

MAP-i  
Doctoral Programme in Computer Science

Engineering Web Applications  
Technologies Course

**Lecturing team**

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# Contents

<b>1</b>	<b>Programmatic Component</b>	<b>2</b>
1.1	Theme, Justification and Context . . . . .	2
1.2	Objectives and Learning Outcomes . . . . .	3
1.3	Detailed Program . . . . .	3
1.4	Teaching Methods and Student Assessment . . . . .	6
1.4.1	Classes . . . . .	7
1.4.2	Group Project . . . . .	7
1.5	Bibliographic References . . . . .	7
<b>2</b>	<b>Lecturing Team</b>	<b>9</b>
2.1	Team Presentation . . . . .	9
2.2	Coordinator . . . . .	10
2.3	Short Presentation of Team Members . . . . .	10
2.3.1	Jácome Cunha . . . . .	10
2.3.2	André Ferreira . . . . .	13
2.3.3	João Pascoal Faria . . . . .	14
2.3.4	João Saraiva . . . . .	17

# Chapter 1

## Programmatic Component

### 1.1 Theme, Justification and Context

Web applications are nowadays ubiquitous: in our personal computers, they are replacing traditional desktop applications; at work, they provide productive cooperative environments, and our smartphones and tablets were conceived with them in mind. This kind of applications delivers incredible services as commodities trading, personal items selling, news browsing, video streaming, social and professional networks, and much more!

Unfortunately, web application development typically suffers from the same issues that traditional software suffered a while ago. Indeed, not all web applications are conceived using development methods that are now standard in software development. This can lead to web applications with many problems ranging from poor usability to security issues.

This course addresses the development of web applications through well established and sound methodologies: software engineering principles are the stepping stones of this course. Instead of focusing on particular web technologies, languages, frameworks, which are inherently changing, we aim to provide well-known software engineering techniques applied to the development of web applications, whilst considering the particularities of the web realm.

In this document we describe the program, the programmatic content, and the teaching methods used in this course.

## 1.2 Objectives and Learning Outcomes

The course here presented aims to provide the foundations to develop the next generation of web applications. Instead of creating ad hoc applications this course provides students with safe and sound methodologies to create reliable web applications. In particular, it intends to address the preparation, design, implementation, analysis, evolution of world wide web applications. Upon successful completion of this curricular unit, students will be able to:

- plan, design, develop, deploy and maintain web applications;
- describe and critically discuss the issues surrounding web applications development;
- create reliable, usable, and accessible web applications;
- adapt to future developments in the world wide web by providing students with a solid grounding in its underlying concepts and principles.

## 1.3 Detailed Program

This course covers the following topics:

1. Technologies
2. Architectures for web applications
3. Development process
4. Requirements engineering
5. Web application design
6. Adaptation
7. Deployment and maintenance
8. Quality assessment

We describe in more detail the topics covered by this course:

## 1. **Technologies**

This topic is quite immense specially in the context of web applications. Moreover, it changes very quickly over time. Thus, instead of teaching a particular language or technology, we focus on the fundamental concepts of the web realm. We briefly discuss basic concepts as HTTP, HTML, dynamic HTML and client-side business logic, dynamic web page and server-side business logic, and web services and remote business logic. The main goal of this first unit is to ensure that all students have the basic knowledge about the world wide web.

## 2. **Architectures for web applications**

Web architecture has evolved in the last few years from monolithic components essentially representing a client and a server to a much more fine-grained level of micro-services where an application is composed of several (eventually hundreds) small services. In this unit we will discuss several possible web architectural patterns.

- Architectural modularity
- Micro services topology
- Service design and topology

## 3. **Development Process**

This unit addresses an overview of the software development process and its abstract instantiation to web applications. Also, we discuss particular processes for web development. Thus, the unit is structured into the following topics:

- Decomposing the software development process
- The web-specific software development process
- Instances of the web-specific software development process

## 4. **Requirements Engineering**

Requirements engineering is a discipline by itself and we do not intend to cover it all during this course. Nevertheless, to achieve the teaching goals it is necessary to introduce some of its concepts. In this unit, we will briefly focus on the following topics:

- Requirements collection

- Requirements analysis

## 5. Web Application Design

The main goal of web application design is to facilitate the understanding of the solution that is going to be developed by reasoning about it in an abstract way only models allow.

