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Machine Learning Approach to Enhanced Microwave Imaging Solutions for Cancer Detection

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Abstract

A machine learning-aided approach is proposed in this work to achieve enhanced microwave imaging solutions for cancer detection. The basic imaging solution coming from the standard quadratic Born Iterative Method is considered as initial guess to be adopted into a deep learning framework, which is able to guarantee a fast and accurate solution even in the presence of strong scatterers. Validation examples on breast phantoms are successfully presented.

1. Introduction

Microwave imaging techniques are largely adopted to identify the physical (size, shape) as well as the dielectric features of a target from the knowledge of the scattered field [1]. A mathematical formulation in terms of Inverse Scattering Problem (ISP) arises, with significant challenges in terms of non-linearity and ill-posedness, thus leading in the years to the development of a variety of non-linear optimization methods to implement a regularization process and obtain a reliable solution. Severe drawbacks of existing solution methods are mainly related to the high computational costs, as well as to reconstruction inaccuracies in the presence of highly dense and strong scatterers, often leading to the algorithm trapping into local minima (false solutions).

The basic challenging idea is to combine the adoption of powerful deep learning algorithms with the standard Born iterative method (BIM) to force a regularization process leading to a significant enhancement in the microwave image reconstruction of the dielectric profile.

2. Method

The basic microwave imaging problem is faced by adopting a formulation in terms of BIM with a quadratic programming approach [2]. This addresses the inverse subproblem in terms of a quadratic programming optimization with linear constraints, which can be solved by an exact method, depending only on *a priori* information about the range limits (lower and upper bounds) of the possible contrast values. However, the presence of highly dense and strong scatterers theoretically prevents the validity of Born approximation, thus leading to inaccurate solutions with high computational cost. To significantly enhance the reconstruction accuracy, the solution achieved with the quadratic BIM is assumed as a starting guess, subsequently processed by deep learning architectures, specifically conceived also to reduce the overall computational cost, while realizing a regularization process able to overcome the intrinsic non-linearity of the original ISP.

The general framework of the proposed machine learning-aided approach to microwave imaging problems is illustrated in Fig. 1. As described above, the inverse subproblem is initially solved by applying the quadratic BIM, so to have a first estimation of the dielectric profile, subsequently processed by a deep learning algorithm (basically modeled as a convolutional neural network) to assure an accurate and fast reconstruction of the dielectric properties of the target even in the presence of strong scatterers.

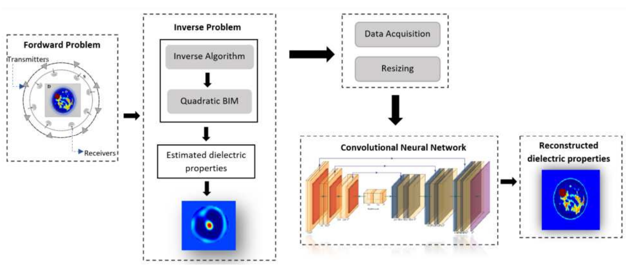

Figure 1. General framework of the proposed machine learning-aided microwave imaging approach.

As a further theoretical enhancement, the application of Complex Valued Neural Networks (CVNNs) is considered to effectively operate in the complex domain, thus fully exploiting both the magnitude and phase information of the scattered field data to successfully retrieve both the dielectric as well as the conductivity map of the target.

3. Numerical Results

Numerical validations of the proposed machine learning-aided microwave imaging approach are performed with reference to the reconstruction of breast tissues. Phantom models taken by a shared numerical repository [6] are considered, by adding tumor inclusions with varying radius in the range from 0.3 cm up to 0.8 cm.

A CVNN architecture, based on a multilayer complex convolutional neural network, is adopted and applied to the standard quadratic BIM solution. The results depicted in Fig. 2 reveal very high performance of the proposed approach, with very accurate final reconstruction images for both the dielectric constant ε_r as well the conductivity σ, when applying both the real-valued neural network (RVNN) as well as the CVNN. As expected, a more accurate result is obtained for the conductivity map σ, when applying the CVNN architecture, due to the full exploitation of the complex information (real and imaginary parts) included into the scattered data.

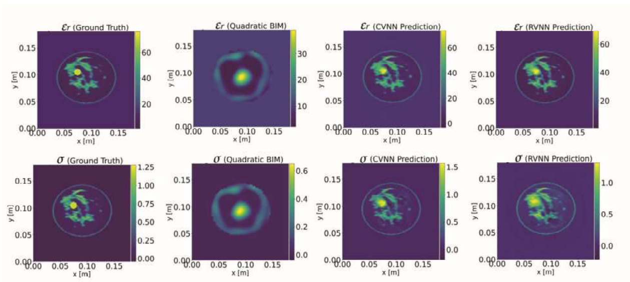

Figure 2. Reconstruction examples of the proposed machine learning-aided microwave imaging approach: breast cancer detection.

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