

Exploiting Radar Data Domains for Classification with Spatially Distributed Nodes

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*Presenter

Outline

- Motivation
- Introduction
- Radar system
- Radar data format
- Feature fusion and classification
- Decision fusion and classification
- Data load
 - Data load (Feature fusion)
 - Data load (Decision fusion)
- Open dataset
- Conclusion

- People detection and monitoring
 - Applications for smart homes, security protection
 - Joint communication, i.e., WiFi routers, - repeaters
- Advantages using RF sensing
 - Remote monitoring, no wearable devices
 - Weather and light independent
 - Penetration capability through objects
 - Data cannot be associated with an individual
- Continuous activities / arbitrary directions
 - Unfavorable aspect angles
 - Inter and intra classes

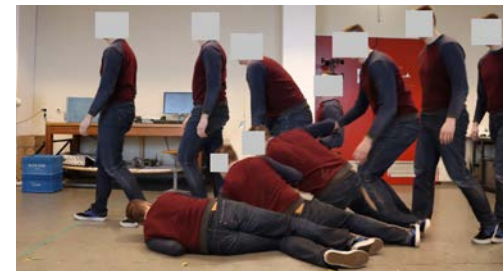


Fig: Motion sequence.

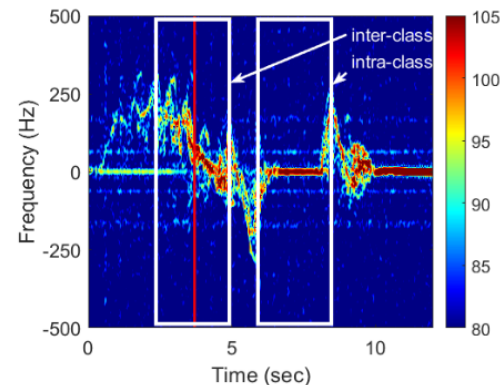


Fig: Inter and intra-class representation [1]

[1] M. G. Amin, A. Ravisankar, and R. G. Guendel, "RF sensing for continuous monitoring of human activities for home consumer applications," in *SPIE Defense + Commercial Sensing, 2019, Baltimore, Maryland, United States, 2019*, vol. 1098907, no. May 2019, p. 6, doi: 10.1117/12.2519984.

