



# Left Ventricle Segmentation in Cardiac Ultrasound Using Hough-Forests With Implicit Shape and Appearance Priors

Fausto Milletari<sup>1</sup>, Mehmet Yigitsoy<sup>1</sup>, Nassir Navab<sup>1,3</sup>, and Seyed-Ahmad Ahmadi<sup>2</sup>

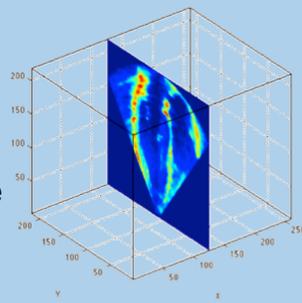
1. Computer Aided Medical Procedures, Technische Universität München, Germany

2. Department of Neurology, Klinikum Grosshadern, Ludwig-Maximilians-Universität München, Germany

3. Computer Aided Medical Procedures, Johns Hopkins University, USA

## Motivation

- US has advantageous properties for cardiac imaging
  - Radiation free
  - Real-Time
- Cardiac functionality assessed via Left Ventricle volume estimation
- Manual segmentation of Left Ventricle is time-consuming



## Related Work

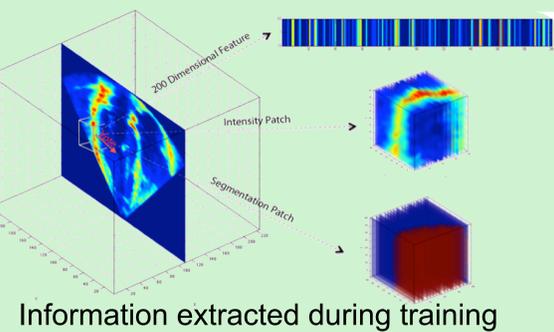
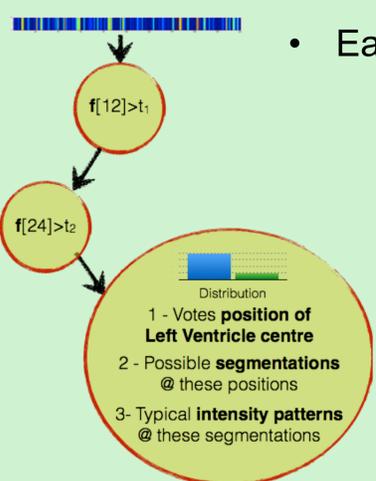
- Pedestrian segmentation using Hough forests [1]
- Automatic LV segmentation based on deep learning [2]

## Our contribution

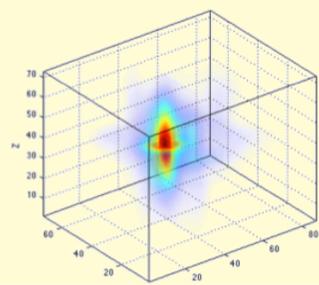
- Fully automatic segmentation method based on Hough forest
  - Incorporates shape and appearance knowledge
  - Predicts position of the LV center
  - Predicts probabilistic segmentation

## Training Stage

- Each data-point from training images
  - Corresponds to a patch
  - Is described by N-dimensional intensity based feature vector
  - Carries spatial displacement between itself and LV center
  - Is associated with segmentation patch from ground truth
  - Is associated with appearances occurring in correspondence of segmentation
  - Foreground = boundaries in US image

