# Potential contour ensembles


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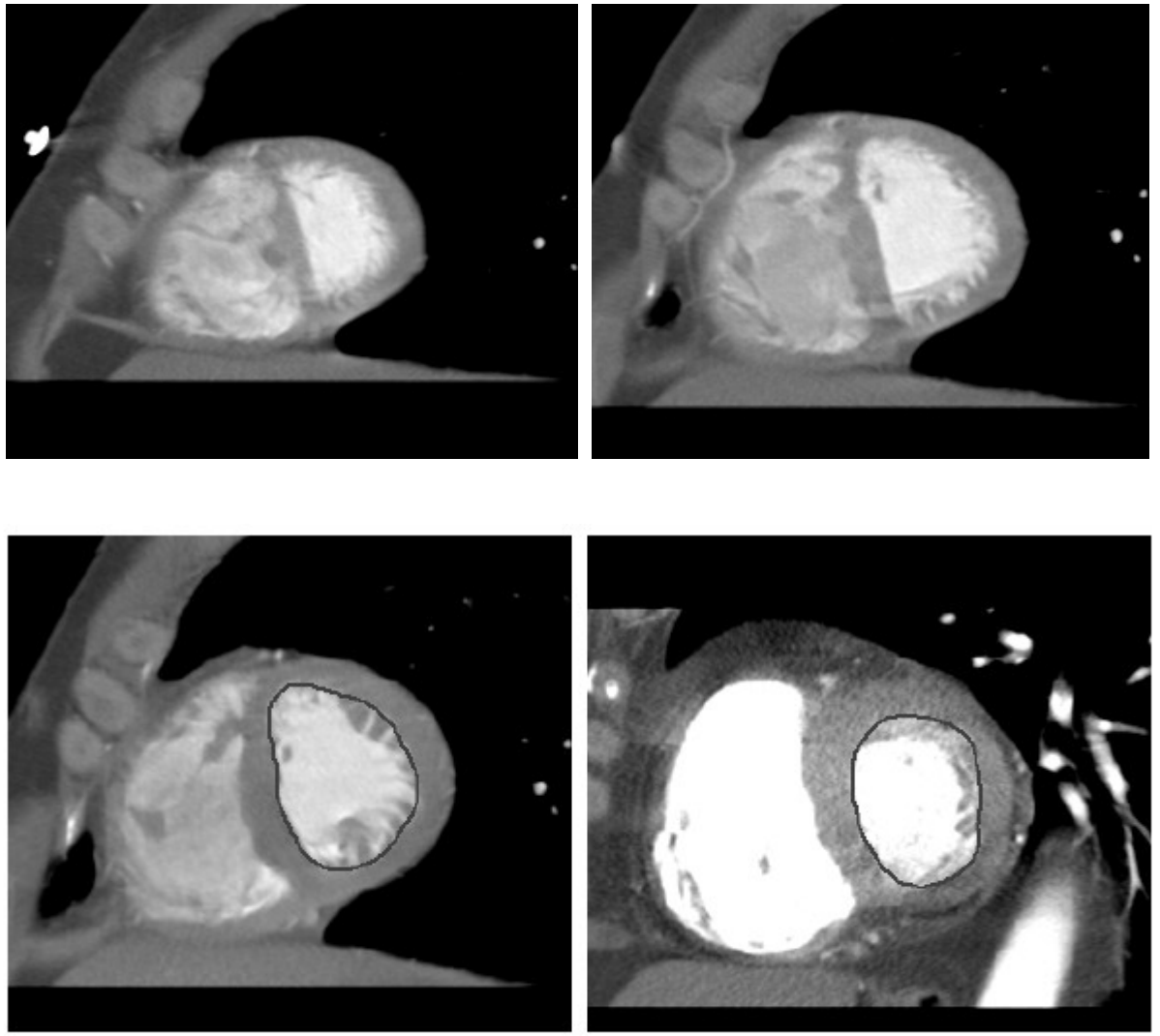
# Problem

