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# Automatic Image Based Classification Capabilities of Targets for Passive ISAR

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- Work carried out during and following:
  - **Multichannel passive ISAR imaging for military applications (MAPIS)** project
  - Project n. B-1359 IAP2 GP of the **European Defence Agency,** 2014/12-2017/12
  - Hosted in the CapTech IAP2 RF Sensors Systems & Signal Processing
  - Funded in cooperation by the **M.o.D. of Italy, Hungary, Germany, Poland, Spain**
  - **Coordinated by** Radar and Surveillance Systems Laboratory of the Italian National Inter-University Consortium for Telecommunications - **CNIT-RaSS, Pisa, Italy**

 

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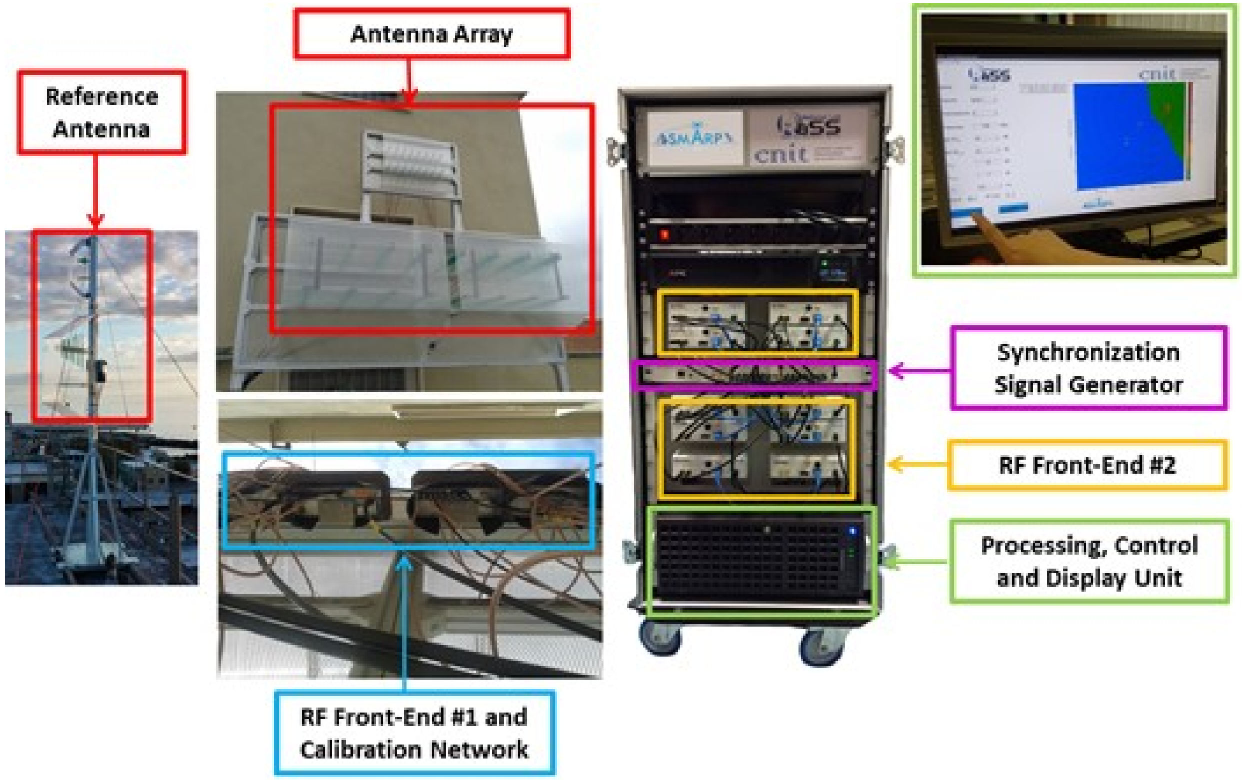
# Motivation, goals

