Would A Generalized Wi-Fi-based Fall Detection System be Possible?

Falling is among the most fatal kinds of incident the elderly face in their everyday life. (Rubenstein et al. 2006)

Background

Wearable sensor approaches

- Developed since the early 90s (Lord and Colvin 1991)
- Commercially available
- Limitations:
  - The elders are **reluctant** to wearing devices. (Steele et al. 2009)

Wearable sensor approaches

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- Commercially available
- Limitations:
  - The elders are **reluctant** to wearing devices. (Steele et al. 2009)
  - The **always-on-body requirement** is not always applicable (e.g. when changing clothes or taking a shower)

Vision-based approaches

- On-trend (Lapierre et al. 2018)
- High accuracy
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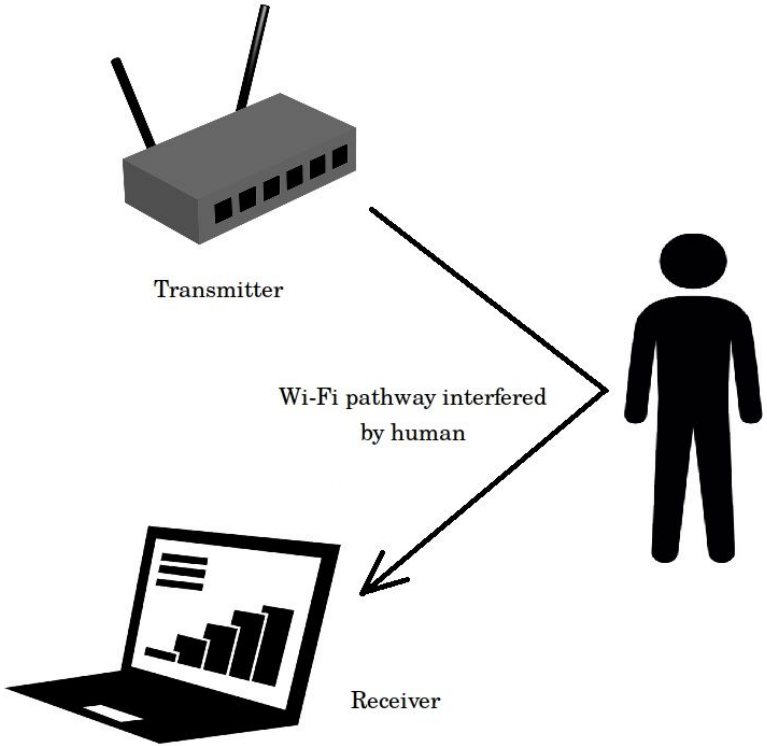
- Limitations:
  - Not effective in **obtrusive scenarios**
  - **Privacy concerns**: malicious intends

… And no one gonna put a camera inside the bathroom…

Right ?

