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# MAP-I doctoral program

# Web-based Geographical Information Systems

## Summary

This document presents a Ph.D. level course, as a joint UM-UA-FEUP proposal in the MAP-I doctoral program, corresponding to a Curricular Unit - UCT - credited with 5 ECTS.

## A. Curricular Unit Program

### 1. Theme, Justification and Context

*The course covers the following knowledge areas of the 1998 ACM computing classification system:*

- *Information Systems: Database management: Database applications: Spatial databases and GIS*
- *Information Systems: Database management: Languages: query languages*
- *Information Systems: Information storage and retrieval / On-line Information Services*
- *Information Systems: Information Interfaces and Presentation: Group and Organization Interfaces: WEB*
- *Computing Methodologies: Image processing and computer vision: Image Representation*
- *Information Systems: Information systems applications*
- *Computer Applications: Physical Sciences and Engineering: Engineering*

According to several studies, almost 80% of all digital data has a **spatial** element in it. In other words, most data can be mapped. With the emergence of intuitive mapping technologies, marked by the recent introduction of ubiquitous and user-friendly Web-based mapping interfaces, Geographic Information Systems (**GIS**) is fast becoming a necessary inter-disciplinary research tool for its replicability, data sharing capacities, and spatial data integration.

**Geographic information systems** use hardware and software to collect, display, and analyze geographically referenced (geo-referenced) information through maps, reports, or charts. GISystems help us to visualize, interpret, synthesize, and share data to reveal patterns and solve problems. The synthesized information can be used by other applications.

## Web Applications

The design of a **Web-based GIS** relies, to a greater or lesser extent, in different technologies and methodologies that belong to the **web engineering** discipline. To be sure that all students have a solid and homogeneous background, these topics will be covered in the first part of the course.

**Web applications** are a particular type of client/server applications, in which a user on a client computer accesses an application that runs on the server computer, the computers being connected via an intranet or Internet. Web applications fit in one of two categories: (i) presentation-oriented applications; (ii) service-oriented applications, which implement the operations related to Web services. The Web application runs on a server under the control of the **Web server**. The client and server applications communicate through **HTTP** requests and responses.

There are several features that distinguish Web applications from traditional software: (i) higher accessibility of information and services; (ii) document-centric hypertext interface; (iii) variable technologies for managing distributed and heterogeneous data; (iv) variable presentation technologies and engines; (v) architecture complexity. Developing Web applications therefore involves several challenges, which imply the adoption of adequate technologies and methodologies. In Web engineering **models** play an important role: addressing the complexity of Web applications and shaping up rigorous and systematic development processes. Commonly, Web applications are structured in three layers: **data** layer, **application** layer, and **presentation** layer. At the data layer, the developer has to deal with data structures, data formats and database management systems. At the application layer, the developer has to choose programming and markup languages, models, protocols, and application architectures. He also defines the **navigation** structure of the application. If the application also integrates logic provided by third parties, remote **Web services** might be used. Finally, at the presentation layer the developer focuses on visual aspects, such as the layout of the application front ends, HTML templates and styles.

The first part of the course discusses a set of technologies, components and architectural patterns that characterize Web applications. The objective is not to teach how to use them, but rather to convey their peculiarities, why they are used, and what is their benefit. Servlets, JavaServer Pages (JSP) and JavaServer Faces (JSF) are all technologies for server-side Web applications. But while Servlets are used in the application layer, JSP and JSF are presentation technologies to build user interfaces. In terms of the process followed in the Web applications development, we will only concentrate on the most prominent **Web-specific processes**: WebML-based method, Web Semantics Design Method, and Object-Oriented Hypermedia Design Method. Finally, the most important topic is discussing the several aspects of Web applications **design**: workflow, data, navigation, presentation, and architecture design. Special focus is put on the abstraction provided by the previous methods, which aids the development.

## Standards to Develop Highly Interoperable Web-GIS Applications

The importance of using **standards** to achieve data integration and high **interoperability** among Web-GIS applications is unquestionable. This is well illustrated in a paper by Dr Carl Reed, the Chief Technology Officer at the Open Geospatial Consortium (**OGC**) [1]. For this reason, teaching standard is a cornerstone of the proposed course. With regard to their purpose, the OGC standards can be used to specify: (i) data encoding (GML), (ii) visual portrayal styles (SLD, SE, KML), (iii) catalogue data (CSW), and (iv) services that retrieve, store, update, remove, and process spatial data from servers' databases (WMS, WFS, WCS, WPS). Beyond the benefit of the interoperability provided by the standards, the other motivation to teach several Web services is to make it clear the benefits, limitations and the spatial data type for which each service was thought.

