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# Machine Learning Enabled Passive WiFi Sensing in Monitor Health, Activity, and Well-Being Information

-- A show case of one-stop LabVIEW solution for complex wireless engineering challenge

Dr. Bo Tan, Qingchao Chen, Dr. Kevin Chetty, Prof. Karl Woodbridge  
[bo.tan@coventry.ac.uk](mailto:bo.tan@coventry.ac.uk), {[q.chen](mailto:q.chen@ucl.ac.uk), [k.chetty](mailto:k.chetty@ucl.ac.uk), [k.woodbridge](mailto:k.woodbridge@ucl.ac.uk)}@ucl.ac.uk

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University College London



# Outline

- A Novel Wireless Technology – Passive wireless sensing
- Diverse Applications – From security to healthcare
- New Era – Needs for artificial intelligence
- Challenge – A long processing chain for heterogeneous tasks
- Integrated Solution – LabVIEW as an engine
- Carry On – Joint force



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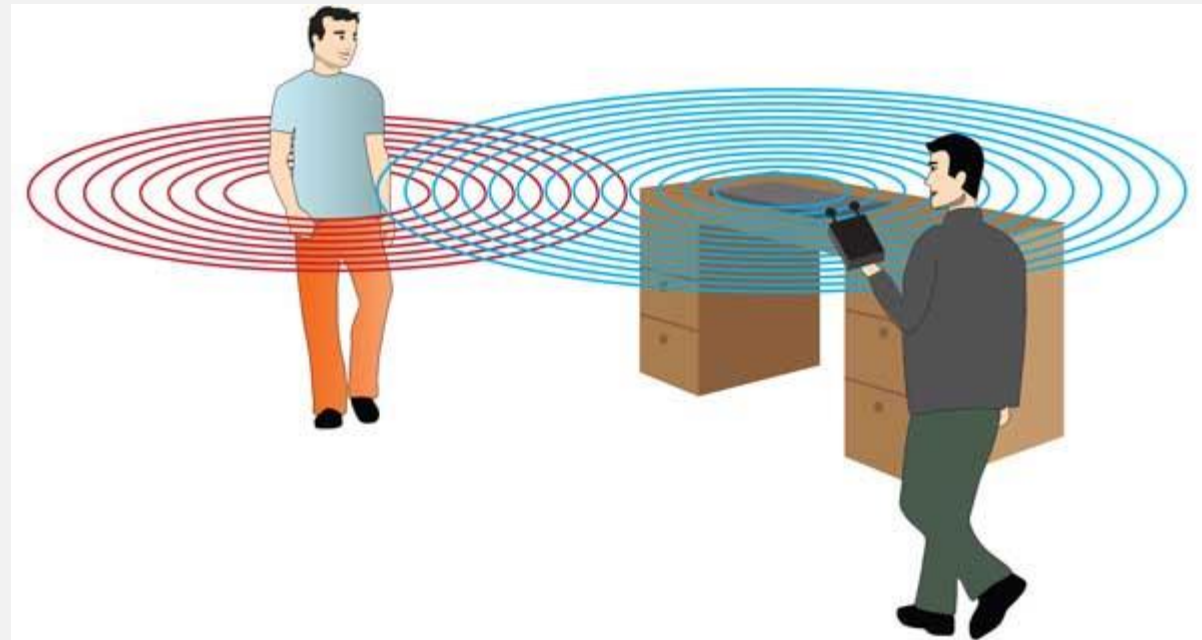
# A Novel Wireless Technology

Passive wireless sensing



# A Novel Wireless Technology

- Passive wireless sensing
- Existing radio frequency source
- Localizing targets
- Instant moving status
- Even through-wall



# A Novel Wireless Technology

## Principle Signal Processing

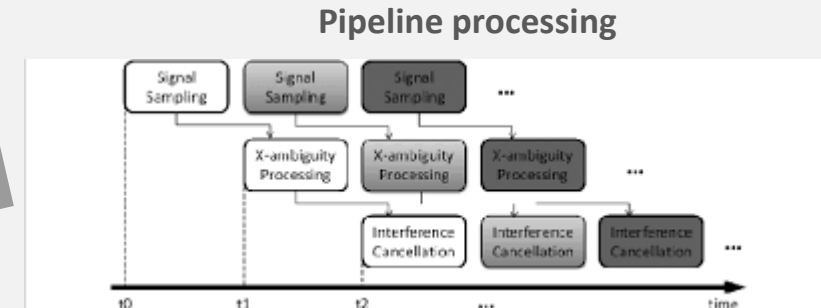
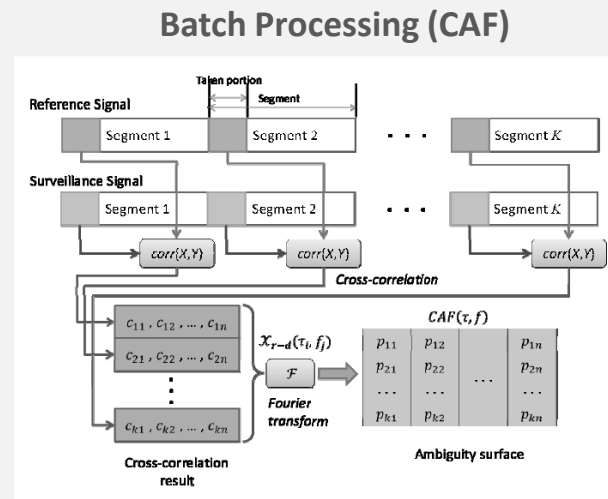
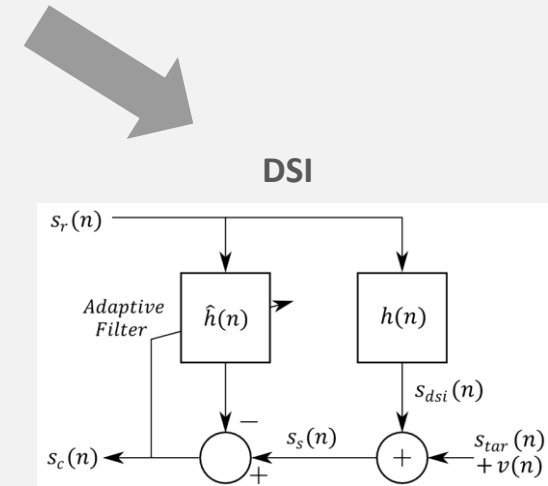
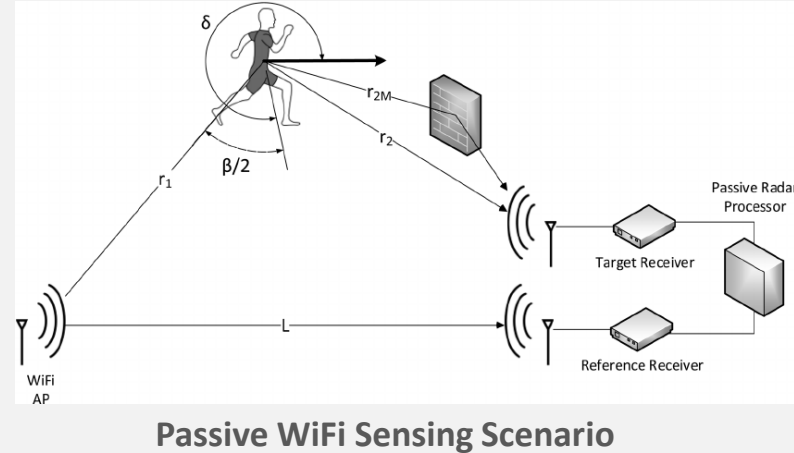
$$CAF(\tau, f) = \int_{t_1}^{t_2} e^{-i2\pi f t} s(t) r^*(t - \tau) dt$$