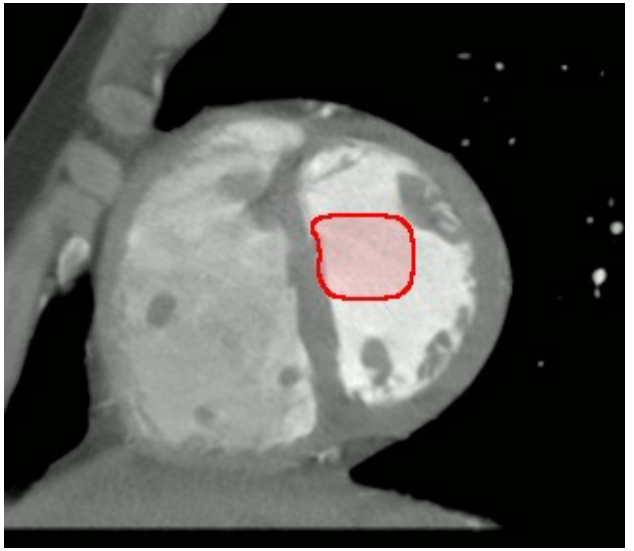


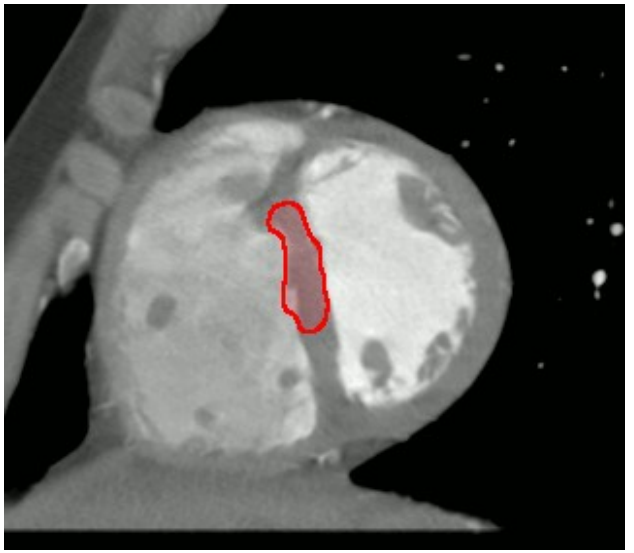
(a) (b)

- Detection of heart ventricle contours
- Pulmonary embolism diagnosis
- ECG-gated 64-row computed tomography scanner
- Contrast injection
- 4D sequences
- Manually drawn contours

# Active contours

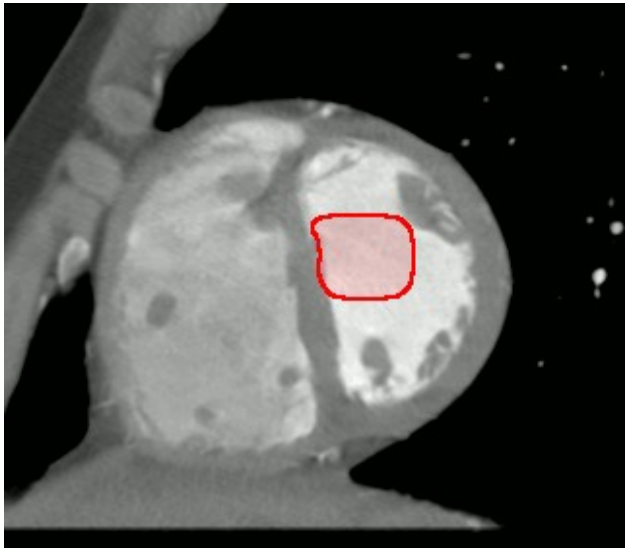
- Image segmentation
- Energy (objective function)
- Optimization (evolution)
- Heuristic expectations  about resulting contour:
  - Image based
  - Domain based
- Snakes, geometric active contours, active shape models

