EIDORS: the past, the present and the future

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Abstract: The Electrical Impedance and Diffuse Optical Reconstruction Software (EIDORS) is a project offering free open-source algorithms for forward and inverse modelling in Electrical Impedance Tomography (EIT) and diffusion-based Optical Tomography (OT). Since its conception in the late 1990s, the project has undergone significant evolution in terms of features and size. In this report, we 1) evaluate the impact of the project by looking at the different applications in which it is used; 2) describe some of the recent additions to the project, including a set of geophysics tutorials; and 3) discuss the future of the project in light of its recent development and the challenges we see ahead.

1 Introduction

The EIDORS project was founded in 1999 with the intention of providing a software library to solve the reconstruction problem for two closely related inverse problems: electrical impedance and near infra-red scattering and absorption tomography. The initial two dimensional reconstruction software was built on Matlab code from the Kuopio group [1, 2]. Three dimensional forward modelling and reconstruction was incorporated using code from the UMIST group [3] and revised with a plugable architecture allowing the incorporation of forward and inverse solvers from different groups [4].

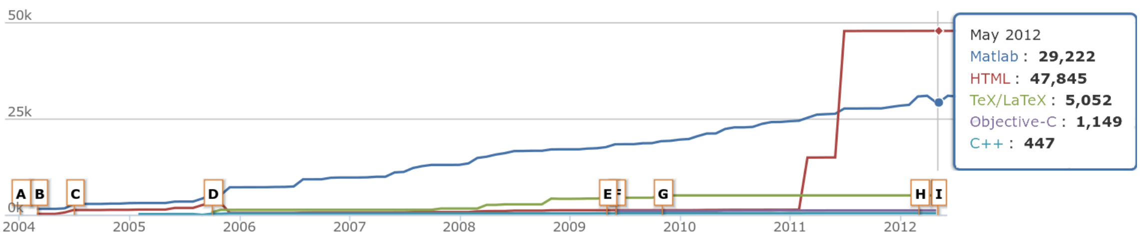

Figure 1: Growth of EIDORS code base (in lines of code) since 2004. ©Ohloh.com

2 Impact

Bar a slowdown in 2009-10, the number of peer-reviewed journal articles using or contributing to EIDORS has risen steadily over the years, and 2012 sets out to be another prolific year. EIDORS features in over hundred peer-reviewed journal publications, at least as many conference papers

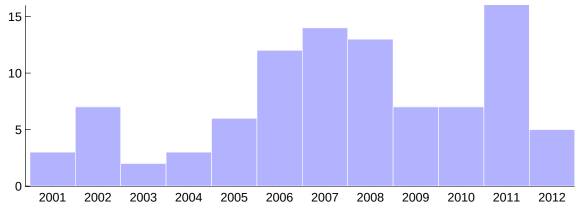

Figure 2: Number of journal publications using or contributing to EIDORS (data obtained with Google Scholar).

and several theses. Since January 2006, EIDORS releases received on average almost ninety downloads per month. The project mailing list[1], established last year, has already 64 members.

The fields where EIDORS is used includes all those relevant to EIT, ERT or ECT, including: (a) Medicine: ventilation and cardiac function monitoring, stroke detection, prostate and breast imaging, telemedicine and multimodality imaging (b) Biology: on-chip cell imaging, electroporation (c) Mathematics: inverse problems, finite element method (d) Chemistry: physical stability in liquid compositions (e) Geophysics: solute transport, mass transfer parameters, soil and rock damage (e.g. in volcanoes) (f) Robotics: touch-sensitive skin (g) Hardware design (systems, electrodes) (h) Computational efficiency studies and, last but not least, (i) Industry: non-destructive evaluation, mixing monitoring, pressure filtration, paste extrusion.

3 Recent developments

3.1 Features

Besides numerous bug fixes, speed improvements, additional tests, improved graphics handling and Octave support, a number of new features have been introduced in EIDORS since version 3.3 [5]. These include: (a) *reconstruction algorithms:* GREIT, TSVD, data 1-norm, absolute solvers, nodal reconstruction and display; (b) *electrode errors:* detection and compensation; (c) *meshing:* improved and expanded interfaces to Distmesh, Gmsh and Netgen, including the ability to build models with internal organs by extrusion; (d) *ready-made models* of human and porcine thorax with various number of electrodes; (e) *cashing:* 64-bit support; (f) support for three new *data formats* (g) and *image filtering*. Meanwhile, the EIDORS repository of contributed data expanded to 19 datasets, featuring: recordings from humans, swine, an old silver mine and various phantoms, FEM meshes of the thorax and the head, as well as software to evaluate EIT systems and a blueprint for a Lego™ robot to control a contrast in a tank.

3.2 Tutorials

An extensive set of tutorials has been created and 78 tutorials now showcase the extend of the numerous applications of the software. Among the various categories, some are dedicated to data structures, basic image reconstruction or description of the pre-packaged FEM models. Various methods to build models, including through Netgen or Distmesh, are detailed. Electrode movement and strange effect analysis are also described. Specific application examples include reconstructions on the thorax or geophysical media.

To illustrate the diversity of the tutorials, three examples are presented here. First, geophysical data acquired at the Pont Péan site were inverted and the reconstructed resistivity shows the presence of an important discontinuity corresponding to a thrust separating two distinct media, Fig.3.

[1] `https://lists.sourceforge.net/lists/listinfo/eidors3d-help`

Then, Fig. 4 demonstrates how a 3D thorax model complete with electrodes and lung regions may be constructed using Netgen. Forward solvers allow to visualize the distribution of current stream lines and equipotentials. Finally, an EIT-based regional analysis applied to lung mechanics during a recruitment manoeuvre in acute respiratory distress syndrome is presented, Fig. 5. The image shows the evolution of regional overdistension and collapse.

