MIT Portugal

Creating Value through Systems Thinking

MIT Massachusetts Institute of Technology

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

MIT Portugal

Creating Value through Systems Thinking

Faculty of Engineering of the University of Porto

CONTENTS

Message from the MIT Portugal Program Directors

The MIT Portugal Program, launched in October 2006, pioneered a model of intense, open and broad international collaborations in Portugal, based on a multi-level partnership between Portuguese Universities, Research Institutions, Companies and the Massachusetts Institute of Technology (MIT).

Last year, our revisited approach was focused on "Engineering Systems in Portugal" promoting the value of multidisciplinarity and cooperation to solve complex real life problems, and was based on four main interrelated vectors: People, Knowledge, Ideas and Institutions.

This has been matured and developed by bringing faculty and students from all over the world to study and conduct research relevant to Portuguese based companies. We have cultivated strong partnerships between Portuguese university groups and industry in targets themes, including Stem Cell Engineering for Regenerative Medicine, Sustainable Energy and Transportation Systems, and Materials and Design-Inspired Products.

But all these efforts and achievements have a major goal: to create a new generation of leaders with unique knowledge and a global perspective that together with companies in Portugal can make a critical contribution to Portugal's economy future growth in international markets.

It is today very clear that we observe increasing differences between countries and regions, the emergence of new market economies of newly industrializing countries, new powers of knowledge in specific areas, and all this in a global world, where goods and information circulate at increasing speed.

During the last decades, the world´s economy has grown rapidly, prospered, created and distributed wealth more evenly among populations. But recent history has also demonstrated that it is not complacent and that the global economy that seemed resilient is subject to shocks and crises of various kinds. It is clear that this breakneck pace of change will not slow down, and therefore there is no time to wait, to see and then adjust - we have to adjust on the move. And the ability to have a country prospering in a dynamic global economy is to base it on local values and skills, i.e. on People, Knowledge, Ideas and Institutions, while connecting it to the network of nations and people that are designing the future. This constitutes the major motivation for any international partnership.

The MIT Portugal Program aims no more and no less than this, to be an open, international platform which may constitute a network of multidisciplinary knowledge that focuses on people, creating value through the development and demonstration of new ideas in Portugal. This is intended to promote, at the Portuguese Universities, scalable living laboratories to develop and test emerging technologies and systems that Portuguese companies may continuously and dynamically develop, explore and export worldwide.

This second annual conference is intended to provide the platform for all the academic, research and business institutions that have been partnering to create a new generation of leaders, to share their experiences and highlight the collaborative research effort of the individual students and its impact on the companies in Portugal.

It is a great moment to find new opportunities for coupling ideas and business interests and to deepen the multi-level partnerships that are promoted by this international platform. Our ambition is that every participant may enjoy and benefit from this great event and that it might promote a great interaction between the students, the faculty, the industry leaders and the community, that make the MIT Portugal Program such a great international experience!

Daniel Roos, Director of MPP at MIT   Paulo Ferrão, Director of MPP in Portugal

Forward

The 2nd MIT – Portugal Annual Conference takes place on the beginning of the last year of the first phase of the MIT Portugal Program, being a good opportunity to identify the main achievements and to foster the discussion with industry, academy and society as a whole to consolidate a strategy for the future.

Having in mind "to develop a new paradigm in Europe, for engineering research and education, based on an application driven approach, combining lectures, internships in industrial technological firms and international research laboratories", the MIT Portugal Program considered the principles of solid scientific background, creativity, innovation, leadership and environmental and economical concern.

The MIT Portugal Program encompasses five scientific domains: Bioengineering Systems, Engineering Design and Advanced Manufacturing, Sustainable Energy Systems, Transportation Systems and, more recently, Engineering Systems Fundamentals.

The Program Goals and Objectives are the following: foster the creation of critical mass in strategic technological domains, through partnerships between Universities and Research Centers; establish world class sustainable advanced education programs capable to attract high quality international students, through the development of new educational and research areas; foster research cooperation and joint degrees among the participating Universities; contribute to the development of Portugal's knowledge base industry, fostering economic growth; deepen University/Industry engagement in research and education.

The real economic and social impact of this first phase of the MIT Portugal Program will be seen as soon as students come to the labour market, showing the positive difference of their knowledge. More than any of the achievements already obtained, this will be the real evaluation of our strategic approach.

We aim to consolidate the experience gained so far and assume the challenges rose by the trends of modern society: continuous learning; internationalization; complexity, globalization and changing challenges; new skills and entrepreneurship.

Our partnership aims to improve the capabilities to design, manufacture and market high added value products and integrated systems in order to reinforce the Portuguese techno-industrial capabilities within the value chain of selected industries. It fosters an entrepreneurial attitude and the development of a practice for multi-disciplinary work in multi-cultural environments. It develops high quality education and research activity to train people for the challenging environment and the complexity of linking management, R&D, design, manufacture, supply chain and new marketing solutions.

Besides the balance of what has been done so far, the main purpose of the 2nd MIT Portugal Annual Conference will be to define a strategy, Creating Value Through Systems Thinking, for new opportunities and new research areas in order to strengthen the Portuguese industry exports capabilities.

The Conference includes a plenary lecture about "Creating value through Systems Thinking" given by Eduard Crawley, Ford Professor of Engineering at MIT and three technical sessions, emphasizing our research strategy, cover the following subjects: Electric mobility-The Spark to Design; Medical Solutions-Cells and Devices; Moving Energy-Cities of Change. The subjects covered also innovation models, challenges and vision for the future. The sessions have the participation of industry, academia and other institutions from Portugal, USA or other countries.

The 2nd MIT Portugal Program Conference is the result of a close cooperation between universities, scientific groups and companies involved in the Program as well as several institutions and individuals which should be acknowledged: FCT – Fundação para a Ciência e Tecnologia; MIT Portugal Program Coordination Office and FEUP Staff. A special thank should be given to Profs. Dan Roos, Paulo Ferrão, Eduardo Oliveira Fernandes, Joaquim Sampaio Cabral and José Viegas and to Miguel Carvalho, Irina Constantino, Carla Monteiro and Célia Couto.

António Torres Marques
Coordinator of the Organizing Committee

The Organizing Committee:
António Torres Marques
Olga Carneiro
Manuel Mota
Rui Reis
João Peças Lopes
João Sousa
Jorge Pinho de Sousa

MIT Portugal

Creating Value through Systems Thinking

Program

2nd Annual Conference
28th September 2010

09:00   RECEPTION

09:30   **OPENING SESSION**
Marques dos Santos, Rector - Porto University
Dan Roos, MIT
João Nuno Mendes, Director - GALP
José Mariano Gago, Minister of Science, Technology and Higher Education

10:00   **KEYNOTE SESSION**
Edward Crawley, MIT

10:30   Coffee-Break

11:00   Electric Mobility: **The Spark to Design**
Luís Reis, GAMEP / INTELI
Rob Farndon, Rolls-Royce
Luís Quaresma, Novabase
Elisabete Pinho, TMG Automotive
Jorge Pinto, Caetano Bus
Debate

12:35   Lunch

14:00   Medical Solutions: **Cells and Devices**
Dava Newman, MIT
Perpétua Pinto-do-Ó, INEB
Miguel Oliveira, 3B's / IBB
Eduardo Pires, CERAMED
Hugo Gamboa, PLUX
Debate

15:30   Moving Energy: **Cities of Change**
João Peças Lopes, INESC Porto
Luís. Martinez, IST-UTL
António Vidigal, CEO - EDP Inovação
Pedro Montalvão, Mota-Engil Energia S.A.
Vitor. Leal, FEUP
Carlos Silva, IST-UTL
Debate

17:15   Coffee-Break

17:30   **CLOSING SESSION**
Sebastião Feyo de Azevedo, Director - FEUP
Paulo Ferrão, IST-UTL
João Sentieiro, President - FCT
Rogério Carapuça, President Novabase
Carlos Zorrinho, Secretary of State for Energy and Innovation
Manuel Heitor, Secretary of State of Science, Technology and Higher Education

DOCTORAL PROJECTS

Bioengineering Systems

Integration of light sensor arrays with microfluidic networks to scale down 2D fluorescence spectroscopy for high throughput organism/cell condition analysis

Bioengineering Systems PhD
IST-UTL
Background: **Biotechnology, Poznan University, Poland**
Poland
Starting Year: **2007 / 2008**
Supervisors: **Joao Pedro Conde (IST-UTL), D. M. F. Prazeres (IST, BERG**
Research team: **V.Chu, A.T. Pereira, A. Pimentel, M. Santos**

Agnieszka Jóskowiak

Objectives

The main objective of presented work is to establish a lab-on-a-chip equivalent of two-dimensional fluorescence spectroscopy (2D FS).

To achieve that an amorphous silicon (a-Si:H) photosensor will be integrated with an appropriate filter (amorphous silicon carbon alloy – a-SiC:H and/or interference filter) and a microfluidic platform to detect specific autofluorophores (tryptophan, NADH, FAD and some vitamins).

Work plan

Fluorescence studies – autofluorescence of individual molecule species and whole organisms (bacteria, yeast, animal cells).

a-Si:H photosensor fabrication, characterisation and optimisation.

Filter design and characterisation.

Tests of integrated device (photosensor with appropriate filter) on a model system – E. coli cells producing green fluorescent protein (GFP).

Production of simple photodetector array for 2-3 chosen autofluorophores. Integration with microfluidics platform.

Construction of a fully integrated detection platform with proper data analysing system.

Results

Figure 1. shows an example of typical representation of results for large scale 2D FS. Excitation-emission matrix for non-induced and induced E. coli strain shows a clear peak for tryptophan and GFP, suggesting the promoter leakage in non-induced cells. Every of the autofluorophores demands a separate filter that would block the excitation light, increasing the detection yield for emission light. Some of the filter characteristics of a-SiC:H 2 m films can be seen in Fig. 2. It also indicates excitation and emission wavelengths of the fluorophores of interest – tryptophan, NADH and FAD. The sensitivity of designed system was tested with a model molecule – green fluorescent protein (GFP). After choosing the optimal filter, an a-Si:H p-i-n photodiode with integrated filter was fabricated (Fig. 3). It was then used to test its sensitivity in GFP detection in solution (Fig. 4, left) and within living cells (Fig. 4, right). The sensor proved to be efficient in both cases, enabling to detect down to 18.5 nM of GFP in solution and giving a good response over a range of cell concentration. Having this proof of concept I can now proceed to autofluorophore detection to establish a 2D FS sensor array.
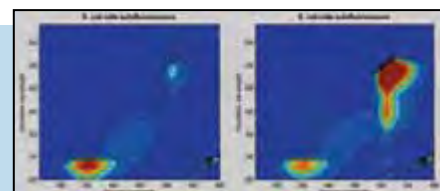

Fig. 1. 2D FS excitation-emission matrix of E. coli strain encoding green fluorescence protein (GFP), before (left) and after (right) induction.
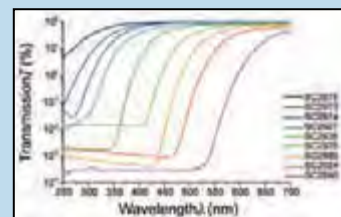
Fig. 2. Filtering characteristics of a range of a-SiC:H filters with varying carbon content (C conc. increasing form right to left).
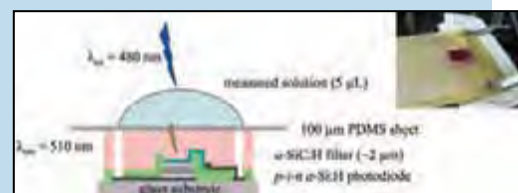
Fig. 3. Integrated device for GFP detection – an a-Si:H p-i-n photodiode with an appropriate a-SiC:H filter. A sample drop is placed on the sensor covered with a protective 100 m thick PDMS sheet.
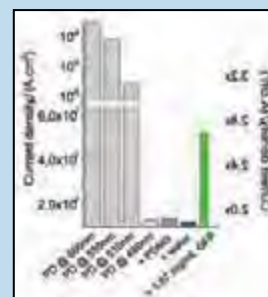
Fig. 4. Green fluorescent protein (GFP) detection in solution (left) and inside living cells (right).

Acoustic Biosensors for Biomedical and Biotechnology Applications

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biotechnology Engineering, UAlgarve, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Guilherme Ferreira (IBB-UTL),**
Cláudia Lobato da Silva (BERG, IBB, IST)
Research team: **Guilherme N.M. Ferreira (PI), Brigitte Tomé, Cláudia Vistas,**
Jorge Carvalho, Luís Rosa, Luísa Pedro, Rogério Rodrigues, Sandra S. Soares.

Ana Carina Silva

Objectives

The main objectives of this PhD is to develop acoustic biosensors to study, in real-time and non-invasively, and optimise stem cell surface attachment, and study and detect the effect of specific growth factors and chemicals in stem cell differentiation.

Work plan

Development of sensor devices for cell-sensing;
Functionalization of acoustic devices with different types of substrates for cell culture;
Monitoring cell behaviour under different conditions and correlate cell adhesion/spreading processes with electric parameters;
Study and evaluate the effect of specific growth factors and chemicals in stem cell differentiation.

Results

Monitoring the biological state of stem cells is essential for the establishment, and maintenance of stable stem cell lines, and to control their differentiation. The Quartz Crystal Microbalance (QCM) (Figure 1), a novel cell-sensing platform, is a piezoelectric device constituted of a thin quartz disk with gold electrodes plated in both sides. The application of an alternating electric field on the electrodes generate acoustic waves perpendicular to the QCM surface, inducing the shear-mode oscillation of the crystal (Figure 2).

The crystal oscillation is sensible to mass deposition at the sensor's surface. Cells adsorption induce the decrease of the oscillating frequency (Figure 3a). Adherent cells promotes also viscoelastic alterations at the QCM's surface that can be quantified by resistance analysis (Figure 3b). The presence of cells at QCM's surface can be confirmed through fluorescence microscopy (Figure 4).

Impedance spectroscopy analysis of the acoustic sensor is also used as a more accurate method to assess the variation of relevant parameters (Figures 5 and 6).

Specific sets of QCMs parameters variations are correlated with the different cellular status, morphology and phenotype.
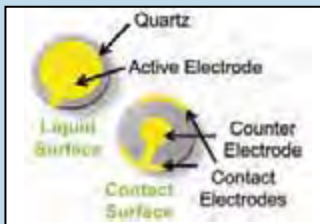

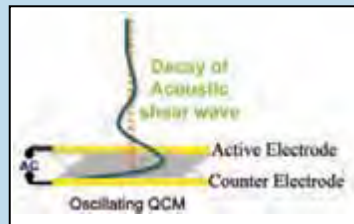**Fig. 1** The quartz Crystal Microbalance.
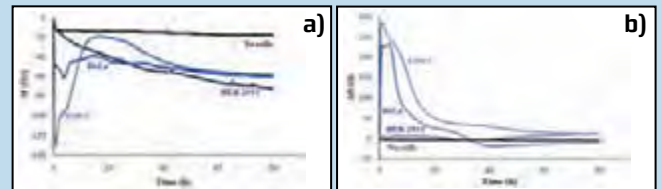

Fig. 2 QCM's shear mode-oscillation.

Fig. 3 Real-time monitoring of **a)** resonance frequency and **b)** motional resistance shifts (ΔR and Δ) during attachment and spreading of mammalian cell lines to an uncoated surface in the presence of serum-free medium.
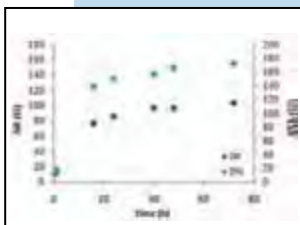

Fig. 6 Time course of R and XL during adhesion of HEK 293T cells to the quartz resonator. Changes of load parameters are given relative to a cell-free but medium-loaded resonator.
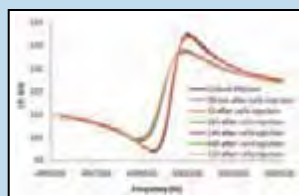

Fig. 5 Impedance spectrum near resonance of a culture medium loaded QCM versus cell loaded QCMs.

Fig. 4 Fluorescence microscopy analysis of seeded cells (Texas Red-X phalloidin)

The Role of TAO K2 in Brain Development

Bioengineering Systems PhD
FCTUNL
Background: **DBCs in Biotechnology, ESB-UCP, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Margarida Archer (ITQB, UNL), Li-Huei Tsai (PILM, MIT)**
Research team: **F. Calderon de Anda, A. Lúcia do Rosário, O. Durak, K. Meletis, M. Archer, L. Tsai.**

Ana Rosário

Objectives

Recently, a novel recurrent microdeletion of chromosome 16p11.2 has been identified that carries substantial susceptibility to autism, one of the genes from the affected region encodes for the protein TAO Kinase 2 (TAO K2).
 The main goal of our project is to establish the cellular and molecular mechanism of TAO K2 in the developing brain, studying his molecular partners and the effect of TAO K2 down-regulation in the mouse model.

Work plan

Our main approach is the acute down-regulation, in the mouse brain, of the gene of interest, to observe the phenotype. We will use biochemical assays to establish upstream and downstream partners of TAO K2 by immunoprecipitation and immunostaining, and evaluate, by western blot, the down-regulation of TAO K2 in cultured neurons and cells lines.
In a final step, we intend to determine the X-ray structures of TAO K2 and its associated partners, to provide insights into their overall folds, have a picture of their active sites at atomic level and a detailed description of their interaction region.
The knowledge will be useful to evaluate available drugs for autism disorders and rationally design more selective and potent drugs.
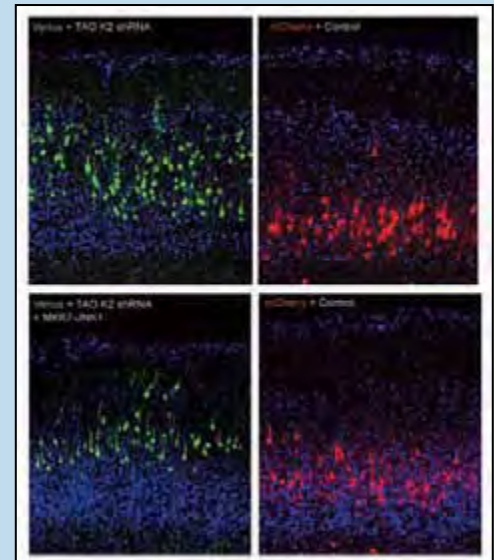
Results

The acute down-regulation of TAO K2 in the mouse brain demonstrates that neuronal migration and axon formation are impaired, and neuronal cells that reach the cortical plate have less complex dendritic arborization. This phenotype suggests impairment in signaling transmission. In cultures we identified that TAO K2 colocalizes with actin, which decreases when cells are transfected with TAO K2 shRNA, suggesting a defect in neuronal migration. An increase in pTAOK2 and pJNK1 was observed when neurons were treated with semaphorin3A, indicating a possible mechanism for cellular differentiation in the cortex of the mouse brain, where semaphorin 3A acts as regulator of TAO K2 signaling, when activated, phosphorilates and activates JNK1 pathway.
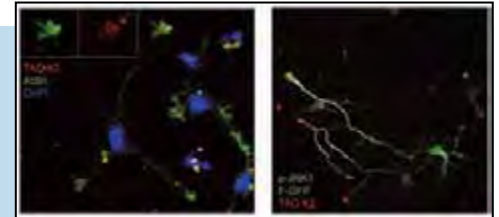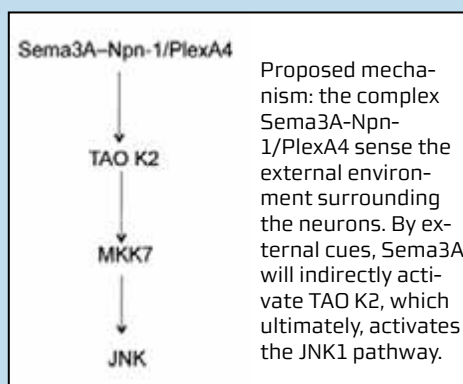
TAO K2 preferentially colocalizes with the actin cytoskeleton, pTAO K2 colocalizes with pJNK1.
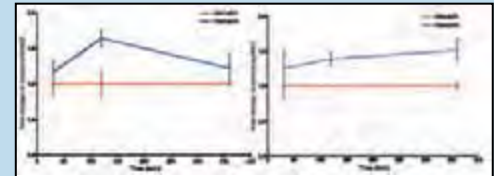
Treatment of cultured neurons with sempahorin 3A transiently increases pTAOK2 and has a long lasting effect on JNK1 activation.

Sema3A–Npn-1/PlexA4

TAO K2

MKK7

JNK

Proposed mechanism: the complex Sema3A-Npn-1/PlexA4 sense the external environment surrounding the neurons. By external cues, Sema3A will indirectly activate TAO K2, which ultimately, activates the JNK1 pathway.

RSequential transfection: TAOK2 down-regulation versus control; TAOK2 shRNA phenotype rescued by over expression of constitutive active form of JNK1 versus control.

Data Mining in Intensive Care Unit Databases

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biomedical Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **João Sousa (IST-UTL), Stan Finkelstein (MIT)**
Research team: **Dr. Michael D. Howell, Dr. Shane R. Reti, Dr. Susana M. Vieira and MSc Federico Cismondi**

André Fialho

Objectives

In the project we are presenting here, we will examine data collected in intensive care units (ICU) of large, hospital-based health systems and try to predict, within suitable confidence limits, which patients will experience key adverse outcomes in the context of current system design and conventional processes of care. Findings from these analyses should offer key benefits for those who design and implement engineering systems interventions in hospitals.

Work Plan and Results

Data mining is the process of extracting patterns from data by following a set of key steps as presented in Figure 2. One of them is modeling, where preprocessed clean data is used to extract models describing important data classes or to predict future data trends. Different models are available, including: neural networks, fuzzy systems, decision trees, support vector machines and Bayesian networks. The problems we addressed using this process are now described:

Problem 1
Septic shock is a common ICU key adverse outcome, translated into —50% mortality rate and high costs of treatments [1].

Goal
Predict the outcome (survive or decease) of septic shock patients, for purposes of therapy management.

MEDAN Database
382 septic shock patients, recorded from 71 German ICUs, from 1998 to 2002 [2].

Methods
Fuzzy Systems or Neural Networks + feature selection (bottom-up and ant colony)

Problem 2
Many questions exist regarding the management of patients with acute circulatory shock. E.g. Which vasopressor agent is best? When should vasopressors be started and at what dosage?

Goal
Predict which patients will require vasopressors during their ICU stay.

MIMIC II Database
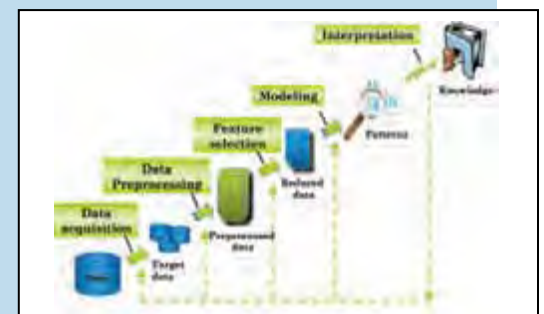26,655 ICU patients from Beth Israel Deaconess Medical Center, Boston, from 2001 to 2007 [4].

Methods
Fuzzy Systems, Neural Networks or 24 Weka software methods [5]
+
feature selection (bottom-up and top-down)

The accuracy of each model may be given by the percentage of test entries that are correctly classified (PCC) or by the relation between true and false positives - area under the Receiving Operating Curve (AUC). Best model results for Problem 1 and 2 were respectively obtained by Fuzzy Systems with bottom-up feature selection [3] (Table 1) and IBk (Instance Based k-neighbour) with top-down feature selection (Table 2)..

Fig. 1. ICU room of an hospital

Fig. 2. Data mining key steps

Bibliography:
[1] American College of Chest Physicians/Society of Critical Care Medicine Consensus Conference: Definitions for sepsis and organ failure and guidelines for the use of innovative therapies in sepsis. Crit Care Med (20) (1992) 864–874
[2] Hanisch, E., Brause, R., Arlt, B., Paetz, J., Holzer, K.: The MEDAN Database (2003) http://www.medan.de, accessed 20 October 2009.
[3] Fialho, A. S., Cismondi, F., Vieira, S. M., Sousa, J.M.C., Reti, S. R., Howell, M. D., Finkelstein, S. N.: Predicting outcomes of septic shock patients using feature selection based on soft computing techniques. Proceedings of International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems, IPMU 2010, Dortmund, Germany, 2010.
[4] Saeed M, Lieu C, Raber G, Mark RG. MIMIC II: A Massive ICU Patient Databse to Support Research in Intelligent Patient Monitoring Computers in Cardiology 2002;29:641-644
[5] Mark Hall, Eibe Frank, Geoffrey Holmes, Bernhard Pfahringer, Peter Reutemann, Ian H. Witten (2009); The WEKA Data Mining Software: An Update; SIGKDD Explorations, Volume 11, Issue 1.