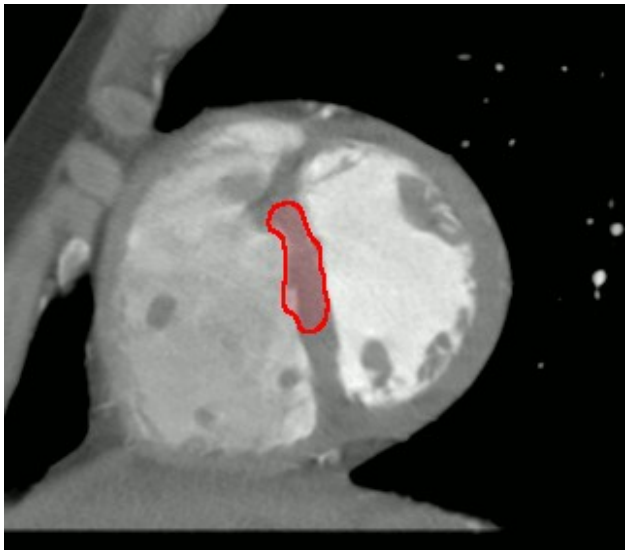




# Relationship

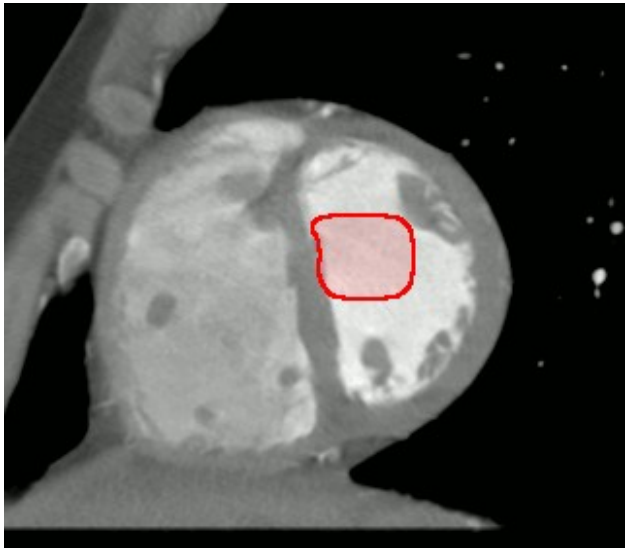
- Contour can be considered as a binary classifier of pixels:
  - Two labels: object and background
  - It reflects decision boundary
- Contour evolution can be considered as a classifier training
- This observation has many consequences

