Swarm and Evolutionary Computation xxx (2018) 1–28

Contents lists available at ScienceDirect

Swarm and Evolutionary Computation

journal homepage: www.elsevier.com/locate/swevo

Bio-inspired methods modeled for respiratory disease detection from medical images

Marcin Woźniak *, Dawid Połap

Institute of Mathematics, Silesian University of Technology, Kaszubska 23, 44-100 Gliwice, Poland

ARTICLE INFO

2010 MSC:
68U10
68T10
90C59

Keywords:
Medical image processing
X-ray imaging applications
Object classifier
Bio-inspired methods

ABSTRACT

Medicine is an important venue for practical applications of science. A fusion of mathematical modeling and programming into computer methods makes a great support for efficient treatment and diagnosis. Computational Intelligence is one of these sciences which bring valuable help in decision support. In this article we present a devoted methodology implemented to simulate medical examinations of pulmonary diseases. We propose Bio-Inspired Methods modeled to work as the automated decision support in a process of diseased tissues detection over input x-ray images. These methods have special features that with devoted modeling make them independently search over the images with a good accuracy. In our approach we use dedicated fitness condition for selected heuristic algorithms. Mathematical model of medical expertise is formulated as a function used to search for special features of pixels that are representing respiratory diseases like pneumonia, lungs sarcoidosis and cancer. Presented decision modeling simulates medical x-ray image examination process to show where potentially diseased tissues are located. To enhance decision support the system returns to the doctor detection results from two tracks. In the first, patient and doctor can see detection from each of the algorithms, and in the second aggregated results. In this way the doctor receives a complex support that simulates consulting the image with various specialists. In benchmark tests, for a set of original x-ray images from various clinics, applied methods were examined to demonstrate benefits of using implemented solution. Results show that proposed methodology is efficient and promising for pulmonary diseases detection.

1. Introduction

Medicine is a field of science where computers and technology can be efficiently applied to help humans. Automated systems assist in surgery, help to compose and test medicaments, and are used in teaching and professional training at medical universities. Various types of screening methods are used to help in medical examinations. Automation of image evaluation processes can help to improve diagnosis for better treatment. Devoted approaches are reported to assist in medical image processing where composed intelligent methods were implemented to extract features responsible for various diseases. Dashtbozorg et al. [1] described developed technique implemented to detect optic discs changes. In this approach images are processed by application of devoted filtering to extract color changes that are used to automatically detect health biomarkers which correspond to diabetic disorders and cardiovascular diseases. Similarly Dong et al. [2] proposed image resolution processing via structure sparse approach to improve selected features of input images. Also adaptive techniques are reported to improve image processing. Lee et al. [3] proposed adaptive color models to detect skin changes. Ramos et al. [4] proposed content based image retrieval using metric learning, where image processing was applied to extract features important for further classification of lung diseases. Magnetic resonance images were used as inputs for the model of Parkinson progression, in which disease symptoms were detected by the use of proposed markers Babu et al. [5].

Very important screening methods, that have many applications in various treatments, are computer tomography and x-ray screening. Research on efficient modeling of decision support systems using these images can be of a valuable help for the development in medicine. Automated detection from computer tomography, where implemented systems were used to examine input images for pulmonary nodules was discussed by Yuan et al. [6]. A discussion of potential benefits coming from similar systems was presented by Girvin and Ko [7]. Machine learning gives a palette of methods to model devoted approaches in radiology Wang and Summers [8]; which can help in diagnostics Le [9]. Among these methods we can discuss neural networks and var-

* Corresponding author.
E-mail addresses: Marcin.Wozniak@polsl.pl (M. Woźniak), Dawid.Polap@polsl.pl (D. Połap).

https://doi.org/10.1016/j.swevo.2018.01.008
Received 29 August 2017; Received in revised form 11 November 2017; Accepted 17 January 2018
Available online XXX

ious bio-inspired approaches. Recurrent neural networks were implemented in x-ray annotation by Shin et al. [10]; while Basu et al. [11] proposed a deep neural network approach to texture analysis. Brain regions analysis for potential risk of Alzheimer from computer tomography images was discussed by Mahanand et al. [12]; where the authors proposed a model based on adaptive classifier. Lu et al. [13] proposed a model using matrix discriminant, in which local features were detected by the composed projections for feature extraction. While bio-inspired methodology was used to detect optic discs by Abed et al. [14] and analyze arm motions as proposed by Obo et al. [15]. The difference between approaches is that neural networks are trained by the use of knowledge about diagnosed objects, while for all applications of bio-inspired methods it is necessary to develop a fitness condition that can model the decision during evaluation process, e.g. some research on bio-inspired methodology by the use of devoted models of fitness functions for test data generation was discussed by Sahin and Akay [16]. Vanneschi et al. [17] presented a multiform genetic algorithm, in which neighbor variables were classified by decision model developed for simulation of redistribution problems. Panda et al. [18] presented an application of docking algorithm that uses an evolutionary approach in decision making for precise registration of medical images. Similarly Li et al. [19] presented an idea based on differential evolution, in which a range of images was classified by applied fitness condition during free-form inspections.