- **Passive radars** – have become attractive for both military & civilian application
  - Advantages: low vulnerability to electronic countermeasure, counter-stealth advantage, no E.M. emission, etc.
- Investigate the possibilities and capabilities of feature based segmentation and classification of targets in passive ISAR rage-crossrange images
- **Automatic detection and classification** of possible targets without a priori target information
  - Segmentation of the possible target, along with image features
  - Classification based on extracted target shape information

# Radar

- SMARP (Software-defined Multiband Array Passive Radar) passive radar demonstrator [1]
- Developed by the Radar and Surveillance Systems Laboratory (RaSS Lab.) of the Italian National Inter-University Consortium for Telecommunications (CNIT), Pisa, Italy



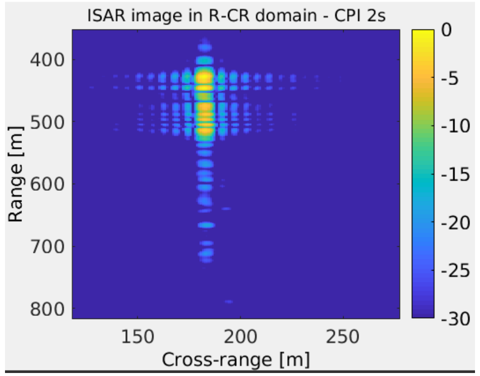

SMARP

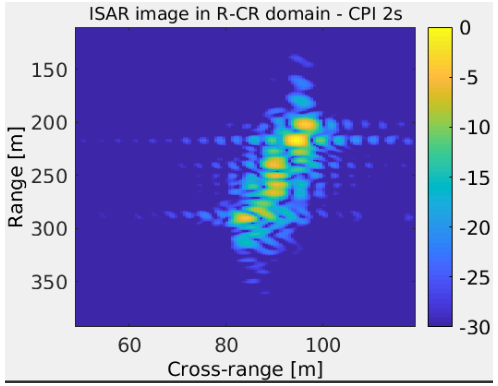
- DVB-T/GSM based passive radar
- dual band and dual polarization passive radar operating at UHF (470-790 MHz) and S-band (2100-2200 MHz)
- acquire up to 25 MHz bandwidth signal at UHF

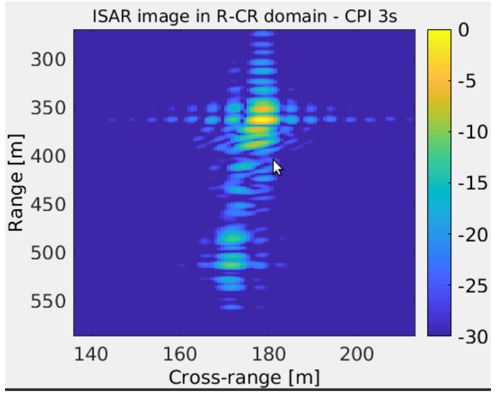
*[1] A. Capria, E. Giusti, C. Moscardini, M. Conti, D. Petri, M. Martorella, and F. Berizzi, "Multifunction imaging passive radar for harbour protection and navigation safety," IEEE Aerospace and Electronic Systems Magazine, vol. 32, no. 2, pp. 30–38, 2017.*

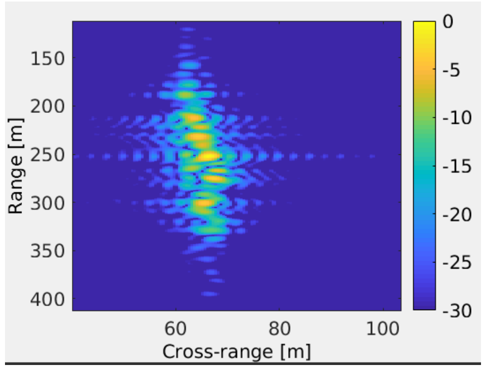
# Data

- Example input range/crossrange images [1]