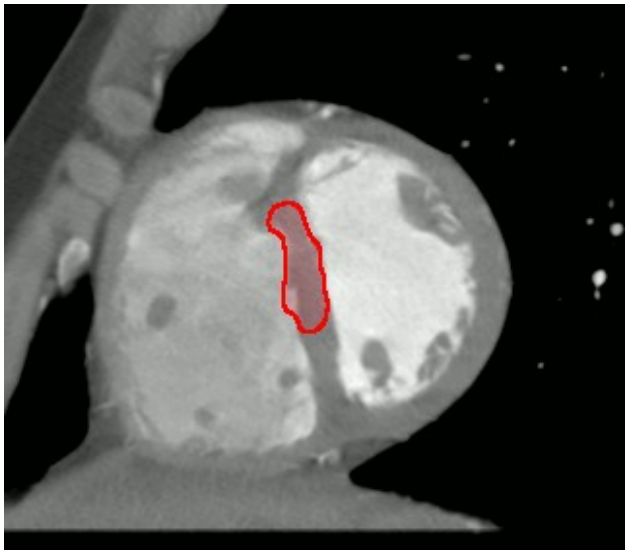




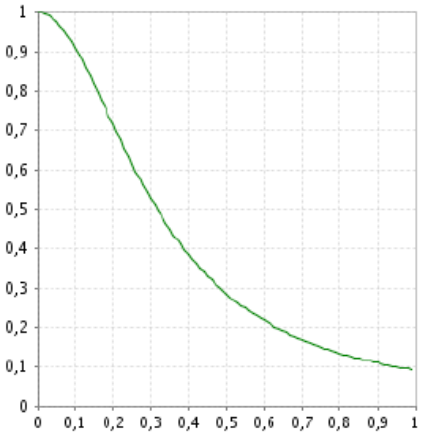
# Differences

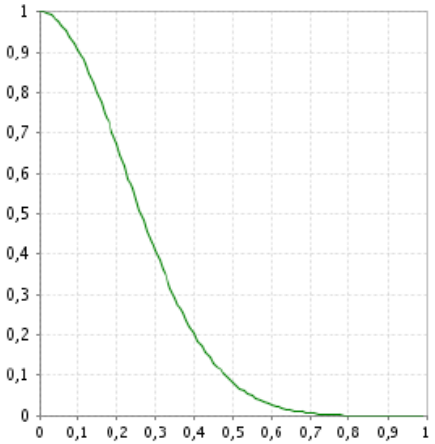
- Contextual classification of pixels
- Context and features need not to be determined explicitely
- Training objective requires evaluation of the either partial or full labeling:
  - Margin maximization
  - Regularization