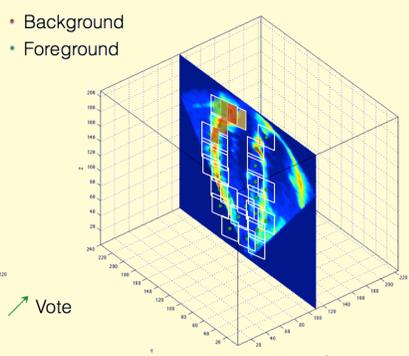
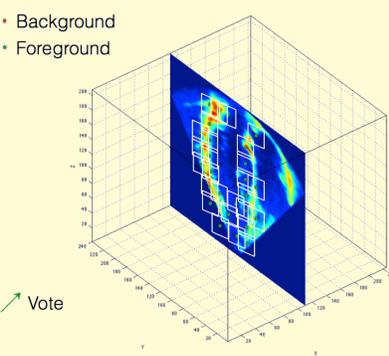
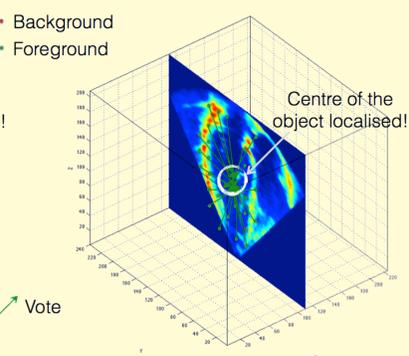
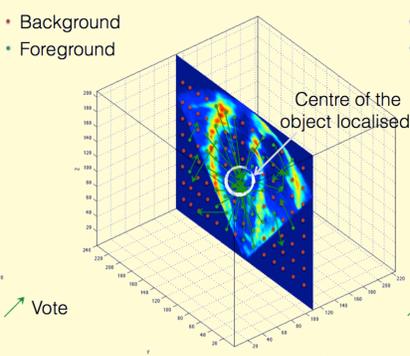
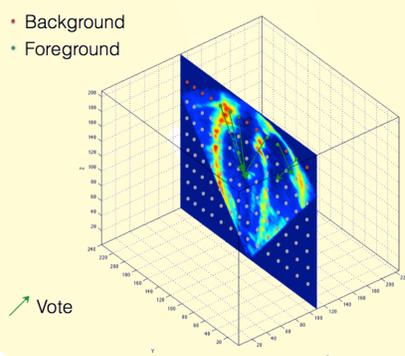


Votes accumulation volume



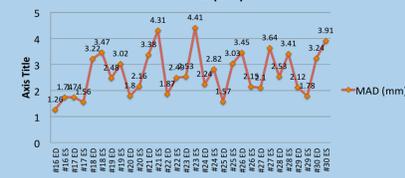
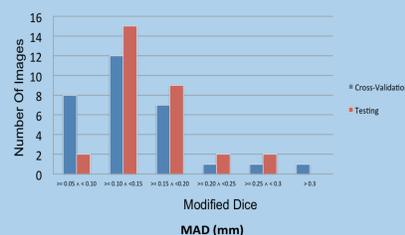
## Testing Stage

- Object center localization
  - Classification of each data-point
  - Data-points that are classified as foreground vote for LV center
  - Votes are weighted by confidence and accumulated into volume
  - Position of maximum accumulation is LV center
- Contour Estimation
  - Each vote falling near LV center re-projected to position  $x$  of the data-point that cast it
  - Obtain segmentation patch  $S_p$  corresponding to the vote from the code base
  - Recover intensity patch  $I_p$  corresponding to  $S_p$
  - Apply segmentation  $S_p$  at location of data-point after weighting with truncated NCC between  $I_p$  and the intensities around  $x$
  - Accumulate segmentation patches and normalize to obtain final segmentation



## Results

- 15 end-diastolic test images:
  - Mean Absolute Distance: 2.37 mm
  - Mean Hausdorff distance: 9.52 mm
  - Mean mod. Dice coefficient: 0.123
- 15 end-systolic test images:
  - Mean Absolute Distance: 2.93 mm
  - Mean Hausdorff distance: 8.64 mm
  - Mean mod. Dice coefficient: 0.166



## Conclusions

- Bigger segmentation patches generate smoother contours
  - More shape than appearance regularization
- Outliers during classification do not degrade performance
  - Unless their votes accumulate in strong peaks
  - Prefer features that are directionally discriminative instead of class discriminative

## References

[1] Rematas, K., Leibe, B.: Efficient object detection and segmentation with a cascaded hough forest. In: Computer Vision Workshops (ICCV Workshops), 2011 on. pp. 966–973 (Nov 2011)  
 [2] Carneiro, Gustavo, Jacinto C. Nascimento, and António Freitas. "The segmentation of the left ventricle of the heart from ultrasound data using deep learning architectures and derivative-based search methods." *Image Processing, IEEE Transactions on* 21.3 (2012): 968-982.