Phantom based System to Evaluate Electrical Impedance Tomography (EIT) Performance

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A systematic methodology for the evaluation of the global performance of medical EIT systems has been developed. It consists of a saline phantom in which calibrated contrasting test objects are reproducibly positioned using a position controller and a set of evaluation parameters to characterize: i) data and image noise, ii) data accuracy, iii) detectability of single contrasts, iv) distinguishability of multiple contrasts, and v) accuracy of reconstructed image i.e. amplitude, resolution, position and shape. Using this approach, CSEM has evaluated three different EIT systems.

Electrical impedance tomography (EIT) is a non-invasive imaging technique with high potential in medicine and other disciplines. Changes in electrical conductivity within a body are visualized using current injections and voltage readings via an array of electrodes arranged around a body. To correctly interpret EIT images it is essential to know the performance characteristics of the EIT system used. While many approaches have been proposed to measure isolated aspects of performance, the goal of this work is to present a systematic methodology to evaluate the performance of complete EIT systems.

Robotic phantom: Components in the system performance evaluation consist of an acrylic phantom, calibrated test objects, a test robot to place and move objects, and analysis software (Figure 1).

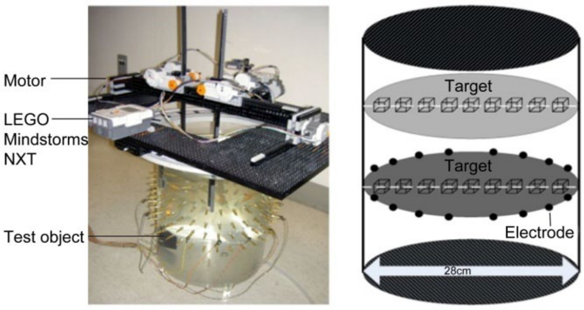

Figure 1: a) Photo of acrylic EIT phantom and position controller; b) Schematic drawing of movement protocols showing horizontal movement of a single object in two planes (3D view).

The robot is programmed to place the calibrated test objects in different locations. The measurements rendered by the connected EIT device-under-test (DUT) are compared to the known test-object locations.

The DUT is connected to the phantom and measurements are performed with three different protocols:

- No test-object in tank, to evaluate system noise and accuracy
- One test object placed in different positions within the tank, to measure amplitude response, position accuracy, resolution, and detectability limits,
- Two test objects placed in different locations, designed to measure limits of distinguishability of contrasts.

The resulting images created by the DUT are analyzed according to the metrics given in Figure 2 and according to the following definitions: The potential position of the test-object is defined by the pixel which has the maximum value in the entire image (arbitrary units, proportional to impedance values). The region of interest (ROI), i.e. the potential boundary of the test-object, is defined by the pixels with >25% of the maximal value.

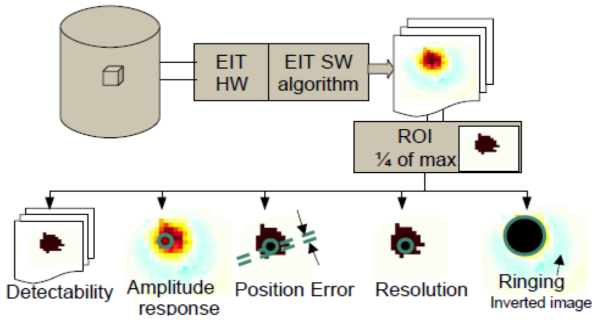

Figure 2: Procedures for analyzing image data. First row: phantom system, EIT measurement system and reconstruction algorithm (DUT); second row: calculation of ROI; third row: calculation of parameters.

Three different EIT systems (coded as A, B, and C) were evaluated and their amplitude response was measured for different radial positions of the test-object (Figure 3).

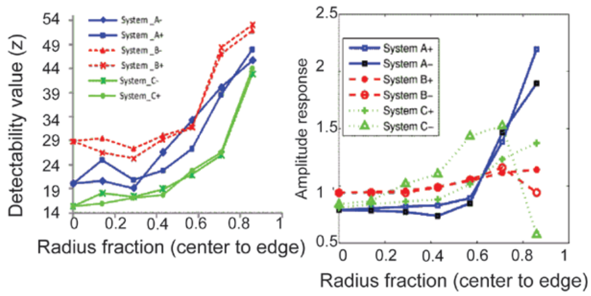

Figure 3: Comparison the amplitude response (AR); + and - are used to indicate the direction of test-object displacement along the X axis. System B is close to expectations (horizontal line).

The robotic approach was indispensible to create reproducible test results. Figure 3 shows the amplitude response for three EIT systems as a function of distance from the center of the acrylic phantom (radius fraction), and clearly reveals differences, strengths and weaknesses of the three EIT systems in a quantifiable way. As more work is needed to define the clinical relevance of the technical metrics.

To encourage use of the methodology presented, all details of the robotic phantom are publicly available under the URL http://eidors3d.sourceforge.net/

This project has been carried out in collaboration with Carleton University, Ottawa, Canada.