Open EIT: a common and open file format for electrical impedance tomography

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Abstract: A common file format for electrical impedance tomography (EIT), which the community could use to store and exchange data, would enable better communication between the different players. These are prerequisites for a quicker pace of innovation. Moreover, data exchange among research groups facilitates cross-validation of results and comparison of findings and methods. Unfortunately, such exchange in the EIT community is currently hindered by the fact that many currently used formats are proprietary, poorly defined or do not contain all the required information. In order to tackle this problem, we decided to initiate a project aiming to establish a common and open file format for EIT. This format is called Open EIT (.oeit). The .oeit files are ZIP-based archives which store EIT data into a standard format with enough information for image reconstruction without the need to refer to the original manufacturer's data format. Storage possibility for proprietary formatted data is also provided, but a file that only contains such data will not be considered a valid .oeit file. In addition to EIT data, we also envision storing auxiliary data from supplementary sensors, the experimental protocol and information about the tested body. All data streams can be synchronized by means of timestamps. In case of medical EIT, another important feature to implement is an easy data anonymization procedure. This paper presents preliminary result based on the contributions of the growing (and open) .oeit developer community and discusses the main topics and themes of the project. We intend it to serve as a basis for a constructive discussion amongst industrial and academic practitioners of all aspects of EIT.

1 Introduction

1.1 Background

Electrical impedance tomography (EIT) is a tomographic imaging technique that makes use of electrical currents injected into a body and of the resulting potential field to calculate the spatial distribution of electrical impedance. This technique showed promising results in various fields of application like earth science, industrial process monitoring and medical imaging. In medical imaging the most promising application is lung function monitoring to prevent ventilator-induced acute lung injury. In this area, EIT covers the need for a cost-effective, ionizing-radiation-free and compact monitoring solution.

As showed by Adler et al [1], EIT has witnessed a dramatic increase in the number of studies over the last decade. Outside academia, commercial interest also increases: the first commercial medical-grade EIT instrument addressing ICU market, PulmoVista 500 (Dräger Medical, Lübeck, Germany), has been brought to the market in 2011.

The downside of worldwide distributed research is that every group has defined their own standards. This is especially true for data storage. Among the multitude of today's research and commercial EIT devices, none share a file format. An early attempt to define a file format was made by Record et al [3], but was not taken up by the community. Twenty years later we feel there is the critical mass in the community to establish a common data storage solution.

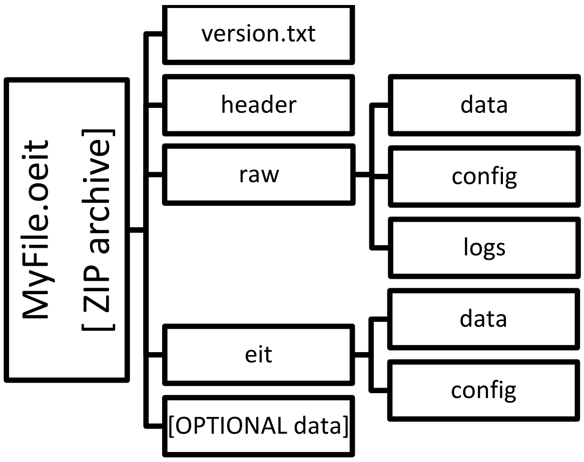

Figure 1: Proposed ZIP-based archive to store .oeit data

1.2 Motivation for a common file format

Today's EIT format landscape is a mixture of many custom file formats, some of which are encrypted or poorly defined. Certain tools such as EIDORS [2] attempt to provide parsers for a multitude of formats. We acknowledge that this approach is reaching its limits, as the number of formats grows and manufacturers change their specifications. Moreover, a common file format would abate obstacles in file exchange, and thus promote cross-validation and comparison of findings and methods. The authors postulate that the solution to the interoperability issues is a common well-defined file format, as well as providing open-source conversion tools between proprietary formats and OEIT. We decided to call the proposed new format Open EIT (.oeit) to reinforce the idea of openness. At the same time, we are well aware of the challenging trade-off between openness and protection of intellectual property and innovation, and aim to allow for both.

2 The .oeit file format

2.1 Objectives

We intend the .oeit file format to address the need of the entire EIT community, with a special focus on thoracic medical imaging for the first version. The technical solution aims at the following goals: 1) easily extendible structure, 2) raw-data storage, 3) storage for standardized device-independent EIT data, 4) timestamp system to synchronize all data streams, 5) configuration storage linked to the corresponding data, 6) storage options for other signals such as ECG, blood pressure and ventilator settings. If required, e.g. for patient data protection, encryption protocols would also be a desired feature.

2.2 Proposed structure

The proposed structure for the .oeit format is depicted in Figure 1. The basic idea is to make use of a ZIP-based archive to store the several folders and files into a single .oeit file. A similar approach is used to store OpenOffice documents. Moreover, the ZIP format is well defined and even recognized by the International Organization for Standardization (ISO), see ISO/IEC JTC 1/SC 34 N 1621.

