Finite element meshes with electrode refinement in EIDORS

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MOTIVATION: The accuracy of solutions to partial differential equations (PDE) obtained with the finite element method (FEM) depends on appropriate choice of domain discretization. The elements must be smaller than the smallest features which may occur in the solution. On the other hand, small elements increase the size of the FEM and hence the amount of computational time and memory required to obtain a solution. Thus, FEMs are often refined such that the local element size reflects the local expected feature size. It follows that for simulations of electrical current, elements must be significantly smaller near the electrodes than deeper in the medium. However, for meshes derived from 3D data, such refinement is difficult to produce with currently available software, decreasing their value in electrical impedance tomography (EIT) and other applications. We present a recent extension of the EIDORS suite addressing this problem.

METHODS: Our approach is as follows. Starting with a triangular surface mesh of the domain and a list of desired electrode shapes and positions, we project the electrode shapes on the surface adding new nodes along the edges of the electrodes. To integrate the new nodes in the surface mesh while preserving the electrode boundaries, we perform simple constrained Delaunay triangulation of the surface mesh in the neighborhood of the electrode. Subsequently, we extrude the electrode surface slightly outwards. Thus prepared surface mesh is saved as an STL file and processed with Netgen [1] to create a highly optimized tetrahedral mesh, from which we extract the new surface triangulation. The sharp edges created by the extrusion of the electrodes forces Netgen to preserve their boundaries and produce local refinement. We then re-integrate the electrodes into the surface by reversing the extrusion. The resulting surface mesh is finally processed with GMSH [2], which converts it to a volume mesh without changing the surface, thus propagating the refinement into the volume.

RESULTS: We present two examples of meshes created by the above procedure: a head mesh with 73 circular electrode in standard locations (Figure 1, left) and a male thorax with 16 rectangular electrodes (Figure 1, right). Both of these are based on meshes contributed to EIDORS in the past by A. Tizzard and coworkers [3, 4].

DISCUSSION: As desired, the element density in the presented meshes is increased around the electrodes (and particularly high on their edges), demonstrating the value of the new EIDORS functionality. It has to be noted, however, that the combination of two meshing programs is cumbersome and not without caveats. We make assumptions in our code about results produced by these programs over which we ultimately have little control. Nevertheless, we believe this is a valuable contribution to EIDORS which, at least temporarily, addresses an important need for more accurate forward solutions and sensitivity matrices for EIT and other applications.

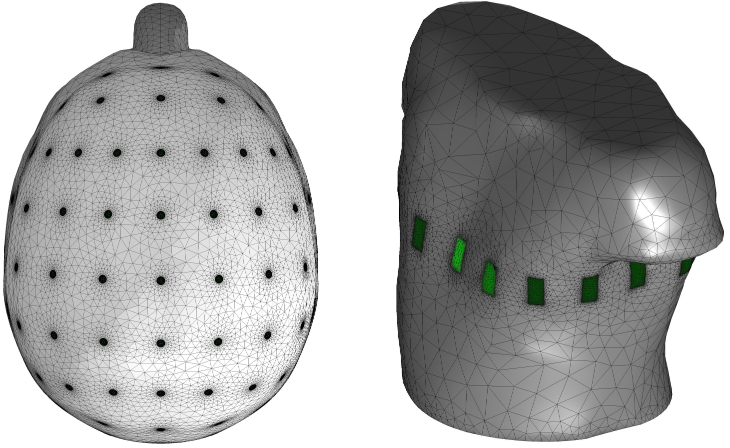

Figure 1 Example FEMs with electrode refinement representing *left:* a human head, and *right:* a male thorax.

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