École Centrale de Lyon Internship report

Analysis and development of computational and experimental methods and tools for brain imaging by EEG

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October 1, 2014

Abstract

This internship, that was part of my second year at École Centrale de Lyon, was entitled *Analysis and development of computational and experimental methods and tools for brain imaging by EEG*. The main goal was to experiment, implement and improve methods leading to the processing of data resulting from EEG.
I took part to the setting of experimental protocols, bibliographic researches and implementation of methods for electrical sources localization and the creation of head phantoms.

Résumé

Ce stage d'application, effectué dans le cadre de la deuxième année de l'École Centrale de Lyon, est intitulé Analyse et développement de méthodes et d'outils computationnels et expérimentaux pour l'imagerie cérébrale par encéphalogramme*. Il consistait à expérimenter, implémenter et améliorer des méthodes permettant de traiter les informations issues des potentiels relevés par encéphalographie.*
J'ai participé à l'établissement de protocoles d'expérimentation, aux recherches bibliographiques et à l'implémentation de méthodes de localisation des sources électriques, ainsi qu'à la création de fantômes de tête, permettant la reproductibilité des expériences.

Keywords : Application intership, 2nd year, École Centrale Lyon, Mines-Télécom, Research, EEG, Mesh, OpenVIBE, Inverse problem, Sources localization

Thanks

I'd like to thank the whole team for this amazing internship. The language have never been a problem between us, mainly because it seemed sometimes more like a friends group than a coworkers team.

So thank's to:

- Axelle for sharing her office and for having taken part to all experiments we did (for work and on the beach with the team);
- Lyes for his constant smile, laugh and for his sport addiction;
- Maksims for his geek talks, for being Linux eager (because of him, I went to *ArchLinux*), his advices and lots of English corrections;
- Rajundra for being so patient with my Maths questions and for not having said anything when I made his office stink because of the latex molds of head;
- Simon, for his German talks, his organization of barbecues and our legendary red wine bottles;
- All the interns, because they were really cool: especially Valentin and Luc, with whom I climbed every other days and thanks to whom I'm now doing 6b, Robin who is an amazing nerd with some brilliant and disappointing talks.
- Yannick, the department secretary, for handling all the red tape needed;
- Dr Andriulli, of course, for the time he spent in teaching me his passion: Mathematics and Electromagnetism, without getting mad because I needed a little time to recall my theorems and for briging me to this unique experience.

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Introduction

Context As part of the engineering course at École Centrale de Lyon, each second year student has to do an *application* internship for three months or more. During this internship he works as a junior engineer, on a mission given by the receiving company or institution.

The goal of this internship is to apply the theoretical concepts learned at school to real features and to have a second insight of how a company works and what is expected from the employees. It's moreover a professional experience relatively close to what the student is going to see or live in his/her first job.

This internship is also a good way to begin to specialize in a domain or sector and to check whether he/she likes it.

Choice of the receiving company I wanted to do something quite technical. First, it's very difficult to get a management internship for only three months. Second, since I'm going to do a dual degree with a Electrical Engineering Master in Berlin, I found it more relevant to go into this subject in depth. I therefore looked for research and development internships in electronics at Thales, Peugeot or Moulinex (for example) but I was always told that three months weren't enough.

I eventually asked some academic institutions. Dr Francesco P. Andriulli was working on a subject related to brain that I found very interesting and he was looking for interns to accelerate his project.

Organization of this document This document introduces briefly the institution where I did the internship and the organization of the department and the team in which I was working in the first part. The second part is a detailed report of what I did during the internship. It's written in a way so that the group of research in which I was working can reuse it. The last part shows how this internship helped me to build my professional objectives and the end of my studies.

PART I

PRESENTATION OF THE INSTITUTION - INTERNSHIP DESCRIPTION

1 Presentation of the institution

1.1 General presentation

Dr Francesco P. Andriulli works as teacher-researcher for Télécom Bretagne, at the Micro-Ondes (Microwaves) department.

Télécom Bretagne was created in 1977. The school is now divided in three cities : Brest (where I was), Toulouse and Rennes. Since 2012, Télécom Bretagne is part of the *Institut Mines-Télécom* that gathers several Engineering Schools like Mines ParisTech, Mines Saint-Etienne, Télécom Bretagne, Télécom ParisTech (see the comprehensive list on the institute website[1]). The main goals of this group is to increase the visibility of the research and the teaching of its members and to have a more global research strategy.

The research part of Télécom Bretagne is divided in several departments based on their main field of work:

- Computer Science
- Electronic Engineering
- Foreign Languages and Culture
- Image & Information processing
- Logics in Uses, Social Science and Information Science
- Microwaves

[1] http://www.mines-telecom.fr/en/institut-mines-telecom-2/presentation-2/institut-mines-telecom-in-brief/

- Networks, Security and Multimedia
- Optics
- Signals & Communication

These department are also part of research networks (gathering CNRS, INSERM and the school) such as Latim, Labsticc, M@rsouin or Pracom.

1.2 Some numbers

- 500 people are doing research at Télécom Bretagne (around 160 teacher-researchers, 200 PhD students)
- 824 students are studying at Télécom Bretagne (around 250 students per year)
- 40 people are working at the Microwaves department (20 of whom are PhD students or post-docs, interns excluded)
- 12 people were working for Dr Andriulli during my internship (7 of whom where interns)

2 Dr Andriulli's group of research

2.1 Field of research, main applications

Dr Andriulli received his PhD degree in electrical engineering from the University of Michigan, Ann Arbor, in 2008. He does his research since then in computational electromagnetics with focus on preconditioning and fast solution of frequency and time-domain integral equations, integral equation theory, hierarchical techniques, integral identities and single source integral equations [1] (for all references, please read in the bibliography at the end of this document). He received the Issac Koga Gold Medal[2] from URSI[3] in 2014.

2.1.1 Mathematics and computation

I realized when I arrived in the team that Dr Andriulli was mostly interested in mathematics. The main goal of his research is to build fast algorithms to solve Maxwell's equations. To explain it simplify, it could be seen as the same type of research as the one which brought to the Fast Fourier Transform (fft) algorithm, based on the Discrete Fourier Transform (DFT).

[2] http://www.ursi.org/en/awards.asp?awardname=Issac%20Koga%20Gold%20Medal
[3] URSI: Union Radio-Scientific Internationale

Therefore, he (and most of his PhD students) learns and combines algebra and analysis theorems to speed-up already known methods, designs new theorem and algorithms. There are then two fields in one: a theoretical one and a more practical one, because their algorithms (but also the concurrent ones) must be implemented and tested. The two main languages used here are MATLAB and FORTRAN (the first for tests and fast design, the latter for efficiency in production).

2.1.2 Brains: Electroencephalography

To be founded, the group has to show the relevance of their research, ie. the gain one can get from their new algorithms. One of the way to achieve this is to confront them to competitive problems of their field.

Dr Andriulli decided to focus on brain activity. He has two fields of interest: Brain-Computer Interface (BCI) and focal epilepsy detection. Both use electroencephalography (EEG) to get potentials on the scalp and then handle the data.

In the case of BCI, people are mainly using only the potentials and then, thanks to some machine learning and other algebra manipulations, they have the computer understood what the user is thinking. The main goal of the group is to increase the resolution and the accuracy of the methods. That can be done by building better algorithms and taking in account more precise physical features (add constrains coming from the Maxwell's equations for example).

For medical uses such as focal epilepsy, people are doing sources localization. It means that, knowing the potential on the scalp, they try to find the sources of the potentials. These algorithms are roughly matrix inversions and multiplications, that can be speeded-up by the group advances.

2.2 Presentation of the team

I worked with Dr Andriulli's post-docs and PhD students. He currently has one post-doc and five PhD students. Most of them are foreign students (Maksims, the post-doc, is Latvian, Lyes is Algerian, Rajendra is Indian, Simon is German and Axelle is the only French person of the team).

The discussions had therefore to take place in English to be understood by everyone.

At the end of the internship, we were eight interns, all French and six of whom who were students at Télécom Bretagne.

For us (interns, post-docs and PhD students) the only chief was Dr Andriulli. I was really surprised that it didn't look like in a company in the academic system: I had always thought that the department chief was giving a sort of schedule and goals to achieve to the other researchers. The truth is eventually that everyone has their own projects, fundings and so on.

3 Development of the internship

3.1 Previewed work

Since I didn't really know what Dr Andriulli and his team were working on, and that he had various tasks to achieve (or to improve) during the summer, we agreed that I would try any topic I was interested in during the first month and then choose a main mission.

There were several fields to enhance:

- Improve the way of doing brain and head phantoms;
- Discover and use scientific visualization tools (to have some beautiful and alluring pictures in the publications and on the research group website[4]);
- *Play around* with BCI tools such as OpenVIBE, BCI2000 or EmotivEPOC;
- *Play around* with the new and expensive EEG machines Dr Andriulli recently bought;
- Create an interface between the new EEG machines and their tools;
- ...and some other task that I didn't know about...

So I tried several of these topics (almost all of them, actually).

3.2 My contacts with the other members of the group

The newest PhD student, Axelle, took care of me from the beginning because she was the most used to supervise the other student project. Moreover, because she had begun her PhD recently, she wasn't too deeply taken up by research yet. I had been said to ask Dr Andriulli and the other PhD students whatever question I had. I met students of Télécom Bretagne who gave a hand on some projects, read their reports and so on.

From about the middle of my internship, the other interns joined the team and I had been affected to the organization of the tasks of three of them. The four other ones had already independent and defined tasks to achieve. We nevertheless met often to compare our results, discuss problems.

[4] http://public.telecom-bretagne.eu/~fandriul/

Dr Andriulli met us regularly to check how things were going or to have our opinions on some decisions he had to take for instance...

3.3 Courses

During the first month of my internship, Dr Andriulli was teaching a course *Integral Operators and Fast Solvers: A Cross-Disciplinary Excursus on the Best of FFT's Companions* for Télécom Bretagne students, that I could follow.

Then, Dr Andriulli taught me electromagnetism (especially the Huygens principle) and an introduction to ways to handle numerical calculations. So I got an insight of Sobolev spaces, operators theory and learned again lots of mathematics that I had forgotten since the *Classe Préparatoire*.

PART II

PRESENTATION AND ANALYSE OF THE WORK DONE DURING THE INTERNSHIP

In this part is explained with more details the tasks I did during my internship. The main goal is to let a written trace of what I achieve during this time, in order to make my work valuable for the research group.

