

# Automata and Applications

Seminário Temático (SEMT)

DCC-FCUP

April 2008

## Abstract

This is a proposal for a Thematic Seminar (SEMT) in the context of the joint PhD program (Minho,Aveiro,Porto) in Informatics (Map-I). The the team responsible for the proposal consists of lecturers from the Computer Science Department, Faculty of Science of the University of Porto.

## 1 Lecturing Team

Nelma Moreira and Rogério Reis

## 2 Course Description

### 2.1 Subject and Context

Automata theory (AT) is one of the foundations of Computer Science and its applications extend to several areas of computer science. Among other recent areas of application of the Automata Theory are computational linguistics, bioinformatics, specification and verification of reactive systems, structured and semi-structured databases, network security, etc. Intensively studied during mid XX's, in the last decade there has been a growing and confluent interest in its theoretical and practical research: the exploration of specific new models and applications has at the same time stimulated a variety of new theoretical studies and formalizations.

In this seminar we will consider regular languages and its extensions to infinite words and regular trees. It is important to note that many algorithms and results for these models reduce or extend similar ones for classical finite automata.

Although regular languages are one of the simplest computer science structures and with widespread uses, several aspects of its descriptive complexity are unknown or not well understood. For instance, the non injective and non complexity preserving conversions between equivalent combinatorial representations and the descriptive complexity of generic languages operations. On the other hand, the enumeration of languages based on their model representations are useful for random generation and average-case analysis.

The first part of the seminar reviews the basics of finite automata over finite words with emphasis in the existence of normal forms, enumeration and conversions between equivalent language representations and their succinctness. We also introduce weighted automata and see how the standard finite automata algorithms extend to them.

The second part considers automata over infinite words and trees and briefly presents the main results about conversions and decidability problems.

The third part focus in some recent applications of automata-theoretical approaches in three different areas. Since the seminar Büchi theorem relating finite automata with monadic second order logic, automata have been successfully applied in many different logical contexts and specially with modal and temporal logics. These logics are particularly adequate for automatic verification of reactive systems. Weighted automata approaches were successfully applied in speech recognition and image processing to deal with probabilistic reasoning. Finally, tree automata and finite automata are theoretical bases for XML technologies such as schemas, transformations and query languages.

Considering the courses available in the Map-i program 2007 edition this seminar will be specially interesting for students attending the courses of *Program Semantics, Verification, and Construction, Model-driven Software Engineering* and *Computer Vision*.

## 2.2 Objectives

This SEMT aims

- to present some recent research work in descriptive complexity of

regular languages and to consider some open problems.

- to present some extended automata models and see how the classical theory extends to them.
- to present recent applications of automata theory to other computer science areas, such as specification and verification of reactive systems, XML processing, computational linguistics, etc.

## 2.3 Syllabus

- Part I: Automata on finite words (4h)
  1. Regular languages and its representations: regular expressions, deterministic finite automata (DFA), non-deterministic finite automata (NFA)
  2. Enumeration and random generation of some classes of DFAs
  3. Conversions between equivalent language representations and their succinctness
  4. Alternating automata
  5. Weighted automata (automata with multiplicities)
- Part II: Automata on infinite words and trees (2h)
  1. Büchi automata
  2. Müller automata
  3. Alternating automata
  4. Tree automata
- Part III: Applications (2h)
  1. Verification of reactive Systems
    - (a) Temporal logics
    - (b) Automata-theoretic approach to decidability
    - (c) Model Checking
  2. XML processing
    - Tree languages and schemas

- XML language containment
- 3. Speech recognition and image processing
  - Weighted transducers
  - Weighted automata for image compression

## 2.4 Student Assessment

Research assignment, which may be a report on a given topic.