Table 1. Problem 1 best model results

AUC	PCC	Specifity	Sensitivity
0.818 (0.02)	0.823 (0.02)	0.833 (0.02)	0.823 (0.03)

Table 2 . Problem 2 best model results

AUC	PCC	Specifity	Sensitivity
0.879 (0.01)	0.882 (0.01)	0.867 (0.03)	0.891 (0.01)

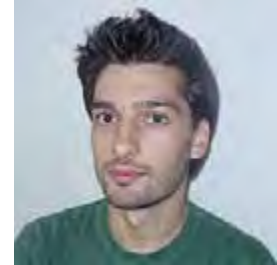# Development of Nanomorphous Silicon Solar Cells in Ceramic Substrates with Biomedical Application

Bioengineering Systems PhD
FCT-UNL
Background: **MSc. Biomedical Engineering, FCT-UNL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Rodrigo Martins (UNL-FCT), Hugo Águas (UNL-FCT) and Nunes da Ponte (UNL-FCT)**

António Vicente

Objectives

This PhD thesis aims at the development and fabrication of high efficiency thin film silicon solar cells deposited on ceramic substrates, with a specific architectural design. The Biomedical Engineering application of these novel and innovative integrated photovoltaic ceramics will also be studied, namely for the design of a self-sufficient renewable energy Field Hospital.

Work plan

This PhD thesis pretends to achieve :

A novel and innovative solution, as an alternative to the traditional micromorphous (n-i-p)1-(n-i-p)2 ("tandem") solar cells (Fig. 1). By using new deposition conditions, specifically, replacing the amorphous n-i-p structure by a nanostructured one, the goal is to overcome the 10% efficiency barrier.

Apply the optimized technology in the Biomedical Engineering context by designing a self-sufficient renewable energy Field Hospital (Fig. 2), with the objective of maximizing the energy harvesting to improve the number and quality of the services provided.

This work also shows very important cross-cutting features, essential to innovative and multi-disciplinary thesis, since it is involved in synergies with multiple companies that composes the consortium of the Solar Tiles project, namely Revigres, Dominó, Coelho da Silva and DeViris, the Technologic Centre CTCV (Centro Tecnológico da Cerâmica e do Vidro), the Agency for Energy - ADENE, the National Institute of Engineering - INETI and the University of Minho.
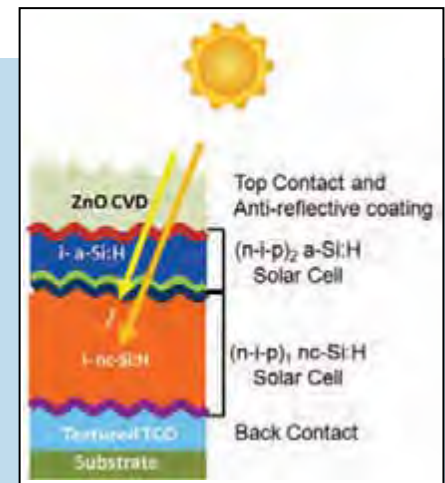

Fig. 1 Tandem Solar Cell..
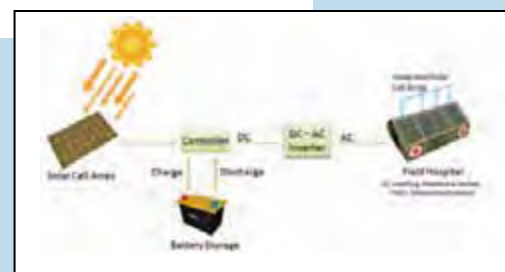
Fig. 2 Off-grid system with battery back-up power.

Results

Preliminary morphologic studies of the ceramic tiles to assess the optimal conditions required to be used as substrate and assure maximum compatibility with the deposited thin film.

For initial optimization of the individual layers, single junction cells were fabricated on glass substrates and led to efficiencies near 5% (Fig. 3).
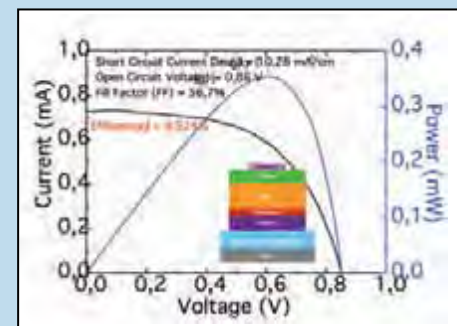
Fig. 3 Sun simulator I-V curve for a produced single junction cell.

Design and operation of bioreactor systems for the expansion and controlled neural differentiation of stem cells

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biological Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Maria Margarida Diogo (IST-UTL),**
Cláudia Lobato da Silva (IST-UTL), and Joaquim Cabral (IST-UTL)

Carlos Rodrigues

Objectives

Development of a bioreactor platform for the controlled and reproducible large-scale expansion and/or differentiation of :

- mouse embryonic stem cell -derived neural stem (mNS) cells

- human pluripotent stem cell-derived neural stem (hPSNS) cells

- human induced pluripotent stem (hiPS) cells

Work plan

The main tasks are:

- optimization of mNS cell expansion and differentiation under static culture conditions

- development of stirred bioreactor systems for the xeno-free expansion of multipotent mNS and hPSNS as well as for hiPS cells under adherent conditions, using microcarriers

- scale-up of the bioprocess from spinner-flasks to large-scale fully controlled bioreactors

Cell cultures will be characterized in terms of fold increase in cell number, viability, growth rate, metabolic profile and expression of specific stem cell markers

Results

- 2-5% oxygen environment led to fold increase values in total mNS cell number about twice higher than those observed under 20% oxygen, without affecting the multipotency of the cells.

- The optimum initial cell density is 104 cells/cm2

- Flow cytometry analysis demonstrated that under 2% O2, cells proliferate more and a lower percentage of cells exits cell cycle.

- Initial results show that, after 6 days, using animal-free media and microcarriers, a 40 fold increase in mNS cell number can be achieved in a spinner-flask

mNS cell Growth Kinetics in Static Conditions under 20 % O2 (–) and 2 % O2 (–)
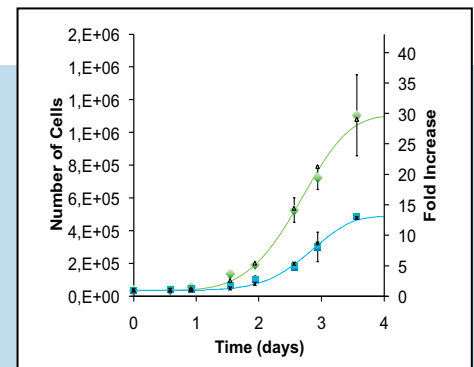
TmNS cell Growth Kinetics in spinner-flasks
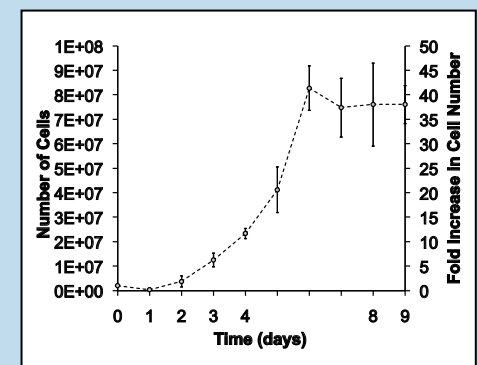
Novel modelling formalisms and simulation tools in Computational Biosystems

Bioengineering Systems PhD

UMinho

Background: **MSc. Mathematics and Computer Science,**
University of Minho, Portugal
Portugal

Starting Year: **2007 / 2008**

Supervisor: **Eugénio Ferreira (UMinho), Isabel Rocha (UMinho),**
Bruce Tidor (MIT)

Research team: **D.Machado,R.Costa,I.Rocha,M.Rocha,B.Tidor,E.C.Ferreira**

Carlos Machado

Objectives

- Integration of different kinds of biological networks.

- Creation of a common modelling framework.

- Support for analysis, simulation and optimization.

- Focus on Metabolic Engineering applications (Fig. 1.)..

Work Plan

- Review modelling formalisms used in Systems Biology.

- Select suitable formalism to create a modelling framework.

- Development of analysis and simulation tools in this framework.

- Implement integrated regulatory and metabolic model of E.coli.

- Experimental validation using bench-scale bioreactors.

Results

Initial research covered mathematical and computational formalisms used in Systems Biology (such as differential equations, boolean networks and process algebras). Petri nets (Fig. 2) are a sound mathematical and graphical formalism with different extensions available, providing the flexibility required to integrate different types of networks. Examples found in the literature cover analysis and simulation of all major kinds of networks (metabolic, regulatory and signalling.)

Fig. 1. Biotechnological production.
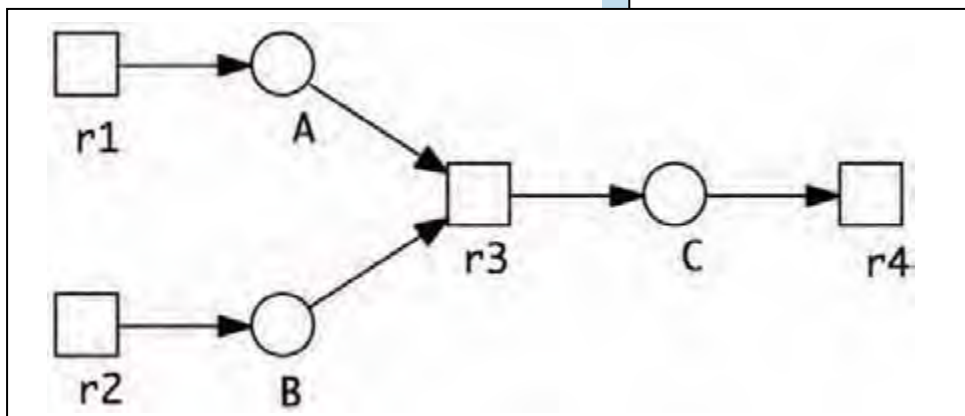
Fig. 2. Petri net model of a small metabolic network.

Optical sensors for biomedical applications

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biotechnology Engineering, University of Algarve, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisor: **Guilherme Ferreira (IBB) , João Conde (IST-UTL)**
Research team: **Guilherme Ferreira (team leader), Ana Carina Silva,**
Brigitte Tomé, Jorge Carvalho, Luís Rosa, Luisa Pedro, Rogério Rodrigues,
Sandra Soares

Cláudia Vistas

Objectives

This PhD aims at the study of hydrogenated amorphous silicon (a-Si:H)   p-i-n photodiode as integrated fluorescence detector for biomolecular recognition, using semiconductor nanocrystals, also known as quantum dots (QDs). .

Work Plan

Development of the sensor device for biomolecular recognition;
Surface functionalization of the biosensor;
Functionalization of QDs with biomolecules;
Integration of a-Si:H photodetector into a microfluidic system;
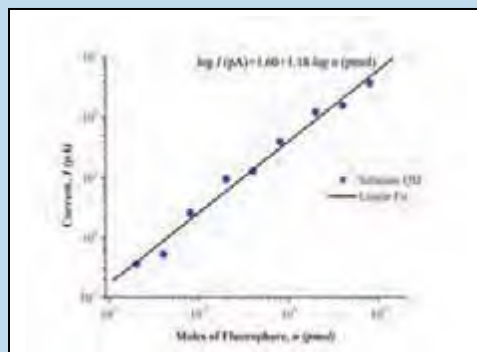Use of such photodetector in biorecognition of relevant molecules.

Results

The QDs are used as fluorescent labels for biomolecules, being optically detected by the a-Si:H photosensor (Figure 1); where an amorphous silicon-carbon (a-SiC:H) filter, integrated in the chip, cuts the excitation light while allowing the transmission of the fluorescence light emitted by labeled biomolecules.

The response of the chips using 600 nm CdSe/ZnS QDs was initially characterize (Figure 2). The detection limit of the devices was 0.01 pmol for the QD600 in solution.
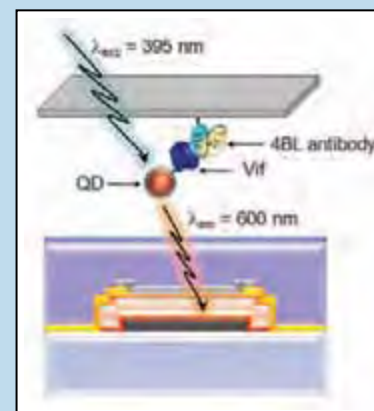
One of the applications developed using these detectors is the detection of the HIV-1 Vif (virion infectivity factor). Anti-HIV-1 Vif single chain fragment antibodies (scFv-4BL) were developed and immobilized on the surface of the biosensor (Figure 3). HIV1-Vif is detected by the fluorescent signal after being conjugated to QDs (Figure 4).
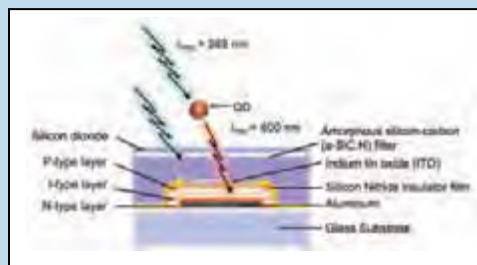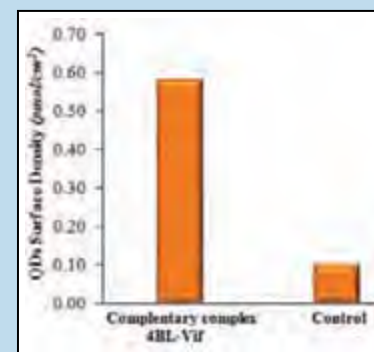

Fig. 1. Schematic diagram of the photodetector.

Fig. 3. Schematic diagram of the detection of HIV-1 Vif using the a-Si:H photosensor.

Fig. 2. QDs Calibration - Photoresponse of the a-Si:H p-i-n photodiode plotted as a function of the number of moles of QDs in solution.

Fig. 4. Surface density of QDs for the 4BL-Vif complex and the control.

Antimicrobial nanocoatings

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biochemistry, University of Coimbra, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Lino Ferreira (CNBC, Biocant), Joaquim Cabral (IBB-IST)**
Research team: **Cristiana Paulo, Paula Lacerda, Miguel Lino, Maria Vidal,**
Lino Ferreira

Cristiana Paulo

Objectives

Microbial biofilms (Fig. 1) are formed when microorganisms irreversibly adhere to any moist surface and produce extracellular components that facilitate adhesion and provide a structural matrix. Their tenacity and resistance to antimicrobials causes a highly negative impact on public health and economy. It is estimated that nosocomial infections affect about 2.0 million people in the U.S. each year and costs more than $11.0 billion to the healthcare providers (Frost & Sullivan, 2003). The design of materials that mitigate or prevent biofilm formation would be beneficial in several other areas including food industry, environment and textiles, especially because such materials with specific and efficient antimicrobial properties currently do not exist. The objective of the PhD is to develop durable antimicrobial materials for application in indwelling medical devices.

Work plan

This project is divided in several tasks, including the (i) development and characterization of new antimicrobial materials, (ii) determination of their antimicrobial activity spectrum and (iii) the evaluation of their cytotoxicity against human cells.

Results

- So far, we were able to generate and characterize new biomaterials with high antimicrobial efficacy.

- The biomaterials proved to be effective against several species of microorganisms.

- Our materials compare favorably to antimicrobial products existing in the market.

- We are in the process of filing a patent with the results obtained during this work.
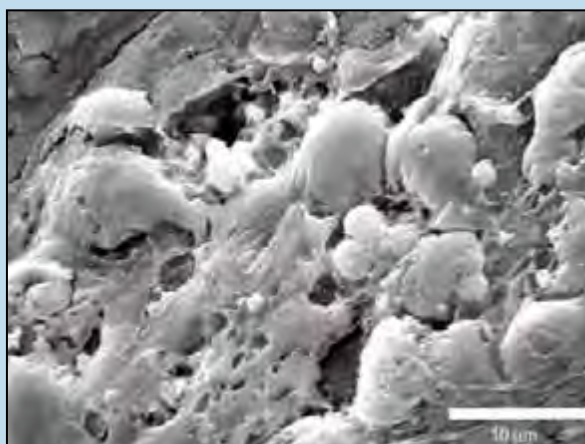
Fig. 1. Scanning electron micrograph of a microbial biofilm.

Source: J. C. Tiller, C. J. Liao, K. Lewis, A. M. Klibanov, PNAS 2001, 98, 5981.

Opportunities Arising at the Intersection of Technologies in Healthcare

Bioengineering Systems PhD
FCT-UNL
Background: **MSc. Biomedical Engineering, University of Minho, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Luis Lages (UNL), Pedro Saraiva (UCoimbra),**
**Charles Cooney (MIT), Luís Perez-Breva (MIT)**

Daniela Couto

Objectives

- Identify the players that can influence the product and market development in combination products, cell-based therapies, and tissue engineering at the regulatory, corporate, and technological levels

- Develop a strategic framework that supports and explains the emergence of new companies with business models that evolve effectively with tissue engineering technologies

- Apply the framework and tools developed to the Portuguese scenario

Work Plan
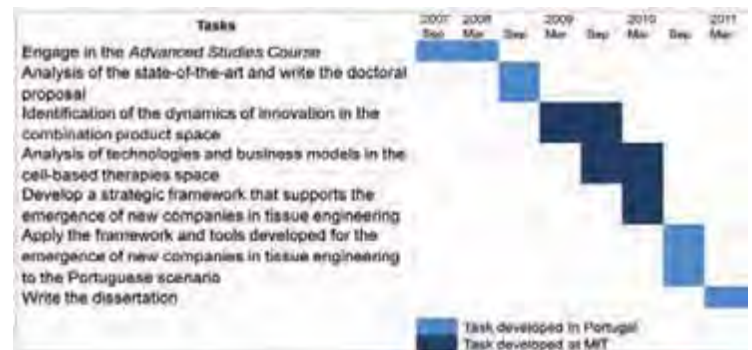
Results

We analyzed the dynamics of combination products and regenerative medicine from the regulatory, corporate, and technological vantage points. A key learning from that analysis is that the regulatory structure for combination products has a strong influence on the role of incumbents and start-ups; through the choice of a primary function.

In the regenerative space, we identified key advantages and challenges associated with the coupling of cell-based therapies and business models, and proposed strategic decisions and evolution pathways to accomplish sustained economic impact in regenerative medicine.

Fig. 1. Intersection of technologies in healthcare analyzed from the regulatory, corporate, and technological levels.
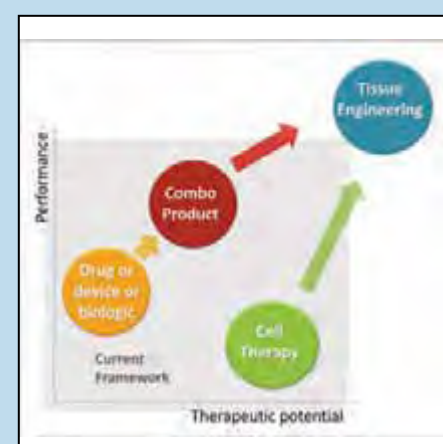
Fig. 2. Emergence of tissue engineering with lessons learned from combination products and cell-based therapies.

Microfabrication of biomaterials for tissue engineering application

Bioengineering Systems PhD
University of Minho
Background: **MSc. Biomedical Engineering, University of Minho, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Rui Reis (UMinho) , Nuno Neves (UMinho),**
Manuela Gomes (UMinho), Ali Khademhosseini (Harvard-MIT - HST)
Research team: **Shilpa Sant, Hyeongho Shin (Harvard-MIT - HST)**

Daniela Coutinho

Objectives

Development of strategies for controlling the stem cell response to biodegradable polymers through the design of innovative micro/nano-engineered structures and surfaces.

- Optimize biomaterials for microfabrication.
- Development of degradable micro-patterned surfaces and micro-architectured hydrogels for tissue engineering applications.

Work plan

The work plan so far was focused on the following topics:

- Development of micro-patterned surfaces of PBS and analysis of the interaction of adipose stem cells with these surfaces.
- Development of a GG hydrogel with highly tunable properties for microfabrication.

## Results

In the last year of the PhD, it was possible to achieve the following results:
- Methacrylation of GG (MeGG) with double bonds (Figure 1).
- Swelling properties highly dependent on the ionic content of the solution (Figure 2).
- The type of crosslinking mechanism used led to the production of hydrogels with different Young's Modulus values and different degradation profile rates (Figure 2).
- Methacrylate groups and UV exposure showed not to influence cell viablity just after cell encapsulation and after 3 days in culture (Figure 3).

In summary, we have achieved the development of highly tunable hydrogels applicable for a wide range of tissue engineering applications using physiologically compatible crosslinking methods.

Production and Chemical Characterization of MeGG
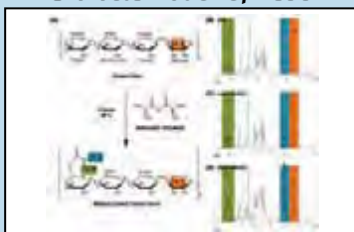
Fig. 1. (A) Schematic illustration of the synthesis of MeGG. 1H-NMR spectra (T=50 ºC) of (B) GG, (C) Low-MeGG and (D) High-MeGG recorder in D2O.

Physical and Mechanical Characterization of MeGG
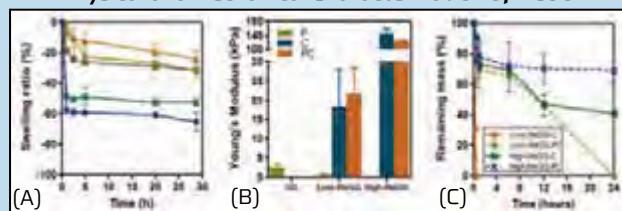
Fig. 2. (A) Swelling ratio of hydrogels in PBS. (B) Variation of Young's modulus of hydrogels the type of crosslinking mechanism.
(C) Degradation profile of hydrogels.

Encapsulation of 3T3 cells on MeGG
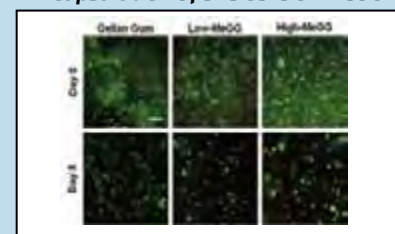
Fig. 3. Fluorescence micrographs of live (green) and dead (red) encapsulated 3T3 cells in GG, Low-MeGG and High-MeGG immediately after encapsulation (day 0) and cultured in vitro for 3 days (scale bars-100 m).

Ex vivo Engineered MicroNiches for HighThroughput Cell Fate Studies

Bioengineering Systems PhD

IST-UTL

Background: **MSc. Biological Engineering, IST-UTL, Portugal**

Portugal

Starting Year: **2007 / 2008**

Supervisors: **Joaquim Sampaio Cabral, Cláudia Lobato da Silva (IST-UTL), Sangheeta Bhatia (MIT)**

Research team: **Braga Malta, D., Underhill, G., Reticker-Flynn, N.E., Xue, Y., Lobato da Silva, C., Cabral, J.M.S. and Bhatia S.N.**

David Malta

Objectives

The current project aims to contribute to a better knowledge of the hematopoietic niche towards the ultimate development of novel strategies for the ex-vivo expansion of human hematopoietic stem/progenitor cells (HSPC). Such advancements could be applied to multiple settings such as cell (e.g. BM transplantation) or gene therapy. The major breakthroughs of this project are expected to boost ex-vivo expansion technologies.

Work Plan

By employing both mesenchymal stem cell-derived stromal cells and cytokines to provide appropriate niche-mediated regulation, we envisage the development of a successful platform for the expansion of umbilical cord blood (UCB) HSPC, making UCB transplantation in adults more widely available. Due to the importance of stromal cells in the maintenance and expansion of HSPC, we will initially focus efforts towards identifying environmental signals (e.g. extracellular matrix, soluble factors) that promote the proliferation of mesenchymal stem cells (MSC), while maintaining multipotency and the capacity to effectively support HSPC culture. ECM components have been suggested to be involved in retaining stem cells within anatomical niches and regulating stem cell signaling and proliferation. Thus, to investigate the effect of combinations of these factors, a matrix microarray platform was developed and is now being updated with broad utility for diverse cell types, including stem cells.

Results

We have developed and established a pipeline for a ECM cellular microarray that enables performing high-throughput cellular studies (Fig. 1). This new ECM array incorporates all commercially available ECM molecules in single and pair wise combinations, total 800 combinations (Fig. 2). We have also developed analysis software that allows process the scanned image of the array in an automated fashion, to convert pixel data in to biological results (Fig. 3). Overall, these initial results show the suitability and robustness of the ECM array platform for stem cell studies.

Fig. 1. ECM array platform pipeline. Glass slides are modified and functionalized with an acrylamide hydrogel to enable molecule entrapment. Them odified slides are then printed with ECM molecules using a DNA arrayer. The ECM arrays are then incubated with cells till the desired end point. The slides are fixed and stained for specific markers and imaged using an automated microscope. The obtained images are processed to extract the data using in house developed software.

ECM Molecules Incorporated

COLLAGEN I	AGRIN
COLLAGEN II	F-SPONDIN
COLLAGEN III	NIDOGEN-1
COLLAGEN IV	NIDOGEN-2
COLLAGEN V	HEPARAN SULFATE
COLLAGEN VI	HYALURONIC ACID
FIBRONECTIN	BIGLYCAN
LAMININ	GALECTIN 1
MEROSIN	GALECTIN 3
VITRONECTIN	GALECTIN 3C
TENASCIN-C	GALECTIN 4
TENASCIN-R	GALECTIN 8
CHONDROITIN SULFATE	TESTICAN 1/SPOCK1
AGGRECAN	TESTICAN 2/SPOCK2
DECORIN	OSTEOPONTIN
ELASTIN	SPARC/OSTEONECTIN
KERATIN	THROMBOSPONDIN-4
MUCIN	BREVICAN
SUPERFIBRONECTIN	FIBRIN

Fig. 2. Second generation ECM array. A) ECM array stanied for the presence of 2 molecules. Brevinca (green) and Condroitin Sulfate (Red). B) List of ECM molecules present in the array.
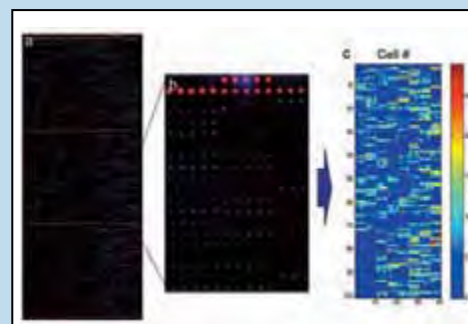
Fig. 3. MSC Adhesome. MSC day 1 adhesion profile. A) ECM array incubated with MSC for 24 hours. Cells were staned with hoesct stain for nuclei. B) zoom in on the ECM array. C) Heatmap of cell adhesion.

