# SOFTWARE INFRASTRUCTURE FOR EEG/ERP RESEARCH

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Abstract: This paper deals with the software infrastructure for EEG/ERP (electroencephalography, event related potentials) research. The requirements for building this infrastructure have arisen from laboratory needs, unavailability of appropriate software tools and incompatibility of previously used commercial solutions. The standardization of EEG/ERP data formats and construction of complex and publicly open software infrastructure is also supported by International Neuroinformatics Coordinating Facility (INCF) since these efforts can significantly accelerate brain research. The presented software infrastructure includes the web based EEG/ERP portal as the central data storage for data/metadata obtained in EEG/ERP experiments and JERPA software as the desktop software tool for computationally demanding operations. Supporting libraries (e.g. library of signal processing methods) developed and integrated to EEG/ERP portal and/or JERPA software are briefly described.

## 1 INTRODUCTION

Our research group at Department of Computer Science and Engineering, University of West Bohemia in cooperation with other partner institutions specializes in EEG/ERP research (electroencephalography, event related potentials). Within our partner network we are responsible, except performing experiments, for EEG/ERP laboratory operation, development of advanced software tools for EEG/ERP research, proposal and modification of signal processing methods, development of hardware for subjects' stimulation during EEG/ERP experiments and integration of software tools and hardware devices into general solution for EEG/ERP research.

EEG/ERP experiments take usually long time and produce extensive data. Since we had had difficulties with long-term storage and management of these data and we have not found any suitable data store for them we started to design and implement a software tool for EEG/ERP data/metadata storage and management. The resulting EEG/ERP portal (Ježek, 2010) together with necessary hardware and software laboratory equipment became the basic building blocks for the next development of software tools and hardware devices for EEG/ERP research.

As the members of International Neuroinformatics Coordinating Facility (INCF) (INCF, 2011) we develop software tools for EEG/ERP research in coordination with other member countries. For example, EEG/ERP portal is currently registered within Neuroscience Information Framework (NIF) (NIF, 2011). Moreover, we are involved in INCF program for standards in electrophysiological data sharing.

The aim of this paper is to emphasize the importance of data and software tools standardization in EEG/ERP research and briefly introduce the proposed and partly implemented software infrastructure for EEG/ERP research.

The paper is organized as follows. At first the existing and complex software solutions for data and tools organization are briefly introduced by focusing on neuroinformatics portals of INCF member countries. Then EEG/ERP domain is shortly described. The fourth section deals with proposal, description and realization of software infrastructure for EEG/ERP research. The essential parts of this infrastructure are briefly described. The concluding remarks include the next vision of described infrastructure and the forthcoming tasks.


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## 2 PORTAL SOLUTIONS IN NEUROINFORMATICS

As INCF members we coordinate our efforts with other INCF member countries. Their software solutions for neuroinformatics research serve also as an inspiration for our approaches. This section provides basic information about activities of the selected INCF member countries and their neuroinformatics portal solutions.

CARMEN (CARMEN, 2011) is a virtual laboratory for neurophysiology, which is developed at eleven UK universities. It enables sharing and collaborative exploitation of data, analysis code and expertise. The complete lifecycle of neurophysiology data is addressed. The primary data types are neural activity recordings (signals and image series).

The infrastructure for brain science information and neuroinformatics within INCF Japan Node (JNODE, 2011) includes developing and publishing brain science databases under so-called platforms. Each platform is being developed to organize specific neuroinformatics databases (e.g. cerebellar or brain machine interface platform). The research results can be shared with the public.

German neuroinformatics node (GNODE, 2011) focuses on the development and free distribution of tools for handling and analysing neurophysiological data. Especially software and hardware infrastructure that eases the acquisition**,** storage and analysis of experimental data in cellular and systems neurophysiology is developed. Standardization of data formats and analysis tools is encouraged.

