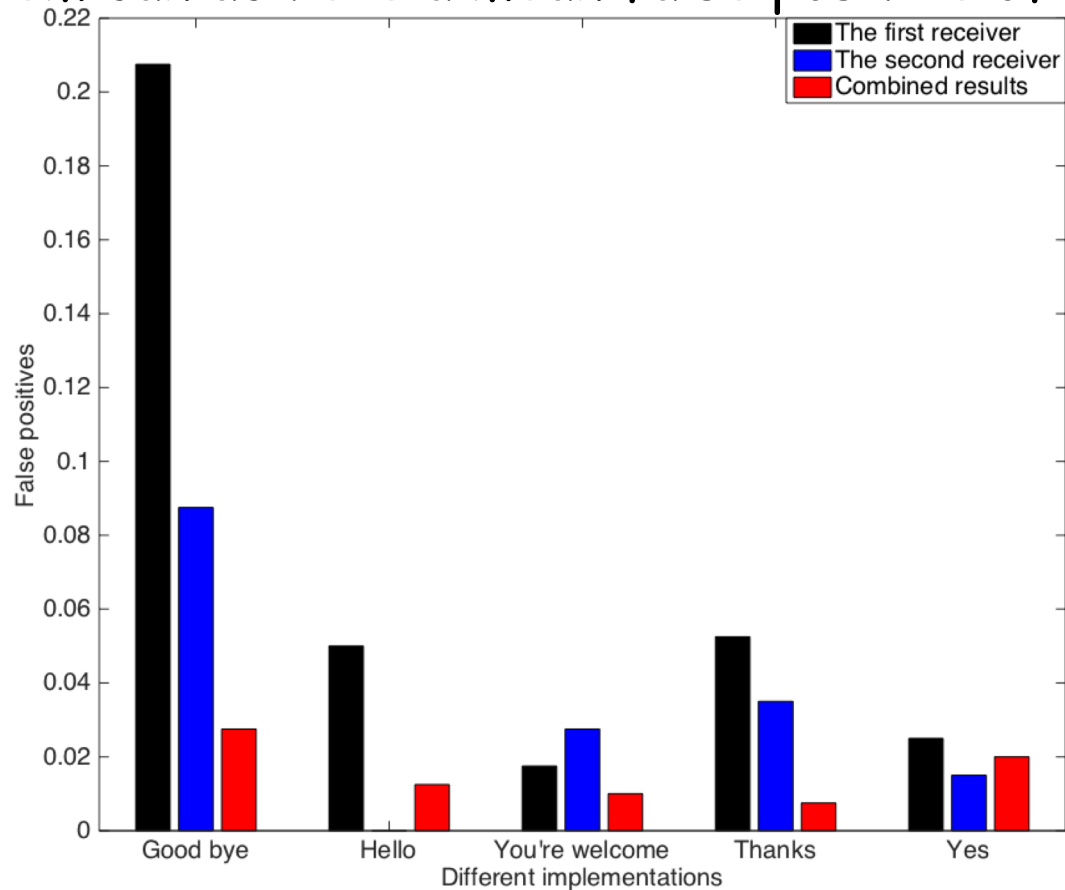
Evaluation Results

- Accuracy
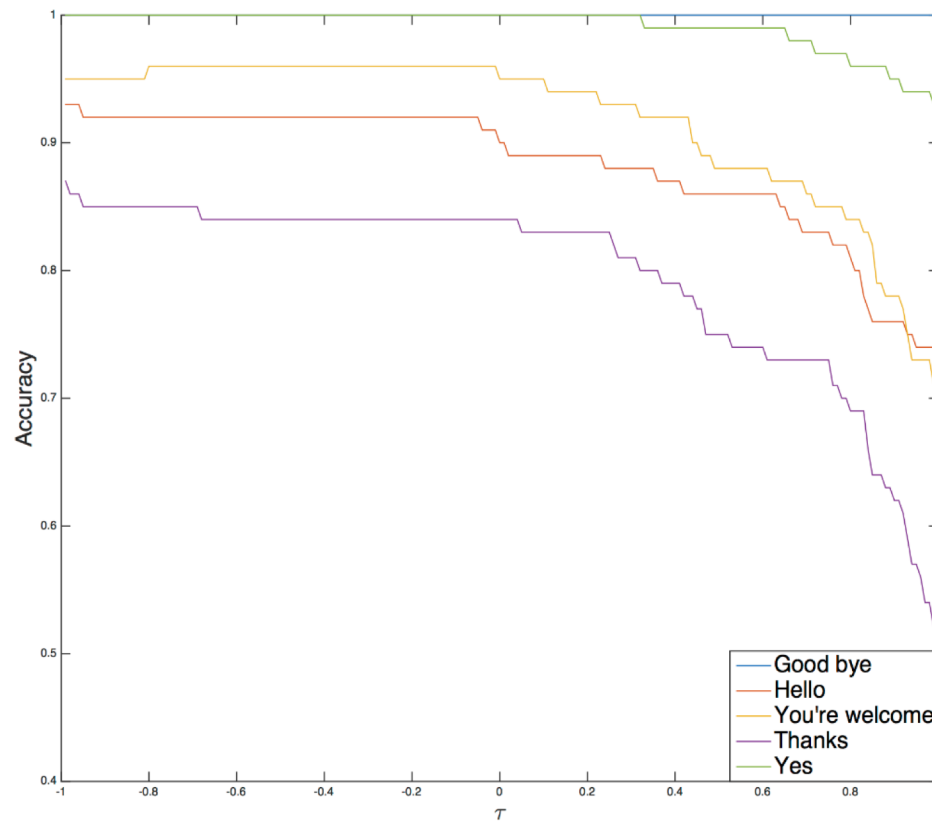 - Our system can achieve a mean prediction accuracy of 93.8%

Evaluation Results

- ## False positive

  - Our system can achieve a mean false positive of 1.55%

Evaluation Results

- Cutoff threshold τ

Conclusion

- CSI measurements contain fine-grained movement information

- Prediction combination model

  - Involve all classifiers in a majority voting game

  - Eliminate "bad players"

  - Achieve better accuracy and a lower number of false positives

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Thanks!