1 Visualization tools

One has to remember that the group of research works on electromagnetic computations. It means that they use and discover powerful mathematical theorems to speed-up calculations in order to simulate or solve large-scale problems. Therefore their publications could become very tough algebra and analysis papers.

In order to be founded they have to show why their work is relevant and to illustrate it even for non-mathematicians. That's why the prettiness of the visualization is very important, so that the people get impressed of the power of the algorithms designed here.

So I did a review of most of the visualization tools used by other scientists, and tried several of them. I wrote a presentation document that summarizes the different tools with pictures, main features and links to the editors' websites. Someone has now to pick the right solution and to learn how to deal with the chosen one.

2 Meshes enhancement

2.1 Presentation of the problem

All the group's calculations are done numerically. This means that the solution will be an approximated one, calculated on discrete elements. The surfaces or volumes have therefore to be meshed in several patches (the more patches, the more accurate the solution). However, the meshes have to follow some rules, so that the calculations run well.

For example, if patches have to tiny angles, some singularities could appear. If there are too many patches in an area, the calculation will last longer, without any gain of accuracy if the solution is constant enough. Surface meshes have to be consistent, which means that two elements cannot be stuck without sharing an edge (CAD meshes are often additions of meshed elements pasted to each other) or create weird angles (the binding between two patches has to be smooth enough).

We had for example a surface mesh of a head that was very smooth and realistic. The counterpart of this smoothness was that the number of patches was very high everywhere and insanely huge in specific areas like the hears, mouth, nostril or eye.

2.2 Looking for a solution

I first tried to edit the mesh by merging patches. This method had two main problems: first, since the patches are flat and not regularly arranged, merging them created flat zones, with complex shape (ie. not triangles) which are not handled by the algorithms for calculation; second, it was very long and unfeasible for every mesh we would have to deal with. It seemed easier to redesign completely the mesh.

Another lead was to use NURBS[5]. It's a mathematical model that is often used to represent curved lines or surfaces. By using this type of model we thought it would be easier to store the geometric shape of the surfaces or volumes and then to rebuild meshes with the desired patch size. However, it's difficult to find NURBS models of heads or brains, and these models are often patches of NURBS. We therefore get stuck here with the same problem as explained above. Because I was out of ideas

[5] Non-Uniform Rational Basis Splines, see http://en.wikipedia.org/wiki/NURBS

and had no relevant technology to help me on this topic, I switched to another one.

3 EEG tools and algorithms

3.1 EGI's *Net Station*

3.1.1 Overview

The group bought at the beginning of the year (2014) EGI[6]'s Geodesic EEG System. It's an *expensive* EEG kit (see Figure II-3.1), including an amplifier, an Apple Mac Pro, and the software suite *Net Station*. EEG Nets (kind of helmet with potential sensors) can also be bought: the group have three 256-electrodes Nets, which provide the densest EEG currently available.

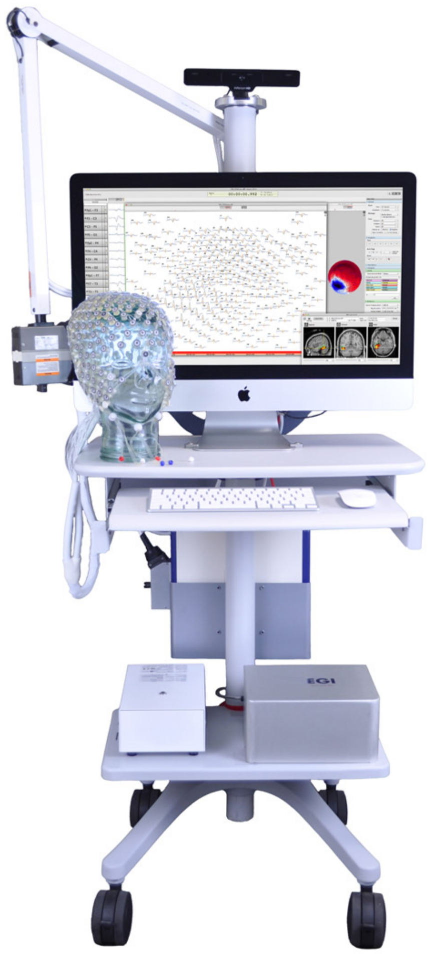

Figure II-3.1: Geodesic EEG System (GES) 400 [2]

Net Station allows the data acquisition from the amplifier, several runtime or offline visualizations and processing. Some license extensions provide also the ability

[6] EGI: Electrical Geodesic, Inc - www.egi.com

to turn the Mac Pro into a *AMP server* (so that another computer on the network can read from the amplifier), algorithms to solve and visualize the inverse problem (showing the currents in the head, see II-3.6) and a way to localize the sensors on the subject's head (see Figure II-3.2).

Figure II-3.2: Geodesic Photogrammetry System (GPS) [2]

3.1.2 *Technical Manuals* simplification

When I arrived, the group had only had a training session with a technician from EGI and Axelle had played around with *Net Station*.

To get familiar with EEG, I began to use *Net Station* while reading the ten *Technical Manuals*. I wrote a lighter guide that summarize the books and explains some features that weren't obvious to me. The file, that is about 20 pages, can be found in Appendix C.

3.1.3 *MATLAB* driver

It would be very useful to be able to use the *AMP server* through *MATLAB* in runtime. An *AMP server* is only a server that can send data by TCP/IP following a certain norm.

I read all the documentation I could find, dig in the code of opensource softwares that had implemented this driver in C++ (like *OpenVIBE*) and wrote a *MATLAB* class to handle the communication and an example script.

However the EGI documentation didn't give the real shape of the packets so I wasn't able to correctly decode the data stream. It's the only thing to add to the program I wrote. We asked EGI support for this issue, but they didn't answer. It has to be asked again.

The full code can be found in Appendix A.

3.2 *OpenVIBE*

Several BCI softwares can be found on the Internet. *BCI2000*[7] and *OpenVIBE*[8] are two opensource examples.

3.2.1 Context and presentation

Context Dr Andriulli is starting a project in collaboration with INRIA, which should lead to an improvement of *OpenVIBE* (relating to accuracy and error ratio). We therefore used this program a lot.

Presentation of the software To use *OpenVIBE* we only need to launch an *Acquisition Server* and a *Designer* subprograms. The first contains drivers that translate the data obtained by the corresponding EEG tool to the *OpenVIBE* format. The latter is where the scenario, processing and visualizations are build.

The program is designed to be very modular. It's made up of a core that handles all the global processing and boxes that can be linked to each other in the *Designer* interface. It's then very easy for the users to create their own scenario by adding the different acquisition, processing or visualization boxes, without doing any programming. It's moreover easier to add a new box when needed, without doing major coding (only the box functionality has to be implemented).

3.2.2 Scenarios

Several scenarios are available. A scenario is a sequence of operation (so here *of boxes*) that do something with some data.

We were interested in having the computer recognizing when we thought of a right- or left-hand movement. To put it simply, the computer is first trained to recognize the potentials produced by the brain when left or right arrows are shown. Then, in another session, he tries to match the signal he receives to the left- or right-hand category.

[7] A product by Shalk Lab, Laboratory of Neural Injury and Repair, NY - http://www.schalklab.org/research/bci2000

[8] A product by INRIA - http://openvibe.inria.fr

This training is made in three step. The following can be found more extensively with a box by box explanation in Robin Nicollet's documentation in Appendix D. However some pieces of information given here are complementary to his document.

Acquisition First, the data are acquired. The program shows arrows on the screen and records the signal produced by the subject and the time when each arrow is displayed.

Training the CSP Then, knowing the category of each signal, it trains the common spatial pattern (CSP). The CSP is a matrix that maximizes the difference between samples category, when multiplied with the CSP-matrix. In the case of our example, there are two types of signals (left- and right-hand movements). The training of the CSP will create a matrix so that :

$$\underline{\underline{M_{CSP}}} \times \underline{\underline{\Phi_{\text{left}}}} - \underline{\underline{M_{CSP}}} \times \underline{\underline{\Phi_{\text{right}}}}$$

is maximal.

Training the classifier Thanks to the CSP, the classifier is trained only on relevant data. Its role is to change the output of the CSP in a scalar number. A threshold has then to be chosen in order to discriminate the original signal.

Online or Replay mode When these two matrix are trained, a new acquisition can be done and the program should be able to distinguish between left- and right-hand movements (if everything above was done correctly). Since it's only simple matrix operations, the process can be done in runtime or post-processed.

3.2.3 Assuring the results independence from the software

Not to depend to much on *OpenVIBE*, we also tried *BCI2000*, and developed our own BCI scenario from scratch in *MATLAB*.

BCI2000 Because of the way it was developed and the design of the interface, it is very difficult to use it correctly. It's moreover slightly bugged. We haven't been able for now to use anything else the P300[9] Spelling scenario, in which the subject has to choose a letter in a grid and recognize it every time it blinks, the computer being then theoretically able to find it back.

MATLAB Another intern developed from scratch a script that follows the same steps as described before. It allows us to double check the data we acquire with this totally independent tool, and to know whether a bad result is due to the subject, the acquisition or to *OpenVIBE* itself.

[9]The P300 (P3) wave is an event related potential (ERP) component elicited in the process of decision making - http://en.wikipedia.org/wiki/P300_%28neuroscience%29

3.2.4 *MATLAB* box

OpenVIBE provides a *MATLAB* box. Instead of coding a C++ box, *MATLAB* function can be implemented, although it will be slower.

The box require 3 functions:

1. box_out = **initialize**(box_in)
2. box_out = **process**(box_in)
3. box_out = **uninitialize**(box_in)

The first one is called when the *Play* button is pushed, the second during the processing at the clock frequency (one of the box parameters) and the latter when the *Stop* button is pushed.

The only constraint is that the functions respect this framework:

```
function box_out = functionName(box_in)

    % YOUR CODE HERE %

    box_out = box_in;
end
```

To pass variables from a function to another or from one call to another, it must be stored in the structure $box\_in.user\_data$. For example :

```
box_in.user_data.my_id_variable = [1 0 0 ; 0 1 0 ; 0 0 1];
```

All the documentation and some tutorials can be found at http://openvibe.inria.fr/tutorial-using-matlab-with-openvibe/

3.3 Modeling heads

We use several different models for head, depending of how advanced and how fast the algorithms are.

Homogeneous sphere To begin with an easy model and be sure that in this case our methods are working, we model the head as a simple homogeneous and isotropic sphere. With such a model, we can use analytic solutions to get the potentials on the scalp and be sure that all the problem we can have while solving the inverse problem (see II-3.6) are due to our algorithms.