Indeed this is the core unit of this course. The ability of reasoning about a (web) application prior to its implementation is of paramount importance. The modelling language taught has a very precise semantics which allows to automatically generate a web application without writing any code. In fact, this is one of the goals of this course: to teach the high value of the abstract reasoning given by formal models.

The modelling language used is *IFML – The Interactive Flow Modeling Language* ([www.ifml.org](http://www.ifml.org)), the OMG standard for modelling user interaction.

Given the properties of the language and tools used, by the end of this unit, the students will be able to design applications and have them running without any code writing.

In this unit, we will focus on the following topics:

- Data design
- Hypertext models
- Hypertext design

## 6. Deployment and Maintenance

In this unit we discuss some typical aspects which must be considered deploying and maintaining web application. Rather than exhaustively analyse all the possible languages/frameworks or web servers we discuss some common decisions that must be taken during these stages. In this unit, we will briefly focus on the following topics:

- Deployment and installation
- Maintenance and evolution
- The role of model-driven design and industry solutions
- DevOps

## 7. Adaptation

Web applications often require tailoring to particular audiences. This may include changes to the language used, the kind of language, or personal preferences by their users. In this unit, we will focus on the following topics:

- Localization and internationalization
- Personalization, adaptation and context-awareness
- Accessibility and users with disabilities

## 8. Quality Assessment

Quality is a property all products must have. This is not different for software products, and in particular, to web applications. Given the model-driven approach used during this course, some benefits, for instance, for testing, can be obtained. In this unit, we will focus on the following topics:

- The need for quality models
- Testing web applications
- Usability evaluation
- Web design methods and quality assessment
- Automatic tools

# 1.4 Teaching Methods and Student Assessment

The best way to understand and master web software engineering is to experience it. In the educational setting, this means:

- to learn the fundamental concepts and principles of the web applications realm;
- to know and understand the solutions and practices proven to be the best, through the exploration of specific examples from the past, the so-called case studies; and
- to apply the knowledge acquired by imitating and adapting known solutions to a specific problem through hands-on development of a web application, in a group project.

### **1.4.1 Classes**

The class meetings are meant to be conversational, and we encourage students to ask questions and make comments. Consequently, the discussion may follow tangents to the prepared lecture, but they should be fruitful, informative, and thought provoking.

In the theoretical classes we use the expositive teaching method. When possible, this involves presenting examples and case studies.

In the practical classes we use the active teaching method so students can practice the knowledge discussed in the theoretical classes. Exercises from the real life will be used whenever possible.

### **1.4.2 Group Project**

Each group of students will be assigned a project which will be graded after an oral presentation (for a more methodological project) or a demonstration (for a more technological project), and a final written report.

Each group is expected to propose a project to work on. This allows students to work on projects for which they are motivated. A small description of such project will be demanded and assessed if useful for the students and the purpose of the course. If changes are necessary to accomplish the learning outcomes they will be proposed to students so they can evolve their initial proposal. The project descriptions should be intentionally vague, since this gives students considerable leeway in making design decisions. Having too specific descriptions would force students down a design path that they might not choose on their own. Regularly, students must complete a smaller part of their project, the one related to what they have learned in the classroom in the previous weeks. These partial achievements should be submitted to the lecturing team so that the students' work can be traced and they get constant feedback.

Once students complete their project, a demonstration or an oral presentation are due, as well as a final written report. The report has two major pieces: first, the discussion of the projects major design decisions and trade-offs; second, a section entitled "If I could do it all over again. . ." describing what they would do differently if they could have a second chance to start from the beginning.