- Comparing time-frequency difference between direct signal channel and reflection signal channel
- Reflection signal channel contains delay and movement status of target
- $CAF(\tau, f)$  is present the location ( $t$ ) and moving status ( $f$ ) of target

# A Novel Wireless Technology

## Assistant Processing

- Direct signal leakage cancellation
- Stationary reflection cancellation
- Batch Processing
- Pipelined processing

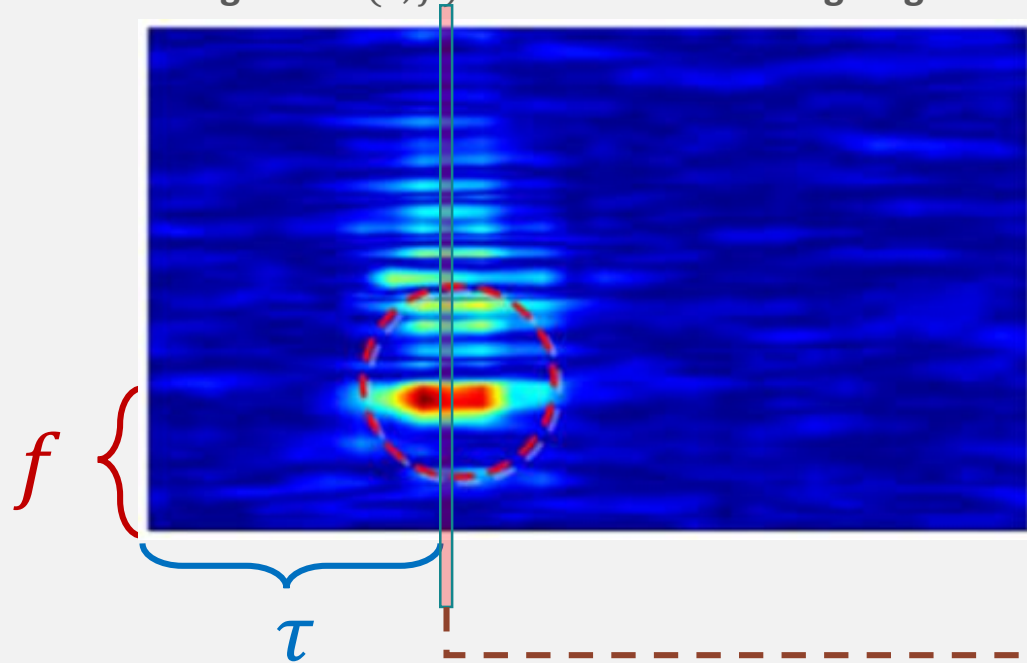




# A Novel Wireless Technology

## A Glance of $CAF(\tau, f)$

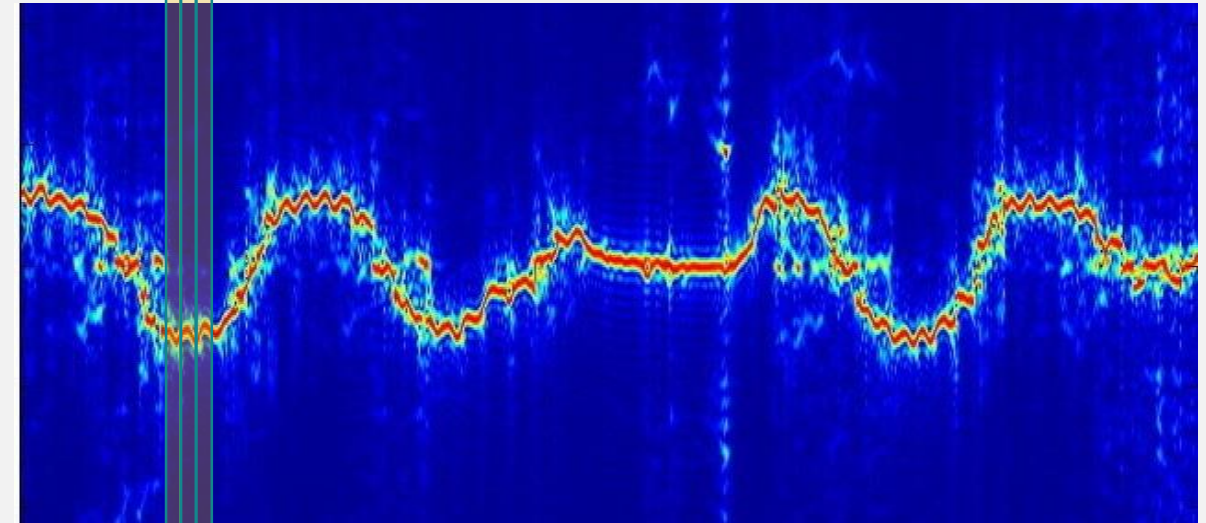
A Single  $CAF(\tau, f)$  of a detected moving target at  $t_i$



$\dots, t_{i-1}, t_i, t_{i+1}, \dots$

$\dots$

Doppler Trace of a Detected Walking Person





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## Diverse Applications

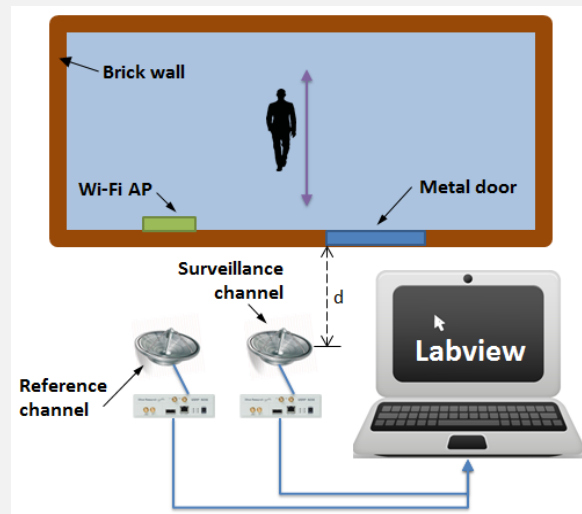
From security to healthcare



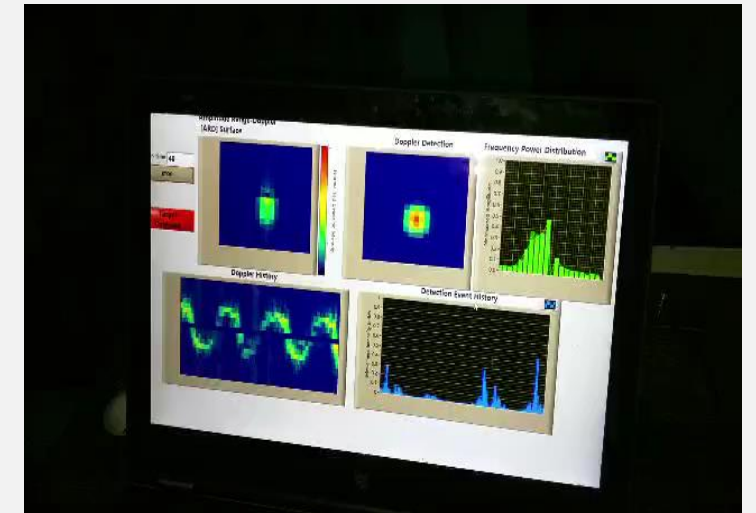
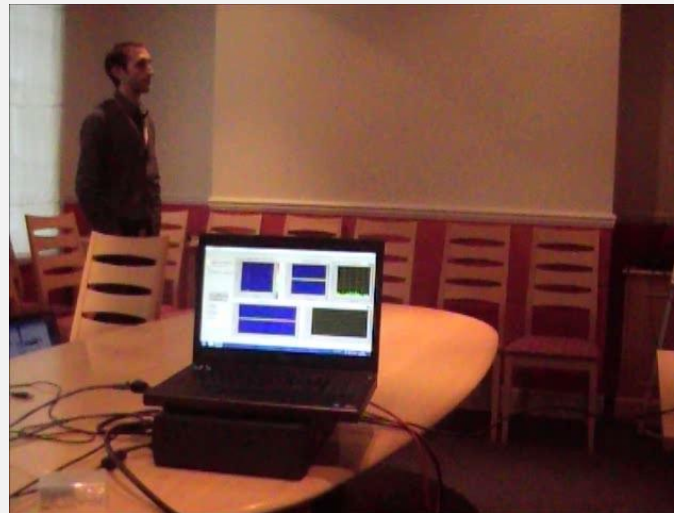