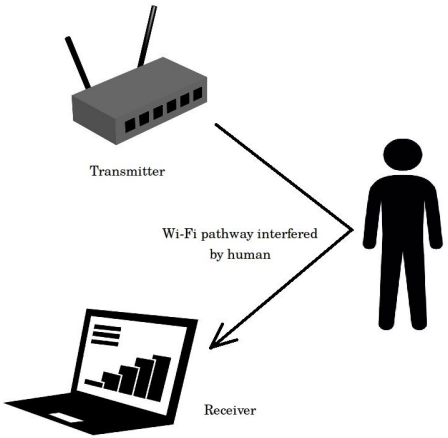
Vision-based approaches



Channel State Information

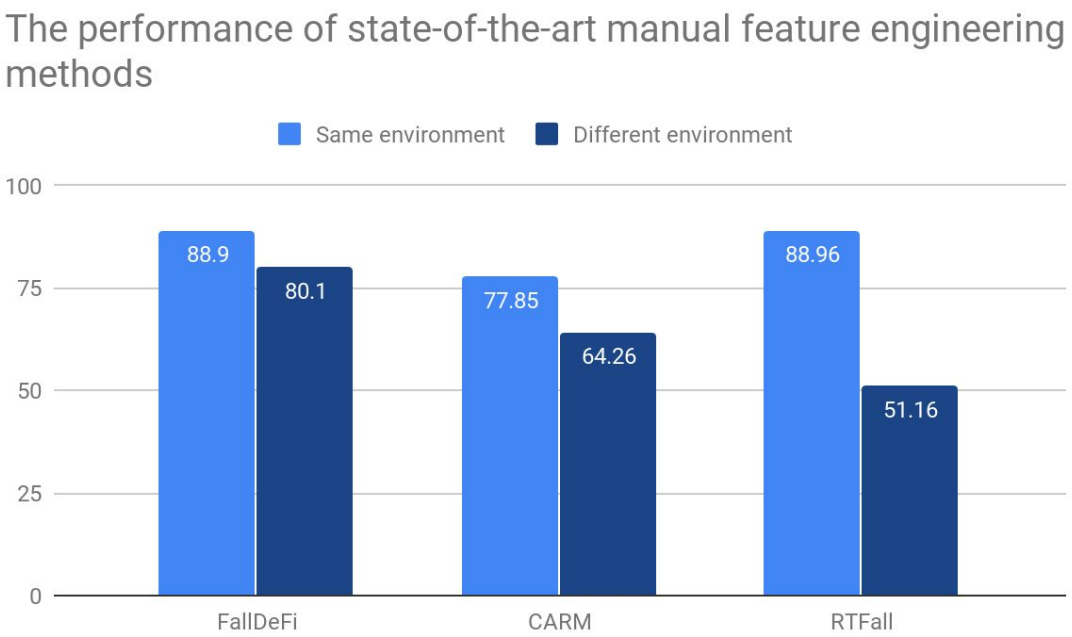
Channel State Information

- Formed by recording the response of receiving antennas in a Multiple Input Multiple Output (MIMO) wireless configuration.
- The received signals **characterizes the environment** they pass through.



Related Works

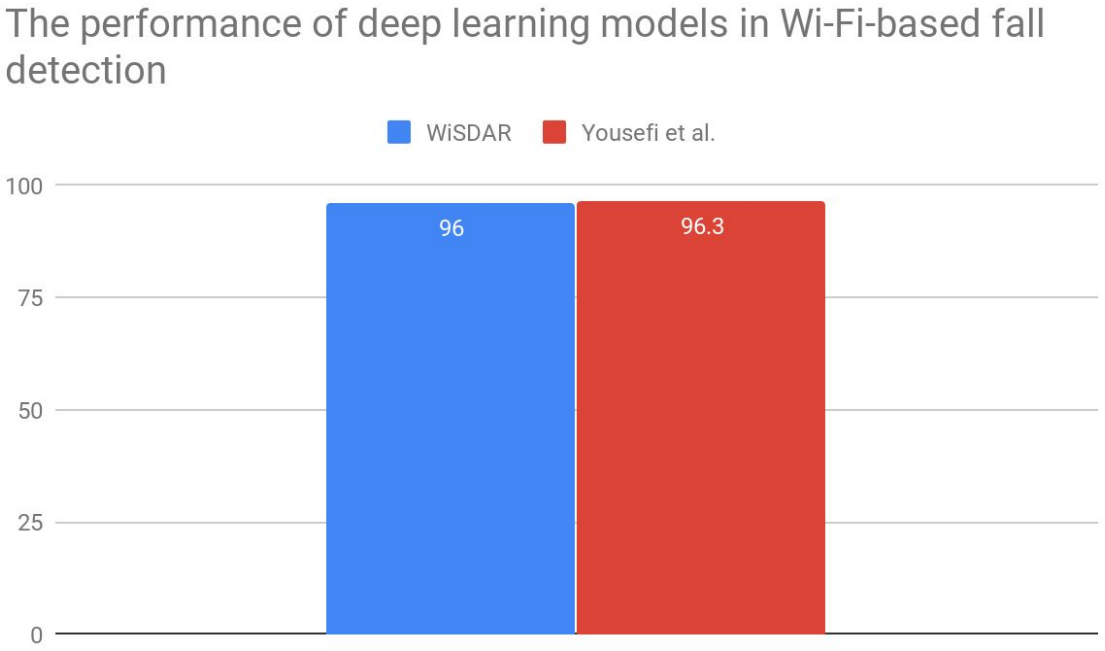
Manual Feature Engineering



Manual Feature Engineering

- **Pros:**
  - Robust across domains
  - Lightweight machine learning models
- **Cons:**
  - Not very high performance compare to deep learning models
  - Many elements (e.g. the number of PCs used) are empirically chosen.
  - Reproduced results are not completely consistent with reported results.

