Preoperative Non-Invasive Staging of Lymph Nodes

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Abstract

In this paper a pre-operative non-invasive technique for evaluation and staging of lymph nodes in order to optimize surgical planning is presented. Lymph node stiffness is an useful information for staging and is usually obtained with surgical intervention. In our work 3D dynamic models of lymph nodes are obtained from medical scans. Lymph node models are inserted in a laparoscopy simulator developed at the ALTAIR laboratory, University of Verona. Interaction through a haptic device gives the surgeon hints about lymph node stiffness.

KEYWORDS: Lymph Nodes Staging, Segmentation, Surgical Simulation

1. Purpose

Morphologic imaging relies only on the shape and size criterion to classify lymph nodes, with nodes that are round or have a short-axis diameter greater than 1cm being suspicious for malignancy [1]. However, these criteria are not always sufficient for a correct differential diagnosis between benignancy and malignancy. Accurate staging of the lymph nodes therefore still relies mainly on surgical exploration and manual lymph node palpation [2]. Nowadays there is emphasis on the development of non-invasive approaches, based on medical imaging, to detect, segment and classify the lymph nodes preoperatively [3, 4]. In this work we give our contribution in this direction, adding a stage in the diagnosis approach: simulated palpation through virtual laparoscopic instruments.

The main problem consists in segmenting lymph nodes and extracting their features for classification. The challenge is that appearance, geometry, and location of lymph nodes have a huge variation, so the segmentation algorithm has to account for these variations in delineation of the lymph nodes. Besides, the feature extraction algorithm should identify discriminative features for node classification.

The goal of this work is to automatically extract useful information from images through segmentation, and use those data to build dynamic model of the lymph nodes.

2. Methods

When tumor manifestation and extent of the disease cannot be evaluated with sufficient accuracy at imaging, in most cases diagnostic laparoscopy is employed [5]. In our system we use the same idea of laparoscopic exploration giving the possibility to the user to feel the shape and stiffness of lymph nodes as in laparoscopy but in a virtual environment.

We extract lymph nodes shape and position from CT images and we analyze the trend of the pixels intensities from one phase to the other to determine tissue properties. In fact, as different research studies have underlined [6] and our experimental setup has confirmed, the trend of absorption and reflux of the contrast agents varies according to the tissues nature. This allows us to distinguish between malignant and healthy masses, even if their grey levels are not visibly different.

Knowing the trends of pixels intensities of both cancerous and normal lymph nodes in all the acquisition phases, and having the stiffness data of sample lymphatic tissues, we calibrate the images to quantify the elasticity/rigidity of the masses and classify them. We use lymph node topology and calibrated data to initialize mass spring models that are inserted in a laparoscopy simulator with force feedback (Figure 1.b).

3. Results

In our study we segment from abdomen CT scans both normal and pathological lymph nodes. In Figure 1.a results of the segmentation process are presented: both benign and malignant lymph nodes, are highlighted which in this study are clearly distinguishable, simply basing on the size criterion.
Based on the indications for the examination, we acquire different contrast-enhanced phases and analyze the intra-phase differences in pixel intensities to define an objective criterion for lymph node evaluation. Our studies highlight that malignant lymph nodes show pixel intensities 40% higher with respect to normal ones when images are acquired without any contrast medium. From both the morphological information (size and shape) and stiffness values it is possible to build a complete model of the lymph nodes. We use a linear map between lymph node Hounsfield mean value and the interval [10-100] MPa to obtain tissue Young modulus and the method proposed in [7] to initialize models. The reconstructed models are then integrated in our laparoscopy simulator.

Using the simulator surgeons can sense the differences in rigidity of the modelled lymph nodes through a haptic device connected to the simulator and stage the lymph nodes. In Figure 1.b a screenshot of the virtual interaction is shown.

4. Conclusion

Results show the feasibility of the approach and in the future we will give a clinical evaluation of this new diagnostic methodology. In order to increase the accuracy of the diagnosis and define complete classification of the lesions, we are studying the possibility to integrate CT acquisitions with other imaging systems. Moreover, it would be possible to define the lymph node stiffness by acquiring the tissues properties from reachable structures, such as neck and axillary lymph nodes, and then calibrate the deeper ones by comparing the intensities of images acquired with conventional CT.

References