

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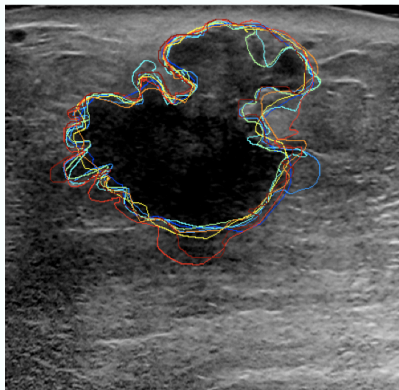
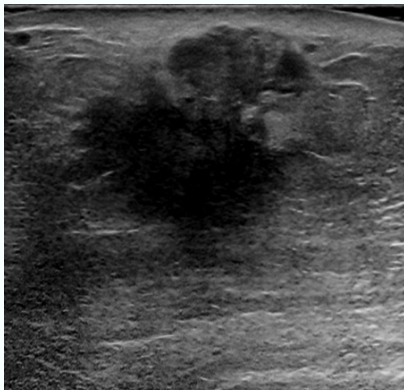
Features Training CostFunction  
Data 12CVB InterIntraObserver Lesion  
ModelLearning SearchSpace Segmentation  
OpenResearch Modeling SuperPixel AreaOverlap Imaging  
Minimization BIRADS Breast Stochastic  
Ultrasound MachineLearning GraphCuts  
ComputerAidedDiagnosisCAD

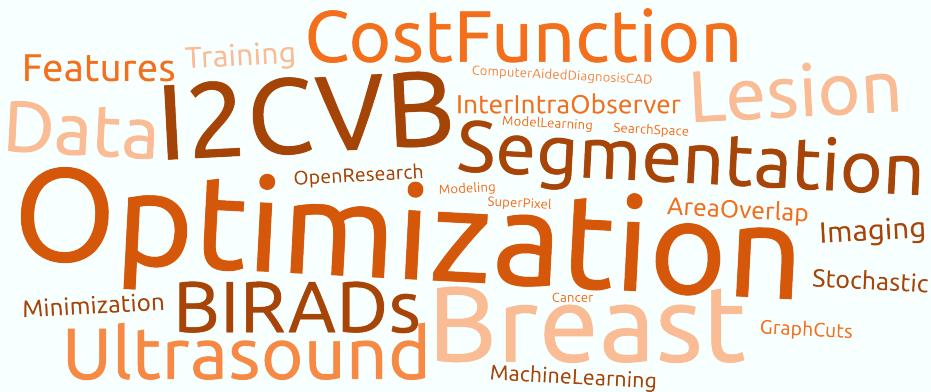
A word cloud on a dark blue background featuring various terms related to medical imaging and machine learning. The words are arranged in a dense, overlapping manner. The most prominent words, shown in a larger font size, include 'Optimization', 'Segmentation', 'Lesion', 'Breast', 'CostFunction', 'Data', '2CVB', 'Imaging', 'Stochastic', 'Ultrasound', 'BIRADs', 'MachineLearning', 'Minimization', 'Features', 'Training', 'OpenResearch', 'Modeling', 'SuperPixel', 'AreaOverlap', 'GraphCuts', 'Cancer', 'MachineLearning', 'InterIntraObserver', 'SearchSpace', 'ModelLearning', 'ComputerAidedDiagnosisCAD', and 'MachineLearning'. The words 'Segmentation' and 'Lesion' are highlighted in a bright orange color, while all other words are in a dark blue color matching the background.