## **1.5 Bibliographic References**

To support this course the following books are recommended:



- *Design patterns: elements of reusable object-oriented software*, Erich Gamma, Richard Helm , et al., 31 Oct 1994.
- *Designing Data-Intensive Web Applications*, Stefano Ceri, Piero Fraternali, Aldo Bongio, Marco Brambilla, Sara Comai, Maristella Matera, 2002, ISBN 978-1558608436, Morgan Kaufmann, The Morgan Kaufmann Series in Data Management Systems.
- *Engineering Web Applications*, Sven Casteleyn, Florian Daniel, Peter Dolog and Maristella Matera, 2009, ISBN 978-3-540-92200-1, Springer, DOI: 10.1007/978-3-540-92201-8.
- *Introduction to Software Testing*, J. Offutt and P. Amman, Cambridge University Press, 2008.
- *Just Enough Software Architecture: A Risk-Driven Approach*, George Fairbanks and David Garlan, 30 Aug 2010.
- *Patterns of Enterprise Application Architecture*, The Addison-Wesley Signature Series, Martin Fowler, 5 Nov 2002.
- *Practical Model-Based Testing: A Tools Approach*, B. Legeard and M. Utting. Morgan Kaufmann, 2006.
- *Refactoring: Improving the Design of Existing Code*, Martin Fowler, Kent Beck, John Brant, William Opdyke, Don Roberts, Addison-Wesley, 2000.
- *Software Architecture in Practice (SEI Software Engineering)*, Len Bass, Paul Clements, et al., 25 Sep 2012.

## Chapter 2

# Lecturing Team

### 2.1 Team Presentation

This course is supported by a team involving researchers from both the University of Porto, Faculty of Engineering (Jácome Cunha and João Pascoal Faria) and University of Minho, School of Engineering (André Ferreira - also with Bosch, Braga, and João Saraiva).

All team members are working, and have worked actively in the past few years, on topics that are directly related to the subjects covered by this course, as detailed below. Moreover, André Ferreira is a collaborator at Bosch, Braga, which will bring an industrial perspective to the course.

André Ferreira (`alferreira@di.uminho.pt`) has quite industrial experience with the course topics and will be responsible for topics 1 and 2.

João Pascoal Faria (`jpf@fe.up.pt`) has considerable experience designing and teaching courses on software engineering, and in particular, in software development processes. Thus, he will be responsible for topics 3 and 4.

Jácome Cunha (`jacome@fe.up.pt`) is an expert in model-driven engineering and thus he will cover topics 5 and 6. Moreover, he has experience teaching these topics in a MSc course.

João Saraiva (`saraiva@di.uminho.pt`) will be responsible for topics 7 and 8 given his experience with testing frameworks and teaching software quality courses.

### 2.2 Coordinator

The coordinator of the unit is Jácome Cunha.

## 2.3 Short Presentation of Team Members

In the sequel we introduce a brief presentation of each team member, which includes, for each of them, up to 5 key publications related to the scientific area in which this course is proposed.

### 2.3.1 Jácome Cunha

Jácome Cunha is an Associate Professor at Faculty of Engineering at University of Porto since September 2021. He obtained his PhD degree in Computer Science from University of Minho (Portugal) in 2011. He continued his career as a post-doc fellow in a joint project, started by him, between University of Minho and Oregon State University (USA). Jácome Cunha was also an Invited Adjunct Professor at Polytechnic Institute of Porto, School of Technology and Management (Portugal), from March 2010 to June 2014. From July 2014 to January 2018 he was an Assistant Professor at Nova University of Lisbon and February 2018 until August 2021 he was an Assistant Professor at University of Minho.

His research is mainly focused on programming languages and software engineering, where he devises methodologies to improve the effectiveness, efficiency, and usability of software, with a special focus on software for non-professional programmers. Most of his work is based on model-driven engineering methodologies. More recently, he started to work on techniques for detecting and improving the energy efficiency of software.

