AVOIDING THE PROBLEM OF FE MESHING: A PARALLEL ALGEBRAIC MULTIGRID WITH MULTIPLE RIGHT-HAND SIDE TREATMENT FOR AN EFFICIENT AND MEMORY-ECONOMICAL COMPUTATION OF HIGH RESOLUTION EEG AND MEG LEAD FIELD BASES

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ABSTRACT

When using the Finite Element (FE) method for volume conductor modeling in EEG/MEG source reconstruction, one problem consists of generating an adequate FE mesh. Therefore, software packages were able to efficiently perform FE computations with even some million unknowns, then we only could transform each voxel from a segmented MR or CT image into a finite element and would avoid the meshing problem. On this paper we will present a new efficient strategy, the parallel algebraic multigrid preconditioned conjugate gradient method with simultaneous treatment of multiple right-hand sides for the computation of EEG and MEG lead field bases. We will show that this method is memory-economical and furthermore exploits a much higher cache hit rate to speed the computation by about a factor of 2 compared to former approaches. Together with the concept of the EEG and MEG lead field bases, the complexity of realistic high resolution FE modeling is significantly reduced. For FE-meshes with some few hundred thousand unknowns, the computations can now be performed in some few minutes on a single processor PC. Our parallel approach furthermore offers the possibility to efficiently treat FE-meshes with some million unknowns so that in the future, the problem of FE meshing can be solved.

KEY WORDS

EEG/MEG source reconstruction, Finite Element Method, Volume Element meshing, Lead Field Bases, Algebraic Multigrid, Preconditioned Conjugate Gradient Methods, Treatment of Multiple Right-Hand-Sides, Cache-Accelerated Parallelization

INTRODUCTION

When changing the FE mesh for volume conductor modeling within the EEG/MEG source problem, the classical frontal or lead field bases require “re-meshing of the FE-mesh which is a lengthy iterative process of updating the boundary and a water phase for which only local time-dependent FE methods for volume conductor problems are presented in [3]. When these are used, the new mesh often cannot be applied to the previous data sets due to fact that the algorithm is not able to deal with the meshing problem. In this paper, we will introduce a new strategy, the simultaneous treatment of multiple right-hand sides. In this way, we will present a performance for the computation of EEG and MEG lead field bases for realistic cortical FE models using parallel computation.

METHODS

In a first step, we compared the AMG-CG pre-conditioner [5] (preconditioned Conjugate Gradient algorithm) to the Multi-Grid (MG) pre-conditioner [3] of the Multilevel-AMG (AMG) code on limited lead field bases. We used the Multilevel-AMG (AMG) code as a preconditioner for the conjugate gradient method (CG) in order to increase the number of cache misses. When using this algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the exact solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache misses. When using the AMG algorithm, the original solution is multiplied by the diagonal of the original matrix, parts of the AMG-CG method in order to reduce the number of cache miss...