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Research paper

Self-potential data inversion through a Genetic-Price algorithm

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ABSTRACT

A global optimization method based on a Genetic-Price hybrid Algorithm (GPA) is proposed for identifying the source parameters of self-potential (SP) anomalies. The effectiveness of the proposed approach is tested on synthetic SP data generated by simple polarized structures, like sphere, vertical cylinder, horizontal cylinder and inclined sheet. An extensive numerical analysis on signals affected by different percentage of white Gaussian random noise shows that the GPA is able to provide fast and accurate estimations of the true parameters in all tested examples. In particular, the calculation of the root-mean squared error between the true and inverted SP parameter sets is found to be crucial for the identification of the source anomaly shape. Finally, applications of the GPA to self-potential field data are presented and discussed in light of the results provided by other sophisticated inversion methods.

1. Introduction

Self-potential (SP) method is one of the oldest passive geophysical method which measures the electrical potential distribution at the ground surface. From last few decades, there has been a growing interest in the SP method with an increasing number of applications in exploration geophysics, hydrogeophysics and environmental problems (Revil and Jardani, 2013). As concerns SP anomalies interpretation, a variety of methods have been proposed that can be roughly categorized into three groups: graphical, tomographic and numerical approaches. Graphical approaches are the oldest ones and are based on the use of nomograms and/or characteristic curves (Yüngül, 1950; Paul, 1965; Rao et al., 1970; Bhattacharya and Roy, 1981; Atchuta Rao and Ram Babu, 1983; Agarwal, 1984; Sundararajan and Srinivas, 1996). Tomographic approaches locate self-potential sources in terms of a charge occurrence probability (COP) function (Di Maio and Patella, 1994; Patella, 1997a, 1997b) or a dipole occurrence probability (DOP) function (Iuliano et al., 2001; Revil et al., 2001; Iuliano et al., 2002), which are computed by cross-correlating field data with electric field components of an elementary point charge or dipole source, respectively. In the broad class of numerical approaches, it is possible to distinguish among methods that solve governing differential equations (Agarwal and Srivastava, 2009, Jardani et al., 2006; Li and Yin, 2012), methods based on spectral analysis (Asfahani et al., 2001; Rani et al., 2015; Di Maio et al., in press), methods based on window-curves (Abdelrahman et al., 2009) and methods that use sophisticated optimization techniques, such as least-squares (Abdelrahman et al., 2006a, 2006b, 2008), genetic algorithms (Abdelazeem and Gobashy, 2006; Göktürkler and Balkaya, 2012), particle swarm optimization (Monteiro Santos, 2010; Pekşen et al., 2011), adaptive simulated annealing (Tlas and Asfahani, 2008), very fast simulated annealing (Biswas and Sharma, 2014) and ant colony optimization (Srivastava et al., 2014).

In this paper, an hybrid algorithm able to solve complex optimization problems is used to interpret SP anomalies. Such an algorithm has been previously used to analyze gravitational wave signals, for which sophisticated techniques for the enhancement of the signal-to-noise ratio are required (Milano et al., 1997; Milano and Koumoutsakos, 2002) and, here, it is first applied for estimation of SP source parameters. The method finds the absolute extreme point of a multimodal scalar function of many variables on the basis of a controlled random search (CRS) algorithm. The CRS algorithms solve global optimization problems by using, first, a random search scheme to locate the most promising area to contain the global minimum and, then, starting a local search to refine the global minimum estimate. The global search is performed maintaining a population of candidate points that tends to cluster around most promising areas, giving also information about the global behavior of the function.

The algorithm here used is an improvement of the first CRS algorithm proposed by Price (1976), where searching for new good candidate points is performed by interpolating the objective

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function by a quadratic form. If the algorithm fails to find a positive definite quadratic form, a global minimization step based on a genetic algorithms approach is executed. In this way, the resulting hybrid algorithm combines features of both CRS and genetic algorithm (GA) methods and it has been proved to give a good gain in performance with respect to both approaches over a wide variety of test problems (Bresco et al., 2005).

