

An optimization approach to segment breast lesions in ultra-sound images using clinically validated visual cues

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

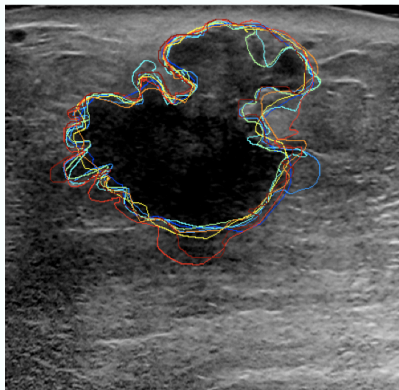
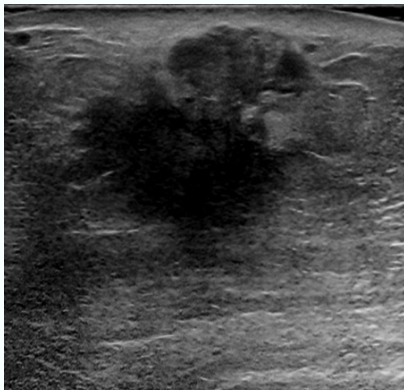
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Stochastic
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Ultrasound Breast GraphCuts
MachineLearning

Lesion Segmentation

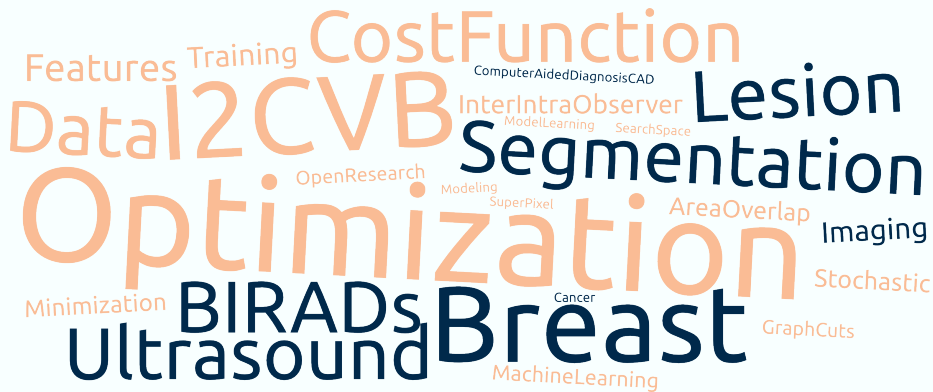
Optimization



Breast Lesion Segmentation in US images



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

Optimization
Segmentation
Breast
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CostFunction
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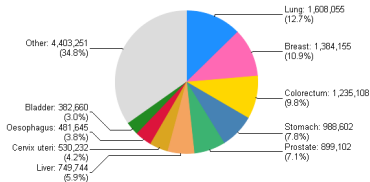
A word cloud centered around the theme of medical image processing and optimization. The most prominent word is 'Optimization' in a large, bold, orange font. Other large words include 'Segmentation', 'Breast', 'Data', 'CostFunction', 'Lesion', 'Imaging', 'Stochastic', 'BIRADs', 'Ultrasound', 'MachineLearning', 'AreaOverlap', 'InterIntraObserver', 'ModelLearning', 'SearchSpace', 'OpenResearch', 'Modeling', 'SuperPixel', 'Cancer', 'GraphCuts', 'Minimization', 'Features', 'Training', 'ComputerAidedDiagnosisCAD', and '12CVB'. The words are arranged in a dense, overlapping manner, with colors ranging from orange to dark blue.