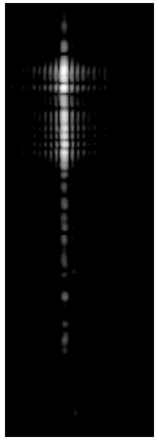


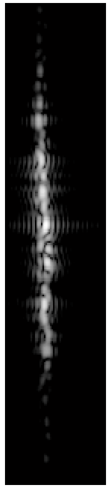




- Rescaled
  - to same m/px on both axes



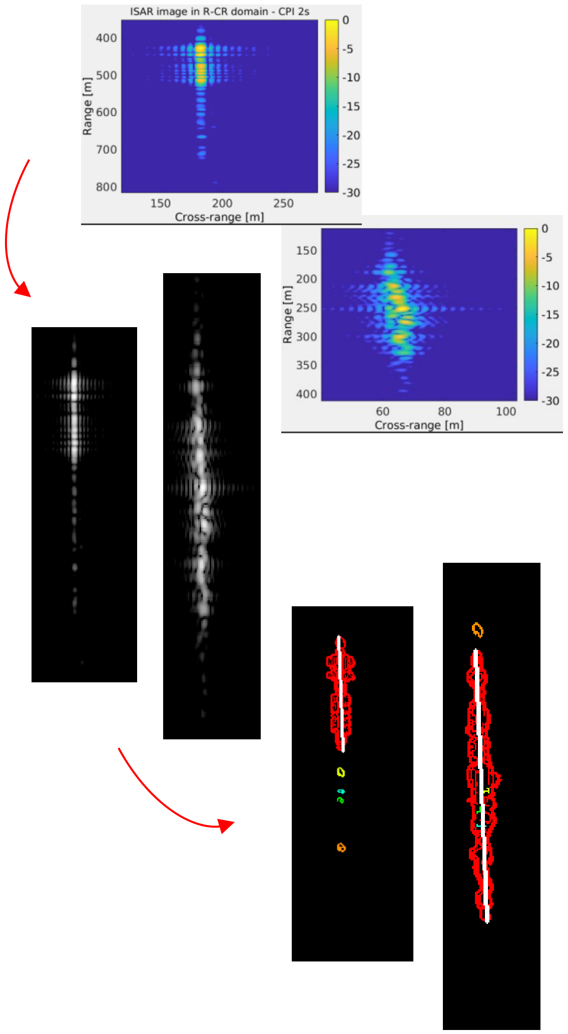


*[1] M. Martorella, "Novel approach for ISAR image cross-range scaling," IEEE Tr. on Aerospace and Electronic Systems, vol. 41, no. 1, pp. 281–294, 2008.*

# Detection, extraction

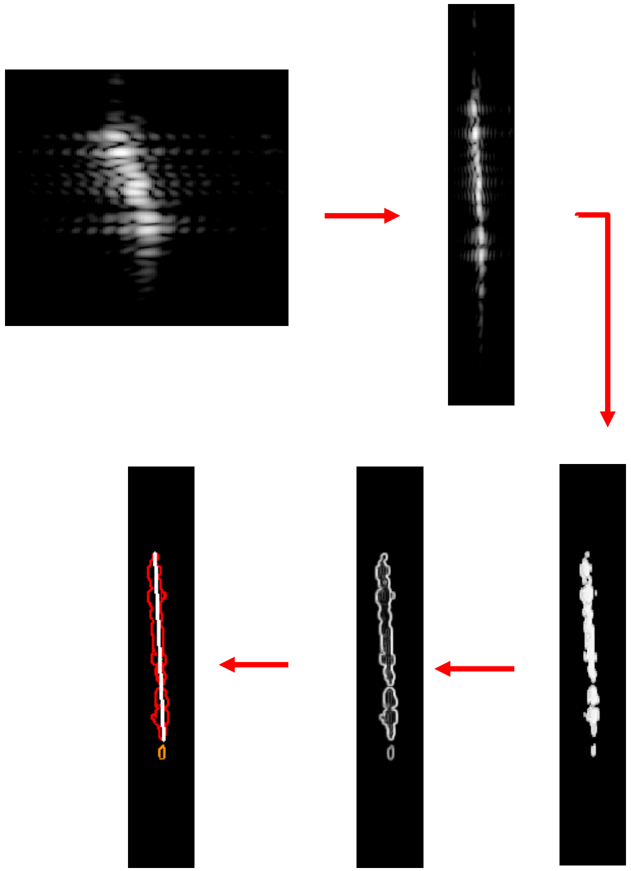
- Target detection and extraction:
  - Generic (discriminative):
    - benefit: no target class or model constraints, versatility
  - Goal:
    - detection of targets
    - extraction of features/target information for classification
  - Method:
    - based on the extraction of fused morphological, texture and edge feature maps
  - Final features:
    - target shape/contour
    - target length