## 2.5 Recommended Bibliography

## References

- [AMR07a] M. Almeida, N. Moreira, and R. Reis. Enumeration and generation with a string automata representation. *Theoretical Computer Science*, 387(2):93–102, 2007.
- [AMR07b] M. Almeida, N. Moreira, and R. Reis. Exact generation of minimal acyclic deterministic finite automata. In *Workshop on Descriptive Complexity of Formal Systems (DCFS07)*, pages 57–68, High Tatras, Slovakia, 20-22/07 2007.
- [EMVM06] Z. Esik, C. Martín-Vide, and V. Mitrană, editors. *Recent Advances in Formal Languages and Applications*. Springer-Verlag, 2006.
- [GTW02] E. Grädel, W. Thomas, and T. Wilke, editors. *Automata, Logics, and Infinite Games*. Springer-Verlag, 2002.
- [KN01] B. Khoussainov and Anil Nerode. *Automata Theory and its Applications*. Birkhäuser, 2001.
- [Lot05] M. Lothaire. *Applied Combinatorics on Words*. Number 105 in Encyclopedia of Mathematics and its Applications. Cambridge University Press, 2005.
- [Rei07] R. Reis. *Autómatos:manipulação, geração e enumeração*. PhD thesis, Faculdade de Ciências da Universidade do Porto, 2007.

- [RMA05] R. Reis, N. Moreira, and M. Almeida. On the representation of finite automata. In C. Mereghetti, B. Palano, G. Pighizzini, and D. Wotschke, editors, *Proc. of DCFS'05*, Rap. Tec. DICO, Univ. di Studi Milano, pages 269–276, Como, Italy, 2005. IFIP.
- [Sak03] J. Sakarovitch. *Éléments de théorie des automates*. Vuibert Informatique, 2003.

### 3 Lecturing Team

Both proponents of this seminar have worked actively in the past few years, on topics that are directly related to the subjects covered by this seminar, as detailed below.

In the context of this seminar, we also would like to have the opportunity to invite an internationally recognized researcher amongst one of the following: Jacques Sakarovitch (ENST, Paris, main topic of research is Automata with multiplicities), Jean-Éric Pin (Director of LIAFA, Paris, the topic could be Automata and Infinite Words) or Sheng Yu (University of Western Ontario, Canada, the topic could be Descriptive Complexity of Regular Languages).

- Nelma Moreira has worked in Automata Theory, Modal Logics, Verification and Logic Programming.
- Rogério Reis, Phd in Automata Theory and has also worked in Cryptography and Combinatorics.

Both proponents are team members of the project ASA (*Automata, Semigroups and Applications*, FCT/PTDC/MAT/65481/2006) which aims to contribute to the development of the theories of automata and semigroups, and some of their applications. They are also team members of the project RESCUE (*Reliable and Safe Code Execution for Embedded Systems*), FCT/PTDC/EIA/65862/2006, where they aim to apply automata-theoretical techniques to verification in the context of PPC (Proof-Carry Code).

# CURRICULUM VITAE

NELMA RESENDE ARAÚJO MOREIRA

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## ADDRESS

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Homepage: <http://www.ncc.up.pt/~nam>

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## PERSONAL DATA

Birth date: 4/06/1961  
Birth place: Paris, France  
Nationality: PORTUGAL

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## ACADEMIC DEGREES

1997	PhD. in Computer Science, Universidade do Porto.
1989	Provas de Aptidão Pedagógica e Capacidade Científica, Universidade do Porto.
1984	Degree in Applied Mathematics, FCUP.

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## ACADEMIC POSITIONS

1997-	Lecturer, Departamento de Ciência de Computadores da FCUP.
1996-1997	Assistant, Departamento de Ciência de Computadores da FCUP.
1989-1996	Assistant, Grupo de Matemática Aplicada da FCUP.
1984-1989	Teacher Assistant, Grupo de Matemática Aplicada da Faculdade de Ciências da Universidade do Porto (FCUP)

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## PRESENT RESEARCH INTERESTS

Automata Theory and formal languages  
Symbolic constraint programming  
Interactive proof assistants and program verification  
Semi-structured documents

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## SUPERVISION OF DIPLOMA THESES