References
Flaim et al. Nat Methods 2005

Efficiently Minimizing Parameter Uncertainty in Biological Systems

Bioengineering Systems PhD
MIT
Background: **Biological Engineering**
Supervisor: **Bruce Tidor (MIT)**
Research team: **E. Ferreira, I. Rocha, L. Rodrigues, M.Mota (U Minho)**

David Hagen

Objectives

Models are a useful representation of what we know and do not know about a biological system. Uncertainty in model parameters represents a lack of biological knowledge. The goal of my thesis research is to design classes of experiments that exercise a biological system thoroughly enough to reduce parameter uncertainty in associated models to nominal levels, thereby eliminating uncertainty in the underlying biological mechanisms and kinetics.

Work plan

We used the Fisher information matrix of the system to represent the uncertainty in the parameters. Our algorithm combines information matrices from multiple experiments in order to determine the next best experiment—the one that is complimentary to the experiments that have already been done. In our procedure, we found the optimal experiment according to our algorithm, performed that experiment synthetically, fit to both the old and new data, and recomputed the uncertainty. We repeated this procedure until the uncertainty in all parameters of the model was reduced below a desired threshold. This procedure was applied to a model of the EGF-NGF pathway, an important pathway in cancer biology. The possible experiments differed in the starting concentrations of the inputs to the systems, EGF and NGF, and up to three proteins in the network could be knocked-down or over-expressed.

Results

Using the optimal experimental design algorithm, we were able to reduce the uncertainty in all parameters (Figure 1), recover the true parameters of the system within a small error consistent with the remaining uncertainty (Figure 2), and reduce the prediction errors of the system (Figure 3). It was found that complimentary experiments were those that explored different behaviors of the system. By exploring new behaviors of the system, it is possible to gain knowledge of the system faster than with experiments that explore behavior that has already been studied. Using our optimal experimental design algorithm is helpful for finding these complimentary experiments.
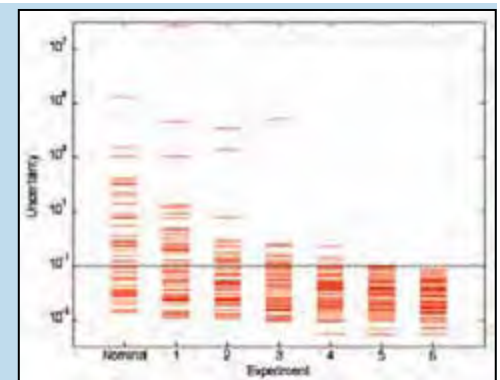

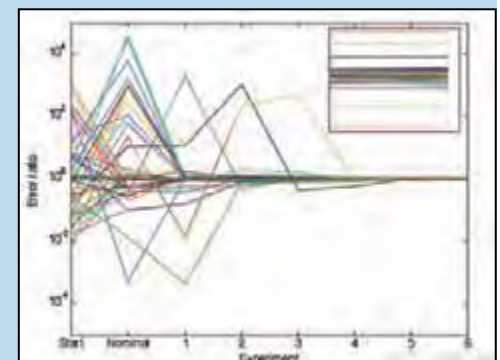**Fig. 1.** Decreasing parameter uncertainty
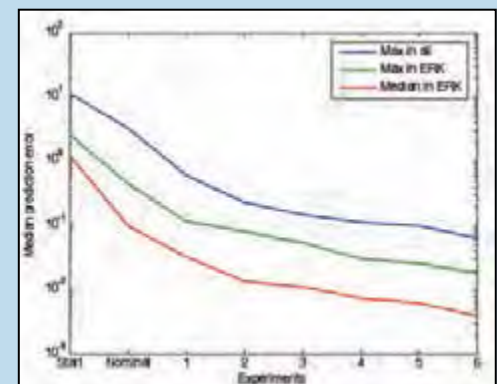

Fig. 2. Converging parameters to true values

Fig. 3. Decreasing prediction error

New Functions of the Endoscopic Capsule

Bioengineering Systems PhD
University of Minho
Background: **MSc. Biomedical Engineering, University of Minho, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Graça Minas (University of Minho),**
José Higino Correia (University of Minho), Michael S. Feld (MIT)
Research team: **Paulo Coutinho, Jelena Mirkovic, Mariana Henriques**

Débora Ferreira

Objectives

This project proposes the integration of new functions in the endoscopic capsule (EC) that can dramatically improve early detection of gastrointestinal (GI) cancers. The main technological innovation is the take-up and integration of microsystems in an EC for spectroscopic clinical assessment of GI tract tissues.

Work plan

CLINICAL STUDY: differentiate normal tissue from dysplasia in the GI tract using spectroscopy techniques. **1**

INSTRUMENTATION DEVELOPMENT: miniature, cost-effective system without optical fibers, spectrograph or CCD camera → increase the collection efficiency and improve throughput **2**

DESIGN & FABRICATION OF MICROSENSORS: monitoring of some physiological parameters **3**

Results

Clinical study: reflectance and fluorescence provide information about tissue parameters - hemoglobin concentration (cHb), collagen, NADH, tissue scattering (A) - from which diagnostic algorithms can be developed and correlated with the disease state of tissue (Fig. 1).

Instrumentation development: device based on 16 thin-film optical filters, for the selection of a few wavelengths significant for diagnosis, photodiodes, for detection of light intensity, and LEDs for illumination (Fig. 2).

Feasibility study: replace the spectrograph by a series of optical filters reduce the number of wavelengths used for diagnosis from 400 to 16, preserving a good accuracy in the extraction of tissue properties (Table 1).
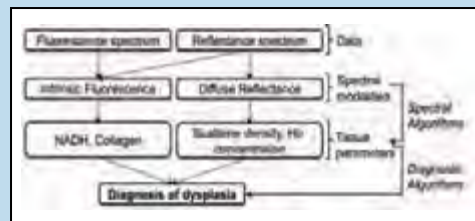
Fig. 1. Spectroscopy approach for the differentiation between normal gastrointestinal tissue and dysplasia (low and high grade) using tissue parameters.
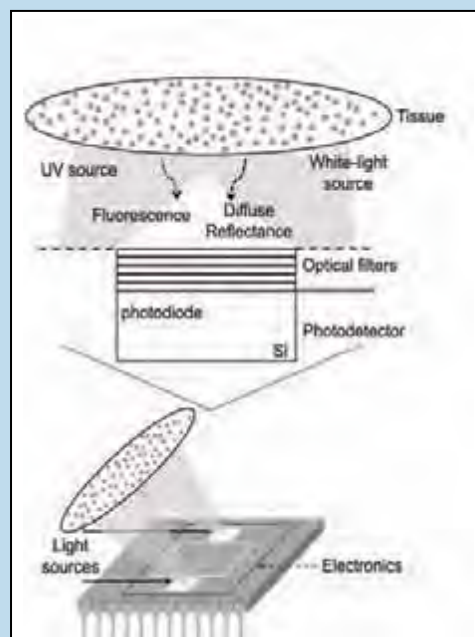
Fig. 2. Miniaturized spectroscopy system (not scaled).

Table 1 Spectroscopic parameters extracted from tissue phantoms, using the full spectrum (350-750 nm) and only 16 wavelengths. Intralipid and hemoglobin are used to simulate tissue scattering and absorption.

Phantoms	Intralipid mass concentration	Hb concentration (mg/mL)	Full Spectrum		16 Wavelengths	
			cHb	A	cHb	A
1	0.5%	0.5	0.498	0.914	0.519	0.903
2	0.5%	1.0	0.944	0.887	1.013	0.673
3	1%	0.5	0.480	1.767	0.499	1.759
4	1%	1.0	0.988	1.782	1.075	1.752

Process design for plasmid DNA production

Bioengineering Systems PhD
MIT
Background: **Chemical Engineering**
Supervisor: **Kristala L. J. Prather (MIT)**
Research team: **G. Monteiro (IST), M. Prazeres (IST),**
G. Lopes (MPP Bioeng. PhD Student)

Diana Bower

Objectives

As more plasmid DNA-based therapies enter late stage clinical trials and are approved for use, the demand for high-quality, pharmaceutical-grade plasmid DNA (pDNA) is anticipated to increase significantly. The overall goal of this thesis is to improve the way gene-based therapeutics are produced by:

•Evaluating the potential of runaway replication plasmids as an alternative production platform for gene therapies and DNA vaccines

•Rationally engineering a strain of Escherichia coli that is designed specifically for pDNA production

•Identifying and addressing the challenges of process design and scale-up associated with a complex biopharmaceutical process using both micro-scale and bench-scale tools

Work plan

•Design and construct a novel DNA vaccine vector with a runaway replication (mutant R1) origin

•Design a fermentation process for high-yield production of the new vector

•Introduce mutations in wild-type E. coli designed to increase pDNA yield à Preliminary work done by DMB; to be completed by MPP PhD student Geisa Lopes

•Develop a fed-batch microbioreactor system that mimics a bench-scale pDNA production process

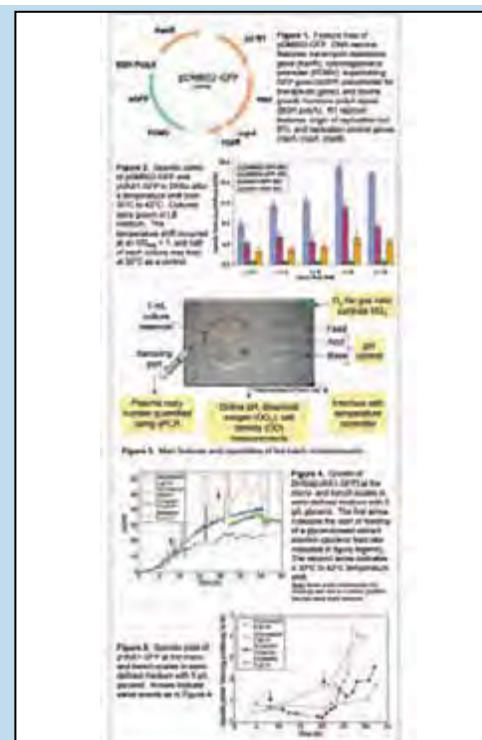•With collaborators at IST, study behavior of new vectors and hosts in downstream processing

Results

pDMB02-GFP: A new vector for DNA vaccine production

We constructed a new vector, pDMB02-GFP (Figure 1), that combines elements of a DNA vaccine vector from pVAX1 (Invitrogen) and the runaway R1 replicon from pCP40 (Gene 22 (1983) 103-113). Based on the published behavior of runaway R1 plasmids, we expected to observe temperature-induced amplification of pDMB02-GFP. Figure 2 shows that while we did not observe amplification of pDMB02-GFP at 42°C vs. 30°C, it produced yields significantly higher than a pUC-replicon DNA vaccine plasmid, pVAX1-GFP. Current work on pDMB02-GFP includes process design studies using fed-batch bench-scale fermentations. We are also probing the molecular biology underlying replication of our new vector to determine if there are limiting factors that can be relieved to further increase yield.

Microbioreactors: A tool for pDNA process development

In collaboration with Prof. Rajeev J. Ram's lab at MIT we have developed a 1-mL fed-batch microbioreactor. Our motivation was to combine the high-throughput nature of shake flasks with the monitoring and control capabilities of bioreactors to develop a tool that can be used to design complex biopharmaceutical processes like pDNA production. Figure 3 shows a photo of the microbioreactor and outlines its main features.

The E. coli strain DH5α[pVAX1-GFP] was used to study pDNA production in the microbioreactor. Figure 4 shows that before feeding began, cell growth was nearly identical in a 0.6-L bench-scale reactor and the microreactor. After feeding started, the cell density depended on the feed rate. For the microreactor run at the high feed rate, the OD600 was lower than the bench scale reactor at the same feed rate due to excess glycerol accumulation that may have been due to an underestimation of the actual feeding rate. Figure 5 shows pVAX1-GFP specific yield at both scales. A temperature shift from 30°C to 42°C after approx. 20 hours of growth was used to increase plasmid amplification. The maximum specific yield depended on glycerol feed rate at both scales. The micro- and bench-scale fermentations with a feed rate of 3 g glycerol/L/hr both produced about 4 µg pVAX1-GFP/mg DCW.

Bioactive Beads for Local Modulation and Sensing of Cell Mechanical Environment in 3D Engineered Tissues

Bioengineering Systems PhD
FCT-UNL
Background: **MSc. Biological Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Ana Aguiar Ricardo (FCT-UNL), Paula Hammond (MIT), Linda Griffith (MIT)**

Eunice Costa

Objectives

Development of cell-sized hydrogel beads with defined mechanical properties and cell-interactive surface properties. Beads will be coated using a layer-by-layer (LbL) approach and incorporated into 3D tissue constructs in order to both provide local modulation of cell behavior (via controlling local mechanics for neighboring cells) as well as record cell physiological function through fluorogenic protease substrates buried within the coating (Fig. 1).

Work Plan

I - Synthesis of biocompatible polymeric beads in supercritical CO_2 (scCO2) with defined size and mechanical properties: explore different monomers, cross-linkers and experimental conditions (FCT-UNL).

II - Beads coating using layer-by-layer deposition in order to incorporate protease substrates and control surface chemical properties: study several biocompatible polyelectrolytes and assembly mechanisms (MIT).

III - Examine bead response in 3D cultures (MIT).

Results

Biocompatible thermoresponsive poly (N-isopropylacrylamide) (PNIPAAm) microspheres were successfully synthesized by dispersion polymerization in supercritical CO_2 with a narrow size distribution. NIPAAm was also copolymerized with methacrylic acid (MAA) yielding pH and temperature responsive PNIPAAm-PMAA microbeads (Fig. 2).

Microbeads showed a high degree of elasticity as assessed by rheological measurements and elastic moduli compliant with soft human tissues at a temperature below the LCST: 0.2 – 1 kPa.

Biocompatible weak polyelectrolytes such as poly L-lysine, poly (methacrylic acid) and tannic acid were adsorbed onto PNIPAAm microbeads (Fig. 3). Tannic acid had the ability to reversibly suppress PNIPAAm thermoresponsive behavior. Experiments for layer build-up and proteases substrate incorporation are under way.
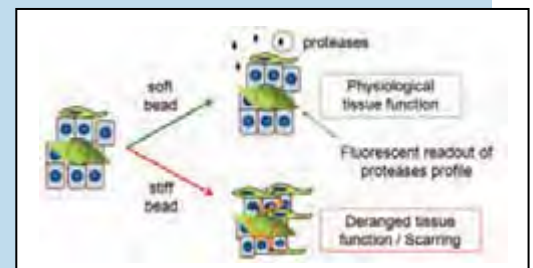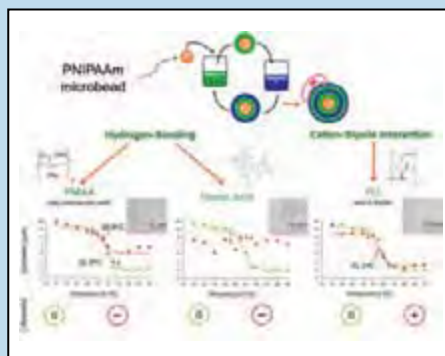

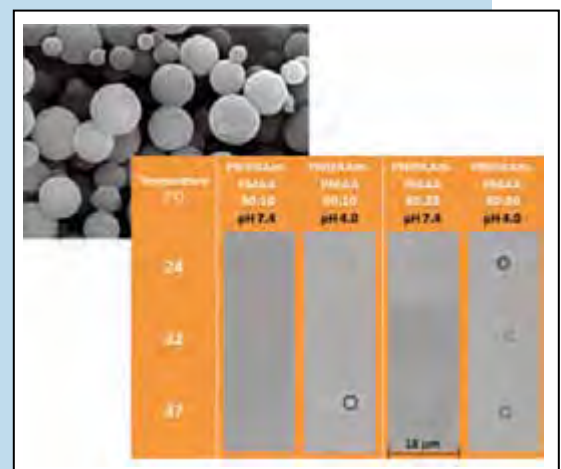**Fig. 1.** Bead modulation and sensing of cell mechanical environment.

Fig. 2. Temperature response of PNIPAAm-PMAA copolymers, synthesized in scCO2, at pH 4.0 and 7.4

Fig. 3. Polyelectrolytes adsorption on PNIPAAm microbeads.

Novel cell factory for the production of complex biopharmaceuticals

Bioengineering Systems PhD
FCT- UNL
Background: **MSc. Biomedical Engineering, University of Minho, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Paula Alves (IBET/ITQB-UNL),**
Ana Teixeira (IBET/ITQB-UNL) and Kristala Prather (MIT)
Research team: **Animal Cell Technology Lab**

Fabiana Fernandes

Objectives

Development of a flexible and re-usable cell factory for the production of complex biopharmaceuticals, using Sf9 insect cells as platform. The strategy relies in a symbioses between recombinase-mediated cassette exchange (RMCE) systems and synthetic biology tools. Different recombinase cassettes will be used for each subunit of the global particle. Then, optimal production of high quality particle will be obtained by fine tuning the expression of each subunit through the implementation of synthetic circuits within the cassettes.

Work plan

Results

We started by looking into promoters for stable protein expression in insect cells. OpIE1/2 promoters are the most well known promoters in Sf9 cells to accomplish that purpose. A vector with GFP under the control of OpIE2 promoter (Fig.1) was transfected into Sf9 cells using cellfectin as transfection agent (Fig.2). Different DNA amounts were used to access the transfection efficiency in two different cell culture conditions: static and suspension. Comparing both cell culture conditions, higher transfection efficiencies were obtained in the suspension cell culture. The minimum DNA amount wich allowed higher tranfection efficiency (over 90%) was 0.3 g of DNA per 1 million cells..

Fig. 1. Vector construction: GFP gene under the control of OpIE2 promoter.
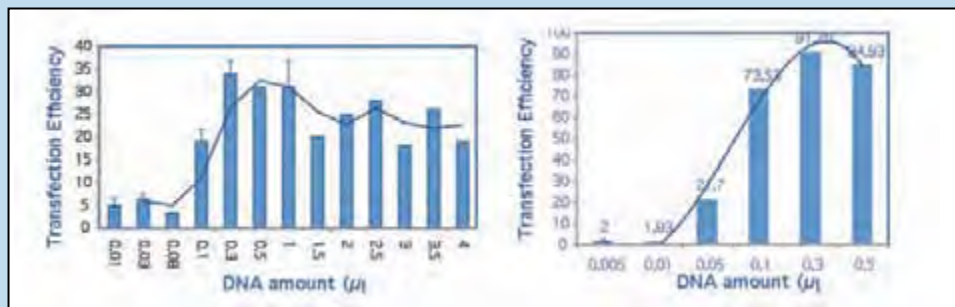
Fig. 2. Transfection efficiencies using different DNA amounts in two distinct cell culture conditions: (a) static and (b) suspension.
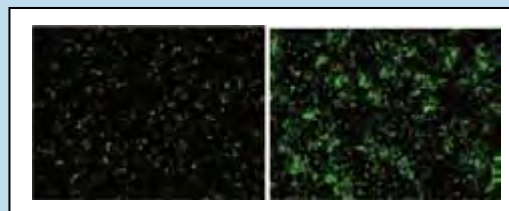
Fig. 3. GFP expression in cells transfected with 0.3 g of DNA in static (a) and suspension (b) cell cultures.

NovaFlow – Novel applications of a state-of-the-art oscillatory flow platform: hydroxyapatite production and its use in bone extracellular matrix growth

Bioengineering Systems PhD
University of Minho
Background: **MSc. Biological Engineering, University of Minho, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **José Teixeira and António Vicente (UMinho)**
Research team: **F. Castro, A. Ferreira, A. Vicente, JA. Teixeira (CEB-IBB, UMinho); F. Rocha (LEPAE-Uporto); A.P. Marques (3B's-IBB, Uminho)**
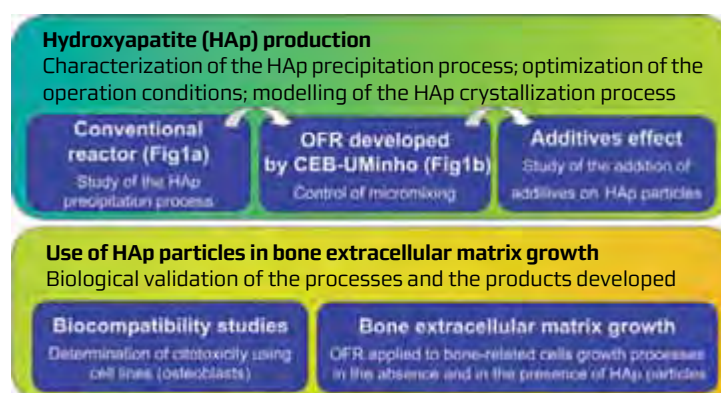
Filipa Castro

Objectives

The present project aims at synthesizing hydroxyapatite (HAp) crystals with a carefully controlled size, with a controlled and narrow size distribution and with a high purity. Thus HAp crystals shall be produced with a high specific surface area, i.e. small crystals, and a high biocompatibility, making them suitable for application in bone substitution.

Work Plan

Hydroxyapatite (HAp) production
Characterization of the HAp precipitation process; optimization of the operation conditions; modelling of the HAp crystallization process

Conventional reactor (Fig1a)
Study of the HAp precipitation process

OFR developed by CEB-UMinho (Fig1b)
Control of micromixing

Additives effect
Study of the addition of additives on HAp particles

Use of HAp particles in bone extracellular matrix growth
Biological validation of the processes and the products developed

Biocompatibility studies
Determination of cytotoxicity using cell lines (osteoblasts)

Bone extracellular matrix growth
OFR applied to bone-related cells growth processes in the absence and in the presence of HAp particles

Results

Initial experiments were performed in the reactor presented in Figure 1a. A saturated solution of calcium was mixed with a solution of phosphate with a molar ratio Ca/P=1.67 and T=37ºC. The pH was continuously measured during HAp precipitation (Fig2), revealing the occurrence of three stages. In those stages the product was characterized through SEM analysis. As it is shown in Figure 2, the particles formed are very small (in the order of nanometers) and have the tendency to aggregate. Further, they have different morphologies during the process, passing through spherical form to needle-like form. The final product was analyzed by X-ray diffraction which confirmed it to be hydroxyapatite (Fig3).
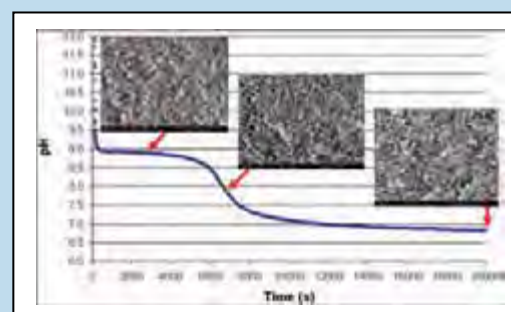

Fig. 2. pH evolution during HAp precipitation and SEM images of the product developed at the different pH stages.
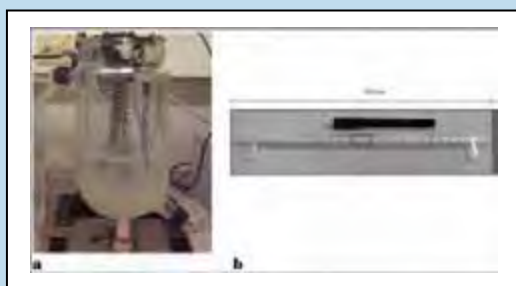

Fig. 1. a) Experimental crystallization apparatus, b) OFR developped by CEB-UMinho.

Fig. 3. X-ray diffraction diagram corresponding to the final product of HAp precipitation.

Rational engineering of E. coli strains and vectors for improved manufacturing of plasmid biopharmaceuticals

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biochemical Engineering, University of São Paulo, Brazil**
Brazil
Starting Year: **2008 / 2009**
Supervisors: **Duarte Miguel Prazeres (IST-UTL), Gabriel Monteiro (IST-UTL), Kristala Prather (MIT)**
Research team: **Pedro Oliveira (IST) and Diana Bower (MIT)**

Geisa Gonçalves

Objectives

The overall goal of this project is to develop and test an E. coli strain specifically adapted to meet the upstream and downstream processing challenges associated with large scale production of plasmid DNA. By rationally engineering specific genes we aim to deliver a host capable of striving in high-density cell cultures while synthesizing large amounts of supercoiled plasmids at high plasmid/impurity ratio. Additionally, we will explore the utility of new kinds of vectors to improve the specific and volumetric yields of pDNA fermentation. After that, we will analyze the impact of the novel strain and vectors on the downstream processing. Ultimately, we will examine plasmid final quality and process economics.

Work plan

This project has the following specific aims with the primary research institution indicated:

1 - Fermentation process and quality control of pDNA (IS2 transposition) handling commonly used laboratory strains of E. coli (IST – 1st semester).

2 - Strain optimization: knockout and over-expression of genes focus on pDNA production. Evaluation of optimized strain (MIT – 2nd semester).

