

Breast Ultrasound Image Segmentation: an optimization approach based on super-pixels and high-level descriptors

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Quality Control by Artificial Vision
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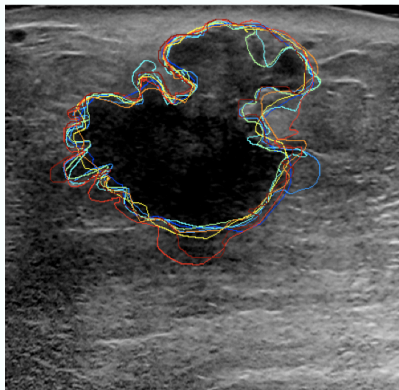
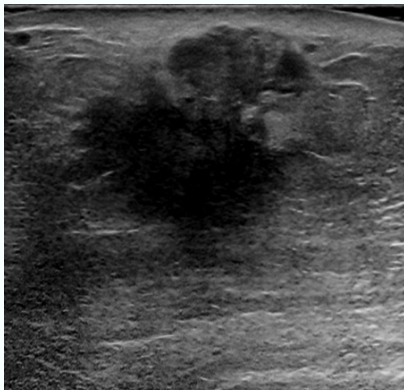


Features Training CostFunction
Data 12CVB ComputerAidedDiagnosisCAD
InterIntraObserver Lesion
ModelLearning SearchSpace
Segmentation
OpenResearch Modeling SuperPixel AreaOverlap Imaging
Stochastic
Minimization BIRADS Cancer
Ultrasound Breast GraphCuts
MachineLearning

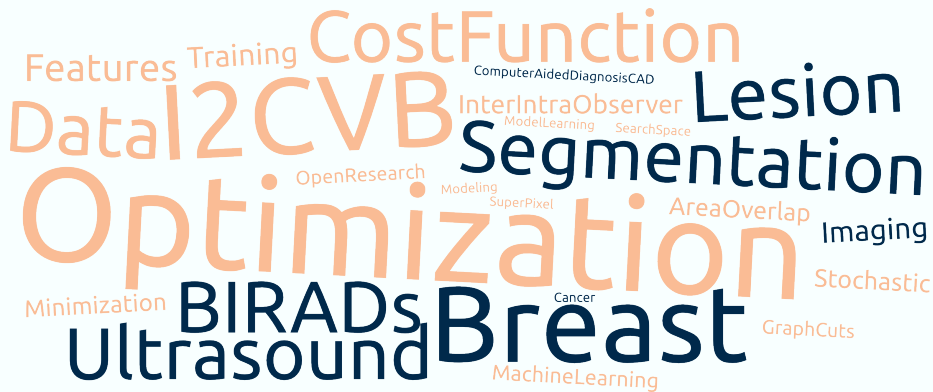
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Breast Lesion Segmentation in US images



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ComputerAidedDiagnosisCAD
ModelLearning SearchSpace
Cancer



A word cloud visualization of terms related to medical image segmentation and optimization. The words are arranged in a dense, overlapping manner, with colors ranging from dark blue to light orange. The most prominent words are 'Optimization' and 'Segmentation', both in large, dark blue font. Other significant words include 'CostFunction', 'Lesion', 'Breast', 'Ultrasound', 'BIRADs', 'Data', '2CVB', 'Features', 'Training', 'Minimization', 'MachineLearning', 'Stochastic', 'Imaging', 'AreaOverlap', 'OpenResearch', 'Modeling', 'SuperPixel', 'Cancer', 'InterIntraObserver', 'ModelLearning', 'SearchSpace', 'ComputerAidedDiagnosisCAD', 'GraphCuts', and 'MachineLearning'. The words are scattered across the page, with some appearing in larger sizes than others, indicating their relative frequency or importance in the context.

