Application for the position of Assistant Professor at the Brown University Department of Neuroscience

Hubert Cecotti, PhD

2012

Contents

1 Cover letter

Dear Members of the search committee,

I am writing to apply for the position of Assistant Professor at Brown University. After several post-doctoral positions, I am extremely interested in obtaining a faculty position in a premier university to pursue an academic career in computational neuroscience.

I am currently a post-doctoral researcher at the University of California, Santa Barbara, in the department of Psychological and Brain Sciences. I am working on a project funded by the US Army about the detection of event-related potentials in the electroencephalogram to create neural interface systems for target detection and to measure attention in dual-task paradigms. In 2010, I was a post-doctoral researcher at Gipsa-lab, in Grenoble, France where I was working on the project RoBIK (Robust BCI Keyboard) funded by the French National Research Agency. In this project, my contributions were related to the selection of the best sensors for Brain-Computer Interface (BCI) based on the detection of the P300 (a brain response), to the improvement of the graphical user interface and the reliability of the P300 detection over time and across subjects. I also got some experience in teaching signal processing in an engineer school in Grenoble.

In 2008 and 2009, I have worked at the Institute of Automation, in Bremen, Germany on the European project Brainrobot. In this project about BCI, I have worked on the improvement of signal processing methods for EEG, for the detection of steady state visual evoked potential (SSVEP) responses. I took part in the development of Bremen-BCI, a speller based on the detection of SSVEP responses. This software was presented in the international fairs CeBit 2008 in Hanover, Germany and RehaCare 2008 in Düsseldorf, Germany. I have also completely developed my own self-paced BCI speller, which does not require calibration and provides efficient performance. I have proposed new strategies for the detection of different brain responses by using convolutional neural networks, by finding appropriate network topologies for the detection and the analysis of brain processes.

My initial background is computer science (pattern recognition, machine learning). I have finished my PhD thesis with distinction in December 2005. The title of my thesis was: Hybrid multi-classifiers system based on a neural and adaptive approach, application to deformed characters recognition. I have worked on several projects with applications on character recognition and more recently on BCIs. My work has been published in several international journals, conferences and workshops. During my thesis, I have used models such as convolutional neural networks, hidden Markov models, statistic models, multi-classifiers strategies, etc. I have implemented all the models I have used during my PhD thesis (C/C++) and during my postdocs (C/C++/Matlab). Furthermore, I was a lecturer in software engineering during two years when I was in France where I taught different topics in computer science.

During my post-doctoral experiences, I have succeeded to bring my knowledge from computer science in different types of research group: engineering, signal processing, cognitive psychology. Thus, I am used to work and collaborate with people from different backgrounds.

I am confident about the performance I could provide at Brown University for both teaching and researching new computational approaches to address issues of neural information processing. I have research experience in neural networks, machine learning, EEG signal processing and recording, brain-computer interfaces.

Thank you very much for your consideration.

Hubert Cecotti

2 Curiculum Vitae

2.1 Personal information

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2.2 Skills

2.2.1 Research interests

Pattern recognition - Machine learning - Brain-Computer Interface - Neural Networks - Image/Signal processing

2.2.2 Techniques

- Image processing
  * Features extraction
  * Binarization - segmentation
- Machine learning - pattern recognition
  * Neural networks
  * Self organizing maps
  * Hidden Markov models
  * Multi-classifiers systems
- Markov decisional processes - stochastic planning
- Offline handwritten character recognition models
- Brain-Computer Interface
  * EEG signal processing, signal recording, graphical user interface design
  * Steady State Visual Evoked Potentials
  * P300 Speller, Rapid Serial Visual Presentation tasks

2.2.3 Software engineering

- Operating systems: MS Windows, Unix, Linux.
- Languages: C/C++, CAML, Java, Fortran, Pascal, Visual Basic, Matlab.
- Programming environments: Borland Builder, Mega, Visual Studio, Websphere Studio.
- Analysis methods: B method, Merise, TLA, UML.
- Database: Cobol, Oracle, SQL, XML.
- Office: LaTeX, MS Office, OpenOffice.
- Internet: HTML, Javascript, JSP.

2.2.4 Languages

French: native - English: fluent - German: intermediate

2.3 Education

- **2006** Qualified for applying in the associate professor positions in French universities in section 27 (Computer science) and 61 (Signal processing).
- **2005** Ph.D. thesis in Computer Science from the University Nancy 2, France. With distinction.
  Title: Hybrid multi-classifiers system based on a neural and adaptive approach - application to deformed characters recognition. Defended on December 7, 2005 at Vandœuvre-lès-Nancy.
  President of the jury: Hazel Everett, Professor at the University Nancy 2.
  Reviewers and members of the jury: Laurent Heutte, Professor at the University of Rouen, Maurice Milgram, Professor at the University Paris 6.
  Member of the jury: Christian Viard-Gaudin, Associate Professor at the University of Nantes.
  Ph.D. advisor: Abdel Belaïd, Professor at the University Nancy 2.
- **2002** DEA d'Informatique Intelligence Logicielle (Master in Computer Science specialized in intelligent software) - University Henri Poincaré, Nancy 1, France.
- **2001** Maîtrise d'Informatique - University of Metz, France.
- **2000** Licence d'Informatique (Bachelor in Computer Science) - University of Metz, France.
- **1999** DEUG MIAS (Mathematics and Computer Science) - University of Metz, France.
- **1997** Baccalauréat S (A-levels specialized in mathematical) Julie Daubié High School, Rombas, France.