Three-layered homogeneous sphere Neurophysicians often use three layered spheres as a model of head [3][4]. Each sphere represent respectively the brain, the skull and the scalp, with their respective average conductivity and radius, as shown in Figure II-3.3. It is often found in literature [4] that considering respectively the conductivities 1, 1/80 and 1 is a good approximation.

The model only needs a vector containing the three conductivities.

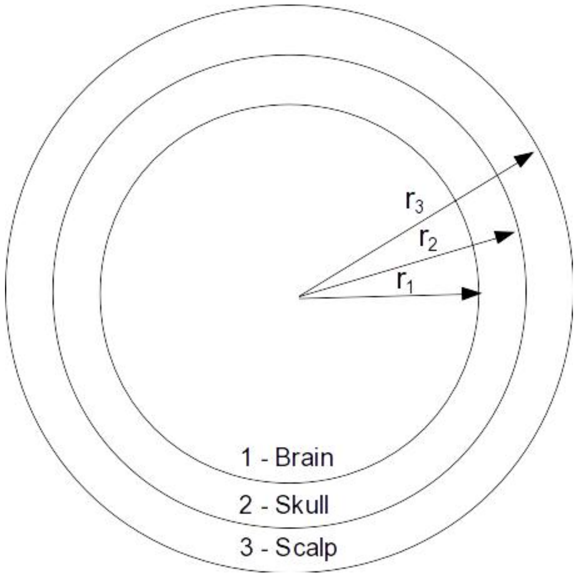

Figure II-3.3: Three-layered sphere model, each layer having a different conductivity

To be more accurate, a 4-layered sphere can be used, adding the CSF layer between the brain and the skull or 5-layered sphere, splitting the brain between white and gray matter.

Inhomogeneous and anisotropic sphere Since the brain and the skull are not isotropic and homogeneous, including these features in the model can improve quality of the solutions. While keeping sphere models, the solution can still be calculated analytically for some simple cases [5].

The model only needs to be given the conductivity as a matrix 3×3 being a function of the space.

MRI-based model The most accurate model is to use MRI data to reconstruct the subject's head with scalp, skull, CSF, white and gray matters. Then by using some known data, anisotropy and inhomogeneity can be added to the model. However, the potentials must then be calculated numerically since there is no analytical solution for such complex shapes. Therefore the mesh obtained thanks to the MRI has to be *good* enough: it must be checked and sometimes improved as presented in II-2.

3.4 Head phantoms

EEG is used to read brain activity. We need yet to be sure of what we read. Since we cannot ask a sick subject to reproduce the same epilepsy several times for example, we construct head phantoms. This is basically a head, made with several layers of gelatin (Agarose) having the same conductivity as the different parts of the head.

3.4.1 Geometry

The phantoms we want to create are three-layered: a brain, a skull and a scalp.

We first use three spheres, but the goal is to create a head with a real shape thanks to a 3D printer[6]. The price of the raw material prevented us to try it during my internship, so we only worked with gelatin spheres.

Another lead was to use molding latex. Dr Andriulli has a skull and a brain replication that we used to create the latex mold. This can be used as a middle-ground between spheres and 3D-printed shapes.

3.4.2 Conductivity

The phantoms are like heads in terms of conductivities. So we add a known concentration of salt to obtain the correspondent conductivities (the cooking recipe we used is mainly described in [7]).

Two previous internship [8][9] worked on finding the salt concentration with several experiments. For a three-layered sphere, they concluded that

$$[Na^+]_{\text{skull}} = 0.7\ g \cdot L^{-1}$$
$$[Na^+]_{\text{brain,skin}} = 2,5\ g \cdot L^{-1}$$

At the end of the last month, we were able to build two-layered conductive spheres (as in Figure II-3.4). However we never had them being *active*.

Another lead would be to use conductive latex [10][11] for the scalp or for the whole head. This would let us make only one phantom and reuse it as often as needed (gelatin moist indeed very fast).

3.4.3 Dipole

Literature [12][13] often models bunches of neurons as electric dipoles. Moreover we found afterwards a publication [14] that validate the model.

These dipoles are modeled in the phantoms by coaxial cables [10][15]. We have to put the coaxial cable(s) in a known position, and then run the EEG processes

Figure II-3.4: 2-layered conductive sphere in gelatin (pict. by G. Doncieux)

to be validated. For now, it never worked. I think the protocol of the experiment should be reviewed and improved (see II-3.7.1).

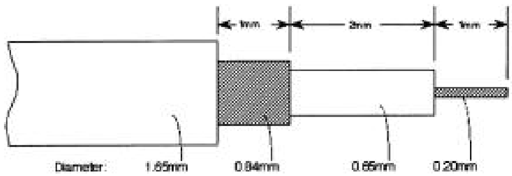

Figure II-3.5: Dimensions of the stainless coax and outer sheath used to generate the dipolar sources [10]

3.5 Direct problem

The direct problem consist in finding the potentials in the whole space or in chosen points, knowing an electrical source in the brain.

3.5.1 Model

The brain is modeled as a set of voxels, in the center of which is a unique dipole. We can then choose the orientation of the dipole or not. Physiologists support fixed orientation [16] because it depends of the position of neurons, which doesn't change. However, since we don't know *a priori* this parameter (although it is often said that neurons are in the radius orientation, so the main direction of the dipoles would be radial), it's seems more efficient to leave it unknown.

3.5.2 Solving the direct problem

Solving the direct problem provides a leadfield matrix $\underline{\underline{G}}$ defined so that:

$$\underline{\Phi} = \underline{\underline{G}}\ \underline{D} \tag{II-3.1}$$

where :

- $\underline{\Phi}$ is the m-vector of m potentials,
- $\underline{D}$ is the $3p$-vector of dipoles, $\begin{bmatrix} D_{3(i-1)+1} \\ D_{3(i-1)+2} \\ D_{3(i-1)+3} \end{bmatrix}_{i\in[\![1..p]\!]}$ containing the dipole amplitude in each direction,
- $\underline{\underline{G}}$ is the leadfield matrix, $\left[\underline{\underline{G}}\right]_{ij}$ being the potential on the i^{th} electrode produced by the ${j_q}^{th}$ dipole in the ${j_d}^{th}$ direction, assuming $j = 3 \times j_q + j_d$

To construct this leadfield matrix we only need to be able to calculate the potential under each electrode produced by each orientation of each dipole.

In the case of homogeneous spheres (even multi-layer spheres) we have an analytical solution. However for more complex shapes, an approximative solution must be calculated numerically (see II-3.3). This is Lyes, Rajendra and Axelle's current work: to calculate the field produced by a dipole in a complex, inhomogeneous and anisotropic medium using numerical methods applied to the Maxwell's equations (I read [17] and [18] to get a little more acquainted to the subject).

For now their Fortran algorithm works well for a dipole away from the outer surface of the sphere. However, the common assertion found in literature [3] is that the active dipoles are close to the cerebrospinal fluid (CSF) which is a layer between the skull and the gray matter: the algorithm should be fixed near the surface to be more physically relevant.

3.6 Sources localization: the inverse problem

3.6.1 Presentation of the problem

Several scenarios (often medical ones) require to know what part of the brain is highly active. For example in the case of focal epilepsy, a very tiny part of the brain produces the disease. Therefore being able to find this part allows a cure by surgery: the surgeon will remove the ill piece of brain. It shows how hot this topic is: any improvement will be highly welcomed.

The goal is, given EEG potentials measured on the scalp, to find where the active sources are (see in II-3.4.3 for further informations on active sources model).

3.6.2 Solving the inverse problem

Axelle had already implemented sLORETA [19], so it helped to understand the main concepts of the inversion.

With three other interns we read publications [12][13] describing algorithms to solve the inverse problem. We mainly followed [12] since it was a more step-by-step explanation and that other papers were sometimes more focused on maths than on implementation ease.

As said before, the goal of these algorithm is to somehow inverse the leadfield matrix $\underline{\underline{G}}$. It is however clear that with such a *naive* method, the contribution to the scalp potentials of the inner dipoles is lower than for the outer dipoles. To improve this, a weight matrix is often used (for example in WMNE or LORETA).

It appeared that all the algorithms dealing with a weight matrix we wrote based on [12] weren't working. Did we fully understand the paper? Did we missed a step? Being unable to find the error, we used [20] to implement the weighting matrix, obtaining better results.

We eventually implemented:

- eLORETA
- LORETA
- MNE
- sLORETA
- WMNE

All this methods are called this way (here fore sLORETA):

```
current =
  sLORETA(coordinates_dipoles, coordinates_electrodes, potentials, G);
```

3.6.3 Testing the implementations

To be sure that our implementations were working well, we tried them with different ways. We simulated a brain activity by applying a distribution of currents on the dipoles, constructed the potentials produced by the dipoles on the sensors locations and tried to find the same distribution of dipoles or the most active ones.

Since Lyes and Rajendra's Fortran program was not fully working at this time and since we used a multi-layered sphere model (1 or 3 layers), we compute the potentials analytically.

We always used the EGI Net (with 256 electrodes) on these experiments because the EPOC wasn't giving any good results.

Theses methods are explained below, titled by the type of distribution used. The graphs given are calculated on a 1-layered sphere, the direct problem solved with an analytic method, N = 7 dipoles on a radius (ie. 1407 dipoles in the brain).

Dirac The first test is to choose a unique active dipole and try to find it thanks to the calculated potentials.

Figure II-3.6 shows the error of localization for each method related to the distance of the dipole to the center. As predicted, MNE works well near the surface and not so good for inner dipoles, whereas sLORETA and eLORETA are very accurate everywhere. LORETA seems to work very randomly: it may be an error in the implementation (to be checked). We see that the weight matrix used in WMNE plays the predicted role (ie. WMNE is more accurate than MNE everywhere).

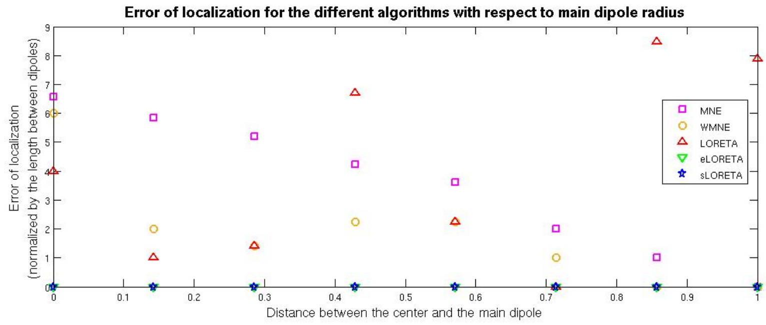

Figure II-3.6: Error of localization of the most active dipole in a Dirac distribution (in term of number of dipoles)

Figure II-3.7 shows the error of amplitude of each dipole (normalized by the maximum of amplitude) for a main dipole at a given distance from the center. The error is very low while the main dipole is away from the surface of the sphere. LORETA is not very accurate (near the surface, the points are out and above the graph).

