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Optimization-Based Tuberculosis Image Segmentation by Ant Colony Heuristic Method

E. Priya, Sri Sairam Engineering College, India*
https://orcid.org/0000-0002-8069-8546

ABSTRACT

Tuberculosis (TB) is a worldwide health crisis and is the second primary infectious disease that causes death next to human immunodeficiency virus. In this work, an attempt has been made to detect the presence of bacilli in sputum smears. The smear images recorded under standard image acquisition protocol are subjected to hybrid ant colony optimization (ACO)-morphological-based segmentation procedure. This method is able to retain the shape of bacilli in TB images. The segmented images are validated with ground truth using overlap, distance, and probability-based measures. Significant shape-based features such as area, perimeter, compactness, shape factor, and tortuosity are extracted from the segmented images. It is observed that this method preserves more edges, detects the presence of bacilli, and facilitates direct segmentation with reduced number of redundant searches to generate edges. Thus, this hybrid segmentation technique aids in the diagnostic relevance of TB images in identifying the objects present in them.

KEYWORDS

Ant Colony Optimization, Bacilli, Fluorescence Microscopy, Morphological Operators, Shape-Based Features, Tubercle Bacilli

INTRODUCTION

Tuberculosis (TB) is the second leading cause of infectious death, after human immunodeficiency virus and is a global health problem. It is one of the leading cause of mortality in India, killing two persons every three minutes, almost thousand every day. This infectious disease most frequently infects the lung, and the condition is known as Pulmonary Tuberculosis (PTB). The symptoms of PTB patients are fever, loss of appetite, weight loss, chest pain or dyspnea (Bhalla et al., 2015).

TB is caused by Mycobacterium tuberculosis which is contagious and spreads through air. Throughout the world, examination of sputum smear stains by microscopy has remained the cornerstone for PTB diagnosis and screening (WHO Tuberculosis Fact, 2007). Manual screening is labor intensive and has a high false negative rate. The procedure is thus a time consuming, inaccurate and inefficient process. It takes about 40 minutes to even 3 hours to analyze a slide which atmost depends on the level of infection (Sotaquira et al., 2009). In low and middle-income countries to assure early detection of the disease TB diagnosis is centered on the microscope, the use of which is fast, cheap and a repeatable method.

Microscopic examination of sputum smears remains the most widely used investigation in clinical practice, especially in developing countries and countries with high prevalence of TB. Sputum smear

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microscopy represents one of the five pillars for tuberculosis control in the directly observed treatment short course strategy (Rao, 2009).

The recent guidelines for diagnosis of TB are primarily based on the demonstration of acid-fast bacilli on sputum smear microscopy. Among the diagnostic techniques of TB, culture of Mycobacterium tuberculosis is the gold standard. However, culture is a slow process and requires specialised laboratories with high skilled technician. It takes about six to eight weeks to declare the severity of the disease. Serological tests are currently not reliable enough for the diagnosis of tuberculosis (Javed et al., 2015; Goyal and Kumar, 2013). Chest radiograph finds a conclusive result only at a later stage of the disease. Though computed tomography is frequently used in the diagnosis and follow-up of TB, it is not adviced in the national and international guidelines. The use of ultrasound and magnetic resonance imaging is lacking in the literature for TB patients. Thus India being a large burden of TB, it is important to establish imaging criteria and recommendations for the diagnosis (WHO Tuberculosis Fact, 2007).

The International Union Against Tuberculosis and Lung Disease and World Health Organization specify that the essential step in the investigation of patients who are suspected of having pulmonary tuberculosis should be the microscopic examination of their sputum samples. Thus sputum smear microscopy has been an integral part of global strategy for the control of TB (Desikan, 2013).

Microscopic examination of sputum smears include two staining procedures such as Ziehl-Neelson (ZN) and auramine stained specimens. ZN is the most extensively used procedure for identifiying Mycobacterium tuberculosis in smear. The ZN staining procedure require basic fuchsin, phenol, absolute alcohol, sulphuric acid and methylene blue. Oil immersion objective of microscopy reveals Mycobacterium as red bacilli. ZN stain method is less sensitive relative to fluorescent stain as it takes more time to scan the view fields under the microscope (Javed et al., 2015).

The other method is the fluorescent staining by auramine. Fluorescence microscopy was introduced in an attempt to improve the results of smear microscopy. The auramine stain enters the wall of Mycobacterium tuberculosis bacterial cell and makes them glow under ultra violet light against dark background. Microscopic examination of the Mycobacteria reveal a glowing yellow white rice shaped bacteria in the smear. Flurescence microscopy technique has the advantage to examine at lower magnification thereby allowing the larger area per unit of time. The sensitivity of fluorescent microscopy is found to be high and is ten percent higher than that of conventional microscopy (Javed et al., 2015; Goyal and Kumar, 2013; Desikan, 2013).

The automated screening for tubercle bacilli has lot many potential benefits such as the ability to screen large number of patients, an inexpensive diagnostic technique, increased resources to monitor patients and reduction in health risk of the technician. Images are then captured with the help of digital camera and is further enhanced through imaging processing techniques (Goyal and Kumar, 2013).

BACKGROUND

Several image analysis techniques have been reported as a tool for bacilli identification in sputum smear samples. Sotaquira et al. (2009) proposed combined YCbCr and Lab color spaces for the segmentation. Hue color component-based approach is developed to segment the bacilli by Makkapati et al. (2009) and classification performed by them is based on bacilli shape characterization. Khutlang et al. (2010) using a combination of pixel classifiers segmented the candidate bacillus. Veropoulos et al. (1998) investigated edge pixel linkage and morphological closing for characterizing the bacilli. Forero et al. (2006) used Gaussian mixture model to parametrise the bacillus data set. Costa et al. (2008) used global adaptive-based threshold segmentation to identify the candidate bacillus. Sadaphal et al. (2008) identified color-based Bayesian segmentation of sputum smears. Raof et al. (2008) conducted multi-level thresholding for identification and classification of tubercle bacili. Lenseigne et al. (2007) proposed pixel level image segmentation algorithm based on support vector machine classifier. Identification of Tubercle bacilli from the conglomeration of TB objects are quite