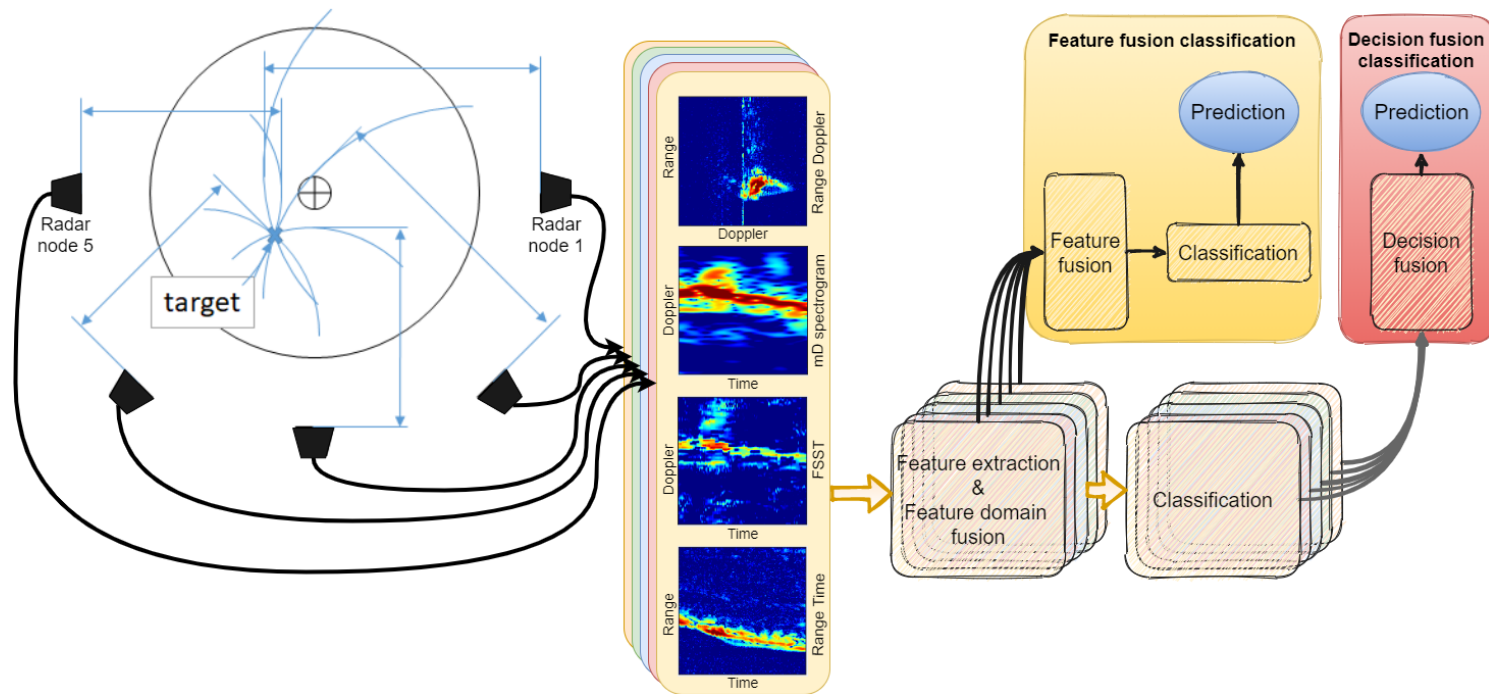


Fig: Data flow graph for feature fusion and decision fusion processing.

Dataset:

1. Walking (translation activities)
2. Stationary condition
3. In-place activities
4. Standing up from the ground
5. Falling down

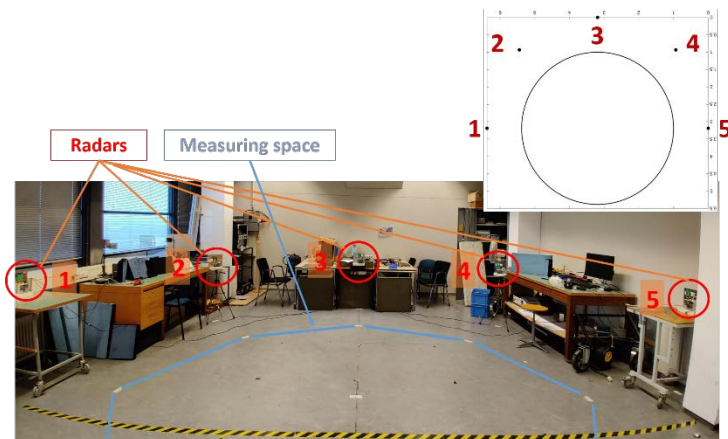


Fig: Radar layout at the TU Delft MS3 laboratory.



Fig: Walking falling merged, standing up, sitting down, standing up from sitting, and start walking.



Vid.: arbitrary activity sequence collected. 4/15



Fig: PulsON P410 radar

Measurement area parameters:

Range: 1 - 5.38m

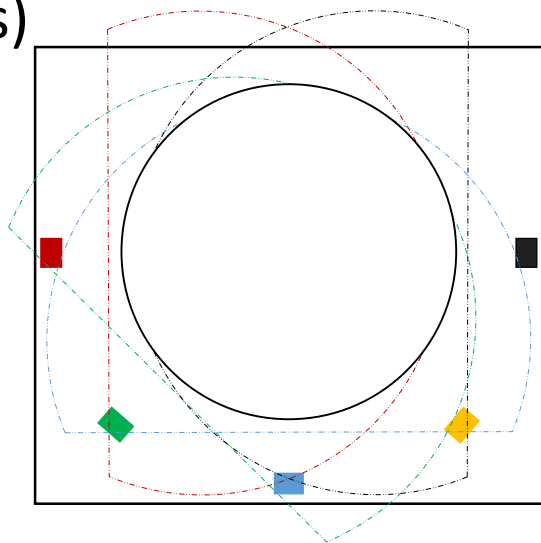
Diameter: 4.38 m

Five radars – Simultaneous monostatic mode

PulsON P410 - Time Domain (Humatics)

Ultra Wideband radar

- Center frequency: 4.3 GHz
- Bandwidth: 2.2GHz
- Monostatic
- 1024 coherent integrations
- PRI 8.2ms → PRF 122Hz
- Omnidirectional broadband antennas



- Range-Doppler
- Micro-Doppler (mD) spectrogram
- Fourier synchro-squeezed transform (FSST) spectrum
- Range-time map