- |      |   |
|------|---|
| 2007 | <i>Desenvolvimento de tecnologias XML para a indexação e pesquisa em documentos</i> , by Norberto Machado Lopes (Co-supervision with Rogério Reis). |
| 2007 | <i>Analizador Sintático GLR para o Yappy</i> , by Ricardo Leite (Co-supervision with Rogério Reis).   |
| 2006 | <i>Ferramentas para geração e enumeração de linguagens regulares</i> , by Marco Almeida (Co-supervision with Rogério Reis).                         |
| 2005 | <i>Ferramentas WEB para acesso a um thesaurus</i> , by Marina Sofia Campos Sousa.   |
| 2005 | <i>Interface gráfico para a edição e a visualização de autómatos finitos</i> , by Vera João (Co-supervision with Rogério Reis).                     |
| 2004 | <i>Sistema de informação para a gestão de pessoas e actividades da UPP</i> , by Vitor Hugo Lopes Félix.   |
| 2003 | <i>Automatic: editor de diagramas de autómatos finitos</i> , Pedro Ângelo (Co-supervision with Rogério Reis).                                       |
| 2001 | <i>Desenvolvimento Centro de Informação da Universidade Popular do Porto</i> , by Luís Pessoa.  |
| 1998 | <i>Gestão da base de dados da biblioteca do CIUP (DCC e LIACC)</i> , by Raquel Maria Castro da Silva.   |
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## MASTER THESES SUPERVISION

- |      |   |
|------|---|
| 2007 | <i>Logic frameworks for reasoning about emotions in BDI Agents</i> . David Pereira, Mestrado em Informática, FCUP, 5/2007 (Co-supervision with Eugénio Oliveira). |
| 2006 | <i>GerExa: uma plataforma para a manipulação de exercícios e exames em XML</i> . Ângela Oliveira, Mestrado em Informática, FCUP, 1/2006.                          |

	<i>Specification of a Language for Timetabling Problems</i> , Dora Melo, Mestrado em Informática, FCUP,12/2006. (Co-supervision with João Pedro Pedroso and Rogério Reis)
2005	<i>Obtenção de expressões regulares pequenas a partir de autómatos finitos</i> , José João Gonçalves Morais, Mestrado em Informática, Faculdade de Ciências da Universidade do Porto, (Co-supervision with Rogério Reis)
In preparation	<i>Solving Math Drills Automatically</i> , Nuno Pereira. Mestrado em Informática. (co-supervision with Ana Paula Tomás)

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#### PHD THESES SUPERVISION

2006-2009	<i>Caracterização da complexidade descritiva de linguagens regulares</i> . Marco Almeida. PhD Thesis (co-supervision with Rogério Reis)
2008-2011	<i>Mobile code security based on Kleene algebras and temporal logics</i> . David Pereira. PhD Thesis - MAP-i program 2007, (co-supervision with Simão Sousa)

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#### PARTICIPATION IN RESEARCH PROJECTS

Team member of the following projects:

2008–2011	Project RESCUE <i>Reliable and Safe Code Execution for Embedded Systems</i> (FCT/PTDC/EIA/65862/2006), funded by FCT.
2007–2010	Project ASA <i>Automata, Semigroups and Applications</i> , (PTDC/MAT/ 65481/ 2006), funded by FCT.
2007–2008	Project <i>Education and Language in Memories of Labour</i> , IPG 118, integrated in the contest <i>Investigação Científica na pré-graduação</i> , Universidade do Porto, (coordinator).
2006–2008	Project "Memórias do Trabalho", Project POCI/ CED/ 60786/ 2004 funded by FCT.
2003–2006	Project AGILMAT - Automatic Generation of Interactive Drills for Mathematics Learning, Project POSI/ CHS/ 48565/ 2002, funded by Fundação para a Ciência e Tecnologia , POSI and FEDER.



2006	Project ‘Memórias e Vivências de Trabalhadores Têxteis do Porto - Condições de Vida e de Trabalho na Indústria Têxtil’, ‘Investigação Científica na pré-graduação’ da Universidade do Porto.
1999–2001	Project ”CORE: Sistemas Formais e Complexidade Computacional”, PRAXIS/ P/ EEI/ 14233/ 98, FCT.
1999–2001	Project ”Ganesh: Ambiente Modular e Distribuído de Ensino de Ciência de Computadores”, PRAXIS/ P/ EEI/ 14232/ 98, FCT.
1994–1997	Project ”PROLOPPE: Programação em Lógica Paralela com Extensões”, do LIACC e CENTRIA (U.N.L), JNICT (Praxis 3/3.1/TIT/24/94).
1989–1991	Project ”Constraint Logic Grammars”, Universidade do Porto and CCE
1988–1990	Project ”Eurotra”, CCE.
1987–1988	Project ”Interfaces Naturais para Acesso a Bases de Dados”, FCUP and INESC-Norte.
1988–1989	Project ”Processamento de Linguagem Natural”, Centro de Informática da Universidade do Porto - INIC.