2.4 Employments

- Since **01/01/2011** Post-doctoral researcher at the Department of Psychology and Institute for Collaborative Biotechnologies, University of California Santa Barbara. The research is supported by the Institute for Collaborative Biotechnologies through contract W911NF-09-D-0001 from the US Army Research Office.
- **01/01/2010 - 31/12/2010** Post-doctoral researcher at Gipsa-lab - CNRS, Saint-Martin d'Heres, France. Research and development of new methods for sensor selection and improved classifier for P300 detection in the French National Research Agency project RoBIK (Robust BCI Keyboard). The research was supported by the French National Research Agency (ANR) through TecSan program (project RoBIK ANR-09-TECS-013).
- **01/02/2008 - 30/04/2009** Post-doctoral researcher at the Institute of Automation, University of Bremen, Germany. Research and development of new techniques for the classification and detection of brain signals acquired via EEG, development of Steady-State Visual Evoked Potentials Brain-Computer Interfaces. The research was supported by a Marie Curie European Transfer of Knowledge grant BrainRobot, MTKD-CT-2004-014211, within the 6th European Community Framework Program.
- **01/09/2006 - 31/08/2007** Lecturer at the ESIAL[1], Nancy, France.
- **01/09/2005 - 31/08/2006** Lecturer at the UHP[2], Nancy, France.

[1] ESIAL: École Supérieure d'Informatique et Applications de Lorraine (Computer engineer school)
[2] UHP: University Henri Poincaré, Nancy 1

- **01/01/2004 - 31/08/2005** Ph.D. student in the READ team at the LORIA[3] (University Nancy 2) Development of an OCR combination framework for the PAPLOO project, in the French national software network of research and innovation. This project has been a collaboration between the Ever-Team Company and the LIIA laboratory from the INSA in Strasbourg, France. The project was aimed toward the recognition and the restructuring of different documents. The research was supported by the RNTL (French national network of software technologies) project PAPLOO.

- **01/12/2002 - 31/12/2003** Ph.D. student in the READ team at the LORIA - Development of intelligent character recognition software for multi-oriented and multi-scaled characters extracted from technical maps. This project was conducted in the READ team of the LORIA laboratory, Nancy, France. The research was supported by a contract with EDF, the French national electricity company.

2.5 Internships

- **2002**: Master's training course - **5 months**.
  Development of a software for path planning [C++ - Linux]. I have experimented stochastic and analytic methods for paths planning using Markov Decisional Processes for mobile robot-cars. This course took place in the MAIA team in the LORIA laboratory.

- **2001**: Master's training course - **3 months**.
  Software development and software update for computing flame temperature and load loss. The software was developed with Visual Basic using old programs initially developed in Fortran. In this project, I analyzed and corrected Fortran programs to transfer them in a Visual Basic interface. This course took place in the Energy group of Mittal Steel Company in Florange, France.

[3]LORIA: Laboratory of IT Research and its Applications

3 Publications

Impact

Papers: 48	Cites/paper: 3.15	h-index: 8	AWCR: 40.75
Citations: 151	Cites/author: 69.59	g-index: 11	AW-index: 6.38
Years: 9	Papers/author: 22.73 hc-index: 8	AWCRpA: 19.01	
Cites/year: 16.78	Authors/paper: 2.75	hI-index: 2.67	e-index: 6.08
		hI,norm: 4	hm-index: 5.25

Table 1: source: Harzing, A.W. (2007) Publish or Perish. http://www.harzing.com/pop.htm

International journals (peer reviewed)

1 B. Rivet, H. Cecotti, E. Maby, J. Mattout, Impact of spatial filters during sensor selection in a visual P300 Brain-Computer Interface, Brain Topography, Vol. 25, No. 1, pp 55-63, 2012.

2 B. Rivet, H. Cecotti, M. Perrin, E. Maby, J. Mattout, Adaptive training session for a P300 speller brain-computer interface, Journal of Physiology-Paris, Vol. 105, No. 1-3, pp 123-129, 2011.

3 H. Cecotti, Spelling with Non-Invasive Brain-Computer Interfaces - Current and future trends, Journal of Physiology-Paris, Vol. 105, No. 1-3, pp. 106-114, 2011.

4 H. Cecotti, A Time-Frequency Convolutional Neural Network for the Offline Classification of Steady-State Visual Evoked Potential Responses, Pattern Recognition Letters, vol. 32, no. 8, p. 1145-1153, 2011.

5 H. Cecotti and B. Rivet, A pilot study for improving the graphical user interface of P300 based BCIs, International Journal of Bioelectromagnetism, 2p, 2011. (short paper)

6 H. Cecotti and B. Rivet, A solution to solve the dilemma of high frequencies and LCD screen for SSVEP responses, International Journal of Bioelectromagnetism, 2p, 2011. (short paper)

7 H. Cecotti and B. Rivet, One step beyond row and columns flashes in the P300 speller: a theoretical description, International Journal of Bioelectromagnetism, 2p, 2011. (short paper)

8 H. Cecotti, B. Rivet, M. Congedo, C. Jutten, O. Bertrand, E. Maby, J. Mattout, A robust sensor selection method for P300 Brain-Computer Interfaces, Journal of Neural Engineering, vol. 8, 2011.

9 H. Cecotti and A. Gräser, Convolutional neural networks for P300 Detection with Application to Brain-Computer Interfaces, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 33, no. 3, p. 433-445, 2011.

10 H. Cecotti, B. Rivet, M. Congedo, C. Jutten, O. Bertrand, E. Maby, J. Mattout, Sélection de capteurs pour interfaces cerveau-ordinateur de type P300, Traitement du Signal, Vol. 27, No. 6, pp 515-540, 2010. (French journal)

11 H. Cecotti, A self-paced and calibration-less SSVEP based Brain-Computer Interface speller, IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 18, no. 2, pp. 127-133, 2010.

Book chapters

12 H. Cecotti, SSVEP Detection with Neural Networks, BrainRobot: Methods and Applications for Brain-Computer Interfaces, Axel Gräser (Ed.), Shaker Verlag, ISBN-978-3-8322-8201-1, pp. 69-87, 2010.

13 H. Cecotti, P300 Detection with Neural Networks, BrainRobot: Methods and Applications for Brain-Computer Interfaces, Axel Gräser (Ed.), Shaker Verlag, ISBN-978-3-8322-8201-1, pp. 89-100, 2010.