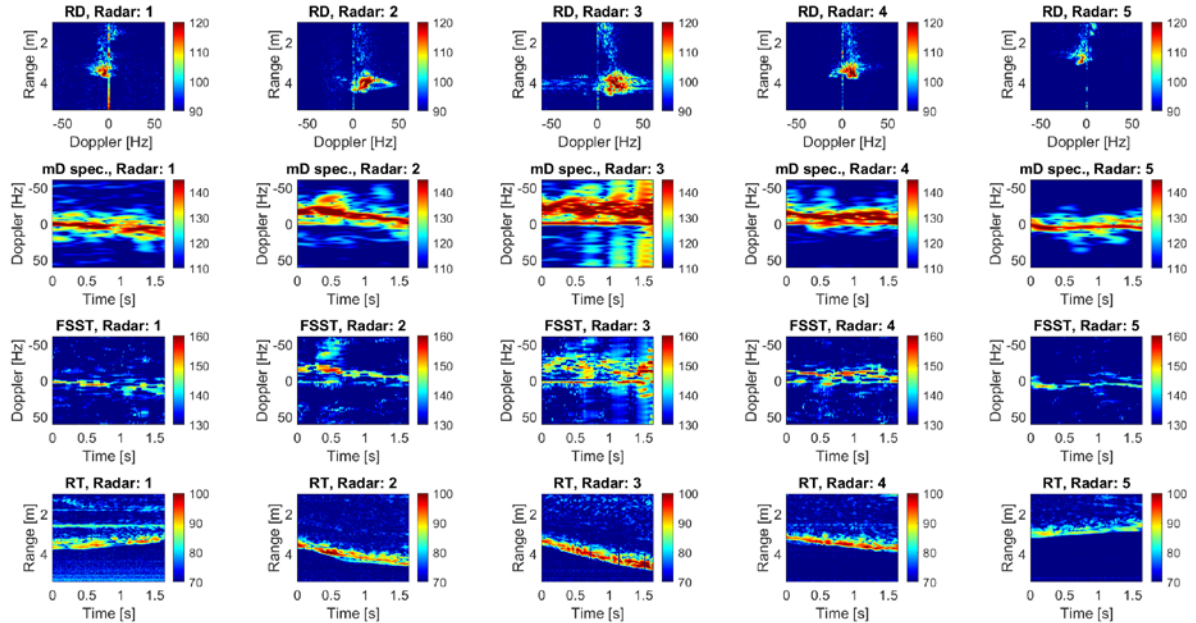
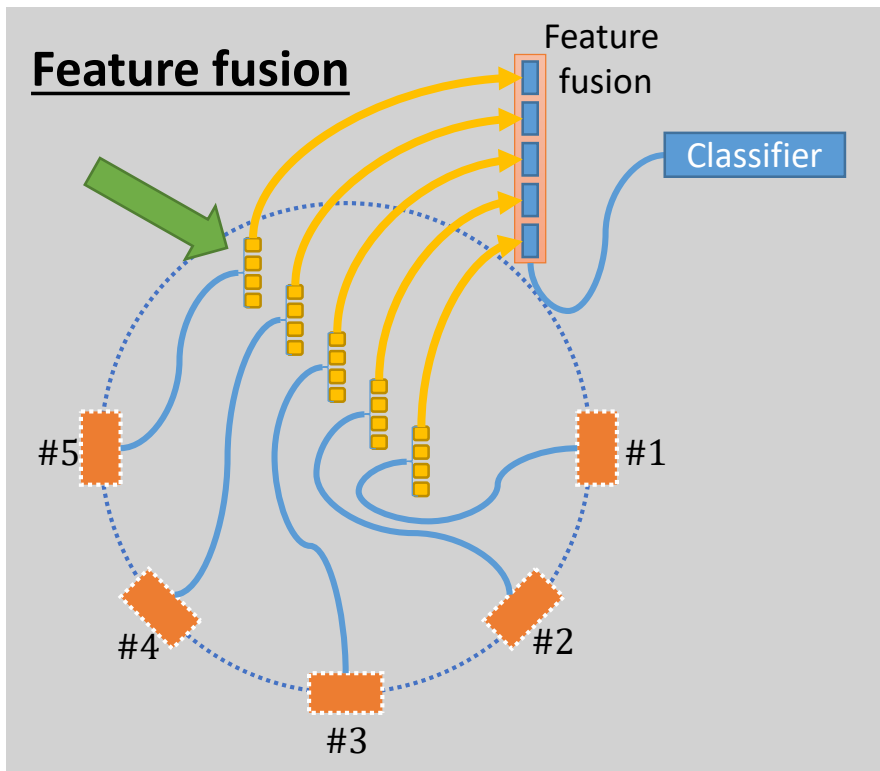
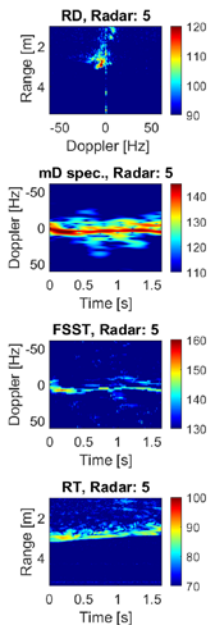









Fig: Four data domains of five radars.