3 - Design of novel runaway replication vectors. Evaluation of optimized vector (MIT – 3rd semester).

4 - Fermentation optimization for novel strain and vector (MIT and IST – 4th/5th semester).

5 - Evaluation of new strain and vector on downstream process (IST – 5th semester).

6 - Performance of economic analysis that compares conventional processes to the developed process (IST – 6th semester).

7 - Thesis writing (6th semester).

Results

Aim 1 – The objective of Aim 1 was to investigate the behaviour of a commonly used laboratory strain on pDNA production. For that, different fermentation strategies were tested: batch versus fed-batch process, complex versus semi-defined medium, at same conditions (37ºC and 30% D.O.):

- IS2 transposition was observed in pVAX1-based plasmid in two different regions, before neomycin resistance and in the middle of GFP gene. Other studies have shown IS insertions in different pDNA vaccine vectors (Prather et al., 2006, Oliveira et al., 2009).

- Nutrient limitation was shown as high-impact factor in IS2 transposition during fed-batch fermentation. Environmental stress such as starvation has been demonstrated as a cause for IS transposition before (Twiss et al. 2005).
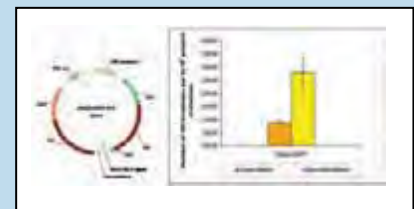
Aim 2 – On-going work.   Aim 3, Aim 4, Aim 5, Aim 6 and Aim 7 – Future work.
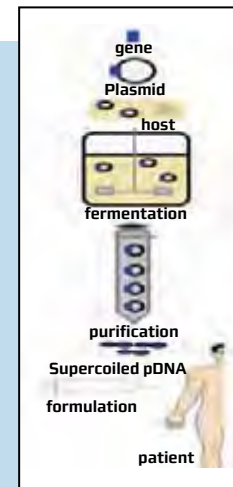
Project overview:

Fig. 1. Plasmid DNA in Gene Therapy

Results:

Fig. 2. Plasmid pVAX-1based plasmid. Shown are the IS2 element identified in this plasmid. A in Gene Therapy. Number of IS2 insertion in pVAX1-based plasmid per 2x108 total plasmid molecules.

On-going work:.

Fig. 3. E. coli metabolism

Engineering Structures for the Profiling and Enrichment of the Proteome

Bioengineering Systems PhD
FCTUNL
Background: **MSc. Applied Chemistry Biotechnology (FCTUNL) Portugal**
Portugal
Starting Year: **2009 / 2010**
Supervisors: **A.C.A. Roque (FCTUNL), O. Iranzo (ITQB/UNL) and C.R. Lowe (Institute of Biotechnology/University of Cambridge)**
Research team: **I.L. Batalha, O. Iranzo, C.R. Lowe and A.C.A. Roque**

Íris Batalha

Objectives

The overall goal of the project is to develop stable and low-cost biomimetic supports specific for the identification and purification of proteins and peptides. Two types of biomimetic ligands will be probed: Synthetic ligands based on combinatorial strategies and biological structures based on engineered domains. The supports to be studied for this application will be agarose and iron oxide superparamagnetic nanoparticles (MNPs).
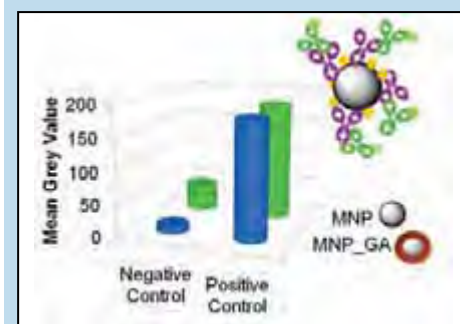
Work plan
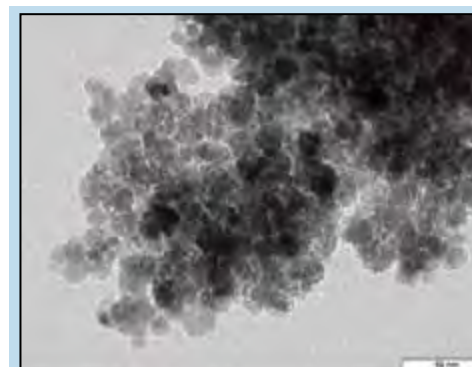
Fig. 1. TEM analysis of MNP_GA

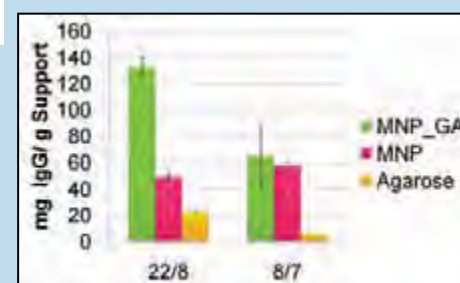Fig. 2. Binding of human IgG to different solid supports modified with biological affinity ligands (n=3)

Results

The proof of concept was established by using MNPs coated with gum arabic (MNP_GA) as a platform for the creation of magnetic bioseparation supports. These supports were further modified with biological (antibodies) and synthetic (artificial protein A and artificial protein L) receptors for a model protein (Immunoglobulin G) at high densities. MNP_GA functionalized with affinity ligands bound approximately 6 times more protein than agarose, which is a remarkable result when considering the low manufacture costs and ease of preparation of the magnetic supports.

Fig. 3. Binding of human IgG to different solid supports modified with synthetic affinity ligands (n=3)

Novel Approaches to Treat Skin Defects

Bioengineering Systems PhD
UMinho
Background: **MSc. Biomedical Engineering, University of Minho, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Alexandra P. Marques (UMinho), Rui L. Reis(UMinho),**
Paula T. Hammond (MIT), Daniel S. Kohane (MIT), Robert S. Langer(MIT)

Isa Monteiro

Objectives

Create a skin-like construct for transplantation, using a Regenerative Medicine approach. The tissue will be obtained by combining scaffolding polymeric structures with cells and bioactive agents. The scaffold is designed in order to allow the co-culture of different cells, creating defined epidermal and dermal-like regions and promoting the migration of endothelial cells. Growth factors are incorporated, and released in a controlled way, contributing for cell survival, migration, vascularization of the new tissue, and for the in situ differentiation of human amniotic fluid stem cells (hAFSCs).

Work Plan

Development and characterization of a porous 3D bilayered scaffold.
Biofunctionalization of the scaffold by incorporation of growth factors: in particles and by layer-by-layer (LbL) technique. Characterization and fine tuning of the release profiles.
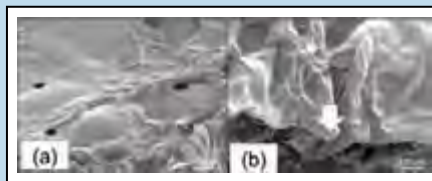Isolation, characterization and establishment of cultures of human dermal fibroblasts, keratinocytes and hAFSCs. Culture of the cited cells on the scaffold: biocompatibility, cell recruitment, migration, cross-talk and stem cell response to stimuli and differentiation.
Transplantation of the construct into 3rd degree burns created in the back of atimic rats. Evaluation of the in situ differentiation of the hAFSCs.
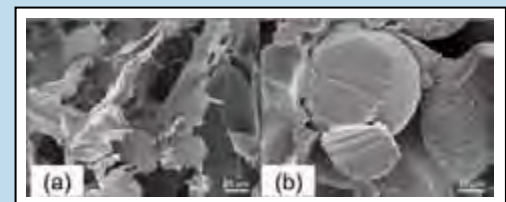
Results

A hyaluronan-dextran scaffold, composed by two distinct regions of different porosities, was created and observed under scanning electronic microscopy (SEM) (Fig. 1). Poly(lactic-co-glycolic acid) (PLGA) particles were produced. Growth factors, namely basic fibroblasts growth factor (bFGF) and vascular endothelial growth factor (VEGF), were encapsulated in the particles. Those particles were then incorporated in the scaffolds (Fig.2). A spray assisted LbL technique was used to create a film on the surface of the scaffold, incorporating epidermal growth factor (EGF) and bFGF (Fig.3). Kinetics studies confirmed the sustained release (Fig. 4). Procedures for isolation, culture, and characterization of human dermal fibroblasts, keratinocytes and hAFSCs were successfully established.
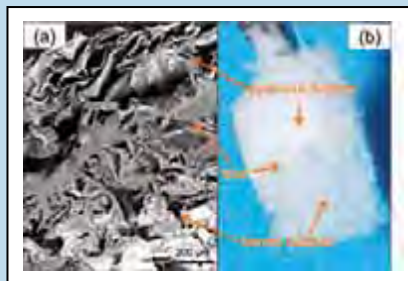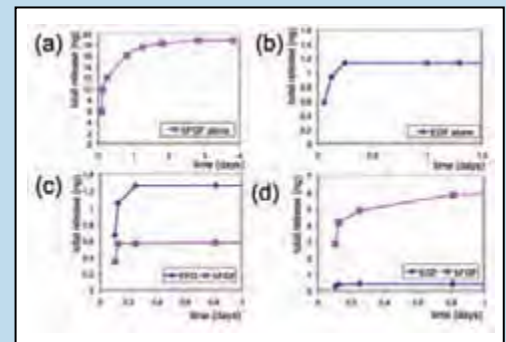

Fig. 1. Bilayered scaffold for full thickness wound regeneration:
(a) transversal cut observed under SEM and (b) macroscopic view.

Fig. 2. SEM images of PLGA particles incorporated in a scaffold: (a) distribution of the particles in the scaffold and (b) detail of a transversal cut on a particle.

Fig. 3. SEM images of LbL on the top of a scaffold: (a) top view (b) transversal cut.

Fig. 4. Release kinetics from LbL films on the surface of the scaffold incorporating: (a) bFGF, (b) EGF (c) EFG first and bFGF later (d) bFGF first and EGF later.

Crude Oil BioDesulfurization

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biological Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **M. Raquel Aires-Barros (IST/ UTL) Daniel I.C. Wang (MIT),**
Carla C.C.R. de Carvalho (IST/UTL)

Isabel Ferreira

Objectives

The global crude oil consumption is 71.7million barrels per day. The new regulations to lower sulfur content in fossil fuels (up to 7.89% w/w) require innovative, economic and efficient methods for desulfurization of crude oil. This project is targeted at the development of a bioprocess for the desulfurization of crude oil. Dibenzothiophene (DBT) has been used as model compound to test the biodesulfurization ability of bacterial strains since it is the most common sulfur compound in crude oil. Both synthetic mixtures and crude oil have been used in the assays.

Work plan

The feasibility of using rhodococci strains (e.g. Rhodococcus erythropolis IGTS8 and Rhodococcus erythropolis DCL14) for the desulfurization of crude oil was investigated. A schematic representation of the experiments is shown in Figure 1

Results

Both R. erythropolis IGTS8 and R. erythropolis DCL14 were able to remove DBT from crude oil. When the influence of the sulfur source during growth was evaluated, the results showed that while with strain IGTS8 no significant effect was observed, with strain DCL14 the absence of sulfur source during growth enhanced the desulfurization rate (Figure 2). Moreover, when in biphasic medium containing 1mM of DBT, R. erythopolis IGTS8 cells were able to metabolize successfully the compound in the presence of C8-C16 alkanes (Figure 3)..

Conclusion

The bacterial cells investigated were able to degradate DBT in both biphasic medium and crude oil while maintaining their viability (Figure4)..
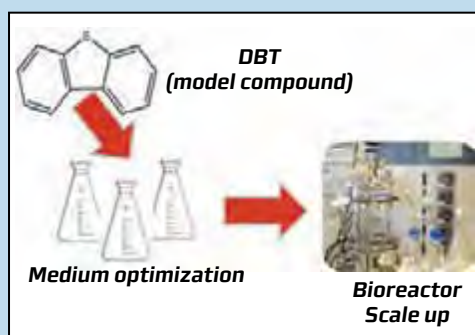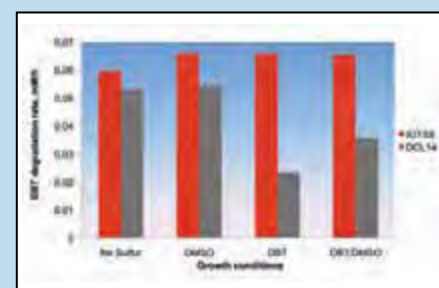

Fig. 1. Work plan

Fig. 2. Effect of the sulfur source used for growth on the biodesulfurization rate.
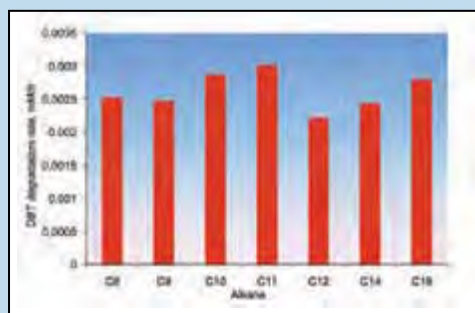

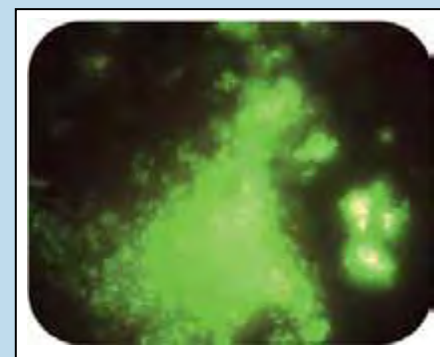**Fig. 3.** Effect of different alkanes on the biodesulfurization rate.

Fig. 4. Viability of R. erythropolis IGTS8 cells during biodesulfurization.

33

Skeletal Muscle Differentiation of Human Mesenchymal Stem Cells (MSC) via Non-Viral Gene Delivery for Therapeutic Applications
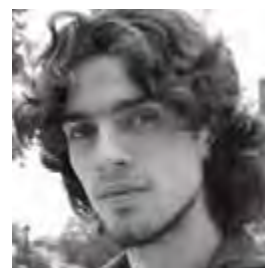
Bioengineering Systems PhD

IST-UTL

Background: **MSc in Biological Engineering, IST-UTL, Portugal**

Portugal

Starting Year: **2007 / 2008**

Supervisors: **Cláudia da Silva (IST-UTL), Joaquim Cabral (IST-UTL), Daniel Anderson, Robert Langer (MIT)**

Research team: **F. Yang (MIT), M. Ma (MIT), N. Hwang (MIT)**

João Guerreiro

Objectives

Efficiently induce human mesenchynal stem cells commitment to the skeletal muscle lineage under defined conditions in view of a future therapeutic application by:

- Avoiding the use of serum, animal products and non-define components as a differentiation factor.
- Applying efficient gene transfer systems to over-express key myogenic activators

Work plan

-Expand hMSC in serum free conditions (1)

-Address differentiation potential of:
 - different myogenic related genes (2);
 - oriented nanofibers (2);
 - combined approach (3).

- Test survival and recovery potential in vivo (4)
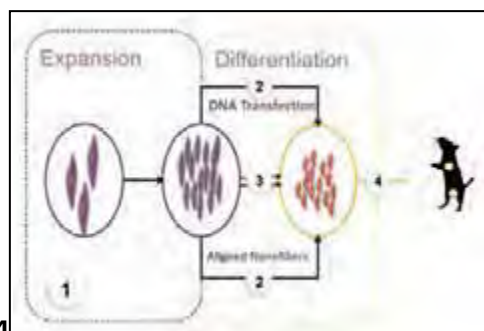
Results

- The gene delivery system was optimized for the MSC and under different serum conditions (Figure 1).
- Several myogenic genes were overrepressed by transfecting them into hMSC. Their effect on the myogenic machinery was followed (Figure 2) and compared to common differentiation cocktails in use.
- A method to produce and assay aligned nanofibers was devised (Figure 3A). Cells successfully adhered and aligned over both synthetic and natural fibers (Figure 3B), presenting myogenic like morphology (Figure 3C)
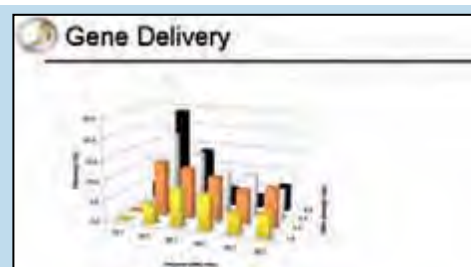

Fig. 1. Transfection efficiency of end modified PBAE (C32-117) in hMSC for different Polymer:DNA ratio (wt:wt) and DNA dosage (g/ 2cm2)
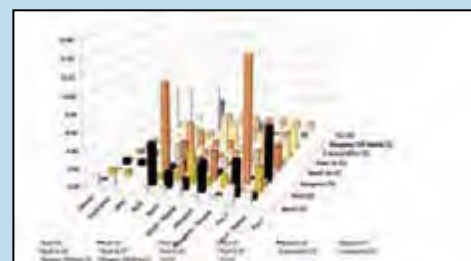

Fig. 2. Gene Expression of MSC after transfection with myogenic factors (MyoD, Pax3 and myogenin).
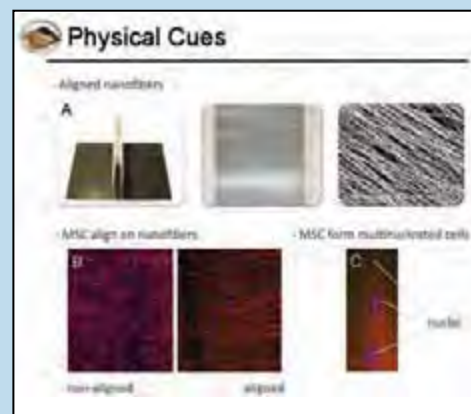

Fig. 3. Aligned nanofibers apparatus deposited in experimental apparatus (A). MSC cell alignment for both aligned and non-aligned nanofibers (B). Detail of aligned MSC showing multinucleated cell (C)

Use of Acoustic Biosensors for screening and measuring binding of biomolecules to ligands

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biological Engineering, UAlgarve, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Guilherme N. M. Ferreira (CBME-IBB, University of Algarve),**
Joaquim S. Cabral (BERG-IBB, IST-UTL)
Research team: **Ana Carina Silva, Brigitte Tomé, Cláudia Vistas,**
Guilherme Ferreira (Team Leader), Luís Rosa, Luisa Pedro,
Rogério Rodrigues, Sandra Soares

**Jorge Carvalho**

Objectives

This PhD aims at the study of acoustic wave biosensors for protein binding measurement and modelling, in order to assess the retention and model the binding mechanism of different biomolecules to immobilized chromatography ligands.

Work Plan

- Sensor surface functionalization;
- Screening analysis of biomolecules;
- Modelling of binding kinetics and equilibrium;
- Assess protein conformational changes occurring during ligand binding.

Results

The detection capacity of an acoustic biosensor is assured by the use of a recognition molecule (ligand). The electrode surface has to be cleaned prior to immobilization to remove any contaminants that may hinder the following procedures. The incubation time for different ligands was checked through cyclic voltammetry (Figure 1). TSM resonators are single-port devices made from thin AT-cut (35º15'') quartz disks with metal electrodes (Au, Cu, Pt, or Ni) printed in both sides. When an alternated current is applied to these electrodes at the resonant frequency of the crystal, a displacement parallel to the surface is induced and the generated acoustic wave propagates perpendicularly to the substrate surface (Figure 2). As a result, these devices are sensitive to mass and physical properties changes at the modified gold surface and bulk (Figure 3). We intend to visualize and measure the conformational changes induced by the ligands upon biomolecule adsorption and apply that knowledge in the optimization of chromatography processes of proteins with industrial relevance (Figure 4).
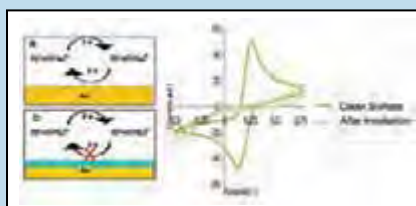
Fig. 1. Sensor surface functionalization with hydroxyundecathiol analyzed by cyclic voltammetry.
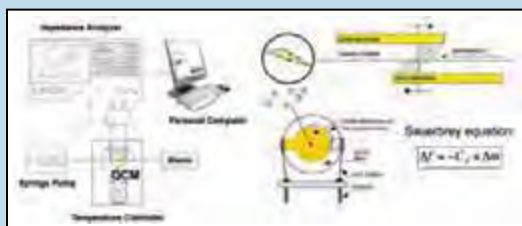
Fig. 2. Schematic diagram of the instrumental setup and 10MHz thickness shear mode (TSM) acoustic sensor.

Fig. 3. TSM acoustic sensors are being used to monitor conformational changes and to correlate the protein GRAVY score with acoustic energy losses.

Fig. 4. Complete simulation of a GST affinity chromatography of 4BL-GST ligand binding and thrombin cleavage of the fusion protein. Resonance frequency (ΔfR), resistance (ΔR) and f2 (a frequency that depends only of adsorbed mass variation) were monitorized.

Histamine-releasing PLGA microparticles: a brain repairing tool

Bioengineering Systems PhD
UC
Background: **MSc. Biochemistry, University of Porto, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **João O. Malva (uc), Liliana Bernardino (UC), Manuel Nunes da Ponte (FCTUNL)**
Research team: **Sofia Grade, Alexandra Rosa, Sara Xapelli, Fabienne Agasse & Lino Ferreira**

Maria Eiriz

Objectives

A. Unravel the effects of histamine in post natal mice neurogenesis, comprising cell differentiation, axonogenesis and new cells functional integration, both in vitro and in vivo.

B. Unravel the role of vasculature and endothelial cell signalling molecules on granule cell migration in adult mice, both in vitro and ex vivo.

Work plan

A1) Evaluate the biocompatibility of the histamine-releasing particles in Subventricular Zone (SVZ) Neural Stem Progenitor Cells;

A2) Evaluate PLGA histamine carrying microparticles effects in in vitro, ex vivo and in vivo differentiation of SVZ new neurons;

A3) Evaluate histamine effects new neurons axon growth.

B1) Characterize the intimate association between vasculature and the different neurogenic niches;

B2) Characterize cell migration in different cell specific BDNF transgenic animals to unravel its role on migration parameters:
      B2.1) In vivo live imaging;
      B2.2) Studies in neural
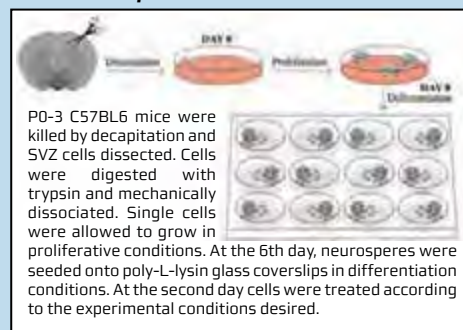   stem cell cultures.

Results

- Histamine-releasing microparticles have no effect on cell death and proliferation (data not shown);

- Histamine induces neuronal in vitro differentiation in SVZ cell cultures (cell counts for NeuN labeling and Single Cell Calcium Imaging);
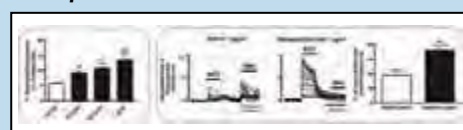
- Histamine-releasing PLGA microparticles induce neuronal differentiation in SVZ-GFP cells grafted on Dentate Gyrus (DG) of organotypic hippocampal slices;

- Histamine-releasing microparticles induce in vivo neuronal differentiation of SVZ-GFP cells grafted on DG;
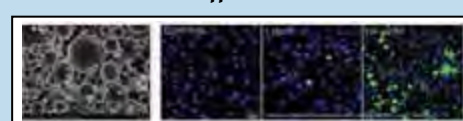
Culture & experimental treatments

P0-3 C57BL6 mice were killed by decapitation and SVZ cells dissected. Cells were digested with trypsin and mechanically dissociated. Single cells were allowed to grow in proliferative conditions. At the 6th day, neurospheres were seeded onto poly-L-lysin glass coverslips in differentiation conditions. At the second day cells were treated according to the experimental conditions desired.

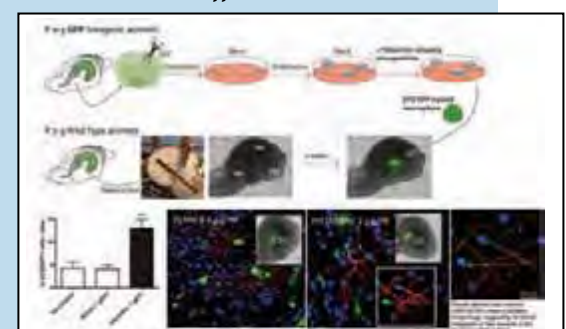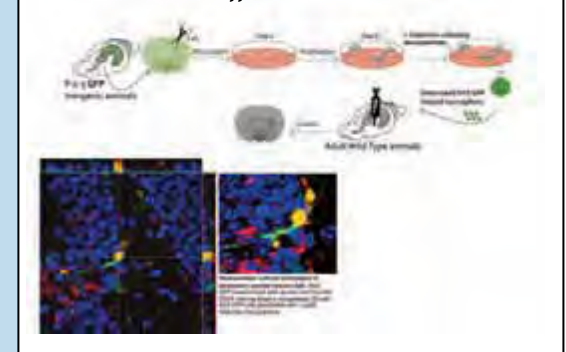*Microparticle distribution*

In vitro histamine effect

Ex vivo histamine effect

In vivo histamine effect

Development of a Cardiac Patch for Biomolecule Delivery

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Pharmaceutical Sciences, University of Coimbra, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Lino Ferreira (CNC/Biocant), Jeffrey M. Karp**
(Harvard-MIT Division of Health Sciences and Technology)
Research team: **Maria Nunes Pereira, Debanjan Sarkar, Woo Kyung Cho,**
Nora Lang, Shwetha Mureli, Lino Ferreira, Jeffrey M. Karp

Maria Pereira

Objectives

Myocardial infarction is a leading cause of death in the developed world. Novel therapies –pharmacological or cellular – are being explored to decrease the mortality and morbidity of patients. However, to reach the clinic, there is the need to develop delivery systems that can efficiently target the damaged tissue, maximizing therapeutic effect and minimizing potential toxicity. We are now developing a biomedical patch that will deliver drugs with regenerative potential to the damaged heart surface in a safe and direct manner. This should stretch and be compliant with heart mechanics while remaining fully adherent to it.