Deep Learning



Deep Learning

- **Pros:**
  - High performance
  - No need for signal processing techniques
  - Easy to reproduce
- **Cons:**
  - Heavyweight
  - Performance would drop in unseen environments

Something from us

Our work

Objective

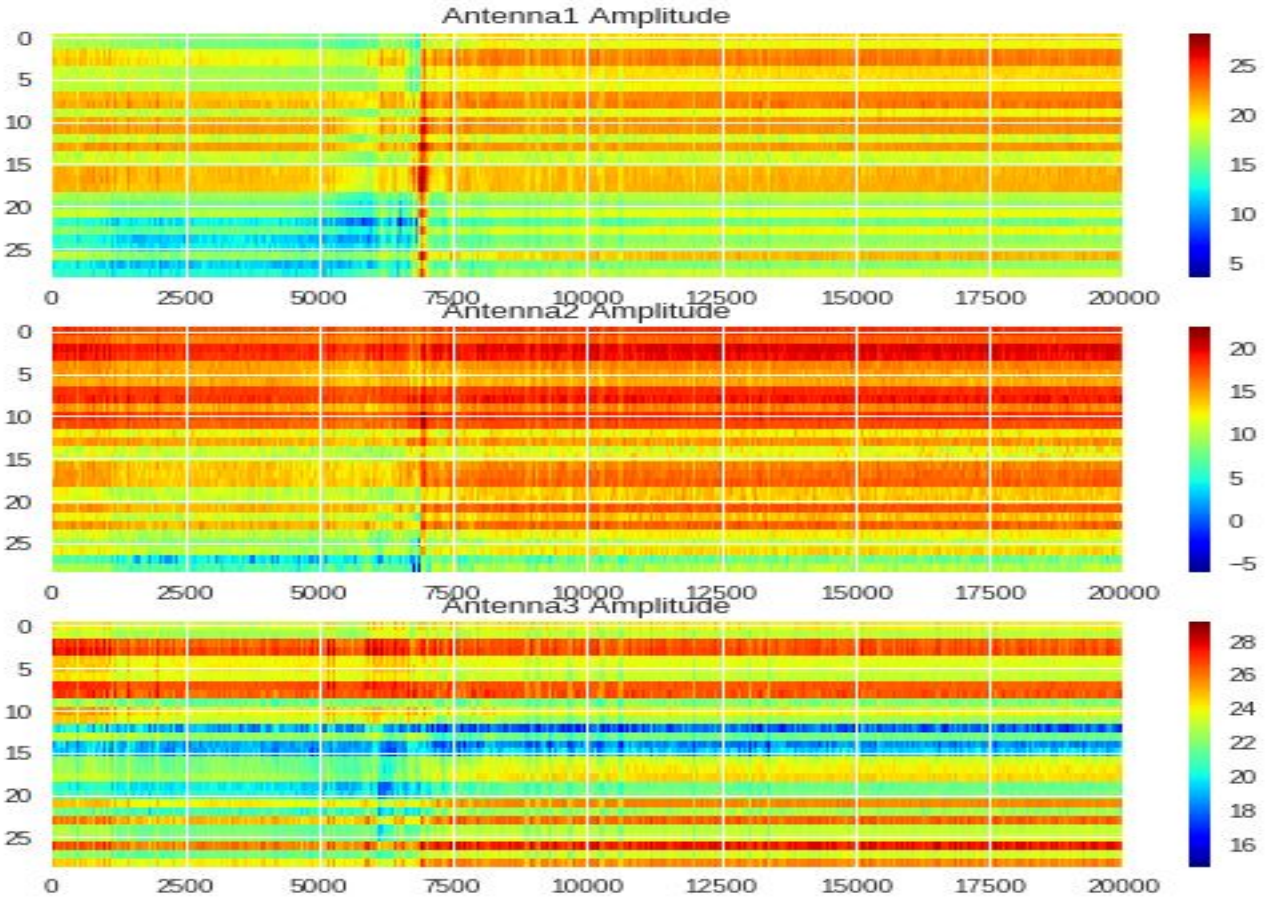
Looking for a generalized deep learning model for Wi-Fi-based fall detection in untrained domains.

