Inverse Scattering from Rough Surfaces Using Evolutionary Strategies

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The scattering of electromagnetic waves, produced by their incidence on a rough surface, has been widely studied in the past. The inverse scattering problem, on the other hand, that consists of the reconstruction of the profile of a surface from scattering data is more complex and has been less studied.

In this paper, we present a study of inverse scattering from rough surfaces. The goal is to retrieve the unknown surface profile function from scattered intensity data, treating the problem as an optimization problem. The angle-resolved scattered intensity used as input data for the algorithms depends on the surface profile function in a complicated way but, for one-dimensional surfaces, the direct problem can be solved numerically.

The closeness of a proposed profile, $z_c(x)$, to the original one can be estimated through the difference between the measured angular distribution of intensity $I^{(m)}(q|k)$, and the angular distribution of intensity $I^{(c)}(q|k)$, obtained by solving the direct scattering problem with the trial profile $z_c(x)$. The goal then would be to find a surface for which the condition $I^{(c)}(q|k) = I^{(m)}(q|k)$ is satisfied. When this happens, and if the solution to the problem is unique, the original profile has been retrieved. We define our fitness (objective) function as

$$f(\zeta(x)) = \sum_{i=1}^{N_{\rm ang}} \int \left| I_s^{(m)}(q|k_i) - I_s^{(c)}(q|k_i) \right| dq, \tag{1}$$

where $N_{\rm ang}$ represents the number of angles of incidence considered. The inverse scattering problem is then reduced to the problem of minimizing $f(\zeta(x))$.

Results for inversion procedures, combining evolutionary strategies (H. P. Schwefel, *Evolution and Optimum Seeking*, Wiley, NY, 1995) and the downhill simplex method (J. Nelder and R. Meade, Computer Journal, **7**, 308, 1965) will be presented. The evolutionary strategies employed are the elitist $(\mu/\rho{+}\lambda)$ and the non-elitist $(\mu/\rho, \lambda)$ strategies with recombination. Here μ is the number of parents in the initial population, λ is the number of offsprings generated by means of the genetic operators, and ρ is the number of members of the population that generate an intermediate population through recombination. Once the evolution strategies have reached the termination criterion, the downhill simplex algorithm is employed to improve the solution.

The results show that surface profiles can be reconstructed from far-field intensity even in the presence of noise and multiple scattering. Some issues concerning the uniqueness of the solution appear in the results and will also be discussed. The procedure employing the non-elitist strategy with recombination $\rho = 2$, appears to be more stable than the other algorithms studied.