Work Plan

Inspired by Gecko lizards, a new adhesive system has been recently described which mimics the nano-patterns present on the Gecko feet1 (figure 1a). This adhesive can strongly adhere to tissue using minimal chemistry and therefore causing minimal inflammatory response, a major side effect with the currently available technologies. The principle behind it is based on mechanical interlocking and contact surface area maximization, resulting from the material topography (figure 1b). Based on this concept, we are now tuning this system to have specific adhesion to the heart surface. In parallel, novel elastomers compliant with heart dynamics will be developed and studied as drug delivery platforms.

Results

We developed a novel family of biodegradable and biocompatible elastomers. The biomaterials were developed by reacting poly(glycerol sebacate) pre-polymer (PGS) and 1,6 hexamethylene diisocyanate (HMD) at different molar ratios (figure 2). Urethane linkages are established, which contribute to a highly elastic physically and chemically crosslinked network. By varying the HMD content this materials can be easily tuned to have ideal mechanical properties to be used as a 'heart patch' (Young's modulus —0.15 MPa).
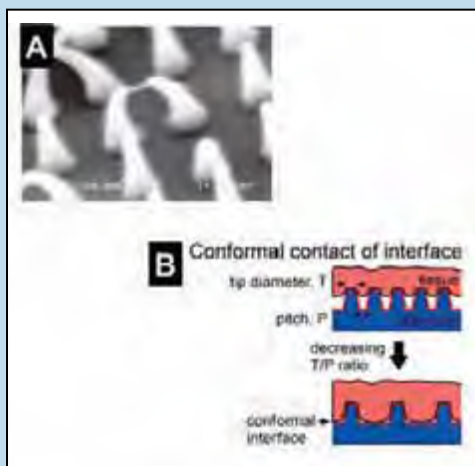

Fig. 1. a) Gecko-inspired tissue adhesive and b) proposed adhesive mechanism1..
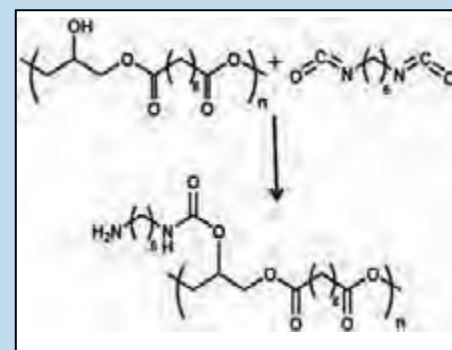

Fig. 2. Synthesis of novel PGS-urethane elastomers.

References
1- Mahdavi et al., A biodegradable and biocompatible gecko-inspired tissue adhesive. Proceedings of the National Academy of Sciences of the United States of America 2008, 105 (7), 2307-2312.

Wearable Brain Cap

Bioengineering Systems PhD
University of Minho
Background: **MSc. Biomedical Engineering, U Minho, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **José Higino Correia (U Minho),**
Paulo Mateus Mendes (U Minho), Rajeev Ram (MIT)
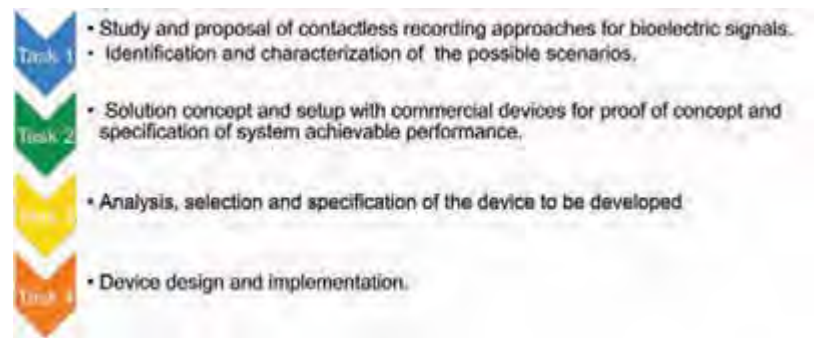Research team: **Kevin Lee (MIT), Nuno Dias (U Minho)**

Mariana Fernandes

Objectives

The main goal of this work is to develop a new generation of contactless electrodes that will avoid the use of gel and complex attachment procedures, and will enable the integration within a wearable device. The main target of this device is the monitoring of bioelectric activity (e.g. EEG, ECG, etc.) and brain-computer interface applications.

Work plan

- Study and proposal of contactless recording approaches for bioelectric signals.
- Identification and characterization of the possible scenarios.

- Solution concept and setup with commercial devices for proof of concept and specification of system achievable performance.

- Analysis, selection and specification of the device to be developed

- Device design and implementation.

Results

Validation and performance analysis of electro-optic methods for biopotential detection. Comparative study between these and purely electronic methods (Figure 1).

Development of flexible PDMS-based dry electrodes for electro-optic acquisition of ECG signals in wearable devices. Comparative study with Ag/AgCl wet electrodes (Figure 2).

Proof of concept of PAAM hydrogel photonic transducing mechanism, enabling its use as a photonic biopotential sensor. Sensitivity and frequency response characterization (Figure 3).;
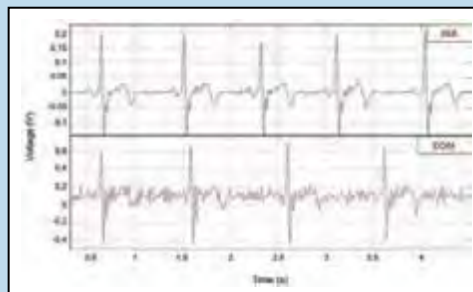
Fig. 1. ECG signal recorded with an in-amp (INA) and with an electro-optic modulator (EOM).
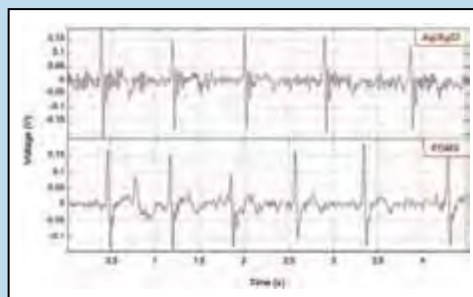
Fig. 2. ECG signals acquired using Ag/AgCl and PDMS-based electrodes (area = 25,3 cm2.) An electro-optic setup was used to record the signals.
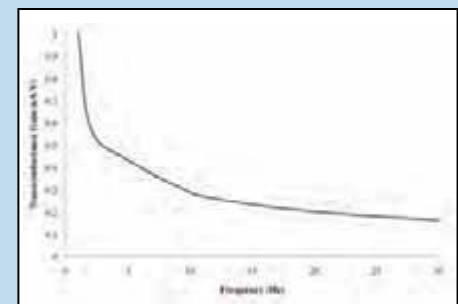
Fig. 3. PAAM Hydrogel frequency response..

Feedback Based Design of Therapeutic Strategies

Bioengineering Systems PhD
MIT
Background: **Biological Engineering**
Supervisor: **Bruce Tidor (MIT)**
Research team: **E. Ferreira (U Minho), I. Rocha (U Minho),**
L. Rodrigues (U Minho), M. Mota (U Minho)

Nirmala Paudel

Objectives

Feedback based designs are commonly used in human engineered system to drive or control the network behavior as desired. A hypothesis is that similar design principles can be used in biological networks to correct them when they go wrong (diseased networks). This hypothesis is further strengthened by the fact that feedback loops are common motifs of biological networks and hence must play a crucial role in regulating the system to achieve a desired output for a given input. In this study a model network has been used to test the hypothesis.

Work plan

Epithelial Growth Factor (EGF) induced EGF Receptor (EGFR) signaling pathway is used as a model system (fig. a). It is one of the most common signaling pathways that is believed to be disregulated in a large number of cancers including melanoma, papillary thyroid cancer, and colon cancer among others [1].

The protein Raf which is a part of this pathway and is commonly mutated in most forms of cancer, is computationally incorporated in the network to represent a diseased version of the network.
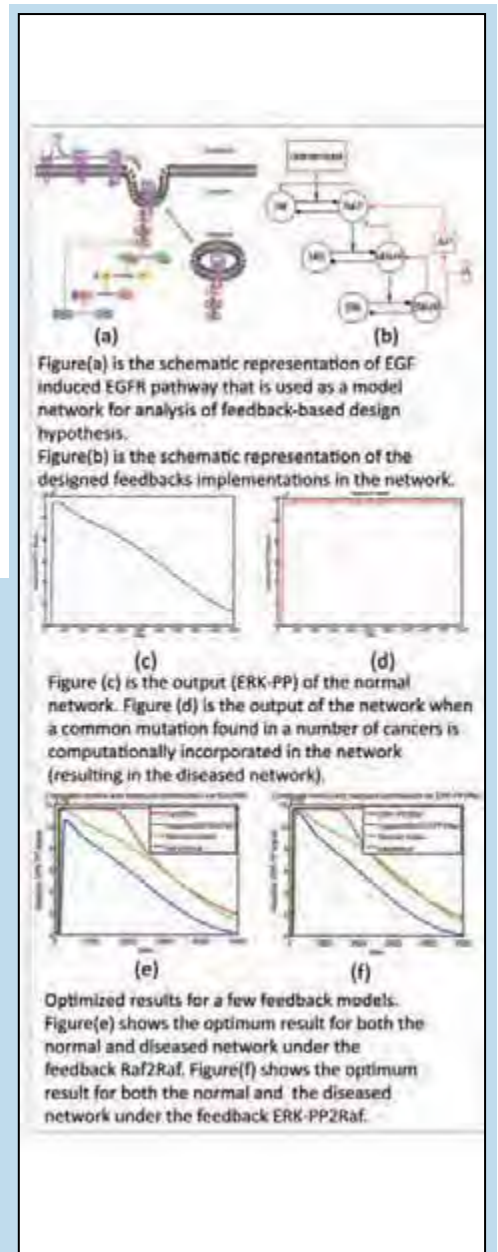
The aim is to design and incorporate a feedback circuit in both the diseased and the normal networks to achieve two fold objectives, the first is to regulate the disregulated networks and the second is to not affect the functioning of cells with the normal networks. While drugs can be designed to kill cancer cells, a large number of normal cells are also killed in the process resulting in undesired side effects. The framework we have considered here aims to address this issue. This is formulated as an optimization problem to find out which feedback models are able to optimize the two fold objectives well and then analyse the kinetic properties of the feedback components.

Results

Simulations so far suggest that while all feedback models considered here, given no constraints on their strength, are able to show the desired trend, the most effective feedbacks are those from the most amplified part of the circuit to the least amplified part. As an example figure (e) and (f) show that ERK-PP2Raf* feedback produces slightly more desired trend than the Raf2Raf feedback.

[1] Roberts PJ and Der CJ, Targeting the Raf-MEK-ERK mitogen-activated protein kinase cascade for the treatment of cancer (review), Oncogene(2007) 26, 3291-3310.

Figure(a) is the schematic representation of EGF induced EGFR pathway that is used as a model network for analysis of feedback-based design hypothesis.
Figure(b) is the schematic representation of the designed feedbacks implementations in the network.

Figure (c) is the output (ERK-PP) of the normal network. Figure (d) is the output of the network when a common mutation found in a number of cancers is computationally incorporated in the network (resulting in the diseased network).

Optimized results for a few feedback models. Figure(e) shows the optimum result for both the normal and diseased network under the feedback Raf2Raf. Figure(f) shows the optimum result for both the normal and the diseased network under the feedback ERK-PP2Raf.

Development of a Functional Electrical Stimulation System to Aid Locomotion in Individuals with Neuromuscular Disabilities

Bioengineering Systems PhD
IST - UTL
Background:**M.Sc. Biomedical Engineering from FCTUNL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Miguel Tavares da Silva (IST - UTL),**
Jorge Martins (IST - UTL), Dava Newman (MIT)
Research team: **The DACHOR Project research team**

Paulo Melo

Objectives

Design, develop and validate a transcutaneous functional electrical stimulation (FES) system prototype to promote locomotion and rehabilitation of the lower limbs' musculoskeletal apparatus, particularly of the ankle-foot complex, in individuals with impaired mobility resulting from neurological conditions such as stroke.

Work plan

The PhD project relies on:
·Multibody dynamics methods for the analysis of the musculoskeletal apparatus in pathological and non-pathological human gait;
·Real-time assessment of the muscles state through electromyography (EMG) sensors and gait phases detection through accelerometer based sensors;
·Development of a miniaturized FES actuator to generate electrical pulse sequences (collaboration with PLUX, Wireless Biosignals), according to a muscle identification algorithm and a control law derived from system dynamics and sensor data.

Results

Successful modification of a commercial muscle stimulator to allow complete customization of the stimulation pulses (Fig. 1);
·Electrical stimulation efficiency is highly dependent on electrode location;
·Tibialis Anterior muscle stimulation produces plenty dorsiflexion of the foot - more than enough for the gait's swing phase (Fig. 2).

Fig. 1. First FES prototype developed, capable of delivering customized electrical stimuli to one muscle group.
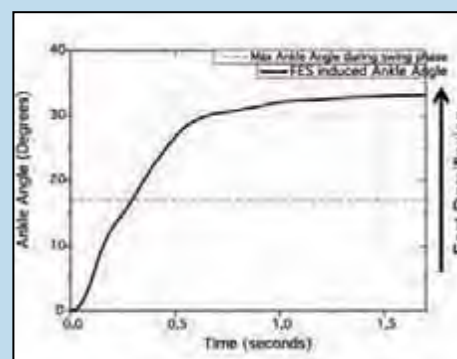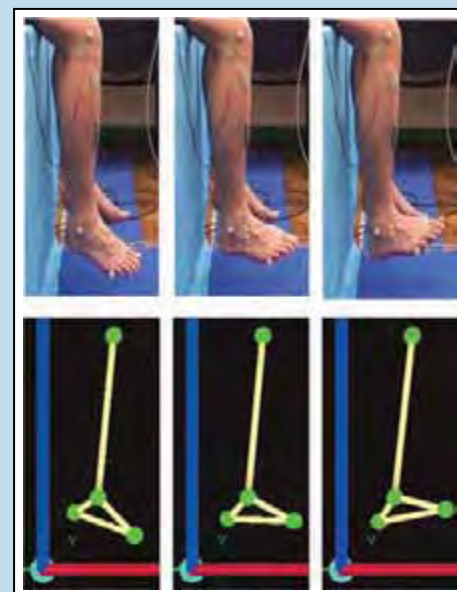
Fig. 2. Stimulation of the tibialis anterior muscle (responsible for dorsiflexion rotation movement of the foot, at the ankle joint, towards the leg).

Novel Approaches for the Isolation and Ex-vivo Expansion of Hematopoietic Stem Cells from Human Umbilical Cord Blood for Cell Therapy

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biological Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Joaquim Cabral (IBB-IST), Cláudia Lobato da Silva (IBB-IST)**
Research team: **Francisco dos Santos (IBB-IST)**

Pedro Andrade

Objectives

This project aims at the development of novel strategies for the isolation and ex-vivo expansion of human hematopoietic stem cells (HSC) from umbilical cord blood (UCB) for use in multiple settings such as cell therapy (e.g. BM transplantation) or gene therapy.

Work Plan

- Selection and optimization of alternative immunoisolation strategies for HSC purification either by magnetic or fluorescence cell sorting (MACS and FACS, respectively);
- Optimization of the culture conditions for the ex-vivo expansion of HSC isolated by different methods, based on the culture system previously established at the Stem Cell Bioengineering Group at IST using human adult BM-derived stromal cells to support hematopoiesis;
- Selection of an appropriate three-dimensional (3-D) matrix to sustain stromal cells envisaging the beneficial effects of 3-D culture versus traditional 2-D culture;
- Design and operation of a prototype perfusion bioreactor system for the expansion of UCB HSC with the matrix-immobilized BM stromal cells

Results

The cytokine cocktail for the expansion of UCB HSC in co-culture with BM MSC was successfully optimized using a factorial design approach. SCF (60 ng/mL), Flt-3 (50 ng/mL) and TPO (50 ng/mL) were found to be the most important factors after 7 days in culture, resulting in significantly higher levels of expansion of total cells (37 - fold), CD34 + cells (20 - fold), CD34 + CD90 + (3.5 - fold) and CFU - MIX (21 - fold), when compared to our previously reported cocktail, where both cytokines were used at 100 ng/mL (6.1 0.6 fold and 5.8 0.9 fold in total cells and CD34+ cells, respectively.
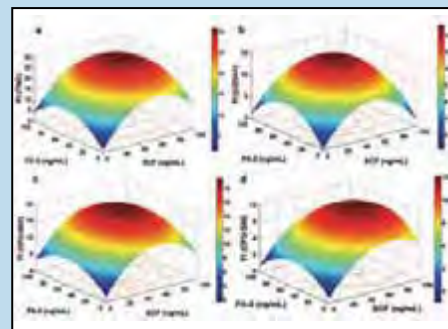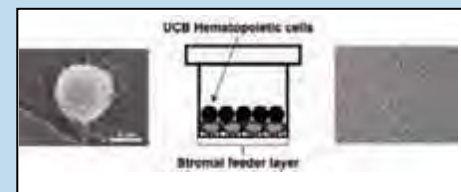
Response	Code Name	SCF (ng/mL)	Flt-3 (ng/mL)	TPO (ng/mL)	Optimized FI
CD34+ cells	Z9	60	55	50	21
TNC	Z9	60	55	50	33
CFU-MIX	M1	52	52	50	17
CFU-GM	G1	68	54	50	13
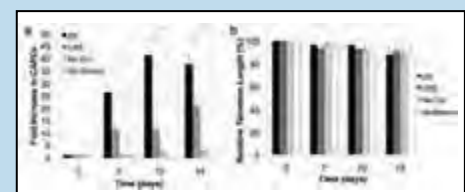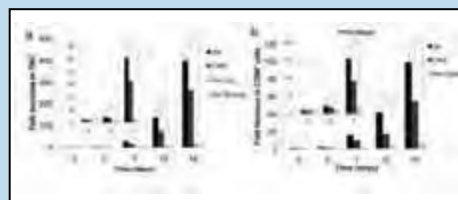
Andrade, PZ et al., Molecular Biosystems, 2010.

New Strategies for the Production of Butanol

Bioengineering Systems PhD
University of Minho
Background: **MSc. Biochemical Engineering,**
Pontifical Catholic University of Valparaiso, Chile
Chile
Starting Year: **2008 / 2009**
Supervisors: **Ligia Rodrigues (UM), Madalena Alves (UM)**

Roberto Marusich

Objectives

Butanol is an aliphatic saturated alcohol that can be used as intermediate in chemical synthesis and as a solvent for a wide variety of chemical and textile industry applications. Moreover, it has been recognized that it has better properties than ethanol for gasoline substitution and can be biologically produced from renewable sources.

In this context, glycerol, generated as a by-product during the production of plant-oil derived biodiesel, arises as a potential substrate candidate for butanol production. Fermentation of low grade glycerol to butanol has been proven. However, there is place for process optimization in order to improve the production yields and reduce the toxicity of butanol to the producing organisms which are the main objectives of this PhD thesis.

Work plan

Pure and mixed culture: Progressive acclimatization to increasing glycerol concentrations and mutation will be used as selection tools in order to obtain overproducing microorganisms

Modeling: Development of energy based models for butanol producing cultures

Synthetic biology: Engineering of Pseudomonas putida strain as a model organism for the production of butanol

from glycerol. Adequate genetic modules will be identified and constructed to facilitate substrate uptake, conduct the required biotransformations and attenuate the toxic effects of butanol, in order to achieve higher butanol yields

Results

Clostridium pasteurianum DMS 525 was assessed for batch fermentation of crude glycerol using a chemically defined medium (Fig. 1 and 2) and a semi-defined medium (Fig. 3 and 4) where pure vitamins were replaced by yeast extract. Main fermentation products were acids, butanol and 1,3-propanodiol. For defined medium butanol yields were around 0,3 g/g. Even though fermentation time decreased considerably when yeast extract was used, butanol yield was lower and there was a higher 1,3-propanodiol production.

Mixed culture fermentations using granular sludge were performed (results not shown). Heat and contact with BES (bromoethanesulfonate) were assessed as pre-treatments and even though glycerol consumption was faster than in pure culture fermentations, solvents were not present as products. Main products obtained were acids and 1,3-propanediol.
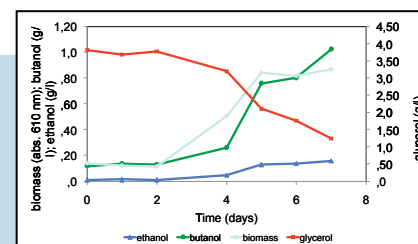

Fig. 1. Biomass and solvent production by C. pasteurianum in defined media with crude glycerol as carbon source
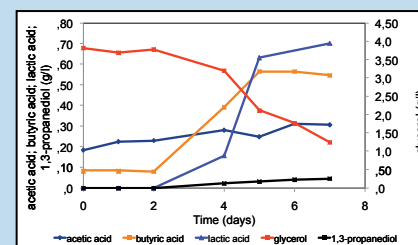

Fig. 2. Acids and 1,3-propanediol production by C. pasteurianum in defined media with crude glycerol as carbon source
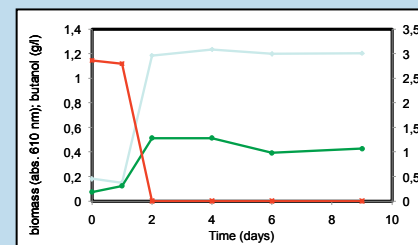

Fig. 3. Biomass and solvent production by C. pasteurianum in semidefined media with crude glycerol as carbon source
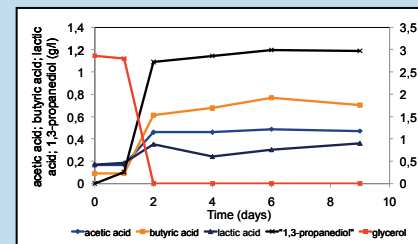

Fig. 4. Acids and 1,3-propanediol production by C. pasteurianum in semidefined media with crude glycerol as carbon source

Monitoring serotonergic neuronal activity in behaving rats

Bioengineering Systems PhD

FCT-UNL

Background: **MSc. Biomedical Engineering, IST-UTL, Portugal**

Portugal

Starting Year: **2008 / 2009**

Supervisors: **Zachary Mainen (ITQB/IGC)**

Research team: **Sara Matias, Guillaume Dugué, Tatiana Vassilevskaia, Magor Lorincz, Susana Lima, Zachary Mainen**

Sara Matias

Objectives

Serotonin (5-hydroxytryptamine or 5-HT) is a neuromodulator involved in many physiological and behavioral functions in mammals' central nervous system (CNS), such as sleep-wake-arousal cycle, regulation of mood and appetite, aggressivity, behavioral suppression, breathing and carbon dioxide sensing, and motor facilitation. However, its roles are still enigmatic and controversial.

To study 5-HT function in behavior, the activity of 5-HT neurons must be monitored and manipulated. This project proposes a new means to monitor 5-HT neurons in the dorsal raphe nucleus with great specificity by using a new and improved genetically encoded calcium indicator (GECI) of the GCaMP family, GCaMP3.

This technique will allow to image activity of 5-HT neurons in vitro or in vivo in real time through fluorescence signals emitted by GCaMP3 expressed solely in these neurons, by fusing it with a specific enhancer and by using a viral infection technique with adeno-assoacited virus. The validation of the infection and imaging procedures will be followed by the use of this tool in behaving rats subjected to different environments and behavioral paradigms to monitor 5-HT activity.