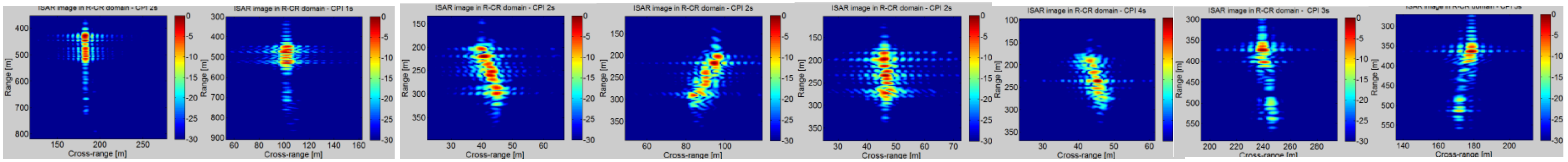
# Detection, extraction

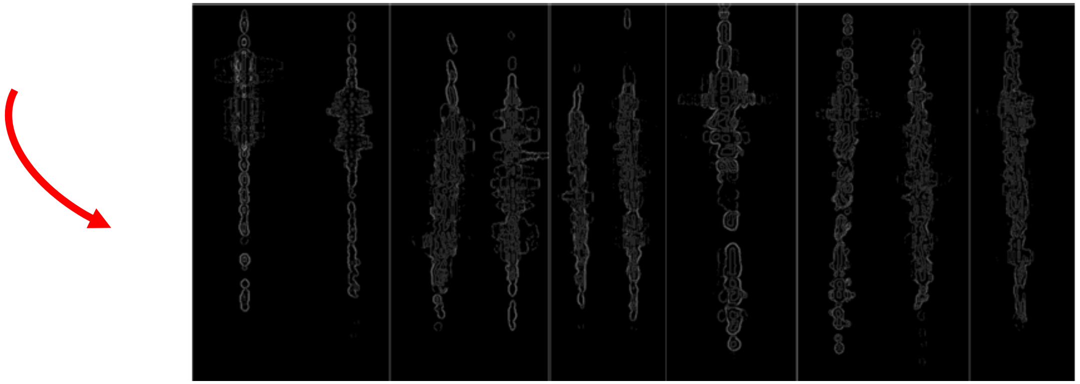
- Detection steps:
  - Filtering, pre-processing
  - Extraction of a fused feature map, based on [1], integrating:
    - Texture Distinctiveness Map [2]
    - Morphological Feature Contrast (MFC) operator [3]
    - Salient direction information [4]
  - Blob detection and extraction
  - Target contour and length extraction



