Differential Evolution for Bioluminescence Tomography

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Abstract

Differential Evolution is a simple and efficient heuristic approach for global optimization. Bioluminescence Tomography generic model leads to non-unique solutions. I present differential evolution technique for Bioluminescence Tomography which enables to provide unique global optimum solution.

Keywords: Bioluminescence Tomography, Differential Evolution

INTRODUCTION

Many of the imaging process now under the research work for betterment and some new are established. Bioluminescence Tomography is one of them which are working in some vivo experiments.

BIOLUMINESCENCE imaging (BLI) is a molecular imaging modality, which can be used to monitor physiological and pathological activities at the molecular level. Various applications include visualizing tumor growth, tracking tumor cell metastasis, and evaluating drug delivery.

Bioluminescence tomography (BLT) uses multiple BLI acquisitions, geometrical structures, and tissue optical properties to reconstruct the bioluminescent source distribution based on a photon propagation model.

PROBLEM

In bioluminescence imaging, cells emits bioluminescent photons is used to create images of body which scatters in the whole body. Due to scattering nature of tissues, Diffusion Approximation offers accurate description

$$-\nabla\cdot(D(\mathbf{x})\nabla\varphi(\mathbf{x})) + \mu_a(\mathbf{x})\varphi(\mathbf{x}) = q(\mathbf{x}),\ \mathbf{x}\in\Omega \tag{1}$$

where
q is the source distribution;
$\mathbf{x}$ is the position vector;
φ is the photon fluence rate;
D is the diffusion coefficient;
μ_a is the absorption coefficient.
D is calculated by $D = [3(\mu_a + \mu'_s)]-1$, while μ'_s is the reduced scattering coefficient.

Using finite element method, equation (1) is

$$\mathrm{M}\Phi = \mathrm{HQ} \tag{2}$$

where
M is a positive definite matrix;

Φ is the discretized photon fluence rate;
H is the source weight matrix;
Q is the discretized source distribution

On removing unmeasurable fluence rate, we got relation between measurable fluence rate and bioluminescence source distribution

$$\Psi = AQ \tag{3}$$

where

Ψ = Measurable fluence rate

$A = M^{-1}H$ (rows of matrix removed correspond to unmeasurable fluence rate)

Q = Source distribution

Equation (3) converted into optimization problem

$$\min \|AQ - \boldsymbol{\Psi}\| \tag{4}$$

Q>0 for all number of source

This is an optimization problem subjected to complex constraints and cannot be effectively solved [1].

METHOD

Differential Evolution is a simple and efficient heuristic for global optimization [4]. Differential Evolution is proposed by Price and Storn. Differential Evolution is a technique that optimizes a problem by trying again and again to improve candidate solution with regard to given measure of quality.

Differential Evolution optimizes by maintaining a population having candidate solution and generating new candidate solution by using its formulae.

$$U = Xr_0 + F \cdot (Xr_1 - Xr_2) \tag{5}$$

where

U is the generated trial vector;
r_0 is the index of the base vector;
r_1 and r_2 are the indices of the difference vectors;
F is the difference scaling factor.

Trial vector my replace with target vector with index i.