Neuroscience Information Framework (NIF) (NIF, 2011) developed within INCF national node of the USA is a dynamic inventory of web-based neuroscience resources: data, materials, and tools. It advances neuroscience research by enabling discovery and access to public research data and tools worldwide through an open source, networked environment. NIF offers e.g. a search portal looking for neuroscience information, tools, data or materials, access to content normally not indexed by search engines, tools for resource providers to make resources more discoverable (e.g. ontologies), standards for data annotation, etc.

## 3 RESEARCH IN EEG/ERP DOMAIN

EEG and ERP techniques are widely used in research of brain processes. These techniques include design and realization of EEG/ERP experiments, recording and collection of EEG/ERP data/metadata, long-term management and sharing of these data, and data analysis and interpretation (signal processing methods and statistical methods).

All these activities are currently partly covered by commercial or open-source software tools and hardware devices. However, especially commercial recording tools are based on proprietary data formats and include limited and closed-source software tools for data processing. This situation seriously complicates the access, storage, management, analysis and public sharing of neuroscience data and metadata and finally slows down brain research.

As the reaction to this situation and laboratory needs, and in accordance with INCF efforts our research group started to develop open source software infrastructure and hardware devices for electrophysiology research. The software infrastructure is described in the following section.

## 4 INFASTRUCTURE IN EEG/ERP RESEARCH

The software tools for EEG/ERP data and metadata management, EEG/ERP signal analysis and processing, and design of EEG/ERP experiments are developed. The simplified component model of EEG/ERP infrastructure is given in Figure 1. Details and dependencies of components within EEG/ERP portal were omitted to maintain the model readability.

### 4.1 EEG/ERP Portal

EEG/ERP portal is the main building block of the presented infrastructure. It serves as a system for storage and management of EEG/ERP resources - data, metadata, scenarios, tools and materials related to EEG/ERP experiments. Thus EEG/ERP portal advances electrophysiology research by enabling access to public data, tools and results of research groups. The main features provided by the system include:

- Management of EEG/ERP data/metadata
- Management of EEG/ERP experimental scenarios
- Management of data related to testing subjects
- Sharing of knowledge and working within groups
- Signal processing methods
- Content management system
- Full text search

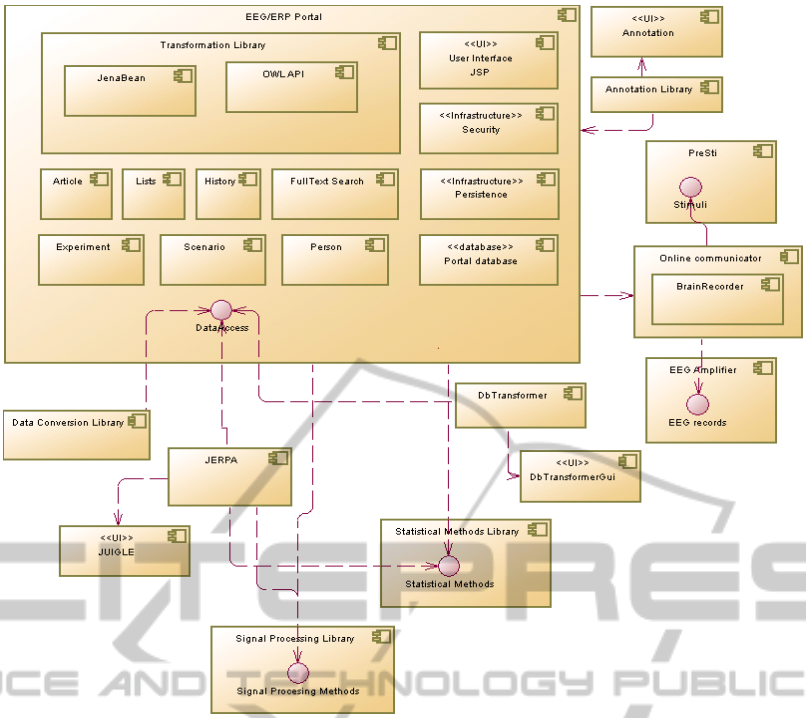


Figure 1: Component model of EEG/ERP infrastructure.