Legend

-  #1 Radar node
-  Data domains of one radar
-  Radar nodes fusion
-  Data domain feature 1
-  Data domain feature 2
-  Data domain feature 3
-  Data domain feature 4

Feature extraction: 1D PCA & 2D PCA

Applied Classifiers:

- Support vector machine (SVM)
- Decision tree (DT)
- KNN classifier
- Naïve Bayes (NB)

Accuracy and F1 score for:

- Training
- Cross validation 70/30
- Leave one person out

Feature extraction: 1D PCA & **2D PCA**

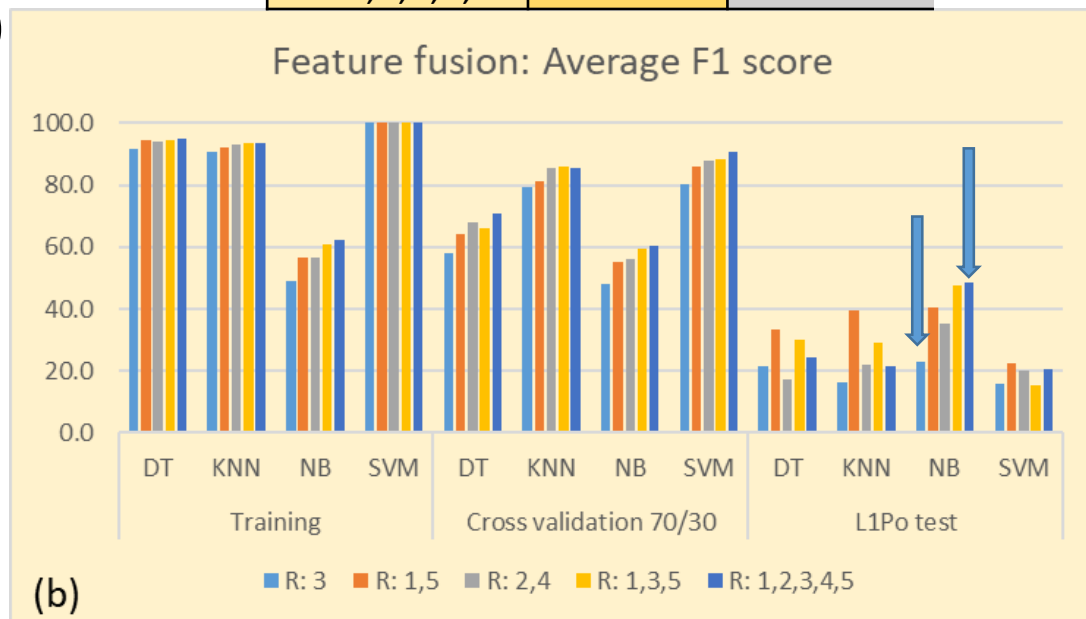
Applied Classifiers:

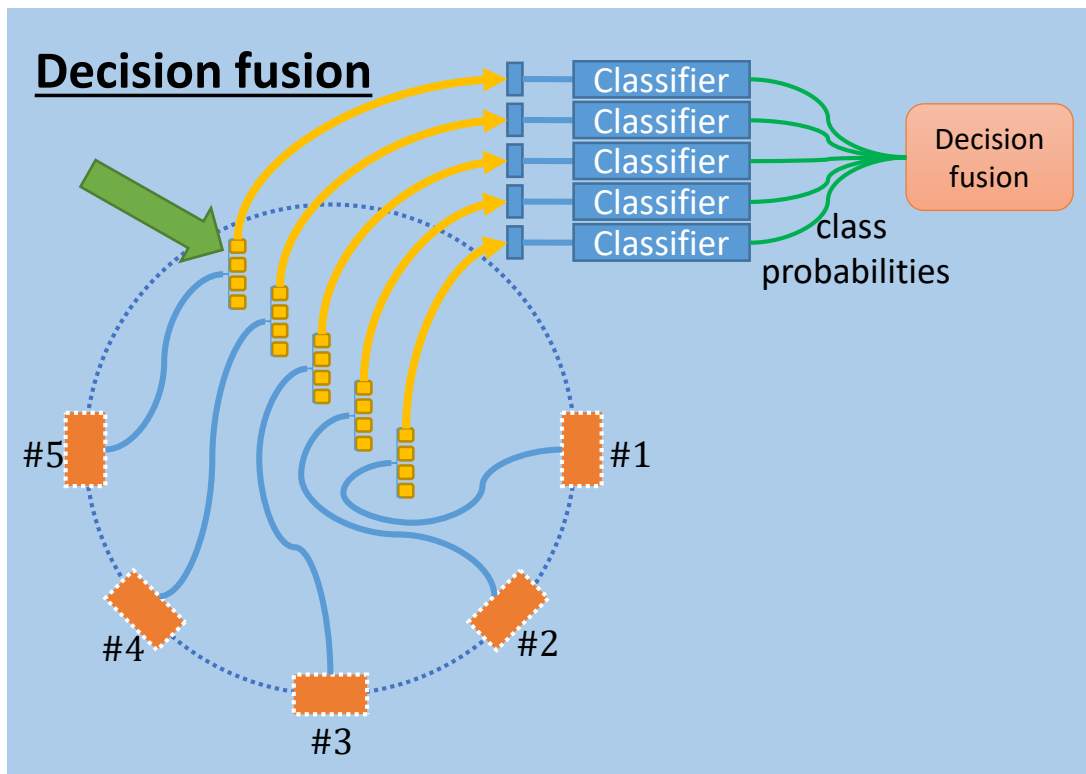
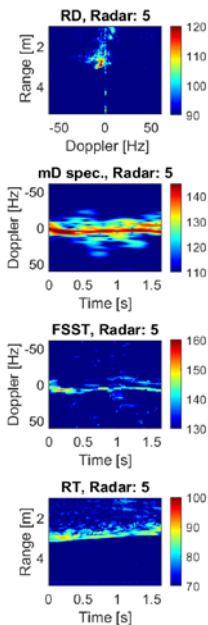
- Support vector machine (SVM)
- Decision tree (DT)
- KNN classifier
- **Naïve Bayes (NB)**

Accuracy and F1 score for:







- Training
- Cross validation 70/30
- **Leave one person out**

Results	L1Po test F1 score	L1Po test Accuracy
Radar nodes	NB	NB
R: 3	22.9	24.3
R: 1,2,3,4,5	48.3	>60





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Feature extraction: 1D PCA & **2D PCA**

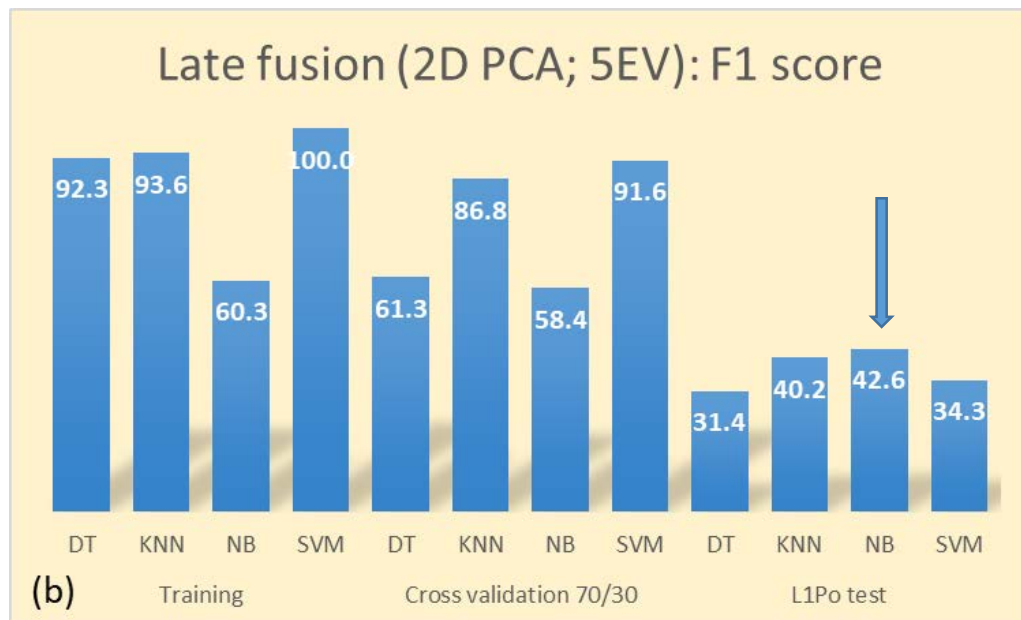
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- **Naïve Bayes (NB)**