CostFunction
Lesion
Segmentation
Optimization
Breast
Ultrasound
BIRADs
Data
2CVB
Features
Training
Minimization
MachineLearning
Stochastic
Imaging
AreaOverlap
OpenResearch
Modeling
SuperPixel
Cancer
InterIntraObserver
ModelLearning
SearchSpace
ComputerAidedDiagnosisCAD
GraphCuts

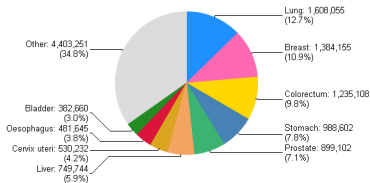
A word cloud centered around the theme of medical image segmentation. The most prominent word is 'Optimization' in a large, bold, orange font. Other large words include 'Segmentation', 'Breast', 'Lesion', 'Data', 'CostFunction', '12CVB', and 'Ultrasound'. Smaller words scattered around include 'Features', 'Training', 'ComputerAidedDiagnosisCAD', 'InterIntraObserver', 'ModelLearning', 'SearchSpace', 'OpenResearch', 'Modeling', 'SuperPixel', 'AreaOverlap', 'Imaging', 'Stochastic', 'GraphCuts', 'MachineLearning', 'Cancer', 'BIRADs', 'Minimization', and 'AreaOverlap'. The words are in various shades of orange and blue, with different font sizes and orientations, creating a dynamic visual representation of the field's terminology.

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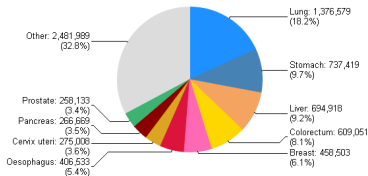


Motivations

Statistics



(a) # of cancer cases



(b) # of cancer deaths

Implications

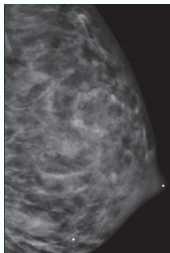
- ▶ 1.4 million cases per year
- ▶ 10.9% of diagnosed cancers
- ▶ 5th cause of cancer death (1th females)



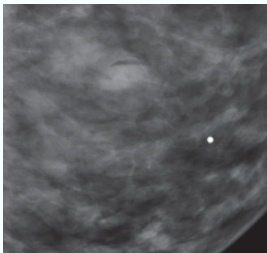
Breast Imaging

Ultra-Sound(US) imaging, the most common adjunct modality

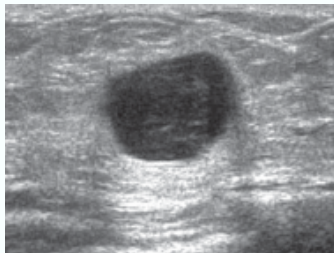
- ▶ Ability to discern solid lesions typologies
- ▶ Lesions shielded by dense breast in Digital Mammography(DM) are distinguishable in US



(c) DM



(d) DM, Region of Interest (ROI)



(e) Breast Ultra-Sound(BUS), ROI



Breast structures under US screening

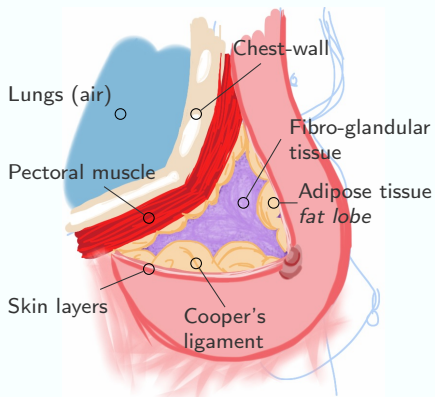


Figure: Breast structure elements.

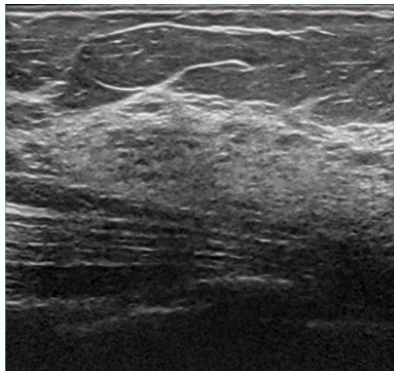


Figure: Breast US image example.