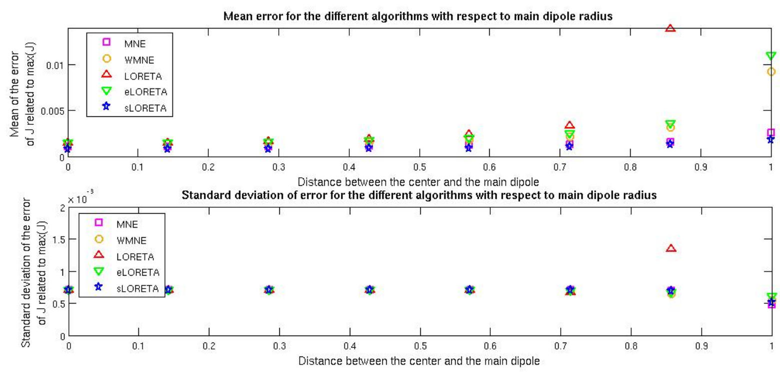

Figure II-3.7: Error of amplitudes of all dipoles in a Dirac distribution

Gaussian To be more realistic, we tried to smoothen the Dirac distribution. Our first idea was to use a Gaussian one: with a chosen radius we tried ether to find all the dipoles or only the central one. [21] used Gaussian (blurred) dipoles.

Figure II-3.8 shows the error of localization for each method related to the distance of the dipole to the center.

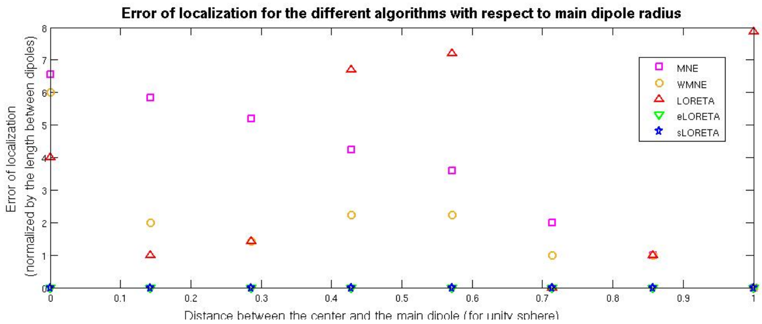

Figure II-3.8: Error of localization of the most active dipole in a Gaussian distribution (in term of number of dipoles)

Figure II-3.9 shows the error of amplitude of each dipole (normalized by the maximum of amplitude) for a main dipole at a given distance from the center.

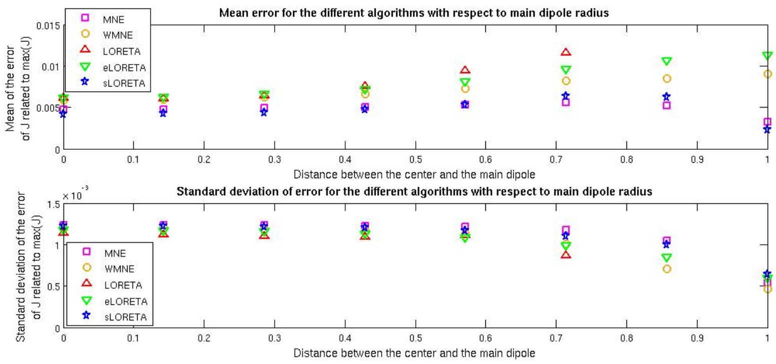

Figure II-3.9: Error of amplitudes of all dipoles in a Gaussian distribution

The Gaussian case is mainly similar to the Dirac one.

Coulomb Another way of testing is to assume that the active dipoles are only on the surface of the head and that their intensity decrease in $\frac{1}{r^2}$ around a chosen one [22].

Figure II-3.10 shows the error of localization for each method related to the distance of the dipole to the center.

We cannot really discuss the two figures because the errors of localization are extremes (the maximum possible is a little more than 14). Because this is not accurate at all, the amplitudes we get have absolutely no relevance.

Other methods We also found other methods that we didn't try, using more complex distributions like in [21] or superpositions of a subject RMI to have a kind of background noise [23].

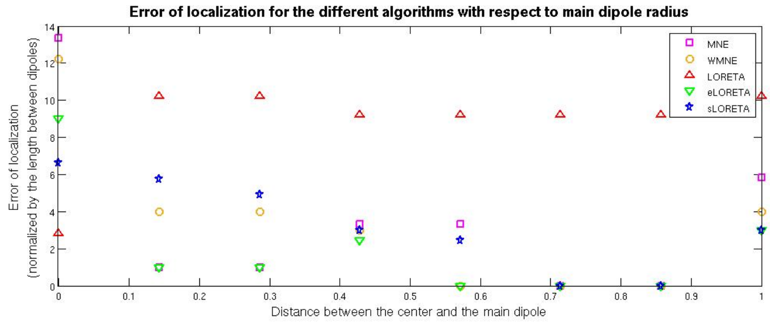

Figure II-3.10: Error of localization of the most active dipole in a Coulomb distribution (in term of number of dipoles)

3.7 Experiments

3.7.1 On brain phantoms

We used our ability to produce spherical phantoms of the head (see in II-3.4) to try to find a dipole (which means a coaxial cable powered by an AC generator) that we previously inserted in the center of the sphere.

To be sure that we weren't giving to much power and tension to the sensors, we created a DIY voltage divider (dividing the voltage by 100). We tried it with the EPOC electrodes but never got any good results. On the one hand we know that EPOC *never* provides good results, on the other hand, there is no doubt that our divider is very noisy.

The next step would be to design this divider on a printed circuit board to see the difference. Another lead would be to use a small battery instead of a generator.

3.7.2 On recorded EEG

The algorithms being very slow for now, they cannot work in runtime (we although created a *MATLAB* box on *OpenVIBE* that applies the sLORETA to incoming potentials). However, it can be easily done on recorded data.

If it was working, we could certainly increase the BCI accuracy since it would rely on more elements (more than 4000 dipoles instead of 256 potentials). We didn't try this process on *OpenVIBE* scenarios, but on our *MATLAB* BCI algorithm. The results are given in Figures II-3.11 and II-3.12.

We see that sLORETA doesn't give good results for now. According to II-3.6.3 eLORETA might have been better. However, this was our first try and can hopefully be drastically improved.

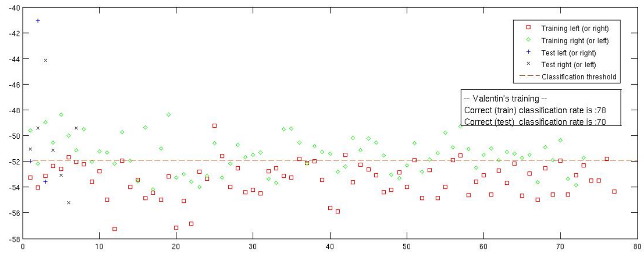

Figure II-3.11: Classification of Valentin's tests and training (CSP and classifier trained on potential amplitudes)

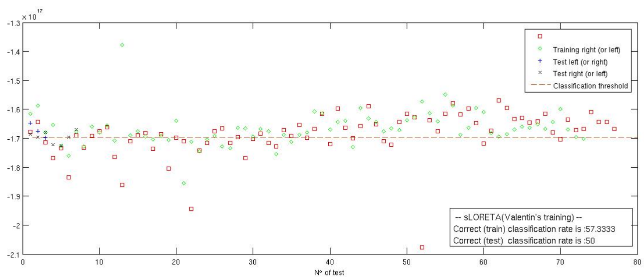

Figure II-3.12: Classification of Valentin's tests and training after sLORETA (CSP and classifier trained on dipoles amplitudes)

PART III

INFLUENCE OF THE INTERNSHIP IN MY PROFESSIONAL OBJECTIVES

1 Definition of my professional goals

Since I was in highschool, I'm very interested in managing projects, making things evolve, leading a group to a common goal. Being in a so generalist engineering school as École Centrale de Lyon ensured me to be able to choose these kind of responsibility. Being aware of this, I thought it was more relevant to begin my professional life as an expert in a domain: that means to specialize, with a Master Degree and (maybe) a PhD.

It would let me do some research if I'm still interested in it or, thanks to the engineer degree, to manage a team. The expertise would let me, I hope, work in an innovative sector.

That's eventually one of the reasons why chose an internship in a physics laboratory.

2 Fields of study

I'm somehow a technologies geek and was really interested by the courses about signal processing and electronics I had during my Engineer curriculum. So I was decided to focus on this topic.

At the beginning of my second year, I chose to study electronic of micro-controllers and of sensors. However a project I took part in discouraged me from studying this field.

I eventually enjoyed very much a lecture about information theory and decided to go into this topic in depth.

When I began this internship, I already was enrolled in a double degree with

TU Berlin for a Master Degree in Electrotechnics. However I was mainly interested in signal processing and information theory and wasn't really eager of electromagnetism. So I didn't choose any specific course in this topic in Berlin.

With Dr Andriulli's lectures, I got a new insight of this field and the mathematics involved seemed very interesting to me. I found back the interest for science that I had during my *Classe Préparatoire*. Recovering this thirst to learn was really pleasant.

I'm therefore going to change my courses choices in Berlin in order to add the *Felder und Wellen* (Fields and Waves) lecture, that is a very theoretical course on electromagnetism.

3 Research or Engineering?

During this 3-months internship, I spoke a lot with the PhD students, looked at their work and took part in some of their tasks. I realized that I found research too slow, although Dr Andriulli's group is very prolific and efficient. Since it's research, we only have a theoretical goal that we hope being reachable. It is sometimes very discouraging and it happened that I felt very useless because I was stuck on the implementation of a paper that I couldn't understand.

It's nevertheless a very interesting experience that I may repeat during a PhD. However, it would be to do engineering and not research (at least it's my opinion for now).

4 Intermediate conclusion

During this second year of Engineering School I radically changed my mind about what I was interested in. This internship gave me a more relevant insight of the work in an academic laboratory and revived my interest for hard sciences.

