Adaptive Business Intelligence (ABI)

Technology Curricular Unit (UTC) proposal for the MAP-I PhD Program

A – Programmatic Component

1. Motivation

Nowadays, business organizations are increasingly moving towards decision-making processes that are based on information. **Business Intelligence (BI)** is an umbrella term that includes methodologies, architectures, tools, applications and technologies to enhance managerial decision making [1]. The goal of BI is to access data from multiple sources and process these data into useful knowledge that can be used to support decision making.

Very recently, a new trend emerged in the marketplace called **Adaptive Business Intelligence (ABI)** [2]. Besides extracting knowledge from data, ABI also addresses the decision-making process. BI systems often include elements of databases, data warehouses and data mining [1], while ABI systems encompass two additional modules: **forecasting** [3] and **optimization** [4], in order to enhance adaptability. In effect, **adaptability** is a vital component of any intelligent system and this issue is expected to gain popularity in the next years. The final ABI goal is to use computer systems that can adapt to changes in the environment, solving complex real-world problems with multiple objectives, in order to aid business managers to make better decisions, increasing efficiency, productivity and competitiveness.

Although being a recent field, the topics covered by ABI (i.e., data mining, forecasting, modern optimization and adaptive systems) have a large research community, with several prestigious international scientific journals (e.g., Data Mining Knowledge Discovery, Decision Support Systems, Machine Learning, IEEE Trans. Neural Networks, International Journal of Forecasting, IEEE Trans. Evolutionary Computation, Journal of Heuristics, Applied Soft Computing) and conferences (e.g. ACM KDD, ACM CIKM, ACM ICIS, IEEE ICDM, IEEE IJCNN, IEEE CEC) available. There are also several international examples of Computer Science PhD programs that include ABI topics, such as:

- Carnegie Mellon University (CMU), USA:
    - **Ph.D. Program in Computer Science** (machine learning, optimization);
    - **Ph.D. Program in Information Systems and Management** (business analytics, data mining, machine learning, time series analysis);
    - **Ph.D. Program in Machine Learning** (data mining, database management systems, machine Learning, optimization);
- Standford University, USA:
    - **Ph.D. in Computer Science** (databases, data mining, machine learning, modern optimization)
- Berkeley University of California, USA:
    - **Ph.D. in Computer Science**, specialization ins Communication, Computation and Statistics (database management systems, data mining, decision support).

The proposed ABI unit had already **five** previous **MAP-I editions**:
- **2013/14** course edition, 11 students, at University of Minho (http://www.map.edu.pt/i/2013/courses);
- **2012/13** course edition, 8 students, at University of Aveiro (http://www.map.edu.pt/i/2012/Courses);
- **2011/12** course edition, 10 students, at University of Porto (http://www.map.edu.pt/i/2011/Courses);
- **2010/11** course edition, 6 students, at University of Minho (http://www.map.edu.pt/i/2010/Courses);
- **2008/09** course edition, 7 students, at University of Porto (http://www.map.edu.pt/i/2008/courses).

The **assessment made by the students** on the previous editions **encourages further editions**. An anonymous questionnaire was launched in the e-learning system and the student's average responses were:
- Question: "This teaching unit is **useful** for the PhD program". Average responses over all ABI editions - **82**% (highly agree).
- Question: "**Positive stimulus** for an active student participation and discussion in class?". Average responses over all ABI editions: **87**% (highly agree).
- Question: "**Positive evaluation** of the teachers global performance in this teaching unit". Average responses over all ABI editions: **85**% (highly agree).

2 Objectives and Learning Outcomes

To learn about the basic ABI concepts, including: characteristics of complex business problems, BI and ABI, data mining, prediction, modern optimization and adaptability;

To master the state of the art of ABI methods and models and tools;

To perform a review essay over an advanced research ABI topic;

To apply ABI in real-world applications.

3 Detailed Program

1 - Introductory ABI concepts: characteristics of complex business problems, BI and ABI, data mining, prediction, optimization and adaptability, state of the art.
2 – Using prediction and optimization to build adaptive systems: application of data mining models and techniques in ABI (e.g. decision trees, neural networks, support vector machine, learning classifier systems, hierarchical and relational clustering, inductive logic programming), application of optimization techniques in ABI (e.g., heuristic search, hill-climbing, tabu-search, evolutionary computation).
3 - Conducting ABI projects and case studies: CRISP-DM, ABI applied to real-world problems (e.g. Finance, Economy, Marketing).
4 - Exploration of ABI tools: DM and optimization tools (e.g. R, WEKA, SAS Enterprise Miner, Rapidminer, Evolution Machine, SCS-C, Aleph, Moss), BI tools (e.g., SAS, MS SQL Server).