# Diverse Applications

## Through-Wall Walking Personnel Detection



- 2.4GHz WiFi Signal
- 25 cm Brick wall
- 2 X USRPs N210
- All outside setting

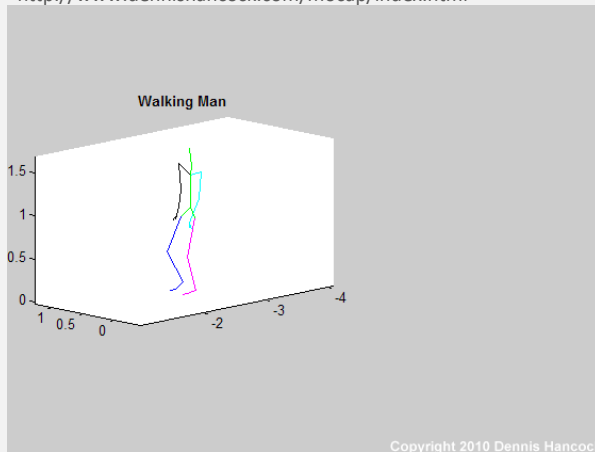


# Diverse Applications

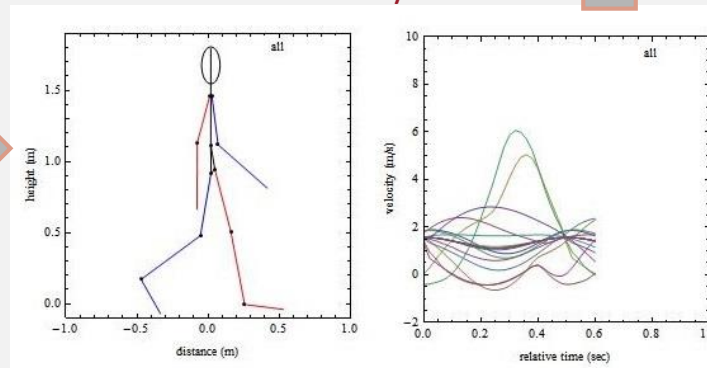
## Line of Sight Gait Awareness

In mind

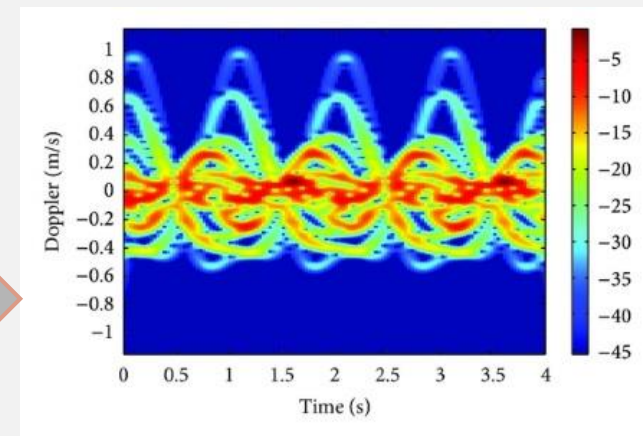
<http://www.dennishancock.com/mocap/index.html>



Ideally



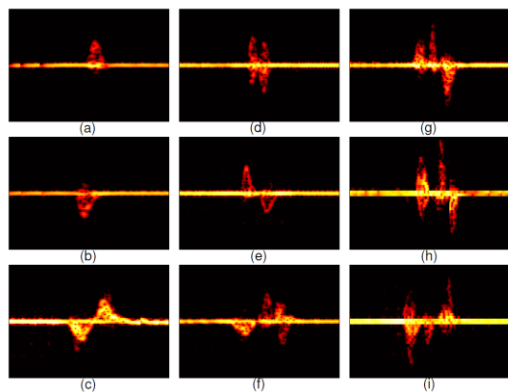
Simulation



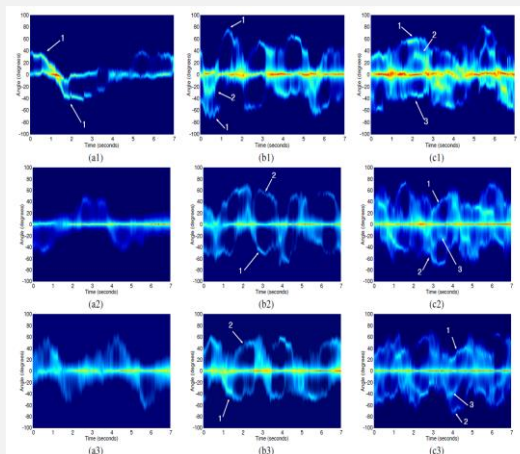
Reality?

# Diverse Applications

## Line of Sight Gait Awareness

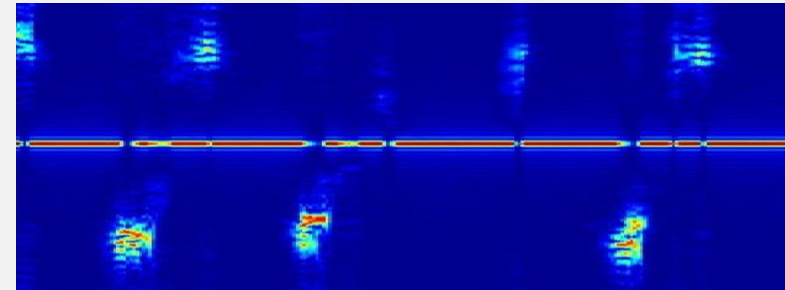


Wi-See [1], by Washington, body gestures, arm waving, etc.