14 H. Cecotti and I. Volosyak, Reliable Stimuli on LCD Screen, BrainRobot: Methods and Applications for Brain-Computer Interfaces, Axel Gräser (Ed.), ISBN-978-3-8322-8201-1, Shaker Verlag, pp. 147-157, 2010.

15 I. Volosyak, H. Cecotti and D. Valbuena, RehaCare 2008, BrainRobot: Methods and Applications for Brain-Computer Interfaces, Axel Gräser (Ed.), ISBN-978-3-8322-8201-1, Shaker Verlag, pp. 215-229, 2010.

16 A. Belaïd et H. Cecotti, La numérisation de documents : Principe et évaluation des performances, Traité IC2, Hermès Science Publications, ISBN-2746211432, pp 311-361, 2006.

International conferences and workshops (peer reviewed)

17 H. Cecotti, R. Kasper, J.C. Elliott, M.P. Eckstein, B. Giesbrecht, Multimodal target detection using single trial evoked EEG responses in single and dual-tasks, 33nd International IEEE Conference of the Engineering in Medicine and Biology Society, 4p, 2011.

18 H. Cecotti, J. Sato-Reinhold, J.L. Sy, J.C. Elliott, M.P. Eckstein, B. Giesbrecht, Impact of target probability on single-trial EEG target detection in a difficult Rapid Serial Visual Presentation paradigm task, 33nd International IEEE Conference of the Engineering in Medicine and Biology Society, 4p, 2011.

19 B. Rivet, H. Cecotti, A. Souloumiac, E. Maby, J. Mattout, Theoretical Analysis of xDAWN Algorithm: Application to an Efficient Sensor Selection in a P300 BCI, European Signal Processing Conference (EUSIPCO), 5p, 2011.

20 H. Cecotti, B. Rivet, Effect of the Visual Signal Structure on Steady-State Visual Evoked Potentials Detection, International Conference on Acoustics, Speech, and Signal Processing (ICASSP), p. 657-660, 2011.

21 H. Cecotti, Classification of Steady-State Visual Evoked Potentials based on the Visual Stimuli Duty Cycle, 3rd International Symposium on Applied Sciences in Biomedical and Communication Technologies, 2010, 5p.

22 H. Cecotti, R. Phlypo, B. Rivet, M. Congedo, E. Maby, J. Mattout, Impact of the time segment analysis for P300 detection with spatial filtering, 3rd International Symposium on Applied Sciences in Biomedical and Communication Technologies, 2010, 5p.

23 B. Rivet, H. Cecotti, R. Phlypo, O. Bertrand, E. Maby, J. Mattout, EEG sensor selection by sparse spatial filtering in P300 speller brain-computer interface, 32nd International IEEE Conference of the Engineering in Medicine and Biology Society, 4p, 2010.

24 H. Cecotti, B. Rivet, M. Congedo, C. Jutten, O. Bertrand, E. Maby, J. Mattout, Suboptimal Sensor Subset Evaluation in a P300 Brain-Computer Interface, European Signal Processing Conference (EUSIPCO), 5p, 2010.

25 H. Cecotti, I. Volosyak and A. Gräser, Reliable visual stimuli on LCD screens for SSVEP based BCI, European Signal Processing Conference (EUSIPCO), 5p, 2010.

26 I. Volosyak, H. Cecotti, A. Gräser, Steady-state visual evoked potential response - Impact of the time segment length, 7th IASTED International Conference on Biomedical Engineering, 5p, Austria, 2010.

27 I. Volosyak, H. Cecotti, D. Valbuena and A. Gräser, Evaluation of the Bremen SSVEP based BCI in real world conditions, 11th International IEEE Conference on Rehabilitation Robotics, pp. 322-331, 2009.

28 I. Volosyak, H. Cecotti, A. Gräser, Impact of Frequency Selection on LCD screens for SSVEP based Brain-Computer Interfaces, 10th International Work-Conference on Artificial Neural Networks, LNCS 5517, pp. 706-713, 2009.

29 H. Cecotti, I. Volosyak, A. Gräser, Evaluation of an SSVEP based Brain-Computer Interface on the command and application levels, 4th International IEEE/EMBS Conference on Neural Engineering, Antalya, Turkey, pp. 474-477, 2009.

30 I. Volosyak, H. Cecotti, A. Gräser, Optimal visual stimuli on LCD screens for SSVEP based Brain-Computer Interfaces, 4th International IEEE/EMBS Conference on Neural Engineering, Antalya, Turkey, pp. 447-450, 2009.

31 H. Cecotti and A. Gräser, Neural network pruning for feature selection - Application to a P300 Brain-Computer Interface, European Symposium on Artificial Neural Networks, Belgium, pp. 473-478, 2009.

32 H. Cecotti and A. Gräser, Convolutional Neural Network with embedded Fourier Transform for EEG classification, 19th International Conference on Pattern Recognition, Tampa, USA, 4p, 2008.

33 H. Cecotti and A. Belaïd, Dynamic filters selection for textual document images denoising, 19th International Conference on Pattern Recognition, Tampa, 4p, USA, 2008.

34 H. Cecotti and A. Gräser, Time Delay Neural Network with Fourier Transform for Multiple Channel Detection of Steady-State Visual Evoked Potential for Brain-Computer Interfaces, European Signal Processing Conference, Lausanne, Switzerland, 5p, 2008.

35 B. Allison, I. Volosyak, T. Lueth, D. Valbuena, I. Sugiarto, M.A. Spiegel, A. Teymourian, I.S. Condro, A. Brindusescu, K. Stenzel, H. Cecotti, A. Gräser, BCI Demographics I: How many (and what kinds of) people can use an SSVEP BCI?, 4th International Brain-Computer Interface Workshop, Graz, Austria, pp. 333-338, 2008.