4 Teaching Methodology and Evaluation

Four teaching methodologies will be applied:
> 1 - Lecture exposition of key ABI issues.
> 2 - Active learning (e.g. think-pair-share, in-class teams [5]).
> 3 - Case-based learning.
> 4 - Project based learning.

Evaluation will include two elements:
> A - review of ABI research article(s) (30%); and
> B - an ABI project that describes the application of ABI tools to real-world datasets (70%).

5 Bibliography

Cited references:

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[2] Z. Michalewicz, M. Schmidt, M. Michalewicz and C. Chiriac, Adaptive Business Intelligence, Springer-Verlag, Leipzig, Germany, 2007.

[3] S. Makridakis, S. Wellwright and R. Hyndman, Forecasting: Methods and Applications, John Wiley & Sons, New York, USA, 1998.

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[5] D. Johnson, R. Johnson and K. Smith, Active Learning: Cooperation in the College Classroom, 2nd edition, Edina, Interaction Book Company, 1998.

Additional references:

[6] P. Cortez. Modern Optimization with R. Springer, 2014.

[7] S. Luke, S. Essentials of metaheuristics. George Mason University. Free access: http://cs.gmu.edu/~sean/book/metaheuristics/, 2009.

[8] Z. Michalewicz, M. Schmidt, M. Michalewicz and C. Chiriac. Adaptive Business Intelligence: Three Case Studies, In Evolutionary Computation in Dynamic and Uncertain Environments, pp. 179-196, Springer, 2007.

[9] E. Turban, R. Sharda and D. Delen. Decision Support and Business Intelligence Systems, Prentice Hall, 2011.

[10] P. Cortez, Data Mining with Neural Networks and Support Vector Machines using the R/rminer Tool, In P. Perner (Ed.), Advances in Data Mining, Proceedings of 10th Industrial Conference on Data Mining, Berlin, Germany, Lecture Notes in Artificial Intelligence 6171, pp. 572-583, Berlin, Germany, July, 2010

B Lecture Team

1. Summary

The lecture team includes the three members of the previous five ABI editions (MAP-I 2008/9, 2010/11, 2011/12, 2012/13 and 2013/14). **Manuel Filipe Santos (MFS)** and **Paulo Cortez (PC)** belong to the Intelligent Data Systems (IDS) - http://algoritmi.uminho.pt/research-teams/ids, research group of the Algoritmi R&D Centre (evaluated as "**Very Good**" by FCT), University of Minho. Both research on

Adaptive Business Intelligence, Decision Support Systems and Data Mining. MFS performed his PhD in Distributed Learning Classifier Systems, while PC performed his PhD in Forecasting, Neural Networks and Evolutionary Optimization. **Rui Camacho (RC)** is from the Laboratory of Artificial Intelligence and Decision Support (LIAAD R&D centre, http://www.liaad.up.pt/, evaluated as "**Very Good**" by FCT), University of Porto. RC researches in Inductive Logic Programming and Data Mining. For more details, see the CVs in section B.3.

The team is willing to write didactic texts related to this unit. An example of this is the **book "Modern Optimization with R"** that PC is publishing with Springer (in press).

2. **Coordinator**

Manuel Filipe Santos (MFS)

3. **CVs**

3.1 Manuel Filipe Santos

Biography: Manuel Filipe Santos received his Ph.D. in Computer Science (Artificial Intelligence) from the University of Minho (UMinho), Portugal, in 2000. He is associate professor at the Department of Information Systems, UMinho, teaching undergraduate and graduate classes of Business Intelligence and Decision Support Systems. He his also researcher at the Business Intelligence Group (big.dsi.uminho.pt) of the R&D Algoritmi Centre, with the current research interests:
- Business Intelligence and Decision Support Systems;
- Data Mining and Machine Learning (Learning Classifier Systems);
- Grid Data Mining.

