Detection for Different Kinds of Underground Objects with a Modified PSO

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1 Introduction

We have improved a detection algorithm of underground objects with particle swarm optimization (PSO) [1]. In this manuscript, we studied our estimation algorithm with PSO for a case of different kinds of the underground objects.

2 Theory

Two dielectric cylindrical objects with arbitrary cross-section shapes are located in a homogeneous lossy soil. Furthermore, we assume that this problem as a two-dimensional one. A ground surface is very smooth and spreaded in the positive and negative x- and z-direction. The positive depth direction is oriented to the negative y-direction. The parameters ε and σ are permittivity and conductivity of materials in this problem. Line sources and receiving antennas are located over the ground surface. From the line sources, E-polarized pulsed electromagnetic waves are radiated. Scattered waves from the soil are measured with the receiving antennas. We also use FDTD method for calculation of propagating wave in the problem region.

We define a cost functional with measured electromagnetic field components and calculated ones for estimated parameters of the objects.

Our update-equations for the velocity vector component $v_{i,d}^{k+1}$ and the position vector component $p_{i,d}^{k+1}$ for the i-th $(i = 1, 2, \cdots, I)$ agent in a PSO swarm are as follows:

$$\begin{aligned} v_{i,d}^{k+1} &= wv_{i,d}^{k} + c_1 r_1 \left(pbest_{i,d} - p_{i,d}^{k}\right) \\ &\quad + c_2 r_2 \left(gbest_{d} - p_{i,d}^{k}\right) + c_3 r_3 \left(best_{m,d} - p_{i,d}^{k}\right) \\ &\quad + c_4 r_4 \left(best_{n,d} - p_{i,d}^{k}\right), \qquad (1) \end{aligned}$$

$$p_{i,d}^{k+1} = p_{i,d}^{k} + v_{i,d}^{k+1}, \qquad (2)$$

where d and k are the numbers of dimension and generation. The parameter w is an inertia weight and $c_\alpha(\alpha = 1, \cdots, 4)$ denotes a weighting coefficient. The parameter *pbest* is an agent's personal best and *gbest* corresponds to the swarm's global best at the generation, respectively. The parameter r_α is a random number between 0 and 1. The parameters $best_m$ and $best_n$ $(m \neq n, m < n)$ are the m-th and n-th excellent agents that are obtained until the k-th generation. Furthermore, the method of referring to the value of the cost functional and reducing the ranges of estimations areas for each parameter of the objects gradually is introduced.

By minimizing a normalized cost functional, we can obtain estimated parameters of the buried objects.

3 Numerical Results

For an air hore and a dielectric cylinder, we estimate locations, radii, and relative permittivities of the cylinders. Note that cross-section shapes of these objects are different radii of circulars. The number of the cylindrical objects is given as *a priori* information.

The relative permittivity and conductivity of the soil are 5.0 and 1.0×10^{-3}(S/m). The soil, including the objects, which is divided into 40 cells × 80 cells. Initial estimation areas for each parameter are as follows: $0 \leq x/\Delta x \pm R/\Delta x \leq 80$, $0 \leq y/\Delta y \pm R/\Delta y \leq 40$, $1 \leq R/\Delta u \leq 10$, and $1 \leq \varepsilon_r \leq 10$. Furthermore, $\Delta x = \Delta y = \Delta u = 0.01$(m), $T = 500\Delta t$(ns), and $\Delta t = 1.0$(ns). Note that R and ε_r are a radius and a relative permittivity of the object. In Eq. (1), $w = 0.5 + [0, 1]/2$ and $[0, 1]$ denotes a random number between 0 and 1. The number of maximum generation $K = 400$ and $c_1 = \cdots = c_4 = 2$.

In our algorithm, several threshold values of the cost functional for a reduction of the estimated areas are set up. These values are used to reduce estimated areas for estimated parameters of the objects. In order to keep the variety of the agents in the PSO swarm, we also introduce an agent update method that uses a random number. The swarm is constructed from four groups and each group has 100 agents. In particular, the estimated area for the locations of the targets divided into four areas. For each area, we assign a small group of PSO respectively. Furthermore, we carry out a line search that is in order to determine the x-axis locations of the objects.

Tables 1 and 2 show true and estimated values of these objects. Note that average values for estimated parameters of several times simulations are showed in these tables. Since our algorithm is based on the use of random numbers, 25 times calculations are performed. Then 21 times simulations are terminated by satisfying the convergence condition of computation is successful. An average number of generations that these values are obtained is 25. From these tables, we can obtain good estimated parameters of the objects.

4 Conclusion

We have considered the estimation algorithm for the detection of different kinds of the underground objects. Numerical results show the validity of our algorithm.

References

[1] J. Kennedy et al., Proc. IEEE Int. Conf. on Neural Networks, vol. 4, pp. 1942–1948, 1995.

Table 1 True and estimated values for object 1.

	$x_1/\Delta x$	$y_1/\Delta y$	$R_1/\Delta u$	ε_{r1}
True	25	21	4	1
Estimated	24.0	20.3	4.6	1.4

Table 2 True and estimated values for object 2.

	$x_2/\Delta x$	$y_2/\Delta y$	$R_2/\Delta u$	ε_{r2}
True	55	19	6	3
Estimated	55.0	19.4	5.4	2.6