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## PUBLICATIONS

### Thesis

1. Restrições Complexas sobre Álgebras de Árvores e Aplicação a Gramáticas Lógicas. PhD thesis, Universidade do Porto, 1997.
2. Representação de semântica de referências temporais em linguagem natural. Master's thesis, Universidade do Porto, Outubro 1988. Apresentado à Universidade do Porto no âmbito das Provas de Aptidão Pedagógica e Capacidade Científica.

### Books (editor)

Natural Language Processing, EAIA 90. LNAI 476, Springer-Verlag.1991 (with M. Filgueiras, L.Damas and A.P.Tomás eds)

## Chapters in books

1. The formal and computational theory of complex constraint solution. In C. Rupp, M. A. Rosner, and R. L. Johnson, editors, *Constraints, Language, and Computation, Computation in Cognitive Science*, pages 149-166. Academic Press, London, 1994.(with Luis Damas and Giovanni Varile)
2. Miguel Filgueiras, N. Moreira, and A. P. Tomás, General introduction. In M. Filgueiras et al. (eds.), *Natural Language Processing – EAIA’90 Proceedings. Lecture Notes in Artificial Intelligence*, 476, 1-3, ©Springer-Verlag, 1991.

## Papers in international scientific periodicals with referees

1. Marco Almeida, Nelma Moreira, and Rogério Reis. Exact generation of minimal acyclic deterministic finite automata. *International Journal of Foundations of Computer Science*. Accepted for publication, 2008.
2. Marco Almeida, Nelma Moreira, Rogério Reis. Enumeration and Generation with a String Automata Representation. *Theoretical Computer Science*. 387(2):93-102, 2007. Special issue "Selected papers of DCFS 2006".
3. Nelma Moreira and Rogério Reis, On the density of languages representing finite set partitions. *Journal of Integer Sequences*, 8, 05.2.8, 2005. MR2152288 (Math Reviews).

## Papers in conference proceedings

1. Silvestre Lacerda, Norberto Lopes, Nelma Moreira, Rogério Reis. A Toolkit for an Oral History Digital Archive Actas XATA 2008, XML: aplicações e tecnologias associadas. José Carlos Ramalho, João Correia Lopes (eds.). Universidade de Évora, 14-15/2, 2007.
2. David Pereira, Eugénio Oliveira, and Nelma Moreira. Formal Modelling of Emotions in BDI Agents. Eighth Workshop on Computational Logic in Multi-Agent Systems (CLIMA-VIII), Porto, Portugal, 10-11/09/2007.
3. Marco Almeida, Nelma Moreira, and Rogério Reis. Exact generation of minimal acyclic deterministic finite automata. Workshop on Descriptive Complexity of Formal Systems (DCFS07), High Tatras, Slovakia, 20-22/07/2007
4. Silvestre Lacerda, Norberto Lopes, Nelma Moreira, Rogério Reis. Ferramentas para a Construção de Arquivos Digitais de História Oral. Actas XATA 2007, XML: aplicações e tecnologias associadas. José Carlos Ramalho, João Correia Lopes e Luís Carriço (eds.). Universidade de Lisboa, ISBN 978-972-99166-4-9, 2007.