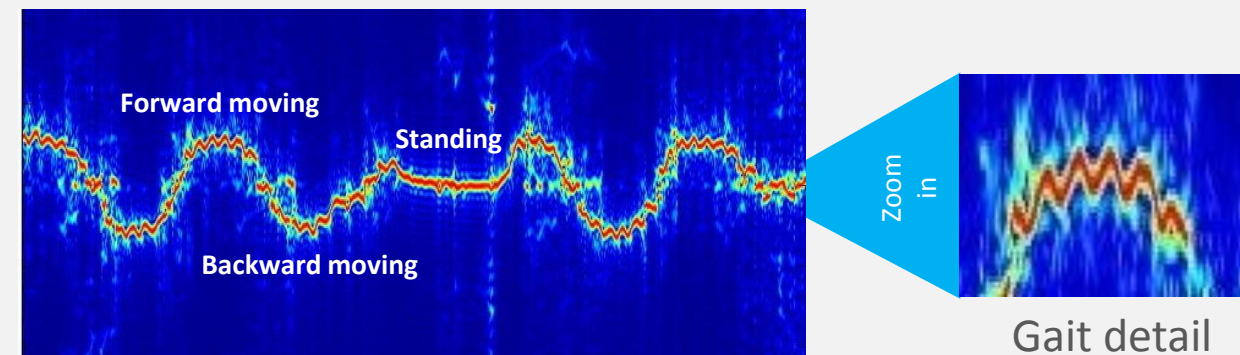


Wi-Vi [2], Wi-track, Vital-radio, by MIT, Walking people with angle information

## Doppler Trace without DSI and Stationary Cancellation



## After DSI, Stationary Cancellation, and improved resolution

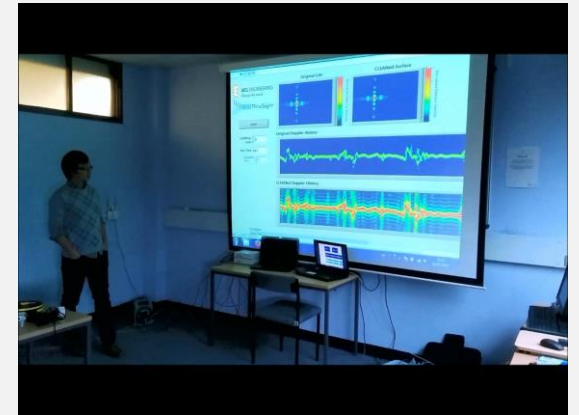
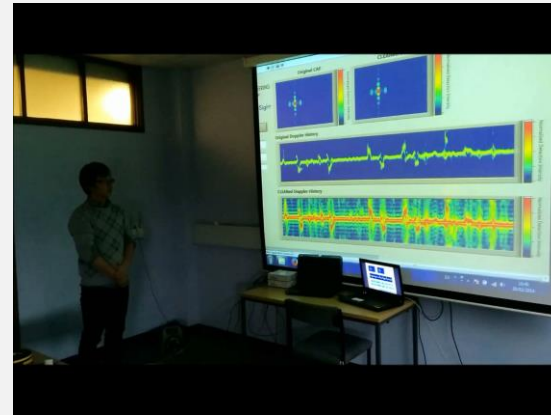
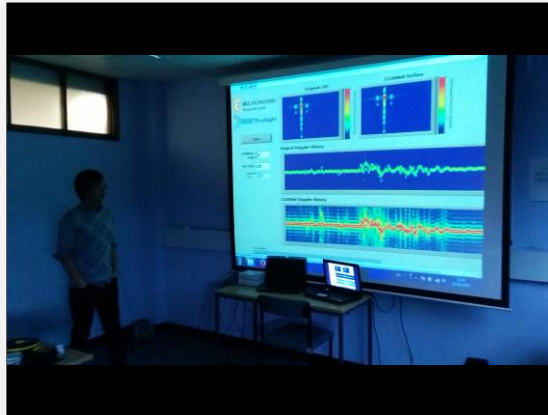
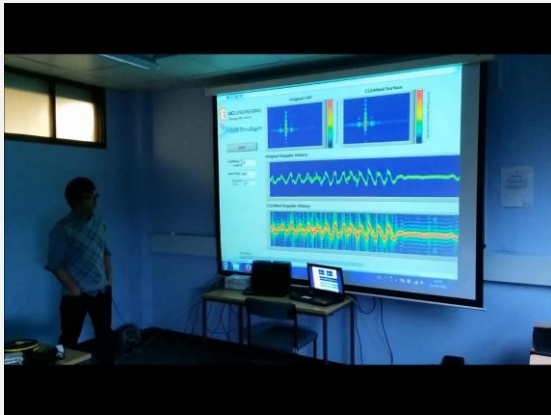


[1] Whole-Home Gesture Recognition Using Wireless Signals

[2] See Through Walls with Wi-Fi!