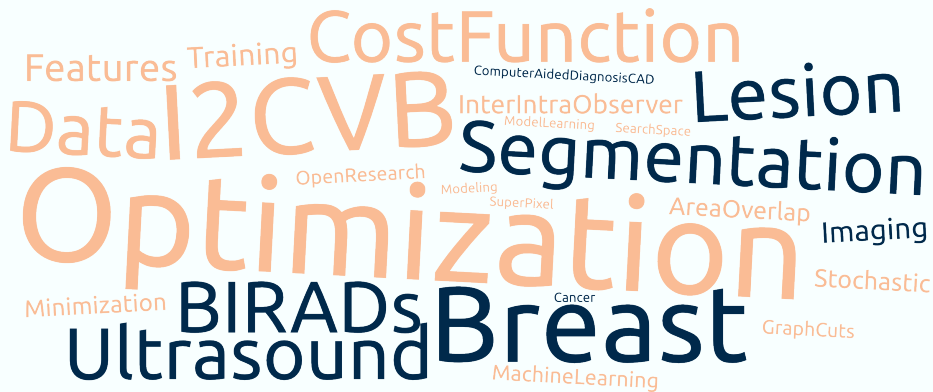
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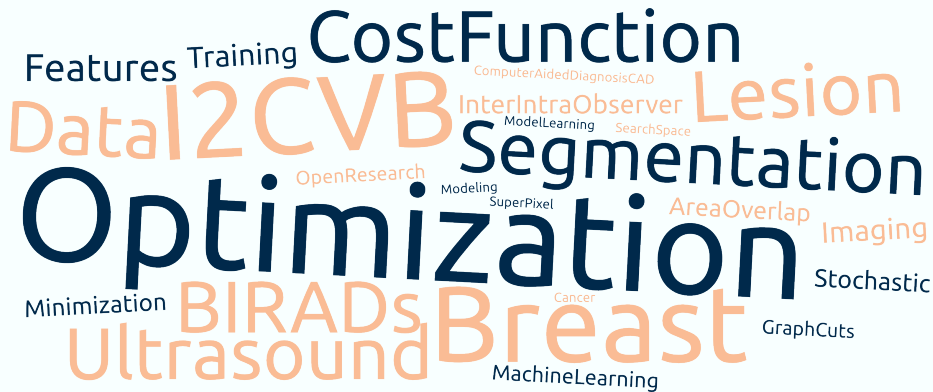


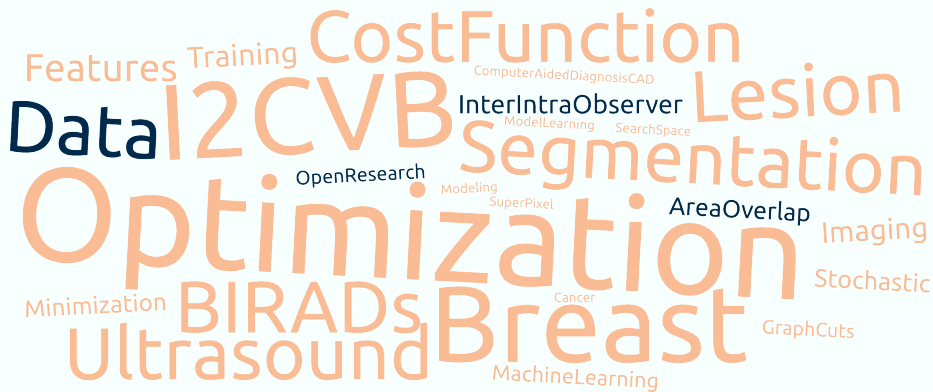
## Breast Lesion Segmentation in US images









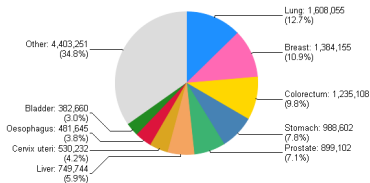




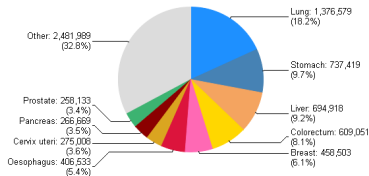


## Motivations

### Statistics



(a) # of cancer cases



(b) # of cancer deaths

### Implications

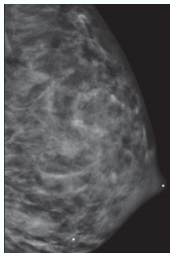
- ▶ 1.4 million cases per year
- ▶ 10.9% of diagnosed cancers
- ▶ 5<sup>th</sup> cause of cancer death (1<sup>th</sup> females)