Jácome Cunha was a member of the several research projects, including “PURE - Program Understanding and Re-engineering: Calculi and Applications”, “SSaAPP - SpreadSheets As A Programming Paradigm”, and “FATBIT - Foundations, Applications and Tools for Bidirectional Transformation”. Currently, he is a member of the projects “GreenSoftwareLab - Towards an Engineering Discipline for Green Software”, and “CLAY - An Environment for Live Construction of Trustworthy Software”. All these projects were/are funded by the Portuguese Science Foundation (FCT). He is also the principal investigator (PI) of the bilateral project “Spreadsheet Model for the Real World”, a collaboration between Portugal and Germany, funded by FCT. He is also the PI of the joint project “Towards Variational Software, Types, and Spreadsheets”, a collaboration between Portugal and the USA, funded by the FLAD foundation.

He was co-general chair of VL/HCC 2018 organized in Lisbon, Portugal. He was also a member of the organizing committee of the Summer

School GTTSE 2011 and 2015, EICS 2018 and RE 2018. He has also served as an (external) Program Committee member of important conferences within the scope of his research, including the HASKELL'09, SLE'11/13, PEPM'12, LDTA'12, ECMFA'13, SBLP'13/14, VL/HCC'16/17/19, SEMS'14/15/17, ICCSA'14, UIST'14, CHI'15/16, EICS'15, INTERACT'15, MODELS'16, OOP-SLA'16, CibSE'17, RE'18. Moreover, he served as a reviewer for several journals, including the Journal of Visual Languages and Computing (JVLC), Journal of Data & Knowledge Engineering (DKE), Journal of Empirical Software Engineering (ESE), Journal of Automated Software Engineering (ASE), IEEE Computer, IEEE Software, Journal of Software: Evolution and Process, Journal of Logical and Algebraic Methods in Programming (JLAMP), Software Quality Journal (SQJ), Journal of Computer Languages, Systems and Structures (ComLan), IEEE Transactions on Software Engineering (TSE), Journal of Systems and Software (JSS) and Science of Computer Programming (SCP).

He co-supervised two PhD student, Jorge Mendes, working on “Design, Implementation and Evaluation of Model-Driven Spreadsheets”, and Rui Pereira, working on “Energyware Engineering: Techniques and Tools for Green Software Development”. He successfully (co-)supervised 16 MSc students, and currently supervises two.

Jácome Cunha has about 10 years experience teaching courses on programming for novice students, secure programming, modelling software, web development, formal methods or spreadsheet engineering. He has taught these courses for undergrad, to MSc, and to PhD students and also in international summer schools.

## Key Publications

- Jácome Cunha, João P. Fernandes, Jorge Mendes, João Saraiva. *Embedding, Evolution and Empirical Validation of Model-Driven Spreadsheets*. IEEE Transactions on Software Engineering (TSE), Volume 41, Number 3, Pages 241-263, IEEE, 2015.
- José Nuno Macedo, Ricardo Moreira, Jácome Cunha, João Saraiva. *Get Your Spreadsheets Under (Version) Control* In Proceedings of the 22th IberoAmerican Conference on Software Engineering (CibSE'19) – Software Engineering Track, (Havana, Cuba, April 22-26, 2019), Curran Associates, 2019.
- Rui Pereira, Pedro Simão, Jácome Cunha, and João Saraiva. *jStanley: Placing a Green Thumb on Java Collections (tool demo)* In Proceed-

ings of the 33rd IEEE/ACM International Conference on Automated Software Engineering (ASE'18) (Montpellier, France, September 3-7), 2018. 856-859.

- Jorge Mendes, Jácome Cunha, Francisco Duarte, Gregor Engels, João Saraiva, Stefan Sauer *Systematic Spreadsheet Construction Processes*. In Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'17), (Raleigh, North Carolina, USA, October 11-14, 2017), IEEE, 2017. 123-127.
- João Campinhos, João Costa Seco, Jácome Cunha. *Type-Safe Evolution of Web Services*. In Proceedings of the 2nd International Workshop on Variability and Complexity in Software Design (VACE'17), co-located with ICSE 2017. (Buenos Aires, Argentina, May 20-28, 2017). 2017. 20-26.
- Jácome Cunha, João P. Fernandes, Jorge Mendes, João Saraiva. *Spreadsheet Engineering*. Revised Selected Papers of the 5th Summer School Central European Functional Programming School, CEFP'13, Cluj-Napoca, Romania, July 8-20, 2013, LNCS, Springer, 2015. 246-299