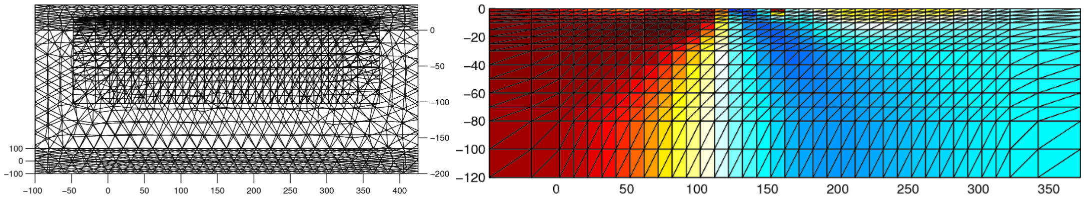

Figure 3: Analysis of the Pont Péan data set. Left: FEM of the forward model representing the geological media. Right: $2\frac{1}{2}$D reconstruction using a one step GN algorithm.

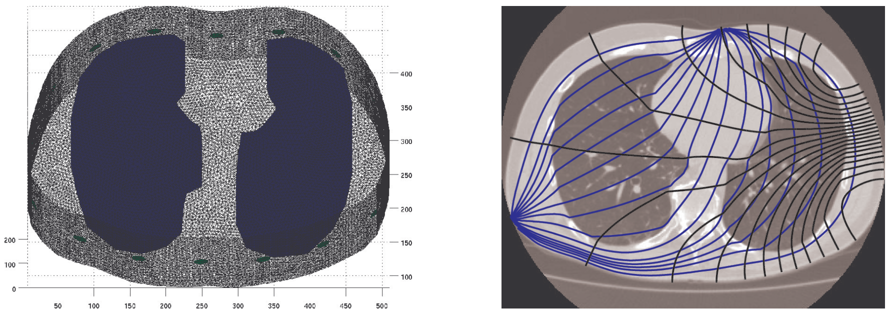

Figure 4: Model of a human thorax including lungs. Left: 3D FEM model. Right: CT image from which the shape was extracted with example current stream lines in blue and equipotential lines (from a different electrode pair) in black.

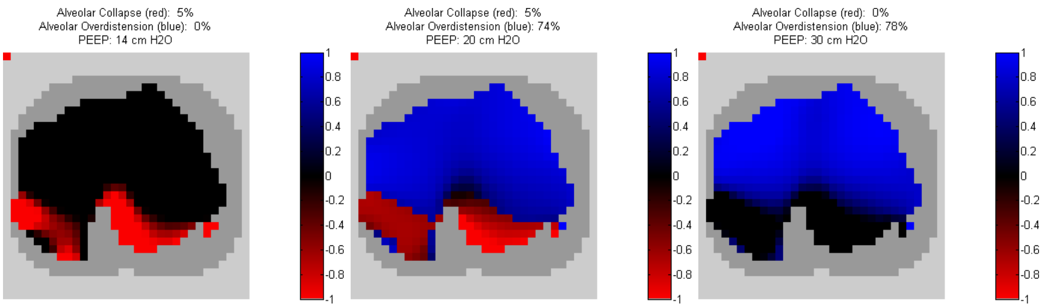

Figure 5: Regional overdistension (blue) and collapse (red) maps during lung recruitment. Grey pixels represent extrapulmonary tissue.

4 Challenges ahead

As EIDORS has grown, it has faced many similar successes and challenges as other open source software projects which have grown out of university labs [6]. Many of the decisions that were made have been shown to be relatively successful. However, as EIDORS grows and becomes more complex, some of the interactions between its components are made more difficult by some of the software architecture choices.

- *Matlab as the core language*. EIDORS is written in Matlab, and supports Octave as a 2nd language. The advantage is that Matlab is very widely used in the scientific computing community, and is thus accessible to users. The disadvantage is that Matlab is a highly unstable platform. Software features change regularly with versions, and older code (even a year or two old) will often no longer function (or worse, function but give the wrong result. In order to defend against this, EIDORS now contains hundreds of lines of code to detect Matlab versions and OSes and conditionally execute parts of code. Unfortunately, this requires large effort and is error prone.
- *Loose object structure* EIDORS uses a partially object-oriented (OO) structure, but with no protection for private methods or members. This decision was made in 2004, when we felt unsure that the Matlab OO structure was stable (a decision vindicated a few years later when the Mathworks introduced a new OO syntax). However, in many ways, the lack of private functions and a proper OO language makes EIDORS software more error prone.
- *Ingredients vs. Cookbook* EIDORS authors have typically seen EIDORS as a set of ingredients (ie. a collection of algorithm pieces that can be put together in both wise and poorly thought-out ways), while many users seem to expect a cookbook (ie. a set of recipes guaranteed to function and work well). The tutorials have been constructed as a way to help users use the provided pieces effectively.
- *First order simplices as main model structure* The basic EIDORS object is a simplex based FEM model, which represents both the forward in inverse parametrization. Later on, features to allow separate parametrization have been added. However, it would been a more clear interface for the user, if both models needed to be explicitly described.

Overall, EIDORS has seen numerous successes: we have seen a relatively constant rate of code growth (≈ 4000 lines/yr) and releases (1/yr) since 2004. The software is being used by an increasing number of academic and industry groups, used (and referenced) in publications, and with an increasing level of interest on the mailing list. As we plan for future growth, and as part of a possible EIDORS 4.0, we need to keep those aspects that makes EIDORS useful, while considering possible design architecture changes.

References

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