Gradient-based inverse scattering approach by using cost functional consisting the approximated stored energy with no information on incident field

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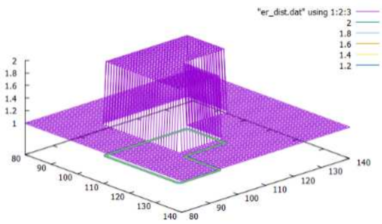
We consider an inverse scattering method using only total electric field data on an observation surface with no knowledge of incident fields. An initial-boundary value problem is set up whose solution coincides with that of the original scattering problem in the interior region bounded by the observation surface if and only if a medium inside the observation surface is the same as that of the original one. A cost functional consisting of the stored energy of the misfit field between the original problem and the boundary value problem with an estimated object is introduced to solve the inverse problem[1].

$$Q(\mathbf{p}) = \frac{1}{2}\varepsilon_0 \sum_{m=1}^{M} \int_{\Omega_i} \left[\varepsilon_r(\mathbf{r}) \left| \mathbf{E}^{eq}(\mathbf{p};\mathbf{r},T) \right|^2 + \mu_r(\mathbf{r}) \left| \eta \mathbf{H}^{eq}(\mathbf{p};\mathbf{r},T) \right|^2 \right] d\mathbf{r} d\mathbf{r} \tag{1}$$

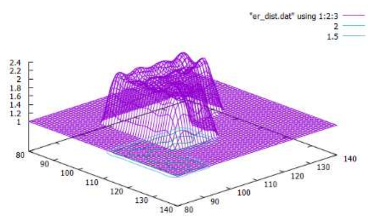
where M successive illuminations are assumed to probe the object. $\mathbf{E}^{eq}(\mathbf{p};\mathbf{r},T)$ and $\mathbf{H}^{eq}(\mathbf{p};\mathbf{r},T)$ are the electric and magnetic fields at the time $t=T$ of the boundary value problem with the electrical property distribution $\mathbf{p}$.
It was confirmed that the proposed inversion approach by using a gradient method can be applied to reconstruct electrical parameter distributions of the unknown object[2]. However, it was difficult to estimate a step size for modifying the solution. To overcome this problem, we proposed an inverse scattering method using following cost functional.

$$Q(\mathbf{p}) = \frac{1}{2}\varepsilon_0 \sum_{m=1}^{M} \int_{\Omega_i} \left[\left| \mathbf{E}^{eq}(\mathbf{p};\mathbf{r},T) \right|^2 + \left| \eta \mathbf{H}^{eq}(\mathbf{p};\mathbf{r},T) \right|^2 \right] d\mathbf{r} d\mathbf{r} \tag{2}$$

where η is the intrinsic impedance of free space. Eq. (2) is obtained by assuming $\varepsilon_r(\mathbf{r})=1$ and $\mu_r(\mathbf{r})=1$ in eq.(1). In this case, the cost functional is considered to estimates the approximated stored energy of the misfit field between the original problem and the boundary value problem with the inverse problem. It was confirmed that the proposed inversion approach by using Real-Coded Genetic Algorithm could reconstruct electrical parameter distributions of the unknown object[3]. In this paper, we solve this problem based on eq.(2) by a gradient method. An example of numerical result is shown in fig.1.



(a) Orignal profle



(b) Reconstructed result

Figure 1. Result of proposed gradient-based inverse scattering method

1. T. Moriyama, M. Salucci, T. Tanaka and T. Takenaka, "Image reconstruction from total electric field data with no information on incident field," Journal of Electromagnetic Waves and Applications, vol.30, pp. 1162-1170, 2016, https://doi.org/10.1080/09205071.2016.1182876
2. T. Moriyama, T. Tanaka and T. Takenaka, "Gradient based Inverse Scattering Algorithm using Energy Functional with Reduced Observation Points," Abstract of URSI GASS 2023, August 2023.
3. T. Moriyama, T. Tanaka and T. Takenaka, "Inverse scattering approach by using cost functional consisting the approximated stored energy with no information on incident field,", Proceedings of 2020 International Symposium on Antennas and Propagation, pp.345-34625, January 2021, DOI: 10.23919/ISAP47053.2021.9391335