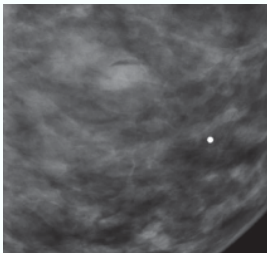
## Breast Imaging

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

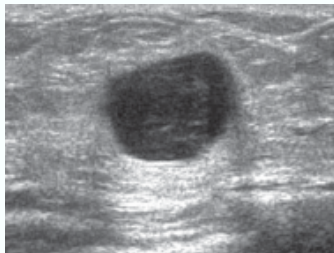
- ▶ Ability to discern solid lesions typologies
- ▶ Lesions shielded by dense breast in Digital Mammography(DM) are distinguishable in US



(c) DM



(d) DM, Region of Interest (ROI)



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



## Breast structures under US screening

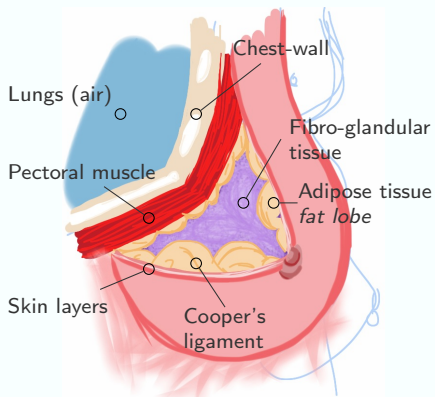


Figure: Breast structure elements.

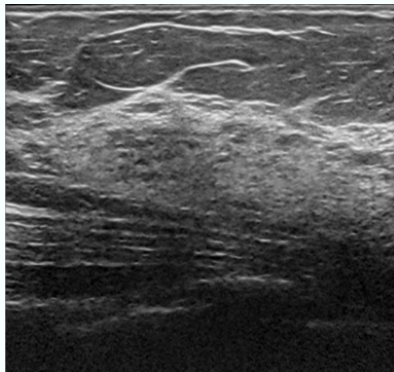


Figure: Breast US image example.



## 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).

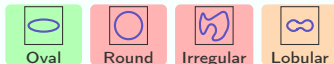


## BI-RADs Lexicon

A standardized toolkit tested for diagnosis

► BKGD Echotexture : adipose, fibro-glandular, heterogeneous

► Mass shape :



► Mass orientation :



► Mass margin :



► Lesion boundary :






► Echo pattern :



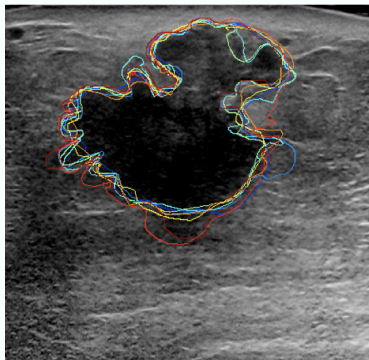
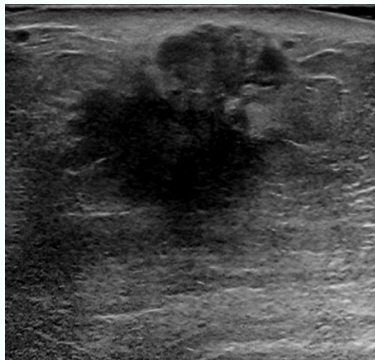
► Posterior acoustic pattern :