36 H. Cecotti and A. Belaïd, Hierarchical Behavior Knowledge Space, LNCS 4472, ISBN-3540724818, 7th International Workshop on Multiple Classifier Systems, Prague, Czech Republic, pp. 421-430, 2007.

37 S. Vajda, H. Cecotti, Y. Rangoni and A. Belaïd, A fast learning strategy using pattern selection for feedforward neural networks, 10th International Workshop on Frontiers in Handwriting Recognition, La Baule, France, 6p, 2006.

38 H. Cecotti and A. Belaïd, Hybrid OCR combination approach complemented by a specialized ICR applied on ancient documents, IEEE 8th International Conference on Document Analysis and Recognition, Seoul, Korea, pp. 1045-1049, 2005.

39 H. Cecotti and A. Belaïd, Rejection strategy for Convolutional Neural Network by Adaptive Topology Applied to Handwritten Digits Recognition, IEEE 8th International Conference on Document Analysis and Recognition, Seoul, Korea, pp. 765-769, 2005.

40 H. Cecotti, S. Vajda and A. Belaïd, HMM based Viterbi paths for rejection correction in a convolutional neural network classifier, Proc. of Neural Networks and Learning in Document Analysis and Recognition, Seoul, Korea, pp. 23-27, 2005.

41 H. Cecotti, S. Vajda and A. Belaïd, High performance classifiers combination for handwritten digit recognition, LNCS 3686, ISBN-3540287574, 3rd International Conference on Advances in Pattern Recognition, Bath, UK, pp. 619-626, 2005.

42 H. Cecotti and A. Belaïd, Hybrid OCR combination for ancient document, LNCS 3686, ISBN-3540287574, 3rd International Conference on Advances in Pattern Recognition, Bath, UK, pp. 646-653, 2005.

43 H. Cecotti and A. Belaïd, A New Rejection Strategy for Convolutional Neural Network by Adaptive Topology, Advances in Intelligent and Soft Computing, Springer, ISBN-3540250549, 4th International Conference on Computer Recognition Systems, pp. 129-136, 2005.

44 A. Belaïd, A. Alusse, Y. Rangoni, H. Cecotti, F. Farah, N. Gagean, D. Fiala, F. Rousselot, H. Vigne, Document Retro-conversion for Personalized Electronic Reedition, International Workshop on Document Analysis, Kolkata, India, pp. 193-218, 2005.

45 H. Cecotti and A. Belaïd, Topologies Adaptatives dans un système NN/SOM, IEEE 3rd International Conference: Sciences of Electronic, Technologies of Information and Telecommunications, Sousse, Tunisie, 2005.

46 H. Cecotti, C. Choisy et A. Belaïd, Réseau de Neurones à Topologie Dynamique, Comparaison avec des invariants pour la reconnaissance de caractères multi-orientés multi-échelles. Colloque International Francophone sur l'écrit et le document, La Rochelle, France, pp. 279-284, 2004.

47 C. Choisy, H. Cecotti and A. Belaïd. Character rotation absorption using a dynamic neural network topology: comparison with invariant features, International Workshop on Pattern Recognition in Information Systems, Porto, Portugal, PRIS 04, pp. 90-97, 2004.

National conferences

48 H. Cecotti, Effect of the Stimulus Duty Cycle on Steady-State Visual Evoked Potential detection, 5th French Conference on Computational Neuroscience, pp. 205-209, 2010.

49 H. Cecotti, Spelling with Brain-Computer Interface - Current trends and prospects, 5th French Conference on Computational Neuroscience, pp. 215-220, 2010.

50 H. Cecotti, G. Saint-Ellier, B. Rivet, M. Perrin, E. Maby, J. Mattout, Reducing Calibration Time for the P300 Brain-Computer Interface Speller, 5th French Conference on Computational Neuroscience, pp. 210-214, 2010.

Abstracts and posters

51 B. Giesbrecht, M.P. Eckstein, H. Cecotti, L. Gibson, J. Touryan, A. Ries, Adaptive Integration and Optimization of Automated and Neural Processing Systems, 2012 ICB Army-Industry Collaboration Conference.

52 H. Cecotti, J. Sato-Reinhold, J.L. Sy, M.P. Eckstein, B. Giesbrecht, Using single trial EEG to detect visual targets with unkown stimulus onsets, Society of Neuroscience 2011.

53 R.W. Kasper, H. Cecotti, M.P. Eckstein, B. Giesbrecht, Electrophysiological consequences of multimodal continuous dual task performance, Society of Neuroscience 2011.

54 H. Cecotti, An Artificial Neural network for SSVEP detection - Application to Brain-Computer Interfaces, 30th Colloquium of Automation in Salzhausen, Germany, 2008.

Preprints

55 H. Cecotti, A Convolutional Neural Network using the Radon and Fourier Transform for multi-oriented character recognition, 2010.

56 H. Cecotti, J. Sato-Reinhold, J.L. Sy, J.C. Elliott, M.P. Eckstein, B. Giesbrecht, Target probability effects on Single-trial evoked related potential detection and behavioral performance in a difficult target detection task, 10p.

57 H. Cecotti, R. Kasper, J.C. Elliott, M.P. Eckstein, B. Giesbrecht, Single trial detection of event-related potentials in single and dual-task conditions during a rapid serial auditory and visual presentation paradigm, 29p, 2011.

58 H. Cecotti, M.P. Eckstein, B. Giesbrecht, Single-trial detection of event-related potentials with unknown stimulus onsets, 23p, 2011.

59 H. Cecotti, M.P. Eckstein, B. Giesbrecht, Supervised spatial filtering techniques for EEG single-trial detection in a rapid serial visual presentation paradigm task, 10p, 2011.

60 H. Cecotti, B. Rivet, Toward Enhancing the User-Friendly Aspect of a P300-based Brain-Computer Interface, 7p, 2011.

4 Teaching and supervising activities

4.1 Teaching experience

Most of my teaching experience is related to my two years of being a lecturer in computer science at the University Henri Poincaré, Nancy, France as well at an engineer school in computer science in Nancy, France (ESIAL). I also have some teaching experience at Phelma, an engineer school in Grenoble, France, where I gave classes in signal processing.

