

# Adaptive Business Intelligence (ABI)

## A – Programmatic Component

### 1. Theme and motivation

Business organizations are increasingly using decision-making processes that are based on data. **Business Intelligence (BI)** is an umbrella term that includes methodologies, architectures, tools, applications and technologies to enhance managerial decision making [1][2]. The goal of BI is to access data from multiple sources and process these data into useful knowledge to support decision making. In 2007, a new trend emerged in the marketplace called **Adaptive Business Intelligence (ABI)** [3]. ABI systems extend the traditional BI model by encompassing two additional modules: **forecasting** [2, 4] and **optimization** [5], 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.

The topics covered by ABI (data mining and data science, forecasting, modern optimization and adaptive systems) have a large research community, with several prestigious international scientific journals (e.g., Decision Support Systems, Machine Learning, Journal of Heuristics, Applied Soft Computing) and conferences (e.g., ACM KDD, IEEE IJCNN, ACM GECCO) available. There are also several international PhD programs that include ABI topics, such as:

- Carnegie Mellon University (CMU), USA (<http://www.cmu.edu/>):
  - **Ph.D. Program in Computer Science** (artificial intelligence, machine learning);
- Stanford University, USA (<http://www.stanford.edu/>):
  - **Ph.D. in Computer Science** (artificial intelligence, machine learning, databases, optimization)
- Berkeley University of California, USA (<http://berkeley.edu/>):
  - **Ph.D. in Computer Science** (artificial intelligence, machine learning, database management systems).

The proposed ABI unit had already **eleven** previous **MAP-I editions**, including:

- 2020-21: 6 students, at University of Porto;
- 2019-20: 3 students, at University of Minho;
- 2018-19: 4 students, at University of Aveiro;
- 2017-18: 9 students, at University of Porto;

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 - **85%** (highly agree).

**Two ABI projects** (element B) of the 2014/15 edition resulted in **papers** published in the KDBI track of the EPIA international conference (Springer LNCS, indexed at Scopus and ISI): <http://epia2015.dei.uc.pt/kdbi/>. One of these papers [6] won the **best EPIA 2015 paper award**. Also, the ABI teachers published **international books**

covering several ABI topics, namely: Business Intelligence and Data Analytics [1, 2]; and Optimization [5].

## 2 Objectives and Learning Outcomes

- To learn ABI concepts: BI, 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:** 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 and deep learning, support vector machine, random forests, hierarchical and relational clustering, inductive logic programming), application of optimization techniques in ABI (e.g., simulated annealing, 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:** Prediction and optimization tools (e.g., R [5], Python [6], WEKA/MOA/Rapidminer).

## 4 Teaching Methodologies 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 [7]).
- 3 - Case-based learning.
- 4 - Project based learning.

Evaluation will include two elements:

- A** - review of ABI research article(s) (30%, individual essay); and
- B** - an ABI project that describes the application of ABI tools to real-world datasets (70%, group project of 2 to 3 students).

ABI course can be offered either in a b-learning or in e-learning mode due to restrictions on classroom teaching.

## 5 Bibliography

### Cited references:

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- [2] J. Moreira, A. Carvalho, T. Horváth, A General Introduction to Data Analytics, Wiley, 2018.
- [3] Z. Michalewicz, M. Schmidt, M. Michalewicz and C. Chiriac, Adaptive Business Intelligence, Springer-Verlag, Leipzig, Germany, 2007.
- [4] R. Hyndman and G. Athanasopoulos, Forecasting: Principles and Practice, Monash University, Australia, 2018.
- [5] P. Cortez. Modern Optimization with R. Springer, 2<sup>nd</sup> edition, <https://www.springer.com/gp/book/9783030728182>
- [6] K. Fernandes, P. Vinagre and P. Cortez. A Proactive Intelligent Decision Support System for Predicting the Popularity of Online News, In Proceedings of 17th Portuguese Conference on Artificial Intelligence (EPIA 2015), Springer, Coimbra, Portugal, LNCS 9273, pp. 535-546, September, 2015.
- [7] D. Johnson, R. Johnson and K. Smith, Active Learning: Cooperation in the College Classroom, 2nd edition, Edina, Interaction Book Company, 1998.