#### **Funded Projects (last 5 years)**

- *Modeling Socio-Cyber-Physical Systems*, under bilateral FCT contract 441.00, 2018-2019.
- *Software Repositories for Green Computing*, under bilateral FCT contract 300/2015, 2016-2017.
- *GreenSoftwareLab – Towards an Engineering Discipline for Green Software*, under FCT contact PTDC/EEI/5341/2014, 2016-2019.
- *CLAY – An Environment for Live Construction of Trustworthy Software*, under FCT contract PTDC/EEI-CTP/4293/2014, 2016-2019.
- *Spreadsheet Models for the Real World*, principal investigator, under bilateral FCT contract 441.00, 2015-2016.
- *Towards Variational Software, Types, and Spreadsheets*, principal investigator, under FLAD contract 233/2014, 2015-2016.

### **(Co-)Supervision of PhD projects**

- Jorge Mendes, *Design, Implementation and Evaluation of Model-Driven Spreadsheets*, University of Minho, 2017.
- Rui Pereira, *Energyware Engineering: Techniques and Tools for Green Software Development*, University of Minho, 2018.

### **2.3.2 André Ferreira**

André Ferreira is an Engineering Manager at Bosch Car Multimedia S.A. and his main responsibility is to lead a systems engineering unit for embedded and cloud based systems. He worked for 12 years in safety critical domains of avionics, aerospace and automotive. Other responsibilities include ensuring collaboration of managed teams across different geographical locations, setting goals and development targets for the engineering unit, coordinate and collaborate in the staffing, coaching and managing a group of engineers. He graduated in Systems and Informatics Engineering in 2007 and obtained his PhD degree in Computer Science from University of Minho (Portugal) in 2016. He is also an Invited Assistant Professor at University of Minho since 2014.

His research focus is on software engineering methods, where he developed methodologies to assess and improve quality of software development processes. More recently, he also initiated work on methods to develop intelligent system for computer vision namely applying machine learning and deep learning techniques for object detection and human action recognition.

He co-supervises one PhD student, Karam Ignaim, working on “Evolutionary Approach for Adopting Software Product Lines in Automotive Industry”. He successfully (co-)supervised 12 MSc students, and currently supervises 4 students.

### **Key Publications**

- Nova, D., Ferreira, A., Cortez, Paulo. *A Machine Learning Approach to Detect Violent Behaviour from Video*. Intelligent Technologies for Interactive Entertainment. In P. Cortez, L. Magalhães, P. Branco, C. F. Portela, T. Adão (Eds.) (pp. 85–94). Cham: Springer International Publishing. 2018.
- Ribeiro, F., Ferreira, A. L., Tereso, A., Perrotta, D. *Development of a Grooming Process for an Agile Software Team in the Automotive Domain*

BT - Trends and Advances in Information Systems and Technologies. In Á. Rocha, H. Adeli, L. P. Reis, S. Costanzo (Eds.) (pp. 887–896). Cham: Springer International Publishing (2018).

- A. Vilaca, P. Cunha and A. L. Ferreira, *Systematic Literature Review on Driving Behavior*, 2017 IEEE 20th International Conference on Intelligent Transportation Systems (ITSC), Yokohama, 2017, pp. 1-8.
- Cunha, Pedro., Ferreira, André L., Cortez, Paulo. *Mining Rational Team Concert Repositories: A Case Study on a Software Project* In E. Oliveira, J. Gama, Z. Vale, H. Lopes Cardoso (Eds.), *Progress in Artificial Intelligence* (pp. 537–548). Cham: Springer International Publishing. (2017).
- Pedro Oliveira, André L. Ferreira, et.al. *An Analysis of the Commonality and Differences Between ASPICE and ISO26262 in the Context of Software Development* In J. Stolfa, S. Stolfa, R. V O'Connor, R. Messnarz (Eds.), *Systems, Software and Services Process Improvement* (pp. 216–227). Cham: Springer International Publishing. (2017)

#### **(Co-)Supervision of PhD projects**

- Karam Ignaim, *Evolutionary Approach for Adopting Software Product Lines in Automotive Industry*, University of Minho, 2021.

