Adaptive Automatic Target Recognition for CT-Based Object Detection Systems

Dong Hye Ye: Research Assistant Professor
(Machine Learning for Image Segmentation and Classification)

Charles Bouman: Showalter Professor
(CT Reconstruction and Artifact Removal)

School of Electrical and Computer Engineering, Purdue University
yed@purdue.edu, bouman@purdue.edu

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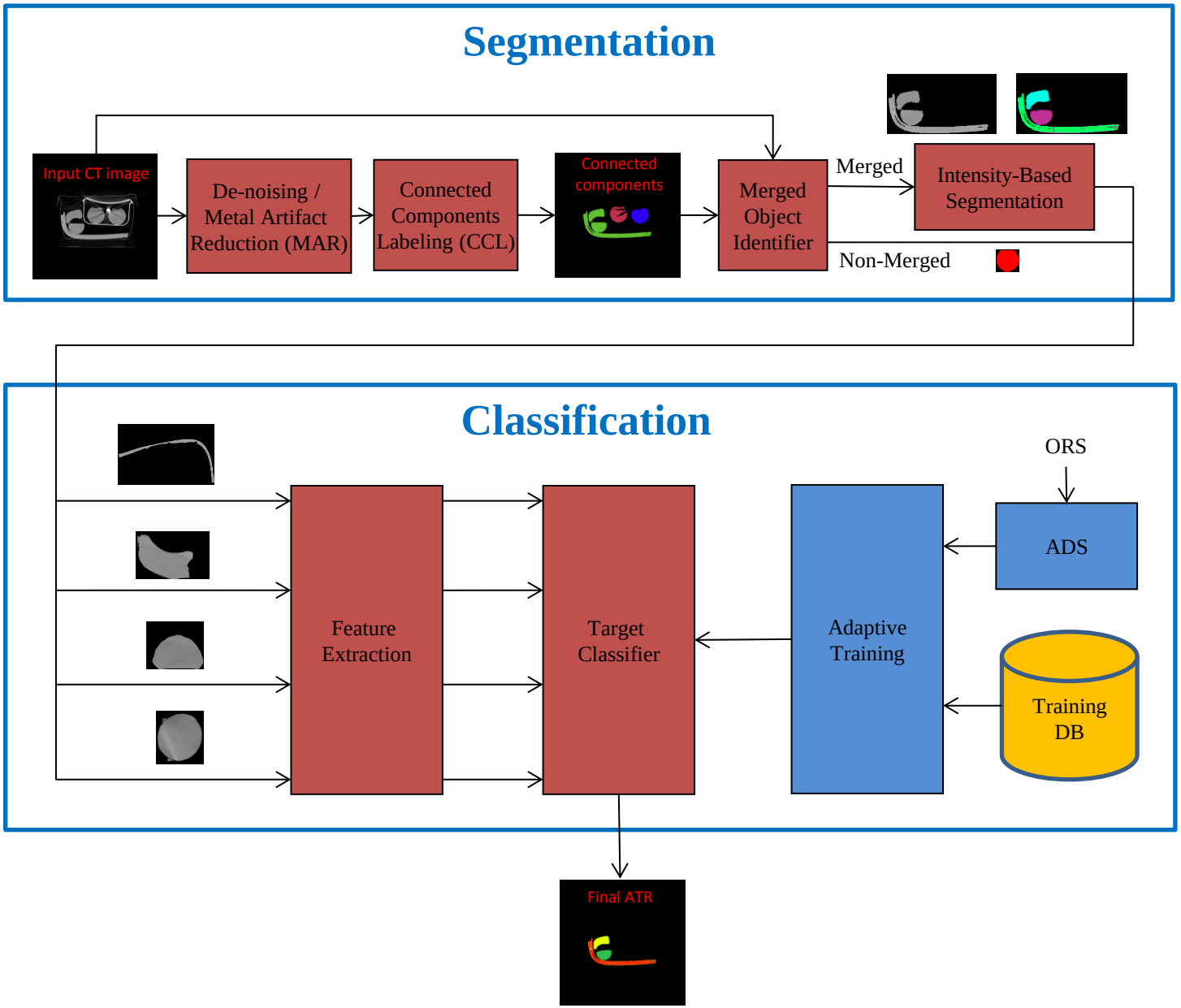
AATR: High Level Overview