State of health from image visual Inspection

Radiologic diagnosis error rates are similar to any other human visual inspection

- ▶ Quality of the images.
- ▶ Ability to interpret the physical properties of the images.

1. Double readings.
2. Computer Aided Diagnosis(CAD).

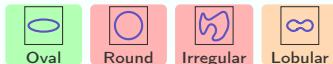


BI-RADS Lexicon

A standardized toolkit tested for diagnosis

- ▶ BKGD Echotexture : adipose, fibro-glandular, heterogeneous

- ▶ Mass shape :



- ▶ Mass orientation :



- ▶ Mass margin :



- ▶ Lesion boundary :






- ▶ Echo pattern :



- ▶ Posterior acoustic pattern :

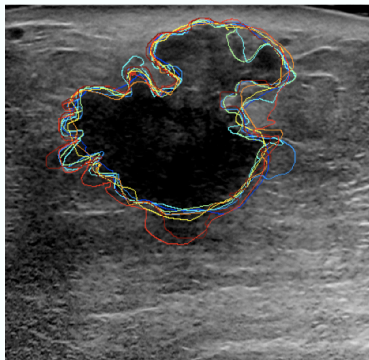
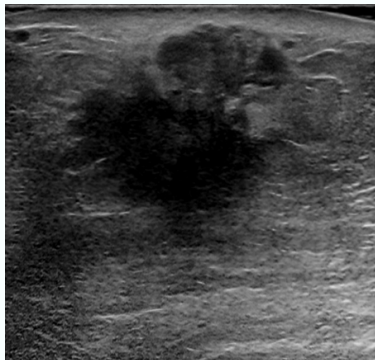


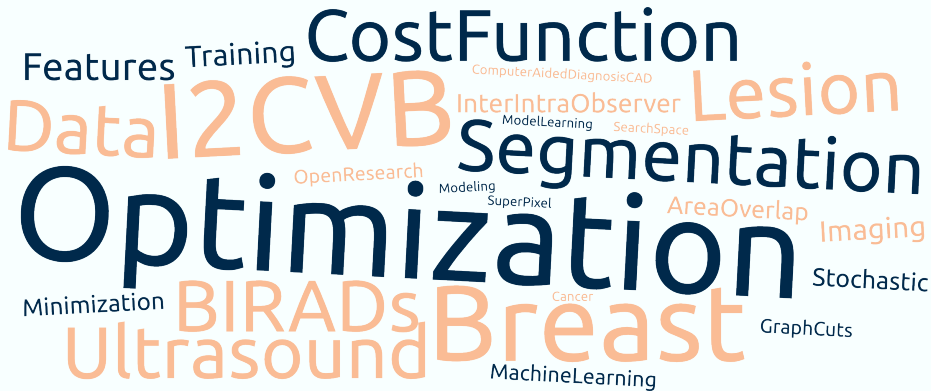
⁰  benign,  malignant and  undetermined



Take away

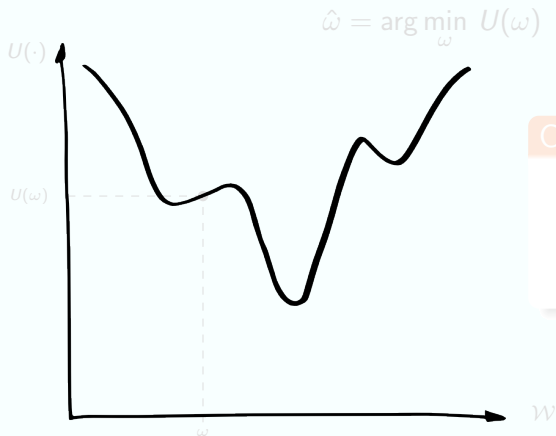
Accurate delineations to develop CAD systems for BUS