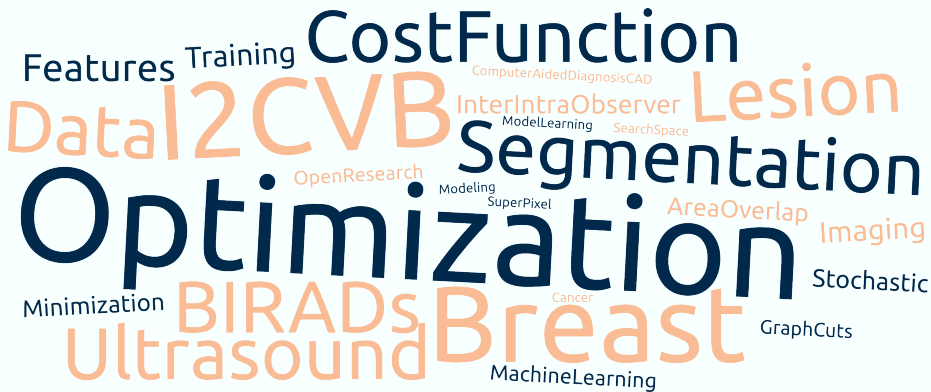


<sup>0</sup>  benign,  malignant and  undetermined



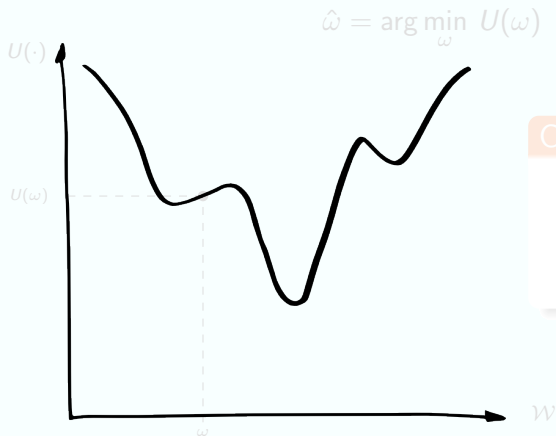
Take away  
Accurate delineations to develop CAD systems for BUS







## Optimization For image segmentation



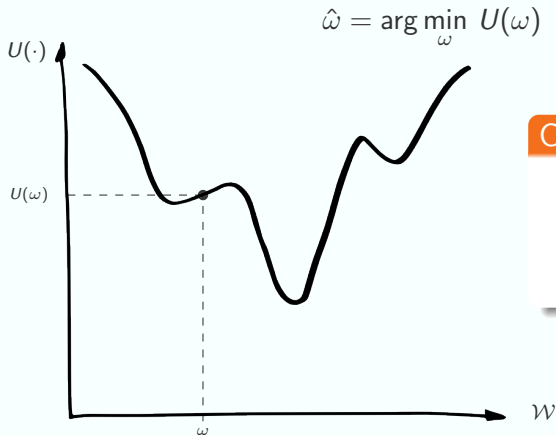
### Considerations

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





## Optimization For image segmentation



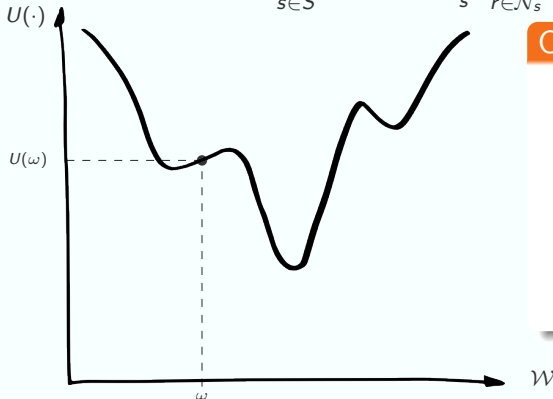
### Considerations

- ▶ Search Space  $\mathcal{W}$
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- ▶ Minimization Strategy