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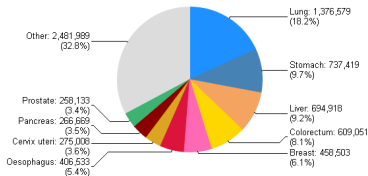


Motivations

Statistics



(a) # of cancer cases



(b) # of cancer deaths

Implications

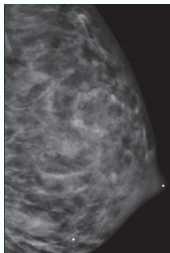
- ▶ 1.4 million cases per year
- ▶ 10.9% of diagnosed cancers
- ▶ 5th cause of cancer death (1th females)



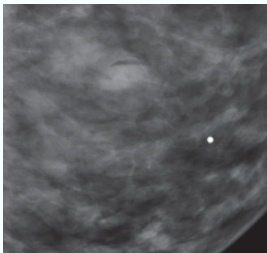
Breast Imaging

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

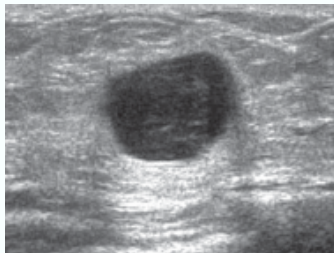
- ▶ Ability to discern solid lesions typologies
- ▶ Lesions shielded by dense breast in Digital Mammography(DM) are distinguishable in US



(c) DM



(d) DM, Region of Interest (ROI)



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



Breast structures under US screening

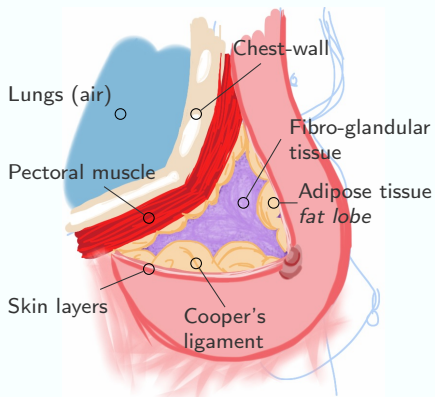


Figure: Breast structure elements.

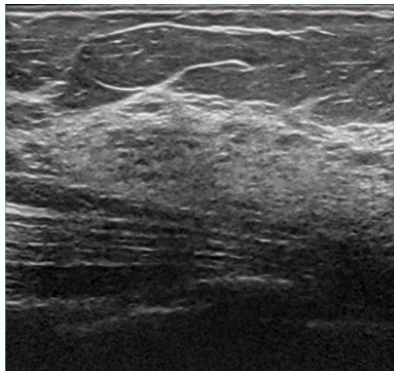


Figure: Breast US image example.



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).

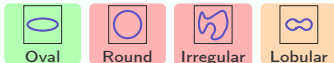


BI-RADS Lexicon

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 :

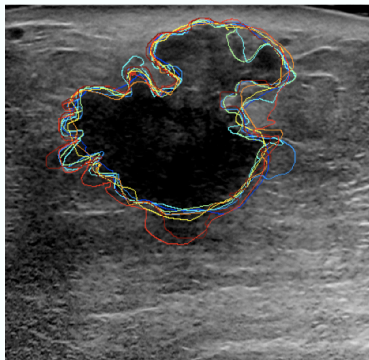
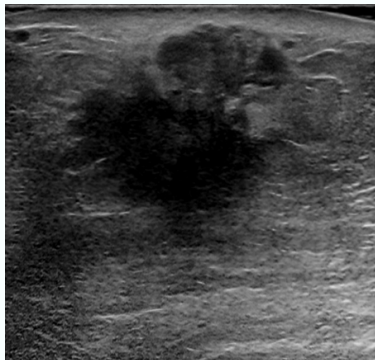