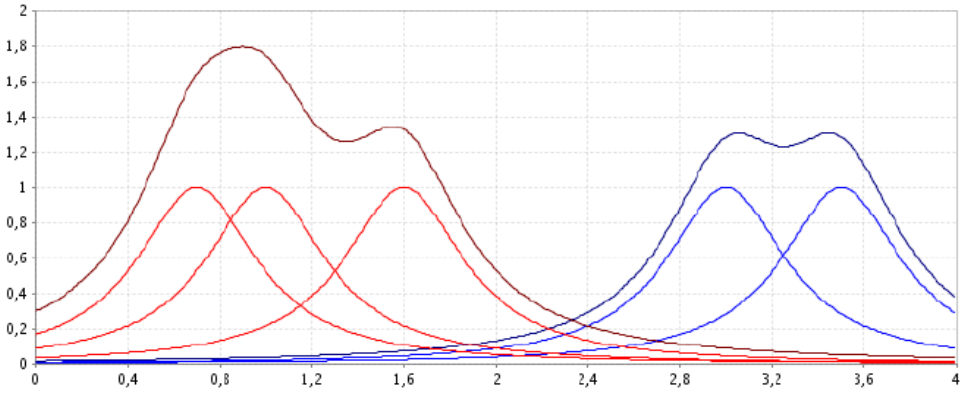
# Potential function classifier

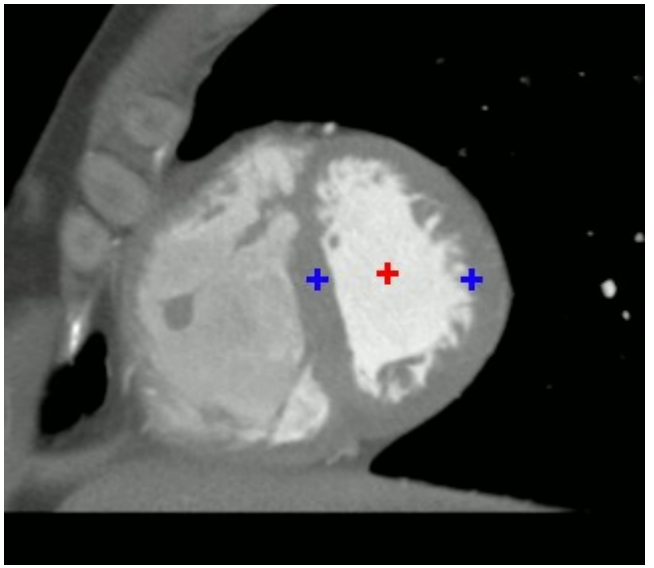



$$\mathrm{P}(d) = \frac{\Psi}{1 + \mu d^2}$$

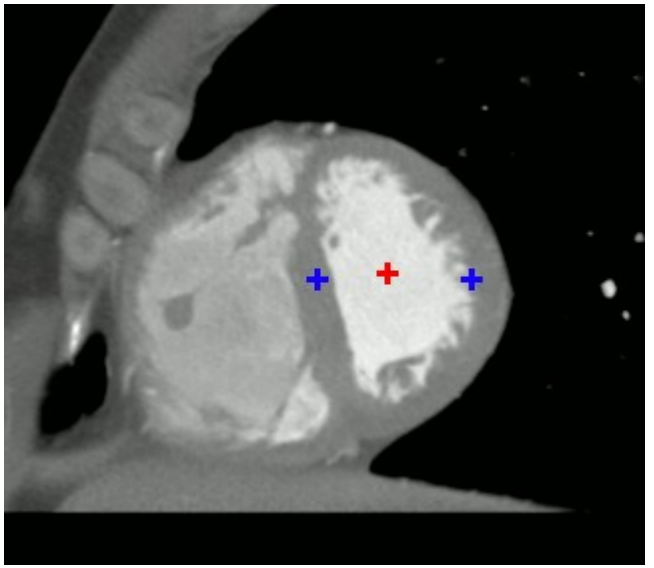
$$\mathrm{P}(d) = \Psi e^{-\mu d^2}$$



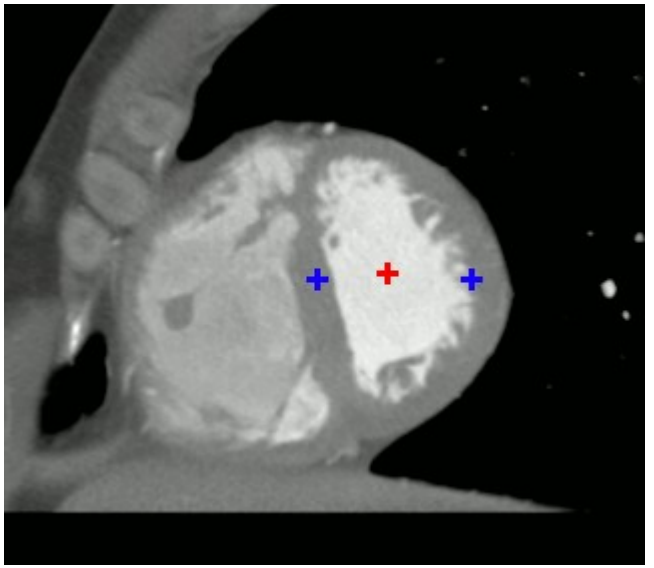
# Potential contour

- Contour:
  - It is smooth
  - It has a small number of parameters
- Parameters:
  - Number of potential sources
  - Position of potential sources
  - Parameters of potential source



# Potential active contour

- Typical limitations:
  - Contour initialization
  - Specific form of energy function
- Simulated annealing:
  - Global optimum
  - Only objective function value is required
  - Large number of iterations
  - Randomized algorithm



# Energy

(c) (d)

- Expectation about optimal contour:

  *It should be the smallest, smooth contour containing all pixels representing blood inside the ventricle.*

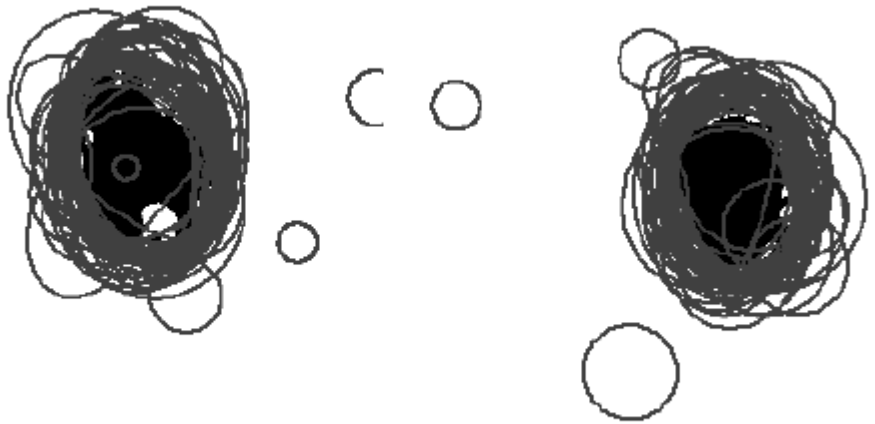
$$\mathrm{E} = w\mathrm{E}^o + \mathrm{E}^a$$