# Diverse Applications

## Through-Wall Body Gesture



# Diverse Applications

## Security Application

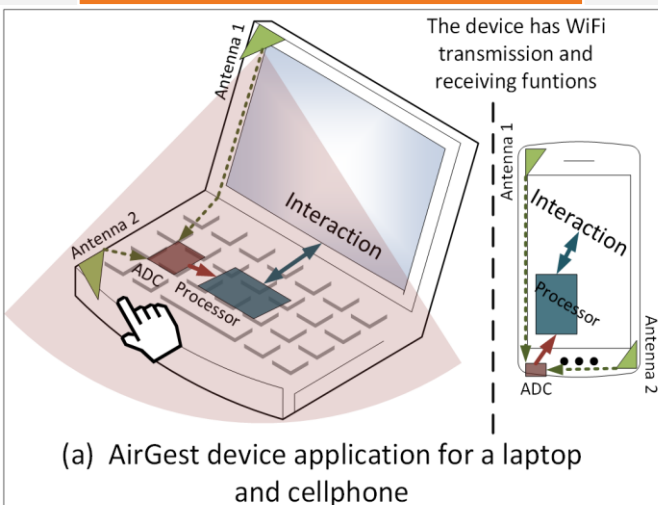




# Diverse Applications

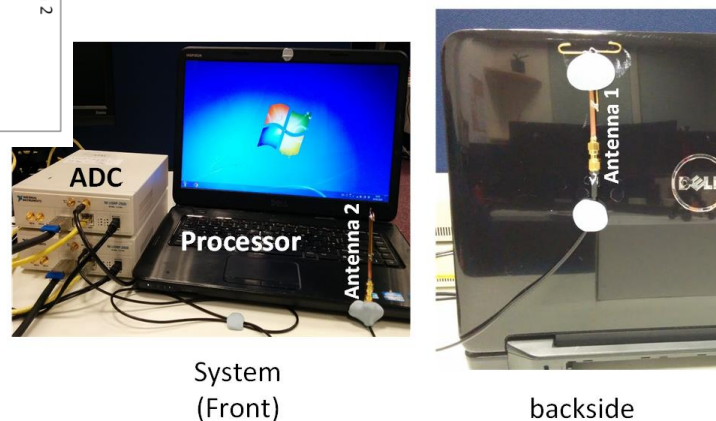
## Impalpable Body Movements

### Concept

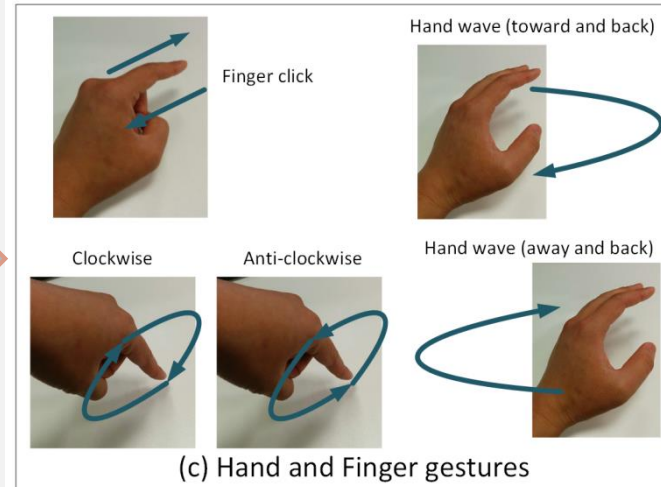


2

### Prototype

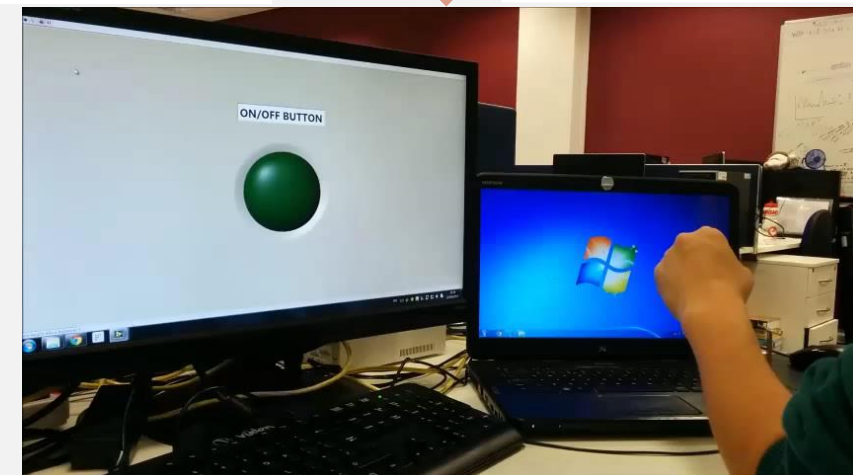


### Prove concept Gesture



3

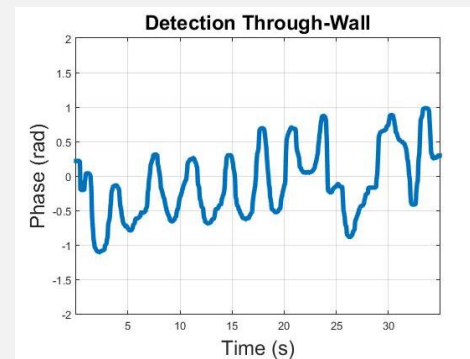
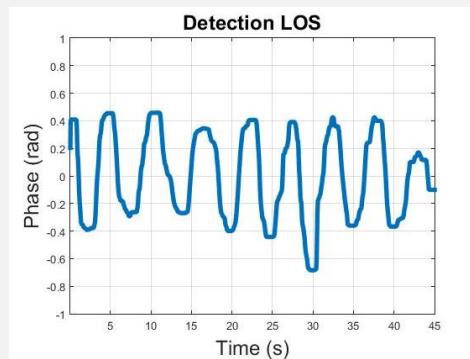
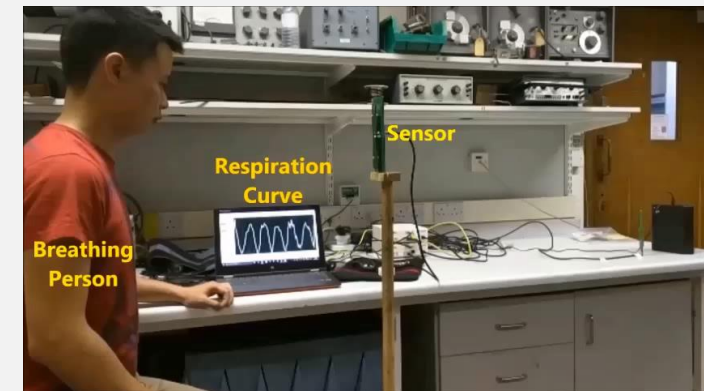
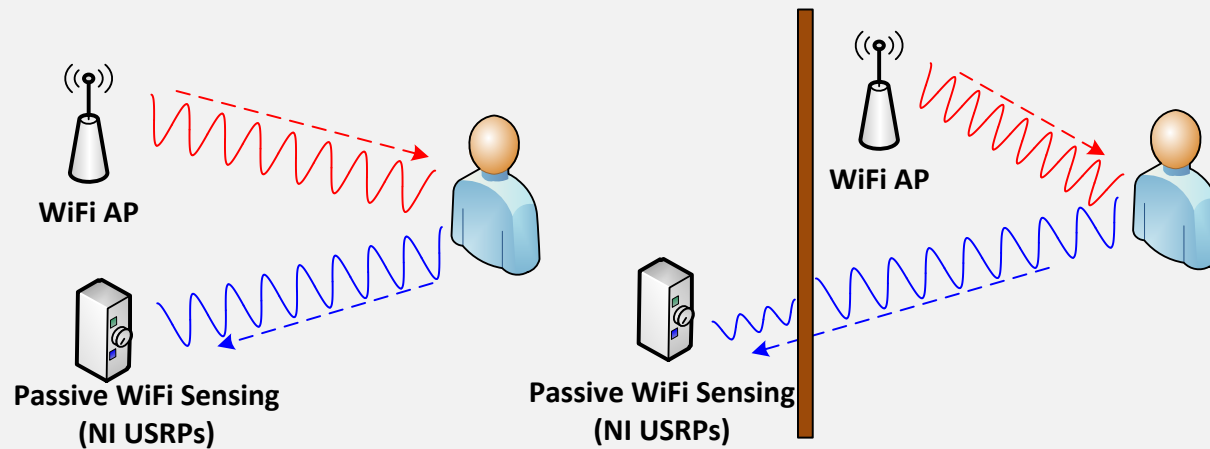
### Real Demo