The system is developed as a standalone software product; the access to resources stored in the database is available through a web interface. It uses the layered architecture (MVC pattern) consisting of persistent layer (relational database), the application layer (object oriented model, ORM provided by Hibernate) and presentation layer (JSP). Spring security framework is used to introduce user roles. Users' authentication and authorized access to data resources and signal processing tools are ensured. Facebook can be also used as an external authentication authority.

To register the EEG/ERP portal as a recognizable source of neuroscientific data and metadata the representation of portal structure in semantic web languages and technologies is often required. Two possible mappings from common data structures to RDF/OWL are currently possible to perform.

DbTransformer library (extended with its graphical user interface) (Mouček, 2011) provides an automatic mapping from the relational database to RDF graph and to RDF/OWL output. Transformational library provides a mapping from object oriented model again to RDF/OWL output. It processes POJO objects and serializes them into output OWL structure. This processing includes parsing Java classes, their methods and attributes using Java Reflection API. The advantage of this approach is that the internal ontology model can be enriched by Java annotations added to classes, their attributes and methods (Annotation library with its graphical user interface in Figure 1).

## 4.2 JERPA and JUIGLE

Because of large EEG/ERP data, computationally demanding signal processing methods and the need to visualize and process EEG/ERP signal off line a desktop software tool for visualization and basic processing of EEG/ERP records was developed. JERPA (Java Event Related Potential Analysis) as the main component of this software was built using the layered architecture. It includes:

- GUI framework (JUIGLE) that provides support for creating graphical components for signal visualization and output of signal processing methods
- Plugin engine for installing new methods as plugins into the system
- Data store engine (connection to EEG/ERP portal, data management)

## 4.3 Library of Signal Processing Methods

Data from EEG/ERP experiments are processed

using signal processing methods. The developed library is intended for processing of EEG/ERP signals and includes wavelet transform, matching pursuit algorithm, FastICA algorithm and Hilbert-Huang transform. The wavelet transform and matching pursuit algorithm are integrated into EEG/ERP portal, FastICA algorithm is integrated as plug-in into JERPA software.

### 4.4 Library of Statistical Methods

The library of statistical methods includes Java implementations of the following statistical methods:

- One way and two way analysis of variance (ANOVA)
- One way and two way multivariate analysis of variance (MANOVA)

While one way ANOVA, implemented in the math library, was refactored, the other methods were newly implemented. MANOVA was implemented with all MANOVA significant statistical tests – Pillai-Bartlett trace, Wilk's lambda, Hotelling Lawley trace and Roy's greatest characteristic root.

### 4.5 Data Conversion Library

There exists a variety of data formats for storing EEG/ERP data. Data conversion library provides conversion methods between European Data Format (EDF), Vision Data Exchange Format (VDEF) and KIV format. The further library extension (conversions from/to SignalML and odML data format) is planned.

### 4.6 Presti

Presti is a software tool for presenting stimuli in ERP experiments. It aims at users without knowledge of programming. The concept of the program is taking advantage of visual programming methodology. The users could easily edit, create and run test scenarios in a simple and intuitive graphical interface.

## 5 CONCLUSIONS

This paper described the software infrastructure for EEG/ERP research. The requirements for building such infrastructure have arisen from laboratory needs, unavailability of appropriate software tools and incompatibility of used commercial solutions. Moreover, the standardization of data formats and construction of complex and publicly open software infrastructure is supported by INCF since these efforts can significantly accelerate brain research.

The presented software infrastructure includes the web based EEG/ERP portal as the central data storage for data/ metadata obtained in EEG/ERP experiments and JERPA software as the desktop software tool for computationally demanding operations. Supporting libraries are developed and integrated to EEG/ERP portal and/or JERPA software.

In near future we plan to perform an extensive testing of online communication module, which will mainly serve for brain computer interface tasks, and continue on EEG/ERP data format standardization task.

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