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# Computer-aided detection system for nerve identification using ultrasound images: A comparative study

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ABSTRACT

Ultrasound-Guided Regional Anesthesia (UGRA) has been gaining importance in the last few years, offering numerous advantages over alternative methods of nerve localization (neurostimulation or paraesthesia). However, nerve detection is one of the most difficult tasks that anesthetists can encounter in the UGRA procedure. The context of the present work is to provide practitioners with a computer-aided system to facilitate the practice of UGRA. However, automatic detection and segmentation in US images is still a challenging problem in many medical applications. This paper addresses two main issues, first proposing an efficient framework for nerve detection and segmentation, and second, reviewing literature methods and evaluating their performance for this new application. The proposed system consists of four main stages: (1) despeckling filter, (2) feature extraction, (3) feature selection, (4) classification and segmentation. A comparative study was performed in each of these stages to measure their influence over the whole system. Sonographic videos were acquired with the same ultrasound machine in real conditions from 19 volunteer patients. Evaluation was designed to cover two important aspects: measure the effect of training set size, and evaluate consistency using a cross-validation technique. The results obtained were significant and indicated which method was better for a nerve detection system. The proposed scheme achieved high scores (i.e. 80% on average of 1900 tested images), demonstrating its validity.



## 1. Introduction

Regional anesthesia presents an interesting alternative or complementary act to general anesthesia in many surgical procedures. It reduces pain scores, improves postoperative mobility and facilitates earlier hospital discharge. Traditionally, this technique is performed with blind guidance of the needle to the target nerve. This method of needle guidance increases the risk of block failure, nerve trauma and local anesthetic toxicity [1]. To reduce these complications, the current trend is to use the Ultrasound-Guided Regional Anesthesia (UGRA) technique. The ability of UGRA to perform nerve block via direct sonographic visualization has an enormous impact on the practice of regional anesthesia [2–5]. Hence, UGRA has been gaining importance in recent years, and emerging as a powerful technique in pain management [3]. However, the lack of qualified practitioners and the gap between technology and practice inhibits the generalization of UGRA to a large number of medical facilities. Performing the UGRA routine requires a long learning process, mainly due to the poor quality of anatomical visualization and the need for experience in tracking and estimating the needle position regarding morphological discrepancies between patients [4,6].

The key problems with UGRA practice is the nerve localization and needle tracking in ultrasound (US) images. Several methods for needle tracking in ultrasound images have been proposed in the literature. Some focus on software aspects using image processing techniques [7] while others are based on improving the physical properties of the needle to make it more echogenic, thus enhancing visualization [8]. Despite fact that the needle detection is among the major problems in UGRA, the nerve (target) detection remains unexploited (to the authors' knowledge) and nerve detection errors can result in accidental intra neural injection which can lead to serious complication. There are very few studies that focus on nerve detection either from a software or a physical standpoint. Recently, Photoacoustic (PA) imaging method were

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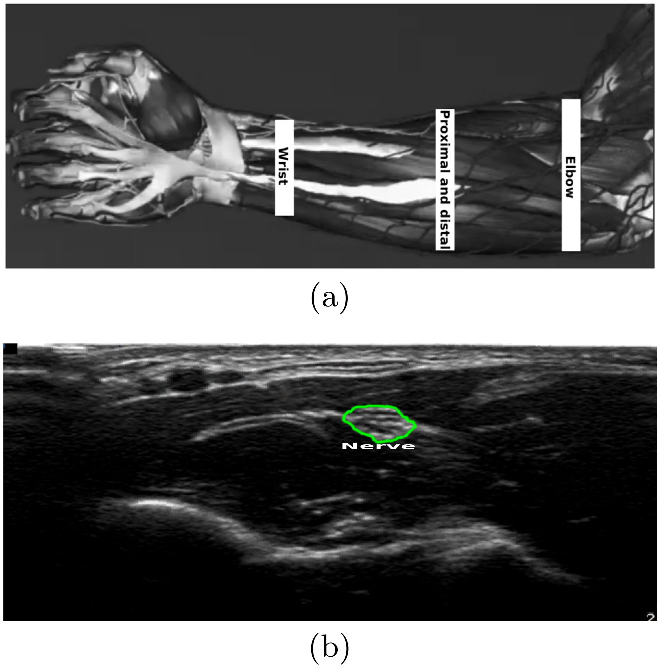


**Fig. 1.** (a) Marking indicates the 3 levels at which an attempt was made to visualize median nerves in the forearm, (b) ultrasound images of the median nerve in the distal forearm.

proposed to improve the nerve visualization [9,8,10]. In [10,11], the authors have developed an intergenerational multispectral PA (IMPA) imaging technique to discriminate nerve tissues. However, the main limitation of this kind of imaging system is their cost which will make it difficult to deploy this solution for regional anesthesia in the near future. In contrast, the present study focuses on software aspects of nerve detection using cross sectional images from ultrasound machines available in the operating room. The development of such a technique will enable easy implementation on ultrasound images at a low cost. Moreover, the development of a UGRA imaging system with better nerve visualization will facilitate nerve detection and increase the performance of the segmentation algorithms.