Optimization For image segmentation

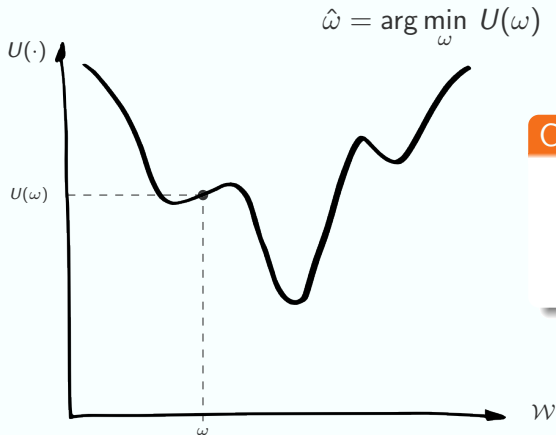


Considerations

- ▶ Search Space \mathcal{W}
- ▶ Cost Function $U(\cdot)$
- ▶ Minimization Strategy



Optimization For image segmentation



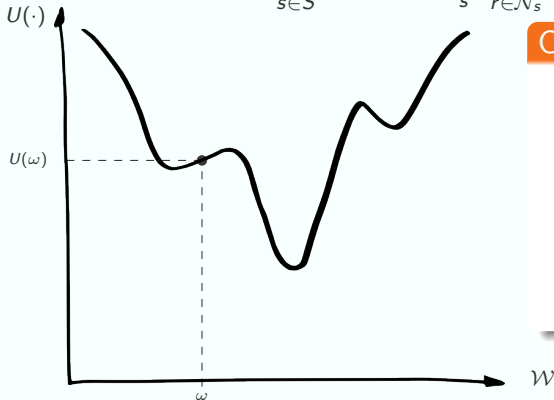
Considerations

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Image Segmentation by Optimization The Metric Labeling Problem

$$U(\omega) = \sum_{s \in \mathcal{S}} D_s(\omega_s) + \sum_s \sum_{r \in \mathcal{N}_s} V_{s,r}(\omega_s, \omega_r)$$

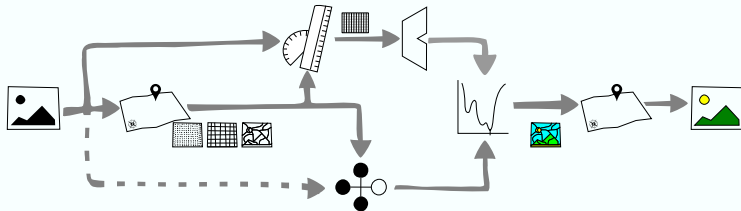


Considerations

- ▶ Image as a discrete set \mathcal{S}
- ▶ Search Space \mathcal{W}
 $(\omega_s = l), l \in \mathcal{L}, \forall s \in \mathcal{S}$
- ▶ Cost Function
- ▶ Minimization Strategy



The Metric Labeling Problem Conceptual schema

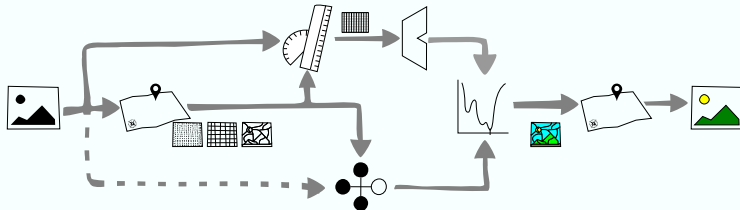


$$U(\omega) = \sum_{s \in S} D_s(\omega_s) + \sum_s \sum_{r \in \mathcal{N}_s} V_{s,r}(\omega_s, \omega_r)$$

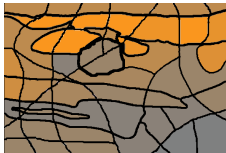
- ▶ $D_s(\omega_s = l_{\checkmark}) \ll D_s(\omega_s = l_{\times})$
- ▶
$$V_{s,r}(\omega_s, \omega_r) = \begin{cases} \beta, & \text{if } \omega_s \neq \omega_r \\ 0, & \text{otherwise} \end{cases}$$
- ▶ $|\mathcal{W}| = |\mathcal{L}|^{|S|}$