**Geography Markup Language** (**GML**) is an XML grammar for the description of application schemas as well as the transport and storage of geographic information. GML, along with XML, is the base of most data and metadata formats used in OGC Web services requests/responses. GML permits data interoperability within a given community. It defines various geographic entities such as features, geometries, topologies, temporal elements, and spatial reference systems.

The importance of the visual portrayal of geographic data cannot be overemphasized. The skill that goes into portraying data is what transforms raw information into a valid decision-support tool. The OGC Web Map Service (WMS) supports very basic styling options on data portrayal. **Styled Layer Descriptor** (**SLD**) extends WMS with user-defined symbolization of data. SLD is a styling language that client and server can both understand. There are two basic ways to style a data set. The simplest one is to color all features the same way. A more complicated one is to style features of the data differently, depending on some attribute. **Symbology Encoding** (**SE**) is an XML language for styling spatial data in the form of features and coverages. SE, along with SLD, is the styling tool that extends WMS, WFS and WCS services. SE defines elements, such as *Filters* and *Symbolizers*, which can be used for rendering features and coverages. The Google **KML** was adopted by OGC as a standard. It is an XML grammar used to encode and transport representations of geographic data for displaying in an Earth browser. In simple words, KML encodes what to show in an Earth browser, and how to show it. Visualization includes not only the presentation of graphical data on the Earth browser, but also the control of the user's navigation in the sense of where to go and where to look.

A **service-oriented architecture** (**SOA**) must support 3 fundamental interactions: publishing resource descriptions (**metadata**) so that they are accessible to prospective users (*publish*); discovering resources of interest (data, services, etc.) according to some search criteria (*discover*); and then interacting with the resource provider to access the desired resources (*bind*). Within such architecture, a **catalogue service** plays the essential role of matchmaker by providing publication and search functionalities, thereby enabling a requester to dynamically discover and communicate with a suitable resource provider without requiring the requester to have advance knowledge about the provider. OGC **Catalogue Service for the Web** (**CSW**) standard specifies an implementation of the mentioned functionalities.

The OGC **Web Map Service** (**WMS**) standard provides a simple HTTP interface for requesting geo-referenced map images from distributed geospatial databases. A **map** is a representation of geographic information, such as a digital image file, suitable to display on a computer screen. WMS specifies operations to return the service metadata, a map with specific layers and dimensions, and information about particular features of a map.
The OGC **Web Feature Service** (**WFS**) standard allows a client to retrieve and update geospatial data (features), encoded in GML, from multiple WFSs. A **feature** is described by a set of properties, where each property can be a {name, type, value} tuple. A geographic feature may have at least one property that is geometry-valued. WFS specifies operations to request the service capabilities, to request the structure of a offered feature, to retrieve features, to service transaction requests that modify features, and to lock one or more feature during a transaction.
A raster-type **coverage** can be seen as a function mapping points from a spatio-temporal extent (its domain) into values of some cell type (its range). Commonly, the range is

multi-value/field. The OGC **Web Coverage Service** (**WCS**) standard defines basic coverage operations, such as spatial, temporal and band subsetting, scaling, reprojection, and format encoding. Products like Matlab, grid-type interfaces, and the OGC Web Processing Service offer more powerful processing capabilities. However, they often lack properties like declarativeness, safe evaluation, and optimizable. The transactional extension of WCS WCS-T) specifies an additional *Transaction* operation that allows to insert, update, and delete coverages from a WCS server.
Finally, the **Web Processing Service** (**WPS**) specifies a standard interface that facilitates the tasks of publishing, discovering and binding to geospatial processes by clients. A **process** can be an algorithm, a calculation or a model that operates on spatial data. The specification provides operations to identify the spatial data required by the calculation, initiate the calculation, and manage the output from the calculation. WPS can process both vector and raster data.

