Towards a common and open file format for electrical impedance tomography

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Abstract

As Electrical Impedance Tomography (EIT) has gained importance for applications as an imaging and monitoring tool, the need to exchange EIT data for analysis has also increased. Unfortunately, such exchange is hindered by the fact that many current formats are proprietary, poorly defined or do not contain all the required information on EIT measurement conditions. To help address this need, this article aims to propose a common file format for EIT, called Open EIT (.oeit). It is meant to serve as a discussion basis for a group of interested contributors. We envision making use of ZIP-based archive files to store the required data. The EIT data - along with additional meta data about the system - will be stored in a standardized way in order to provide users with sufficient information for image reconstruction and data analysis.

Introduction

Electrical Impedance Tomography (EIT) is a tomographic imaging technique which makes use of electrical currents to probe the inside of a medium. Nowadays, EIT's principal fields of application are medical imaging, earth sciences and monitoring of industrial processes. One of the most promising applications is lung functional imaging, where EIT offers a cost-effective radiation-free compact bedside monitoring solution.

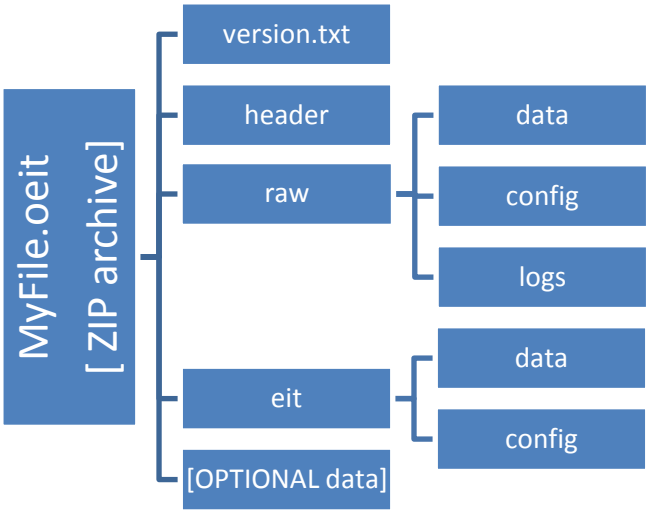

Figure 1: Proposed file structure for Open EIT file format

The journey of modern EIT started with the first published EIT image by Henderson and Webster [1] in 1976. Since then, tremendous work has been done in the field and a lot of scientific knowledge has been recorded by research groups worldwide. In parallel, several attempts have also been made to commercialize EIT technology, concluded by the first medical grade commercial thoracic EIT instrument brought to the market by Dräger Medical at the end of 2011. The multitude of available research and commercial devices, almost each of which using a custom file format, has been a hindrance to interoperability and data exchange among the different research groups, and hence to cross-validation and comparison of findings and methods. A first attempt to define a common file format has been done by Record and Riu [7] without really spreading through the community. Nevertheless, 20 years later, we feel that there is still a great need in the EIT community to agree on a common file format to exchange and store data. This article aims to present first ideas which could be exploited in the future Open EIT (.oeit) file format. In a broader perspective, we seek to gather a group of contributors around the OEIT project and come up with a first version of the file format at the XV. ICEBI and XIV. EIT conference in 2013 [6].

Motivation behind the OEIT file format

Up to now, the file format landscape in EIT is a mixture of custom file formats, some of which are encrypted or poorly defined. This prevents effective and efficient data sharing. Some proprietary formats have been reverse-engineered and procedures to read them have been made available in the open source MATLAB Toolbox EIDORS [2]. The authors of the present paper postulate that there is a better way: to use a common well-defined file format. We decided to call it Open EIT, to reinforce the idea of openness we would like to communicate through this initiative.

The authors are well aware that intellectual propriety and innovation must be protected. However, in our analysis, preventing third parties to access data are not beneficial for the community and slow down the progress in the field. Thus, our aim is to create a file format that by defining a device-independent standard data storage offers a tradeoff between openness and protection of intellectual propriety, which at the end should benefit everyone.

Objectives of the .oeit file format

In this section we list the basic requirements for the OEIT file format. While our initial focus is on thoracic medical imaging, we aim to cater to the needs of the entire EIT community. The future OEIT technical solution should provide the following:

- An easily extensible structure
- A raw-data storage
- A storage for standardized device-independent EIT data
- A timestamp system to synchronize all data streams
- A configuration storage linked to the corresponding data
- Storage options for other signals such as ECG, blood pressure and ventilator settings
- "Nice to have": file encryption, e.g., for patient data

To serve as a discussion basis for the community, the authors present some ideas and preliminarily concepts in the next section. At this point, we would like to highlight the fact that those are only propositions that need to be further debated. A first document in the form of an invitation by Gaggero and Grychtol has already been made available online via a “Google Group” [5] set-up for discussing the topic.