One of the promising solutions is Computer Aided Detection (CAD) that has the potential to bridge this gap and support the practitioner by highlighting regions of interest in US images. In the last few decades there has been growing interest in CAD systems in different medical applications [12,13]. Modern approaches to automatic detection in US images involve four basic stages [14,15]: (1) despeckling filter, (2) feature extraction, (3) feature selection and (4) classification. Each of these stages has been widely investigated in the literature, because each one presents challenging issues to be solved. Despeckling filters are used to increase the contrast of the Region of Interest (ROI) and reduce background speckle [16–18]. Concerning feature extraction numerous texture descriptors have been proposed to characterize the ROIs [19–25]. Feature selection is used to select the most significant feature to increase the accuracy of detection [26,27]. Classification is the stage in which a candidate ROI is identified as positive or negative class [15,28]. Several studies have reported significant improvements in medical practice and efficiency when using a CAD system [29–32]. Nerve detection is among the difficult tasks that the anesthetist can encounter in the UGRA procedure, as illustrated in Fig. 1 which shows the median nerve in a US image. While the CAD strategy can provide anesthetists with a useful tool that enables automatic nerve detection in US images, a key issue is that the US imaging modality is associated with poor visual properties of the nerve, which makes automatic localization a very challenging problem. Very few studies can be found in the literature that address this issue [33–35]. In [34], a method based on the combination of a monogenic signal and a probabilistic active contour was proposed to detect the sciatic nerve. The technique proposed in [35] is based on the combination of median binary pattern MBP [36] and Gabor filter to characterize and classify pixels belonging to the median nerve tissues. Recently, a machine learning framework was also proposed to enable robust detection of the median nerve [37,38]. However, these studies do not provide an overview or extensive evaluation of the state-of-the-art techniques used in US images.

This raises the following questions: (1) how do state-of-the-art techniques perform nerve detection in the UGRA application? (2) which type of method at a given stage can lead to the best performance of the proposed framework?

A number of authors have reviewed computer vision and machine learning methods in US images for several medical applications. In [14], the authors surveyed many approaches of each step of a CAD system for a breast cancer application. They conducted an extensive literature review and discussed the advantages and limitations of each stage. However, the study did not take into account the performance evaluation which is a critical step to measure the limitations of a method for a given application effectively. Many studies have attempted to carry out comparative studies of detection techniques in US images. In [19] a comparative study for myocardial infarction detection systems was conducted. In [20], the authors reported a comparative analysis of wavelet techniques. In [16], the authors compared despeckling techniques. Most of these comparative studies focus on one stage of the CAD system. The main weakness with this methodology is that one cannot draw any effective conclusion about the performance of the whole pipeline. It would be more relevant if an evaluation study considered all the main stages of a CAD system. In this work we propose a framework for median nerve segmentation consolidated by a comparative study of the performance of each component of the framework. Fig. 2 depicts

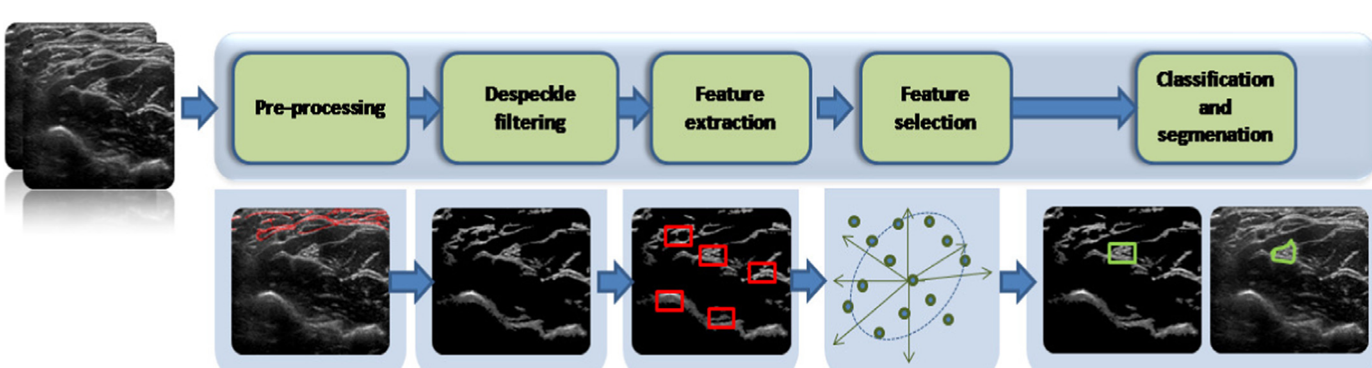


**Fig. 2.** Phases of the proposed nerve localization system.