Work Plan

1) Targeting GCaMP3 to 5-HT neurons

GCaMP3 will be targeted to 5-HT neurons using adeno-associated viruses (AAVs) to deliver the GCaMP3 coding sequence under the control of a short (1.8 kb) 5-HT neuron-specific enhancer

This enhancer has been isolated from the regulatory sequence of Pet1, a transcription factor whose expression is restricted to 5-HT neurons

2) Characterizing GCaMP3 signals in vitro

The second step of this project will be to validate the efficiency of GCaMP3 for reporting activity in 5-HT neurons

GCaMP3 signals will be imaged from acute raphe slices submitted to electrical and/or optogenetic stimulations

Electrophysiological recordings performed in parallel from GCaMP3-positive cells will allow to unambiguously and quantitatively relate optical signals to specific firing patterns (e.g. single spikes versus bursts

3) Monitoring GCaMP3 signals in behaving animals

First aim: test a variety of conditions that are known to activate groups of DRN 5-HT neurons

Second aim: perform a series of more systematic behavioral mapping experiments in the vein of the aversion/inhibition hypothesis. This hypothesis postulates that 5-HT transients play an important role in behavioral inhibition and/or aversive responses

Results

Aim 1. I will perform somnographic measurements to test whether GCaMP3 can report variations in tonic firing related to the sleep-wake cycle, as predicted from electrophysiological recordings. Complementary to this, I will test whether pharmacological silencing of 5-HT neurons results in decreased baseline GCaMP3 fluorescence, by injecting 8-OH-DPAT, an agonist of 5-HT1a autoreceptors. These receptors are present on the somatodendritic tree of 5-HT neurons and their activation tends to suppress firing in these cells. I will then analyze fluorescence signals in response to somatosensory, visual, acoustic and noxious stimuli which normally drive DRN neurons, as well as during spontaneous repetitive behaviors (such as chewing, licking or grooming) which also activate some of them

Aim 2. A more thorough analysis will be performed using traditional models of fear and/or anxiety-related behaviors. This will include 1) exposure to natural (vocalizations, cat urine) or artificial (startling) alerting stimuli, 2) exposure to adverse social experiences and 2) models involving a conflict between exploratory/appetitive and avoidance behaviors (such as the open-field test or the punishment-induced suppression test).
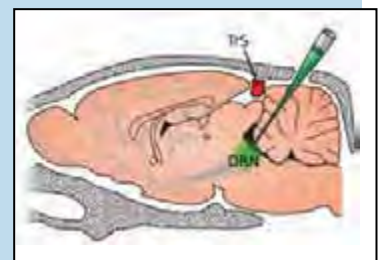
Synthetic Stem Cell Niches

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Bioengineering, Hacettepe University, Turkey**
Turkey
Starting Year: **2008 / 2009**
Supervisors: **Claudia Lobato da Silva (IST-UTL),**
Lino Ferreira (CNC-UC), Robert Langer (MIT)
Research team: **Sezin Aday, Thomas Kraehenbuehl,**
Claudia Lobato da Silva, Robert Langer, Lino Ferreira

Sezin Aday

Objectives

Hematopoietic stem cells (HSCs) from umbilical cord blood (UCB) are a rare and hetereogeneous population of hematopoietic precursors which are important source of differentiated cells for regenerative medicine. These cells may have potential use for the vascularization of wounds, ischemic heart, diabetes-related vascular diseases, bone grafts and general tissue engineering applications.

One of the main limitations in using UCB-HSCs for regenerative medicine is related to the low number of cells isolated from a typical blood sample. Therefore the development of platforms to efficiently expand these cells is needed. Another limitation is related to the control of their in vivo vascular differentiation. The UCB-HSCs can give rise to several cell lineages and therefore it is important to develop platforms to induce rapidly in situ their vascular differentiation for therapeutic angiogenesis.

Work plan

During this project, we aim at developing a new set of microtechnologies able to interact with UCB-HSCs in suspension while promoting either their expansion or differentiation into vascular cells. Our ultimate goal is to design synthetic stem cell niches to control stem cell fate. To show the relevance of the expanded UCB-derived HSCs for regenerative medicine, we will evaluate their vascular differentiation potential in comparison to freshly isolated cells. This project has the contribution of CNC/Biocant, MIT, IST and the support of the stem cell cryopreservation company Crioestaminal.

Results

We developed so far part of the microtechnologies able to induce the differentiation of stem cells into vascular cells. Presently we are characterizing their biological effect against human cells.
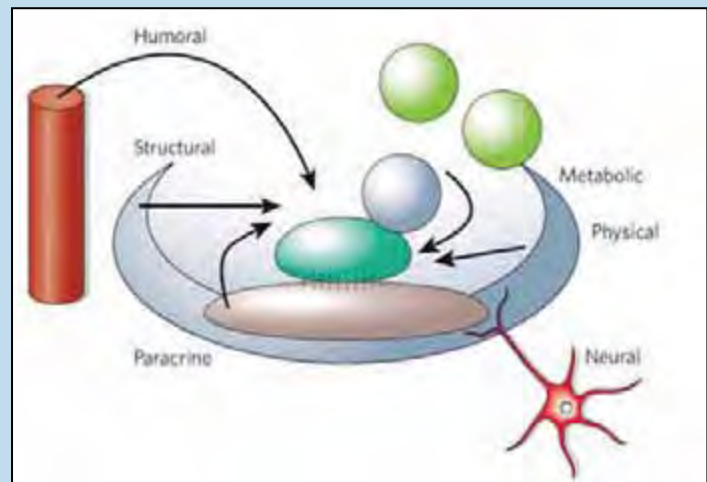
Elements of the local environment that participate in regulating the system of a stem cell in its tissue state are depicted (Source: David Scadden, Nature 2006, 441, 1075).

Phase 1:
Development of the microtechnologies

Phase 2:
Biological effect:
expansion and vascular differentiation

Adipose Tissue-Derived SSEA-4 Subpopulation Differentiation Towards the Endothelial Lineage

Bioengineering Systems PhD

University of Minho

Background: **MSc. Chemistry & Physics, University of Transilvania of Brasov, Romania**

Romania

Starting Year: **2008 / 2009**

Supervisors: **Alexandra Marques (UM), Manuela Gomes (UM).**

Silvia Mihaila

Objectives

The major challenge in bone tissue engineering is the lack of vascularization of the constructs in order to produce a functional bone substitute. We intend to propose a strategy based on the co-culture of adipose derived cells with angiogenic and osteogenic potential on polymeric 3D scaffolds for the formation of a pre-vascularized bone-like construct. Selection of targeted subpopulations will allow studying the performance of the model and the conditions that lead to maximum functionality. The aim of the first task of the PhD project was to select the SSEA-4+ human adipose stem cells (hASCs) in order to explore the effect of the culture conditions over the differentiation potential of this subpopulation into the endothelial lineage.

Work Plan

Human lipoaspirates were obtained from individuals undergoing plastic surgery. Stromal vascular fraction (SVF) was obtained after enzymatic digestion. The SSEA-4+ cells were isolated from the SVF using an immunomagnetic sorting technique and cultured either in EGM-2MV or MEM. The identity of cells under different conditions was established by immunocytochemistry and flow cytometry considering the expression of mesenchymal (CD105, CD90, CD73), haematopoietic (CD45, CD34), endothelial (CD31, vWF), and embryonic stem cell (SSEA-4) markers. Endothelial phenotype was assessed based on the ability of the cells to scavenge the Low Density Lipoprotein (LDL) complex and on their capacity to form capillary-like structures on Matrigel. RT-PCR was used to confirm at the molecular level the expression of endothelial phenotype-related genes.

Results

After selection of SSEA-4+hASCs endothelial-like colonies characterized by cobblestone morphology were observed (Fig1). Pure endothelial-like cultures were characterized by the expression of endothelial markers, the ability to scavenge LDL complex (Fig 2) and to form capillary-like structures when seeded on Matrigel (Fig.3), demonstrating their functional competence in vitro. The endothelial differentiation was further evidenced by an increased expression of CD31 and CD105 (Fig 4). Up regulated expression of CD31 and vWF was confirmed at molecular level (Fig 5).Therefore, a protocol for isolation and endothelial differentiation of SSEA-4+hASCs was established, demostrating the potential of this subpopulation for bone TE applications.).
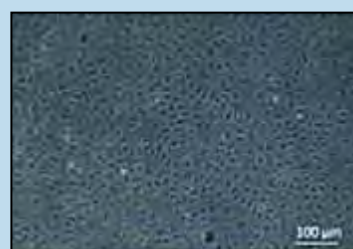

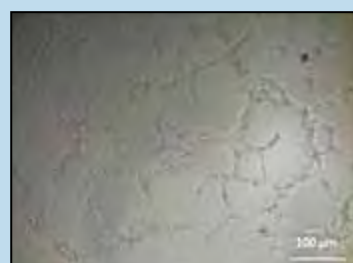**Fig. 1.** Differentiated SSEA-4+hASCs in P3

Fig. 2. Immuno-cytochemical staining of differentiated SSEA-4+ASCs demonstrating endothelial cell features: a)CD 31(red) and vWF)green) expression, b) Dil-ac-LDL uptake(red),Cell nuclei counterstained with DAPI (blue)

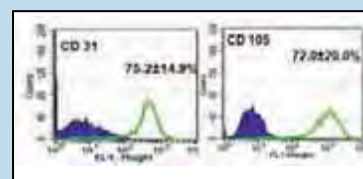**Fig. 3.** Functional in vitro competence of differentiated cells by possesing the ability to formcapillary like strucutres in Matrigel

Fig. 4. Percentage of differentiated cells expressing endothelial markers (CD 31 and CD105)
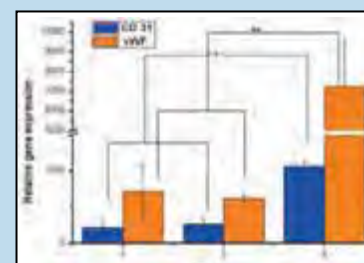

Fig. 5. Up regulated expression of endothelial specific markers confirmed at molecular level)

Multibody Dynamics and Control of a Hybrid Active Orthosis

Bioengineering Systems PhD
IST-UTL
Background: **Biomedical Engineering (IST), Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Miguel Silva (IST-UTL), Jorge Martins (IST-UTL),**
Dava Newman (MIT), Hugh Herr (MIT)
Research team: **D. Young (MIT), R. Opperman (MIT)**

Sofia d'Orey

Objectives

The main objective of the PhD is to contribute to the development of a hybrid active ankle foot orthosis, a device which is designed to compensate for impaired limb function and which will be both powered and activated by functional electrical stimulation. This contribution will be made mainly through experimental data collection and analysis, and controller design, using EMG (electromyography) and potentially IMU (inertial measurement unit) sensing schemes.

Work plan

A Vicon system was used to collect motion capture data using a full body Helen Hayes marker set, in conjunction with EMG, force plate and IMU data. Images of the experimental setup can be seen on the top right. The subjects were asked to walk at a consistent speed in several different terrains: level ground, up and down stairs and up and down a ramp. Pre-processing of the data was done using using MATLAB and the data was then imported into Opensim, an open-source software for development of musculoskeletal models and kinematic and dynamic analyses.

A full-body Opensim model, shown on the right, was then used to perform inverse kinematics analysis, which allows to obtain joint angles from marker data. Furthermore, inverse dynamics will also be performed, which allows to obtain joint torques and individual muscle forces and will be determinant in controller design.

Results

A full data set has been collected for a total of six male subjects, and inverse kinematics analysis has been performed on this data. In addition, EMG data is being processed in order to perform inverse dynamics analyses and obtain muscle forces for the major muscle groups, with particular regard for the lower leg. The results for inverse kinematics are shown in the figure on the right for a single subject, for the trials where he walked down the ramp, for both the knee angle throughout a full gait cycle. Distinct patterns in these angles are found for the five different terrains (level ground, up and down stairs and up and down the ramp).

Knee Angle for the RampDown trials for Subject DW
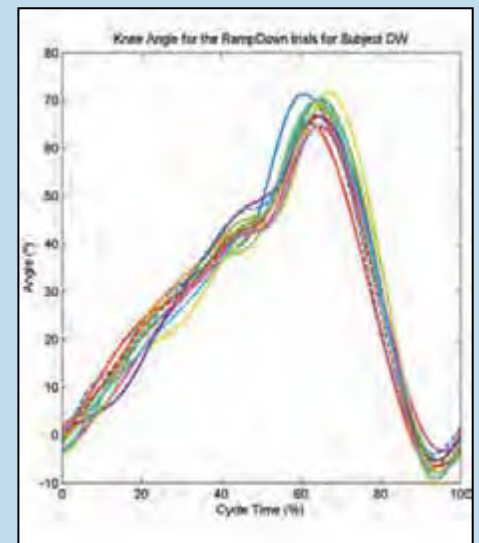
mGluR-dependent LTD and its regulation in the Visual Cortex by Eye Opening and the Onset of Pattern Vision

Bioengineering Systems PhD
IST-UTL
Background: **MSc. Biotechnology, Madurai Kamarai University, India**
India
Starting Year: **2008 / 2009**
Supervisors: **Ramiro D Almeida (CNCUC), Ana Luísa Carvalho (CNCUC) and Martha Constantine Paton (MIT), Joaquim Cabral (IST-UTL)**

Swarnadeepa Pandian

Objectives

i) What is the developmental timing of Group I mGluR dependent LTD in the developing visual cortex and is it up or down regulated after eye

ii) Are there morphological differences in layer V VC neurons in Flailer vs WT or heterozygous Flailer mice

iii) Behavioral study to analyze social behaviour of Flailer vs Wild type mice .

iv) Will ligand activation of mGluRs in VC increase, or decrease, levels of phospho-EF2, FMRX1 and ARC

Work plan

Metabotrobic glutamate receptor-dependent long term depression at excitatory synapses is rapidly becoming recognized as an important form of neuroplasticity in hippocampus, cerebellum, and visual cortex. This form of plasticity requires activation of the Type I G protein coupled glutamate receptors (mGluR1 and mGluR5) which are activate Phospholipase C and generate IP3 thereby releasing Ca++ from intracellular stores, and activating Protein Kinase C. This form of plasticity reduces AMPA glutamate receptors at synapses, and not only triggers, but requires local dendritic protein translation. The Constantine-Paton laboratory (C-PL) has long been interested in activity-dependent changes in excitatory synapses during development.

What is the develomental timing of Group I mGluR dependent LTD in the developing visual cortex and is it up or down regulated after eye opening? Electrophysiological recording in VC layer 5 pyramids have demonstrated that stimulation of input visual cortical layers drives mGluR-dependent LTD in layer 5 VC pyramidal neurons. Normally this in vitro this form of LTD is driven by low frequency application of paired pulse stimuli for a long time (e.g. — 15 min). It is hypothesized that this is the situation in the visual cortex before eye-opening and that such low frequency stimulation will be replaced with robust activation when the eyes open. Therefore C57black mice pups and Flailer heterozygous pups in a C57black background will be examined immunohistochemically (IH) for Group I mGluRs using commercially available antibodies to GluR1 and GluR5. Identification of these receptors will be carried out in 100 micron thick coronal cortical brain slices from P12 (before eye opening; BEO) and P16 (after eye opening; AEO) mouse pups using commercially available antibodies. Other relevant proteins to be examined for localization and developmental level changes will be be 1) phospho-elongation factor 2 (pEF2) which we have previously shown controls the rapid synaptic synthesis of CamKII at visual synapses (Scheetz et al., 2000), ARC protein, the product of an immediate early gene linked to mGuR dependent-LTD, and FMRX1 the fragile X protein of mice. This should tell us: 1) what layers of cortex are enriched in these proteins ; 2) whether they are significantly up- or down-regulated after eye-opening and the onset of pattern vision; 3) whether their regulation or levels differ between C57 black mice, Flailer heterozygotes and Flailer homozygotes. In parallel, western blotting will be performed on synaptic fractions from the three strains of mice BEO and AEO using antibodies to these three molecules to obtain quantitative measures of any differences.

Are there morphological differences in layer V VC neurons in Flailer vs WT or heterozygous Flailer mice? The Flailer crosses to C57Bl mice were performed using-C57 GFP mice (Feng et al 2000). These mice strongly express GFP driven by the thy-1 promoter in layer V cortical neurons. Consequently it will be possible to study the detailed morphology of layer V pyramids in the superficial layers of the visual cortex between Flailer and WT or heterozygous mice. The mice pups will be raised to — P26 for these studies , 300 um vibratome sections will be fixed in paraformaldehyde, optical sections through the GFP filled neurons will be analysed in confocal microscope

Behavioral studies – The mice are bieng video taped for 24 hours and using an automated software various behavioural aspects are being analysed viz self grooming. Flailer shows highly significant levels of repetitive self-grooming behavior when compared to wild type BL6JA(W-J) mice. They also show deficits in social behavior, (e.g lack of reciprocal interactions such as sniffing and grouping which we are now quantitatively analysing with the automated procedure. The Flailer mouse may therefore be a new model for social deficit disorders and point to MyoVa deficits as a cause for some of these traits.

Novel biotechnological applications for the riboflavin producer Ashbya gossypii

Bioengineering Systems PhD
UMinho
Background: **M.Sc. Biotechnology UMinho, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Lucília Domingues (UMinho), Merja Penttilä (VTT)**

Tatiana Aguiar

Objectives

•Explore Ashbya gossypii's potentialities as a cell factory organism.
•Engineer A. gossypii as an alternative production system.

Work plan

•Study the effect of different culture media and environmental conditions on protein production and secretion
•Characterize the A. gossypii secretome using computational and analytical approaches
•Characterize the glycan profile of the proteins secreted by A. gossypii
•Develop genetic engineering strategies based on integrated data from the computational, proteomic and transcriptomic analyses performed (Fig. 1)

Results

•Initial research was focused on the posttranslational modifications carried out by A. gossypii when grown in complex and minimal defined medium. The samples collected are being subjected to glycan analysis by mass spectrometry, after which we will have the glycan profile of A. gossypii available.
•Regarding the protein secretion in A. gossypii, computational and proteomic analyses were initiated, but not yet conclusive. Further analyses and protocols optimization need to be performed.
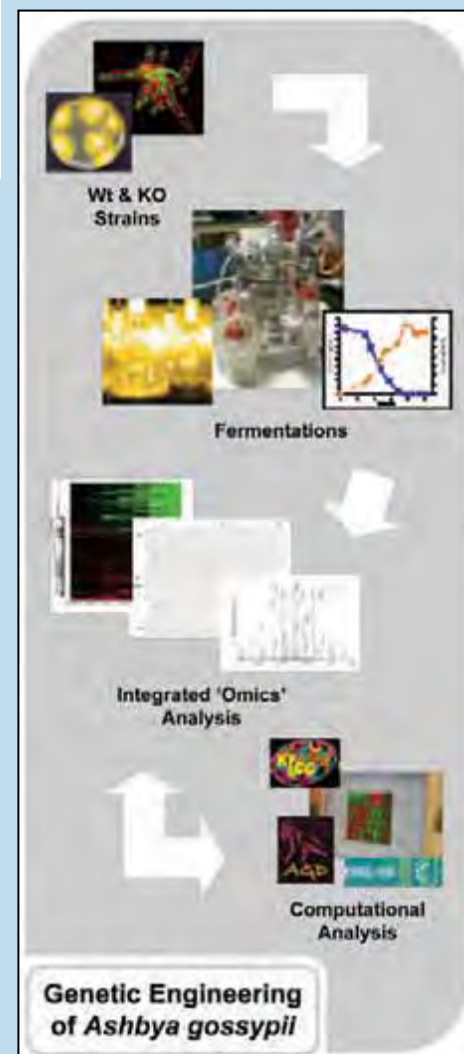
Fig. 1. Schematic work plan

Leaders for Technical Industries

Technologies for Flexible Sensors in the Design of a Smart Stent-Graft

Leaders for Technical Industries PhD

University of Minho

Background: **MSc. Polymer Engineering, University of Minho, Portugal**

Portugal

Starting Year: **2008 / 2009**

Supervisors: **António Pontes (U Minho), Júlio Viana (U Minho),**

Brian Wardle (MIT)

Research team: **L.A. Rocha, J.C. Viana, A.J. Pontes, J. Machado da Silva,**

J. G. Mendes, J.R.S. Tavares, A. Rodrigues, Brian Wardle, I. Santos

Alexandra Sepúlveda

Objectives

The research topic of this work develops around stent-grafts. These devices are used in the treatment of Abdominal Aortic Aneurism (AAA). Building on existent stent-grafts, a new device with an embedded flexible pressure sensor with monitoring capabilities and passive telemetry for minimally invasive endovascular surgery is proposed. The conductive elements of the sensor are supported by a thin flexible substrate of polydimethylsiloxane (PDMS) produced using SU-8 molds. The electric components (capacitor and inductor) are produced using two different techniques: the first technique uses nano-engineering Aligned Carbon Nanotubes (ACNTs), while the second uses inkjet printed conductive inks.

Work plan

The main tasks associated with this work are: continuous reviewing of the state-of-the-art; development of a manufacturing process to build thin flexible substrates with a conductive layer for inductor construction; design and manufacturing of a new flexible implantable capacitive pressure sensor; characterization of the new sensor, including mechanical and electrical characterization and optimization; final assembling of the smart stent-graft and testing.

Results

Since the sensor will be attached to the stent-graft, the capacitive sensor must be foldable, extremely flexible and characterized by a very small profile. Due to the application specifications, a new fabrication process was developed (Fig.1). The proposed process uses ACNTs to build the conductive elements. The ACNTs are embedded in a flexible substrate of PDMS, a transparent, nontoxic and biocompatible silicone elastomer. Chemical vapor deposition (CVD) is used to growth forests or "carpets" of vertically aligned CNTs (Fig.2). The key step of the fabrication process is the ACNTs – PDMS impregnation, and respective mechanical and electrical properties, required for the sensor design. First measurements to a series of samples, PDMS membranes with embedded ACNTs (Fig.3), indicate an electrical conductivity of 11,43 S.m-1 with a standard deviation of 13,37 S.m-1.
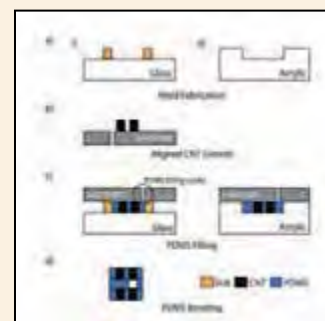

Fig. 1. Fabrication process flow for the development of a flexible pressure sensor.
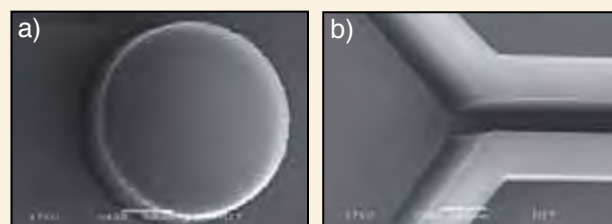

Fig. 2. SEM images of two different experimental CNT-based structures: *a)* Single dot and *b)* Y-Shaped

Fig. 3. PDMS membrane with embedded ACNTs.

New materials and solutions for next generation train seats

Leaders for Technical Industries PhD
FEUP
Background: **BSc in Mechanical Engineering (Automotive),**
MSc in Mechanical Engineering (Transport)
Starting Year: **2009 / 2010**
Supervisors: **Francisco Pires (FEUP), Frank III Field (MIT),**
Pedro Camanho (FEUP)
Research team: **Development of Integrated Systems for**
Smart Interiors

Anton Sabaleuski

Objectives

The current research will focus on the development of methodological tools which support the main design decisions. It is split in two fundamental phases according to the major steps of product development:

Concept Generation. The main objective is the construction of a computational model for train seats that allows the robust and reliable assessment of solutions, which employ different materials and designs. The essential advantage of the model, over the existing ones, will be the opportunity to analyze the performance in key groups of critical characteristics.

Concept Selection. The research will support the decision of selecting a final candidate for the developing product. The objective of that phase of the research will be a methodology for the selection of a final design and materials for the application considering explicitly the expectations of the customers, the restriction imposed by suppliers and the preferences of the decision-makers inside the company outlined by the government regulations and directives.

Work plan

1) Understand deeply the Development Process and Design Decisions
This step will facilitate the familiarization with the engineering problem and the way products are designed, tested, and built within the company. In addition, current competencies of the company and knowledge gaps, which must be covered in order to deal successfully with new materials, will be better understood.

2) New Materials and Solutions for seats and new Development Methods
A reliable computational model will be created permitting to undertake several virtual iterations and perform modifications to the different designs and materials. The outcome of this phase will be several potential designs based on different structural materials.

3) Multi-attribute Analysis of the Design Problem
Although the weight and cost are obvious relevant attributes of the product, some other attributes, such as manufacturability, easy maintenance and appearance might be significant decisive factors. The hierarchy of relevant attributes will lead to the adaptation of one or more methods of multi-attribute analysis.

4) Real-time integration of the outputs from Multi-Attribute Analysis
The advantages and possible limitations of the developed methodologies will be critically assessed. The final product will be compared to the "ideal" solution and the best examples from the industry which will support the decisions on pricing and marketing strategy.

5) Prototyping and Testing
Tests and experiments on a real prototype of a final design will indicate the validity of the computational model and the accuracy of the estimated level of the important attributes.