### GIS and Database Management Systems

Currently, **database management systems** (**DBMS**) perform a critical role in the storage, management and retrieval of **spatial information** in GIS. Generally, these DBMS supporting GIS are extensions of a relational or object-relational database management system, which provides spatial data types and operators, spatial functions and spatial index mechanisms for multi-dimensional data access and optimization. One important aspect, in what seems to be this consensual approach of extending a DMBS, is that DBMS developers have been making an effort to increasingly incorporate ISO and OGC standards in their solutions, thus contributing to higher degrees of interoperability and interchange of spatial data between these systems.

Furthermore, in the last years there has been an increase in the demand of efficient **temporal data** management for most of the application domains managing spatial data. The fact is that time stamping spatial data with dates is starting to become insufficient for solving problems and providing answers that involve spatial and temporal attributes seamless integrated. Moreover, without proper support for temporal data management, spatial SQL queries become too complex to formulate if certain temporal requirements are involved. Consequently, the research community on spatial databases is actively working on the representation and processing of spatiotemporal data in databases.

### GeoVisualization

The aim of information visualization is to offload the cognitive process to visual perceptive system by visually representing large amounts of data in such a way that the observation of data can be an adequate mean to effectively discover and provide explanations about patterns, individual or groups of information items and to effectively support the decision making process. Currently, the number of information visualization techniques is vast. Taxonomies classify these techniques depending on (i) whether or not they deal with inherently graphical data; (ii) a set of subcategories divided by data-oriented goals: scientific visualization, GIS, multi-dimensional plots, multidimensional tables, information landscapes and spaces, node and link, trees, and text-forms; (iii) the dimensionality of information; (iv) the underlying primary data type, among others. **Static visual representations** (Time Series Graph, Stacked Bar Chart, Parallel Coordinates, dance maps, change maps and chess maps, etc.), allow the conclusion of quantitative facts as well as the exploration of special data features, data values, time steps and positions according to the underlying time scales, without limitations. However the application of these techniques has most often restricted to depict one variable or a limited number of variables, whereas the analysis of multivariate correlations is reduced. **Dynamic visual representations** usually make direct use of time to depict data where the most natural approach is to map the temporal aspects of the data directly onto the time control of a dynamic representation, where the representation of data elements changes over the time (size, shape, color, texture, transformation of elements). The interdisciplinary field of GeoVisualization studies the visual presentation of spatial structures having an inherent form of representation due to their physical characteristics, such as it happens with spatio-temporal data. In geovisualization, abstract-based information is often overloaded onto the spatial structures. Consequently, information visualization techniques have been brought to this research area.

Among the several possibilities to visually represent spatio-temporal information, the use of **animation techniques** has been studied. It is considered a well-suited visual tool for qualitative analysis and provides the ability to represent change over time and thus facilitates an understanding of process, rather than of state. However some authors may disagree with the total effectiveness of dynamic map displays, making the issue depend on the interaction and data-exploration tools that are available to the users to explore data. A wide range of animation techniques has been proposed in the context of geovisualization: observations, simulated walkthroughs and fly-throughs over 2D/3D landscapes or cityscapes, performed in real-time or in differed time. Some of these techniques also focus on the improvement of the visual stimulation in animation through the use of dynamic variables. Currently, geovisualization is mostly focused in the research of static and dynamic representation methods for Exploratory Data Analysis of time-dependent spatial data.

## 1.1 Description of the Course

This course aims to provide students with solid foundation skills on Geographical Information Systems. It is targeted to graduate students and researchers familiar with database systems design and implementation, and programming, wishing to advance in the representation, management and visualization of geographical data using state of the art technologies and standards.

The first module of the course summarizes fundamental knowledge about Web engineering. We start by presenting a few basilar Web technologies, such as HTML and XML languages, HTTP protocol, representative Java-based technologies (servlets, JavaServer Pages and JavaServer Faces) and Web services. Next, we introduce Web-specific development processes, namely WebML, WSDM, and OOHDM. The last section is devoted for presenting how to design a Web application.

The second module covers the foundations of geographical information systems, namely, data input and validation, data storage and management, data output, visualization and interaction and data transformation. It emphasizes the role of spatial DBMS for storage and management of data in GIS.

The third module will provide students with the concepts and technologies necessary to design a Web-GIS that is highly interoperable with other systems. To achieve this goal, it is necessary to present a few representative ISO and OGC standards for data encoding, portrayal, cataloguing and processing, and the Web services that can handle different types of spatial data: maps, features and coverages. To facilitate the Web-GIS design, we provide some examples of frameworks and APIs to store, discover, process, retrieve, and display spatial data through the use of OGC standards.