The Metric Labeling Problem Conceptual scheme



$D_S(\omega_S = I)$ Interpretation



(a) I is fat



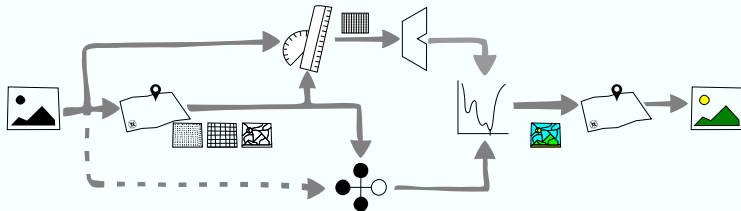
(b) I is lungs



(c) I is lesion



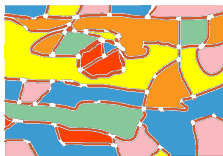
The Metric Labeling Problem Conceptual schema



$V_{s,r}(\omega_s, \omega_r)$ Interpretation



(d)



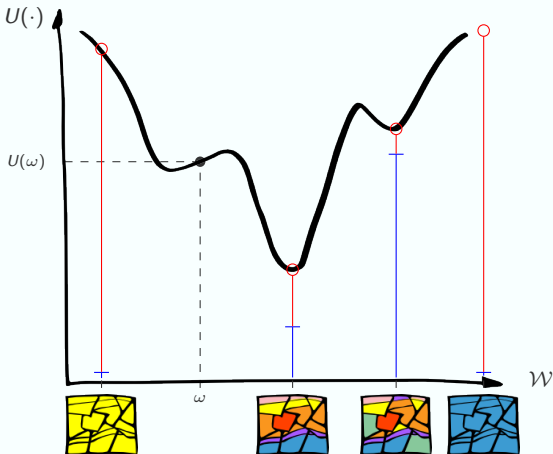
(e)



(f)

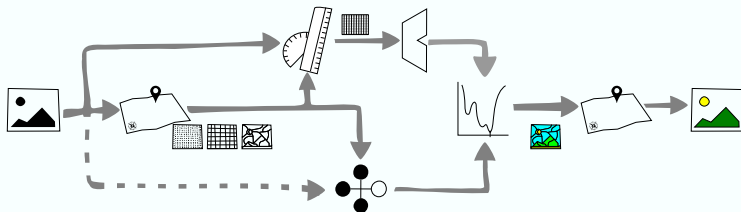


Interpretation of the Minimization Stage





Take Away



$V_{s,r}(\omega_s, \omega_r)$ Interpretation

$$\hat{\omega} = \arg \min_{\omega} U(\omega)$$

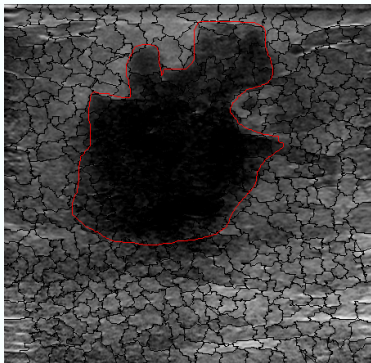
$$U(\omega) = \sum_{s \in S} D_s(\omega_s) + \sum_s \sum_{r \in \mathcal{N}_s} V_{s,r}(\omega_s, \omega_r)$$

A word cloud of terms related to medical image segmentation. The words are arranged in a circular pattern, with 'Optimization' and 'Segmentation' being the largest and most central. Other prominent words include 'Breast', 'Lesion', 'Data', 'CostFunction', 'Training', 'Features', 'Imaging', 'Stochastic', 'GraphCuts', 'MachineLearning', 'Ultrasound', 'BIRADs', 'Minimization', 'OpenResearch', 'Modeling', 'SuperPixel', 'AreaOverlap', 'InterIntraObserver', 'ModelLearning', 'SearchSpace', 'ComputerAidedDiagnosisCAD', 'Cancer', and 'AreaOverlap'. The words are in various shades of orange and blue.

