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A Compensation Technique to Find Compromise Solution for SPFD Method in Containing Errors for In- and Outflow of Current on the Boundary

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Scalar potential finite difference (SPFD) [1] method has been commonly used to estimate internal electric fields in the human body exposed to electric fields in the frequency range where quasi-static approximation can be applied. The simultaneous linear equations of the SPFD calculation is consistent only when the sum of the right hand side vector elements is zero. Here, the right hand side vector corresponds to the current distribution on the surface of biological object. However, the sum of the right hand side vector elements hardly become zero when the actual exposure scenario is assumed, because the boundary condition of current distribution on the surface of biological object is derived from another numerical scheme which essentially contains numerical errors. Some iterative methods can not be applied to this inconsistent linear equations because a significant error or divergence occurs. Therefore, the purpose of this study is to avoid inconvenience in solving such a large scale simultaneous linear equations, and to investigate the high efficiency technique for SPFD method.

In this study, a compensation technique is proposed to overcome this problem. This technique is to modify the right hand side vector so that the linear equations has the compromise solution which minimizes the residual norm. This compensation approach is combined with conjugate gradient (CG) method. A small size circuit with 4-node is solved with the proposed technique, when the total current sum up to not zero value on the boundary as a simple example. As obtained solution of potentials at each node is compared with the solution obtained by the Moore-Penrose pseudo-inverse matrix [2] technique, these two solutions indicate good agreement each other. Therefore, it is found that our approach is efficient to obtain compromise solution as well as the the Moore-Penrose pseudo-inverse matrix approach. Consequently, an appropriate solution was obtained by the proposed compensation method for induced electric field analysis in a voxel human model.

Furthermore, the proposed method allows to apply various numerical methods for linear equations such as AMG[3]-CG, ICCG, and ILUCG, which enable far faster computations than conventional approach using SOR method. Figure 1 shows comparison of calculation times between various kinds of matrix equation solvers, when the induced electric field is calculated with the whole body human model consists of 320 x 160 x 870 voxels.

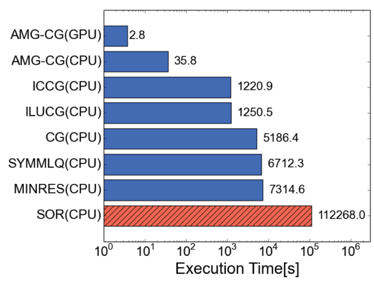

Figure 1. Comparison of calculation times between various kinds of matrix equation solvers.

References

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