Collecting Big Data by 3D EM Simulation: Needs, Challenges, Solutions, and Limits

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Abstract— Rapid identification of object from radar cross section (RCS) signals is important for many traffic control, space, and security applications. The identification problem is typically solved using artificial neural networks (ANNs). However, for high-percent correct identification we need big data of monostatic and bistatic RCS. Generally, for a single object, RCS data in a dense grid of directions should be collected for excitation by plane waves incoming also from a dense grid of directions in a broad frequency range. It is practically impossible to collect such an amount of data by measurement, and even for 3D EM simulation the task remains very challenging [1].

There are many other areas that require collecting big data by 3D EM simulation. For example, training of deep neural networks to be used for design of antennas may require even 100,000 samples [2], while ability of collecting 10 million samples can also be of interest [3].

Big data are not needed only in the case when machine learning is used for processing of it, as mentioned in the two previous cases. For example, microwave imaging applied to detection of brain stroke requires evaluation of near field in the 3D dense grid of points all over the human head model due to each of 24 antennas in the helmet antenna system in a broad frequency range [4].

In this work we focus on the collecting of the big data using higher order Method of Moments (MoM) applied to Surface Integral Equations (SIEs) [5]. To achieve this goal by using reasonable computing resources it is necessary to apply advanced techniques at all stages of the simulation process including pre-processing and post-processing. Advanced techniques, which should enable collecting of big data can be divided into three groups.

In the first group are techniques that should maximally reduce the number of unknowns (degrees of freedom) of the 3D EM model. In addition to usage of higher order basis functions and symmetry planes as the core solver techniques, the number of unknowns can be reduced in the pre-processing phase by "smart 3D EM modelling" [6] and "controllable decimation of initial geometrical model" [7]. In the second group are advanced algorithms that enable parallelization at CPU and GPU of all critical stages of the simulation, including in-core and out-of-core solution of the MoM matrix equation. In the third group are techniques optimized for efficient post-processing of data (evaluation of radiation pattern and near field in the vast number of directions and points, respectively).

Ability of collecting big data based on these three groups of advanced techniques will be demonstrated using typical examples of interest and their limits will be outlined.

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