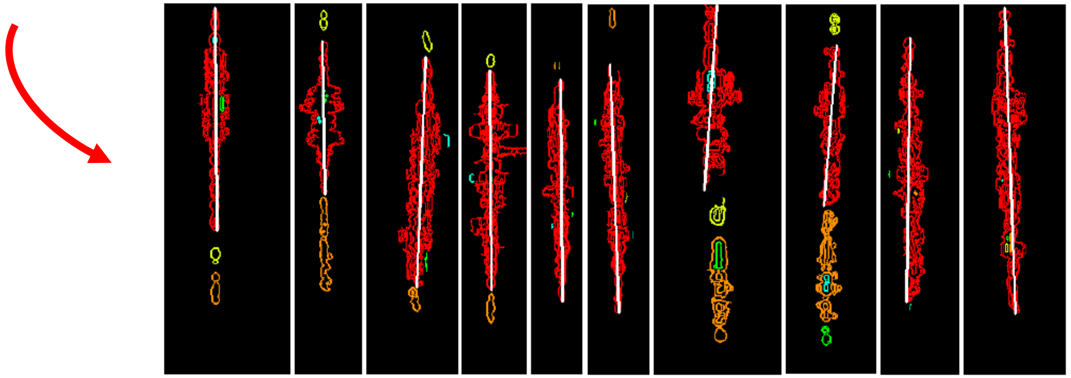
*[1] L. Kovács, A. Kovács, Á. Utasi, T. Szirányi: Flying Target Detection and Recognition by Feature Fusion. Optical Engineering, SPIE, Opt. Eng. 51 (11), 117002, 2012.*
*[2] K. Fergani, D. Lui, C. Scharfenberger, A. Wong, D. Clausi: Hybrid structural and texture distinctiveness vector field convolution for region segmentation. Computer Vision and Image Understanding, vol. 25, pp. 85–96, 2014.*
*[3] Zingman, D. Saupe, K. Lambers: A morphological approach for distinguishing texture and individual features in images. Pattern Recognition Letters, vol. 47, pp. 129–138, 2014.*
*[4] A. Kovács. T. Szirányi: Improved force field for vector field convolution method. In Proc. of IEEE International Conference on Image Processing (ICIP), pp. 2853 –2856, 2011.*