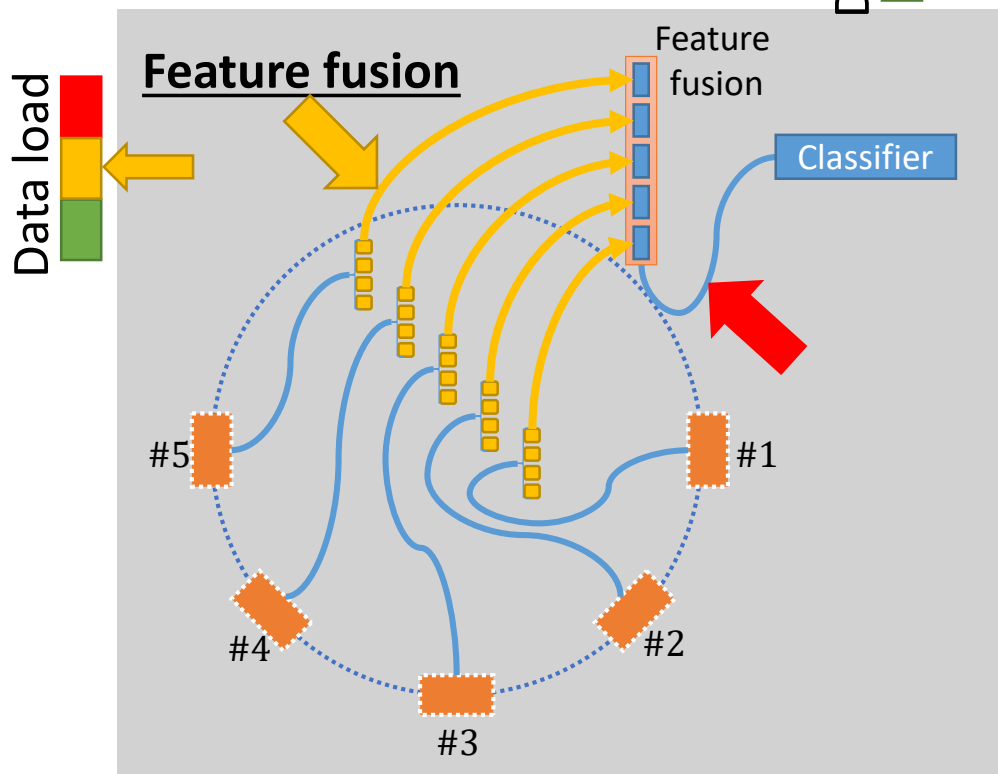
Accuracy and F1 score for:

- Training
- Cross validation 70/30
- **Leave one person out**








Results	L1Po test F1 score	L1Po test Accuracy
Radar nodes R: 1,2,3,4,5	NB 42.6	NB/KNN 58.0