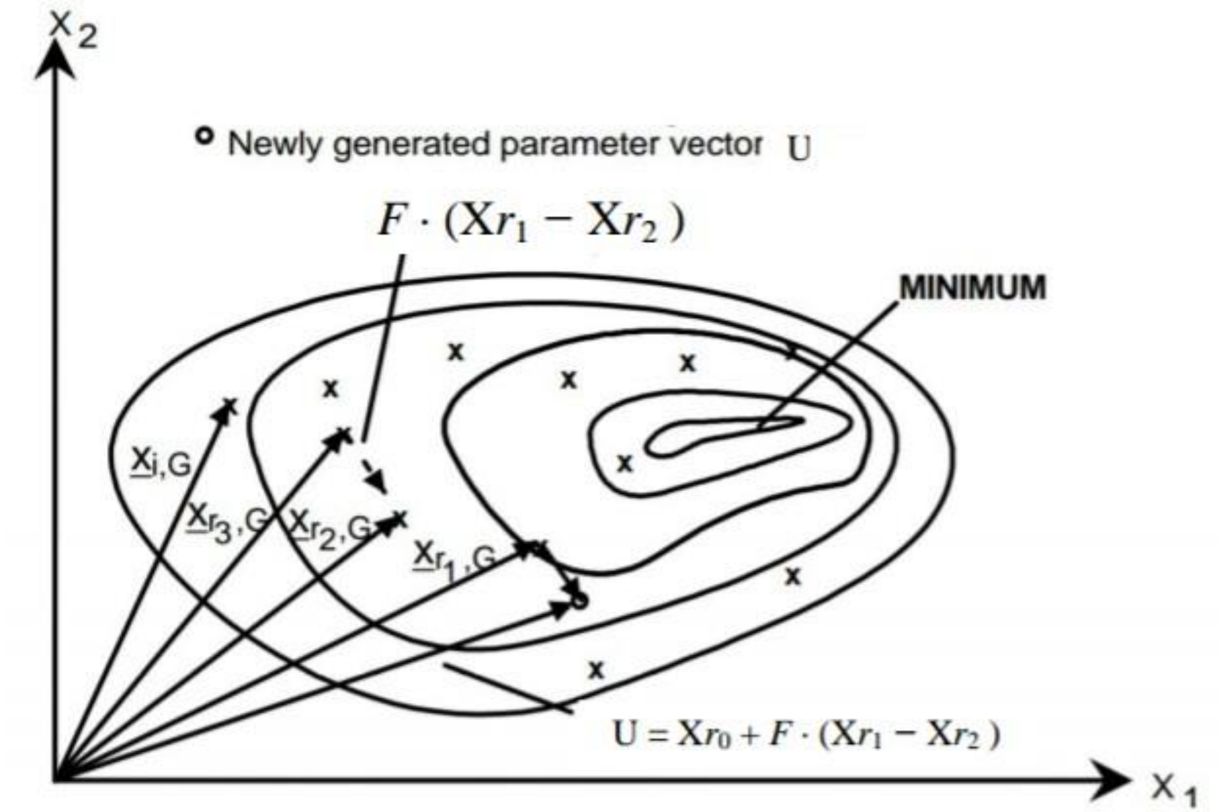

Figure 1: An example of a two-dimensional cost function showing its contour lines and the process for generating U

Algorithm

- Set the number of bioluminescence source S <= 0.
- Initialize all candidate solution X with random position in the search space
- Repeat until termination criteria is not met
  - Randomly pick three solution Xr_0, Xr_1, $X r_2$
  - $U = Xr_0 + F \cdot (Xr_1 - Xr_2)$
  - Crossover
  - Evaluate U
  - If U<X
  - Replace
- $X^{opt} <= \min X_i$