The fourth module covers the representation of time-varying data in GIS. It starts with a discussion on architectural approaches for representing complex (spatial and spatiotemporal) data in DBMS. It focuses on the dynamics of spatial information and presents a selection of data models and query languages for representation and processing of discretely and continuously changing spatial data. It also emphasizes benchmarks in performance evaluation of spatial and spatiotemporal databases.

The fifth module covers concepts and techniques on information visualization and on the field of geovisualization. The purpose is to provide the students with a good survey on visual representations of spatial and spatio-temporal information. To achieve this purpose, the most well-known scientific visualization and information visualization techniques will be presented and classified according to several criteria, such as data, task, representation and underlying models, among others.

## 1.2 Related Courses

- *Ph.D. in Spatial Information Science and Engineering*, University of Maine. Courses: Information System Software Engineering, Database Systems, Geographic Information Systems.
  `gradcatalog.umaine.edu/preview_program.php?catoid=25&poid=3083&returnto=372`
- *Ph.D. in Earth Systems and Geoinformation Sciences*. School of Computational Sciences, George Mason University, USA. The courses of the *Geographic Information Systems* core are: Introduction to GIS, Advanced GIS, GIS and Natural Resources, Geographic Information Analysis, Spatial Data Structures, Map Projections and Coordinate Systems, Algorithms and Modeling in GIS, Distributed GIS, GIS Interoperability.
  `www.scs.gmu.edu/Academics/PHD_ESGS_main.html`
- *Ph.D. in Geospatial Information Sciences*. University of Texas, Dallas. Courses: Spatial Data Management, GIS Application Software Development, Internet Mapping and Information Management.
  `www.utdallas.edu/dept/graddean/CAT2006/SS/Final_Doctor%20of%20Philosophy%20in%20Geospatial%20Information%20Sciences%20RB%20(02-28-2006).htm`
- *Ph.D. and M.Sc. in Geospatial Information Science and Engineering.* State University of New York, College of Environmental Science and Forestry. Courses: GIS for Engineers, Introduction to Spatial Information, Spatial Analysis and GIS-Based Modeling. `www.esf.edu/ere/graduate/gisce/`
- *Ph.D. in Advanced Spatial Analysis and Visualisation*, University College London, University of London, UK. Courses: GI Systems and Science, Digital Visualisation.
  `www.bartlett.ucl.ac.uk/casa/programmes/postgraduate/mres-advanced-spatial-analysis-visualisation`
- *Ph.D. in Geographic Information Science*. Department of Geography, State University of New York at Buffalo.
  `www.geog.buffalo.edu/academic_programs/graduate/phd_gis.shtml`

## 2.1 Objectives

This course is designed to provide students with an integrated view of geographical information systems. The goal is to develop solid skills and knowledge to (1) understand the different data models, query languages and geo-visualization techniques for dealing with spatial and spatiotemporal data, (2) recognize the importance of standards in the managing of spatial data, (3) be able to search for and use the most recent techniques and tools for developing Web-GIS, and (4) be able to discuss and recognise interesting research topics in this domain.

## 2.2 Learning Outcomes

Students should develop the following competences in this curricular unit:

- To be able to distinguish, capture, process, combine, store and visualize different types of geo-referenced information;
- To recognize that the use of standards enables the development of highly interoperable applications;
- To understand the role of spatial databases in geographical information systems;
- To understand and use spatial data models and query languages;
- To understand the most important data structures and access methods for spatial data representation and retrieval and to be able to optimize spatial operations using adequate indexing mechanisms.
- To design and implement a Web-GIS application that is highly interoperable;
- To be able to discuss recent advances in spatiotemporal databases and Web-based GIS, to identify challenges and research topics in these areas;
- Exhibit the ability (i) to communicate appropriately in written and oral, (ii) to work productively as a team, and (iii) to reflect and develop critical thinking about spatial data knowledge and engineering.

## 3. Syllabus

**1. Web Engineering**

1.1 Web Technologies
  The HyperText Transfer Protocol (HTTP)
  The HyperText Markup Language (HTML)
  The eXtensible Markup Language (XML)
  Servlets
  JavaServer Pages
  JavaServer Faces
  Web services

1.2 Web-Specific Development Processes
  The Web Modelling Language (WebML) model
  The Web Semantics Design Methods (WSDM)
  The Object-Oriented Hypermedia Design Method (OOHDM)

1.3 Web Applications Design
  Workflow design
  Data design
  Navigation design
  Presentation design
  Architecture design.