5. David Pereira, Eugénio Oliveira, and Nelma Moreira. Modelling emotional bdi agents. In Workshop on Formal Approaches to Multi-Agent Systems (FAMAS 2006), Riva del Garda, Italy, 2006.
6. Marco Almeida, Nelma Moreira, and Rogério Reis. Aspects of enumeration and generation with a string automata representation. In H. Leung and G. Pighizzini, editors, Proceedings of the 8th Int. Workshop on Descriptive Complexity of Formal Systems (DCFS06), Computer Science Technical Report NMSU-CS-2006-001, pages 58-69, Las Cruces, New Mexico, June 2006. NMSU.
7. Ana Paula Tomás, Nelma Moreira, Nuno Pereira. Designing a Solver for Arithmetic Constraints to Support Education in Mathematics. IFIP Conference on Artificial Intelligence Applications & Innovations (AIAI) 2006, Athens, Greece. ©Springer-Verlag
8. David Pereira, Eugénio Oliveira, Nelma Moreira and Luís Sarmento. Towards an Architecture for Emotional BDI Agents. EPIC05 – 12th Portuguese Conference on Artificial Intelligence. Universidade da Beira Interior. IEEE. 2005. ISBN 0-7803-9365-1.
9. Rogério Reis, Nelma Moreira and Marco Almeida, On the Representation of Finite Automata, Proceedings of the 7th Int. Workshop on Descriptive Complexity of Formal Systems (DCFS05), C. Mereghetti, B. Palano, G. Pighizzini and D. Wotschkes, 2005.
10. José João Morais, Nelma Moreira and Rogério Reis. Acyclic Automata with easy-to-find short regular expressions. Proceedings of the Tenth International Conference on Implementation and Application of Automata, CIAA 2005. pp 349-350., LNCS 3845, Springer Verlag, 2006.
11. Nelma Moreira and Rogério Reis. Interactive Manipulation of Regular Objects with FAdo. In Proceedings of 2005 Innovation and Technology in Computer Science Education (ITiCSE 2005) (and ACM Digital Library), 2005.
12. Ângela Oliveira and Nelma Moreira. GerExa: Plataforma Integrada para a Organização, Geração e Avaliação de Exercícios e Testes. In Actas da 3a Conferência Nacional XML: Aplicações e Tecnologias Associadas, Universidade do Minho, Isbn 972-99166-1-6, 2005.
13. João Pedro Pedroso and Nelma Moreira and Rogério Reis. A Web-Based System For Multi-Agent Interactive Timetabling, ICKEDS 2004, First International Conference on Knowledge Engineering and Decision Support, Porto, 21-23 of July, 2004.
14. Nelma Moreira José Paulo Leal and Pedro Ribeiro. Edic: Uma abordagem para apresentação de conteúdos pedagógicos na web. In Proceedings of the International Conference on New Technologies in Science Education, CINTEC 2001, Aveiro, 2001.

15. Luís Damas and Nelma Moreira. Constraint categorial grammars. In Nuno Mamede and Carlos Pinto-Ferreira, editors, Proceedings of the 7th Portuguese Conference on Artificial Intelligence (EPIA 95), volume 990 of Lecture Notes in Artificial Intelligence. Springer-Verlag, 1995.
16. Luís Damas, Nelma Moreira, and Sabine Broda. Resolution of constraints in algebras of rational trees. In Miguel Filgueiras and Luís Damas, editors, Progress in Artificial Intelligence - 6th Portuguese Conference on Artificial Intelligence (EPIA 93), volume 727 of Lecture Notes in Artificial Intelligence, pages 61-76. Springer-Verlag, 1993.
17. Luís Damas, Nelma Moreira, and Giovanni B. Varile. The formal and processing models of CLG. In Fifth Conference of the European Chapter of the Association for Computational Linguistics, pages 173-178, Berlin, 1991.
18. M. Filgueiras, A.P. Tomás, N. Moreira, J.P. Leal, and R. Reis. Natural language and natural menus interfaces. In Preprints of the TC-7 IFIP International Conference Modelling the Innovation, Roma, March 1990. Also in M. Carnevale, M. Lucertini, S. Nicosia (eds.), Modelling the Innovation: Communications, Automation and Information Systems, North-Holland, 1990.
19. Sergio Balari, Luís Damas, Nelma Moreira, and Giovanni B. Varile. CLG(n): Constraint logic grammars. In H. Karlgren, editor, Proceedings of the 13th International Conference on Computational Linguistics (COLING), volume 3, pages 7-12, Helsinki, 1990.
20. Nelma Moreira. Semantic analysis of time and tense in natural language: an implementation. In J.P. Martins and E.M. Morgado, editors, Proceedings of the 4th Portuguese Conference of Artificial Intelligence, number 390 in LNAI, Berlin, 1989. Springer-Verlag.
21. Isabel Labouriau e Nelma Moreira. Soluções periódicas das equações de Fitzhugh para o impulso nervoso. In Actas do VII Congresso do Grupo de Matemáticos de Expressão Latina, 1985.