#### **2.3.3 João Pascoal Faria**

João Pascoal Faria holds a PhD in Electrical and Computer Engineering from FEUP (1999), with a thesis on “Data-Driven Active Rules for the Maintenance of Derived Data and Integrity Constraints in Interactive Database Applications”. He is currently Associate Professor at FEUP in the Software Engineering Group, senior researcher at INESC TEC, and President of the Sectorial Commission for Information and Communications Technology (CS/03) in the scope of the Portuguese Quality Institute (IPQ). He has around 30 years of research & development experience in software engineering, specializing in model-driven software engineering, model-based testing and software process improvement. He is the main author of a rapid application development tool (SAGA), based on domain specific languages, with 30 years of market presence and evolution (1989-present). He supervised or co-supervised approximately 50 master thesis and 5 PhD thesis concluded. He published more than 60 articles in international journals

and conferences on several software engineering topics, he served as chair of several conferences and reviewer for several journals and conferences.

### **Key Publications**

- Mushtaq Raza, João Pascoal Faria, Rafael Salazar, *Assisting software engineering students in analyzing their performance in software development*, Software Quality Journal: 1-29, 2019.
- João Soares, Bruno Lima, João Pascoal Faria, *Automatic Model Transformation from UML Sequence Diagrams to Coloured Petri Nets*, In Proceedings of the 6th International Conference on Model-Driven Engineering and Software Development, MODELSWARD 2018, Funchal, Madeira - Portugal, January 22-24, 2018.
- Mushtaq Raza, João Pascoal Faria, *A model for analyzing performance problems and root causes in the Personal Software Process*, Journal of Software: Evolution and Process, vol. 28, Issue: 4, pp 254-271, John Wiley & Sons, April 2016.
- João Pascoal Faria, Ana C. R. Paiva, *A Toolset for Conformance Testing against UML Sequence Diagrams based on Event-Driven Colored Petri Nets*. International Journal on Software Tools for Technology Transfer, December 2014.
- António Miguel Cruz, João Pascoal Faria, *A Metamodel-based Approach For Automatic User Interface Generation*, In MODELS'10 Proceedings of the 13th International Conference on Model Driven Engineering Languages and Systems (pp. 256-270), Berlin, Germany: Springer-Verlag, 2010 (*best paper award*).

### **Funded Projects (last 5 years)**

- PROMESSA – *PROject ManagEment intellingent aSSistAnt*, under P2020 contract n. 039887, 2019-2022.
- *SafeCities – Building Urban Safety*, under contract POCI-01-0247-FEDER-041435, 2019-2022.
- *NanoSTIMA – Macro-to-Nano Human Sensing: Towards Integrated Multimodal Health Monitoring and Analytics*, under Norte2020 contract NORTE-01-0145-FEDER-000016, 2015-2019.



- *Simprove – The biomedical simulation centre of the future*, under contract NORTE-01-0247-FEDER-017566, 2017-2019.
- *AIMS2 – Accelerated Improvement Method Support 2*, under contract POCI-01-0247-FEDER-006405, 2015-2017.
- *BESTCASE-RL1-SIBILA – Towards Smart Interacting Blocks that Improve Learned Advice*, under ON.2 contract NORTE-07-0124-FEDER-000059, 2013-2015.
- *PBGT: Pattern-based Testing of Graphical User Interfaces*, under FCT contract PTDC/EIA-CCO/119479/2010, 2012-2015.
- *AutoSeer: Automated Test Oracles for Software Error Detection*, under FCT contract PTDC/EIA-CCO/116796/2010, 2012-2015.
- *AAL4ALL: Padrão de Cuidados Primários para serviços de AAL*, under contract SI IDT - 13852/2011, 2011-2015.
- *AIMS – Accelerated Improvement Method Support*, under contract SI IDT - 21562/2011, 2011-2014.