CONCLUSION

This internship introduced me to the research world in a very practical way. If it seems that the way the PhD students were working (as part of a team) is quite unusual in France, I nevertheless got a good insight of how things are done, of the fundings problematics and the quest for visibility sought by the researchers.

It also brought me to some questions about my interest for sciences and how close I saw it to my future work. The questions are not fully answered for now and I hope that my enrollment to a Master Degree will help me to find answers. I indeed regained a real interest for sciences that I had kind of lost, but the time of research seemed very slow to me and I think that it would really discourage me from this path.

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APPENDIX

A *MATLAB* driver for EGI's AMP server

A.1 amp_script.m

```
clc
clear all

ip = '127.0.0.1';

amp = AmpServerConnector(ip);

amp.openConnexion('tCommands');
amp.sendCommand(amp.cmd.PowerOn);
amp.sendCommand(amp.cmd.Start);

amp.openConnexion('tStream');

[data, header] = amp.listenToStream();

amp.send('tStream', amp.cmd.StopListeningToAmp);

% NumAsFloat32 = typecast( uint32( bin2dec( op ) ), 'single')
amp.closeConnexion('tStream');

amp.sendCommand(amp.cmd.Stop);
amp.sendCommand(amp.cmd.PowerOff);
amp.closeConnexion('tCommands');
```

A.2 AmpServerConnector.m

```
% AmpServerConnector do .....
% PROPERTIES
%    serverHost - IP or DNS Name of the server
%    portCommands = 9877
%    portNotifications = 9878
%    portStream = 9879
%    tCommands - TCPIP object listening the commands (port 9877)
%    tNotifications - TCPIP object listening the notification (port 9878)
%    tStream - TCPIP object listening the stream (port 9879)
%    cmd - (struct) contains the used Telnet commands
%
% METHODS
%    AmpSeverConnector - Class constructor
%    openConnexion(connexionName) - Opens the TCPIP object called
%       'connexionName'.
%    closeConnexion(connexionName) - Closes the TCPIP object called
%       'connexionName'.
%    send(connexionName, command) - Sends the command 'command' to the
%       TCPIP object called 'connexionName.
%    sendCommand(command) - Sends the command 'command' to the
%       TCPIP object tCommands.
%    chooseConnexion(connexionName) - Returns the TCPIP object called
%       'connexionName'.
%
classdef AmpServerConnector
    properties
        serverHost;
```

```
        portCommands = 9877;
        portNotifications = 9878;
        portStream = 9879;
        tCommands;
        tNotifications;
        tStream;
        cmd = struct( ...
            ... for tCommands ...
                'Start',                '(sendCommand cmd_Start 0 -1 -1)', ...
                'Stop',                 '(sendCommand cmd_Stop 0 -1 -1)', ...
                'PowerOn',              '(sendCommand cmd_SetPower 0 -1 1)', ...
                'PowerOff',             '(sendCommand cmd_SetPower 0 -1 0)', ...
            ... for tStream ...
                'ListenToAmp',          '(sendCommand cmd_ListenToAmp 0 -1 -1)', ...
                'StopListeningToAmp',   '(sendCommand cmd_StopListeningToAmp 0 -1 -1)' ...
        );
    end

    methods (Access = public)
        function obj = AmpServerConnector(serverHost)
        % AmpServerConnector    Class constructor
        % INPUT
        %   serverHost: (string) DNS Name or IP of the server
        % OUTPUT
        %   obj: the object
        %
            obj.serverHost = serverHost;
            obj.tCommands = tcpip(obj.serverHost, obj.portCommands);
            obj.tNotifications = tcpip(obj.serverHost, obj.portNotifications);
            obj.tStream = tcpip(obj.serverHost, obj.portStream);
        end

        function openConnexion(obj,connexionName)
        % AmpServerConnector.openConnexion     Opens a connexion
        % INPUT
        %   connexionName: (string) name of the connexion (tCommands,
        %   tNotifications or tStream)
        % OUTPUT
        %   none
        %
            connexion = obj.chooseConnexion(connexionName);
            if( strcmp(connexionName, 'tStream') )
                set(connexion,'InputBufferSize', 1000000);
                set(connexion,'OutputBufferSize', 1000000);
            end
        fopen(connexion);

        end

        function closeConnexion(obj, connexionName)
        % AmpServerConnector.closeConnexion     Closes a connexion
        % INPUT
        %   connexionName: (string) name of the connexion (tCommands,
        %       tNotifications or tStream)
        % OUTPUT
        %   none
        %
            connexion = obj.chooseConnexion(connexionName);
            fclose(connexion);
        end

        function send(obj, connexionName, command)
        % AmpServerConnector.send     Sends a command on a connexion called
        % 'connexionName'
        % INPUT
        %   connexionName: (string) name of the TCPIP object where to send
        %       the command
        %   command: (string) command to send
        % OUTPUT
        %   none
        %
```

```
            connexion = obj.chooseConnexion(connexionName);
            if( strcmp(connexion.status, 'open') )
                convertedCommand = double(command)';
                fprintf(connexion, convertedCommand);
                tmp = 0;
                while(connexion.BytesAvailable <= 0)
                    drawnow
                    tmp = tmp + 1;
                    if( tmp >= 40 )
                        display('AmpServer doesn''t answer');
                        break ;
                    end
                end
                if(connexion.BytesAvailable)
                    display(strcat(command, ' >> ', fscanf(connexion, '%s', ↩
                        connexion.BytesAvailable)));
                end
            else
                display('No Connexion')
            end
        end

        function sendCommand(obj, command)
        % AmpServerConnector.sendCommand     Sends a command on a connexion
        % INPUT
        %   command: (string) command to send
        % OUTPUT
        %   none
        %
            send(obj, 'tCommands', command);
        end

        function [data, header] = listenToStream(obj)
        % AmpServerConnector.send     Sends a command on a connexion
        % INPUT
        %   none
        % OUTPUT
        %   data: (uint32)
        %   header: (uint8)
        %
            connexion = obj.chooseConnexion('tStream');
            if( strcmp(connexion.status, 'open') )
                convertedCommand = double(obj.cmd.ListenToAmp)';
                fprintf(connexion, convertedCommand);
                tmp = 0;
                while(connexion.BytesAvailable<=0)
                    drawnow
                    tmp = tmp + 1;
                    if( tmp >= 4000 )
                        tmp
                        display('AmpServer doesn''t answer');
                        break ;
                    end
                end
                for i=1:5
                    header = fread(connexion, 32, 'uint8')
                    data = fread(connexion, 280, 'uint32')
                end
            else
                display('No Connexion')
            end
        end
    end

    methods (Access = private)
        function connexion = chooseConnexion(obj, connexionName)
        % AmpServerConnector.chooseConnexion    Returns the connexion called
        % connexionName
        % INPUT
        %   connexionName: (string) name of the connexion to choose
        % OUTPUT
        %   connexion: (TCPIP Object) the connexion called connexionName
        %
```

```
            switch connexionName
                case 'tCommands'
                    connexion = obj.tCommands;
                case 'tNotifications'
                    connexion = obj.tNotifications;
                case 'tStream'
                    connexion = obj.tStream;
            end
        end
    end

end
```

B Visualization review

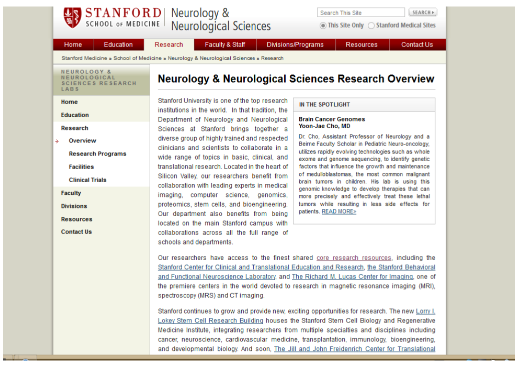
This section is the printing of the review on visualization tools I made. It's given here because it's relevant material for the future work of the group.

MO – How do others do ?

7 mai 2014

Neuroimaging ?

Picture are very rare on labs website… or quite old



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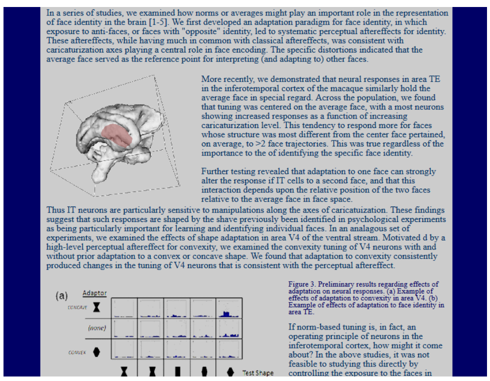
IN THE SPOTLIGHT

Brain Cancer Genomes
Yoon-Jae Cho, MD

Dr. Cho, Assistant Professor of Neurology and a Beirne Faculty Scholar in Pediatric Neuro-oncology, utilizes rapidly evolving technologies such as whole exome and genome sequencing, to identify genetic factors that influence the growth and maintenance of medulloblastomas, the most common malignant brain tumors in children. His lab is using this genomic knowledge to develop therapies that can more precisely and effectively treat these lethal tumors while resulting in less side effects for patients. READ MORE>

Our researchers have access to the finest shared core research resources, including the Stanford Center for Clinical and Translational Education and Research, the Stanford Behavioral and Functional Neuroscience Laboratory, and The Richard M. Lucas Center for Imaging, one of the premiere centers in the world devoted to research in magnetic resonance imaging (MRI), spectroscopy (MRS) and CT imaging.