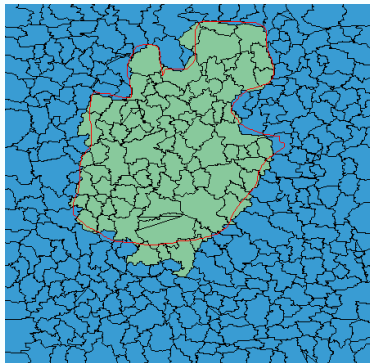
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Cancer



Qualitative results Super-pixel classification vs Area-Overlap



(g) Original Image, Ground Truth and Super-Pixels delineation.

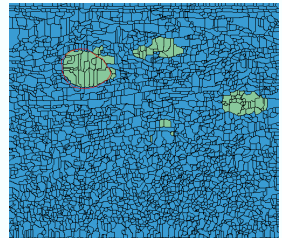
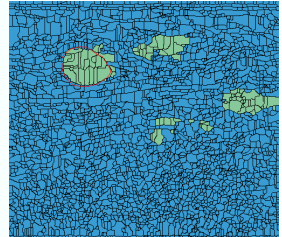
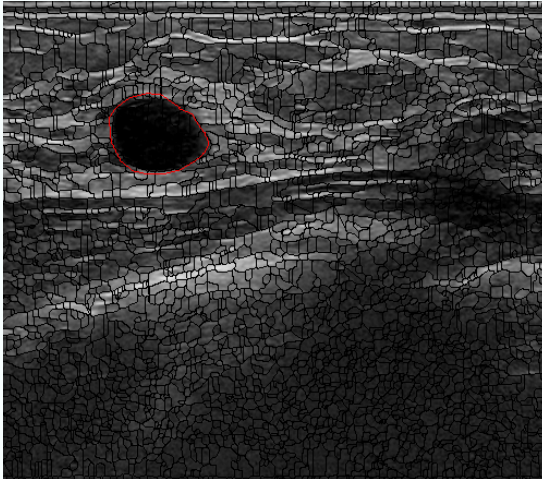


(h) $\{\text{lesion}, \overline{\text{lesion}}\}$ labeling results, GT and SP delineation.



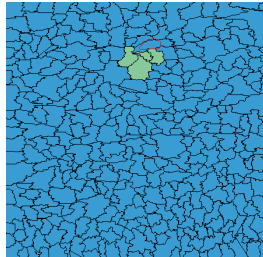
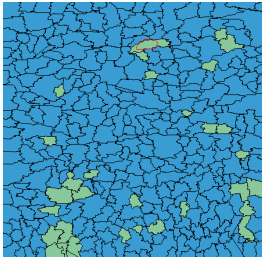
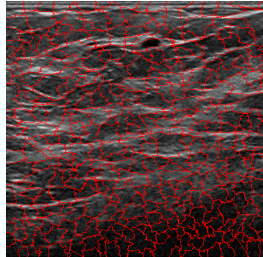
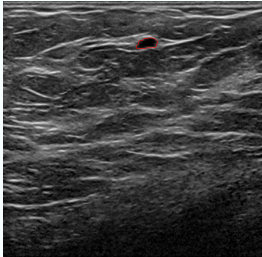
Qualitative results

Influence of the Smoothing Term to False Positive Ratio





Qualitative results When False Negative Emerge





Database size: 16
 GT: multi-label
 Task: $\mathcal{L} = \{\text{lesion}, \overline{\text{lesion}}\}$
 Training: Leave-one-Patient-Out
 AOV: .623 FPR: .4 FNR: .008

Experts[2]

Dataset

Experts[2]

Other

Other+ML

ML

ML+ACM

ACM+Other

AOV

Result

Testing