**2. Geographical Information Systems**

2.1 Representation of spatial objects
  Modeling the geographic space
  Representation modes (raster and vectorial)
  Representing objects in layers (spaghetti and topological models)
  Spatial data formats and exchange standards

2.2 Data models and query languages

2.3 Spatial data structures and access methods

2.4 GIS and spatial databases commercial systems

2.5 Creating and extracting metadata from spatial data.

**3. Standard Web-based Geographic Information Systems (Web-GIS)**

3.1 The importance of standards to achieve data integration and interoperability

3.2 The UML notation used in standards' specification

3.3 Standards for data encoding and presentation
The INSPIRE initiative
Keyhole Markup Language (KML)
Geography Markup Language (GML)
Styled Layer Descriptor (SLD) and Symbology Encoding (SE)

3.4 Standards for Web services
Web Map Service (WMS)
Web Feature Service (WFS)
Web Coverage Service (WCS)
Web Processing Service (WPS)
Catalogue Service for the Web (CSW)

3.5 Frameworks to manage (store, discover, process, and provide) spatial data through the use of OGC standards (GeoServer, MapServer, rasdaman)

3.6 APIs to visualize spatial data as maps (OpenLayers, Google Maps API)

3.7 Design a standard Web-GIS application.

**4. Representation of time-varying spatial data**

4.1 Architectural approaches for representing spatial and spatiotemporal data into databases (monolithic, extensible and layered architectural approaches)

4.2 Spatial and spatiotemporal data acquisition from satellite images

4.3 Spatiotemporal data models and query languages

4.4 Benchmarking in spatiotemporal databases.

**5. Spatiotemporal data visualization**

5.1 Cartographic representations of change.
Dynamic variables: temporal existence, location, interval, texture, rate of change, sequence and synchronization

5.2 Static maps: dance maps, change maps, chess maps

5.3 Dynamic maps: animation (linear and cyclic time)

5.4 Exploratory Data analysis: visual methods designed to facilitate exploration, analysis, synthesis, and presentation of geo-referenced information;
Temporal brushing and temporal focusing.

## 4. Teaching and evaluation methodologies

The **teaching methodology** includes (i) theoretical lectures, (ii) practical tutorials on some syllabus topics and (iii) project supervision. The contact time is divided among these three components, in percentages near 50% for component (i), 25% for (ii), and 25% for (iii).

The **evaluation** of the Unit includes two components: a written examination and a project. The written examination has a weight of 40% in the final grade. The project, with a weight of 60% in the final grade, consists of an oral presentation, a paper documenting the project undertaken and the developed product.

The elements to evaluate the presentation (20%) and paper (20%) will be the structure, clarity, scientific correctness and critical thinking (conclusions). The elements to evaluate the developed product (20%) will be the technology content, achieving the objectives proposed in the project statement and originality.

## 5. References

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[1] *Data Integration and Interoperability: ISO/OGC Standards for Geo-information*, Directions Magazine, November 2004. URL: www.directionsmag.com/articles/data-integration-and-interoperability-isoogc-standards-for-geo-information/123610


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[2] *Geographic Information Systems and Science (3rd ed)*. Paul Longley, Mike Goodchild, David Maguire and David Rhind. Wiley, 2011. ISBN 978-0-470-72144-5.

[3] *Geospatial Web Services: Advances in Information Interoperability*. Peisheng Zhao and Liping Di, IGI Global, 2011.

[4] *Web GIS: Principles and Applications*. Pinde Fu and Jiulin Sun, ESRI Press, 2010.

[5] *Web Applications Engineering*. S. Casteleyn, F. Daniel, P. Dolog and M. Matera. Springer-Verlag, 2009.

[6] *Standard-Based Data and Information Systems for Earth Observation (Lecture Notes in Geoinformation and Cartography)*. Liping Di and H. K. Ramapriyan (editors), Springer-Verlag, 2009.

[7] *Spatial Data on the Web: Modeling and Management*. Alberto Belussi, Barbara Catania, Eliseo Clementini, and Elena Ferrari (editors). Springer, 2007. ISBN 9783540698784.