Relevant publications in the last 5 years:

His most significant publications for the field in the last 5 years are:
[1] Tiago Miranda; António G Correia; Manuel F Santos; Luís R Sousa; Paulo Cortez NEW MODELS FOR STRENGTH AND DEFORMABILITY PARAMETERS CALCULATION IN ROCK MASSES USING DATA MINING TECHNIQUES ASCE's International Journal of Geomechanics, 2010 20-30.
[2] Ana Azevedo, Manuel Santos, A Perspective on Data Mining Integration with Business Intelligence in "Knowledge Discovery Practices and Emerging Applications of Data Mining: Trends and New Domains", IGI Global 2010, ISBN 978-1-60960-069-3.
[3] Henrique Santos; Manuel Filipe Santos; Wesley Mathew Supervised Learning Classifier System for Grid Data Mining Data Mining: Trends and New Domains, Viena, Intech, 2010, ISBN 978-953-7619-X-X.
[4] Júlio Duarte, Maria Salazar, Cesar Quintas, Manuel Santos, José Neves, António Abelha and José Machado Data Quality Evaluation of Electronic Health Records in the Hospital Admission Process, IEEE/ACIS 2010 Japan August, 2010 (ISI proceedings).
[5] Modelling intelligent behaviours in multi-agent based HL7 services, IEEE/ACIS 2010 Japan, August, 2010 (ISI proceedings).

[6] I. A. Iurgel; R. E. da Silva; M. F. dos Santos Towards virtual actors for acting out stories Edutainment 2010, China, August, 2010 (ISI proceedings).

[7] Manuel Filipe Santos; Wesley Mathew; Henrique Dinis Santos, Grid Data Mining by means of Learning Classifier Systems and Distributed Model Induction, GECCO 2011, July, Dublin.

[8] Ana Azevedo, Manuel Filipe Santos: Closing the Gap between Data Mining and Business Users of Business Intelligence Systems: A Design Science Approach. IJBIR 3(4): 14-53 (2012)

[9] Filipe Portela, Manuel Filipe Santos, José Machado, Álvaro Silva and António Abelha. Pervasive and Intelligent Decision Support in Critical Health Care using Ensemble. Lecture Notes in Computer Science (LNCS) - Information Technology in Bio- and Medical Informatics. Volume 8060, 2013, pp 1-16. ISBN: 978-3-642-40093-3. Springer. (2013).

[10] Fernando Marins, Luciana Cardoso, Filipe Portela, Manuel Santos, António Abelha and José Machado. Intelligent Information System to Tracking Patients in Intensive Care Units. Lecture Notes in Computer Science (LNCS) - Ubiquitous Computing and Ambient Intelligence. Volume 8276, 2013, pp 54-61. ISBN: 978-3-319-03175-0. Springer. (2013).

[11] Azevedo, A. Santos. M.F. Extending QMBE Language with Clustering , International Journal of Decision Support System Technology (IJDSST), edited by Pascale Zaraté. IGI Global, Volume 5, Issue 3, Pag. 59-77, 2013 (Scopus).

[12] Filipe Portela, Jorge Aguiar, Manuel Filipe Santos, Álvaro Silva, António Abelha, José Machado and Fernando Rua Martins. Assessment of Technology acceptance in Intensive Care Units. IJSSOE - International Journal of Systems and Service-Oriented Engineering. IGI Global. (2013).

[13] Filipe Portela, Pedro Gago, Manuel Filipe Santos, José Machado, António Abelha, Álvaro Silva, Fernando Rua. Implementing a Pervasive Real-time Intelligent System for Tracking Critical Events with Intensive Care Patients. IJHISI - International Journal of Healthcare Information Systems and Informatics. IGI Global. (2014).

[14] João M. C. Gonçalves, Filipe Portela, Manuel F. Santos, Álvaro Silva, José Machado, António Abelha, Fernando Rua. Real-time Predictive Analytics for Sepsis Level and Therapeutic Plans in Intensive Care Medicine. IJHISI - International Journal of Healthcare Information Systems and Informatics. Springer. (2014).

[15] Filipe Portela, Rui Veloso, Sérgio Oliveira, Manuel Filipe Santos, António Abelha, José Machado, Álvaro Silva and Fernando Rua. Predict hourly patient discharge probability in Intensive Care Units using Data Mining. ScienceAsia Journal (ICCSCM 2014). ISSN: 1513-1874. Science Society. (2014). (accepted for publication).