### Additional references:

- [8] S. Luke, S. Essentials of metaheuristics (second edition). George Mason University. Free access: <http://cs.gmu.edu/~sean/book/metaheuristics/>, 2015.
- [9] D. Delen, E. Turban, D. Sharda, Business Intelligence: A Managerial Perspective on Analytics, Pearson Prentice-Hall, New Jersey, USA, 2014.
- [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. **Manuel Filipe Santos** and **Paulo Cortez** belong to the Intelligent Data Systems (IDS) - <http://algoritmi.uminho.pt/research-teams/ids>, research laboratory of the ALGORITMI R&D Centre, University of Minho. Both research on Adaptive Business Intelligence, Decision Support Systems and Data Mining. M.F. Santos performed his PhD in Distributed Learning Classifier Systems, while P. Cortez performed his PhD in Forecasting, Neural Networks and Evolutionary Optimization. **Rui Camacho** is from the Laboratory of Artificial Intelligence and Decision Support (LIAAD) R&D centre, <http://www.liaad.up.pt/>, of INESC-TEC and Faculty of Engineering University of Porto (FEUP). R. Camacho researches in Inductive Logic Programming and Data Mining.

### 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 with habilitation at the Department of Information Systems, UMinho, teaching undergraduate and graduate classes of Business Intelligence and Decision Support Systems. He is the head of Intelligent Data Systems lab and the coordinator of the Information Systems and Technology group ([www.algoritmi.uminho.pt](http://www.algoritmi.uminho.pt)) of the R&D ALGORITMI Centre, with the current research interests: Business Intelligence; Intelligent Decision Support Systems; Data Mining and Machine Learning (Learning Classifier Systems); and Grid Data Mining. He is part of the steering committees of the master's course in Engineering and Management of Information Systems and the Doctoral Program in Information Systems and Technology.

#### Relevant publications in the last 5 years:

He is co-author of more than 300 indexed (e.g., ISI, Scopus) publications in international conferences, books and journals (e.g., published by IEEE, Elsevier or Springer). He has more than 1615 scopus citations, 3775 google scholar citations. His scopus h-index is 20 and google scholar h-index is 28. His relevant publications in this area, in the last 5 years, are:

1. Hak, Francini & Guimarães, Tiago & Santos, Manuel. (2022). Towards effective clinical decision support systems: A systematic review. *PloS one*, 17.8: e0272846.
2. João Lopes, Mariana Faria, Diogo Peixoto, Rui Macedo, Hugo Peixoto, Tiago Guimarães Manuel Santos and Agostinho Barbosa (2022). Determining Internal Medicine Length of Stay by means of Predictive Analytics, *EPIA 2022, Lecture Notes in Computer Science, Subseries Lecture Notes in Artificial Intelligence*.
3. Mosavi, N., Santos, M.F. (2022). Implementation Consideration for the Applied Business Intelligence in Healthcare. *Advances in Intelligent Systems and Computing*. Springer Verlag, Germany, pp 183–189, Vol. 1391.
4. Mosavi, Nasim Sadat & Santos, Manuel Filipe. (2022). Characteristics of the Intelligent Decision Support System for Precision Medicine (IDSS4PM). *Lecture Notes in Networks and Systems*, 217, pp. 675 - 683.
5. Data extraction and exploration tools for business intelligence, Cardoso, M., Guimarães, T., Portela, C.F., Santos, M.F., *Advances in Intelligent Systems and Computing*, Elsevier, 2020.
6. Mosavi, Nasim & Santos, Manuel Filipe. (2021). Implementation Considerations for the Applied Business Intelligence in Health care. In *International Conference on Decision Science & Management* (pp. 183-189). Springer, Singapore.
7. A data mining study on pressure ulcers, Mota, F., Abreu, N., Guimarães, T., Santos, M.F., *DATA 2019 - Proceedings of the 8th International Conference on Data Science, Technology and Applications*, 2019, Pages 251-258.
8. A regression data mining approach in Lean Production, Bragança, R., Portela, F., Santos, M., *Concurrency Computation*, Volume 31, Issue 22, 25 November 2019

9. Adaptive business intelligence in healthcare - A platform for optimising surgeries, Ferreira, J., Portela, F., Machado, J., Santos, M.F., *Advances in Intelligent Systems and Computing*, Volume 932, 2019, Pages 611-620
10. Iron value classification in patients undergoing continuous ambulatory peritoneal dialysis using data mining, Peixoto, C., Peixoto, H., Machado, J., Abelha, A., Santos, M.F., *ICT4AWE 2018 - Proceedings of the 4th International Conference on Information and Communication Technologies for Ageing Well and e-Health*, Volume 2018-March, 2018, Pages 285-290

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

He participated in various R&D projects, being Coordinator/Principal Investigator of 8 projects, namely:

- CONTROLO INTELIGENTE DE INFEÇÃO HOSPITALAR, Referência 02/SAMA2020/2019;
- Apoio à Decisão Inteligente na otimização de tempos de resposta e de recursos para melhoria da qualidade de serviço, Referência 03/SAMA2020/20;
- Gestão inteligente de internamento como forma de aumentar a qualidade e eficiência, Referência 04/SAMA2020/2019;
- Data Science aplicada à diabetes para aumento de qualidade de vida do doente e de racionalização de custos, Referência 01/SAMA2020/2019;
- ICDS4IM - Intelligent Clinical Decision Support for Intensive Medicine DSAIPA/DS/0084/2018
- Deus Ex Machina – Symbiotic technology for societal efficiency gains NORTE-01-0145-FEDER-000026.
- INTELLITAG - Intelligent tagging systems.

#### **Supervision of Graduate Students:**

He has supervised/co-supervised more than 95 MSc theses, 12 PhD theses and 2 postdoc. Currently he supervises/co-supervises 9 PhD and 15 MSc students.

### **3.2 Paulo Cortez**

#### **Biography:**

**Paulo Cortez** (PhD, Habilitation) is **Full Professor** (with tenure) at the Department of Information Systems, University of Minho. He is also **Member of the Directive Board** of the ALGORITMI Centre. His current research interests are in the fields of: Business Analytics 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 200 indexed (e.g., ISI, Scopus) publications in international conferences and journals (e.g., published by IEEE, Elsevier or Springer). He has more than 11900 google scholar citations and his google scholar h-index is 44 (<http://scholar.google.com/citations?hl=en&user=fQ42U-8AAAAJ>). His relevant publications in the last 5 years are:

- [1] Ferreira, L., & Cortez, P. (2023). AutoOC: Automated multi-objective design of deep autoencoders and one-class classifiers using grammatical evolution. **Applied Soft Computing**, 110496.

- [2] Ribeiro, R., Pilastrri, A., Moura, C., Morgado, J., & Cortez, P. (2023). A data-driven intelligent decision support system that combines predictive and prescriptive analytics for the design of new textile fabrics. **Neural Computing and Applications**, 1-21.
- [3] Pereira, P. J., Cortez, P., & Mendes, R. (2021). Multi-objective Grammatical Evolution of Decision Trees for Mobile Marketing user conversion prediction. **Expert Systems with Applications**, 168, 114287.
- [4] Gonçalves, J. N., Cortez, P., Carvalho, M. S., & Frazão, N. M. (2021). A multivariate approach for multi-step demand forecasting in assembly industries: Empirical evidence from an automotive supply chain. **Decision Support Systems**, 142, 113452.
- [5] Zola, P., Cortez, P., & Brentari, E. (2021). Twitter alloy steel disambiguation and user relevance via one-class and two-class news titles classifiers. **Neural Computing and Applications**, 33, 1245-1260.
- [6] Zola, P., Ragno, C., & Cortez, P. (2020). A Google Trends spatial clustering approach for a worldwide Twitter user geolocation. **Information Processing & Management**, 57(6), 102312.
- [7] Cortez, P., Pereira, P. J., & Mendes, R. (2019). Multi-step time series prediction intervals using neuroevolution. **Neural Computing and Applications**, 32(13):8939-8953.
- [8] Gonçalves, S., Cortez, P., & Moro, S. (2019). A deep learning classifier for sentence classification in biomedical and computer science abstracts. **Neural Computing and Applications**, 32 (11), 6793-6807.
- [9] P. Zola, P. Cortez, M. Carpita, Zola, P., Cortez, P., & Carpita, M. (2019). Twitter user geolocation using web country noun searches. In **Decision Support Systems**, 120:50-59 (ISI impact factor 3.565)

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

He participated in 19 R&D projects, including:

- **Evolvable Mechanisms of Cyber-Physical Systems**, prospective project of the Digital Transformation (DTx) Collab, January 2019 to current date (Coordinator).
- **Artificial Intelligence for Business Processes (FOF.BI.57)**, P2020, Consortium: ALGORITMI/CCG, UMinho and Bosch, July 2018 to December 2021 (Coordinator).
- **IRMDA - Intelligent Risk Management for the Digital Age**, Project Individual P2020, Consortium: ALGORITMI/CCG, UMinho and Wedo Technologies, November 2018 to December 2019 (Coordinator).
- **TexBoost - Less Commodities more Specialities (PP1, CCG team)**, Project: nº 24523, Programa Mobilizador, Aviso Nº10/SI/2016, Consortium: ALGORITMI/CCG, UMinho; Citeve and others, July 2017 to June 2020 (Coordinator of PP1).
- **PROMOS - Predicting and Optimizing Marketing Campaigns For Mobile Devices**, Project: NORTE-01-0247-FEDER-017497, December 2016 to November 2019 (Coordinator)

#### **Supervision of Graduate Students in the last 5 years:**

Supervised 1 Postdoc and 7 PhD theses.