Proposed file format

For the file format used to store the data, we propose to reuse a commonly used format, thus enabling the use of preexisting and well tested libraries to read and write information. We believe that ZIP-based archive files would be sufficiently cross platform, well-defined and standard to suit our needs. Indeed, the ZIP file format has been recognized as a standard by the International Organization for Standardization (ISO), see ISO/IEC JTC 1/SC 34 N 1621 [3], which recommends to refer to the PKWARE application note [4] for file format specifications. Other projects are also using similar approaches to store data in a single file, e.g., Open Office documents. Similarly, the OEIT file will use a custom .oeit extension instead of the general .zip extension.

At present, we propose that each .oeit archive contains three main folders (see Figure 1): 1) “header” for all meta data files, 2) “raw” to store the proprietary EIT data and 3) “eit” to store standardized EIT data.

The folder “header” may contain meta data such as: a) information about the subject of study (e.g. patient, animal, field, volcano), b) information about the acquisition system (hardware manufacturer, hardware version, software version, etc.) and c) information about the electrodes (position, size, manufacturer, model, conductivity, etc.). We intend to store meta data in an xml format to avoid common problems with plain text files such as charset incompatibility. It may also be worthwhile integrating some elements of the DICOM format especially in case of patient data.

The folder “raw” is designed to store the byte flow transmitted from the hardware to the receiving software; this storage must be done without altering the data. The idea behind this is that it will always be possible to retrieve the original data acquired by the EIT instrument or to store some information in a proprietary format. The storage into the data subfolder is done on a frame by frame basis (a frame contains the data generated by the EIT instrument during one imaging period). The frames are stored in binary format in dedicated files (.rframes) and separated within each file by timestamp and pointers to configuration files associated to the particular frame. The raw data byte structure in itself does not have to be disclosed to the public and could be encrypted. Many frames can be store in one .rframes file, but it is recommended to find a balance between length and number of files, to optimize file handling.

The “eit” folder stores standardized EIT data and is subdivided into subfolders “data”, which contains the data, and “config”, which contains standardized configuration information. As in the “raw” folder, data are stored into binary .sframes files as described above. The standardized EIT data must provide sufficient information to allow reconstruction without reference to any device-specific information. A possible solution is to store the recorded amplitude and phase, or demodulated In-phase (I) and

Quadrature (Q) vector, in SI units (Volts). Naturally, to allow image reconstruction, also the frame-by-frame configuration parameters must be available, and these would be stored in the "config" folder. Again, the aim is to allow accurate representation of data and image reconstruction, and not to expose any system-specific industrial know-how. Thus, a standardized configuration file may contain: a) current frequency, b) measurement strategy and c) image rate.

Additionally, the OEIT file format could allow storing further information in optional folders. The information stored in those folders should be provided such that users can easily read them. Possible additional information is: ECG, two-point measurement, ventilator settings, temperature, pressure, screen shots, etc.

One of the major challenges when designing such a multipurpose and easily extensible format is to avoid misuse and ensure each file contains sufficient information in the spirit of this initiative. Thus we feel the need to define minimum requirements for valid .oeit files. The main requirement is to provide the end-user with sufficient data and meta information to do image reconstruction and data analysis without having access to the raw data. For instance, files which only provide raw data in proprietary format will not be considered valid .oeit files, even if a parser or format specification is made publically available. However, if no raw data are provided and all data are stored into the standardized format, it will be considered as a valid .oeit file.

Summary and outlook

In this paper we presented ideas to serve as a basis for discussion on a future file format to store and exchange EIT data. We believe that one of the major requirements is to base our technical solution on an easily extendable structure like ZIP archive files. We chose the name of the format to be "Open EIT (.oeit)". The backbone of this format is a folder, which contains standardized EIT data stored in a manufacturer-independent way and which provide sufficient information for image reconstruction by third parties. We hope to release a first draft in July 2012, and aim to release a first version of the file format before the end of 2012. In the longer term, we envision applying for an officially recognized ISO format. Since defining a file format for a whole community of user must be participative, we opened an online discussion group [5] which everyone is welcome to join and share ideas.

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