4.2 Classes

Computer science - office

Public: Bachelor degree in science (1st year) (2nd semester - 2007)
Number of hours: 48h
Content: Introduction to operating systems (Linux, Windows) - Office (Word, Excel, Powerpoint), HTML, etc.
The goal was to formally introduce to students different office tools to write reports and do presentations. Although most of the students know about Office, they lack the rigor and the curiosity to use adaptive functions in relation to their precise needs in order to work efficiently. Responsibilities: Two sections; after each class, the work was evaluated.

Animation 2D and interactivity

Public: Bachelor degree in Math-CS (1st year) (2nd semester - 2006 and 2007)
Number of hours: 100h
Content: Introduction to image processing and image coding - HTML - CSS - Javascript.
The goal of this class was to introduce image processing to students and how to create webpages with css stylesheets and Javascript. Responsibilities: Three sections in 2006, two sections in 2007.

Functional programming - CAML

Public: Bachelor degree in Math-CS (1st year) (2nd semester - 2006)
Number of hours: 40h (TP)
Content: Functional programming, recursivity, programming language CAML.
The goal of this class was to introduce the functional programming with the CAML language. Students were required to use functional programming instead of imperative programming. Responsibilities: Two sections. After each class, the exercises of the students were evaluated. I participated in the redaction of new exercises. It was interesting to teach functional programming to students who are not familiar with other programming approaches. Functional programming allows for explaining recursivity and data structures.

Database

Public: Bachelor degree in science (2nd year) (2nd semester - 2007)
Number of hours: 20h
Content: database - relational model - requests and relational algebra - SQL
The goal of this class was to teach database, SQL requests, and triggers. Responsibilities: One section.

Data structures

Public: Master 1 CS (1st semester - 2005)
Number of hours: 15h
Content: data structures (skip-list, different types of trees) - Implementation of data structure - Complexity - Benchmarks.
The goal of this class was to introduce the problem of complexity, computation time, different data structure, and different functions (access, suppression, search, etc.) Responsibilities: One section.

Algorithms and distributed computing

Public: Master CS (1st year) (2nd semester - 2007)
Number of hours: 30h
Content: Petri nets - TLA - distributed computing for networks - graph
The goal of this class was to present distributed computing methods and their applications in networks. Responsibilities: One section.

C and Shell UNIX

Public: ESIAL 1st year (2nd semester - 2007)
Number of hours: 20h
Content: Language C (introduction, makefile, files, variables, memory) - UNIX - Script C-SHELL
The goal was to give a strong base to engineering students in C. Responsibilities: One section.

Database and information systems

Public: Engineer school ESIAL (2nd year) (2nd semester - 2007)
Number of hours: 50h
Content: database - SQL - optimization of requests - project management - UML - Java - JSP - Servlet
In this class, the goal was to simulate a big project where each student had a special role. The goal of the project was to realize a website for managing the different internships of the students and to keep the history of the relationships between companies, students, and lecturers. Responsibilities: Four sections.

Interoperability of applications

Public: Engineer school ESIAL (3rd year) (2nd semester - 2007)
Number of hours: 20h
Content: database - Enterprise Resource Planning (ERP) - Manufacturing execution system (MES) - UML - Use of Mega - Visual Basic graphical user interface.
In this class, the goal was to create a link between an MES (FlexNet) and an ERP (Adonix) by using a data communication standard B2MML. A main challenge was first to understand the different entities in the MES and the ERP. Responsibilities: One section.

Machine learning

Public: Master - System engineering at the University of Bremen, Germany (2nd semester - 2008)
Number of hours: 8h
Content: Introduction to machine learning and to supervised neural networks (multi-layer perceptron), to hidden Markov models (Viterbi, Baum-Welsch, etc) Responsibilities: One section.

Signal processing

Public: Engineer school Phelma (1st and 2nd year) (2nd semester - 2010)
Number of hours: 40h
Content: signal processing, FFT, matlab, blind source separation, image processing, speech processing. Responsibilities: One section. Each project was evaluated.

4.3 Supervising

- **2010** - Co-supervising of an engineering student during his master thesis.
- **2010** - Co-supervising of American students in a training course for EEG signal acquisition.
- **2008** - Guidance of PhD students (Thorsten Lüth, Diana Valbuena, Aavo Moltsar) at the IAT, University of Bremen. (Guidance in signal processing, pattern recognition).
- **2007** - Supervising of two students in the engineer school ESIAL during their second year for their project of initiation to research. The subject of their project was to analyze different methods for the normalization of Arabic handwritten words and to analyze image features in a database of Arabic words.
- **2005** - Supervising of a student (equivalent bachelor degree) during his graduation project. He had to continue the development of a graphical user interface to combine the results of different commercial OCR. He had to improve the way ground truth documents are presented in the interface. The goal was to improve the interface to include more OCR in order to combine them.
- **2004** - Supervising of a student preparing for a master's degree in cognitive science during his graduation project. The goal of the project was to program some image processing functions that could be used in a convolutional neural network.
- **2003** - Co-supervising of a student in the engineer school ESIAL during his first year during his internship. He had to develop a hidden Markov model with a circular topology that would automatically shift some data.
- **2003** - Supervising of a group of students preparing for a master's degree in computer science during their initiation to research. They had to program a feed forward neural network and test it on the recognition of handwritten digits.