# Examples



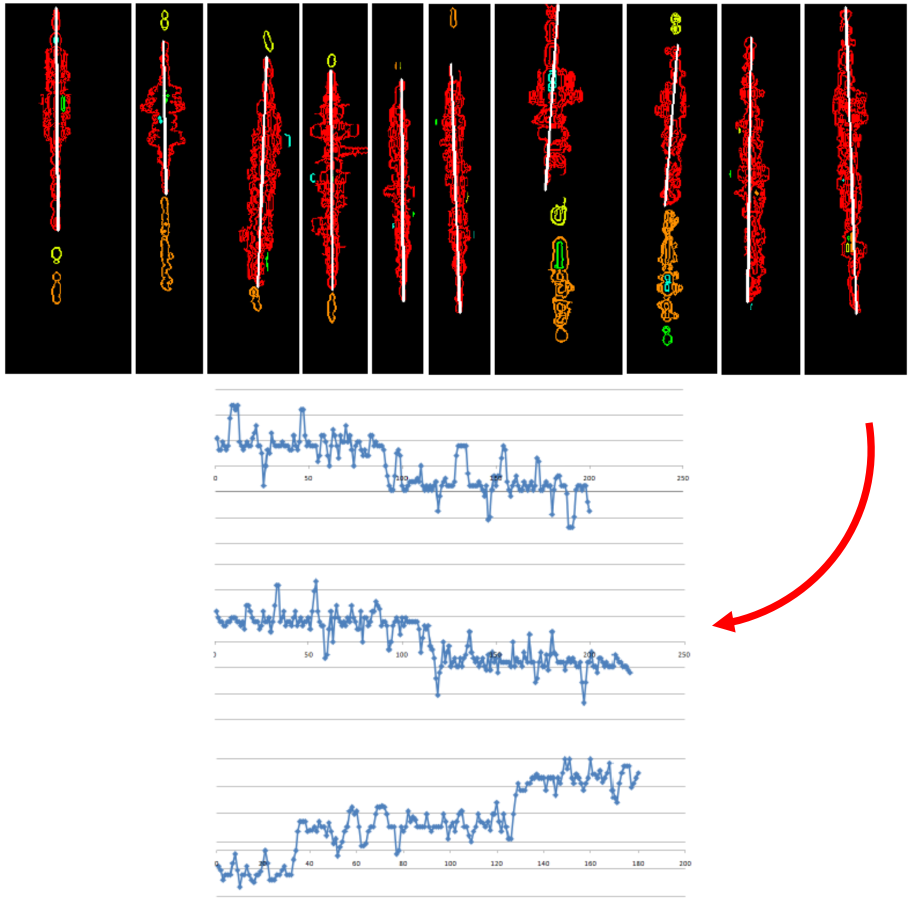


Different px/px and m/px resolutions



# Classification

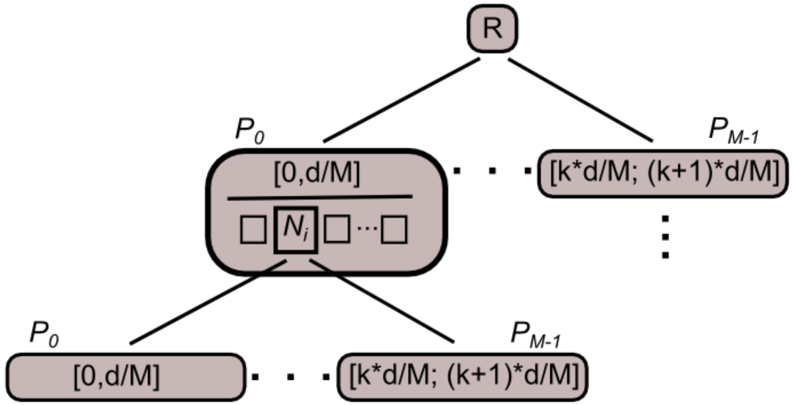
- Using extracted features of known targets to recognize targets from the same class later
- Must work with a low number of samples
  - Content based retrieval approach
- Feature representation
  - feature maps → objects → contours → tangent/turning functions
- “Training”: indexing known samples
- Classification: retrieval step
  - Search for similar samples in the index
  - Propose class of best match(es)



# Classification

- Index structure
  - Structure based on BK-trees (BK*-tree [1])
  - Metric tree for single feature
  - Quick building
  - Distance metric:
    - compare turning functions
- Easy to extend and update with new elements
  - No training/re-training needed

All elements in a sub-tree of a node belong to the same difference interval w.r.t. the node

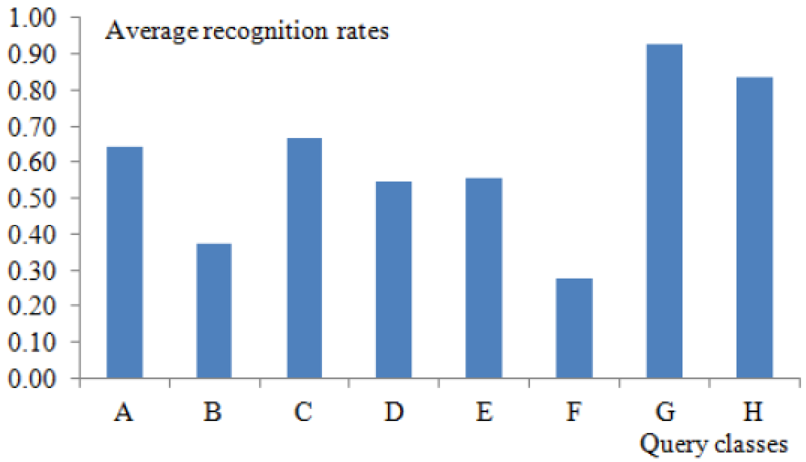


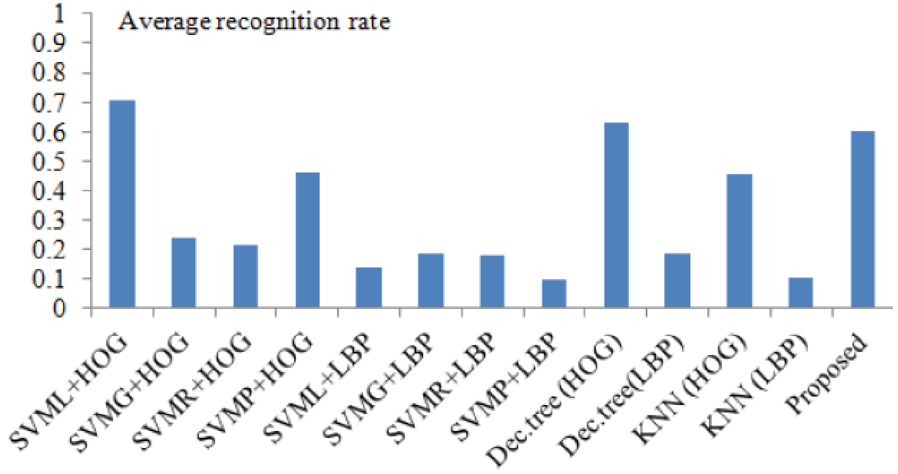


*[1] L. Kovács, "Parallel multi-tree indexing for evaluating large descriptor sets," in Proc. of IEEE Intl. Workshop on Content-Based Multimedia Indexing (CBMI), 2013, pp. 173–178.*