1.1. An X-ray examination

It has been more than a century since Wilhelm Conrad Roentgen used the x-ray light to take the photo of the hand of his wife. The discovery of the x-ray, and therefore radiology, started a new era in medicine and technology. Today using x-ray we can visualize various structures of the human body. Over the years many types of x-ray apparatus were designed, we have: point devices, intra-oral, pantomographs, general diagnostic apparatus, soft-tissue mammographs for women's breast glaucoma, and computerized tomographs for a transverse view of patient's cross-sections. A medical examination by the use of x-ray is easy, fast, and painless. The principle is the usage of the radiation of about 0.02 [mSv] for frontal view and 0.08 [mSv] for a side view. The source is emitting the waves with length ranging from 10 [pm] to 10 [nm] which are being received by the detector. During examination the emitted radiation penetrates our body and leaves the image of human cells/tissues/organs on the detector. Earlier the image was retrieved by chemical reaction with photostimulable storage phosphor on the x-ray film, but now mostly by the use of digital converters. Due to different absorption capacity of our tissues we see the organs in various contrast. Bones, as the organs of higher density, are visible as solid structures, lungs and other organs are visible in darker reflections of gray, while the air appears as a black space. The examination is done from Posterior to Anterior (PA) while standing up in front of the apparatus, but it is also possible to have a lateral or Anterior to Posterior (AP) screening. X-ray is used to examine lungs, heart, chest wall, etc. It is helpful to diagnose short breath, persistent cough, and a variety of lung diseases, among which are pneumonia, sacroidosis, cancer, and health complications like fluid or air collection around the lungs. However we must remember that it is not recommended to perform an x-rays examination often. Therefore automated approaches to help on diagnosis increase chances to start proper treatment much earlier, without unnecessary repetitions of the screening.

1.2. Related works

Human organism is unfortunately vulnerable to many diseases associated with tissues deformation and damages, among which we can define various types of cancer and pulmonary diseases. Since digital x-ray detectors produce electronic files there are various possibilities for intelligent automated classification support. However methodology must be relevant to diagnosed organs and the initial information that the doctors are gathering during examinations. Alshamlan et al. [20] discussed an application of bio-inspired methods to select features for cancer evaluation. Tan and Gilbert [21] proposed application of decision trees to automate cancer detection from genes. A review of similar approaches was presented by Ref. [22]. Diagnosis of pulmonary diseases is based on evaluation of screening, where doctors search for degenerated tissues by comparing visible features. To use this information for automated image diagnosis we need devoted model. Lin et al. [23] developed automated image classification approach by application of fractional Brownian motion model, where computed tomography approach was used to differentiate image features assessing changes in saturation attenuation value. In Woźniak and Połap [24] we discussed results of our tests on using heuristics for image processing, where we proposed a fitness function for classification of image pixels presenting degenerated features encoded in pixels. Shunmugapriya and Kanmani [25] proposed a hybrid model of bio-inspired method that simulates bee colony for feature classification by a hybrid decision support for diseases symptoms from data sets. Nebti and Boukerram [26] proposed a model of bio-inspired classifier, which was used for facial recognition where particle swarm and bee colony algorithms cooperated with transforms, support vector machines and decision trees to select special facial features from input images.

In this article we present a model of Bio-Inspired Methods (BIMs) implemented for medical image processing. The novelty of this approach is in the use of BIMs to serve as automated Decision Support System (DSS) alone or as a part of large and specialized solution. We propose to simulate medical examinations of pulmonary diseases by the use of BIMs. In our approach we use dedicated fitness condition for selected heuristic algorithms. Proposed mathematical model of medical expertise is formulated as a function. This is used by proposed BIMs to search for special features of pixels that are representing respiratory diseases like pneumonia, lungs sarcoidosis and cancer. Presented decision modeling simulates medical x-ray image examination process to show where potentially diseased tissues are located. We decided to use these methods due to special features that in composition with devoted modeling make them independently search for degenerated tissues over entire image. These methods do not have special model constraints therefore using them we are able to simulate evaluation of all pixels in x-ray images according to given conditions. In this way we can compare many pixels and present to the doctor these where degenerated tissues might be located. Additional advantage of the solutions is to present the doctor detection results from two tracks: from each of the algorithms separately, and in the second one as an aggregated result. In this way the doctor receives a set of images with marked locations of potentially degenerated tissues. This gives a complex support that simulates consulting the image with various specialists. Our idea was examined in benchmark tests for a set of original x-ray images from various clinics. The results show that proposed methodology is efficient and has a very high potential for further development.

2. The idea to use bio-inspired methods as detection support in medical examinations

Doctors estimate x-ray images by the way the tissues are visible. Typical examination is done by comparing sections of the image, and decision about presence of degenerated tissues is based on differences in Hue-Saturation-Brightness. Changes in these three features show that something is happening to the tissues. If there is a change only in brightness or hue it does not have to mean that this tissue is deformed. However if all of Hue-Saturation-Brightness are changed that means the tissues are potentially deformed, and appropriate treatment must be