## Image Segmentation by Optimization The Metric Labeling Problem

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

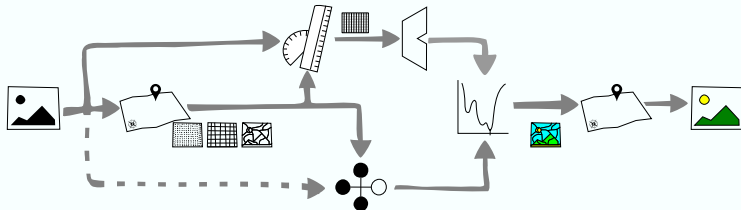


### Considerations

- ▶ 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

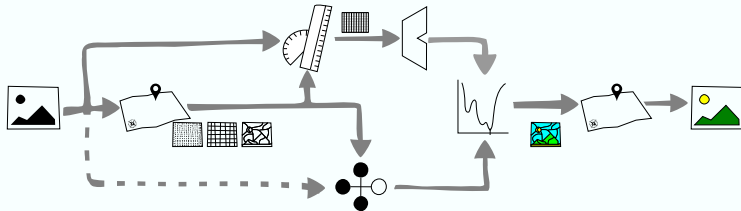


$$U(\omega) = \sum_{s \in S} D_s(\omega_s) + \sum_s \sum_{r \in \mathcal{N}_s} V_{s,r}(\omega_s, \omega_r)$$

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



## The Metric Labeling Problem Conceptual schema



$D_s(\omega_s = I)$  Interpretation



(a)  $I$  is fat



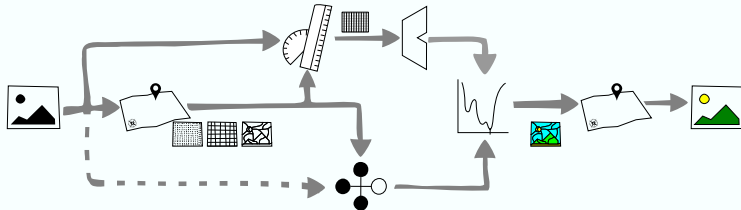
(b)  $I$  is lungs



(c)  $I$  is lesion



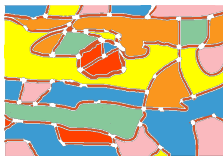
# The Metric Labeling Problem Conceptual schema



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



(d)



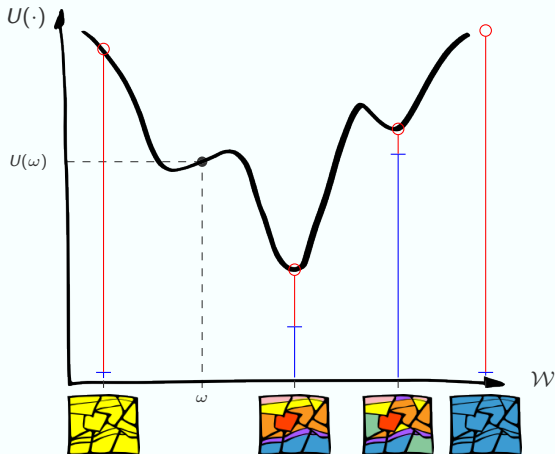
(e)

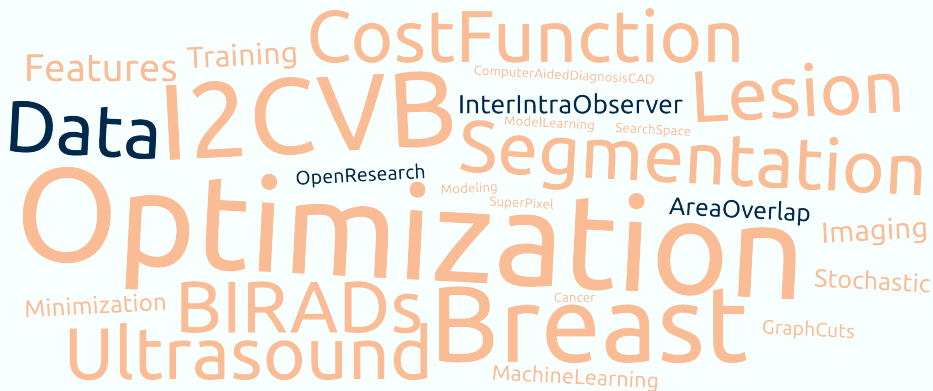


(f)