1

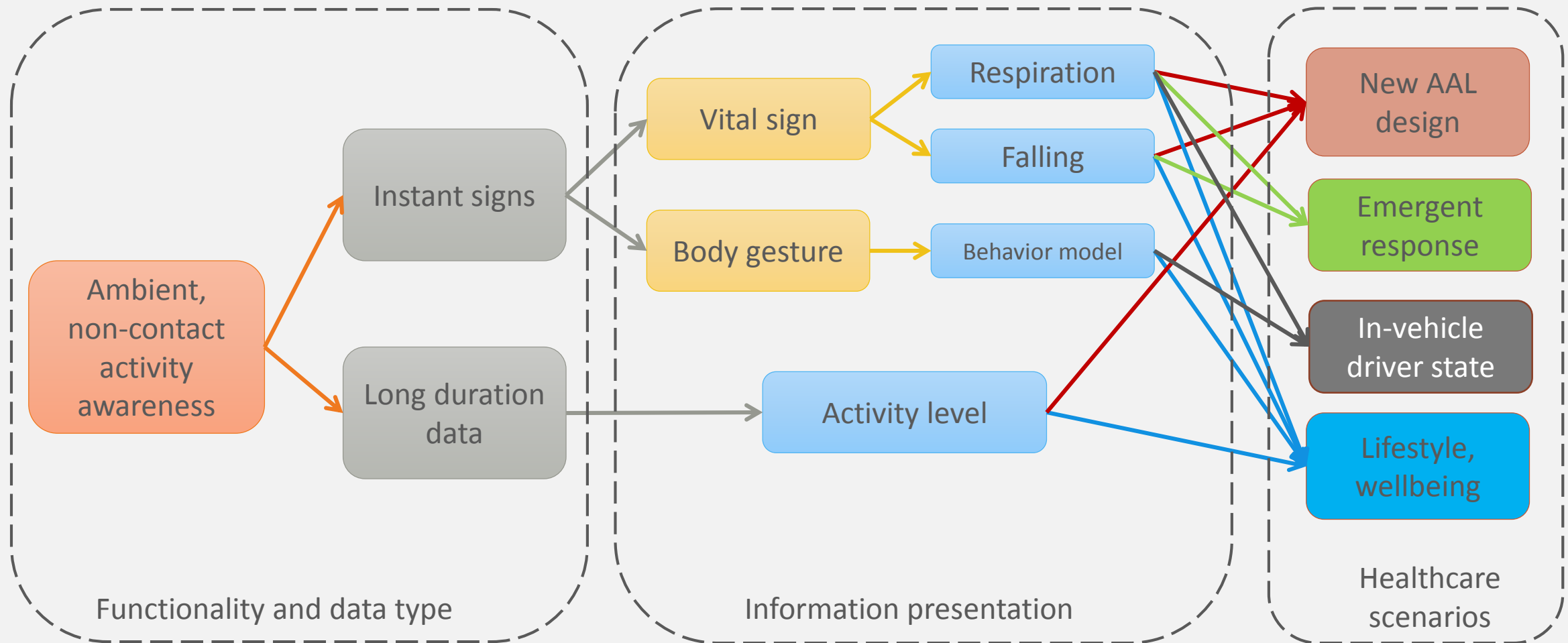
# Diverse Applications

## Impalpable Body Movements





# Diverse Applications





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New Era

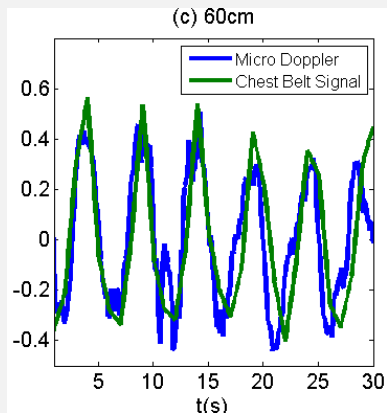
Needs for artificial intelligence



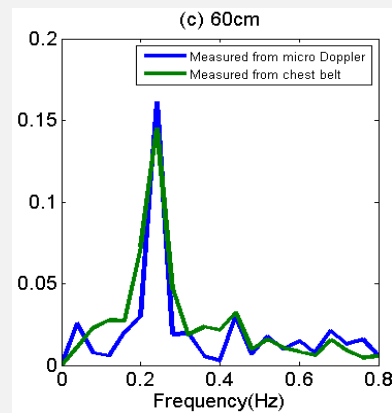
# New Era

- Easy to recognize

## Breathing detection

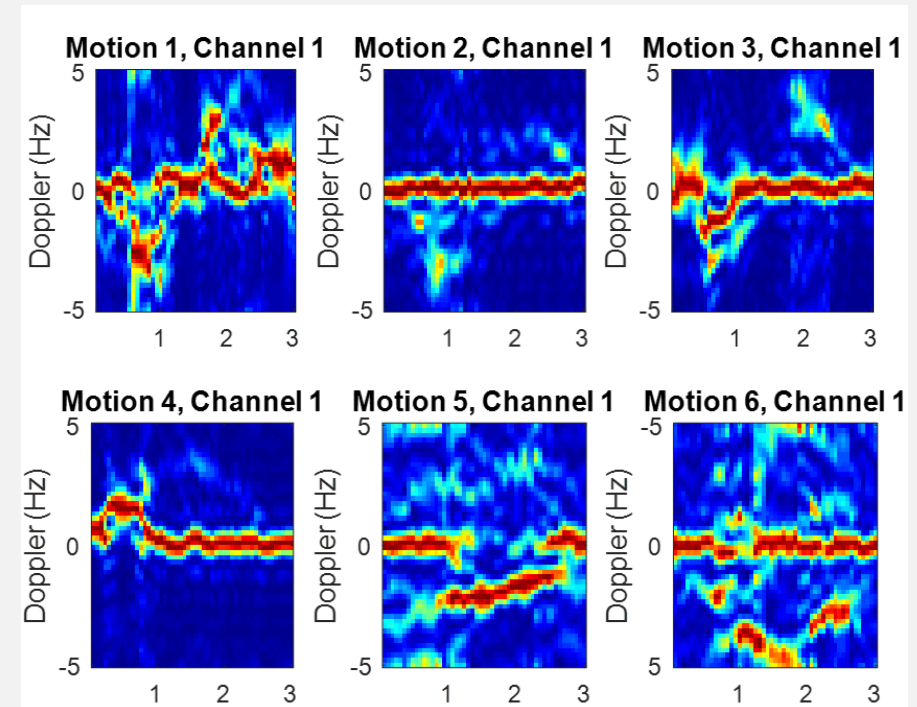


FFT



- Hard to say

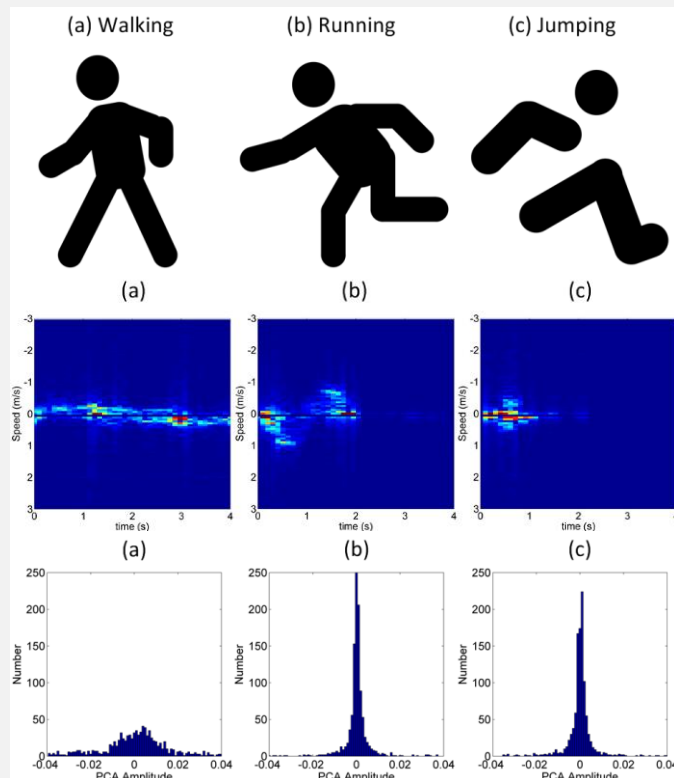
## Doppler Trace of Some Daily Activities



# New Era

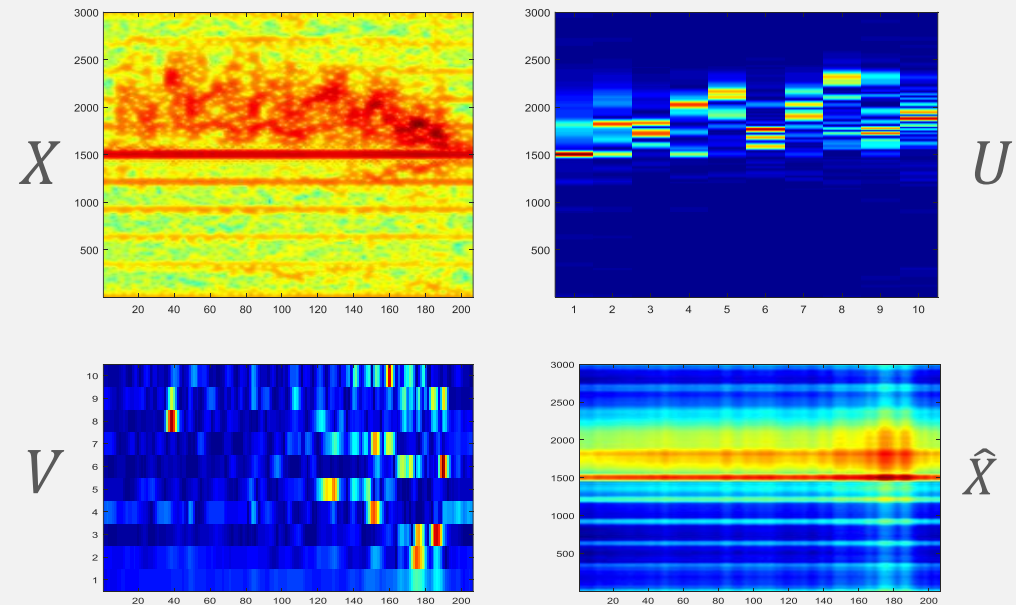
## Feature Extraction

- PCA



- SVD

$$X = U\Sigma V^*$$



# New Era

## Classifying

- PCA + SVM (single surveillance channel)

	a	b	c	d	e	f
a	1.00	0.00	0.00	0.01	0.00	0.03
b	0.00	0.94	0.00	0.07	0.01	0.08
c	0.00	0.01	1.00	0.18	0.04	0.03
d	0.00	0.02	0.00	0.65	0.24	0.01
e	0.00	0.01	0.00	0.04	0.60	0.04
f	0.00	0.02	0.00	0.06	0.11	0.81
	a	b	c	d	e	f

