Chapter 6
Computerized Detection of Lung Nodules on Chest Radiographs:
Application of Bone Suppression Imaging by Means of Multiple Massive-Training ANNs

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ABSTRACT

Most lung nodules missed by radiologists as well as Computer-Aided Diagnostic (CADe) schemes overlap ribs or clavicles in Chest Radiographs (CXRs). This chapter introduces an image-processing technique for suppressing the contrast of ribs and clavicles in CXRs by means of anatomically specific Multiple Massive-Training Artificial Neural Networks (MTANNs). For bone suppression, an MTANN is trained by use of input CXRs and the corresponding "teaching" images. The authors employed bone images obtained by the use of a dual-energy subtraction technique as the teaching images. For the effective suppression of ribs, having various spatial frequencies, the authors developed a multi-resolution MTANN consisting of multi-resolution decomposition/composition techniques and three MTANNs for three different-resolution images. After training with input CXRs and the corresponding dual-energy bone images, the multi-resolution MTANN was able to provide "bone-image-like" images which were similar to the teaching bone images. By subtracting the "bone-image-like" images from the corresponding CXRs, the authors were able to produce "soft-tissue-image-like" images in which ribs and clavicles were substantially suppressed. A single set of multi-resolution MTANNs cannot suppress all bone structures in a CXR, because the orientation, width, contrast, and density of bones differ from location to location, and the capability of a single set of multi-resolution MTANNs is limited. To address this issue, the authors developed anatomically specific multiple MTANNs which consist of eight sets of multi-resolution

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MTANNs that were designed to process different segments in the lung fields in a CXR. Each set of anatomically specific MTANNs was trained with only the samples in the corresponding segment in the CXR. In order to make the contrast and density between the segments consistent, the authors applied a histogram matching technique to input images. To improve the performance of their CADe scheme, the authors incorporated their MTANN bone suppression into their CADe scheme for nodules in CXRs. In their CADe scheme, 64 morphologic and gray-level-based features were extracted from each nodule candidate in both the original and the "soft-tissue-image-like images," and a nonlinear support vector classifier was employed for the classification of the candidates. The authors used a validation test database consisting of 118 CXRs with pulmonary nodules and a publicly available database containing 126 nodules. When their technique was applied to non-training CXRs, bones in the CXRs were suppressed substantially, while the visibility of nodules and lung vessels was maintained. With the use of "soft-tissue-image-like images," the performance of the authors' CADe scheme was improved from a sensitivity of 76% to 84% with 5 false positives per image. Thus, the authors' image-processing technique for bone suppression by means of anatomically specific multiple MTANNs is useful for radiologists as well as for CAD schemes in the detection of lung nodules on CXRs.

INTRODUCTION

Computer-Aided Detection (CADe) (Giger,, et al., 1988; van Ginneken,, et al., 2001) for lung nodules on Chest Radiographs (CXRs) has been investigated for assisting radiologists in improving their sensitivity in the detection of lung nodules. Although a great deal of work has been done by researchers to improve the performance of CADe schemes for nodule detection on CXRs, CADe schemes still produce a relatively large number of False Positives (FPs). This would distract radiologists in their detection and reduce radiologists' efficiency. In addition, radiologists may lose their confidence in the CADe scheme as a useful tool, which may result in less improved performance of radiologists.

A major challenge for current CADe schemes for nodule detection on CXRs is to detect the nodules overlapping ribs, rib crossings, and clavicles, because a majority of FPs are caused by these structures (Matsumoto, et al., 1992; Xu, et al., 1997). This leads to lowering the sensitivity as well as the specificity of a CADe scheme. In order to detect nodules that overlap ribs and clavicles and to reduce the FP rate often caused by ribs and clavicles in standard CXRs, Kido et al. developed a CADe scheme based on single-exposure dual-energy computed radiography (Kido,, et al., 2002a; Kido,, et al., 2002b). A dual-energy subtraction technique (Glocker & Frohnmayer, 1925; Jacobson & Mackay, 1958) is used for separating soft tissue from bones in CXRs by use of two x-ray exposures at two different energy levels. The dual-energy subtraction technique produces soft-tissue images from which bones are extracted. By use of dual-energy soft-tissue images, the performance of their CADe scheme was improved. In spite of its great advantages, only a limited number of hospitals use a dual-energy radiography system, because specialized equipment is required. Also, the radiation dose can be more than double compared to that for standard CXR.

To address the issue of the availability of dual-energy radiography systems, Suzuki et al. developed an image-processing technique called Virtual Dual-Energy (VDE) radiography for suppressing ribs and clavicles in CXRs by means of a multi-resolution MTANN (Suzuki,, et al., 2004; Suzuki,, et al., 2006). The real dual-energy images were used as the teaching images for training of the multi-resolution MTANN. Once the multi-resolution MTANN was trained, real dual-energy images were no longer necessary.

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