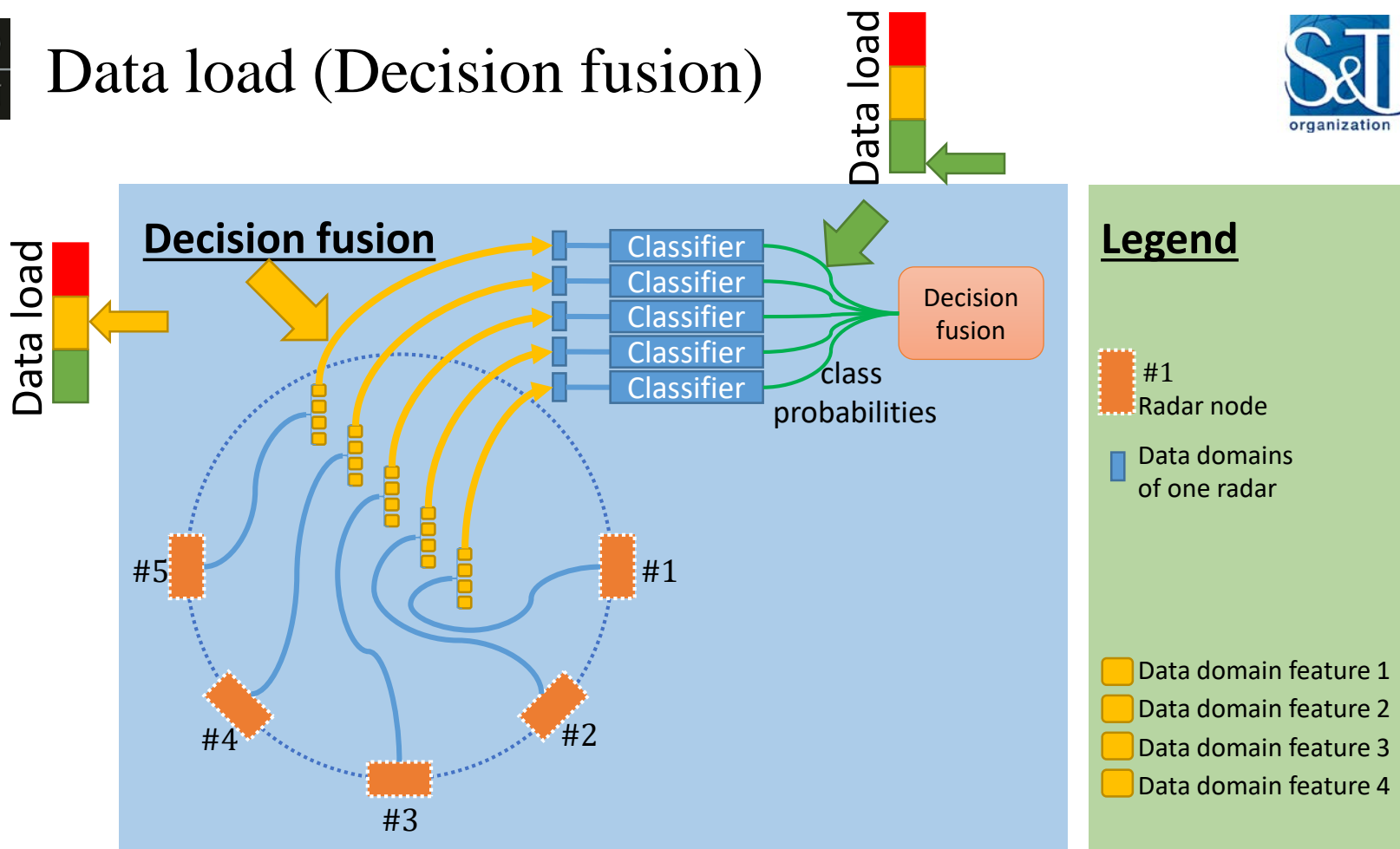
Data load (Feature fusion)



