Optimal Electrode Placement in Transcranial Direct Current Stimulation via Genetic Algorithm

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***Abstract*— Transcranial direct current stimulation (tDCS) is thought to be more appropriate for stimulating deeper brain areas rather than conventional techniques. Effectiveness of tDCS, however, strongly depends on electrode positions and the amount of injected currents. This paper is aimed to apply the genetic algorithm method for determining optimal location of electrodes and relative injected currents in a multiple electrode scheme. The objective of the presented technique is to maximize average magnitude of current densities delivered to the target area. Here, a 3D finite element method in ANSYS software package is employed for calculating delivered current densities. The proposed approach also considers safety constraints such as maximum allowed current injection. The effectiveness of the proposed algorithm is demonstrated through a standard four-layer head model. Owing to the results, the presented approach provides a promising tool for neurologists to stimulate patients more effectively.**

Keyword- Brain stimulation, finite element method, genetic algorithm, transcranial direct current stimulation (tDCS).

I. Introduction

Several therapeutic tools have been exploited for wide range of neurological conditions namely depression, epilepsy, and Parkinson's disease [1]. Recently, transcranial direct current stimulation (tDCS) as an appropriate neuromodulatory technique for stimulating deeper brain areas attracts attention of several neurologists [2]. In tDCS, the brain is stimulated by DC currents injected through two sets of electrodes, i.e., cathode and anode electrodes, that are placed on scalp [1]. Since tDCS system is inexpensive, well-tolerated, and flexible throughout the stimulating period, its application is thought to become more popular among neurologist [3]. Alongside the mentioned advantages, tDCS is more attractive for stimulating deeper brain areas rather than conventional approaches. However, there are various parameters contributing on stimulation performance like number, size, and shape of electrodes, their locations, and relative current injections. Hence, to have an effective stimulation, it is vital to tune the above-mentioned parameters appropriately. Several efforts can be found in the literatures dedicated to optimize the stimulating parameters of tDCS. In the following, some of the relative investigations are briefly reviewed to illustrate contribution of this paper.

In [4], a new approach has been proposed to optimally find the electrode locations through the evolution strategy algorithm. The objective of the proposed approach is to minimize the amount of injected current so that a predefined current density is delivered to the target area. Fixing electrode locations, the Simplex algorithm has been employed in [5] to find current injections with the goal of maximizing average current density at target areas. In this paper, anode and cathode electrodes are assumed to be placed at anterior and posterior respectively. Since the electrode locations are not optimized in [5], the resultant stimulation might be suboptimal. Dmochowski et al. [6] have used multiple small electrodes array and variety of optimization approaches to achieve effective and targeted stimulation. In this paper, maximal current density is calculated by considering to the maximum allowed current injection in a cortical area. Owing to the results, implementing large-pad electrodes would improve focality at cortical target area by 80% and intensity at cortical target area by 98%. In [7], various electrode configurations are tested to estimate the focused electric field distribution. The obtained results show that employing a ring-type electrode would lead to better field concentration. An optimization problem has been proposed in [8] for determining locations and current injections of a set of electrodes to reach the maximum intensity or focality at target point under safety constraints. This paper assumed that the injected currents are independent which can restrict application of the proposed formulation in real world.

This paper intends to determine optimal number and location of electrodes and respective current injections in a multiple electrode scheme. This distinguishes this paper from the previous researches since the number of electrodes was assumed to be known in previous papers.

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