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 Mr. Joan Massich

Global assessment: 70%

Well below average				Average			Well above average
5%	10%	25%		50%	75%	90%	95%

(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"? ☑ Yes ☐ 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...).

Thesis report for « Deformable object segmentation in Ultra-Sound images »
by Joan MASSICH

The applicative context of this thesis concerns segmentation of breast cancer lesions in ultrasound echography. This is a hard and state-of-art problem in the field of medical image analysis, due to the difficulties linked to ultrasonic image formation (inducing low contrast, speckle, shadowing, etc.). In terms of methodology, the objective of Mr. Joan Massich is the development of a fully automated segmentation method based on machine learning and optimization techniques.

The manuscript presented by Mr. Joan Massich is composed of 4 chapters, i.e. an introduction giving the applicative context, a review of lesion segmentation methods in ultrasound images, the description of the main contribution and a conclusion. The manuscript is clear and well-written. I provide a chapter-by-chapter analysis below.

Chapter 1 provides a detailed introduction to the aim of the thesis work. Starting with the description of the role of different imaging modalities for the assessment of breast cancer, it then focuses on ultrasound imaging and provides an extensive description of the specific role of this modality in breast cancer detection and staging. The chapter then introduces the notion of CAD in breast lesion detection and the prominent role of segmentation in this context. This chapter is clear, uses a rich iconography and constitutes a very nice introduction to the problematic of breast cancer imaging.

Chapter 2 is background review of lesion segmentation in ultrasound imaging. The literature covered by this chapter is extensive and the author first proposes to structure it through well-defined categories, i.e. the degree of interaction involved, the core methodology employed (i.e. active contours, machine learning, etc.) and the image features used. One important aspect of segmentation is the quantitative evaluation of the results, and the author details quite extensively the assessment criteria used in the literature to compare a given segmentation result with a ground truth. The chapter ends with a discussion analyzing previous studies dealing with breast lesion segmentation in terms of methodology and quantitative performance, using the Area overlap (AOV) as main criteria. While this chapter is overall extensive and adequate, it is a bit regrettable that the work done by the author (reference [61]) is not clearly in the next chapter. Moreover, it would have been interesting to add at this level a section giving some overall conclusion about the review and explaining the methodological directions chosen with regards to this review.

Chapter 3 represents the core of the thesis, since it describes the contributions developed by Mr. Joan Massich for the segmentation of breast lesion.

This chapter starts by presenting a first method called "Gaussian constrained segmentation" (GCS). The first step of GCS consists in generating a seed region, obtained by computing the posterior probability of the pixels of belonging to a lesion and thresholding the so-obtained probability map. This posterior probability is obtained from prior probabilities of intensity, texture and position of lesion estimated from a set of training, annotated images. A region growing is applied to the seed and a 2D Gaussian is then fitted on the obtained region. As a second step, an image synthetizing the data characteristics (homogeneity, texture, etc.), Ψ , is generated and multiplied by this 2D Gaussian. The final segmentation is then obtained by thresholding the resulting image, the threshold being optimized to minimize the variance of the lesion and background. Qualitative results provided by GCs are provided and the reader is referred to chapter 2 for a quantitative evaluation, which shows that the AOV associated to GCS 64%, which represents a performance that could be improved. While the overall approach underlying GCS approach is clear, its description suffers from a lack of details, e.g. what criteria is used to stop the region growing, what is the annotated training set, what are the texture features used to compute the prior probability, what are the details of the processing steps (median filtering, morphological operators) used to generate Ψ ? Moreover, it would have been clearer to briefly recall the obtained quantitative results and above all explain from them the need to develop another technique.

The second part of chapter 3 is devoted to the description and evaluation of a second approach. The segmentation task is tackled in this part as a labeling problem, solved using optimization techniques. In order to decrease the complexity, the sites considered for labeling are superpixels, built using the Quick-Shift or the Global Probability Boundary techniques. A SVM classifier is used to generate the labeling cost of a given superpixel and the optimization step then consists in minimizing the labeling cost plus an original smoothing term, enforcing similar labeling of spatially neighboring superpixels. This non convex optimization problem is solved using graph cut. The whole procedure can thus be seen as an a posteriori regularization of the SVM output: the expected solution should indeed be close to the SVM classification (data term) while constraining spatially neighboring sites to have similar labels. While the overall structure of the approach is clear, the construction of the data term from the SVM output should have been more clearly detailed: what is the width of the RBF used? How is the cost formulated from the hinge cost function, etc.? In the same way, the details of the construction of the smoothing term based on Markov Random field techniques should have been more accurately exposed.

Being based of a machine learning approach the selection of the features used for the classification/cost generation is an important issue. Intensity, texture and localization are used in this work. Consistently with the Stavros criteria widely accepted in the echographic breast imaging community, the author first introduces an original feature mimicking the evaluation of echographic images as anechoic, hypoechoic, etc. This feature is complemented by a more detailed description of the intensity and corresponding to the distance of a given superpixel to the tissue classes, measured by comparing the associated histogram through the Quadratic Chi distance. The texture features are based on a descriptor provided by SIFT technique, i.e. namely on an 8-bins histogram of the local gradients orientation. Each superpixel is then described through a "Bag of features" using a dictionary of 36 SIFT words learned from training data. The intensity and texture features are embedded in a multiresolution scheme, obtained by computing the related quantities from the site and its neighbors. Resolution can thus be chosen by varying the size of the neighborhood and 3 levels are used in this work. The last feature is based on the probability of a given spatial location to belong to a particular tissue, this posterior probability model being built from the training set. This part of chapter 3 nicely introduces computer vision techniques which are not so common in medical image processing using a rich iconography and clearly illustrates the associated concepts.

The approach is evaluated from a database consisting of 700 images, using a Leave-One-Out strategy. This evaluation is quite thorough: the grouping of several features is tested through 8 experiments as well as the individual influence of each feature. These experiments show that the approach does not bring a substantial improvement in terms of AOV, whatever the feature configuration (AOV smaller than 61%). Interestingly, the introduction of the proposed regularization term is shown to bring a noticeable reduction of the False Positive rate, at the cost of a slight increase of the False Negative rate. While the work associated to this section is interesting and substantial, it would have been informative to add a discussion comparing in details the obtained results with the GCS and other state-of-the-art methods. In particular some interpretations and perspectives regarding the relatively low obtained AOV as well as the observed decrease of FP would have been of great interest.

Overall, Mr. Joan Massich has shown in this thesis a very good knowledge of the applicative context of echographic breast imaging. He has performed a structured analysis of the existing literature about segmentation of breast lesion. His methodological contributions are twofold. He has first proposed an improvement of the Gaussian constrained segmentation method and has tested this approach of a limited set of 25 images. Mr. Joan Massich has published this aspect of his work in three international conferences proceedings. Mr. Joan Massich has then proposed a computer vision-based approach, relying on the optimization of a cost function including a data term from SVM classification and an original term enforcing the spatial smoothness of labeling. The presentation of this aspect could have been improved by providing more details about the core items of the method. The proposed approach has been thoroughly evaluated on a database of 700 images. While some aspects of the results are clearly improvable (AOV), the approach succeeds in decreasing the false positive rate, which is a common problem in computer aided systems when localizing classification approaches. It is also to be noted that the work

As a conclusion, and based on the above remarks, I thus recommend the oral defense of Mr. Joan Massich for the PhD degree.