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

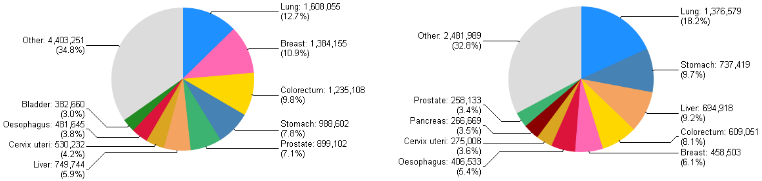
Doctoral Day
7th October 2015

Joan Massich
joan.massich@u-bourgogne.fr

Université de Bourgogne

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

Despite its limitations, Digital Mammography (DM) is the main image modality for breast screening. Other image modalities such as Magnetic Resonance Imaging (MRI), Tomography, or Ultra-Sound (US) are being developed.

Ultra-Sound(US) imaging, advantages:

- Ability to discern solid lesions typologies
- Lesions shielded by dense breast in DM are distinguishable in US

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

For each description section a single category is given based on some criteria

- **BKGD Echotexture :** *Adipose, Fibro-Glandular or Heterogeneous* based on the visual texture present surrounding the lesion.
- **Mass shape :** *Oval, Round, Irregular, Lobular* based on general shape of the lesion
- **Mass orientation :** *Parallel, Non-Parallel* with respect to the general orientation of the skin layers
- **Mass margin :** *Circumscribed, Indistinct, Angular, Microlobulated, Spiculated* based on the delineation of the lesion
- **Lesion boundary :** *Abrupt interface, Echogenic halo* to differentiate when hyperechoic tissue surrounds the lesion
- **Echo pattern :** *Anechoic, Hyperechoic, Complex, Isoechoic, Hypoechoic* based on the lesion appearance with respect to the adipose tissue
- **Posterior acoustic pattern :** *Shadowing, Combined, Enhancement, No patter* based on how the background tissue posterior to the lesion is depicted

Optimization
For image segmentation

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

Considerations

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

Image Segmentation by Optimization
The Metric Labeling Problem

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

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

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

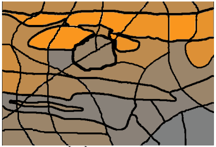
Cost function

- D_s is the Data-Term
- $D_s(\omega_s = l_{\checkmark}) << D_s(\omega_s = l_{\times})$
- $V_{s,r}$ is the Pairwise-Term
- $$V_{s,r}(\omega_s, \omega_r) = \begin{cases} \beta, & \text{if } \omega_s \neq \omega_r \\ 0, & \text{otherwise} \end{cases}$$

The Metric Labeling Problem

Interpretation of the Cost function terms

$D_s(\omega_s = l)$ Interpretation

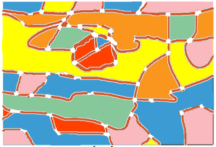

(c) l is fat


(d) l is lungs


(e) l is lesion

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


(f)


(g)

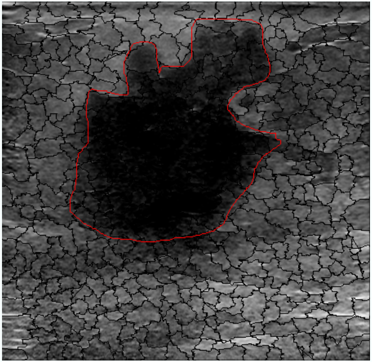

(h)

The Metric Labeling Problem
System Configuration

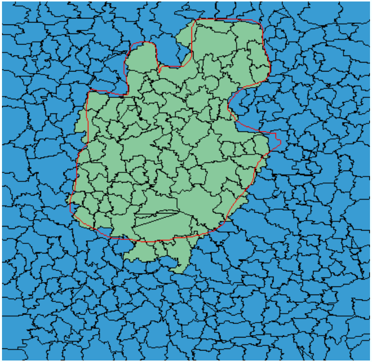
Table: Design choices summary

$\mathcal{S}$	Quick-Shift super-pixels
	Background Echotexture: encoded in Appearance and SIFT-BoW
$D(\cdot)$	Echo Pattern: encoded in Appearance, Atlas and Brightness
	Acoustic Posterior: encoded in Atlas and Brightness
$V(\cdot,\cdot)$	Homogeneity
$\arg\min U(\cdot)$	Graph-Cuts

Qualitative results
Super-pixel classification vs Area-Overlap

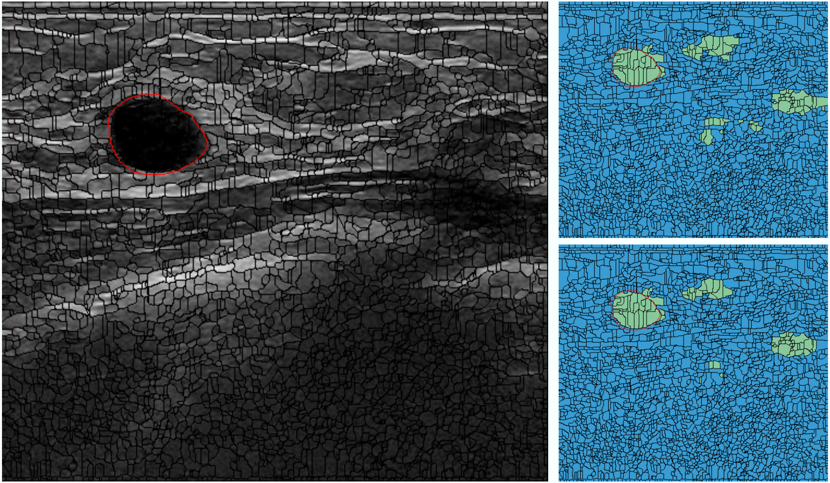


(i) Original Image, Ground Truth and Super-Pixels delineation.

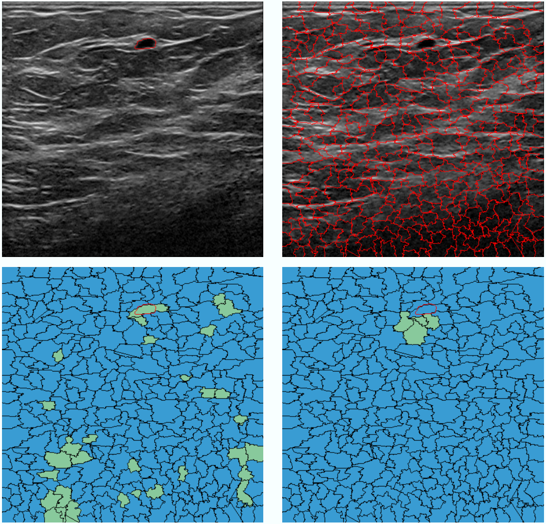


(j) $\{\text{lesion}, \overline{\text{lesion}}\}$ labeling results, GT and SP delineation.

Qualitative results
Influence of the Smoothing Term to False Positive Ratio

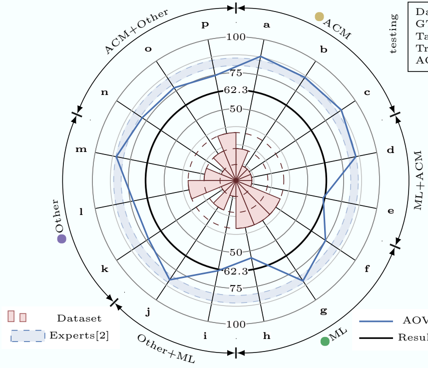


Qualitative results
When False Negative Emerge



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
techonlogy used for:																
detection																
segmetnation																
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



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