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## COMMUNICATIONS

### Oral communications

1. Marco Almeida, Nelma Moreira, and Rogério Reis. Aspects of enumeration and generation with a string automata representation. Workshop on Descriptive Complexity of Formal Systems (DCFS06). June 2006, Las Cruces, NM.

2. Luis Damas and Nelma Moreira. Resolution of Constraints on Trees and Higher Order Tree Descriptions. 5rd Portuguese Advanced School on AI – “Constraint Programming”, Estoril, 10/1996.
3. Luís Damas and Nelma Moreira. Constraint Categorical Grammars. 7th Portuguese Conference on Artificial Intelligence, EPIA 95.
4. Luís Damas and Nelma Moreira. Constraint Categorical Grammars. European Research Conference on Logic, Language and Information: Inference and Information Structure within Computational Semantics, Espinho, 12/1994.
5. Luís Damas, Nelma Moreira, Sabine Broda. Resolution of Constraints in Algebras of Rational Trees, 6th Portuguese Conference on Artificial Intelligence, 1993.
6. Nelma Moreira, Semantic Analysis of Time and Tense in Natural Language: an implementation , 4th Portuguese Conference of Artificial Intelligence, 1989.
7. Uma Forma Normal para Autómatos Finitos Determinísticos e suas Consequências, Jornada de Ciências da Computação, DCC-FCUP 06/ 2006.
8. CCLG: Gramáticas de Categorias com Restrições, no Centro de Linguística da Universidade do Porto, 06/1998.

### Posters in conferences

1. José João Morais, Nelma Moreira and Rogério Reis. Acyclic Automata with easy-to-find short regular expressions (Poster) Tenth International Conference on Implementation and Application of Automata, CIAA 2005.
2. Nelma Moreira and Rogério Reis. FAdo: Interactive Tools for Learning Formal Computational Models. (Poster) Encontro Nacional de Visualização Científica, Centro Multimeios de Espinho, Portugal, 17/9/2005.
3. José Paulo Leal and Nelma Moreira. Using matching for automatic assessment in computer science learning environments. WBLE 2000, Porto Portugal.

Porto, 14 de Abril de 2008

# CURRICULUM VITAE

ROGÉRIO VENTURA LAGES DOS SANTOS REIS

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## PERSONAL DATA

Birth date: 19/03/1961  
Birth place: S.Lourenço, Portalegre  
Nationality: PORTUGAL

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## ACADEMIC DEGREES

2007	PhD. in Computer Science, Universidade do Porto.
1991	Provas de acesso à categoria de assistente de investigação.
1986	Degree in Pure Mathematics, FCUP.

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## ACADEMIC POSITIONS

2007-	Lecturer, Departamento de Ciência de Computadores da FCUP.
1998-2007	Invited Assistant, Departamento de Ciência de Computadores da FCUP.
1992-1997	Research Assistant, Universidade do Porto.
03/1991-1992	Research Assistant, CIUP-INIC.
09/1988-02/1991	Research Assistant, CIUP-INIC.

10/1986-03/1987 Scholarship JNICT, project “Compreensão de Linguagem Natural e Tradução assistida”

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#### PRESENT RESEARCH INTERESTS

Automata Theory and formal languages  
Criptography  
Enumerative Combinatorics

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#### SUPERVISION OF DIPLOMA THESES

- |      |   |
|------|---|
| 2006 | <i>Ferramentas para geração e enumeração de linguagens regulares</i> , by Marco Almeida, (co-supervision with Nelma Moreira).     |
| 2006 | <i>Programa de detecção de plágios em textos de programas</i> , by Tiago Caxias, (co-supervision with David Pereira).             |
| 2005 | <i>Interface gráfico para a edição e a visualização de autómatos finitos</i> , by Vera João, (co-supervision with Nelma Moreira). |
| 2003 | <i>Automatic: editor de diagramas de autómatos finitos</i> , Pedro Ângelo, (co-supervision with Nelma Moreira).                   |
| 2000 | <i>Geração de sequências aleatórias</i> , by Carla Barbosa.   |
| 2000 | <i>Entropia, informação, aleatoriedade e redundância</i> , by Pedro Medas.  |
| 2000 | <i>Serviços de gestão e autenticação de chaves públicas e autenticação de documentos</i> , by Pedro Medas.                        |
| 2000 | <i>Dinheiro electrónico, problemas e protocolos</i> , by José Ferreira.   |
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#### MASTER THESES SUPERVISION