[8] *Web Mapping Illustrated: Using Open Source GIS Toolkits (1st ed)*. Tyler Mitchell. O'Reilly, 2005.

[9] Maceachren, A. M. How Maps Work: Representation, Visualization, and Design, The Guilford Press, 2004.

[10] *Core Servlets and JavaServer Pages (2nd ed)*. Marty Hall and Larry Brown. Sun Microsystems, 2004.

# B. Academic Staff

**António Joaquim André Esteves**, received his Ph.D. in Informatics from Universidade do Minho in 2001. He is currently a lecturer at the Department of Informatics and a member of CCTC R&D center. He is supervising M.Sc. and under-graduation students, and he is author of several recent papers centered on the areas of managing geo-referenced data, developing OGC-based Web services, and integration of data from in-situ and satellite sensors with Civil Protection Grid applications. He participated in Cyclops, EELA-2, and GISELA EU projects, and he was also involved in other projects funded by Portuguese institution, such as CROSS-Fire and GAsPar. His current scientific interests are software engineering, Web-GIS, Web-services and data standards, and distributed data storage.

**Supervision:**

**MSc students:**

- Mauro Nuno Barbosa de Castro, *Desenvolvimento de um Sistema de Localização baseado em Tecnologia RFID*, Universidade do Minho, December 2011.
- Miguel Angel Lopez Mamani, *Web Portal for Touristic Social Communities*, to be concluded in 2012.
- Alfredo de Moura, *Simulation of precipitation in an Aluminium-Scandium alloy*, to be concluded in 2012.

**Research Projects:**

- *EELA-2*, *E-science grid facility for Europe and Latin America: Deployment of e-Infrastructures for scientific communities*, INFRA-2007-1.2.3: e-Science Grid infrastructure, JRU Portugal. Member of the research team from April/2008 to March/2010.
- *CYCLOPS Cyber-Infrastructure for Civil protection Operative Procedures*, 6 FP, Research Infrastructure-Communication Network Development, proposal nº 031874. Investigator external to the research team during 2008.
- *CROSS-Fire-Collaborative Resources Online to Support Simulations on Forest Fires: a Grid Platform to Integrate Geo-referenced Web Services for Real-Time Management*, GRID/GRI/81795/2006. Member of the research team during 2009 and 2010.
- *GISELA: Grid Initiatives for e-Science virtual communities in Europe and Latin America*, 7 FP project, member of the research team from September/2010 to August/2012.
- *GAsPar: General-purpose Aspect-Oriented framework for heterogeneous multicore Parallel systems*, PTDC/EIA-EIA/108937/2008. Member of the research team from June/2010 to May/2013.
- *SeARCH: Services and Advanced Research Computing with HTC/HPC clusters*, Ref. CONC-REEQ/443/2001. Member of the research consortium.

**Selected Publications:**

António Esteves and António Pina. *A WCS-based Approach to Integrate Satellite Imagery Data in Wildfire Simulation*, 8th International Conference on Web Information Systems and Technologies (WEBIST), Porto, Portugal, April 2012.

António Pina, António Esteves, Joel Puga, and Vítor Oliveira. *A Geographical Information System for wild fire management*, 5th Iberian Grid Infrastructure Conference (Ibergrid'2011), pp. 144-155, Santander, Spain, June 2011.

António Pina, Bruno Oliveira, Luís M. Ribeiro, Joel Puga, António Esteves, Alberto Proença, and Domingos X. Viegas. *Cross-Fire - a grid platform to integrate geo-referenced Web Services for real-time risk management*, VI International Conference on Forest Fire Research (ICFFR), Coimbra, Portugal, November 2010.

António Esteves, Marco Caldas, António Pina, and Alberto Proença. *An OGC/SOS Conformant Client to Manage Geospatial Data on the GRID*, 4th Iberian Grid Infrastructure Conference (Ibergrid'2010), pp. 383-394, Braga, Portugal, May 2010.

António Pina, Bruno Oliveira, Joel Puga, António Esteves and Alberto Proença. *A Platform to support Civil Protection applications on the GRID*, 4th Iberian Grid Infrastructure Conference (Ibergrid'2010), pp. 355-367, Braga, Portugal, May 2010.

António Pina, Bruno Oliveira, Joel Puga, António Esteves and Alberto Proença. *FireStation on the grid - a step further on the adoption of OGC/SDI standards*, Enabling Grids for E-sciencE Conference (EGEE'09), Barcelona, Spain, September 2009.

