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Electrical impedance tomography sensitivity analysis of a human head model

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Background, Motivation and Objective. Electrical Impedance Tomography (EIT) is a noninvasive tomographic imaging technique that creates resistivity distribution images from potential measurements when electric current is injected in the target [1]. EIT has a wide potential in clinical application due to the possibility for continuously imaging in acute situations, such as bedside diagnosis in intensive care unit (ICU) [DOI:10.1186/1475-925X-4-27]. In this work the assessment of EIT for intracranial monitoring is performed via sensitivity analysis to identify hemorrhage and ischemia in the brain tissue.

Methods. A numerical phantom of a human head consisting of three main tissues (scalp, skull, brain) was generated based on a pediatric head modeling data set available online [2,3]. MATLAB was employed to extract the 3D surfaces of the segments and to export stereolithography files of each. Surface files were further edited using 3D editing software Blender to clean, refine and to add two layers of 16 electrodes each in the surface of the scalp. Finally, the Gmsh software was employed to generate a 3D finite element mesh of the head with seventy thousand tetrahedral elements. EIT forward problem was solved by the finite elements method [DOI: 10.1088/0266-5611/30/4/045013], imposing 1mA current to different skip-m current injection patterns, where m is the number of non-current carrying electrodes between the ones injecting current. Ground potential was located at the geometric center of the mesh. For a healthy patient, scalp resistivity was set to 2.5Ωm, skull resistivity to 47.94Ωm and brain resistivity to 7.36Ωm [DOI:10.1088/0031-9155/41/11/002]. Ischemia (9.823Ωm) and hemorrhage (1.419Ωm) regions [DOI:10.1088/0967-3334/27/5/s13] were simulated as spheres with 20cm³ [4] in different positions within the brain along three orthogonal axes. To determine the sensitivity of EIT measurements for such conditions, the L2-norm of the difference vectors ΔV between pathological and healthy conditions were computed. The Jacobian of the forward problem with respect to each element of the brain tissue was calculated and its singular values were determined.

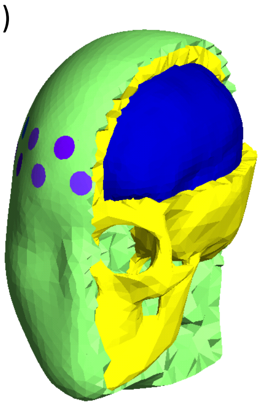
Results. The resulting head model is shown in Figure 1a), where it is possible to see the different tissues of the model and the disposition of the surface electrodes. The L2-norms of ΔV in relation to the reference potentials (skip-8 = 1,48[V], skip-0 = 0,87[V]) for different skip-m current patterns are shown in Figure 1b). The singular values of the Jacobian matrix (for different skip-m patterns) are presented in Figure 1c).

Discussion and Conclusions. From Figure 1b), the greatest differences of L2-norm of ΔV happen in the case of hemorrhage rather than ischemia, explained by the larger resistivity variation with respect to healthy brain tissue, making it easier to detect hemorrhage rather than ischemia. In addition, it is easier to detect anomalies next to the electrodes rather than far from them and it is easier when the anomaly is located close to the plane of the electrodes. Figure 1b) also presents that using larger skip-m current pattern amplifies ΔV, increasing the SNR of the measurements. In fact, for 32 electrodes displaced in two layers, skip-8 pattern forces the current to cross the head (diametrical injection pattern). Although skip-8 and skip-7 are very similar, in accordance with [DOI: 10.1016/j.conengprac.2016.03.003], even skip-m patterns are better since they result in a larger number of independent measurements. The advantage of skip-8 over skip-0 can be seen in

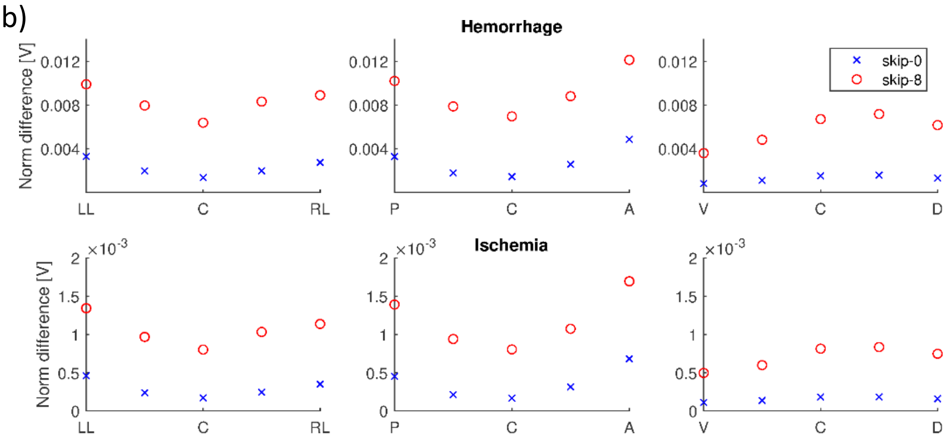
Figure 1c). The zoomed region presents the first 100 largest singular values of each case. It can be seen that these are, in general, larger for skip-8, resulting in better sensitivity to changes within the brain tissue. The main cause for this behavior is the skull bone that shields the brain when small skip-m patterns are used. This work presents the advantages of using skip-8 pattern in the head. this information will be used when implementing the inverse problem solver.

Figure 1: **a)** Resulting head model **b)** 2-norm of the difference vector between the reference potentials (skip-8 = 1,48[V], skip-0 = 0,87[V]) and each case potentials. Legend: LL: left lateral; C: center; RL: right lateral; P: posterior; A: anterior; V: ventral; D: dorsal **c)** Singular values for different skip-m current injection pattern.

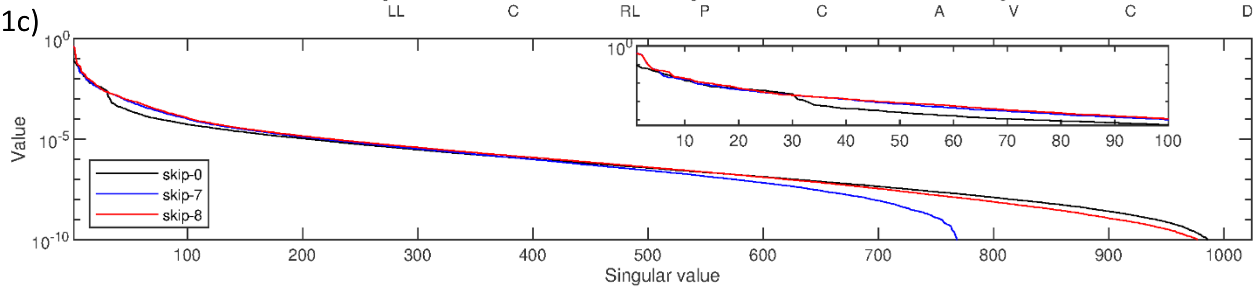
1a)



1b)



1c)



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