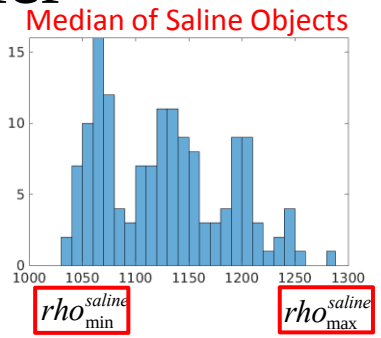


AATR: Specifications

- Target PD/PFA: Find the best parameter in 10-fold CV which maximizes weighted PD and matches target PFA

$$\arg\max_{q} \sum_{i} T_{PD}^{i} \times CV_{PD}^{i}(q) \quad \text{s.t. } CV_{PFA}(q) < T_{PFA}$$

- MinMass/MinThickness: Bulk/Sheet Classifier
  - Bulk: Threshold by MinMass
  - Sheet: Threshold by MinThickness

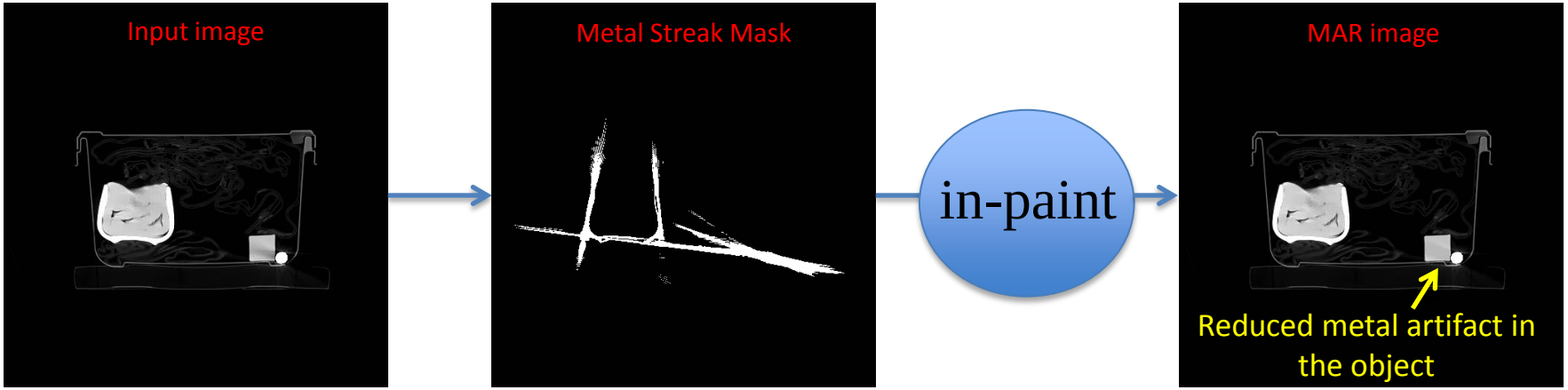


- Objects of Interests: Ground-Truth in Training DB
  - Known (Saline, Rubber, Clay): Manual Ground-Truth
  - Unknown: Selected Objects by Median

$$rho_{\min} < median < rho_{\max}$$

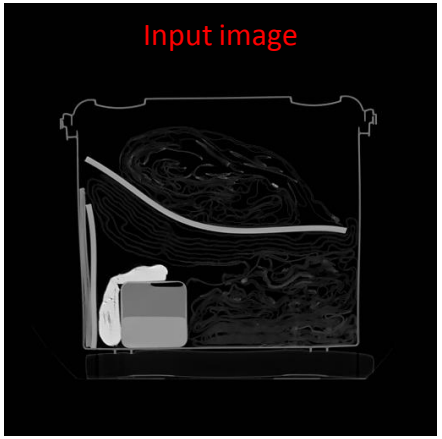
Segmentation: Metal Artifact Reduction

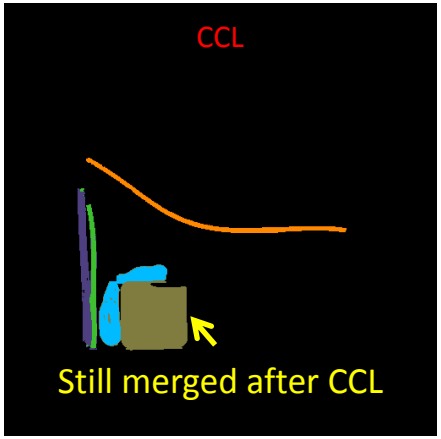
1. Detect metal streak mask: Beam-hardening model
2. In-paint streak mask region: Dictionary-learning

