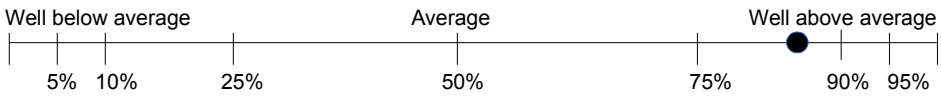
Universitat de Girona
Escola de Doctorat

DOCTORAL THESIS
REVIEW REPORT

Information on the doctoral thesis
Title **Deformable object segmentation in Ultra-Sound images**
Submitted by **Joan Massich**

Global assessment: 85 %



(Indicate the relative position of the thesis to other theses in the same area.)

Do you think the thesis can be defended?

- ☐ Without changes
- ☒ With minor changes
- ☐ With major changes
- ☐ Not in its current version

Do you think the thesis deserves the distinction "cum laude"? No

(As a reference, if you consider that the Thesis is above average you should answer Yes to this question)

REASONED REVIEW (the reviewer has to justify the global assessment and the proposed changes in the document in terms of the technical aspects and results (theoretical framework, relevance, objectives, methodology, discussion, conclusions, bibliography, worth publishing) and in terms of the formal aspects (presentation, how well it is written, spelling...).

Summary and recommendation

Joan Massich's thesis addresses the highly topical and challenging area of automatic analysis of *Breast Ultra-Sound* (BUS) images. This is particularly interesting and important when it is considered in the framework of massive screening where a system for automatic analysis could improve the detection of a breast cancer at a very early stage, when it is still possible to successfully attack the disease with a suitable therapy. In particular, BUS imaging has proven to be a successful adjunct

image modality for breast cancer screening with respect to other reference technique such as the *Digital Mammography* (DM), specially in cases where the DM is not sufficiently reliable (e.g. very dense breast).
The thesis gives a valuable contribution to this field. In the first part (chapters 1, 2) the author introduces the imaging modalities used in breast screening placing special emphasis in US screening of the breast and provides a state-of-the-art in segmentation of breast lesions in US data. In particular, he points out some problems that make difficult a fair comparison between different methods such as the lack of a common dataset and of common assessment measures.
In the second part of the thesis (chapters 3, 4), the author firstly reviews the segmentation method based on *Gaussian Constrain Segmentation* presented in [J.Massich, F.Meriaudeau, E.Pérez, R.Martí, A.Oliver, and J.Martí. *Lesion segmentation in breast sonography*. International Workshop on Digital Mammography, LNCS 6136, pp 39-45. Girona, Spain. June 2010] and in [J.Massich, F.Meriaudeau, M.Sentís, S.Ganau, E.Pérez, R.Martí, A.Oliver, and J.Martí. *Automatic seed placement for breast lesion segmentation on US images.* International Workshop on Digital Mammography, LNCS 7361, pp 308-315. Philadelphia, Pennsylvania. July 2012]. Subsequently, he introduces a novel segmentation scheme based on an optimization framework. In particular, for each image a first-level segmentation is performed in order to decompose the image in groups of contiguous pixels sharing some characteristic (*superpixels*). Each superpixel is then characterized by means of a set of features extracted from the images and fed to a classifier trained to recognize the superpixels belonging to a lesion. The final labeling of the superpixels takes into account both the output of the classifier and the relationship among near superpixels so as to ensure spatial coherence in the final segmentation; this is made so as to minimize a cost related to the configuration assumed by the labels in the final segmentation.
For each of the steps described above, the author delineates some possible solutions and discusses pros and cons for each of them, thus providing a flexible framework in which each subtask can be designed individually. The proposed approach has been tested on a dataset of real BUS images: several possible configurations of the general method have been considered and their results have been compared.
The obtained results demonstrate the potential of the proposed approach and encourage to take this work further.

Presentation
The thesis is well presented, and interesting to read.

Contents
The thesis represents a large body of work and is innovative in several areas.

LIST OF QUESTIONS AND COMMENTS

General comments

- Sect. 3.2.2: some details about how the PDFs are estimated from training data would be useful. Is the estimate parametric or non parametric (e.g. Parzen) ?

- Sect. 3.3.2: it is said that the speckle noise is not removed because it could be profitable for the classification process. Could the author motivate such statement ? There is some reference in literature or some experimental evidence ?

- Sect. 3.3.4: the features describing the brightness of the regions apparently are not normalized (see eqq. 3.5 and 3.6) while, if figs. 3.12 and 3.14 are considered, they appear to be normalized between 0 and 1. Could the author clarify this point ?

- Sect. 3.3.4 (Describing the overall appearance of the region): the description of the features is not very clear and could be improved. What is a MAD brightness model and how is it calculated ? Which kind of models are defined ? Are they tissue models (muscle, pleura, fat, …) or echo pattern models ?

- Sect. 3.3.4 (Describing the texture appearance of the regions): To generate the visual dictionary the k-means clustering is used. How is chosen the value for k ?

- Sect. 3.3.4 (Describing the location of the region): How is managed the atlas option ? Is it a feature added to the other features ? Or is it combined with the output of the classifier ?

- Sect. 3.3.5: In this section several criteria to select the most adequate classification technique are described. How such criteria have lead to the choice of SVM RBF and how is the parameter σ chosen ? Did the author consider other classification architectures ?
- Sect. 3.5 (Quantitative results): the cross-validation is carried out as a multiple randomized sampling of the pool of superpixels. Which is the size of the training set and of the test set in each round of the cross-validation ? How many rounds are performed ?

Minor comments and typos

- p. 10: “Position Emission Tomography” should be “Positron Emission Tomography”
- p. 28: “projectes” should be “projects”
- p. 47: “weather” should be “wether”
- p. 49 (caption fig. .5): maybe “quantified” should be “quantized”
- p. 50: “unpropper detection” should be “improper detection”
- p. 52: the last term of eq. 2.1 should be $\frac{|A \wedge M|}{|A \vee M|}$
- p. 53 (eqs. 2.4 and 2.5): the term $|A| \wedge |M|$ should be $|A \wedge M|$
- p. 54: “Precission” should be “Precision”
- p. 54: “the inverse of the TPR” should be “the complement of the TPR”
- p. 57: “Multipel grader” should be “Multiple grader”
- p. 72 (fig. 3.6): it is not clear which is the method from that the images in the figure have been extracted,
- p.73: “ while the later” should be “ while the latter”
- p. 74: “part of the designing process” should be “part of the design process”
- p. 82: the eqs. 3.5, 3.6 are totally obscure: the notation is not clear and there are several smbols used but not introduced before (e.g., $\mu(.)$ and Md(.).
- p. 83: “Figures 3.13 and 3.14 replicate the study for a different image example ...” should be “Figures 3.14 and 3.15 replicate the study for a different image example ...”
- p. 102: “biological behabiours ...” should be “biological behaviours ...”
- p. 111: in *Superpixel multi-resolution feature description* there are two median descriptors while one of them should be a mean descriptor.
- p. 117: “more profound” should be “deeper”
- p. 118: “Figures 3.38 to 3.40 show few quantitative results ...” should be “Figures 3.38 to 3.40 show few qualitative results ...”.
- pp. 119-120 (figs 3.36 and 3.37): in the graph the FN ring is not present.
- Bibliography: some references are incomplete