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Electromagnetic Breast Imaging and Uncertainty Quantification with Bayesian Neural Networks

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Abstract— Breast cancer is commonly defined as abnormal cells' exponential growth in the breast area and its cure is still a great challenge of modern medicine. In order to observe the appearance of tumors as soon as possible, regular, inexpensive, and non-intrusive breast imaging checks should be carried out in order to start treatment as early as possible. Among imaging modalities, the electromagnetic (EM) one is widely investigated due to its low cost and assumed safety [1-3]. The breast is immersed in a known coupling medium and illuminated by a series of transmitters. The resulting field is collected by a series of receivers from which the spatial distribution of the electromagnetic parameters (permittivity and conductivity) can be retrieved (inverse scattering problem) and anomalies of interest identified.

In the context of solving such problems, two main families of solutions can be distinguished: classical inversion methods like the Contrast Source Inversion (CSI) method [4], and in a more recent fashion, good progress has been achieved in applying learning frameworks to solve inverse scattering problems, delivering state-of-the-art performance. However, the reason for such a success may be confusing. Indeed, because of the large number of parameters included in a deep learning model, many questions arise about their initialization, while other questions also arise about the quantification of uncertainties as well as the existence of a physical framework in what may look like a black box. To tackle this problem, Bayesian Neural Networks [5] have become highly attractive due to their ability to quantify uncertainties.

This contribution is therefore part of a two-pronged dynamic using Bayesian Neural Networks, the first is to continue obtaining more and more qualitative results, while the second is to propose a precise and detailed framework for the choices made, those being on the basis of the underlying physics and/or empirical behavioral observations of the *a priori* distributions of Bayesian neural network parameters. We propose a methodological participation applicable to Bayesian convolutional neural networks, showing the efficiency of such an approach with both simulated and real EM breast imaging datasets.

Further research should focus on data fusion, such as multi-frequency data and/or multi-physics data with emphasis on the fact that electromagnetic low-resolution and acoustic high-resolution imaging complementarity has been shown to improve the quality of the reconstructed images [6], providing well-contrasted zones.

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