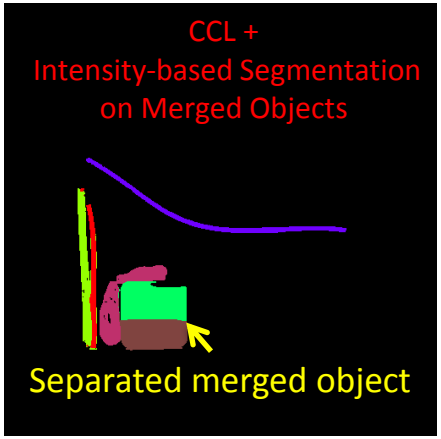


ICIP 2015 Best Paper Runner-Up

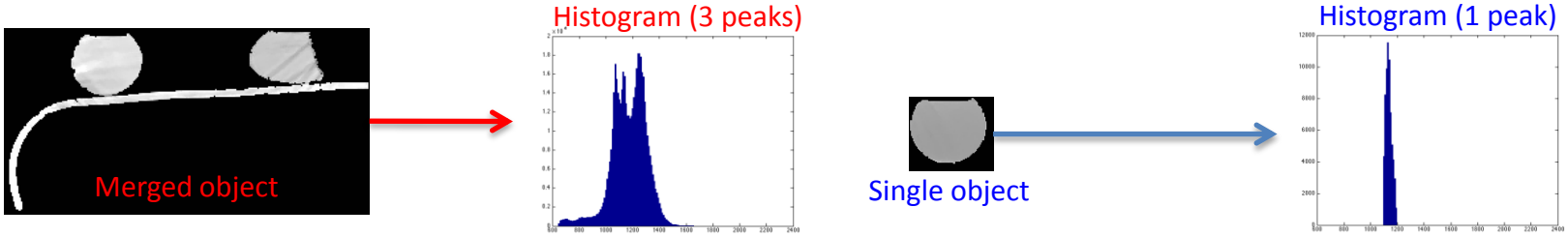
Segmentation: Merged Object Separation







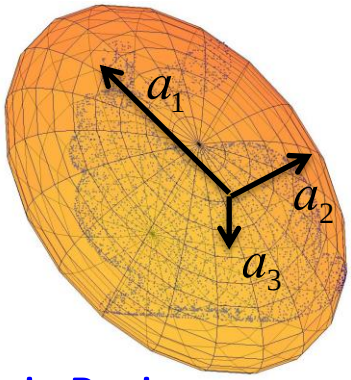
1. Identify merged objects: Histogram Peak Analysis

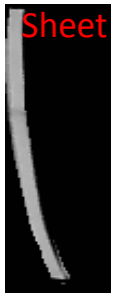


2. Apply multi-label segmentation: Potts Model
   - Intensity-based fidelity + Label smoothness regularization
   - Convex optimization with probability constraints

Classification: Features

- Shape Features: Minimum volume enclosing ellipsoid
  - Ellipsoid axes : a_1, a_2, a_3
  - Axis ratio: $\min\{a_1, a_2, a_3\} / \max\{a_1, a_2, a_3\}$
  - Volume ratio: object volume / ellipsoid volume