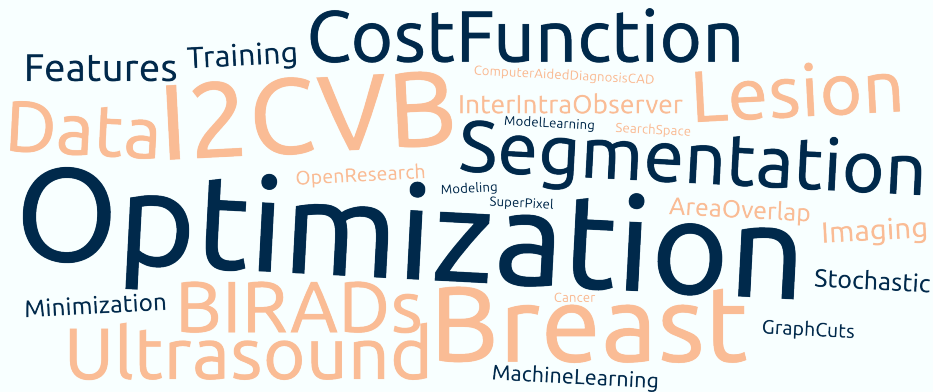
⁰  benign,  malignant and  undetermined



Take away

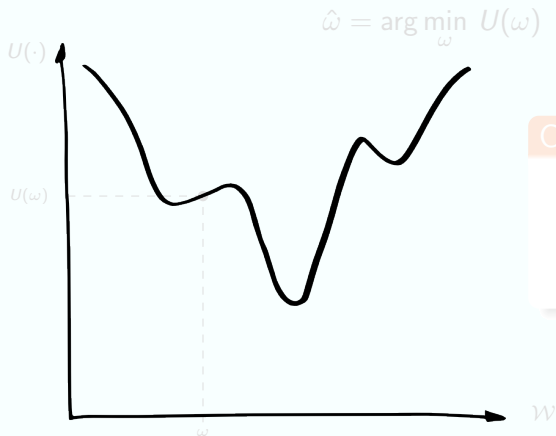
Accurate delineations to develop CAD systems for BUS







Optimization For image segmentation

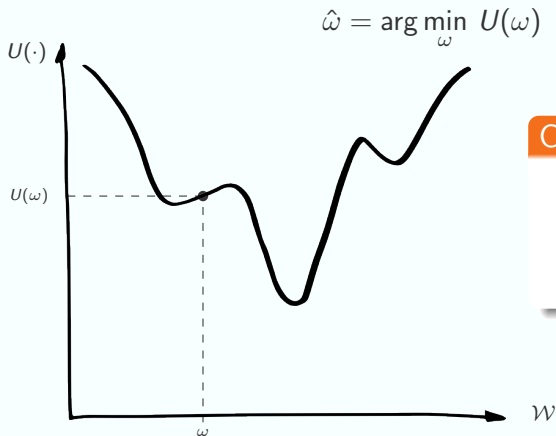


Considerations

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



Optimization For image segmentation



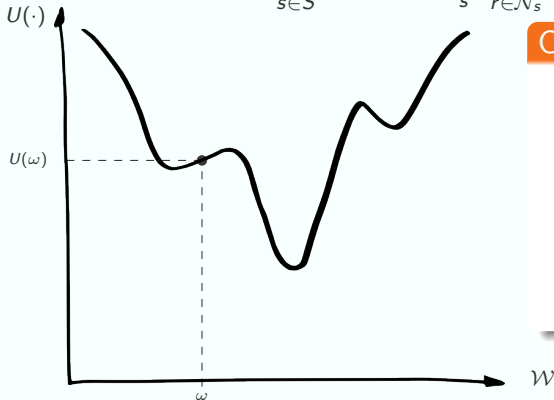
Considerations

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Image Segmentation by Optimization The Metric Labeling Problem