5 Research activities

5.1 PhD thesis abstract

My thesis is about a hybrid multi-classifiers system based on an adaptive and neural approach. The creation of the topology in a multi-classifier system depends of the features of each used classifier. The purpose of the system is to exploit in the best way the different strengths of each classifier for improving the global recognition rate and the system reliability. I have tested several combination rules such as voting methods, statistics, and neural techniques. This kind of system needs a good behavior analysis for every classifier and all their possible errors. To improve and complete the classifiers fusion, I have used a convolutional neural network with an adaptive topology. Several geometrical transformations have been integrated inside the network with a judicious topology adjustment. This solution has been compared with classifiers using invariant features sets using the Fourier or Fourier-Mellin descriptors in the case of multi-oriented and multi-scale character recognition. I have compared the invariant approach versus the adaptive one. A special self-organizing map has been added in order to correct the geometrical deformations of rejected characters by adapting the classifier topology to improve the system reliability. This approach allows recognizing erroneous characters thanks to the system modification without relearning.

To show and prove the pertinence of the proposed system, I have tested the system on character recognition, and especially deformed character recognition. These characters come from different kind of documents: handwritten digits coming from pin code, technical maps, historical documents, and present-day juridical documents.

Keywords

machine learning - pattern recognition - feature extraction - neural network - self-organizing maps - Markovian models - multi-classifiers systems - handwritten character recognition

5.2 Detailed PhD research

5.2.1 A hybrid multi-classifiers system

In spite of the improvements of classification techniques, they can be unable to process large database that contain a high variability across samples. For this reason, a single classifier or a single expert is not enough for providing reliable results. I have proposed a hybrid multi-classifiers system that combines several generic and specialized classifiers. The system is composed of several steps:

1 Generic classifiers are combined in parallel. Voting methods, statistical methods considering the history of their potential combination (Behavior Knowledge Space) or neural networks have been tested for combining the classifier outputs. The goal was to highlight the strength and weakness of each classifier in order to optimize their combination.

2 In spite of the the combination of generic classifiers, the results remain sub-optimal and can still be improved. The result of the combination is analyzed to extract the remaining potential errors that could occur.

3 A specialized classifier is trained in relation to the potential errors to solve the problems that the generic classifier combination was unsuccessful. The goal of the specialized classifier is to complete the generic classifier combination by processing only classes that may be not well recognized, *e.g.* characters with accents. The specialized classifier uses all the information from the other classifiers to focus on particular problems.

5.2.2 Application to character recognition

My model has been used for the recognition of printed text. The generic classifiers were commercial OCR (Optical Character Recognition). The specialized classifier, ICR, (Intelligent Character Recognition) is based on a convolutional neural network. Its topology is tuned in relation to the different types of errors (confusion, addition, suppression, fusion of characters) of the different classes. The model has been validated on different types of documents and it has been used on juridical documents coming from the official journal of the European Community. This study has allowed for evaluating the performance of current commercial OCR. In this study, the OCR combination has allowed for increasing the reliability of the detection.

My system was tested on images of old documents that contain more challenges and are the source of more errors for commercial OCR. I have tested my model on pages of a French dictionary of the XVIII century (*Le dictionnaire de Trévoux*). This study was part of a joint work between the READ team of LORIA and the ATILF[4] in a project for the digitization and restoration of old French books. The pages of the dictionary were very noisy and contain characters that are not used anymore. These characters disturb commercial OCR and involve errors. In this situation, the ICR is trained to recognize these particular characters.

5.2.3 Combination of stochastic classifiers and neural networks

I combined several stochastic classifiers (based on Markov random field) and neural networks. This study stressed the importance of the reading sense of the image for the stochastic models. The different sense of reading in an image can be used to obtain different classifiers. With Dr. Szilárd Vajda, I established strategies based on incremental and selective learning to speedup the training of some neural networks.

5.2.4 Adaptive filtering

Before the classification of images, several pre-processing steps were needed in order to remove some noise and to enhance some characteristics of the image. A challenge is to find a set of filters and to know where to apply them. In this study, my research was oriented toward the use of multi-classifier systems with a dynamic selection of the classifier. Each classifier has the role of a filter. The filters are trained to correct a particular noise or deformation. The classifier selection is achieved thanks to a non-supervised training procedure based on the pixel values. This method has been successfully evaluated on the French journal *Le Petit Niçois* and old arabic documents. This filtering approach allowed for increasing the recognition rate of two commercial OCR.

5.2.5 Deformed character recognition

I have mainly used the retinal approach for the classification of images. Although this approach remains the best for the classification of straight or lightly deformed characters, this solution may not be so efficient when characters are too deformed. The images can possess a particular deformation like the multi-orientation. In this case, the extraction of rotation invariant features can facilitate the classification stage. I have considered strategies based on the Fourier transform and the Fourier-Mellin transform. The methods based on rotation invariant features were more efficient when the multi-orientation was well distributed across images. However, the approach based on inputs at the pixel level was more efficient for noisy characters, which have only few possible orientations.

[4] *Analyse et Traitement Informatique de la Langue Française, CNRS, Nancy, France*

5.2.6 Adaptive data normalization

I have proposed a normalization model based on a stochastic model that was initially developed in the READ team. This non-symmetrical model base on a Markov random field allows the recognition of images through several hidden Markov models. This model has been used for the normalization of images through the analysis of the Viterbi paths. Thanks to the non-symmetry of the model, 16 normalization models have been created to translate horizontal and vertical deformations. These models have been used for improving the reliability of the classifier. I have also proposed a model that combines a convolutional neural network and a self-organizing map. The goal of the self-organizing map was to reorder neurons in a layer of the convolutional neural network. The neurons of the self-organizing maps contain the information relative to the position of the neurons in a convolutional layer.

5.3 Postdoctoral activities: Brain-computer interfaces & EEG signal processing

My first postdoctoral experience was at the Institute of Automation (IAT) in the University of Bremen, Germany. I was supervised by Prof. Axel Gräser. My research was supported by the European project Brainrobot. The goal of this project was to provide a new communication means to severely disabled persons. For these persons, their only control can be their gaze and brain signals. The communication between a device (wheelchair, robotic arm) or a computer is possible thanks to a brain-computer interface (BCI). The BCI translates the user's wish into commands. My main contributions was related to the creation and improvement of signal processing methods to speed up the detection of some particular brain responses. The goal was also to increase the accuracy of the detection.

