Study on a Fast Solver for Poisson's Equation Based On Deep Learning Technique

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Computational electromagnetic simulation plays an essential role in research and engineering, such as antenna design, nano-optics and many other related areas. In practice, computational electromagnetic simulation needs to solve matrix euqations with millions of unknowns, so it is always accompanied with a large amount of computation. Therefore, the speed of electromagnetic simulation still cannot satisfy the demand of applications requiring real-time responses, such as radar imaging, biomedical monitoring, and etc. Acceleration of electromagenetic simulation has been widely explored and discussed. One method of acceleration is to divide the whole simulation into offline and online processes by pre-computing part of models and storing the results in memory. Another method is to apply learning techniques to accelerate simulations, such as artifical neural network and support vector machine (SVM). With the development of high performance computing and deep learning techniques, significant progress has been achieved in voice and image processing due to the strong approximation capability of the deep neural network. Recently, deep neural network has been applied to approximate complex physical systems, such as fluid dynamics and Schrödinger equations.

In this study, the feasibility of applying deep learing techniques to accelerate electromagnetic simulation is investigated. This paper aims to compute 2D or 3D electric potential field distribution by solving Poisson's equation. A deep convolutional neural network is proposed to solve Poisson's equation. The network takes permittivity distribution and locations of excitation as input, and the output of the network is electric potential distribution in the computation domain. The finite-difference method is utilized to generate training and testing data by solving Possion's equation in a domain with inhomogeneous permittivity distribution and point-source excitation. In the offline process, the network 'learns' from data set including the permittivity distribution, location of excitation and potential field distribution. In the online process, the network can correctly solve Possion's equation and predict the correct potential field distribution in the computational domian. The convolutional neural network model was implemented in Tensorflow on an Nvidia K80 GPU card. The Adam optimizer is used to train and optimize the model. Numerical experiments show that the prediction errror of 2D and 3D simulation can reach below 1.5% and 3%. The model proposed is an end-to-end method driven by data, and the computing time is reduced significantly compared with traditonal method. This study shows a great potential to build a fast solver based on deep learning technique for certain electromagnetic problems.