Results

Seat developers are continuously looking for new opportunities to shorten the costly procedure of prototyping and testing. Engineers and managers working in companies with similar stakeholders' structure and business environment will also benefit from this research. The developed methodology will bring into the light the influence of each stakeholder on the engineering decision-making process and the interrelations among them
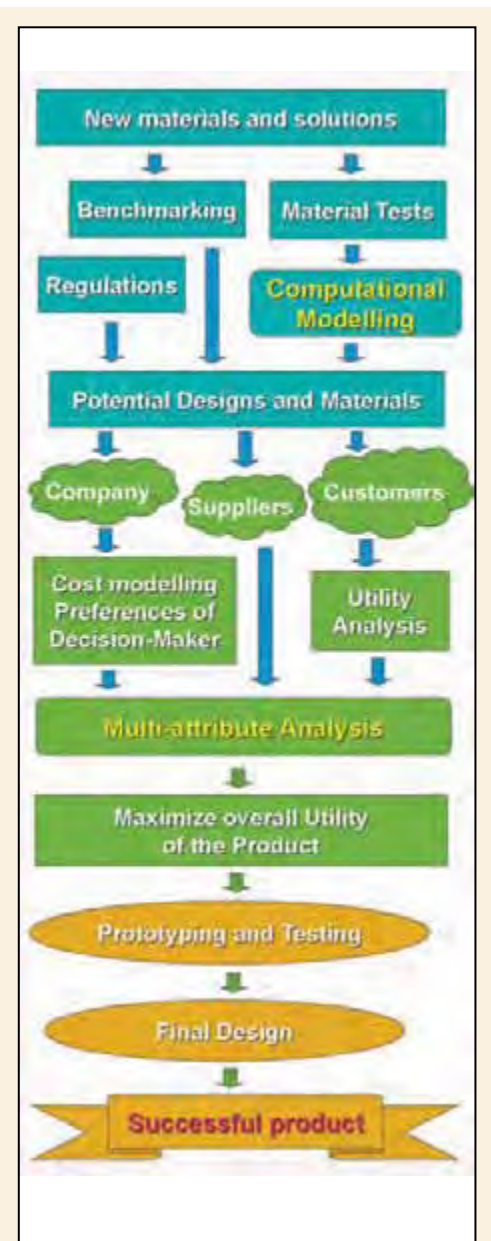
Cork Composites and ECO-Design

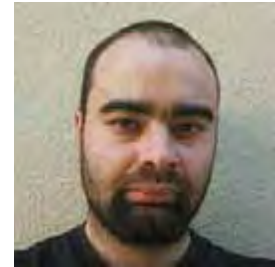**Leaders for Technical Industries PhD**
IST-UTL
Background: **MSc. Mechanical Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Luís Reis, Luís Sousa (IST-UTL)**
Research team: **Luís Reis (IST), Luís Sousa (IST),**
A. Ferreira (FEUP), D. Wallace (MIT)

Bruno Soares

Objectives

It is the purpose of this research to thoroughly analyze the use of cork as one of the most suitable materials for use with Design For Environment (DFE) in mind, and the impact of DFE in nice products such as Kayaks (Picture 1).
Specifically:

- To study a design methodology, economic viability and applicability of cork agglomerates in nautical applications and related components, as a competitive material with polymer foams and honeycomb in structural panels.
- Create a base methodology considering cork agglomerates Life Cycle Assessment (LCA).
- Develop the base methodology in a way that allows designers to incorporate new technical options and see their influence on LCA.
- Develop technical solutions that allow improving the manufacture, production and performance of the Kayaks

Work plan

The methodology used encompasses the following main steps:

- Thesis Research (bibliographical study, article analysis, prior and state of the art analysis)
- Design, manufacturing and testing of sandwich test specimens and analyses of results (will be important as a foundation for ECODESIGN (picture 2))
- Internships @ Mar Kayaks (industry practices, industry methodologies, product design) and Amorim Cork Composites (Industry practices and methodology, cork manufacture)

Results

So far we have begun testing some cork composites (Picture 3 as an example) for its mechanical characterization in order to discover what type of materials can cork replace with little to no performance loss.
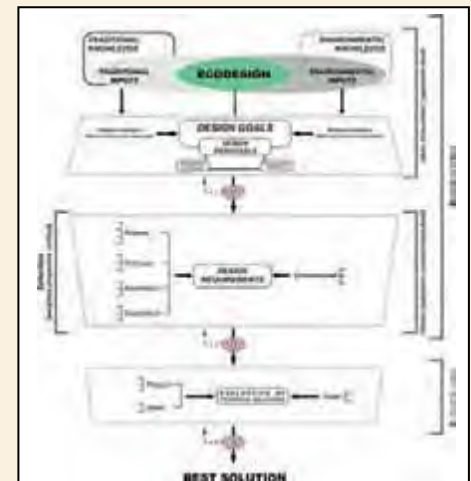
The final result is to have a clear understanding of where cork is, when looking at the sustainability issue, to obtain relevant data of cork in order to be used in an ECODESIGN approach, and what must be done to incorporate cork into products, in order to reach a compromise between environmental impact and technical performance.

Picture 1

Picture 2

Picture 3

Lean design

Leaders for Technical Industries PhD
IST-UTL
Background: **Msc in Engineering Design, Bsc. Mechanical Engineering,**
IST-UTL, Portugal
Portugal
Starting Year: **2009 / 2010**
Supervisors: **Elsa Henriques (IST-UTL), Daniel Whitney (MIT)**
Research team: **Carla Pepe (IST), Elsa Henriques (IST), Dan Whitney (MIT),**
Rob Farndon (R-R), Arlindo Silva (IST), Renato Natal (FEUP)

Carla Pepe

Objectives

▶ To investigate the possible use of standard activities to improve product development processes and their implications on the innovative environment of the design team;

▶ To identify space in the design process where automated tools would be helpful and to quantify as much as possible how helpful they would be, using "Value Stream Mapping" and "Design Structure Matrix" tools.

Work plan

The work plan consists of five top-level activities:
Case study identification;

▶ Understanding the Rolls-Royce product development based on turbine blade case;

▶ Develop of "Value Stream Mapping" and "Design Structure Matrix" for the blade design process;

▶ Identification of standardization potential as regards impact on process innovation and efficiency;

▶ Definition of a framework to drive standardization of activities with space for improvement (introduction of KBE applications).

Results

▶ The main output of this project is a process framework to identify improvements to design process, using Value Stream Mapping and Design Structure Matrix tools.

▶ This framework was developed studying the Trent XWB High Pressure Turbine Blade detailed design phase and it is being validated and extended analyzing the High Pressure Turbine Disc preliminary and detailed design process.

Fig. 1. High Pressure Turbine Blade

Fig. 2. Project Work Plan
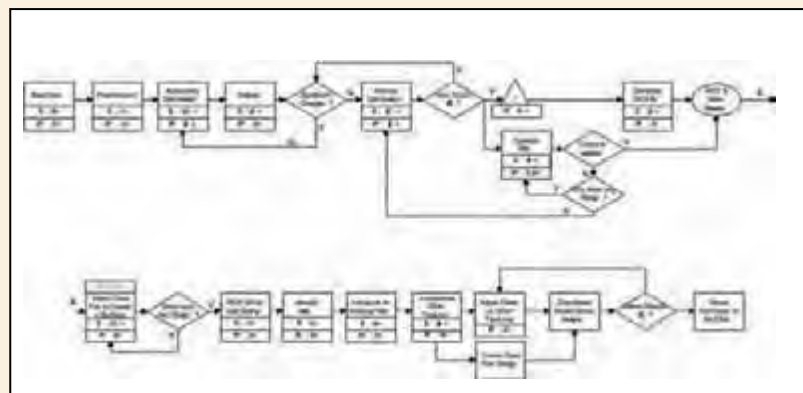
Fig. 3. Value Stream Mapping

Efficient Buffer Design Algorithms for Production Line Profit Maximization

Leaders for Technical Industries PhD
MIT
Background: **Mechanical Engineering**
Supervisor: **Stanley B. Gershwin (MIT)**

Chuan Shi

Objectives

The objective is production line manufacturing systems. In particular, we present accurate and fast algorithms for the following three topics:
1. Production line profit maximization subject to a production rate constraint;
2. Profit maximization for lines controlled by a loop system;
3. Production line profit maximization subject to a time-window constraint and a production rate constraint.

Work plan

We have been doing research on the following three major topics during the past three years. The first topic deals with production line profit maximization, subject to the production rate constraint. In particular, we develop an algorithm for solving problem (1) efficiently.

$$\max_{\mathbf{N}} \quad J(N_1,\cdots,N_{k-1}) = AP(N_1,\cdots,N_{k-1}) - \sum_{i=1}^{k-1} b_i N_i - \sum_{i=1}^{k-1} c_i n_i(N_1,\cdots,N_{k-1})$$

$$\text{subject to} \quad P(N_1,\cdots,N_{k-1}) \geq \dot{P},$$

$$N_i \geq N_{\min}, \forall i = 1,\cdots,k-1, \tag{1}$$

In the second topic, we impose an arbitrary single loop on either the whole line or a part of the line. Therefore the total number of work-in-process in all buffers within the loop remains constant at any given time. We present an evaluation algorithm for such system and solve the optimization problem. In the third topic, we come back to production lines (without a loop). But in addition to the production rate constraint, we consider another nonlinear constraint, the time window constraint. That is, the time for a part waiting for the next operation after the previous operation should be kept less than a fixed value, to guarantee the quality of the part.

Results

An accurate, fast and reliable algorithm that solves Topic 1 has been developed and published in Shi, C., S. B. Gershwin 2009, An efficient buffer design algorithm for production line profit maximization. International Journal of Production Economics 122(2) 725 – 740. The algorithm has been extended to Topics 2 and 3.
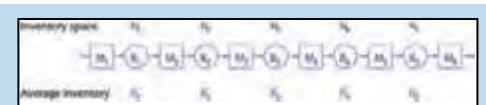

Fig. 1. A production line model. Squares represent machines, while circles represent buffers.
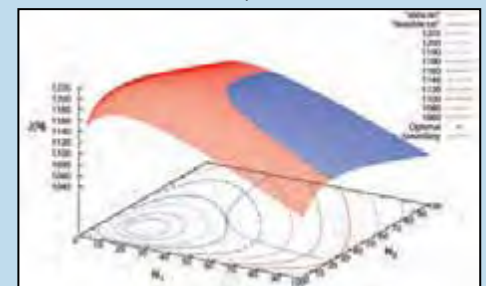

Fig. 2. An example of Topic 1: the blue region is the feasible region under the production rate constraint. The red cross indicates the optimal solution. This confirms that both the cost function as well as the production rate constraint are nonlinear. An algorithm that solves problem (1) efficiently and accurately has been developed (see Shi and Gershwin 2009).
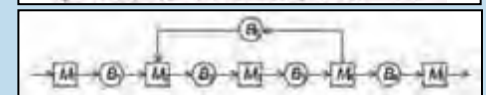

Fig. 3. A production line with a loop structure.

Fig.4 . An example of Topic 3.

Single line for assembly just-in-sequence multiple models

Leaders for Technical Industries PhD
IST-UTL
Background: **MSc. Engineering and industrial management, University of**
Minho, Portugal
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Valério de Carvalho (UM), Ana Paula Povoa (IST-UTL),**
Stanley B. Gershwin (MIT)
Research team: **Cláudia Sofia Rodrigues Duarte**

Cláudia Duarte

Objectives

This year Autoeuropa is beginning to assemble just in sequence four different vehicles. This is a challenge and this project aims to obtain sequencing policies to ensure the delivery of the vehicles just in sequence without degrading the efficiency of the system.

The car sequencing problem involves finding an arrangement of the vehicles in a sequence, thus defining the order in which they will pass along the assembly line. We intend to formulate:

the decision problem that consists in deciding whether it is possible to find a sequence that satisfies all capacity constraints;

the optimization problem that involves finding a minimum cost sequence, where the cost function evaluates constraint violations.

Work plan

Task 1 – Bibliography compilation;

Task 2 – Study and characterization of Autoeuropa current manufacturing system;

Task 3 – Definition of conceptual design and production mix alternatives for a single line assembly;

Task 4 – Development of optimization models and heuristic approaches to the model;

Task 5 – Development of recommendations and systematization of methods and models;

Task 6 – Preparation of case studies for teaching at post-graduation level and dissemination purposes within the industry;

Task 7 – Write PhD thesis.
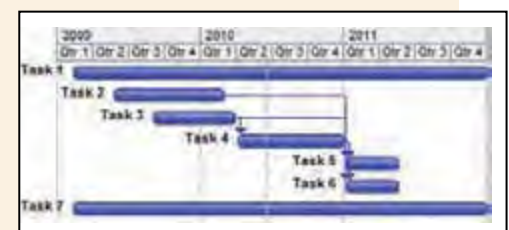
Results

Development of a sequencing model able to obtain an arrangement of vehicles just in sequence that answer efficiently to:

▷ Changes in demand;

▷ Changes in layout and buffer capacity;

▷ Changes in mix sequence restrictions (1:3, 1:4....).

Producer Responsibility Framework for Eco-design of Electrical and Electronic Products

Leaders for Technical Industries PhD
IST-UTL
Background: **MSc Engineering Design, IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **P. Ferrão (IST-UTL), F. Margarido (IST-UTL), A. Brito (UM)**
R. Kirchain (MIT)
Research team: **P. Ferrão, R. Kirchain, J. Gregory, S. Fredholm**

Eduardo Santos

Objectives

The feedback loop from the end-of-life to the design stages of the product life cycle is ineffective for many products, including electronics.

The objective is to develop a framework to ensure the eco-design of electrical and electronic products and use it to develop a tool that integrates the Producer Responsibility principle addressing end of life product management.

Work plan

The challenge is to integrate the best available Producer Responsibility models addressing end of life product management with proven Eco-design methodologies and tools. This requires a work plan which was devised to include 5 main tasks, presented in Figure 2 at the right.

Results

The Extended Producer Responsibility principle has guided most advanced E-waste management systems, where manufacturers and importers of electrical and electronic equipments are responsible for managing those products when they are discarded. E-waste from 10 categories is presently segregated in 5 different flows, to be treated with a combination of manual dismantling and automatic separation technologies to separate material content of waste for recycling and recovery.

In parallel, the design process of electrical and electronic equipments appears to be company specific and promoting Eco-design in such context is done using a wide range of tools and methods. Preliminary results indicate that there is an opportunity for a Producer Responsibility framework, that integrates and circulates knowledge between end-of-life and Eco-design actors, in order to promote the design of products for sustainability.
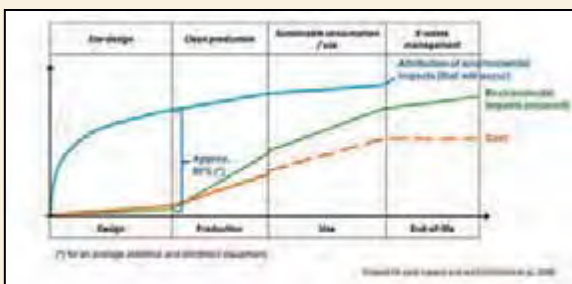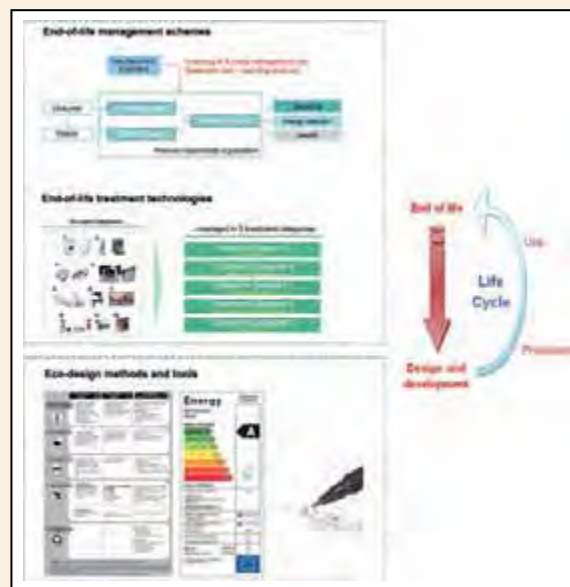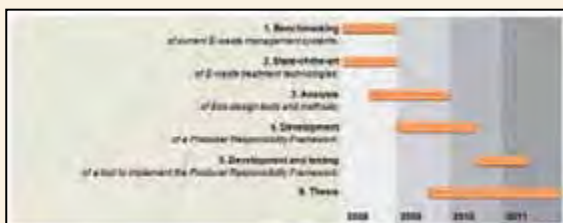

Fig. 1.

Fig. 2.

Fig. 3.

Cost Model of Joining Technologies and Assembly of EV Battery Pack

Leaders for Technical Industries PhD
Supervisors: **Rich Roth (MIT), Randolph Kirchain (MIT)**
Research team: **Hadi Zaklouta (MIT), Rich Roth (MIT) and Randolph Kirchain (MIT) in collaboration with General Motors**

Hadi Zaklouta

Objectives

To explore the tradeoff between outgoing product quality and cost of rejects in cases with
- extremely expensive components
- high consumer expectations and confidence
- joining technologies with different cost and quality implications
- testing strategies with different cost and quality implications
- So what is the optimal choice of joining and testing strategies?
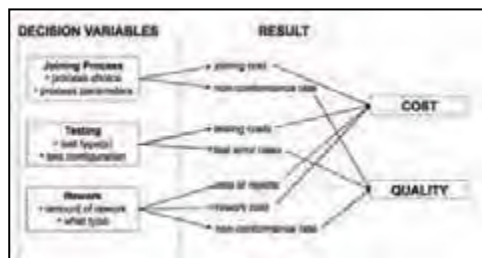
Application to Electric Vehicle Battery Assembly

All decision variable consequences are important but here specific items have an especially large impact
- reject rate: battery disassembly and scrapping Li-ion cells is expensive
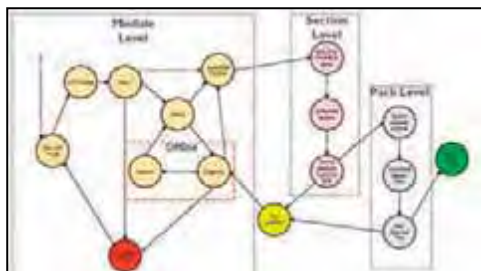
Fig. 1. a simplified schematic of one possible battery pack assembly setup including joining and testing processes

- test error rate: determination of quality is critical
- non-conformance rate: bad welds lead to battery pack failure

Cost Methodology

A Process Based Cost Model (PBCM) which includes testing processes is developed. This can be applied to the specific case of battery pack assembly and can be adjusted to explore different joining and testing technologies.

Fig. 2. retest reject strategy depicting all sources of test errors

Testing/Quality Methodology

The assembly process is not perfect, but includes sources of errors from the joining or testing processes. Joining is imperfect and testing declarations of quality may be erroneous. The flow of conforming and non-conforming products is probabilistic in nature and is incorporated into the cost model.

Results

Simulation has shown that output costs are multimodal. This is due to the stochastic occurrence of scrap costs at various points in the assembly process or external failure costs if a non-conforming product reaches the consumer.

Therefore, an expected value approach is not a sufficient metric of comparing joining and testing strategies.

Fig. 3. cost output of an example assembly situation with 1 point where scrapping can occur and a low probability of non conforming products reaching the consumer

The optimal test configuration is highly influenced by costs, joining quality and error rates. This can be demonstrated in the case where optimality is defined by minimum expected value.

Fig. 4. choice of optimal testing strategy based on minimizing expected value of cost is highly sensitive to individual cost parameters including warranty and scrap cost as well as test costs and error rates.

Discussion Topics
- Where do electric vehicle battery packs lie in joining/testing strategy decision space ?
- How does uncertainty and multimodality influence choice of joining and testing strategies?

Further Directions
- Modeling the effects of rework on product quality
- Detailed modeling of external failure costs including warranty and loss of goodwill

Performance analysis of a ZigBee based medical sensor network

Leaders for Technical Industries PhD
University of Minho
Background: **MSc. Electric Engineering, Rio de Janeiro Federal University, Brazil; Electronics Engineering, Rio de Janeiro State University, Brazil**
Spain
Starting Year: **2007 / 2008**
Supervisors: **J. H. Correia (UMinho), José A. Afonso (UMinho); Ricardo Simões, (Polytechnic Institute of Cávado and Ave)**
Research team: **Bruno Fernandes, Ana Carolina Matos, Duarte Pereira**

Helena López

Objectives

▶ Understand the potential offered by low power radio technologies applied to patient health monitoring under several scenarios.

▶ Examine usability, financial, ethical and social issues related to the interaction of different actors (hospital managers, caregivers, patients and their families) in the medical environment and the system.

Work plan

▶ Specify, prototype and deploy a vital signs monitoring system targeted to a hospital.

▶ Evaluate the benefits it creates, detect the usability issues, measure its performance, discuss the technological limitations and propose improvements.
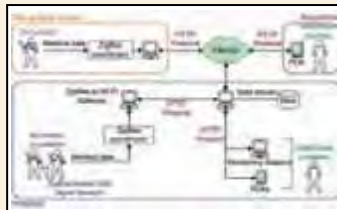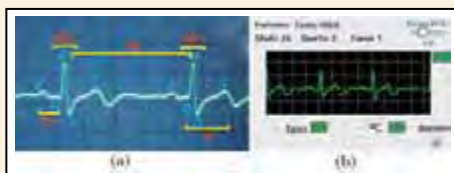
Delivery ratio tests results

Results

▶ A prototype system is under test in one of the internment floors of the Guimarães Private Hospital. Presently, the system is able to monitor ECG, heart rate and skin temperature. A SpO2 sensor is under development.

▶ The developed Web-based applications allow information to be displayed in any computer with access to the Internet, and a PDA-based application is under development.
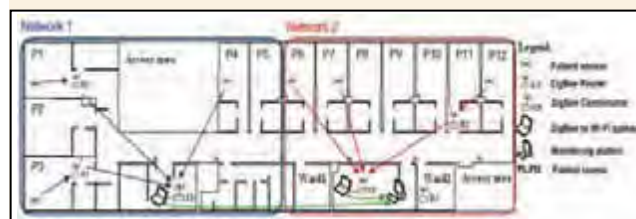

System architecture

Wireless ECG sensor prototype

ECG signal measurement

Wireless temperature sensor prototype

Network schematics

Delivery ratio and latency measurement results

From Tooling Design to Tools Life Cycle Design: Shifting the Paradigm

Leaders for Technical Industries PhD
IST-UTL
Background: **MSc. Mechanical Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Paulo Peças (IST-UTL), Richard Roth (MIT),**
António Pontes (UMinho), Elsa Henriques (IST-UTL)

Inês Ribeiro

Objectives

This project aims to shift the cost paradigm in the mould industry into the sustainable design one. The mapping of design and manufacturing decisions in several case studies and the impact of these decisions throughout the mould life cycle aim to define mould design decisions leading to sustainable design practices for the mould industry. By this, the main goal of the project is achieved, in which not only cost impacts influence the mould project, but also the environmental impacts and other aspects involving the mould performance throughout its life cycle.

Work plan

This research project will evolve different activities, being the main ones: Literature review; Definition of case studies to analyze throughout their life cycle; Investigate the decisions taken in the mould design phase; Impact assessment of the decisions previously defined regarding their impact in the mould life cycle in terms of economical, environmental and functional aspects (using LCC, LCA and MaU analyses); Aggregation of these three dimensions of analysis into a single framework and subsequent mapping of sustainable design decisions.

Results

The literature review, which will continue throughout the project, was already started. Also cost and environmental models were already developed applied to several case studies evolving different mould features and the impacts of these design decisions. This simple approach allowed understanding the type of results possible to obtain with this life cycle methodology. Currently I am in an internship in a mould making company in order to better understand design decisions and to develop new case studies.
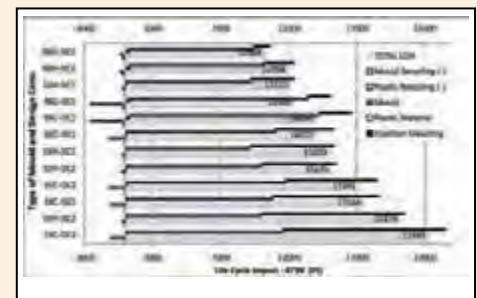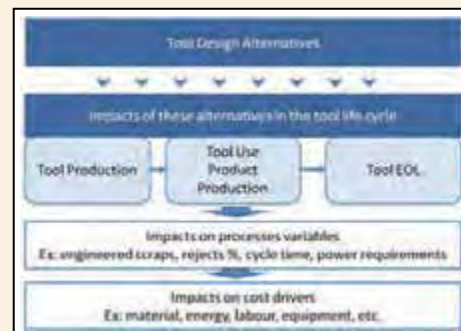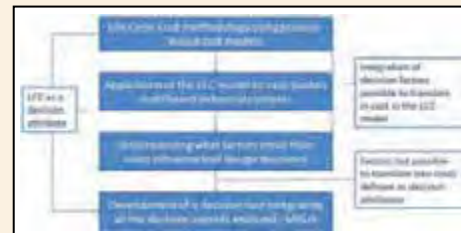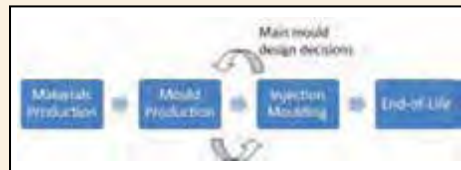
HMI on Sensitivity Functions approach: case of non-visual senses

Leaders for Technical Industries PhD

IST-UTL

Background: **MSc. Product and Systems Design Engineering, University of the Aegean, Greece**

Greece

Starting Year: **2008 / 2009**

Supervisors: **Mihail Fontul (IST-UTL), Elsa Henriques (IST-UTL), Qi Hommes (MIT), Lia Patricio (FEUP), Paraskevas Papanikos (U Aegean)**

Malliaros Ioannis

Objectives

The broad objective of this research is to develop a new generation of interfaces between human and electronic / mechanical devices in the automotive area. The aim of this study is to propose a methodology which will contribute to attain the non-visual feeling.

▶ To establish connections between the Product and Process design and the "feeling" evoked by non-visual senses (kinesthetic, acoustic and haptic)

▶ Bring a further understanding on the interaction between the user and the interfaces through non-visual senses. (kinesthetic, acoustic and haptic)
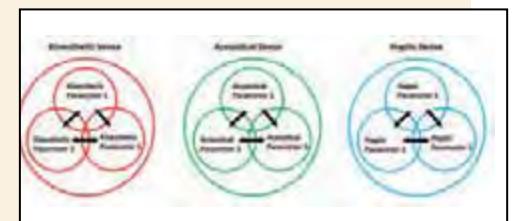

Fig. 1.