Stanford continues to grow and provide new, exciting opportunities for research. The new Lorry I. Lokey Stem Cell Research Building houses the Stanford Stem Cell Biology and Regenerative Medicine Institute, integrating researchers from multiple specialties and disciplines including cancer, neuroscience, cardiovascular medicine, transplantation, immunology, bioengineering, and developmental biology. And soon, The Jill and John Freidenrich Center for Translational



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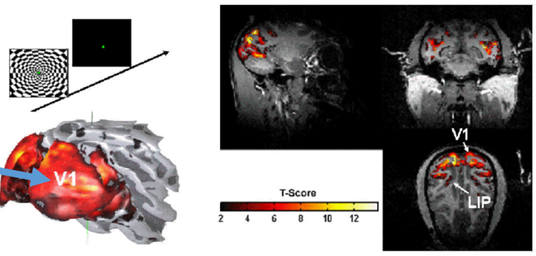

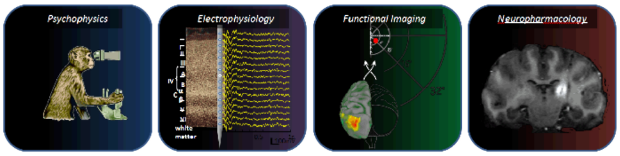

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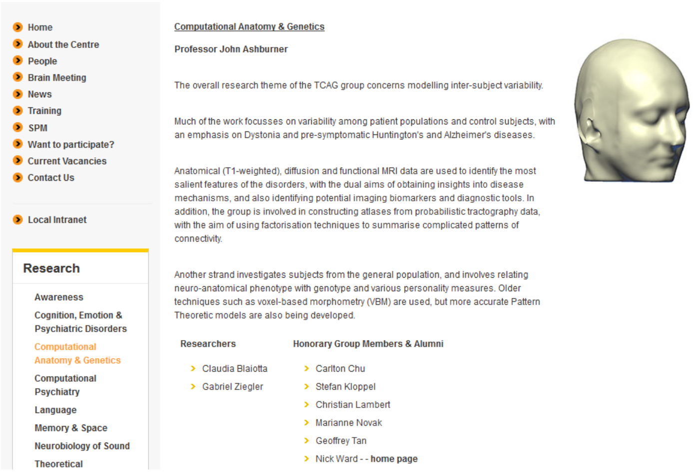

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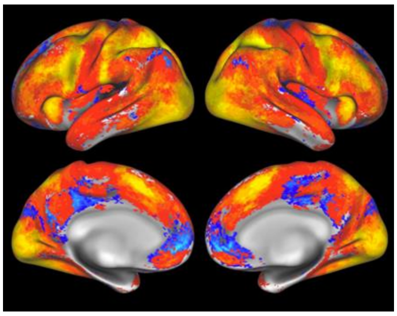

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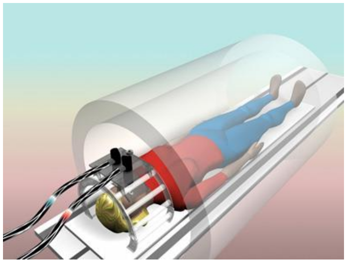

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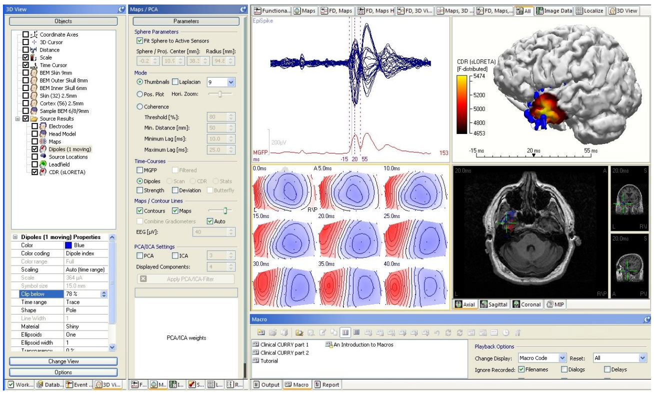

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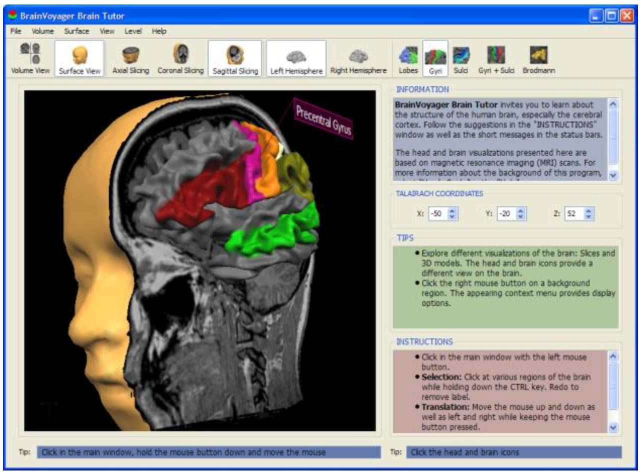

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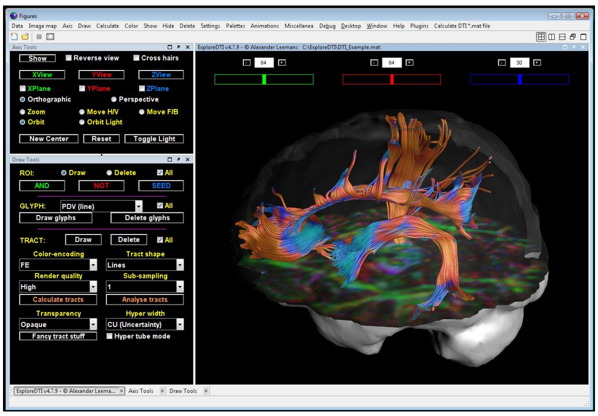

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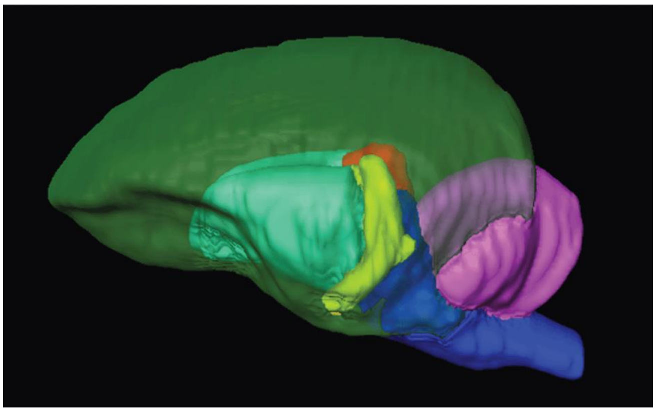

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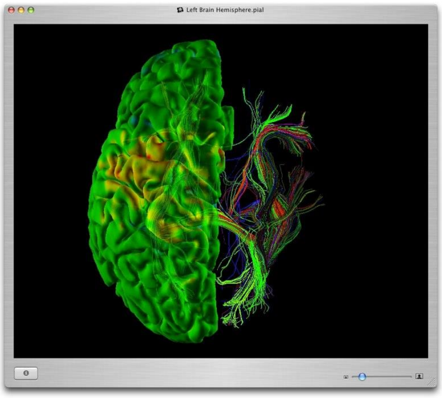

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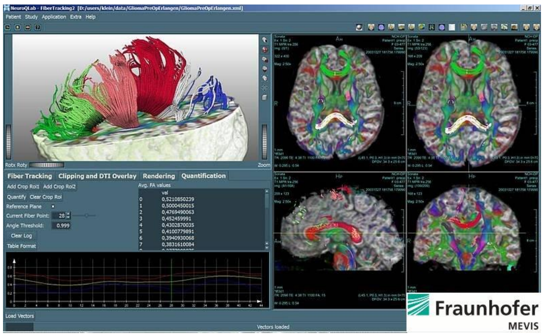

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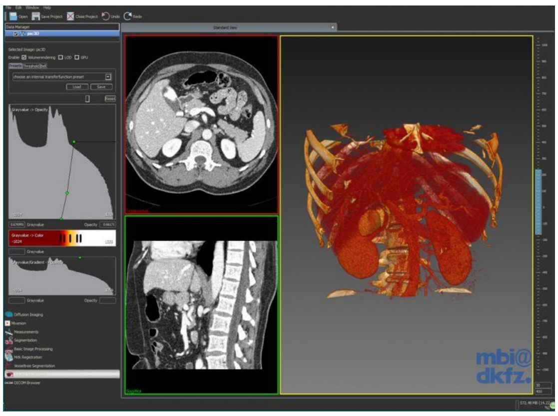

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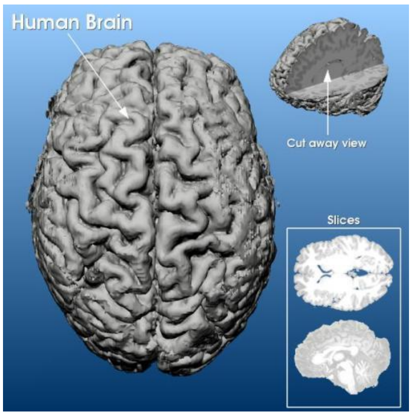
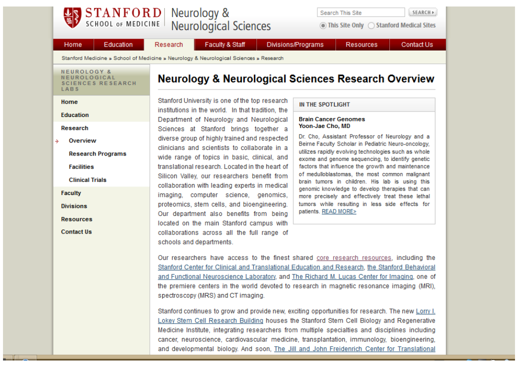


C EGI guide

This section is the printing of the lighter guide I wrote about EGI's *Net Station* suite.

Neuroimaging ?

Picture are very rare on labs website… or quite old



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Neurology & Neurological Sciences Research Overview

Stanford University is one of the top research institutions in the world. In that tradition, the Department of Neurology and Neurological Sciences at Stanford brings together a diverse group of highly trained and respected clinicians and scientists to collaborate in a wide range of topics in basic, clinical, and translational research. Located in the heart of Silicon Valley, our researchers benefit from collaboration with leading experts in medical imaging, computer science, genomics, proteomics, stem cells, and bioengineering. Our department also benefits from being located on the main Stanford campus with collaborations across all the full range of schools and departments.