# Evaluation

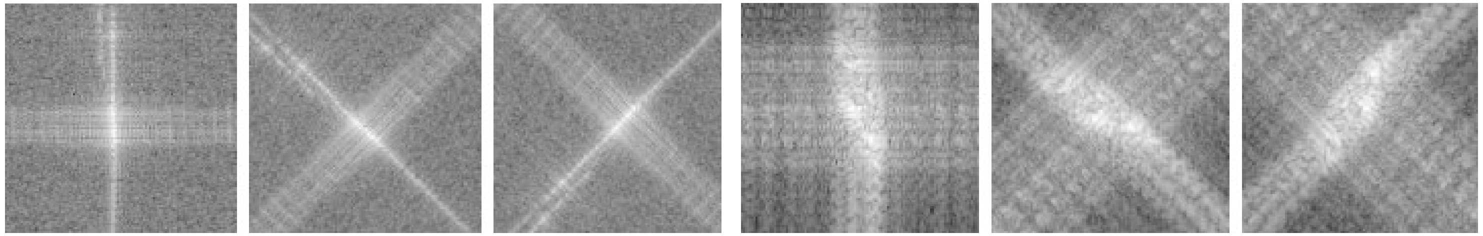
- Dataset of 128 real passive ISAR range-crossrange images of 8 targets (A-H)
  - 2 aerial (planes), 6 nautical (ships)
- Compared with SVM classifications
  - using histogram of oriented gradients (HOG) and
  - local binary pattern (LBP) features
  - linear (SVML), Gaussian (SVMG), RBF (SVMR) and polynomial (SVMP) kernels
  - decision tree (Dec.tree) and k nearest neighbor (kNN) learner templates
- Random 75% of the dataset used for training and 25% for testing

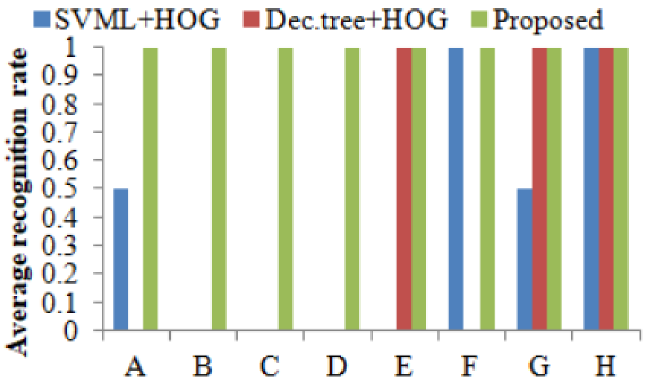


# Evaluation

- Extended evaluation
  - created 2 rotated (with 45 and 135 degrees) versions of 1 raw input image from each class (16 images in total)
  - classify rotated versions using the proposed approach and the best performers