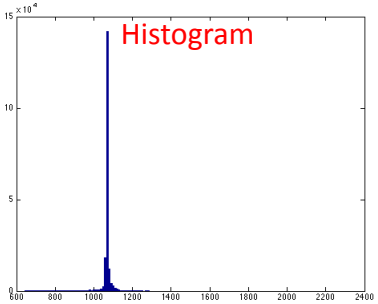




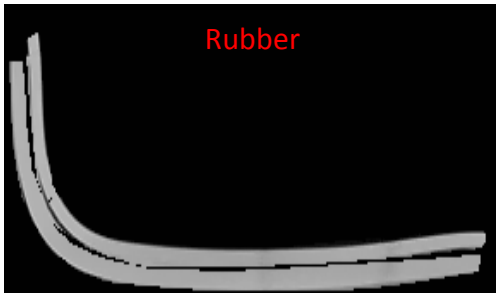
Small Axis Ratio
0.1425

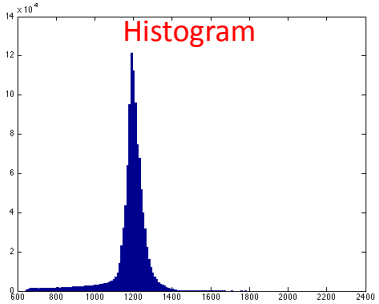
Large Axis Ratio
0.5879

- Target Features: Normalized Histogram



Location of Max histogram: 1070

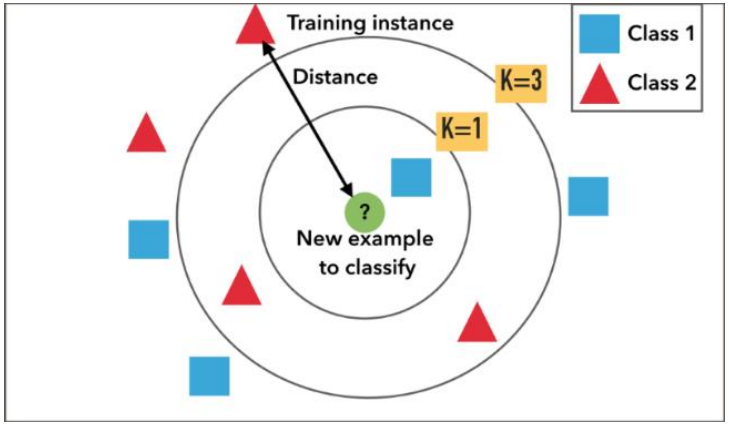




Location of Max histogram: 1190

Classification: Classifier

- k-Nearest Neighbor (kNN) classifier
  - Inference based on the distance to the training data
  - Very efficient training: kd-tree



- Parameters
  - Distance: $d_{ij} = \sqrt{(\mathbf{f}_i - \mathbf{f}_j)^T \mathbf{V}^{-1} (\mathbf{f}_i - \mathbf{f}_j)}$
    - Euclidean, Standardized Euclidean, Mahalanobis

$(\mathbf{V} = \mathbf{I})$ Identity $(\mathbf{V} = \mathbf{S})$ Standard Deviation $(\mathbf{V} = \mathbf{C})$ Covariance

  - Number of neighbors: k=[1,2,…,7,8]

Performer Training / TO4 Data

AM 1: AROC

OOI	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]
S	70	2	84	3
S	80	5	89	6
S	85	8	90	7
S	90	10	91	10
S	95	20	91	10

AROC	0.9342

AM 2: PD/PFA for Varying OOIs (ORS #1 only)

OOI	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]
C,S,R	90	10	89	14
C	90	10	94	
S	90	10	90	
R	90	10	86	

AM 3: Varing PD Weight

OOI	Req PD [%]	Req PFA [%]	AATR PD [%]	AATR PFA [%]
C,S	C:90, S:90	10	C: 96 S: 83	12
C,S	C:20, S:90	10	C: 95 S: 87	13
C,S	C:90, S:20	10	C: 96 S: 83	14

AM 4: PD/PFA for Varying Mass

OOI	Min Mass [g]	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]	Incremental Mass Rnge [g]	AATR Incremental PD [%]
S	400	90	10	96	7	N/A	N/A
S	300	90	10	93	9	300 - 400	90
S	100	90	10	91	11	100 - 300	90

AM 5: PD/PFA for Varying Thicness

OOI	Min Thickness [mm]	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]	Incremental Thickness Rnge [mm]	AATR Incremental PD [%]
R	10	90	10	94	8	N/A	N/A
R	6.5	90	10	91	9	6.5 - 10	86
R	0	90	10	88	9	0 – 6.5	80

ALERT Testing / TO7 Data

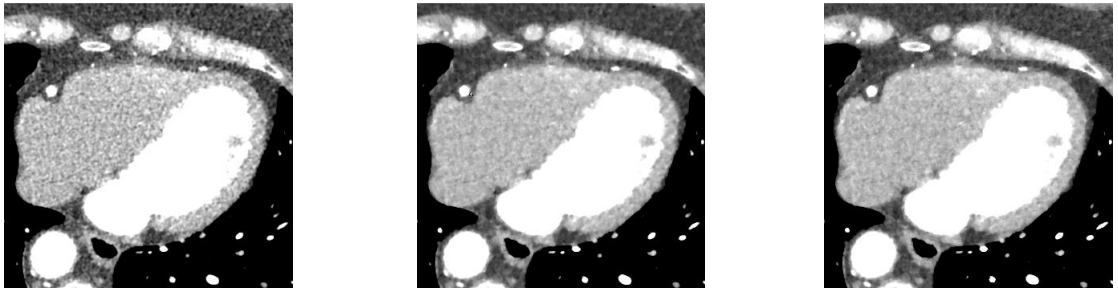
AM 2: PD/PFA for Varying OOIs

OOI(s)	Required PD [%]	Required PFA [%]	AATR PD [%]	AATR PFA [%]
m1	90	10	83	14
m2	90	10	100	13
m3	90	10	100	12
m4	90	10	100	6

Future Works

- Deep Learning for CT De-noising **ICASSP 2018 Invited**
  - Improved Segmentation/ Feature Extraction

FBP (PSNR: 18.73dB)	De-noising (PSNR: 19.68dB)	Ground-Truth MBIR



- Deep Learning for Target Classification
  - Higher PD/ Lower PFA
- Generative Adversarial Networks (GAN)
  - Synthetic Normalized Histogram for Unknown Materials