



# Fully automatic catheter localization in C-arm images using l1-Sparse Coding

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## Motivation

- Minimally invasive procedures rely on navigation
- Automatic Catheters tracking and detection
  - ✓ Facilitates navigation
  - ✓ Enables 3D reconstruction of the catheters w.r.t. Patient
  - ✓ Reduces surgery time and exposure to radiations



## Previous Work

- Methods based on Manual Initialization [1]
- Methods based on blob detection and geometric constraints [2]

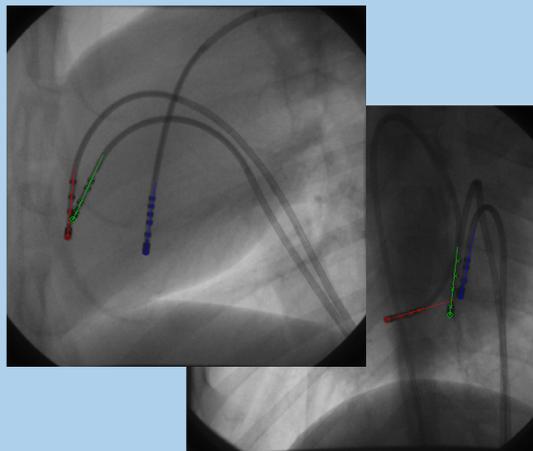
## Our contribution

- Robust detection and tracking method based on:
  - Blob-like feature detection to constrain search space
  - Feature-specific intensity context (intensity profiles)
  - Hypotheses selection and scoring using l1-sparse coding

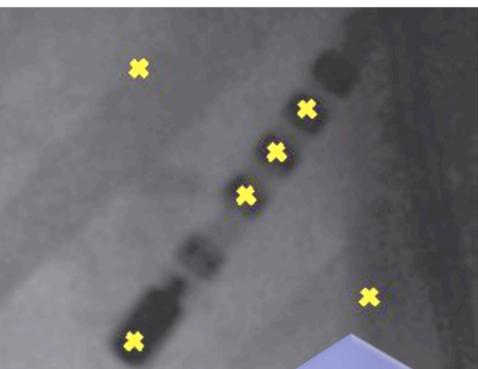
## Training Stage

- Dictionaries used for **tips** detection
  - Dictionary  $D_T$  containing patches collected around annotated tips
  - Dictionary  $D_E$  containing patches collected around annotated electrodes
- Dictionaries used for **candidate** scoring
  - Dictionaries of intensity profiles collected from annotated catheters  $D_K$
  - Meta-data: for each profile store electrodes positions
  - Dictionaries of "negative" intensity profiles  $D_N$  collected from background

## Results

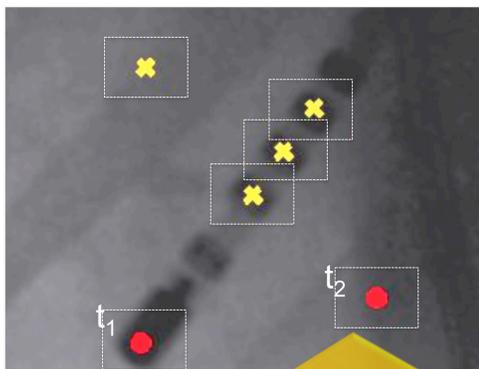


- Tested on 2835 images (20 sequences)
- Three catheters
- 50 intensity profiles used for training
- ~ 97% global detection rate
- Average precision ~ 0.5 mm ± 0.1 mm



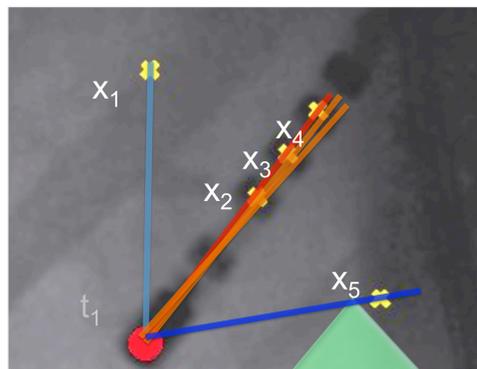
### Pre-processing step

- Image enhancement via Homomorphic filter
- Noise Suppression via bilateral filtering
- Interest Point detected via determinant of Hessian



### Tips detection step

- Two dictionary containing
  1. Patches depicting tips  $D_T$
  2. Patches depicting electrodes  $D_E$
- Enable tip discrimination
- Through reconstruction errors  $\|D_T \hat{\alpha}_t - y_i\|_2^2 < \|D_E \hat{\alpha}_e - y_i\|_2^2$



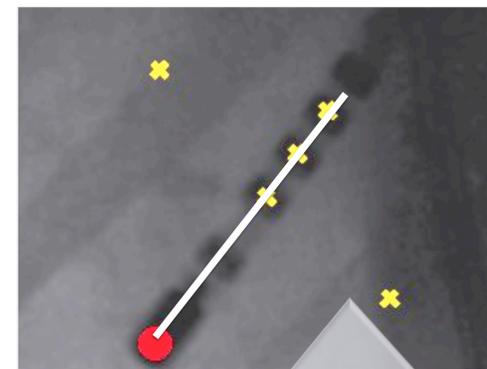
### Candidate catheters scoring

- Each Candidate catheter is represented by line joining  $n$ -th catheter tip and  $i$ -th electrode
- Intensities are sampled from lines
- Intensities reconstructed via each  $k$ -th catheter specific dictionary, solving:

$$\hat{\alpha}_{ni}^k = \min_{\alpha_{ni}^k} \|D_k \alpha_{ni}^k - I_{ni}\|_2^2 + \lambda_3 \|\alpha_{ni}^k\|_1$$

- And dictionary encoding "negative" profiles:

$$\hat{\beta}_{ni}^k = \min_{\beta_{ni}^k} \|[D_N, D_{j \neq k}] \beta_{ni}^k - I_{ni}\|_2^2 + \lambda_4 \|\beta_{ni}^k\|_1$$



### Hypotheses selection

- Candidate catheters are scored according to:

$$E_{ni}^k = \begin{cases} d E_P & \text{if } E_P \geq E_N \\ d \frac{E_P}{E_N - E_P} & \text{if } E_P < E_N \end{cases}$$

- $E_P$  and  $E_N$  are reconstruction errors obtained via catheter specific and "negative" profiles dictionaries

- Multiple Catheters → Hungarian Algorithm for best global hypothesis selection

## Meta-Data

- Each catheter specific dictionary word is associated with ground truth position of electrodes w.r.t. tip
- Therefore we can recover undetected electrodes

## References

- [1] - Wu, W., Chen, T., Barbu, A., Wang, P., Strobel, N., Zhou, S.K., Comaniciu, hypothesis fusion for robust catheter tracking in 2d x-ray fluoroscopy. In: CVPR, IEEE (2011) 1097-1104
- [2] - Ma, Y., Gogin, N., Cathier, P., Housden, R.J., Gijbbers, G., Cooklin, M., O'Neill, M., Gill, J., Rinaldi, C.A., Razavi, R., et al.: Real-time x-ray fluoroscopy-based catheter detection and tracking for cardiac electrophysiology interventions. Medical physics 40(7) (2013) 071902