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

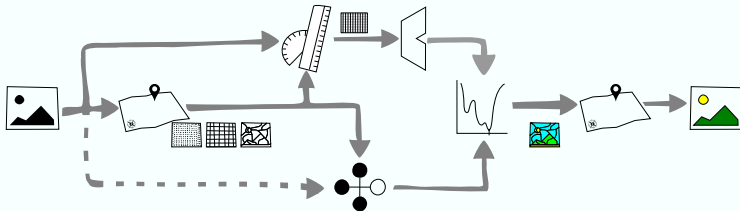


Considerations

- ▶ 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

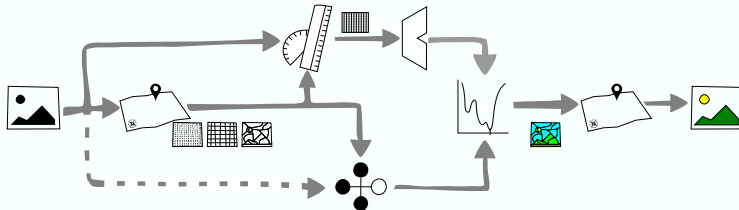


$$U(\omega) = \sum_{s \in S} D_s(\omega_s) + \sum_s \sum_{r \in N_s} V_{s,r}(\omega_s, \omega_r)$$

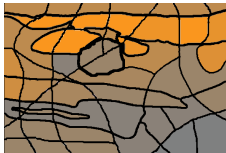
- ▶ $D_s(\omega_s = l_{\checkmark}) \ll D_s(\omega_s = l_{\times})$
- ▶
$$V_{s,r}(\omega_s, \omega_r) = \begin{cases} \beta, & \text{if } \omega_s \neq \omega_r \\ 0, & \text{otherwise} \end{cases}$$
- ▶ $|\mathcal{W}| = |\mathcal{L}|^{|S|}$



The Metric Labeling Problem Conceptual scheme



$D_S(\omega_S = I)$ Interpretation



(a) I is fat



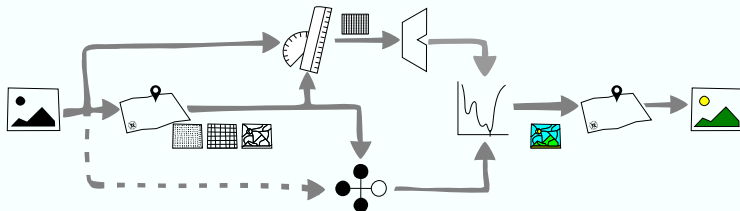
(b) I is lungs



(c) I is lesion



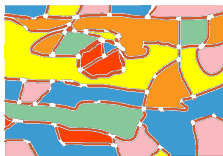
The Metric Labeling Problem Conceptual schema



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



(d)



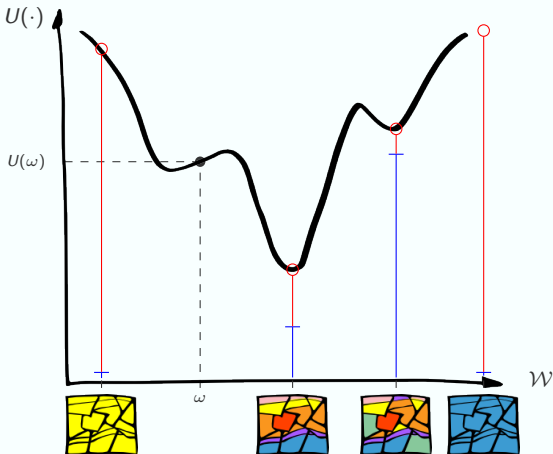
(e)



(f)

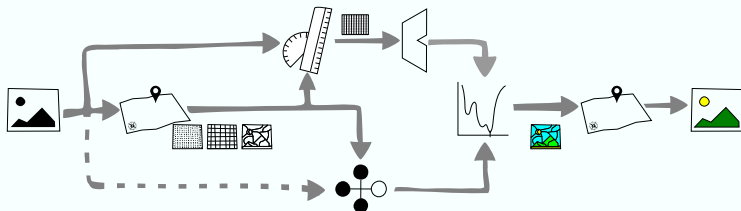


Interpretation of the Minimization Stage





Take Away



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

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

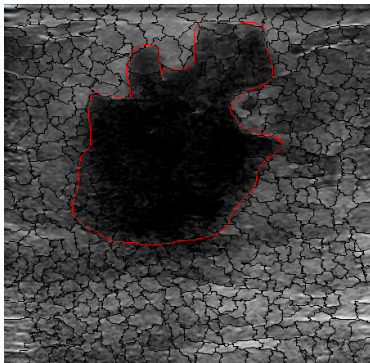
$$U(\omega) = \sum_{s \in S} D_s(\omega_s) + \sum_s \sum_{r \in \mathcal{N}_s} V_{s,r}(\omega_s, \omega_r)$$

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.

