

Tuberculosis screening of chest radiographs

Stefan Jaeger, Sameer Antani, and George Thoma

New intelligent image-processing software examines chest x-rays for infections.

Tuberculosis (TB) is one of the most common causes of death by an infectious agent,¹ with an estimated nine million new cases appearing every year. About one-third of the world's population is infected with *Mycobacterium tuberculosis*, the bacterial strain that causes the majority of cases. TB is most prevalent in sub-Saharan Africa and Southeast Asia, where widespread poverty and malnutrition reduce resistance to the disease. Despite progress made in prevention, diagnosis, and treatment, the emergence of multi-drug-resistant bacterial strains and opportunistic infections in immunocompromised patients, for example, those with HIV (human immunodeficiency virus), has exacerbated the problem. However, the likelihood of curing TB is improved when it is diagnosed at an early stage. Computer-aided screening and diagnosis have received increasing attention with the advent of digital chest x-rays (CXR), which allow image processing that traditional film x-rays do not. Here, we describe our progress—in collaboration with the Academic Model Providing Access to Healthcare (AMPATH)—toward improving TB diagnosis with intelligent software designed for portable scanners that can easily be used in remote locations.

Several skin tests are available—based on immune response—for determining whether an individual has been exposed to TB. However, it is often not possible to make a final diagnosis based on these tests alone. Thus, physicians typically use additional tests—including posteroanterior x-rays of the patient's chest—to confirm or rule out infection. The abnormalities displayed in radiographs in TB are generally diffuse, and the distinction between normal anatomical structures and abnormal patterns is difficult to determine. Furthermore, low-contrast images complicate identification of the subtle radiographic manifestations of TB. The lack of adequate radiological services in the worst-affected areas necessitates an automated,



Figure 1. Contrast-enhanced chest x-ray, normalized with a histogram-equalization technique, showing a nodule in the right lower lobe.²

computer-aided means to screen CXRs in the field, so that at-risk individuals can be referred for further evaluation and treatment.

We addressed the detection of TB and other diseases in CXRs as a pattern-recognition problem. We developed our algorithms using x-rays from the Japanese Society of Radiology Technology database.² In a preprocessing step, we first enhanced the contrast of the image using a histogram equalization technique (see Figure 1). Our processing steps include lung field extraction from the other structures in the x-ray—such as the heart, clavicles, and ribs—based on an adaptive segmentation method. Deviations from the typical lung shape and areas of increased lung opacity indicate abnormalities, such as consolidations (i.e., airspace fillings) or nodules (i.e., spherical abnormal structures). We captured these abnormalities with a bag-of-features approach that included descriptors for shape and texture. To detect nodules, for example, we first applied a Gaussian filter and

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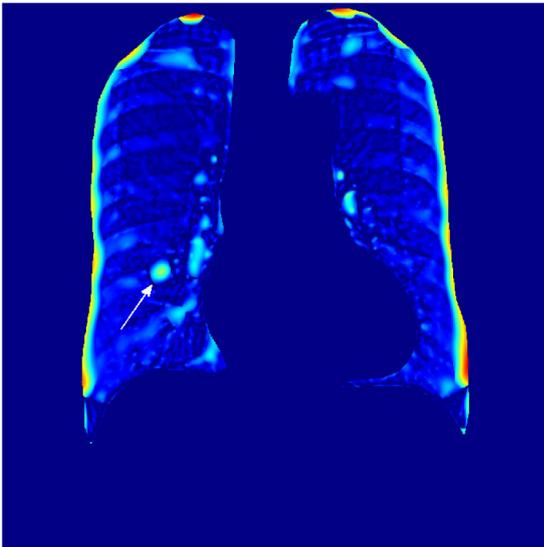


Figure 2. Application of our algorithms to the x-ray in Figure 1 revealed regions of high curvature, such as the nodule in the right lower lobe.

computed the eigenvalues of the Hessian matrix. We then computed a multi-scale similarity measure that responds to spherical 'blobs' with high curvature (see Figure 2). Finally, we used these features to train a binary classifier that discriminates between normal and abnormal CXRs.³

In summary, we have implemented a preliminary system that is capable of detecting some manifestations of disease in CXRs. In principle, our novel algorithms can be implemented on any portable x-ray unit. In the future, we will implement additional detectors for all the major radiographic abnormalities and train our system on a large set of x-rays acquired from various sources, including those from portable x-rays in the field.

Author Information

Stefan Jaeger, Sameer Antani, and George Thoma

Communications Engineering Branch
National Library of Medicine (NLM)
Bethesda, MD

Stefan Jaeger is a visiting scientist at the NLM. He received his diploma and PhD in computer science from the Universities of Kaiserslautern and Freiburg, Germany. His research interests are in biomedical imaging and medical informatics. He is associate editor of *Electronic Letters on Computer Vision and Image Analysis*.

Sameer Antani is a scientist whose research includes biomedical imaging and informatics. He is a member of SPIE, vice-chair for the IEEE Technical Committee on Computational Life Sciences, and an editorial board member of *Computers in Biology and Medicine* (Elsevier).

George Thoma is chief of the Communications Engineering Branch of the Lister Hill National Center for Biomedical Communications, a research and development division of the NLM. In this capacity, he directs intramural research and development in mission-critical projects. He earned his BS from Swarthmore College, and MS and PhD from the University of Pennsylvania, all in electrical engineering. He is a fellow of SPIE, and on the program committee of the SPIE Document Recognition and Retrieval conference.

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