Detection of Pulmonary Nodules in CT Scans

Martin Dolejší, Jan Kybic
Czech Technical University Prague
dolejm1@fel.cvut.cz

Abstract. A computer-aided diagnosis (CAD) system to detect small-size (from 2mm to around 10mm) pulmonary nodules in helical CT scans is developed. This system uses two different schemes to locate juxtapleural nodules and non-pleural nodules. For juxtapleural nodules, morphological closing and thresholding is used to find nodule candidates. To locate non-pleural nodules, 3D blob detector uses multiscale filtration. System was tested on 5 cases with total sensitivity of 95%, with about 10 false positives/slice.

1 Introduction

Lung cancer is one of the leading causes of death. Surgery, radiation therapy, and chemotherapy are used in the treatment of lung carcinoma. In spite of that, the five-year survival rate for all stages combined is only 14%. However, early detection helps significantly — it is reported that the survival rate for early-stage localized cancer (stage I) is 49%.

CT is considered to be the most accurate imaging modality available for early detection and diagnosis of lung cancer. Volumetric CT chest images can be acquired with 1–3 mm axial collimation. However, the large amount of data per examination makes them tedious and difficult to interpret, leading to a high false-negative rate for detecting small nodules. Although CT may be capable of depicting lung nodules as small as 1 mm, a simulation study demonstrated [4] the overall detection rate to be only 63% for nodules 1–7 mm in diameter. As the size of the nodule decreased, the sensitivity fell and only 1% of nodules less than 1.5 mm in diameter were detected. Computer-assisted tools to improve the detection of small nodules from chest CT are therefore needed [1] and are being actively developed [1,4,5].

We are proposing a new fully automatic and fast detection algorithm for both juxtapleural and non-pleural nodules. It is based on segmentation based on thresholding, blob detector using multiscale LoG filters with postprocessing, and mathematical morphology tools. It is designed to have a good sensitivity and few false negatives, help identifying suspect regions for a human observer, or as a first step to a more precise (but slower) automatic nodule classification system.

2 Methods

Our algorithm consists of four steps:

2.1 Separation of the lungs from the other anatomic structures by segmentation: Lungs can be easily separated from other anatomic structures by single thresholding at -350HU, see Fig. 2.1. After thresholding the background (the outside of the body) is eliminated by suppressing all components adjacent to image edges by flood-filling.

2.2 Detection of juxtapleural nodule candidates: Smoothed lung mask (Fig. 2.2) is created by morphological closing with a circle element of 15mm in diameter. Map of juxtapleural nodule candidates is then generated as a difference between the smoothed and the original lung masks. Objects not located on lung boundary are eliminated. Boundary of lungs is generated from smoothed mask as $E = S - \bigcap_{d \in D} S_{-d}$, where S is smoothed mask, $\bigcap_{d \in D} S_{-d}$ morphological erosion by structure element D. Disc element 7mm in diameter is used. Finally, objects of area greater than 10mm^2 in each slice are eliminated because of small dimensions of juxtapleural nodules. In Fig. 2.3 small juxtapleural nodule is marked by square, other objects created by thresholding could be eliminated, see Fig 2.4.

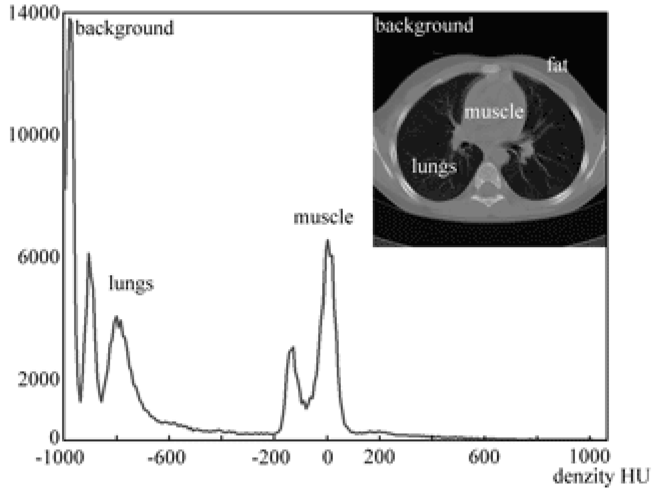

Fig 2.1 Original CT slice and its histogram

2.3 Detection of non-pleural nodule candidates: For non pleural modules, 3D blob detector is used. To accommodate different dimensions of the nodules, the detection is performed at different scales. The detector consists of several (4) LoG (Laplacian of Gaussian) filters of diameters 9, 13, 17, and 21mm, corresponding to different dimensions of nodules. For each filtration local maxima are found. If the position of the maxima does not change significantly between scales, its position interpreted as a potential non-pleural nodule centre (Fig 2.5). Separability of the LoG filters is used to accelerate the procedure.