# Classifier ensemble


- Classifier ensembles:
  - Ensemble members can be weak classfiers
  - They must be trained independently (diversity)
  - Members answers must be aggregated
- Bagging, boosting, random forests
- Independent training:
  - Random subsets of a training data
  - Random classifier models

# Potential contour ensemble

- Independent contour evolution (hypothesis):
  - Training objective is the same
  - Early stopping of randomized optimization algorithm



(a) (b)

# Aggregation

- Best member

$$c(x,y) = c_{\arg\min_{i=1,\ldots,N} \mathrm{E}_i}(x,y)$$

- Votes of members

$$c(x,y) = \begin{cases} \text{object} & \text{if } \sum_{i=1}^{N} \mathrm{I}(c_i(x,y) = \text{object}) > tN \\ \text{background} & \text{otherwise} \end{cases}$$

- Weighted votes of members

$$c(x,y) = \begin{cases} \text{object} & \text{if } \sum_{i=1}^{N} e_i \mathrm{I}(c_i(x,y) = \text{object}) > t \sum_{i=1}^{N} e_i \\ \text{background} & \text{otherwise} \end{cases}$$

where

$$e_i = 1 - \frac{\mathrm{E}_i - \mathrm{E}_{min}}{\mathrm{E}_{max} - \mathrm{E}_{min}}$$

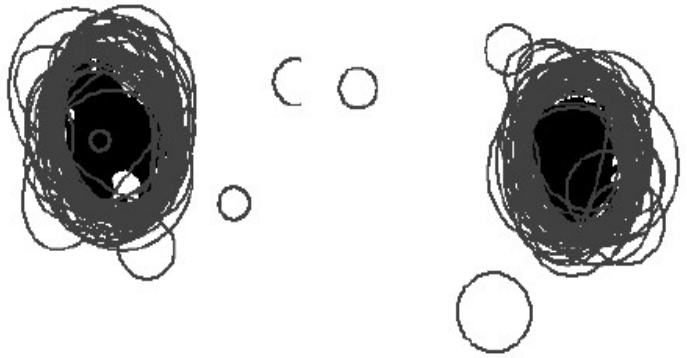
# Experiments

- Assumptions:
  - The method should require a reasonable number of iterations
  - The results should be repeatable
- Compared models:
  - Potential contour ensemble with 50 members
  - Traditional potential contour trained 50 times longer than members of the ensemble
- Comparison for 160 images in experiments repeated 10 times

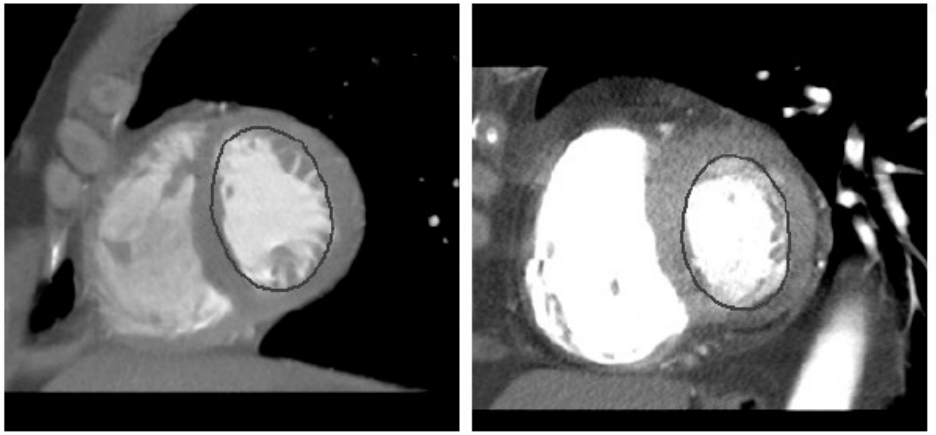
# Evaluation

- Repeatability:
  - The same method was repeated 20 times
  - Probablity of assigning a given label to a pixel was calculated
  - Sum of entropies for all the pixels
- Segmentation:
  - Precision (how many background pixels was incorrectly classified as pixels of the object)
  - Recall (how many object pixels was incorrectly assigned to the background)