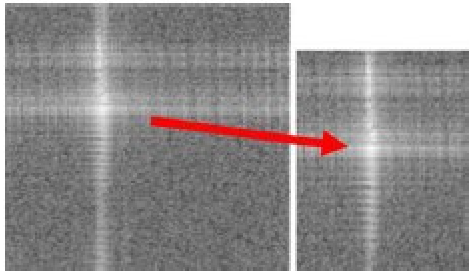


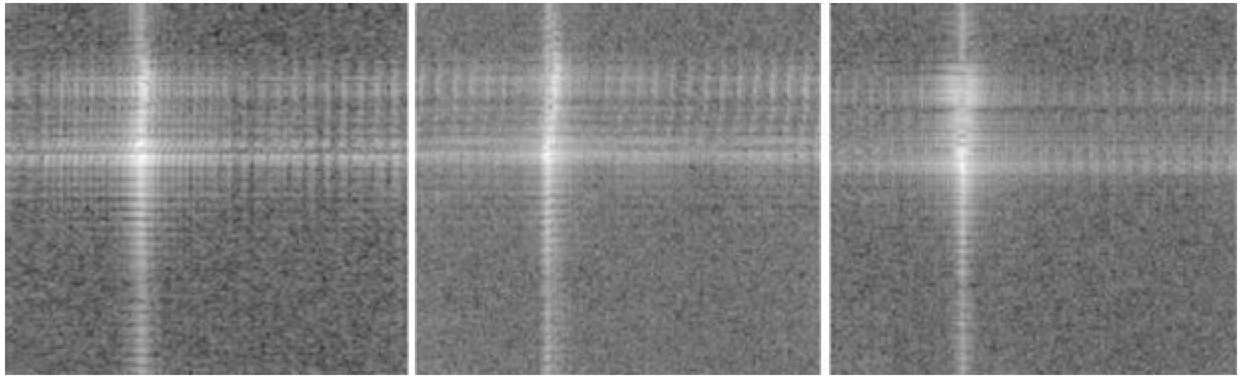


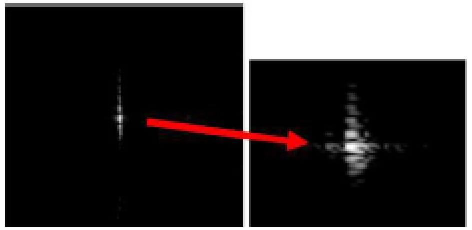

 

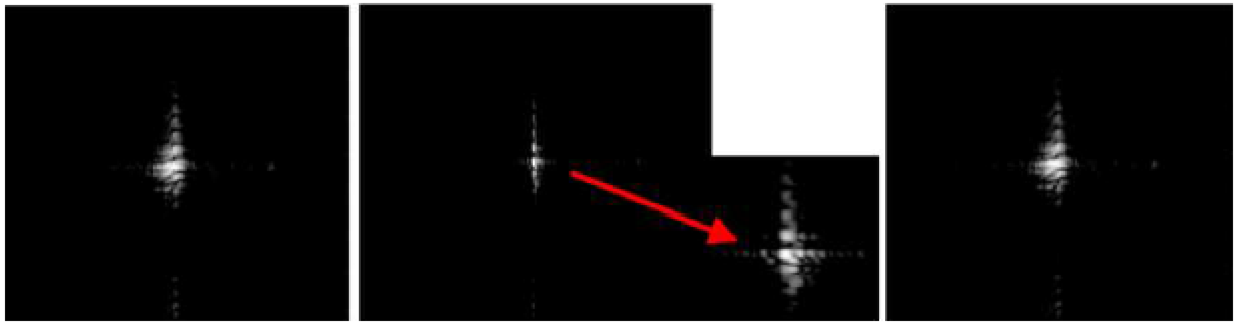
# Evaluation

- Examples for queries & responses









# Evaluation

- Measured training/indexing and prediction/retrieval times

| Methods | Indexing/training (s) | Classification/prediction (s) |
|---|---|---|
| Proposed | 2.87 | 0.20 |
| SVML+HOG | 17.39 | 1.79 |
| SVMP+HOG | 58.38 | 8.63 |
| Dec.tree(HOG) | 107.12 | 0.11 |
| KNN(HOG) | 23.02 | 16.30 |

- Proposed method
  - lightweight and fast both in indexing and in retrieval
  - only needs to build the index once (later elements added to the index) vs others: training needs to be repeated

# Future work

- More data
- More extensive evaluations
- Increase robustness
- Increase classification performance
- Processing image sequences

*A. Manno-Kovacs, E. Giusti, F. Berizzi, L. Kovács: Image Based Robust Target Classification for Passive ISAR, IEEE Sensors Journal, accepted Oct. 2018.*

# Thank you!

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