Participation in R&D projects in the last 5 years:

He participated in various R&D projects, being Principal Investigator of 3 FCT projects, namely:
Intcare – Intelligent Decision Support System for Intensive Care Medicine
Gridclass – Learning Classifier Systems for Grid Data Mining
Intcare II – Intelligent Decision Support System for Intensive Care Medicine

Supervision of Graduate Students:

Supervised 20 MSc theses and 6 PhD theses. Currently he is supervising 5 PhD students.

Other relevant topics of his CV:
- **Co-organized** the EPIA 2007 – 13th Portuguese Conference on Artificial Intelligence.
- **Reviewer** of several conferences (e.g. AAMAS, EPIA, ICEIS, ICAART, MEDI) and journals (e.g. European Journal of Operational Research, Intelligent Decision Making Support Systems);
- **Co-organizer of** the Ubiquitous Data Mining workshop of ECAI 2012, 2010, Knowledge Discovery and Business Intelligence - KDBI 2009, 2011, 2013 and MASTA 2013 thematic tracks of EPIA; WISA/CISTI 2011, Intelligent Systems/ESM 2011 and

3.2 Paulo Cortez

Biography:

Paulo Cortez (PhD, Habilitation) is **Associate Professor** (with tenure) at the Department of Information Systems, University of Minho. He is also **Coordinator** of the Information Systems and Technologies (IST) research group of ALGORITMI Centre (with 33 PhD researchers). His current research interests are in the fields of: Business Intelligence and Decision Support Systems; Data Mining and Machine Learning; Neural Networks and Evolutionary Computation; and Forecasting.

Relevant publications in the last 5 years:

He is co-author of more than eighty indexed (e.g., ISI, Scopus) publications in international conferences and journals (e.g., published by IEEE, Elsevier or Springer). His google scholar h-index (when excluding self-citations) is 17 (http://scholar.google.com/citations?hl=en&user=fQ42U-8AAAAJ). His relevant publications in the last 5 years are:

[1] **P. Cortez** and J.Peralta Donate. Global and Decomposition Evolutionary Support Vector Machine Approaches for Time Series Forecasting. In *Neural Computing and Applications*, Springer, In Press (ISI impact factor 1.168)

[2] S. Moro, **P. Cortez**, P. Rita. A Data-Driven Approach to Predict the Success of Bank Telemarketing. In *Decision Support Systems*, Elsevier, In Press (ISI impact factor 2.201)

[3] J. Peralta Donate, P. Cortez, G. Sánchez and A. de Miguel. Time series forecasting using a weighted cross-validation evolutionary artificial neural network ensemble. In *Neurocomputing*, Elsevier, 109:27-32, June 2013 (ISI impact factor 1.634).

[4] M. Stepnicka, **P. Cortez**, J.P. Donate, L. Stepnickova. Forecasting seasonal time series with computational intelligence: on recent methods and the potential of their combinations. In *Expert Systems with Applications*, Elsevier, 40(6):1981-1922, May 2013, ISSN 0957-4174 (ISI impact factor 2.203).

[5] P. Cortez and M.J. Embrechts. Using Sensitivity Analysis and Visualization Techniques to Open Black Box Data Mining Models. In *Information Sciences*, Elsevier, 225:1-17, March 2013, ISSN 0020-0255 (ISI impact factor 2.833).

[6] P. Cortez and J.P. Donate. Evolutionary Support Vector Machines for Time Series Forecasting. In A. Villa et al. (Eds.), Artificial Neural Networks and Machine Learning - ICANN 2012, **22nd International Conference on Artificial Neural Networks,** Lecture Notes in Computer Science 7553, pp. 523-530, Lausanne, Switzerland, September, 2012, Springer, ISSN 0302-9743, ISBN 978-3-642-33265-4 (ISI, Scopus)

[7] P. Cortez, M. Rio, M. Rocha and P. Sousa. Multiscale Internet Traffic Forecasting using Neural Networks and Time Series Methods. In *Expert Systems*, Wiley-Blackwell, 29(2):143-155, May 2012 (ISI impact factor 1.231).