#### **(Co-)Supervision of PhD projects**

- Bruno Miguel Carvalhido Lima, *Automated Scenario-based Testing of Distributed and Heterogeneous Systems*, PRODEI, Faculty of Engineering of the University of Porto, ongoing, FCT grant SFRH/BD/115358/2016. (PhD supervisor)
- João Pedro Matos Teixeira Dias, *A Live Approach for Developing Internet-of-Things Systems*, PRODEI, Faculty of Engineering of the University of Porto, ongoing. (PhD co-supervisor)
- Mushtaq Raza, *Automated Software Process Performance Analysis and Improvement Recommendation*, MAP-i, Faculty of Engineering of the University of Porto, awarded June 2017, FCT grant SFRH/BD/85174/2012. (PhD supervisor)
- Inês Coimbra Morgado, *Automated Pattern-Based Testing of Mobile Applications*, Faculty of Engineering of the University of Porto, awarded January 2017, FCT grant. (PhD co-supervisor)

- António Miguel Cruz, *Automatic Generation of User Interfaces from Rigorous Domain and Use Case Models*, Faculty of Engineering of the University of Porto, awarded January 2011. (PhD supervisor)
- Ana C. R. Paiva, *Automated Specification-Based Testing of Graphical User Interfaces*, Faculty of Engineering of the University of Porto, awarded February 2007. (PhD co-supervisor)
- Maria Clara dos Santos Pinto Silveira, *A Reutilização de Requisitos no Desenvolvimento e Adaptação de Produto de Software*, Faculty of Engineering of the University of Porto, awarded April 2006. (PhD co-supervisor)

#### 2.3.4 João Saraiva

João Saraiva is an Associate Professor at the Department of Informatics, Universidade do Minho, and a researcher member of HASLab/INESC TEC. He obtained a MSc degree from University do Minho in 1993 and a Ph.D. degree in Computer Science from Utrecht University in 1999. His main research contributions have been in the field of program language design and implementation and in program analysis and transformation. He counts with over 50 international publications in this area and he has served in over 25 programme committees of international events.

He has experience in participating, coordinating and evaluating research projects in this area, both at national level with projects funded by FCT (projects: PURE, IVY, AMADEUS, CROSS, SSaaPP, FATBIT and GSL) and at international level with projects: "Embedded Attribute Grammars" funded by EPSRC - The Engineering and Physical Sciences Research Council, UK, contract GR/S02266/01 (project developed at Oxford Computing Laboratory with Prof. Dr. Oege de Moor), and "Applied Semantics II" an European Union Thematic Network, EU contract IST-2001-38957 (where the he was the site coordinator). He was in the evaluation committees of the grant agencies: ANII *Agencia Nacional de Investigación e Innovación*, Uruguay (Fondo Clemente Estable 2007 (FCE 2007), and NWO - Netherlands Organisation for Scientific Research (Physical Sciences division of the Free Competition, in astronomy, computer science or mathematics, 2009) and the Austrian Science Fund (FWF).

João Saraiva is one of the founders of the successful series of summer schools on Generative and Transformational Techniques in Software Engineering (GTTSE), organized in 2005, 2007, 2009, 2011, and 2015 (volumes 4143, 5235, 6491, 7680 and 10223 of LNCS - Tutorial by Springer-Verlag) in

Braga. He was the organizing chair of ETAPS'07, The European Joint Conferences on Theory and Practice of Software, organized in Braga in 2007.