Dataset

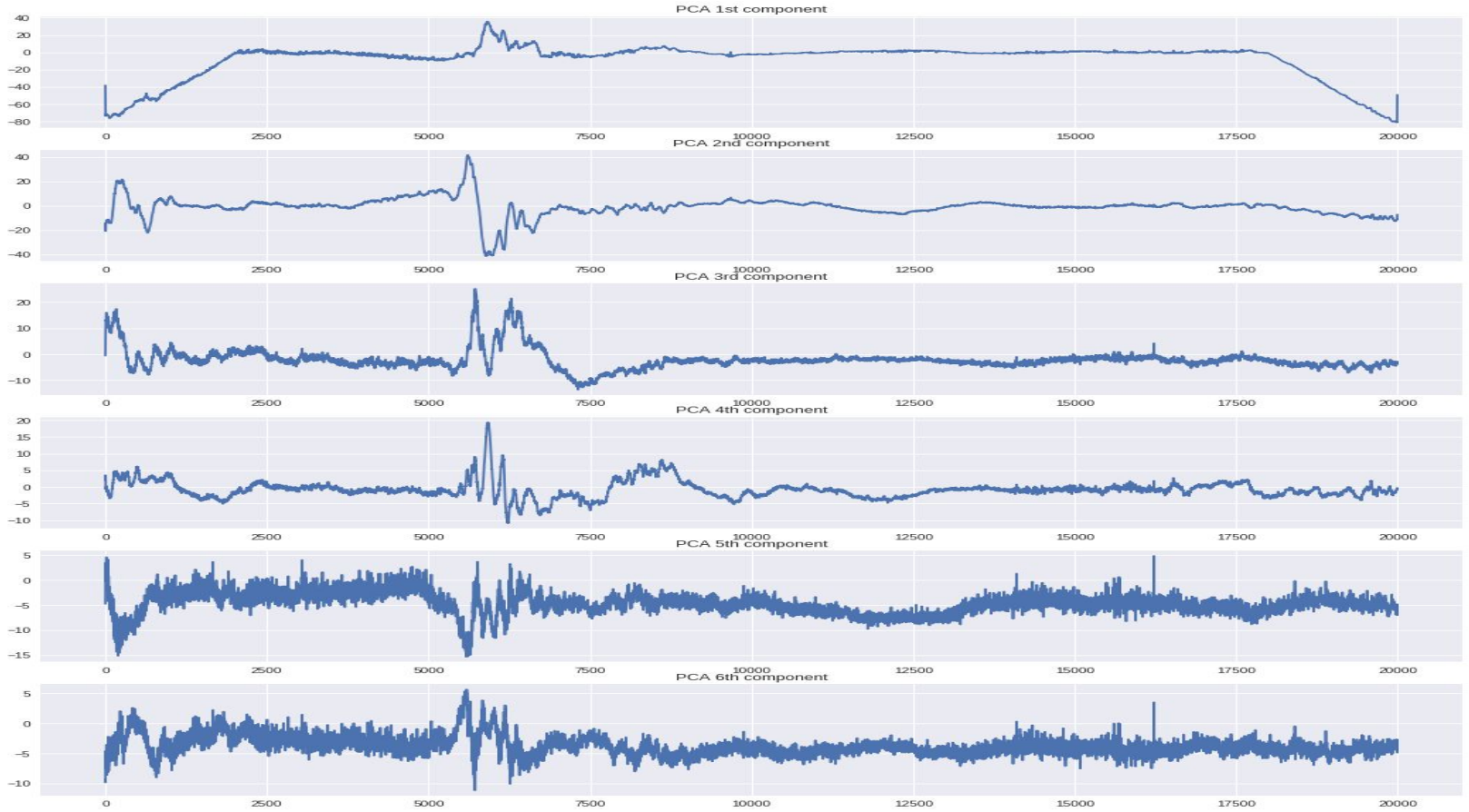
- A 4GB dataset from **Stanford University**
- 7 classes of activities
  - Lie down
  - Fall
  - Walk
  - Run
  - Jump
  - Sit down
  - Stand up
- No specific environment label

- A 2GB FallDeFi dataset from **Cork Institute of Technology,** Ireland
- 7 classes of activities
  - Fall: 4 subclasses with 5 orientations
  - Walk
  - Jump
  - Bend pick
  - Sit down: 2 subclasses
  - Stand up: 2 subclasses
  - Random events
- 5 environments

Dataset


Antenna1 Amplitude
0
5
10
15
20
25
0
2500
5000
7500
10000
12500
15000
17500
20000
25
20
15
10
5
Antenna2 Amplitude
0
5
10
15
20
25
0
2500
5000
7500
10000
12500
15000
17500
20000
20
15
10
5
0
−5
Antenna3 Amplitude
0
5
10
15
20
25
0
2500
5000
7500
10000
12500
15000
17500
20000
28
26
24
22
20
18
16

Dataset


PCA 1st component
PCA 2nd component
PCA 3rd component
PCA 4th component
PCA 5th component
PCA 6th component