2.3 Proposed data storage strategy

The most challenging part of the .oeit format is to support most of the current injection, voltage application, current measurement and voltage measurement strategies available in today's devices, as well as any future variants, while maintaining a clear structure that is easy to parse and write.

We propose to store the EIT data in binary format (little-endian) as a series of files with the extension .sframes stored inside the eit/data folder, see Figure 1. Each .sframes file can contain one or more frame; a frame contains enough data for one image. In order to optimize file handling performance, which could be application specific, we allow the binary data to be stored into several files. The content of each file is described in the manifest file, which records the frames stored in each .sframes file, thus facilitating access to a specific frame. Each frame of EIT data within a .sframes file is preceded by a timestamp and a configuration reference index number. The timestamp (uint64) stores the time and date of the frame acquisition with microsecond resolution, the zero is the same as UTC on 1 January 1972, 0 hours. The reference index (uint32) relates to a systematically named configuration file (e.g. config_[reference index]) which provides all information concerning measurement strategy required to understand the data stored in that frame, as described below. The storage mode in the data block could be switched between storing amplitude, amplitude and phase, and real (in-phase) and imaginary (quadrature) data. The binary format can also be selected, between int8, int16, int32, int64, float and double.

In the configuration file the gain factor is also provided to allow normalization of the data in their respective SI units. The measurement strategy is also stored in the configuration file thus the reconstruction algorithm can be matched. Supported strategies are pair drive and multiple drives such as a trigonometric pattern. One measurement strategy and one frequency are described within one single configuration file. Figure 2 illustrates an example for a mono-frequency system. In this particular example, we depict the way changes in instrument configuration during data acquisition are handled. In the case of a multifrequency system, each data block refers to an appropriate configuration file. In case multiple frequencies are recorded at the same time, for example using multiple demodulators while injecting a multi-frequency signal, the data block are still referencing multiple configuration files, but the timestamp will be the same, which indicates that the data were recorded at the same time.

The header could store meta data such as information about electrodes (position, size, manufacturer, model, etc), EIT instrument (manufacturer, model, software version, etc), test conditions, subject of study (patient, animal, volcano, etc). This means that meta data are not supposed to change within the same .oeit file. If meta data changes, e.g. two different patients, it is required to store the data in separate files. XML shall be used to store the information to avoid common problem related to plain text file such as charset compatibility issue.

The raw folder is reserved to store the byte flow provided by the EIT instrument. That means that proprietary data and their respective configuration file could also be stored within the .oeit format. The only requirement for those data is to follow a frame-based storage logic. Raw data are stored into data blocks with timestamp and a reference to a configuration file following the same data structure as the standardized eit data. The binary files are stored with a dedicated .rframes extension. The idea is to provide companies with the possibility to store files within a standard format and only grant access to selected data. Nevertheless a .oeit file that only stores raw data and no standard EIT data will not be considered as a valid .oeit file. In case only selected data are provided, the minimal requirement for the file to be considered valid is that the accessible data and configuration files provide enough information for image reconstruction. In this respect the authors would like to encourage everyone to store their data into the standard format and only use the raw format if storage for specific data is not provided in the current standard.

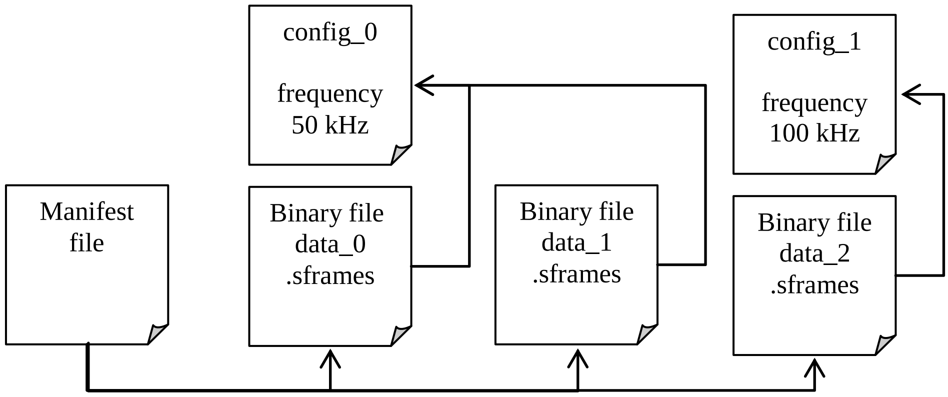

Figure 2: Example illustrating the files organization in case the system changes frequency during data acquisition

3 Summary and conclusion

In this paper, we present ideas concerning the future open common file format to store EIT data, called Open EIT (.oeit). The goal of this format is to store manufacturer-independent EIT data. A single valid .oeit file should provide sufficient information for image reconstruction by third parties. We selected a ZIP-based archive structure to support the folder and file storage in a single file. In this way, changes to the format for future versions and features can be implemented very easily. Anonymization of data, for example patient information, can also be easily achieved by deleting the specific files or folders. Once well-defined, we envision to apply for official recognition by the ISO. Defining such a file format with the aim of addressing the needs of the whole EIT community should be a collaborative project. We have therefore set up an online discussion group [4], where everyone is welcome to join and share ideas.

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