In the following, a general description of the hybrid Genetic-Price algorithm is given, and the results of its application to the inversion of SP anomalies due to simple polarized geometrical source models are reported. In particular, the study is performed on SP synthetic data generated by sphere, horizontal and vertical cylinder and inclined sheet like sources, with different level of random noise added to the initial data. For each case, values of the unknown depth, polarization angle and shape factor are found and the root-mean squared (RMS) errors are estimated. Finally, the

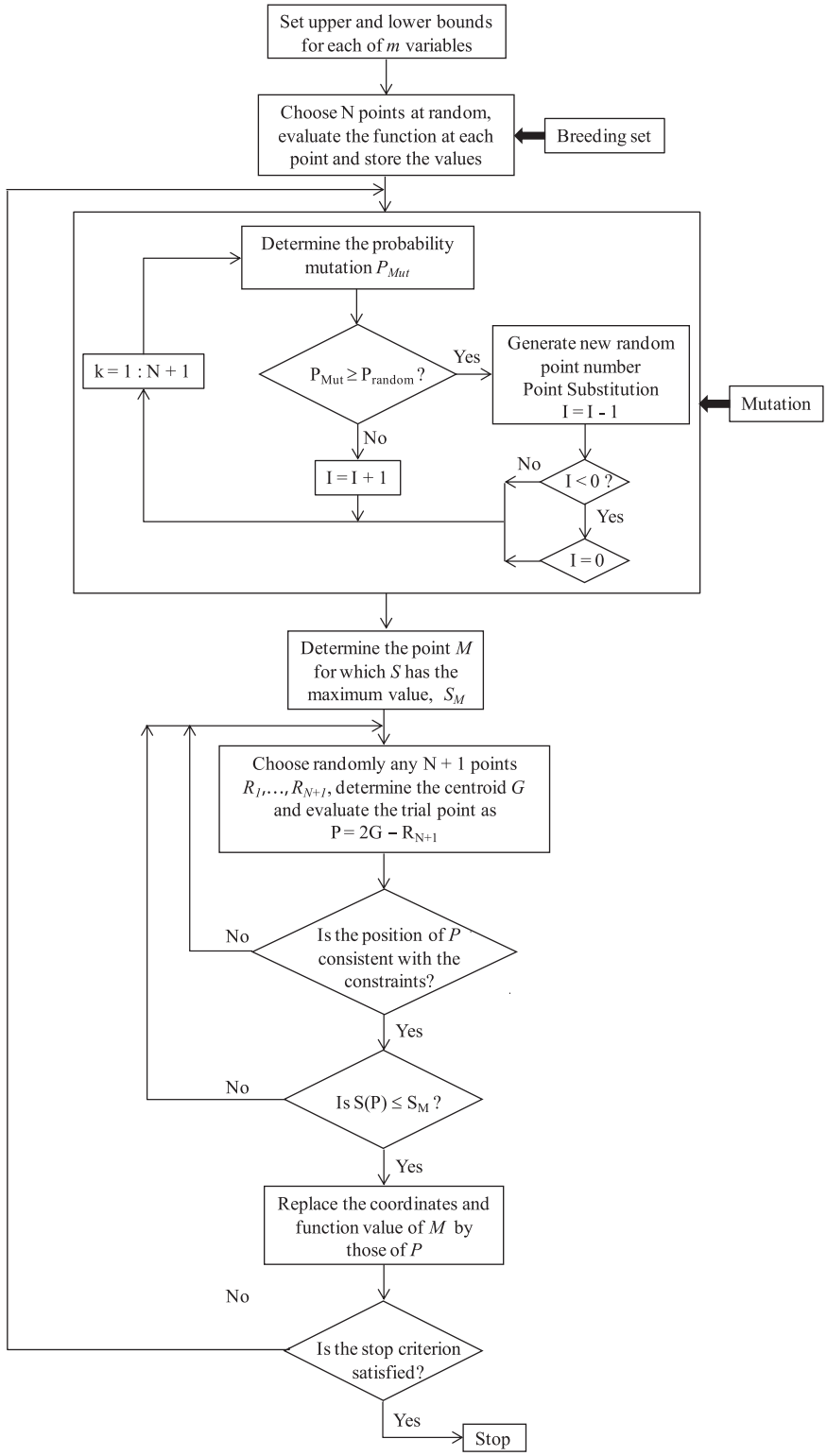

Fig. 1. Simplified flow diagram of the Genetic-Price's algorithm.