I have proposed new neural network architectures for the detection of steady-state visual evoked potential (SSVEP) and P300 responses. The topology of the neural network embeds neuroscience knowledge to drive the classifier learning and better model the P300 response. This classifier was successfully evaluated on a database of the 3rd BCI competition with an accuracy of 95.5%. This method allows for a view of the spatial distribution of the P300 wave through the analysis of the weights in the network.

For the detection of SSVEP responses, I have proposed a new neural network model that includes the Fourier transform between two hidden layers. This network can determine spatial filters, temporal filters and then consider high-level features in the Fourier domain. Compared to other neural architectures, this model has the best recognition rate.

I have conducted experiments on more than one hundred subjects to validate the methods. I participated in the development of Bremen-BCI, an SSVEP based BCI that was successfully presented during the international fair CeBIT 2008 in Hanover, Germany, and RehaCare 2008 in Düsseldorf, Germany. The system was tested during these fairs on more than 130 persons. I have completely developed a new BCI system that requires no calibration step and allows the user to spell words through the detection of SSVEP responses. The detection method is based on the Principal Components Analysis. The graphical user interface includes different constraints that are related to the number of visual stimuli and the switch between commands.

As the quality of the visual stimulus and the graphical user interface have an impact on the detection of a brain response. I have compared and evaluated several solutions of visual stimuli to evoke SSVEP responses (flickering LEDs, flickering boxes on an LCD screen). Although the frequency of flickering LEDs can be chosen, the LCD screen allows placing the visual stimuli and the application at the same location.

5.3.1 Sensor selection for P300 based BCI

At Gipsa-lab CNRS in Grenoble, France, my research was dedicated to the improvement of BCIs based on the P300 detection. I was in the team of Dr. Bertrand Rivet and Prof. Christian Jutten. The goal of the RoBIK (Robust BCI Keyboard) project was to provide an adaptive and robust BCI speller that could leave the stage of laboratory demonstrator to be used by patients at home. I have participated in the development of a new method for sensor selection in the P300-Speller paradigm. This method is based on the backward elimination with a cost function related to the signal to signal-plus-noise ratio. This cost function offers better performance and avoids further mining evaluations related to the P300 recognition rate or the character recognition rate of the speller. The proposed method was tested on data recorded on 20 subjects. Furthermore, I have proposed new strategies for improving the P300 speller based on different feedbacks to the user. These improvements include modifications of the graphical user interface and the choice of some parameters. During this project, some experiments about the detection of SSVEP responses have been conducted. The goal was to increase the number of commands in an SSVEP-BCI by combining different frequencies.

5.3.2 Single-trial detection of event-related potentials

These works correspond to my postdoctoral research at the University of California - Santa Barbara, where I work on the detection of event-related potentials in the EEG signal. I am in the laboratory of Dr. Barry Giesbrecht. In rapid serial visual presentation tasks, a stream of images containing target and non-target images is presented to the user. The goal is to detect the brain responses that are associated to the presence of a relevant stimulus (visual or auditory), *e.g.* a target. The main challenge is to improve the accuracy of the detection with only one single-trial. Other challenges include the creation of new paradigms and the detection of targets in multi-task conditions. Several studies have been conducted for the impact of different parameters: the target probability, the number of tasks during the experiment (single versus dual-task) and the modality (visual, auditory).

5.4 Main software development

- Within the framework of a contract of EDF with the READ team, I have realized a software for multi-oriented and multi-scales handwritten character recognition. [Unix - Windows - C/C++ - XML]
- Within the framework of the RNTL project Paploo, I have developed a system for OCR combination. In this project, I have also participated with Yves Rangoni to the development of software for document labeling: DOCLIP (Document Ocr Combination Labeling Interface Paploo). [Unix - Windows - C/C++ - Java - XML]
- Development of a software for handwritten digits recognition based on convolutional neural networks [Windows - C/C++].
- Development of Bremen-BCIs, an SSVEP based Brain-Computer Interface. Presentation of the software in CeBIT 2008 and RehaCare 2008. [Windows - C++]
- Development of SSVEP-BCI spellers in the Brainrobot project [Windows - C++ - DirectX - Matlab]
- Development of SSVEP and P300 BCI spellers in the RoBIK project [Windows - C++ - DirectX - Matlab]

5.5 Other responsibilities

- Reviewer for the following conferences and journals: CIFED04, CIFED06, ICDAR05, EUSIPCO10, FAHR2010, Journal of Neural Engineering, Journal of Neural Computation, Journal of Physiology-Paris, IEEE Image processing, IEEE Biomedical engineering, IEEE Neural Networks, Biomedical engineering, International Journal Artificial Intelligence in Medicine.
- Participation to CeBIT 2008 where the IAT had a booth to present several BCI.
- Participation to RehaCare 2008 (an international fair for rehabilitation products) where the IAT had a booth to present a BCI speller.

6 Research plan

My research plan focuses on non-invasive Brain-Computer Interface (BCI) for both healthy and disabled people. This research plan includes a strong base in machine learning for the detection of brain responses and applications in biomedical engineering.

6.1 Introduction

The objective is to research new paradigms and signal processing methods to increase the interest and performance of BCI for both healthy and disabled people (students, gamers, soldiers, patients, etc), *e.g.* to increase the attention and cognitive performance of healthy people in particular settings or the communication means for disabled persons. To achieve this goal, it is important to monitor the brain activity and classify/detect its different state. Whereas advanced brain monitoring has become a common tool to measure high workload in specific works (air traffic controllers, soldiers for tactical commands), BCI has still to be proven efficient in some particular context. One of the objectives is to better understand the brain processes involved during attention state by researching new paradigms and learning models, *e.g.* neural network architectures, to better understand brain networks but also to use these models for classification and detection. The goal is to use plausible models of the brain, artificial neural network, to model some brain processes: if it can be implemented then it can be better understood. This virtuous circle between artificial neural networks and brain networks shall benefit different applications, *e.g.* classification of images, signals, attention regulation and monitoring.