### Key Publications

- Rui Pereira, Marco Couto, Francisco Ribeiro, Rui Rua, Jácome Cunha, João Paulo Fernandes, João Saraiva, *Energy efficiency across programming languages: how do energy, time, and memory relate?* SLE 2017: 256-267
- Jácome Cunha, Martin Erwig, Jorge Mendes, João Saraiva. *Model inference for spreadsheets*. Journal on Automated Software Engineering 23(3): 361-392 (2016)
- Rui Pereira, Marco Couto, João Saraiva, Jácome Cunha, João Paulo Fernandes, *The influence of the Java collection framework on overall energy consumption*, Proceedings of the 5th International Workshop on Green and Sustainable Software, GREENS@ICSE 2016, Austin, Texas, USA. 2016: 15-21. ACM Press.
- Jácome Cunha, João Paulo Fernandes, Jorge Mendes, João Saraiva, *Embedding, Evolution, and Validation of Model-Driven Spreadsheets*. IEEE Transactions on Software Engineering 41(3): 241-263 (2015)
- Jácome Cunha, João Paulo Fernandes, Jorge Mendes, João Saraiva, *MDSheet: A Framework for Model-driven Spreadsheet Engineering*, In the Proceedings of the 34th International Conference on Software Engineering (ICSE' 12), Formal Demonstration, Zurich, Switzerland, pages 1412-1415, June 2012.
- Don S. Batory, Maider Azanza, João Saraiva, *The Objects and Arrows of Computational Design*, 11th International Conference on Model Driven Engineering Languages and Systems (MoDELS 2008), Toulouse, France, September 2008, volume 5301 of LNCS, pag. 1-20, Springer.

### Funded Projects (last 5 years)

- *GreenSoftwareLab: Towards an Engineering Discipline for Green Software*, under FCT contract PTDC/EEI-ESS/5341/2014. 2016-2019. (Principal Investigator)
- *Towards a Software Engineering Discipline for Green Software*, 2016-2017 FCT/Slovakia bilateral agreement (ref.: 441).

- *Software Repositories for Green Computing*, Funded by FLAD/NSF program "Portugal - EUA: Parcerias e Rede para Investigação 2015" through a project grant (ref. 300/2015), in collaboration with Crista Videira Lopes from University of California at Irvine, USA.
- *AutoSeer: Automated Test Oracles for Software Error Detection*, under FCT contract PTDC/EIA-CCO/116796/2010. 2012-2015.
- *FATBIT: Foundations, Applications and Tools for Bidirectional Transformation*, under FCT contract FCOMP-01-0124-FEDER-020532. 2012-2014.
- *Strictification of Circular Programs*, FCT/DAAD bilateral agreement 2010-2011. (Principal Investigator)
- *SSaaPP: SpreadSheets as a Programming Paradigm*, under FCT contract PTDC/EIA-CCO/108613/2008. 2010-2013. (Principal Investigator)
- *CROSS: - An Infrastructure for Certification and Re-engineering of Open Source Software*, under FCT contract PTDC/EIA-CCO/108995/2008. 2010-2013.

#### **(Co-)Supervision of PhD projects**

- Rui Rua, *The GreenSource Repository* University of Minho, since September 2018. (Post-doc supervisor)
- José Nuno Macedo, *Automatic Generation of Program Executions*, University of Minho, since September 2018. (PhD supervisor)
- Marco Couto, *Greenaware Software Product Lines* University of Minho, since September 2014. (PhD supervisor)
- Rui Pereira, *Design, Implementation and Evaluation of Model-Driven Spreadsheets*, FCT grant SFRH/BD/112733/2015, University of Minho, awarded in October 2018.
- Jorge Mendes, *Energyware Engineering: Techniques and Tools for Green Software Development*, FCT grant SFRH/BD/112651/2015), University of Minho, awarded in February 2018. (PhD supervisor)
- Pedro Martins, *Embedded Attribute Grammars*, University of Minho, awarded in July 2014. (PhD supervisor)

- Jácome Cunha, *Foundations of Spreadsheets*, FCT grant SFRH/BD/30231/2006, University of Minho, awarded in March 2011. (PhD supervisor)
- João Carlos Cardoso Silva, *Formal Methods and Reverse Engineering Applied to Interactive Systems*, FCT grant SFRH/BD/30729/2006, University of Minho, awarded in December 2010. (PhD supervisor)
- João Paulo Fernandes, *Design, Implementation and Calculation of Circular Programs*, FCT grant SFRH/BD/19186/2004, University of Minho, awarded in March 2009. (PhD supervisor)
- Fábio Tirelo, *Semântica Multidimensional de Linguagens de Programação*, Departamento de Informática, Universidade do Federal de Minas Gerais, Belo Horizonte, Brazil, awarded in March 2009. (PhD co-supervisor)