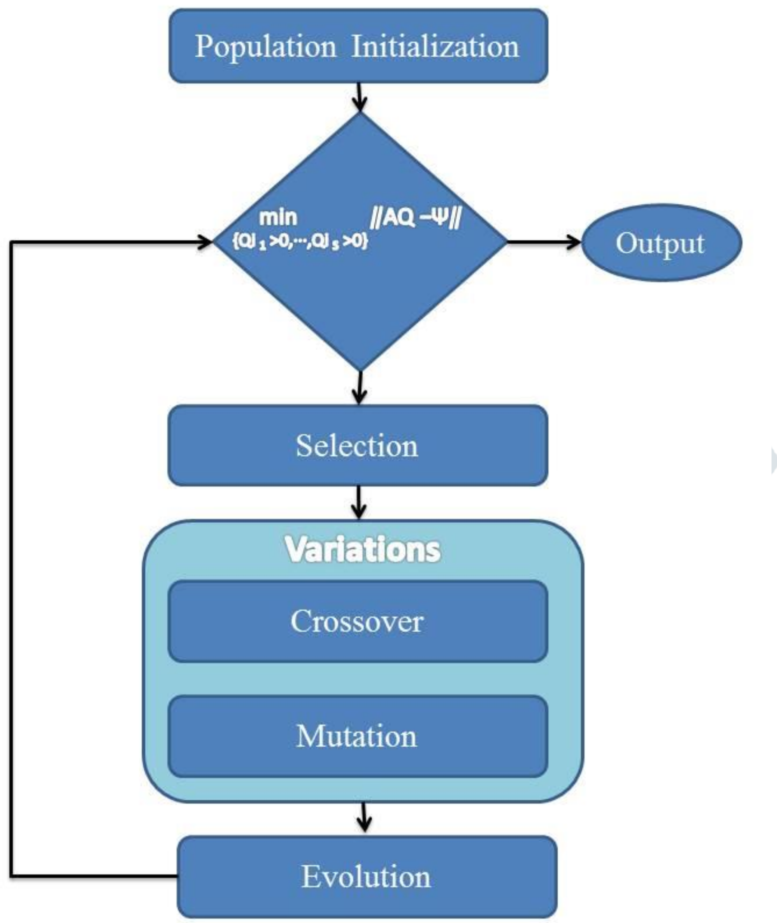

Figure 2: An example of Flowchart of Differential Evolution for given Problem

EXPERIMENT AND ANALYSIS

The numerical experiments are performed on a circle digital phantom with radious 1.5cm [3].

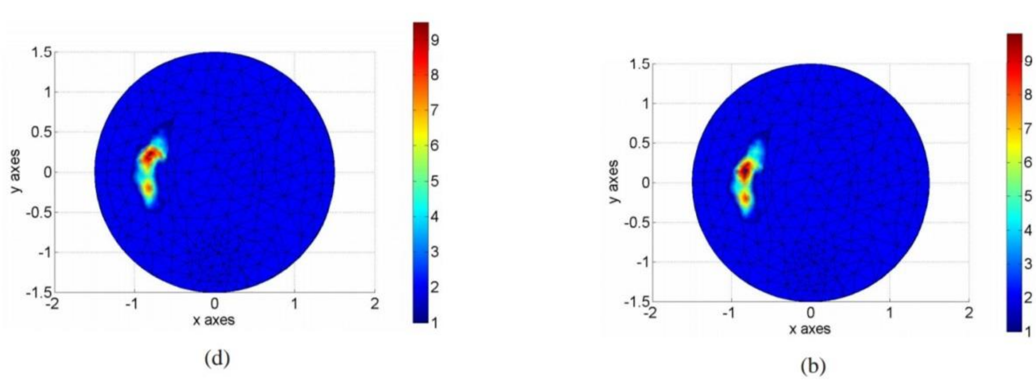

Figure 3: Simulated boundary photon fluence rate. (a) Boundary photon fluence rate from two point sources. (b) Boundary photon fluence rate from three point sources.

Difference between phantom (a) and (b) cannot observe directly and the number of source cannot confidently estimate through surface signal.

(a) (b)

Figure 4: Reconstruction Result of (a) and (b)

We applied differential Evolution approach. This used differential evolution flowchart.

As the number of generation is increasing, on each generation it is near to optimal solution [2].

DISCUSSION

In this paper, we discuss about a Reconstruction BLT model as regularized BLT model that incorporates the number of sources as a constraint and devised a scheme to determine the number of sources automatically. The regularized BLT model significantly reduced the number of variables in the optimization procedure, and more importantly, produced a unique solution.
DE also has the ability to locate the global optimum regardless of the initial values, and exhibits a fast and reliable convergence behavior.

CONCLUTION

We proved that the proposed method is able to accurately localize and quantify light source distribution from noisy measurements and inaccurate optical parameters. The determined bioluminescent source locations are accurately and reliably.

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