Guidelines for Student Reports

RECONSTRUCTING BURIED OBJECT WITHIN BORN I APPROXIMATION BY MEANS OF GPR DATA AND AN INTERVAL ANALYSIS BASED OPTIMIZATION ALGORITHM

A. Malacarne

Abstract

Interval Analysis (IA) consists of a set of rules and tools for the analysis and optimization of functions where the variables at hand are intervals of numbers and not single values as in classical arithmetical/ optimization problems. For example, an interval of real values (a real interval) can be defined as a one-dimensional compact set (a segment) between two extreme points, namely the Infimum and Supremum of the interval values. Firstly proposed to determine the error bounds on the rounding operations in numerical computation, IA has then been applied to solve linear and non-linear equations as well as optimization problems . Referring to the last point, IA offers ad-hoc global optimization techniques able to identify the global optimum with the desired level of accuracy.

Consequently, IA-based optimization seems to be an useful tool to solve the so called “inverse scattering problems”. In such problems the geometrical and the electrical properties of an unknown object (namely scatterer) are usually computed by minimizing a suitable cost function that measures the distance between the electrical field collected in probes surrounding the investigation domain and the electrical field generated numerically by a trial solution. In dealing with inverse scattering problem classical optimization algorithms (deterministic and stochastic) could be trapped in local minima and then the inversion process failed.

On the contrary, an algorithm based on IA iteratively divide the space of the solution in intervals and it discharges intervals in which it is sure the optimal solution does not lie. As a consequence, the algorithm is able to minimize the cost function related with the inverse scattering problem and then obtaining the unknown scatterer parameters with a desired level of accuracy.

This project is aimed to implement an inversion algorithm for microwave imaging based on the Interval Analysis for the reconstruction of buried objects from the GPR acquired data, when the characteristics of the object respect the 1st Born Approximation.

Reference Bibliography: Interval Analysis and Inverse Scattering [1]-[4]; Compressive Sensing and Direction-of-Arrival [6]-[8]; Compressive Sensing and Inverse Scattering [5]-[13].

[1] P. Rocca, M. Carlin, L. Manica, and A. Massa, "Microwave imaging within the interval analysis framework," Progress in Electromagnetic Research, vol. 143, pp. 675,Äì708, 2013

[2] P. Rocca, M. Carlin, G. Oliveri, and A. Massa, "Interval analysis as applied to inverse scattering," IEEE International Symposium on Antennas Propag. (APS/URSI 2013), Chicago, Illinois, USA, Jul. 8-14, 2012.

[3] L. Manica, P. Rocca, M. Salucci, M. Carlin, and A. Massa, "Scattering data inversion through interval analysis under Rytov approximation," 7th European Conference on Antennas Propag. (EuCAP 2013), Gothenburg, Sweden, Apr. 8-12, 2013.
[4] P. Rocca, M. Carlin, and A. Massa, "Imaging weak scatterers by means of an innovative inverse scattering technique based on the interval analysis," 6th European Conference on Antennas Propag. (EuCAP 2012), Prague, Czech Republic, Mar. 26-30, 2012.
[5] L. Poli, G. Oliveri, and A. Massa, "Imaging sparse metallic cylinders through a Local Shape Function Bayesian Compressive Sensing approach," Journal of Optical Society of America A, vol. 30, no. 6, pp. 1261-1272, 2013.
[6] F. Viani, L. Poli, G. Oliveri, F. Robol, and A. Massa, "Sparse scatterers imaging through approximated multitask compressive sensing strategies," Microwave Opt. Technol. Lett., vol. 55, no. 7, pp. 1553-1558, Jul. 2013.
[7] L. Poli, G. Oliveri, P. Rocca, and A. Massa, "Bayesian compressive sensing approaches for the reconstruction of two-dimensional sparse scatterers under TE illumination," IEEE Trans. Geosci. Remote Sensing, vol. 51, no. 5, pp. 2920-2936, May. 2013.
[8] L. Poli, G. Oliveri, and A. Massa, "Microwave imaging within the first-order Born approximation by means of the contrast-field Bayesian compressive sensing," IEEE Trans. Antennas Propag., vol. 60, no. 6, pp. 2865-2879, Jun. 2012.
[9] G. Oliveri, P. Rocca, and A. Massa, "A bayesian compressive sampling-based inversion for imaging sparse scatterers," IEEE Trans. Geosci. Remote Sensing, vol. 49, no. 10, pp. 3993-4006, Oct. 2011.
[10] G. Oliveri, L. Poli, P. Rocca, and A. Massa, "Bayesian compressive optical imaging within the Rytov approximation," Optics Letters, vol. 37, no. 10, pp. 1760-1762, 2012.
[11] L. Poli, G. Oliveri, F. Viani, and A. Massa, "MT-BCS-based microwave imaging approach through minimum-norm current expansion," IEEE Trans. Antennas Propag., vol. 61, no. 9, pp. 4722-4732, Sept. 2013
[12] G. Oliveri, N. Anselmi, and A. Massa, "Compressive sensing imaging of non-sparse 2D scatterers by a total-variation approach within the Born approximation," IEEE Trans. Antennas Propag., 2014, in press.
[13] M. Salucci, G. Oliveri, A. Randazzo, M. Pastorino, and A. Massa, "Electromagnetic subsurface prospecting by a multifocusing inexact Newton method within the second-order Born approximation," J. Opt. Soc. Am. A., vol. 31, no. 6, pp. 1167-1179, Jun. 2014.

This report is submitted in partial fulfillment of the degree of the course "TADIB".
Supervisors: Prof. Andrea Massa, Dr. Luca Manica, Dr. Matteo Carlin.