Reconstruction of Electrical Impedance Tomography Using Fish School Search, Non-Blind Search, and Genetic Algorithm

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ABSTRACT

Electrical Impedance Tomography (EIT) is a noninvasive imaging technique that does not use ionizing radiation, with applications both in environmental sciences and in health. Image reconstruction is performed by solving an inverse problem and ill-posed. Evolutionary Computation and Swarm Intelligence have become a source of methods for solving inverse problems. Fish School Search (FSS) is a promising search and optimization method, based on the dynamics of schools of fish. In this article, the authors present a method for reconstruction of EIT images based on FSS and Non-Blind Search (NBS). The method was evaluated using numerical phantoms consisting of electrical conductivity images with subjects in the center, between the center and the edge, and on the edge of a circular section, with meshes of 415 finite elements. The authors performed 20 simulations for each configuration. Results showed that both FSS and FSS-NBS were able to converge faster than genetic algorithms.

KEYWORDS

Electrical Tomography Impedance, Fish School Search, Genetic Algorithm, Image Reconstruction, Non-Blind Search, Reconstruction Algorithm

INTRODUCTION

Ionizing radiation is commonly used in medical image machines, as mammography, positron emission tomography or x-rays. Besides the benefits that using those electromagnetic waves may provide, there are many associated risks to whom operates those machines or is submitted to these kind of exams. Also, the prolonged exposition to ionizing radiation may cause many diseases, such as cancer (Rolnik & Seleghim Jr, 2006). Possibly, this issue is one of the most debated subjects in Public Health all over the world, strengthening the search for imaging technologies that are: efficient, low-cost, simple and safe to those that uses them.

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A promising imaging technique, that does not use ionizing radiation, is Electric Impedance Tomography (EIT) (Bera & Nagaraju, 2014; Rolnik & Seleghim Jr, 2006). EIT is about a non-invasive technique that builds images of an interior body (or any object), using electrical properties, measured over the surface of interest. Those measurements are acquired from electrodes’ disposition around the transversal section of interest, and the application of a low amplitude and high frequency current through them creates an electric potential, known as "border potential". This low-voltage signal is measured and, in a computer, they are used in a reconstruction algorithm that rebuilds the image of the body’s inside region of interest (Rasteiro, Silva, Garcia, & Faia, 2011; Tehrani, Jin, McEwan, & van Schaik, 2010; Brown, Barber, & Seagar, 1985).

In medical sciences, EIT can be applied in several situations, such as: breast cancer (Cherepenin et al., 2001), pulmonary ventilation monitoring (Alves, Amato, Terra, Vargas, & Caruso, 2014), in the detection of pulmonary embolism or blood clots in the lungs (Cheney, Isaacson, & Newell, 1999). Likewise, it can be applied in fields as Botanics, generating images of the trees’ trunks’ insides, allowing the knowledge of its biological conditions without damaging it (Filipowicz & Rymarczyk, 2012); in monitoring multiphasic outflow in pipes (Rolnik & Seleghim Jr, 2006); in Geophysics, EIT is largely used to find underground storage of mineral and different geological formations (Cheney et al., 1999).

When compared with techniques, like Magnetic Resonance Tomography, or X-Ray Tomography, EIT has a relatively low cost, since, in simple manners, it needs an equipment able to generate and measure current and electric potential, and a computer, able to rebuild the image (Tehrani et al., 2010). Also, since it uses only the electrical properties (conductivity and permittivity) of the body, there are no associated risk to its use, unlike acquisition methods that uses ionizing radiation.

However, Electric Impedance Tomography images have, still, low resolution and undefined borders, which harms its popularity and diffusion among the imaging field. This motivates researchers of EIT to seek new methods of image reconstruction that are also able to overcome these techniques disabilities, creating images with good resolution and low computational cost, making of it a reliable and easy tool on diseases’ diagnostics.

Mathematically, EIT reconstruction problem is known as ill-posed and ill-conditioned, meaning that there are not only one solution (image) for a given potential border distribution. Many algorithms are applied in order to solve EIT problem, and, however, the image generated is not totally reliable or well defined (Rolnik & Seleghim Jr, 2006).

Thus, an alternative way used in the attempt of solving the EIT problem is managing it as an optimization problem, which the objective is minimize the relative error between the measured border potential of an object and the calculated border potential of the solution candidate (Feitosa, Ribeiro, Barbosa, de Souza, & dos Santos, 2014; Ribeiro, Feitosa, de Souza, & dos Santos, 2014a, 2014b, 2014c).

A heuristic that may be used in order to solve this as an optimization problem is the Fish School Search (FSS) (Bastos-Filho, de Lima Neto, Lins, Nascimento, & Lima, 2008; Bastos-Filho & Guimarães, 2015). This technique is inspired in fish schools’ behavior on food search. The search process on FSS is made by a population which its individuals (the fishes) has a limited memory. Each school represents a possible solution for the system. The fishes interact among each other and with the environment that surrounds them, and, by influence of the collective and individual movement’s operator and food operator, the school increases the possibility of convergence to the food surroundings, which means the best position and solution to that problem (Lins, Bastos-Filho, Nascimento, Junior, & de Lima-Neto, 2012).

In this work, a relatively simple approach to image reconstruction problem of EIT is proposed, using Fish School Search (FSS). However, it was modified, presenting two ways of solution candidates (fish) initialization: one completely random and other, among the random candidates, one solution derived from the Gauss-Newton reconstruction method. Taking into account Saha and Bandyopadhyay (2008) this initialization method was called Non-Blind Search.
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