- |                |   |
|----------------|---|
| In preparation | <ul style="list-style-type: none"><li>• <i>Análise da Segurança dos protocolos Peer-to-Peer</i>, João Miguel Mendes, Mestrado em Informática, FCUP.</li><li>• <i>Estudo e implementação de crivos de primos</i>, José António Nunes Borges, Mestrado em Engenharia Matemática, FCUP, (co-supervision with António Machiavello).</li><li>• <i>Criptografia das curvas elípticas</i>, Ivone de Fátima da Cruz Amorim, Mestrado em Engenharia Matemática, FCUP, (co-supervision with António Machiavello).</li></ul> |
|----------------|---|

- *Protocolos para Eleições Electrónicas*, Alexandra Goreti Pinto Queirós, Mestrado em Engenharia Matemática, FCUP, (co-supervision with António Machiavello).
  - *Infraestrutura de chaves públicas*, Bruno Caxeira, Mestrado em Informática, FCUP.
- 2007      *A criptanálise da Enigma: 1932-1939*, Bruno Flávio de Castro Ribeiro, Mestrado em Engenharia Matemática, FCUP, (co-supervision with António Machiavello)
- 2006      *Ferramentas para Determinação e Avaliação de Soluções em Problemas de Horários*, Dora Melo, Mestrado em Informática, FCUP, (co-supervision with João Pedro Pedroso).
- 2005      *AGISA - Ambiente de Gestão Integrado da Sala de Aula*, Sónia Alexandra Ferreira da Silva e Sousa, Mestrado em informática, FCUP, (co-supervision with Luís Damas).
- 2004
- 1999      *Obtenção de expressões regulares pequenas a partir de autómatos finitos*, José João Gonçalves Morais, Mestrado em Informática, FCUP, (co-supervision with Nelma Moreira).
- 1999      *Um sistema de "mirroring" de FTP e HTTP que optimiza recursos usando uma estratégia de avaliação retardada.*, Carmen Lima, Mestrado em Ciência de Computadores, FCUP, (co-supervision with Luís Damas).

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#### PHD THESES SUPERVISION

- 2006-2009      *Caracterização da complexidade descritiva de linguagens regulares*. Marco Almeida. PhD Thesis (co-supervision with Nelma Moreira)

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#### PARTICIPATION IN RESEARCH PROJECTS

Team member of the following projects:

- 2008–2011      Project RESCUE *Reliable and Safe Code Execution for Embedded Systems* (FCT/PTDC/EIA/65862/2006), funded by FCT.
- 2007–2010      Project ASA *Automata, Semigroups and Applications*, (PTDC/MAT/ 65481/ 2006), funded by FCT.



2007–2008	Project <i>Education and Language in Memories of Labour</i> , IPG 118, integrated in the contest <i>Investigação Científica na pré-graduação</i> , Universidade do Porto, (coordinator).
2006–2008	Project "Memórias do Trabalho", Project POCI/ CED/ 60786/ 2004 funded by FCT.
1999–2001	Project "CORE: Sistemas Formais e Complexidade Computacional", PRAXIS/ P/ EEI/ 14233/ 98, FCT.
1999–2001	Project "Ganesh: Ambiente Modular e Distribuído de Ensino de Ciência de Computadores", PRAXIS/ P/ EEI/ 14232/ 98, FCT.
1994–1997	Project "PROLOPPE: Programação em Lógica Paralela com Extensões", do LIACC e CENTRIA (U.N.L), JNICT (Praxis 3/3.1/TIT/24/94).
1987–1991	Project YAP: development and implementation of a Prolog compiler, CIUP-INIC.
1987–1988	Project "Interfaces Naturais para Acesso a Bases de Dados", FCUP and INESC-Norte.
1986–1987	Project <i>Tradução Assistida por Computador</i> JNICT, FCUP.

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