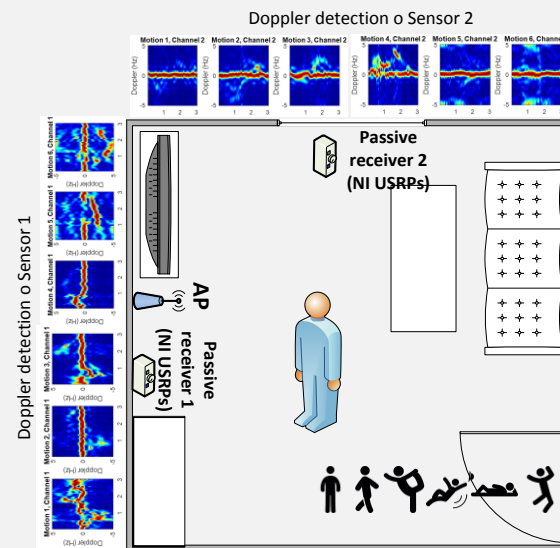
- SVD + SRC (2 surveillance channels)

		Classified Results					
		M1	M2	M3	M4	M5	M6
Ground Truth	M1	95.8%	0%	0%	0%	0%	0%
	M2	0%	91.7%	8.3%	0%	8.3%	0%
	M3	0%	0%	91.7%	33%	0%	0%
	M4	4.1%	0%	0%	67%	0%	0%
	M5	0%	0%	0%	0%	83.3%	29.2%
	M6	0%	8.3%	0%	0%	8.3 %	70.8%

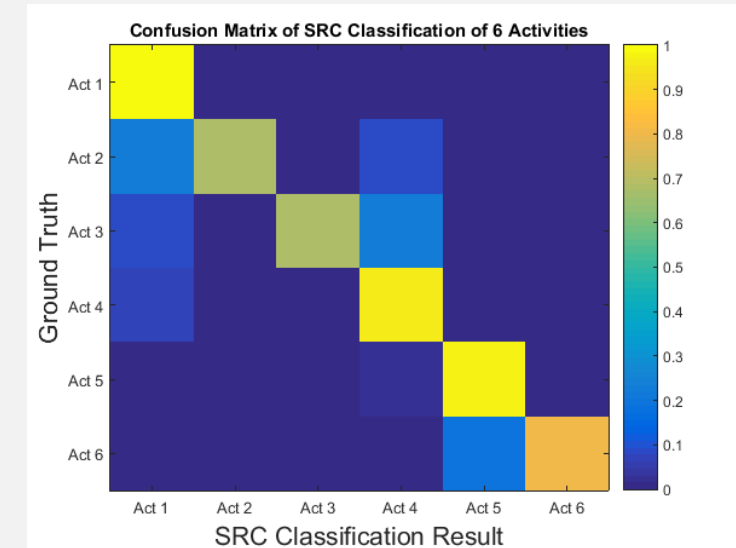
# New Era

## Result in SPHERE House

- SHERE House
  - Sensor Platform for Healthcare in a Residential Environment
  - EPSRC flagship IRC
  - Sensor network design and data mining for residential healthcare
  - Roll out for 100 houses in Bristol



- 1) Picking-up
- 2) Sitting-down
- 3) Standing-up
- 4) Falling
- 5) Standing-up (post fall)
- 6) Getting-up from lying



SVD + SRC Result

# New Era

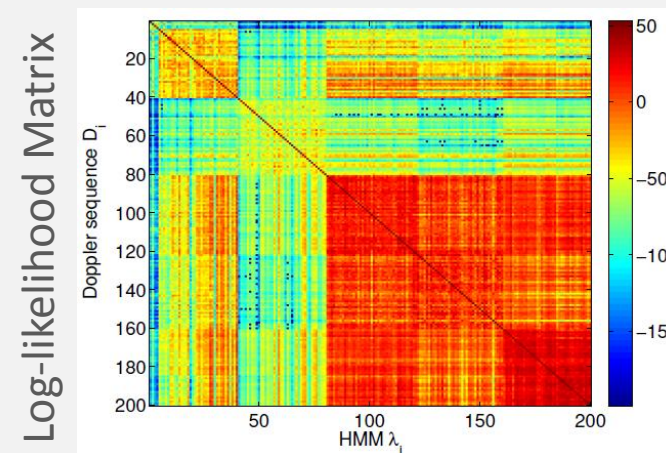
## Limitations and Potential Solution

### ○ Slide Windowing Limitation

- PCA, SVD and physics features need sliding window
- Pre-defined fixed window slide over the Doppler trace
- Varying activity duration
- Size of the window impact the recognition result

### ○ HMM-Log-likelihood as Feature

- Every activity/gesture is considered as time sequential event
- Every movement can be trained by HMM processing
- Movements fall in same activity will have max similarity – Log-likelihood as measurement



Recognition Result

	(2)	(3)	(4)	(5)	(6)
(2)	0.76	0.03	0.04	0.11	0.06
(3)	0.00	1.00	0.00	0.00	0.00
(4)	0.00	0.00	0.65	0.01	0.34
(5)	0.00	0.00	0.37	0.61	0.02
(6)	0.00	0.00	0.20	0.00	0.80
	(2)	(3)	(4)	(5)	(6)

predict activity class

actual activity class



# New Era

## Further Topics

- Scenario
  - Multiple signal courses
  - Multiple users
- Signal Processing
  - Delay estimation
  - Angle estimation
  - Localization
- Machine Learning
  - Sequential modelling
  - Behavior modelling

### EPSRC IRC Next Steps Plus

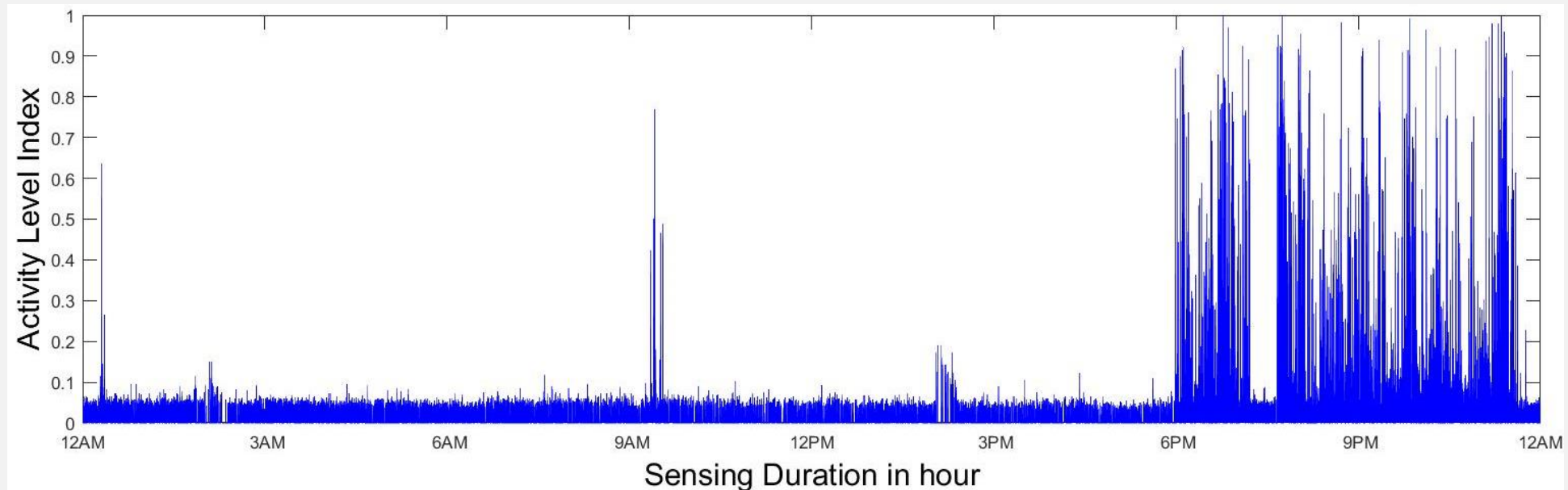
**OPERA - Opportunistic Passive Radar for  
Non-Cooperative Contextual Sensing**