2.4 Ellipsoid fitting and measurements: We shall find an ellipsoid model described by $\frac{(x-x_0)^2}{a}+\frac{(y-y_0)^2}{b}+\frac{(z-z_0)^2}{c}=r^2$ and further rotated by angles φ and υ around coordinate axes, that maximizes the following criterion: $X=\sum_{x\in ielipsoid} f(x)-T$, where $f(x)$ is the image and T the threshold. For the first experiments threshold was set to -700 HU.

Fig 2.2
Smoothed lung mask

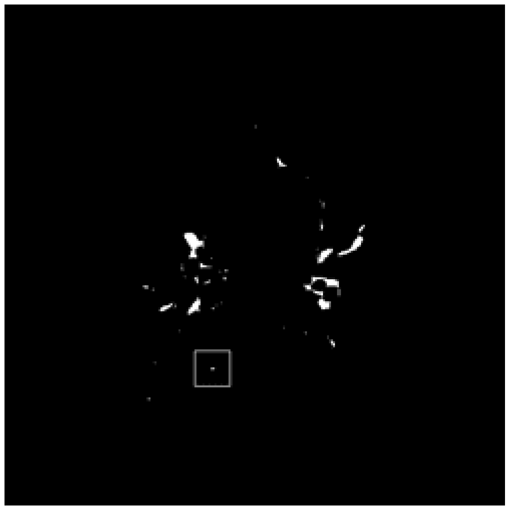

Fig 2.3
One juxtapl. nodule (square) & other objects

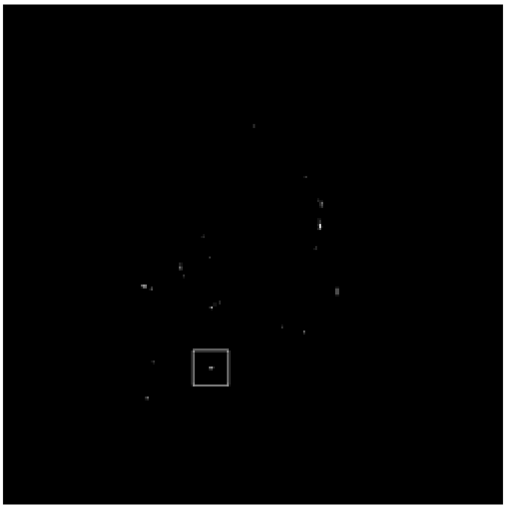

Fig 2.4
Potencial juxpl. nodules >10mm^2 eliminated

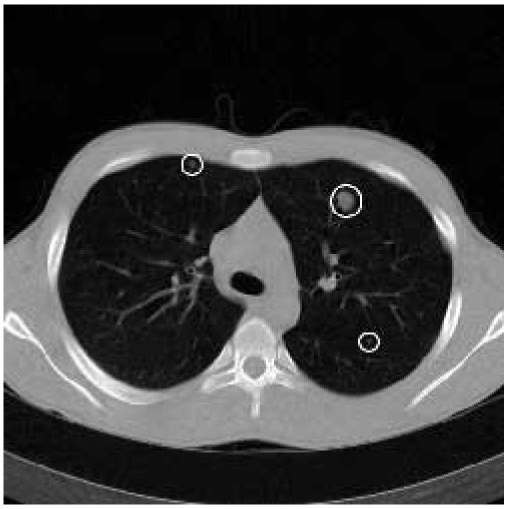

Fig 2.5
Three non-pleural nodules (circles)

3 Results

Our algoritm was applied to 5 CT scans (1405 slices) from Somatom AR Star CT machine for which nodule information was available. In total, 40 nodules was known, 12 juxtapleural and 28 non-pleural. System worked with sensitivity 91.67% on juxtapleural and 96,43% on non-pleural nodules, combined sensitivity is 95%. About 10 false positives per slice is generated (8 from 3D blob detector and 2 from juxtapleural detection).

4 Conclusions

The detector works with 95% sensitivity on this data and can thus be used to point out suspect regions. The 8 false positives (detections) on each slice should be improved significantly by applying further classification steps after the detection. There are about 10 objects detected by our algoritm which apear to be juxtapleural or non-pleural nodules missed by the human observer.

Acknowledgements

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