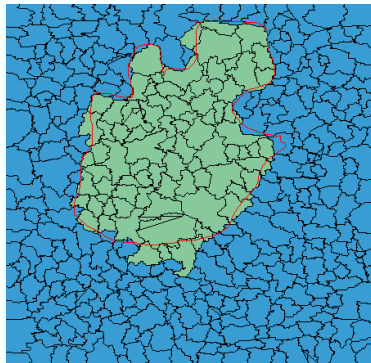
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Qualitative results Super-pixel classification vs Area-Overlap



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

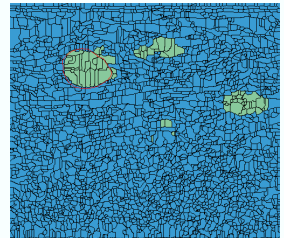
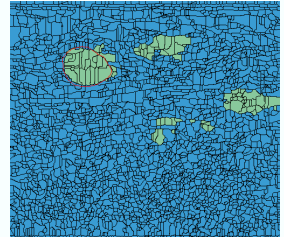
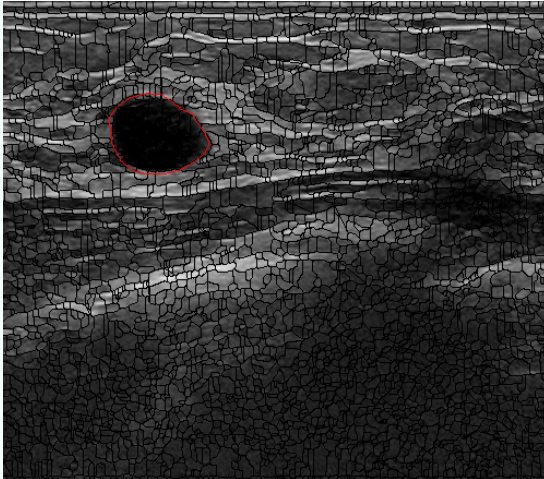


(h) $\{\text{lesion}, \overline{\text{lesion}}\}$ labeling results, GT and SP delineation.



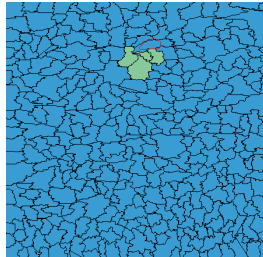
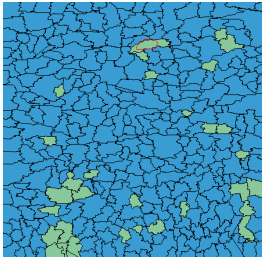
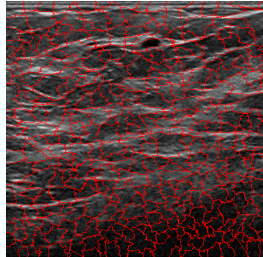
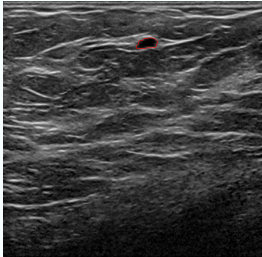
Qualitative results

Influence of the Smoothing Term to False Positive Ratio





Qualitative results When False Negative Emerge





Quantitative Results

Method Id:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
Dataset size:	76	20	32	20	42	480	347	352	25	120	6	400	50	20	118	488
technology used for:																
detection																
segmentation																
post-processing																
AOV (in %):	88.1	86.3	88.3	85.2	62.0	75.0	84.0	54.9	64.0	83.1	73.3	73.0	85.0	78.6	77.6	74.5