# New Era

## Interpreting the Life Style by Using Wi-Fi Signal

24 Hour Activity Monitoring of Single Resident





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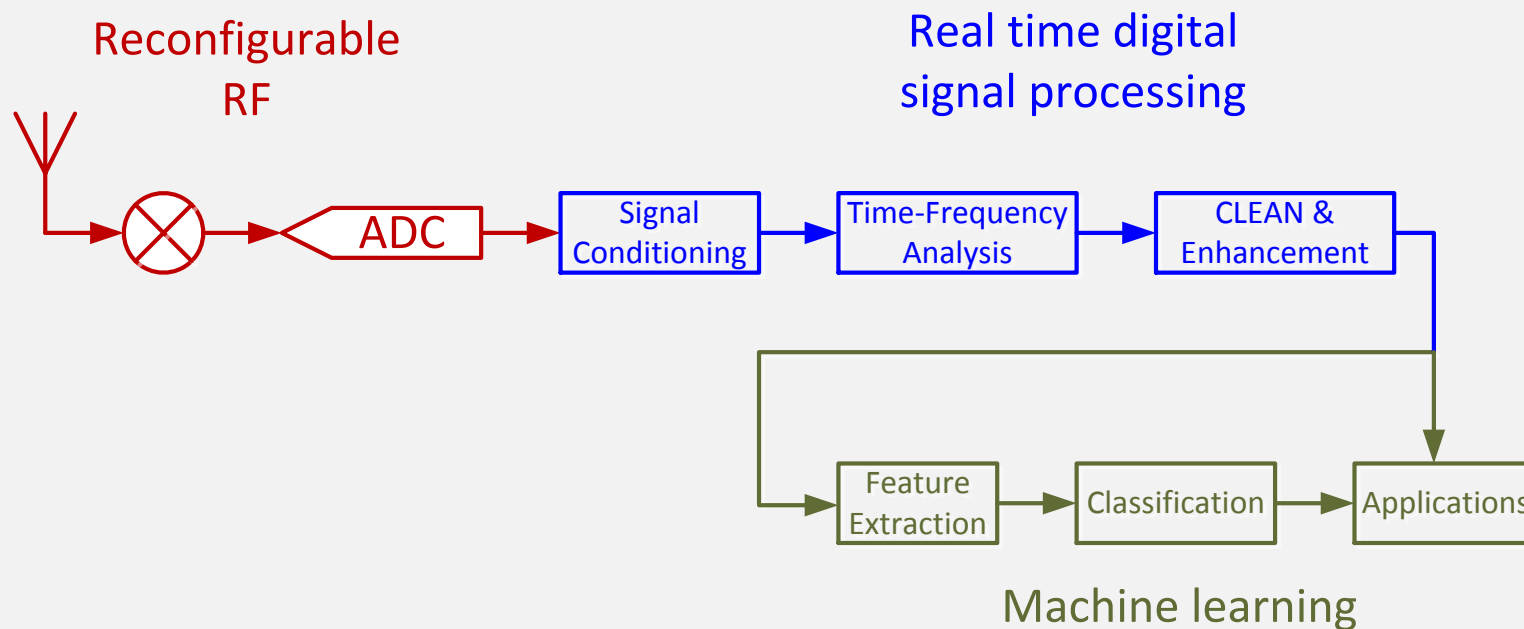
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## Challenge

A long processing chain for heterogeneous signals



# Challenge



## Challenges:

- RF, DSP, Machine learning and applications
- Diverse knowledge, running on difference developing environment
- Diverse experts with different skill sets
- Challenges for both technique development and project management



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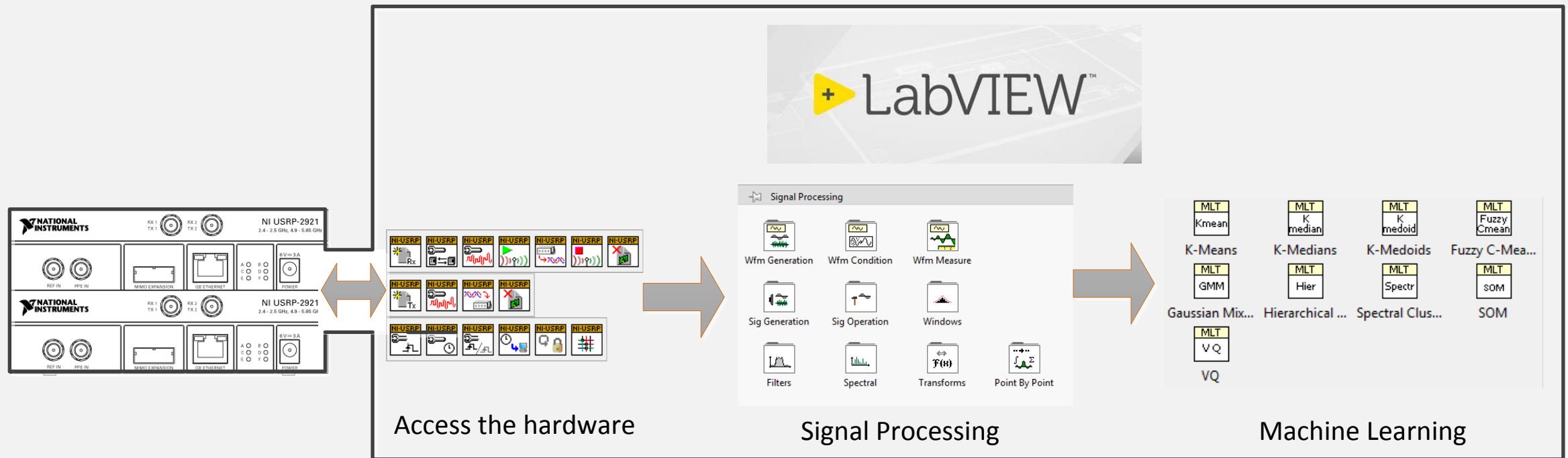
# Integrated Solution

LabVIEW as an engine



# Integrated Solution

## LabVIEW as a Hub to Tackling all challenges





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# Carry On

Impact and Joint Force





# Carry On

## Impact

### ○ Academic

- 20+ research papers in radar, signal processing, healthcare, IoT and communications
- Joint research between UCL, University of Bristol, Coventry University



### ○ Industry

- Honeywell: smart home
- London Metropolitan Police: security



### ○ IP

- Apparatus and method for performing passive sensing WO 2015063488 A1: refereed by Qualcomm
- UCL Business online licensing



# Carry On

## Joint Force

### ○ UCL

- Department of Electronics and Electrical Engineering
- Department of Security and Crime Science

### ○ Coventry University

- Centre for Mobility & Transport
- Future Cities Group

### ○ University of Bristol

- Department of Electrical and Electronics Engineering
- Digital Health Engineering Group



Thank You

Q&A