IN THE SPOTLIGHT

Brain Cancer Genomes
Yoon-Jae Cho, MD

Dr. Cho, Assistant Professor of Neurology and a Beirne Faculty Scholar in Pediatric Neuro-oncology, utilizes rapidly evolving technologies such as whole exome and genome sequencing, to identify genetic factors that influence the growth and maintenance of medulloblastomas, the most common malignant brain tumors in children. His lab is using this genomic knowledge to develop therapies that can more precisely and effectively treat these lethal tumors while resulting in less side effects for patients. READ MORE>

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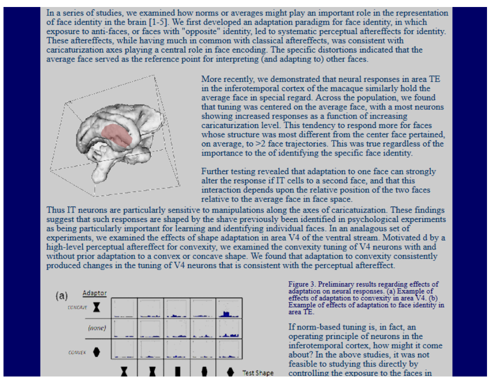

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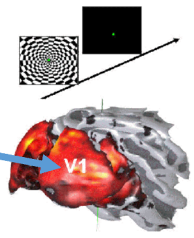

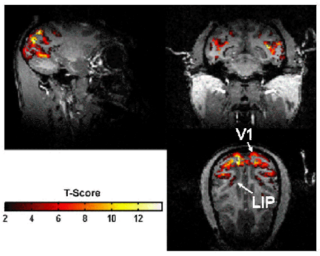

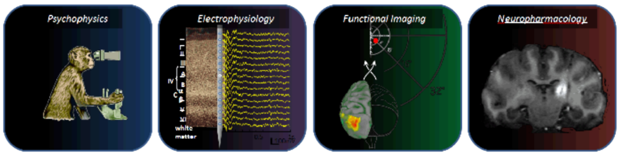

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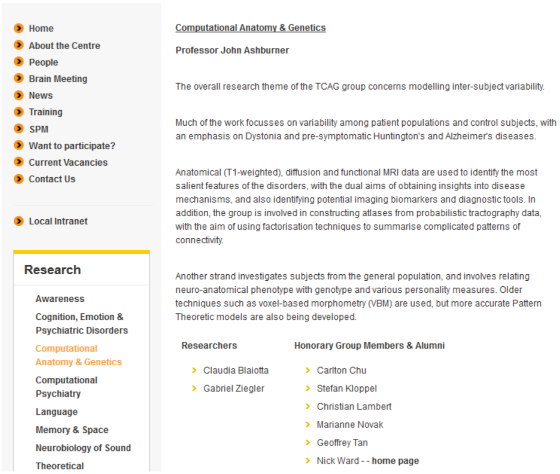

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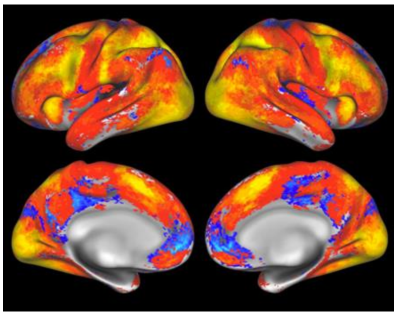

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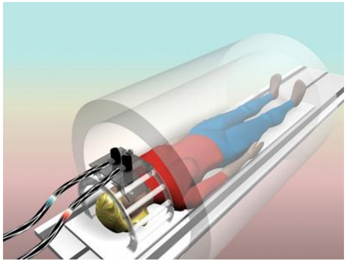

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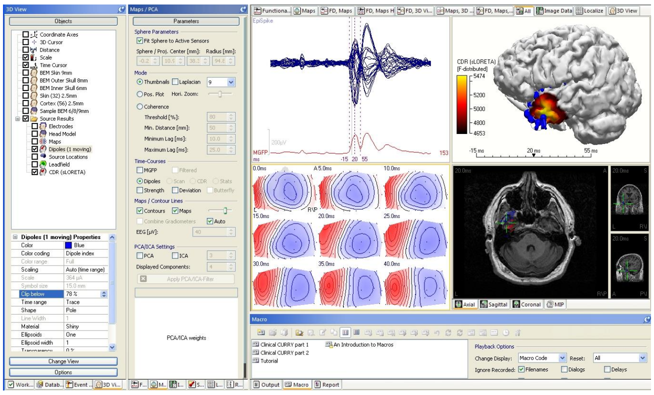

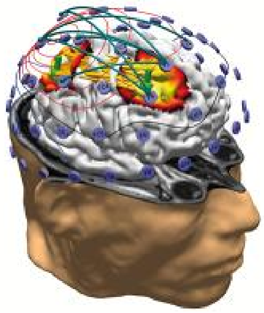

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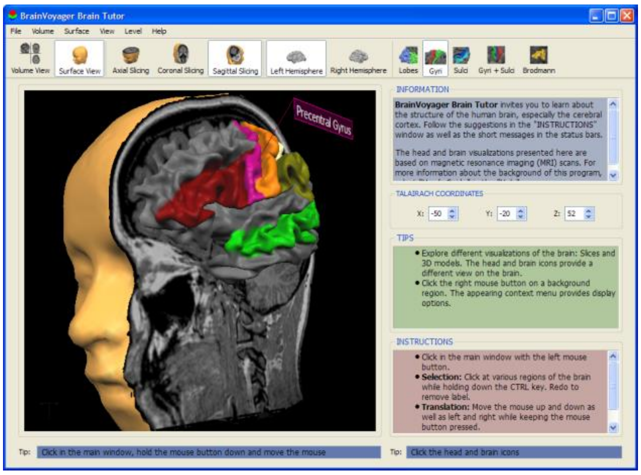

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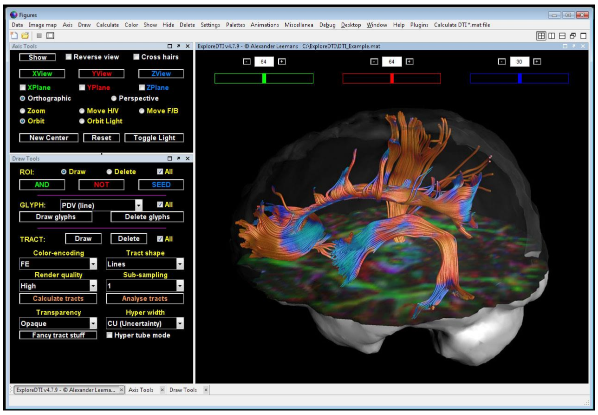

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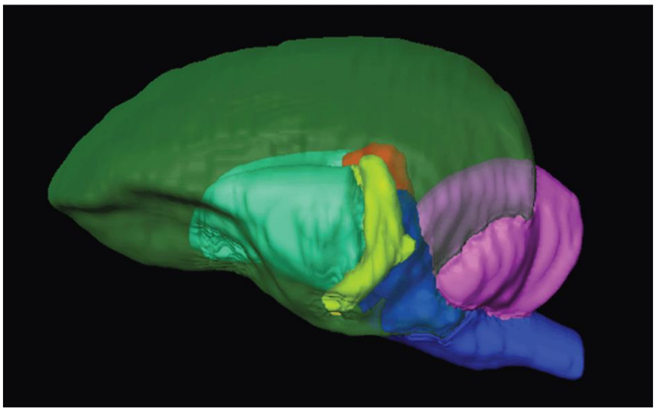

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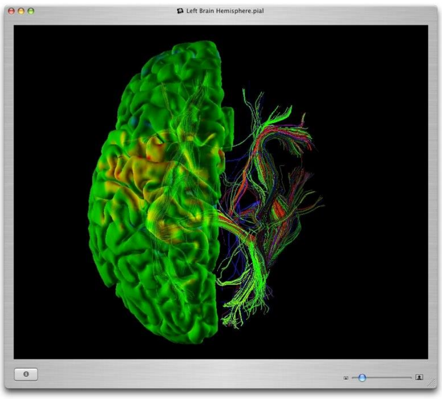

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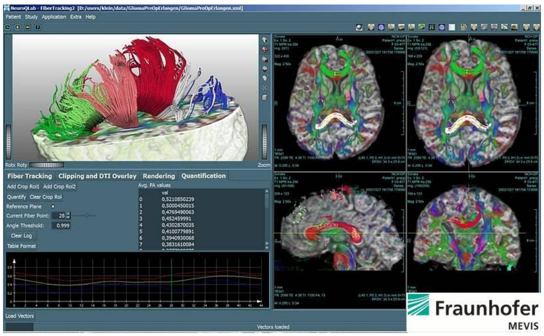

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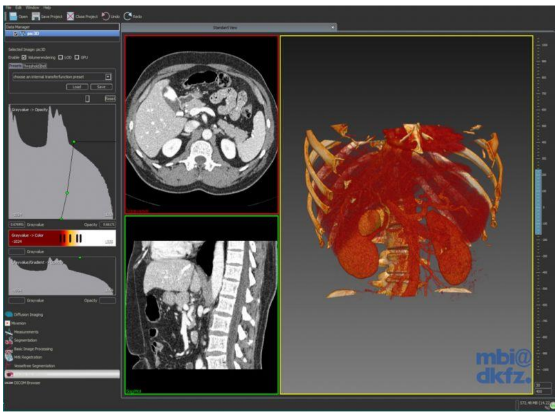

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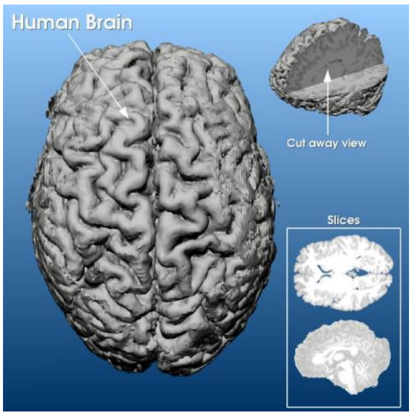


D *OpenVIBE* fast tutorial - R. Nicollet

This section is a light documentation of the *Motor Imagery CSP* scenario. It was written by Robin Nicollet who did his internship with me. He let me reproduce it there, so that my report be more comprehensive.

1- Copying openvibe default scenarios

The easiest way to create a working BCI chain is to use the existing motor imagery CSP scenarios located in the share/openvibe/scenarios/bci-examples folder. One should copy that folder somewhere else before doing any changes to the scenarios.

2- Understanding acquisition

The “Acquisition Client” box is the box connected to the OpenVibe acquisition server. This box receives the stream of data as configured in the Acquisition Server. The sampling rate is specified in the Acquisition Server. The only output of that box of interest to us is the signal, represented by a pink triangle.

The raw signal can be down sampled by adding a “Signal Decimation” box. Specifying a factor of 10 in that box will output 1 out of 10 samples (this process divides the sampling frequency by 10). That factor can only be an integer: you won’t be able to divide the original sampling frequency by 2.5 without using (very) complex tricks.

The acquired signal -eventually down sampled- goes through an Identity box. This box is used only to make the box layer cleaner by reducing the number of links that needs to be changed when one box is deleted / added.