[8] P. Cortez. Data Mining with Multilayer Perceptrons and Support Vector Machines. In D. Holmes and L. Jain (Eds.), **DATA MINING: Foundations and Intelligent Paradigms, Volume 2: Core Topics including Statistical, Time-Series and Bayesian Analysis**, ISRL 24, chapter 2, pp. 9-25, 2012. Springer (ISI).

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[10]   M. Rocha, P. Sousa, P. Cortez and M. Rio. Quality of Service Constrained Routing Optimization using Evolutionary Computation, In *Applied Soft Computing*, Elsevier, Elsevier, 11(1):356-364, 2011 (ISI impact factor 2.415, Scopus)

[11]   P. Cortez and M. Embrechts. Opening Black Box Data Mining Models Using Sensitivity Analysis. In Proceedings of the 2011 **IEEE Symposium on Computational Intelligence and Data Mining (CIDM)**, pp. 341-348, Paris, France, April, 2011 (ISI, Scopus).

[12]   P. Cortez, Sensitivity Analysis for Time Lag Selection to Forecast Seasonal Time Series using Neural Networks and Support Vector Machines, In Proceedings of the **IEEE International Joint Conference on Neural Networks IJCNN**, pp. 3694-3701, Barcelona, Spain, July, 2010. (ISI, Scopus).

[13]   P. Cortez, Data Mining with Neural Networks and Support Vector Machines using the R/rminer Tool, In P. Perner (Ed.), Advances in Data Mining, **Proceedings of 10th Industrial Conference on Data Mining**, Berlin, Germany, Lecture Notes in Artificial Intelligence 6171, pp. 572-583, Berlin, Germany, July, 2010 (ISI, Scopus)

[14]   P. Cortez, A. Cerdeira, F. Almeida, T. Matos and J. Reis. Modeling wine preferences by data mining from physicochemical properties. In *Decision Support Systems*, Elsevier, 47(4):547-553, 2009. ISSN: 0167-9236. (ISI impact factor 1.873, Scopus, ACM Portal)

[15]   R. Costa, N. Cachulo and P. Cortez. An Intelligent Alarm Management System for Large-Scale Telecommunication Companies. In L. Lopes et al. (Eds.), Progress in Artificial Intelligence, **14th Portuguese Conference on**

Artificial Intelligence (EPIA'2009), Lecture Notes in Artificial Intelligence 5816, pp. 386-399, Aveiro, Portugal, October, 2009. Springer. ISBN-10 3-642-04685-1. (34% acceptance rate, ISI, Scopus, DBLP)

Participation in R&D projects in the last 5 years:

He participated in 5 R&D projects, being Principal Investigator of 1 project, namely:
- **Principal Investigator (PI)** of the project **PTDC/EIA/64541/2006 - SPAM Telescope Miner: worldwide unsolicited email detection using data mining techniques**, financed by FCT, from January 2008 to December 2010. Budget: 70000 euros.

Supervision of Graduate Students in the last 5 years:

Supervised 2 PhD thesis and 12 MSc thesis. Currently he is supervising 6 PhD students.

Other relevant topics of his CV:
- **Associate Editor** of the Expert Systems (Wiley, ISI, since 2013) and **Neural Processing Letters** (Springer, ISI, since 2008) journals.
- **Reviewer** of several ISI journals: Information Sciences, Data & Knowledge Engineering, Artificial Intelligence in Medicine, Computer Journal, Decision Support Systems, Neurocomputing, Expert Systems, Intelligent Data Analysis and Artificial Intelligence Communications.
- **Program Committee Member** of 66 int. conferences/workshops, such as: IDEAL 2013, IEEE CIDM 2013, ACM WIMS'13, ECAI2010, IEEE IJCNN 2012, IEEE FUZZ 2013, DDDM of IEEE ICDM 2011, PAKDD-09, AAMAS09, IEEE CBMS 2011.
- **Co-organizer** of 12 Workshops, such as: Machine Learning track of IBERAMIA 2012; Knowledge Discovery and Business Intelligence (KDBI EPIA 2013); Ubiquitous Data Mining (UDM-IJCAI 2013; UDM-ECAI 2012).
- **Invited lecturer** in the International Summer School of Neural Networks in Classification, Regression and Data Mining (2010; 2012).
- Acted as **external examiner** of 14 MSc and 6 PhD thesis.
- **Author** of the open source RMiner library, which facilitates the use of Data Mining applications in R (http://www3.dsi.uminho.pt/pcortez/rminer.html).
- He is **vice-president** of the Portuguese Association for Artificial Intelligence (APPIA).
- He has a **strong post-graduate teaching experience**, having taught 27 MSc course units and 6 PhD course units in MAP-I Universities, University Institute of Lisbon, Polytechnic Institute of Bragança and Universitat Politècnica de Catalunya – BarcelonaTech.