António Esteves, António Pina, Vítor Sá, Marco Caldas, Nuno Lebreiro and Luiz Lopes. *A Prototype to Integrate a Wireless Sensor Network with Civil Protection Grid Applications*, 3rd Iberian Grid Infrastructure Conference (Ibergrid'2009), Valencia, Spain, pp. 352-364, May 2009.

António Esteves, António Pina, Vítor Sá, Marco Caldas, Nuno Lebreiro and Luiz Lopes. *Integrating a Wireless Sensor Network into Grid Civil Protection Applications*, EGEE User Forum/OGF25 & OGF Europe's 2nd International forum, Catânia, Italy, March 2009.

**José Manuel Matos Moreira**, received his Ph.D. in Computer Science and Networks from the École Nationale Supérieure des Télécommunications de Paris (France) and the Faculdade de Engenharia da Universidade do Porto (Portugal) in 2001. He is currently an Assistant Professor at the Department of Electronics, Telecommunications and Informatics of the Universidade de Aveiro and a researcher at IEETA, a non-profit R&D institute affiliated to the same university. His background includes programming languages, data structures and databases. His main research activities have focused on spatiotemporal databases, particularly, in the study of data models, query languages, data structures and access methods for efficient representation and management of spatial (geographical) data that change over time. Recent works also focus on (1) the representation of spatiotemporal knowledge and the development of ontologies and semantic enabled applications for planning touristic itineraries in the Web, and (2) the study of spatiotemporal recommender systems and collaborative filtering techniques.

**MSc students:**

- José Manuel Marques Lopes. Sistema WebSIG para a gestão da política educativa em São Tomé e Príncipe. Universidade de Aveiro, 2011.

- Maria Cesaltina Mendonça Semedo. Sistema de suporte à decisão para gestão do Porto da Cidade da Praia. Universidade de Aveiro, 2011.

- Pedro José Correia Alves dos Reis. Aplicação de árvores de decisão em sistemas de alarmística. Universidade de Aveiro, 2010.

- Jair José Lopes Delgado. Sistema de informação de apoio à deteção de perdes de energia elétrica – o caso da Electra. Universidade de Aveiro, 2010.

- Elcelina Rosa Correia Carvalho Silva. Técnicas de data e texto mining para anotação de um arquivo digital. Universidade de Aveiro, 2010.

- Miguel dos Santos Malheiro. Guia turístico pessoal baseado em contexto através de PDA e GPS (servidor). Universidade de Aveiro, 2008.

- Vitor Alexandre Figueiredo. Guia turístico pessoal baseado em contexto através de PDA e GPS (cliente). Universidade de Aveiro, 2008.

- Sónia Rodrigues. Avaliação em e-/b-learning: Implementação de um sistema de auto-avaliação de um projecto de apoio online no ISCAP. Universidade Portucalense, 2007.

**PhD students:**

- Salvador da Conceição Alves de Miranda Lima. Semântica, ontologias e interoperabilidade em Sistemas de Informação Turística na Web: Modelo Semântico para o planeamento de itinerários turísticos. Dissertação para a obtenção do grau de Doutor em Informática da Universidade Portucalense em 2010.

**Research Projects:**

- *Casa Sapo Real Estate Analytics*, 2010 – 2011. Financing: QREN - Quadro de Referência Estratégico Nacional, Portugal. Partners: Janela Digital, Universidade de Aveiro (GOVCOPP, IEETA, Centro de Estudos em Optimização e Controlo) and INESC Inov (Lisboa). Role: Participant as co-author and scientific advisor.

- *URBIS - Efficient management and visualization of spatiotemporal urban data*, 2008 – 2010. Financing: FCT (the national foundation for science and technology), Portugal. Partners: INESC-Porto and IEETA. Role: Participant and local coordinator at IEETA.

**Selected Publications:**

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**Supervision:**

**MSc students:**

- João Barbosa, *Visualização de estatísticas pessoais e sociais para um produto web e mobile,* Mestrado Integrado em Engenharia Informática e Computação, FEUP.

**Research Projects:**

- *URBIS - Efficient management and visualization of spatiotemporal urban data*, 2008 – 2010. Financing: FCT (the national foundation for science and technology), Portugal. Partners: INESC-Porto and IEETA. Role: Participant from INESC Porto.

**Selected Publications:**

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