The “Graz motor imagery BCI stimulator” box generates the stimulations. OpenVibe uses codes to represent events in the timeline. Codes represent events like “Start of Trial”, “Start of session”, “End of Trial”, “Left” (left cue displayed), “Beep” (emits a sound) etc… The parameters of this box are very important because the length of the session depends on them, as well as the quality of the user output. BCI users need at least 500ms to understand the cue (left or right) and then think of it. As a consequence, cues should be displayed at least 2.5 seconds, letting the user focus on a motor imagery for 2 whole seconds. We generally use 3.5 seconds so that a sampling rate of 100 will give us 300 samples to analyze. Also, the intervals given to the user to rest should be sufficient enough to let him keep his attention throughout the process. They should also be short enough to avoid too long sessions. People generally have a hard time staying concentrated more than 25 minutes, and the electrodes will also dry after some time, introducing artefacts towards the end of the session.

The Graz visualization box simply displays the cues (purple triangles, “stimulation” signal type).

Finally the “generic stream writer” box is used to save all the data we will need. This is simply the signal and the stimulations. As everything runs on a single core, this box might be slow if the recording happens at a too high frequency, generating non-constant time in OpenVibe and thus corrupting the data. With a 1000Hz output we experienced variable-length cues, whereas they should have had a constant length of 3.5s. The reason is that writing 256*1000 double values per second takes a lot of computing power and also the disk might not be ready to write as fast as the data comes. The signal decimator can be put between the identity box and this box to reduce the sampling frequency to 100Hz.

Is is very important to specify the ouput file in that last box and check after acquisition that the output file has been correctly written by openvibe. It might be smart to check during the first seconds of acquisition that the file has been created, to avoid 30-minutes sessions with no recording at the end.

3- Training the CSP (feature extraction)

The signal is read from the recorded file by the “Generic File Reader”. This box has no parameters except the file to read. It outputs the stimulations and the signal that are stored in the file.

Then the signal is filtered. Here we have no idea if the box is working completely, partially or not at all. The way this box works is unknown and we can’t know what filter order should be used. If it’s not working then the only solution would be to create a “Generic File Reader” that reads the signal and the stimulations and then two “csv file writer” to output the stimulations and the signal in two CSV files. Then filter the signal data with matlab and read it back with a CSV File reader. One issue here might be that the CSV file reader is unstable. The fix we did isn’t yet in the official version. An alternative way would be to use the matlab scripting box (not tested by us).

That filtered signal will then be split into chunks of samples taken while the subject was thinking of left or right movements. The rest of the data is ignored by the CSP. These “stimulation based epoching” boxes must be configured to accommodate the stimulations. The offset is the time after with samples will be considered, and the duration represents the number of samples indirectly. A formula for the duration is (cue display length – offset). The offset should be 0.5s. That’s the time it will take for the user to start thinking of the wanted movement.

The CSP box takes two inputs to discriminate, and the stimulations. The stimulations is used only to receive the event signalling the end of the training session. Then the two other inputs are the signals to discriminate. As an output, the CSP Spatial Filter will generate a file containing the filter configuration. That is basically a matrix that maximizes the difference between the first samples (Left) and the second ones (Right) when multiplying this matrix by the signals. Remember to specify the output file and check at the end that it has been written properly. The OpenVibe console will also display a message like “CSP Spatial Filter trained successfully” if the training worked.

The last box “Player Controller” is just used to stop the scenario when the training is finished.

4- Training the classifier

The beginning of this scenario is the same as the previous.
After the Identity box, the CSP Spatial Filter that has been trained is used to train the classifier only on relevant distinguishable data. Make sure that the CSP configuration is overwritten by carefully choosing the configuration file that you created during the former step.

Time based epoching here does the same as for the CSP training. It selects chunks of a certain length, depending on the stimulations.

Then the time based epoching creates overlapping (in time) signals of same length to aggregate the data. For example 1s length and 0.1 second offset will create 30 output signals (for 3second length signals). The offset between two of these signals will be 0.1s and each chunk will last 1s.

After that the DSP box is used. Simply put, this box applies a mathematical formula to the signal. Here it's used with formula x*x, with multiplies the signal by itself (get the power). Then the signal is averaged (no idea why nor how). Then it's put through a DSP 'log(1+x)' box. This is used to give a normal distribution to the signals, because that's one condition for the classifier to work best.

The classifier configuration box is pretty straightforward, just select the algorithm. LDA is supposed to work pretty well for this two-task BCI and is also very simple.

5- Testing online or offline.

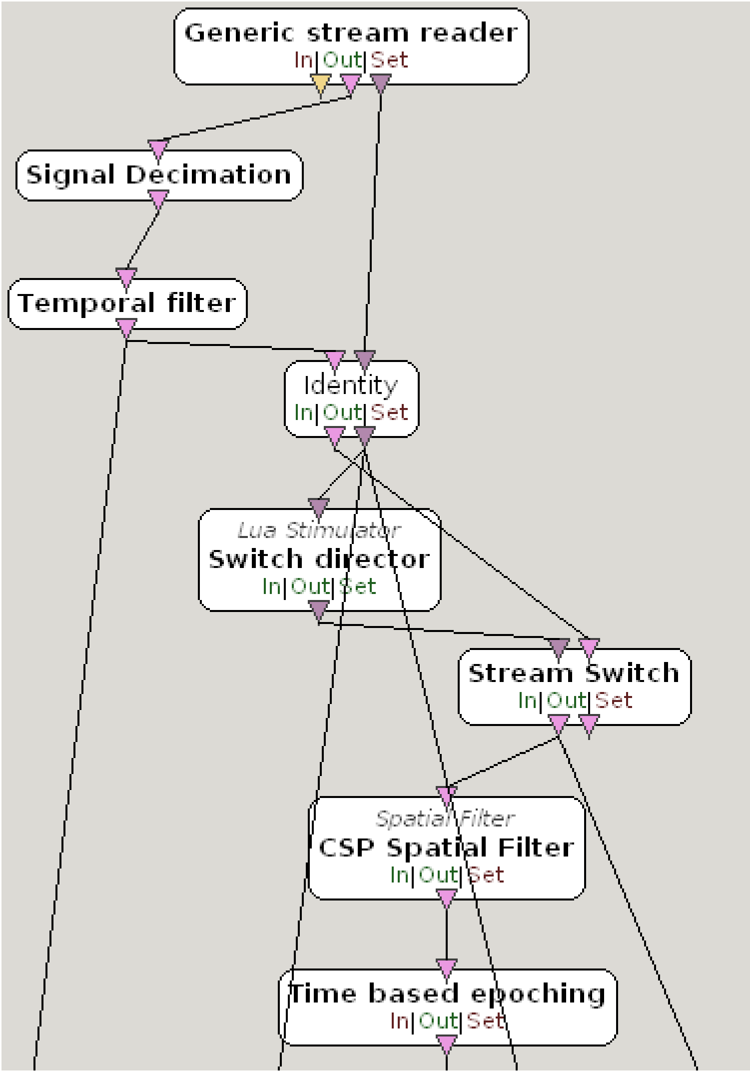
The two last scenarios are straightforward if the two previous are understood. They acquire the data either from a file or the server, filter it, feed it to the CSP, then generate feature vectors and ask the classifier what the final output is. The Offline scenario proposes a classification rate whereas the online mode gives no classification results without tweaking the scenario. One can use the offline mode copy, paste and link the necessary boxes to have a classification rate in the online mode.

6- Notes about boxes

The filter box doesn't work exactly as expected. Take a signal and test it through your filter to be sure it has the right spectrum on the output.
The CSV File reader doesn't work for the 'signal' type.

7- Modifying openvibe scenarios to make classification work

The concerned scenario is the replay scenario. Apparently it wouldn't be a good idea to make the same changes to the online scenario although this is still being discussed with Jussi T Lindgren (INRIA OpenVibe developer).
So the trick is to move the stream switch director and the stream switch to before the CSP Spatial Filter. It should look like this:



The signal decimation is optional of course but we rather use a sampling frequency of 100Hz to process data faster without almost any losses in information, when it has been recorded at 1kHz. The easiest solution is to record directly at 100Hz of course.

E Evaluation sheet

You'll find here the evaluation sheet filled by Dr Andriulli at the end of my internship. It is used by the school to give me a final mark.

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TRAINEESHIP APPRAISAL FORM

Please fill the form after report reading and send it to Elisabeth Moragues
elisabeth.moragues@ec-lyon.fr
during the next month

For intern use of Ecole centrale de Lyon only: **Application** □ **Césure**□

Student's Name / Surname: Olivier Churlaud

Name of Firm: **Telecom Bretagne**

Address, telephone, fax of the traineeship: **Technopole Brest Iroise, 29238 Brest Cedex 3**
Tel: 02 29 00 16 21

Traineeship supervisor, name & position held:

Francesco P. Andriulli, Associate Professor

Traineeship period (from, to): **from 05/05/2014 to 08/08/2014**

I - ENVIRONMENT OF THE TRAINEESHIP

Subject of the traineeship: **Computational and experimental activities in neuroimaging**

Equipment used by the student: **Equipments in an electroencephalography lab**

Specific responsibilities: **Code development and testing,**
validation activities in experimental facilities

II - STUDENT'S BEHAVIOUR DURING THE TRAINEESHIP

*Please give a note from **1** (minimum note) to 5 (maximum note)*

- Global behaviour 5
- Punctuality 5
- Adaptability 5
- Motivation 5
- Personal organisation 5
- Initiative, autonomy 5
- Sense of responsibility 5
- Human contact 5
- Quality of oral report and argumentation 5

III – APPRECIATION OF RESULTS

*Please give a note from **1** (minimum note) to 5 (maximum note)*

- Global quality of obtained results 5
- Results accuracy 5
- Scientific knowledge involved 5
- Awareness of realities and quality and production costs 5
- Results pertinence toward the enterprise 5

IV – QUALITY OF WRITTEN REPORT

*Please give a note from **1** (minimum note) to 5 (maximum note)*

- Global quality of the written report 5
- Quality of plan not applicable
- Presentation of the context and the aims of the mission 5
- Explanation of the reasoning 5
- Line of argument 5
- Quality of conclusion 5
- Written expression 4

V – OTHER COMMENTS ABOUT THE STUDENT

(particularly regarding how well (s)he meets the firm's needs and compared with other trainees in the firm)

This is an excellent students who performed very well in this internship.

Date: 13/08/2014

Signature of Supervisor
and Department Head
and stamp of the Firm

Francesco Andriulli

For direct contacts with Supervisor and Department Head,
give here your phone and fax numbers:

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