### **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 is also researcher at the Laboratory of Artificial Intelligence and Decision Support (LIAAD) that is part of INESC-TEC, with the current research interests:

- Inductive Logic Programming;
- Parallel Algorithms for Data Mining
- Data Mining and Machine Learning;
- Relational Data Mining;
- Applications of Chemoinformatics;
- Applications of Bioinformatics;
- Applications of Biomedicine.

### **Relevant publications in the last 5 years:**

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

- [1] A Deep Learning Approach to Infer Morphological Characteristics of the Heart from Cardiac Sound Analysis, Rui Camacho, Jorge Oliveira, and Luís Andrade, 13th International Conference on Bioscience, Biochemistry and Bioinformatics (ICBBB 2023) (Best presentation of Session 6)
- [2] Goncalves, CAO; Camacho, R ; Goncalves, CT; Vieira, AS; Diz, LB; Iglesias, EL; “Classification of Full Text Biomedical Documents: Sections Importance Assessment”, 2021, APPLIED SCIENCES-BASEL, vol. 11, N. 6
- [3] Michael A P Domingues; Rui Camacho ; Pedro Pereira Rodrigues; “CMIID: A comprehensive medical information identifier for clinical search harmonization in Data Safe Havens”; 2021; J. Biomed. Informatics, vol 114
- [4] Cavadas, B; Leite, M; Pedro, N; Magalhaes, AC; Melo, J; Correia, M; Maximo, V ; Camacho, R ; Fonseca, NA ; Figueiredo, C ; Pereira, L; “Shedding Light on the African Enigma: In Vitro Testing of Homo sapiens-Helicobacter pylori Coevolution”; 2021; MICROORGANISMS, vol 9, N. 2
- [5] Bruno Cavadas; Rui Camacho ; Joana C Ferreira; Rui M Ferreira; Ceu Figueiredo ; Alvis Brazma; Nuno A Fonseca ; Luisa Pereira; “Gastric Microbiome Diversities in Gastric Cancer Patients from Europe and Asia Mimic the Human Population Structure and Are Partly Driven by Microbiome Quantitative Trait Loci”; 2020, MICROORGANISMS, vol 8,N. 8
- [6] Mafalda Falcão Ferreira, MSc.; Rui Camacho; Luís Filipe Teixeira, “Using Autoencoders as a Weight Initialization Method on Deep Neural Networks for Disease Detection”, BMC Supplements, BMC MEDICAL INFORMATICS AND DECISION MAKING, vol 20, N. 5; 2020
- [7] Empowering Distributed Analysis Across Federated Cohort Data Repositories Adhering to FAIR Principles; Artur Rocha ; José Pedro Ornelas ; João Correia Lopes ; Rui Camacho ; 2019, ERCIM NEWS, vol 2019, N. 118
- [8] Comparative study of feature selection methods for medical full text classification;  
C Adriano Gonçalves, E Lorenzo Iglesias, L Borrajo, R Camaccho Bioinformatics and Biomedical Engineering: 7th International Work-Conference

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

He participated in various R&D projects:

- PRODUTECH SUSTENTÁVEL & CIRCULAR (POCI-01-0247-FEDER-046102) Soluções inovadoras, sustentáveis e circulares com impacto na fileira das tecnologias de produção.
- Safe Cities (POCI-01-0247-FEDER-041435)
- EUCAN\_CONNECT – Connecting Europe and Canada in personalized & preventive health care, H2020 project
- RECAP - “Research on European Children and Adults born Preterm“, H2020 project :
- E-COMAPERD - “European Comparative Effectiveness Research on Internet-based Depression Treatment”, H2020 project
- NanoStima (Norte2020) project
- ICE.Mobilidade (SI IDT – 13843/2011) projecto QREN;
- IC4Depression (projecto europeu).
- FCT project : ADE - Adverse Drug Effects Detection

Principal Investigator of the project: **ILP-Web-Service: An Inductive Logic Programming based Web service**

**Supervision of Graduate Students:**

Has supervised 3 Posdoc studnets, 62 MSc theses and 7 PhD theses. Currently supervises 4 PhD students and 4 MsC students.