Implementing Computer Assisted Detection systems for the analysis of lung Computed Tomography scans

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Screening programs are of paramount importance for early cancer diagnosis in asymptomatic subjects and consequent mortality reduction. The development of Computer Aided Detection (CAD) systems would significantly improve the prospects for the screenings, by working either as second reader to support the physician's diagnosis or as first reader to select images with highest cancer probability. The main purpose of the MAGIC-5 [1] collaboration is the development of CAD systems for the analysis of medical images on distributed databases by using also a GRID connection. The collaboration involves physicists, computer scientists, mathematicians, and physicians from several Italian universities, INFN sections, and hospitals. Up to now, the attention has been focused to the analysis of x-ray mammograms, lung CT scans, and brain NMR images. Here we will shortly describe some of the features of the lung CT image handling and processing.

We are currently working on three aspects of lung CAD systems:

- lung segmentation, performed so that nodule detection can operate in optimal conditions (false positive reduction, efficiency improvement)
- pathologic tissue detection
- annotated image-database management with multiple search keys.

The lung segmentation algorithm in CT images. We have proposed a new segmentation method for the delimitation of the lung parenchyma in thorax Computed-Tomography (CT) datasets [1], which will be used as preprocessing step in the CAD system for lung nodule detection that is being developed by the MAGIC-5 Collaboration.

The code of our fully automated and three-dimensional (3D) algorithm was written in C++/ROOT. After reading the CT slice sequence, the algorithm begins its flow, consisting in various steps: gray-value threshold calculation, 3D Region Growing (RG), wavefront simulation for external bronchi extraction, lung "fusion" solution, inclusion of nodules by 3D morphology. Noteworthy is the external bronchi extraction: with the goal of a correct handling of the hilar region, we segment the airways out, starting from the trachea down to the bronchi entrance into the lungs. After removing the extrapulmonary airways, the clean-cut lungs remain.

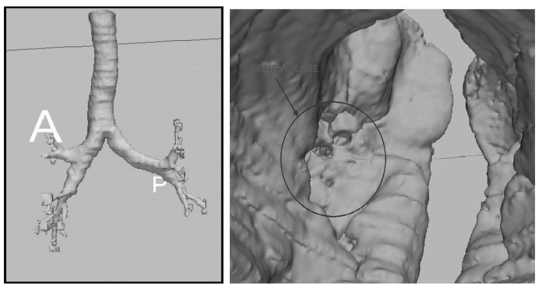

Figure 1. The extracted extrapulmonary airways (left) and the hilar region after the airways removal.

In *Fig. 1* the segmented external airways are shown on the left. The final lung masks (*Fig. 2*)

[1]Medical Applications on a Grid Infrastructure Connection, http://mag09xl.to.infn.it/site/

cover the pulmonary parenchyma, the lung nodules, internal blood vessels and airways. The algorithm was applied to about 200 CT scans from the MAGIC-5 database. Qualitative (visual inspection) and quantitative (sensitivity for nodule inclusion) tests were carried on, with satisfactory results.

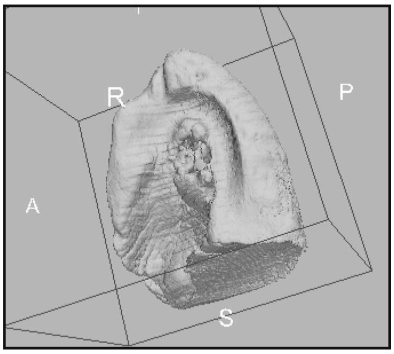

Figure 2. An output lung mask.

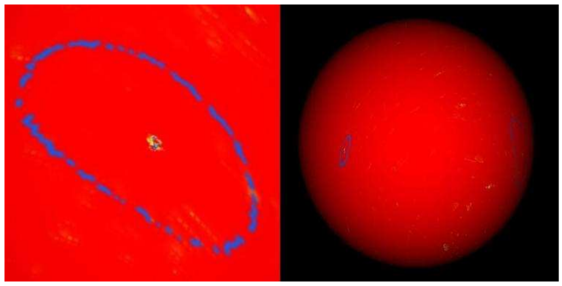

Figure 3. (Right) Lung surface after uniformization; nodules are marked from the radiologist annotations, and a curvature function is mapped in color. (Left) A nodule detail.

Lung Uniformization for Juxta-Pleural Nodule Detection. Lung nodules are dense, roughly spherical, $\sim$ 3-10 mm objects . This work [2] focuses on juxta-pleural nodules, i.e. nodules growing from the pleura, or originated from the lung parenchyma but in contact with the pleural sheet. Several mathematical approaches can be followed to uniformize the lung surface, e.g. [3] and [4]. Following these approaches, the lung masks, with patched vessel entry points, are triangulated and uniformized to the sphere surface. In our work the local mean and gaussian curvatures of the original lung surface are then mapped to the spherical lung representation. Pleural nodules, high curvature formations which stretch out towards the interior of the lung surface, can thus be put in evidence by color. In Fig.3 a lung surface can be seen, after uniformization to the sphere, with an appropriate curvature function mapped on it: the position of some nodules reported by a radiologist have been evidenced. Color mapping puts in evidence the nodule positions. The preliminary tests performed on a few CT images look promising. Of course false positive regions exist, and must be discriminated. We are evaluating the use of spherical wavelets to characterize the regions of interest, and we are implementing optimal ways to quantify the compactness of high-curvature regions.

Lung CT datasets and the annotation protocol. In Italy, to the best of our knowledge, there exist no archives of images, annotated by radiologists of various experience and according to well defined protocols, to be used as a "gold standard" for CAD system development. Nowadays the ANODE09 initiative (http://anode09.isi.uu.nl/) is going to compare lung CAD systems with a single evaluation protocol. This is due to the existence of multiple commercial systems and to the large number of published papers. So the opportunity to test algorithms on large common database is very attractive.

The construction of our lung CT database was developed mainly by following these steps:

1. the analysis of the technical and software resources necessary to implement the best configuration and the inclusion criterions;

2. the choice of standard protocols for the selection of the cases, and the development of a graphical user interface.

Expert radiologists annotated for more than two years about 200 scans in terms of size and spatial location of the nodules; they used the LUNA (LUng Nodule Annotation) automated tool (developed by the Collaboration) and a common annotation protocol. The resulting annotated database is used to develop and validate the CAD algorithms.

REFERENCES

1. G. De Nunzio et al., *An innovative lung segmentation algorithm in CT images with accurate delimitation of the hilus pulmunis* Proc. MIC-2008 (Dresden - Germany)
2. G. De Nunzio et al., *Lung Uniformization for Juxta-Pleural Nodule Detection* Proc. MIC-2008 (Dresden - Germany)
3. S. Angement et al., IEEE Trans. Medical Imaging, 18 (1999), pp. 700-711
4. S.J. Rahi et al., Report of Dept. of Biochemistry and Biophysics, Univ. of Pennsylvania, School of Medicine, Philadelphia, Pennsylvania