Domain Generalization via Data Augmentation

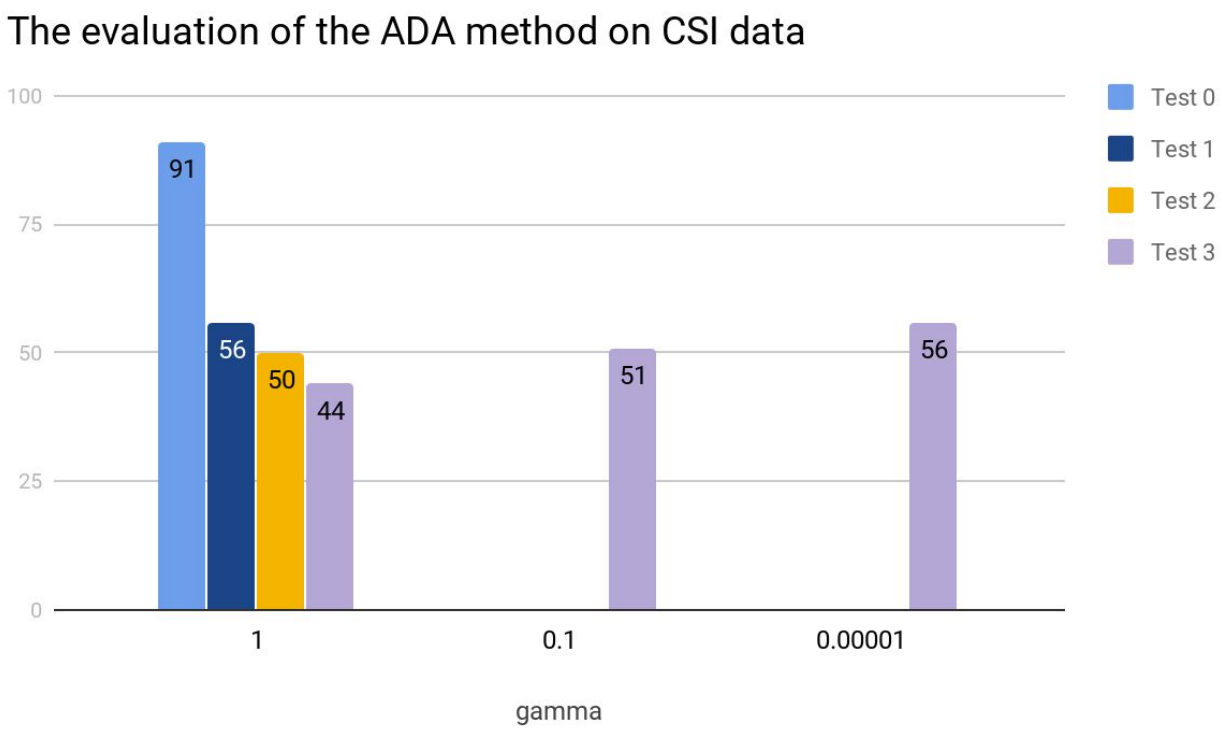
- The concept is to **generate hard data points** from a fictitious distribution.
- The fictitious distribution is **not random** but optimized for the given data.
- The distance of new data points is controllable via a hyperparameter gamma.

Domain Generalization via Data Augmentation

- The concept is to **generate hard data points** from a fictitious distribution.
- The fictitious distribution is **not random** but optimized for the given data.
- The distance of new data points is controllable via a hyperparameter *gamma*.
- Generated data is used along the original data to train the classifier.
- We use a small 6-layer ConvNet for our evaluation on the FallDeFi dataset.

Results

- **Test 0:** Train and test on 3 environments.
- **Test 1:** Train on 3 environments, test on 2 environments.
- **Test 2:** Train on 4 environments, test on 1 environments.
- **Test 3:** Train on 1 environment, test on 4 environments (with 3 different *gamma* values)


The evaluation of the ADA method on CSI data
100
75
50
25
0
91
56
50
44
51
56
1
0.1
0.00001
gamma
Test 0
Test 1
Test 2
Test 3

Something from us

Preliminaries and Future Works

Preliminaries

The latent space of CNNs is not good enough for generalizing time series data.

Preliminaries

CNNs are not particularly suitable for working with time series.

Future Works

We need to try ADA with models that work better with time series:

- Recurrent Neural Networks
- Hierarchical Attention Networks

Future Works

We will incorporate signal processing techniques to see if that help in generalizing deep learning models

Future Works

We will also experiment with different parameters for ADA:

- Different values of gamma
- Different numbers of source domains

Future Works

We might also experiment with different generalization methods, especially ones employing feature augmentation.

Thank You