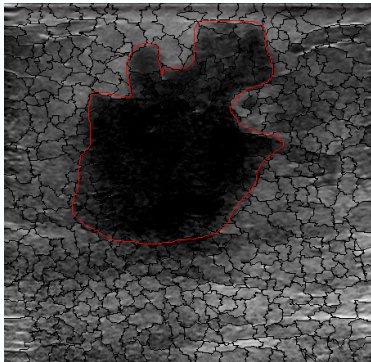
## Interpretation of the Minimization Stage



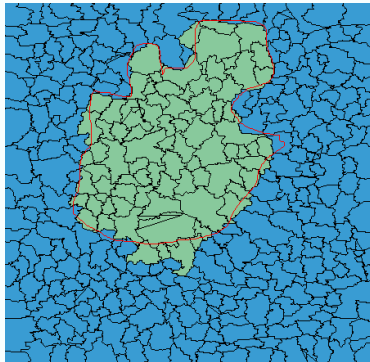




## Qualitative results Super-pixel classification vs Area-Overlap



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



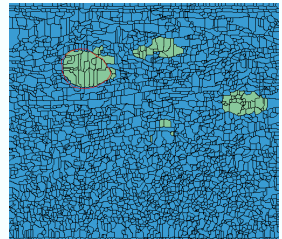
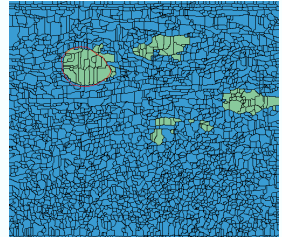
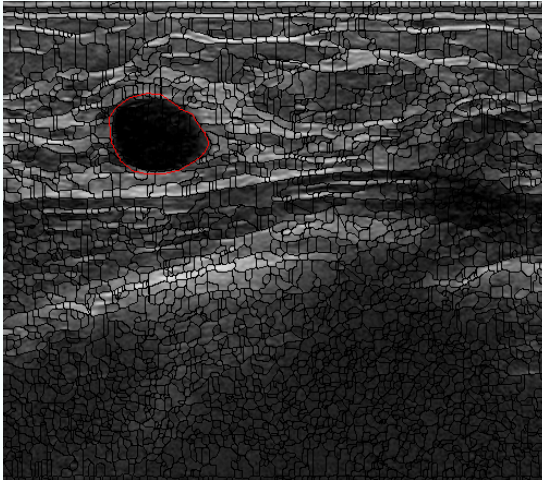
(h)  $\{\text{lesion}, \overline{\text{lesion}}\}$  labeling results, GT and SP delineation.





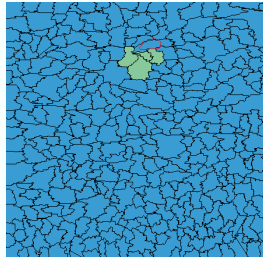
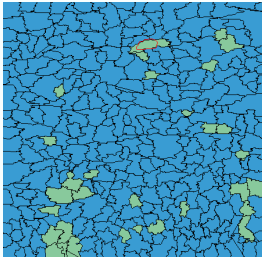
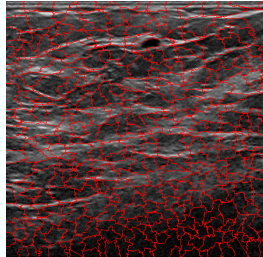
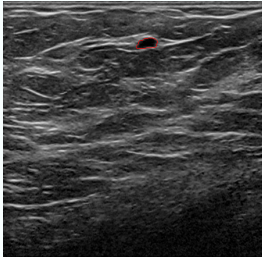
## Qualitative results

### 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