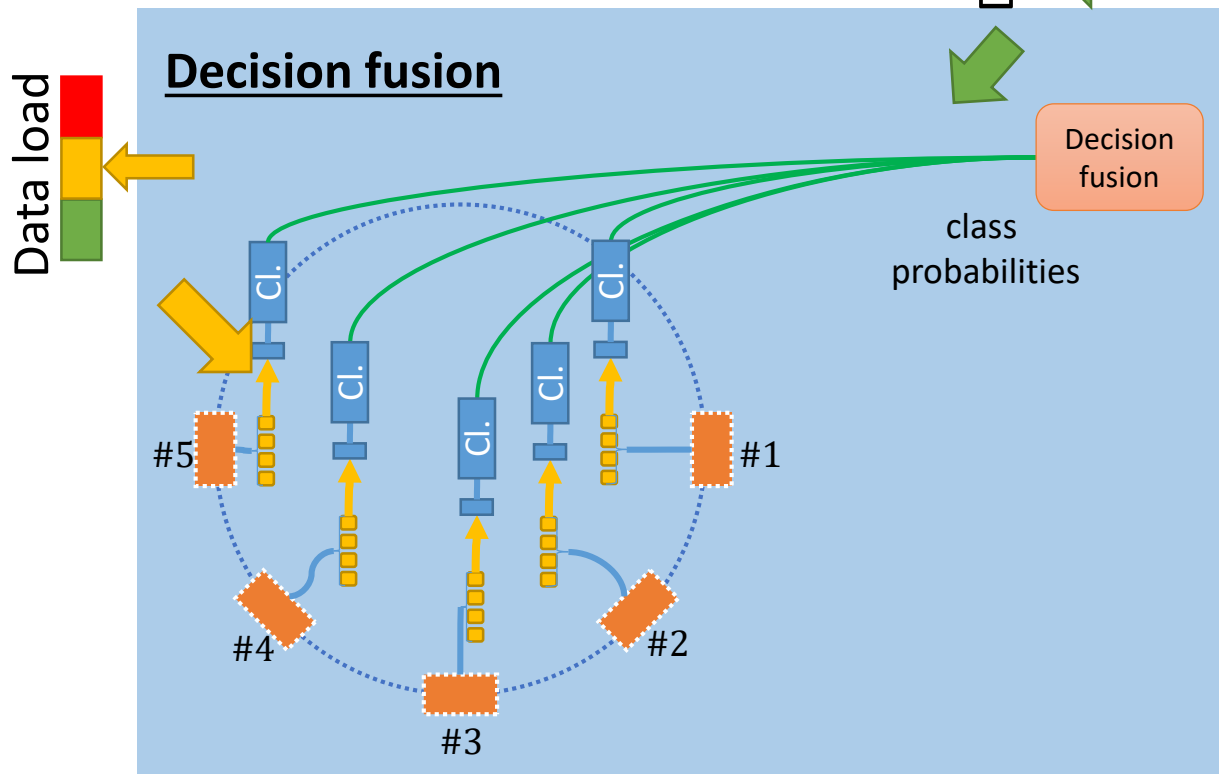
Legend

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Data load (Decision fusion)



Data load (Decision fusion)

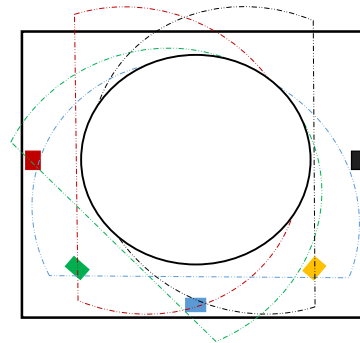


Legend

-  #1 Radar node
-  Data domains of one radar
-  Data domain feature 1
-  Data domain feature 2
-  Data domain feature 3
-  Data domain feature 4

doi: <https://doi.org/10.4121/16691500.v2>

- Distributed radar network
- Synchronized nodes
- Ground truth labeled
- Continuously recorded
- Free in aspect angle



[2] Guendel, R.G., Unterhorst, M., Fioranelli, F., Yarovoy, A.. 'Dataset of continuous human activities performed in arbitrary directions collected with a distributed radar network of five nodes'. (4TU.ResearchData, 2021 [Online]. doi:<https://doi.org/10.4121/16691500.v2>. Available from: https://data.4tu.nl/articles/dataset/Dataset_of_ontinuous_human_activities_performed_in_arbitrary_directions_collected_with_a_distributed_radar_network_of_five_nodes/16691500/2

- Data domains: range-Doppler, micro-Doppler spectrogram, FSST spectrum, and range-time map
- Classifiers: KNN, NB, SVM, DT
- Feature fusion and decision fusion
- Feature fusion: max F1 score: 48.3% (2D PCA; NB classifier)
- Decision fusion: max F1 score: 42.6% (2D PCA; NB classifier)
- Individual domain classification results are provided (paper)
- Comparable results using 1D PCA (paper)

Thank you for your attention.
Any questions?

Tab: Channel coding from the user manual PulsON P410 (Time Domain).

17	Code Channel	UINT8	Specifies the index of the active UWB pseudo-random coded channel. Radars on separate channels will exhibit minimal interference. Channels 0-10 are currently supported.
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Unbalanced data

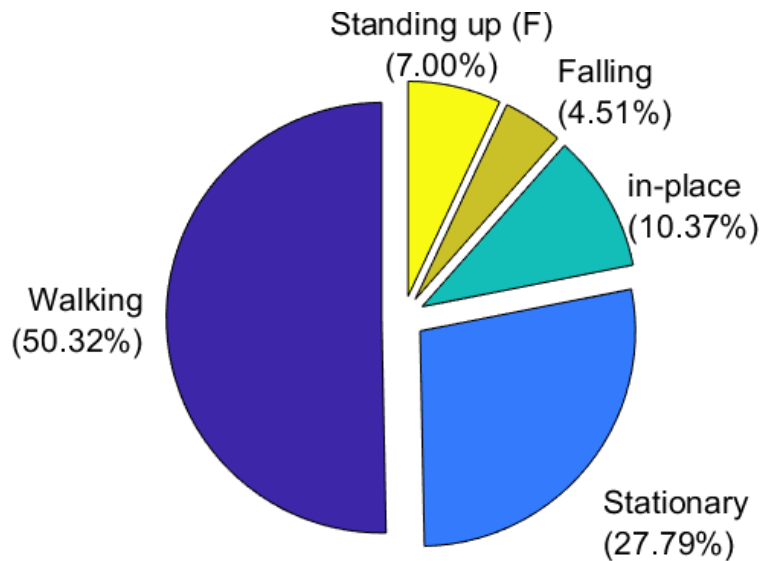


Fig: Dataset distribution.