3.3 Rui Camacho

Biography: Rui Camacho received his Ph.D. in Electrical Engineering and Computers from the University of Porto (UP), Portugal, in 2000. He is Associate Professor at the Informatics Engineering Department of the Faculty of Engineering at UP, teaching undergraduate and graduate classes of Machine Learning and Data Mining. He his also researcher at the Laboratory of Artificial Intelligence and Decision Support (LIAAD), with the current research interests:
- Inductive Logic Programming;

- Data Mining and Machine Learning;
- Relational Data Mining;
- Applications of Bioinformatics.

Relevant publications in the last 5 years:

His most significant publications for the field in the last 5 years are:

[1] Tiago Loureiro, Rui Camacho, Jorge Vieira e Nuno A. Fonseca, ``Improving the performance of Transposable Elements detection tools'', Journal of Integrative Bioinformatics, 10(3):231-242, doi:10.2390/biecoll-jib-2013-231

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[2] Rui Camacho, Rita Ferreira, Natacha Rosa, Vânia Guimarães, Nuno A. Fonseca, Vítor Santos Costa, Miguel de Sousa, Alexandre Magalhães,``Predicting the secondary structure of proteins using Machine Learning algorithms'', International Journal of Data Mining and BioInformatics, Vol6, N6, pp 571-584, 2012

[3] Célia Talma Gonçalves, Rui Camacho, Eugénio Oliveira, "BioTextRetriever: a tool to retrieve relevant papers" International Journal of Knowledge Discovery in Bioinformatics (IJKDB), Editor: Jason T. L. Wang, vol 2, N 3, pp 21-36, July-September 2011, IGI Publishing

[4] Rui Camacho, Max Pereira, Vítor Santos Costa, Nuno A. Fonseca, Carlos Adriano, Carlos J. V. Sim\~oes, Rui M. M. Brito, ``A Relational Learning approach to Structure-Activity Relationships in Drug Design Toxicity studies'', Journal of Integrative Bioinformatics, 8(3), pp 182-201, September, 2011.

[5] Miguel M de Sousa, Cristian R Munteanu, Alejandro Pazos, Nuno A Fonseca, Rui Camacho e Alexandre Lopes Magalhães, ``Amino Acid Pair- and Triplet-wise Groupings in the Interior of Alpha-Helical Segments in Proteins'', Journal of Theoretical Biology, 271(1):136-144, February 2011.

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Participation in R&D projects in the last 5 years:

He participated in various R&D projects:
ICE.Mobilidade (SI IDT – 13843/2011) QREN project;
IC4Depression (european project).

Principal Investigator of the project:

ILP-Web-Service: An Inductive Logic Programming based Web service

Supervision of Graduate Students:

Has supervised 15 MSc theses and 6 PhD theses. Currently supervises 2 PhD students.

Other relevant topics of his CV:
- Co-organized the ILP 2004 – International Conference on Inductive Logic Programming.
- Co-organized the ECML/PKDD 2005 – European Conference on Machine Learning and the European Conference on Principles and Practice of Knowledge Discovery in Databases.
- Was guest editor of the Machine Learning journal Vol. 64, N. 1/2/3, 2006.
- Belongs to the editorial board of the International Journal of Computational Intelligence in Bioinformatics and Systems Biology (IJCIBSB)
- Made review work for the following international journals: Journal of Computational Intelligence; IEEE journal of Systems Man and Cybernetic (SMC-B); Data & Knowledge Engineering (DKE), journal of Artificial Intelligence Research (JAIR); Machine Learning journal.
- Foi avaliadoe de váras propostas de projecto no departamento de informática da Katholieke Universiteit Leuven, Bélgica.
- É ``International Colaborator'' do "Núcleo de Apoio à Pesquisa

para Aprendizado de Máquina em Análise de Dados" da USP, Brasil.
- Foi examinador externo de um trabalho de doutoramento da University of New South Wales, (Austrália)