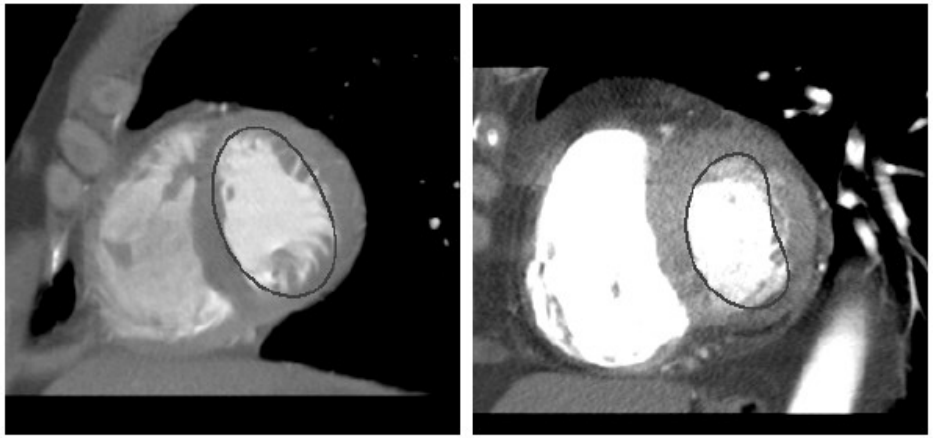
# Results



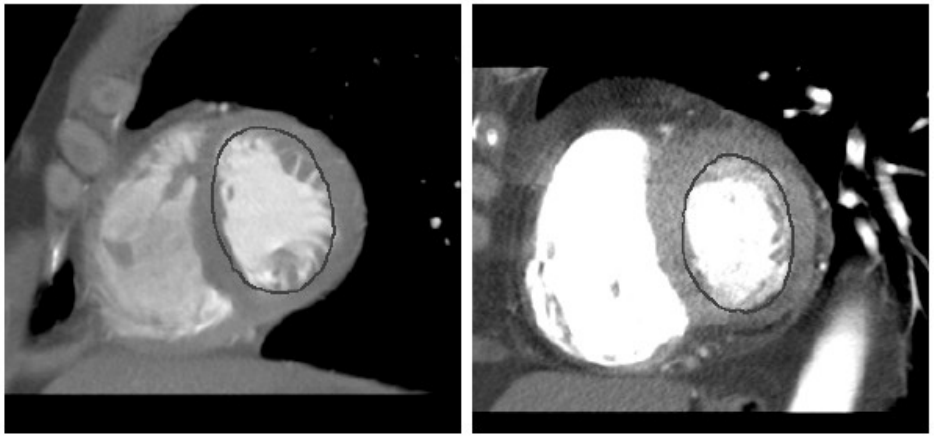
(a) (b)



(e) $A^v$ (f) $A^v$



(c) $A^b$ (d) $A^b$



(g) $A^w$ (h) $A^w$

# Results

- At least two times lower (better) values of repeatability measure
- Best member aggregation gives the best combined results but those results are not guaranteed
- Weighted votes of members aggregation gives the best balance of precision and recall values

(c)

| | $F_1$ | | | $P$ | | | $R$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | better | value | change | better | value | change | better | value | change |
| $A^b$ | 86,3% | 0,917 | +0,067 | 87,7% | 0,895 | +0,115 | 42,4% | 0,944 | -0,003 |
| $A^v(0.5)$ | 76,6% | 0,896 | +0,046 | 82,1% | 0,870 | +0,091 | 46,2% | 0,931 | -0,016 |
| $A^w(0.5)$ | 75,6% | 0,892 | +0,042 | 72,8% | 0,836 | +0,056 | 68,4% | 0,961 | +0,014 |

# Summary

- Conclusions:
  - Contour ensembles can be successfully used for image segmentation
  - Contour ensemble increases the stability of the results in case of randomized optimization algorithms
- Further investigation:
  - Other contour models.
  - Heuristic training of regular classifier models.