Moreover, it is important to understand the cognitive workload level of an individual while performing a task to evaluate the skills of the person, the difficulty of the task, and the key points of the task that may require an increased workload level. This can be used for adapting classical human-computer interface where the brain signal is only used to adapt the interface and not to be a real interface.

6.2 Possible applications

Several applications are possible for my research plan:

- Monitoring the attention of persons to know when a person is focused, when a person may make an error, when a person has enough attention to process new information.
- BCIs that can work in real conditions, *e.g.* in a hospital, at home, in a classroom, give a great challenge. The goal is to propose applications, which can be used efficiently by a patient or a healthy user. Indeed, current BCI do not provide reliable performance over time and across subjects. I want to address this issue with a pragmatic and user-centered approach that combines advanced method in machine learning and human-computer interaction. Indeed, brain signals vary over time and it is important to catch a drift that may occur over time.

6.3 Research directions

My research plan has three main directions:

- Signal processing/machine learning applied on the detection of signals. My main research focuses on artificial neural networks for the classification and the extraction of high-level features. These methods can be applied on other types of problems (from image processing, character recognition, any signal classification). I want to focus on neural networks with deep architecture, on their topologies, to extract different kinds of features. Indeed, the goal is not only

to obtain a good performance for the classification, but to provide key insights of the type of extracted features. Whereas neural networks with deep architectures have been applied mainly on 2D problems, *e.g.* images. Their uses on 3D data like voxels from fMRI data could help understanding some brain processes by keep structural constraints for the classification.

- Human-machine interface. The design of paradigms for monitoring the brain activity requires a specific adaptation of the graphical user interface, it has to be optimized to increase the user's convenience: it depends on the subject. Such paradigms can be oriented toward disabled persons, healthy persons for video games, to monitor attention and provide neurofeedback. The classification of data shall be part of a whole framework where it is possible to get the feedback of the classification/detection.

- Computational neuroscience. The outcome of the research from the previous two points can provide new knowledge about attention and cognitive processes. It can provide new insights for people with a deficit of attention. The creation of software with neurofeedback could be used to establish new software, from video games to educational technologies for patients suffering of neurological disorders.

6.4 Challenges

A significant challenge in the achievement of this research is that the utility of a tool based on brain monitoring is highly dependent on the ability of the user to learn this new mode of communication; an ability that is highly dependent on the individual. Efforts to overcome these hurdles have been facilitated by advances in signal processing and machine learning techniques that increase the reliability and the accuracy of brain response detection. Despite recent advances in the BCI field, only few systems succeed to leave the laboratory stage. For example, a common BCI benchmark known as the P300 speller (a BCI that uses known electrophysiological responses to attended stimuli to spell words on a screen), was first proposed in 1988, but the P300 speller commercially available to patients was not released until 2009 by the G.tec company. This large gap in time between the proposal of the initial concept to a commercially available product highlights the difficulty for transferring a technology, and probably the lack of a user-centered research.

Indeed, the lack of robustness of the system over time and across subjects is still a drawback for many applications. A current trend is to better consider human-computer interface models where the needs of the user are the driving force in all aspects of system development. The same way the introduction of the personal computer has changed daily life, a personal electroencephalography (EEG) system coupled with efficient software could broaden the use of brain monitoring for increasing the cognitive performance of individuals. For the moment BCI/brain monitoring applications need further research to leave the highly controlled laboratory environment to be used at home or in hospital for patients, on the battlefield for soldiers, on a classroom for students.

Among the current new machine-interfaces, eyetrackers are challenging BCIs. Eyetrackers are easy to wear, they do not require a particular preparation (no electrode). However, they require a calibration step when the person moves. Such cumbersome calibration can be a drawback for a person who is moving. With a BCI based on visual stimuli, it is possible to set particular stimuli in the environment. With this solution, a person can freely move in a house and the detected brain responses are interpreted over time. For instance, there is a particular stimulus on a blackboard, the brain response associated to this stimulus can provide a feedback directly to the user. In this situation, an eyetracker cannot compete as it should always know where the gaze of the subject is pointing. Furthermore, monitoring the brain activity can provide other information than just monitoring the gaze.

6.5 Personal experience

This research plan draws on my BCI experience attained during my postdoctoral positions and my pattern recognition experience attained during my PhD and postdoctoral years. First, I have participated in the European project BRAINROBOT when I was a postdoctoral researcher at the Institute of Automation, University of Bremen, Bremen, Germany. I have co-developed a speller that was presented at the international fair RehaCare in Düsselforf in 2008. I have also developed my own SSVEP-BCI speller. I have proposed new algorithm for the detection of Evoked-Related Potentials and SSVEP responses with neural networks. I have participated in the project RoBIK (Robust BCI keyboard) from the French National Research Agency, where I have worked on improving the P300 speller (accuracy, sensor selection,...). I have proposed several improvements for the graphical user interface of the P300 allowing a better detection. My experience in both software engineering and computational neuroscience allows me to be autonomous in my research. Although I do enjoy teamwork, I have never relied on other persons to progress in my research or to develop software. Hence, I can do quickly efficient and independent research without the help of undergrad or grad students as I master completely the whole processing chain: from programming the applications, the algorithms, preparing the subjects, to the analysis of the results.

7 References

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8 Publications to download

You can download the following papers:

- H. Cecotti, A Time-Frequency Convolutional Neural Network for the Offline Classification of Steady-State Visual Evoked Potential Responses, Pattern Recognition Letters.
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- H. Cecotti, B. Rivet, M. Congedo, C. Jutten, O. Bertrand, E. Maby, J. Mattout, A robust sensor selection method for P300 Brain-Computer Interfaces, Journal of Neural Engineering, vol. 8, 2011.
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