Work plan

To develop a methodology for each non-visual sense with the following goals (fig 1):

▶ Analysis of the requirements for interaction between the user and the interface for each non-visual sense

▶ Identification each sense parameters

▶ Analysis of how interactions among sense parameters affect the desired feeling

To develop a general methodology merging all the non-visual senses (fig 2):

▶ Analysis of the non-visual senses as a system

▶ Integration of the procedures for each non-visual sense into a holistic methodology

▶ Analysis of how interactions among non-visual senses affect the general feeling

Fig. 2.
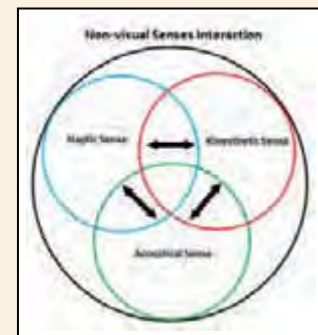
Results

For both research and industrial application purposes, this approach will bring a further understanding of the interactions among the sense parameters. The expected result will be a valid tool for the ICI manufacturing companies to achieve the expected non-visual feeling as request by OEM clients.

Research framework

Technological, economic and social implications in the design of a stent-graft

Leaders for Technical Industries PhD
FEUP
Background: **MSc. Mechanical Engineering and Industrial Design, FEUP, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **João Manuel R.S. Tavares (FEUP), Luis Rocha (UMinho)**
Research team: **L.A. Rocha, J.C. Viana, A.J. Pontes, J. Machado da Silva,**
J.G. Mendes, J.M.R.S. Tavares, A. Rodrigues, Brian Wardle, Fabio Fachin,
A. Sepúlveda

Isa Santos

Objectives

The medical device sector is unique. Normally, its products are brought to market at high risk and their value to users and service providers is frequently poorly established. Furthermore, they are subject to the scrutiny of different agencies around the world, such as NICE (National Institute for Health and Clinical Excellence) or FDA (Food and Drug Administration), to assess their clinical and cost-effectiveness. The methodologies required for this assessment are not yet well established or sufficiently robust, and they can vary dramatically from one jurisdiction to another influencing the product's success and potentially leading to economical losses.

A possible solution to minimize losses and delays would imply the assessment of both the clinical and cost-effectiveness during the early stages of product development. Thus, this project aims to study product development methodologies and to propose a process of concept selection based on the medical device expected clinical and economical effectiveness (cost-benefit). The methods proposed will then be applied in the development of a smart stent-graft (Figure 1) for the treatment of aortic aneurysms (Figure 2).

Work plan

▶ Review of the state-of-the-art (product development methodologies, concept selection, stent-grafts);

▶ Development of a new method of concept selection;

▶ Development of a smart stent-graft (identification of customer needs, definition of specifications, concept generation, concept selection, product design)
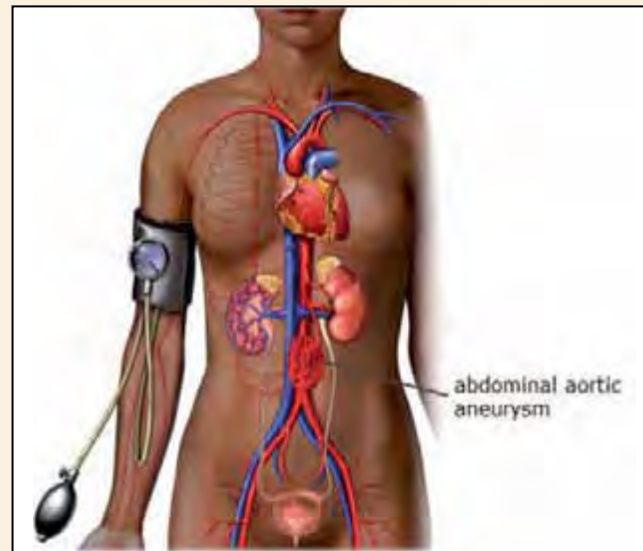
Results

From this research, the following outcomes are expected:
▶ a process to select concepts based on their expected cost and benefit; and,
▶ a prototype of a smart stent-graft.
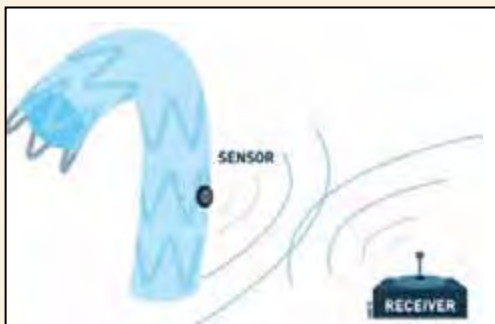
Fig. 1. Possible design of a smart stent-graft

Fig. 2. Abdominal aortic aneurysm

Integrated design and decision tools during the conceptual design phase

Leaders for Technical Industries PhD

IST-UTL

Background: **MSc. Aerospace Engineering, IST-UTL, Portugal and Supaero, Toulouse, France**

Portugal

Starting Year: **2007 / 2008**

Supervisors: **Prof. Paulo Gil (IST-UTL), Prof. Olivier de Weck (MIT), Prof. Pedro Oliveira (UMinho)**

Research team: **I. M. L. Ferreira (IST-UTL), P. J. S. Gil (IST-UTL), O. Weck (MIT), P. Oliveira (UMinho)**

Ivo Ferreira

Objectives

The main goal of this research project is the development of new tools to allow interaction and incorporation of changes more easily in the conceptual design phase of complex systems, when only 5% of the total cost is expended but up to 80% of system cost and performance is defined.

It focuses on the problems and needs regarding the representation of   complex engineering systems throughout the conceptual design phase in a concurrent real time environment (Fig. 1).

Decision support and knowledge management tools are being developed to enhance integration of the different subsystems, facilitate justification of design decisions, and simultaneously convey the impact of parameters on the objectives and constraints.


Fig. 1.

Work plan

A research over existing cutting-edge dynamic visualization tools combined with known system engineering paradigms has led to a proposal of an integrated conceptual design process that, contributes to the understanding of complex systems by enabling heuristics operations that find hidden relations between parts, and allows using concurrent engineering and multidisciplinary optimization (MDO) methods for systems design.

Future work will allow the development of a prototype tool implementing the proposed process. Its performance will be measured through case studies in both the automotive and the aerospace fields by measuring the gains in the quality of the design process.

Fig. 2.
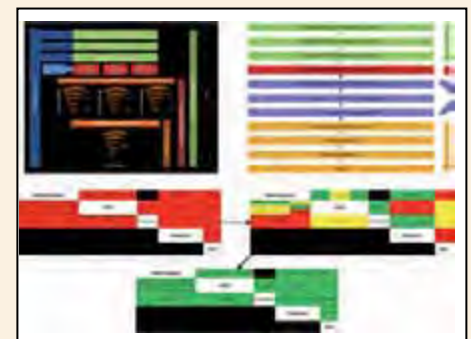
Results

▶ An integrated design process to be used from the concept map of the system objective statement to MDO, using a state-like definition of the system and real time Design Structure Matrix (DSM) visualization to represent the interactions of different subsystems (Fig. 2).

▶ An intuitive, "easy to use", decision support tool based on an adaptive perceptron supervised learning neural network algorithm was developed to be used by system designers to provide suggestions based on past similar design solutions (Fig. 3).

Fig. 3.

V2G Aggregation Business IT Platform

Leaders for Technical Industries PhD
U Minho
Background: **PhD, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Dr. João Luiz Afonso - (U Minho)**
Alberto Rodrigues da Silva (IST-UTL)
Research team: **João Carlos Amaro Ferreira (U Minho)**
João Luiz Afonso (U Minho)
Alberto Rodrigues da Silva (IST-UTL)

João Ferreira

Objectives

Motivation/Context: Electrical Vehicle (EV) can be an energy player if we aggregate them, that means to build up a community. Also EV community can deal with intermittent behavior of the renewable energy sources.

Objectives: Design a IT Platform to create and handle EV community, based on social networks collaborative approach (See Figure 1).

Results

A conceptual system is proposed to create and manage the EV community with a credit-based approach is the innovative proposal of this paper. We think that using this credit-base system together with rankings, users would enjoy it as an open and healthy competitive environment. Also in future to increase the market share of EV and PHEV, there is a need of these types of systems to explore the energy market potential of this type of vehicles. Also renewable energy source integration could benefit from a community coordination action, where users' will capture renewable excess production at lower prices.

Work plan

Development of an intelligent system to associate EVs as a strong energy market player

Social networks approaches to raise collaboration among the community users Credits mechanisms to avoid disruptive users' behavior.

Based on Geographic Information System (the aggregation makes sense) of nearby EVs

The principal sources of uncertainty for an Aggregator are: (1) the duration of the periods during which each EV in the community ; (2) is connected to the grid; (3) the distances travelled by each EV; and (4) the SOC of each EV at any point in time. Based on the stock exchange metaphor, the aggregation model permits to understand fairly how much users are collaborating towards the common goal, as well as they are able to be connected during critical hours (hours that most of EVs are unplugged due to the moving purposes of their owners). Changes on user predefined behavior is penalized if it is not reported to the system previously (remove user credits).
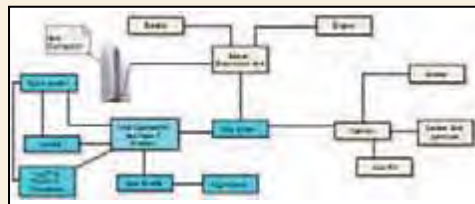

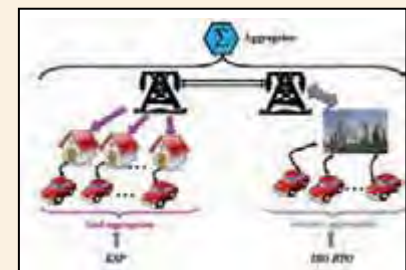**Fig. 1.** Current proposal (blue modules) and relation with EV, Smart Grid and Energy Market

Fig. 2. EV can be a energy player if we aggregate them = Build Community. 100 EV with 10Kw is 1MW
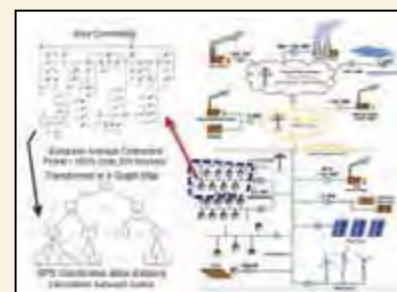

Fig. 3. Electrical network distribution with low voltage distribution area community converted into a geo-reference graph used to create the driver community.

Fig. 4. Aggregator X

Fig. 5. Credits mechanisms proposed

Decision Making Methodology on Human and Machine Interface (HMI) Innovative Processes

Leaders for Technical Industries PhD
IST-UTL
Background: **Msc Engineering Design, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
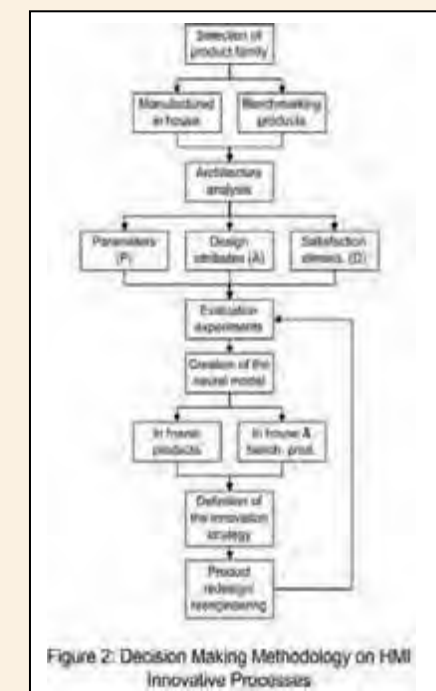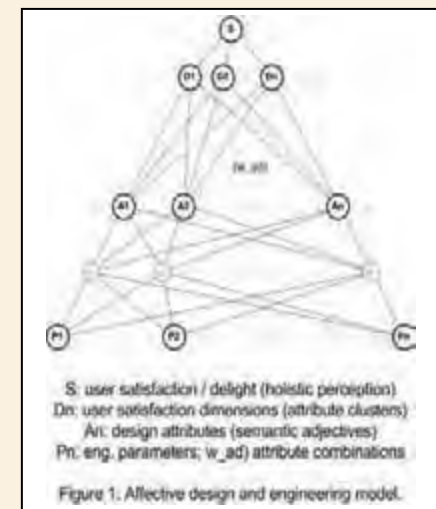Supervisors: **Mihail Fontul (IST-UTL), Elsa Henriques (IST-UTL)**

José Gaspar

Objectives

1) Build a model that relates the user satisfaction with design attributes and engineering parameters of an in-car interface.
2) Identify the eng. parameters with larger impact on user satisfaction.
3) Evaluate the impact of such solutions on cost.
4) Integrate the results in a cost / user satisfaction approach.
5) Support the HMI innovation strategy.

Work plan

2010.04 – Bibliographical review.
2010.06 – General user satisfaction model (DAP).
2010.07 – Particular user satisfaction model (In progress).
2010.12 – Data collection.
2011.05 – Data analysis.
2011.07 – Model validation.
2011.09 – Engineering parameters selection.
2011.12 – Cost modeling.
2012.07 – Thesis compilation.

S: user satisfaction / delight (holistic perception)
Dn: user satisfaction dimensions (attribute clusters)
An: design attributes (semantic adjectives)
Pn: eng. parameters; w_ad) attribute combinations

Figure 1. Affective design and engineering model.

Results

Affective design and engineering model (figure 1) built upon three layers of references (DAP): D) satisfaction dimensions, A) design attributes and P) engineering parameters.

Artificial neuronal networks are being developed to link the DAP layers.

A decision making methodology (figure 2) is proposed to explore the application of the satisfaction model (figure nº1).

Three approaches to build the innovation strategy are to develop: selection of the attributes that can be combined (redesign), parameters that can be improved (reengineering) and the redesign & reengineering mix.

Several reports and presentations were done until now and a journal paper is on-working.

Figure 2: Decision Making Methodology on HMI Innovative Processes

Increasing flexibility and collaboration in the automotive supply chain network

Leaders for Technical Industries PhD
FEUP
Background: **MSc. U Minho, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Jorge Pinho de Sousa (FEUP), João Claro (FEUP),**
Richard de Neufville (MIT)

Lia Oliveira

Objectives

The main goal of this research project is to design a methodology and a set of tools for supply chain management, to help coping with more and more demanding market requirements. Higher levels of flexibility and collaboration in complex supply chain networks will allow a significant increase of competitiveness. Therefore this research aims at creating a methodology for supporting supply networks coordination activities, a collaborative platform to guarantee higher levels of visibility and information sharing among the supply network partners, and a set of tools that can help these companies to set up and operate more successful networks.
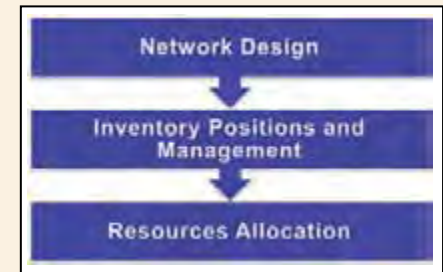
Results

The main expected result of the research is a comprehensive framework (a methodology and a set of computer based tools) to support strategic and tactical decision making in the planning of complex supply chains. This framework will hopefully have a considerable impact in the performance of companies, especially in improving their flexibility to deal with rather dynamic, unstable business environments, and more demanding markets.

Network Planning

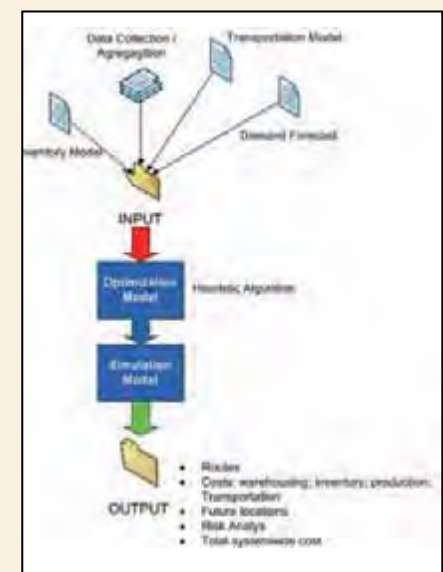## Work plan

The main phases of this research are:

> *1 -* state-of-the-art, and requirement analysis

> *2 -* aggregate modeling of supply-chains and performance assessment of logistic systems

> *3 -* detailed modeling of some relevant problems, to be identified in the FLEXINET pilots

> *4 -* design, evaluation and implementation of algorithmic procedures based on multi-objective metaheuristics

> *5 -* design of Decision Support tools and development of prototypes to assess the developed concepts and techniques.

Network Design

Materials Selection Considering Technical Performance, Process Cost and Life Cycle Evaluation

Leaders for Technical Industries PhD
IST-UTL
Background: **MSc., IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Arlindo Silva (IST-UTL), Elsa Henriques (IST-UTL)**
Research team: **Arlindo Silva and Elsa Henriques (IST-UTL), Pedro Camanho**
(FEUP), Rich Roth and Randy Kirchain (MIT), Marco Leite

Marco Leite

Objectives

The aim is to study how to use, not only engineering properties, but also a well defined set of economical and environmental criteria for materials selection since the early phases of product development.

Results

The outcome of the project is a structured and enhanced method for material selection that throughout the product development process, will conduct the designer on a step by step basis, from what seems to be suitable materials to the "best" material for the application in predefined complex scenarios derived from targets on product performance, economical achievements and environmental impacts over lifecycle.

Work plan

As a first introductory study for this project, several materials selection models were built under the generic name of Materials Selection Engines (Fig. 1), where technical, economic and environmental tools were combined to assist in the decision making process of selecting materials.

The first internship occurred at SODECIA – Technological Center. Main effort is to develop a model to assist in the decision to bid for the requests for quotation that the company receives, minimizing references of steel gages and steel grades, while maximizing performance and minimizing cost. Another effort was made earlier on, to develop a deeper understanding of the system dynamics involved in the major materials selection decisions at corporate level, based on a literature survey and on the available information at SODECIA (Fig. 2).

A second internship occurred at GM Tech Center with MIT-MSL support. The objective was to study materials and technology selection in the early stages of product development and the implications on product design.

To build a "compound" measure for selecting materials using data from technical, economical and environmental fields.

Fig. 1. Material Selection Engine
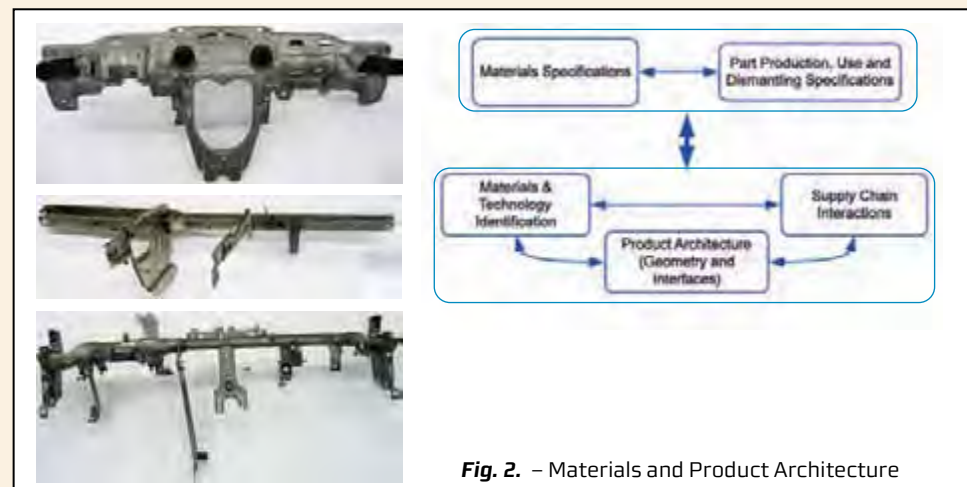
Fig. 2. – Materials and Product Architecture

Leaders for Technical Industries PhD
FEUP
Background: **MSc. Metallurgical and Materials Engineering, FEUP, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Marcelo Moura (FEUP), Lucas Silva (FEUP),**
**Antonio Torres Marques (FEUP), Manuel Freitas (IST-UTL),**
Thomas Eagar (MIT)

Maria Fernández

Objectives

The main objective of this project is to define methodologies to conduct repairs in aeronautical structures of composite. By defining conception rules that promote optimization of the structures, when those materials are subjected to fatigue load. This project intends to study the repair specificities inherent to the referred materials. It is expected that the current methods of aeronautical repairs can be improved technologically and economically.

Work plan

Experimental tests and numerical analyses will be executed to define the repair strategies. Experimental testing could be a long and expensive process which justifies the use of suitable numerical methods to carry out the optimization procedure. Special attention will be given to cohesive zone modeling in order to improve a previously developed model adequate for static analysis [de Moura, 2006]. This cohesive zone model was already used in the optimization of bonded joints subjected to static loadings [Campilho, 2009]. The 1st stage will be dedicated to the development of the cohesive numerical model adequate to fatigue loading simulation. The 2nd stage will be devoted to the experiments, where some cases selected from the numerical studies will be tested.
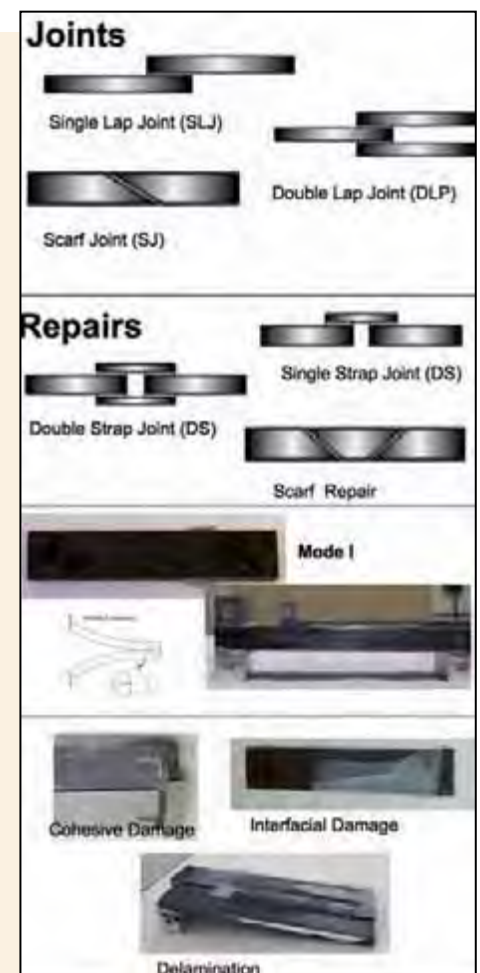

Results

MODE I:

There are three types of damage cohesive damage, interfacial damage and delamination.

This types of failure affect drastically the fatigue crack growth rate:

the interfacial damage has a faster FCG than the cohesive failure;

when delamination occurs, the FCG rate is slower than a cohesive failure, because of the fiber bridging.

A more stable crack growth is also needed, because there is a lot of dispersion in the obtained results.
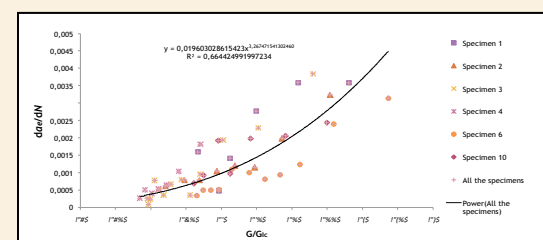
Sustainable automotive components for interior door trims

Leaders for Technical Industries PhD
FEUP
Background: **MSc. Mechanical Engineering,**
MSc. Industrial Design, FEUP, Portugal
Portugal
Starting Year: **2008 / 2009**
Supervisors: **José Luis Esteves (FEUP), Júlio Viana (UMinho)**
Research team: **J.C. Viana(UMinho); J.L. Esteves (FEUP); N.C. Loureiro (FEUP);**
Luis Reis (IST); Bernardo Ribeiro (UMinho); Francisco Brito (UMinho);
A.T. Marques (FEUP);

Nuno Loureiro

Objectives

This work aims at developing new material solutions for eco-sustainable automotive components, enabling the use of emerging green composites, based on biodegradable polymer matrices and natural reinforcements in automotive components of an urban vehicle.

As a case study, a door trim module will be considered. The new material solutions, based in biodegradable polymers and natural reinforcements, will meet current standards for automotive door trims.
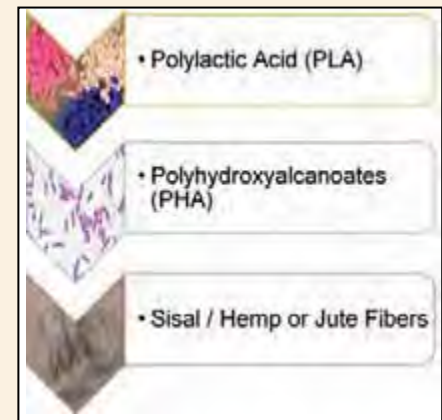
Work plan

1 CONCEPT DEVELOPMENT In this phase the material and technology solutions will be developed. Special emphasis will be put in the development and characterization of material solutions based in biodegradable polymers and natural reinforcements from 100 % of renewable resources.

2 TECHNOLOGY DEVELOPMENT In this phase the interior door module will be developed, based in the material solutions developed in T1.

3 SUSTAINABILITY AND ECONOMICAL ANALYSIS The material solutions will be analyzed in terms of their environmental impact. Also, their economical viability will be considered.

4 PROTOTYPE DEVELOPMENT In this phase a full functional prototype of the interior door module will be developed, considering manufacturing techniques.

- Polylactic Acid (PLA)
- Polyhydroxyalcanoates (PHA)
- Sisal / Hemp or Jute Fibers

Compound Injection Moulding

Results

At the end, together will a physical prototype, the following results are expected:

New eco-sustainable material system solutions comprising of biodegradable polymers and renewable resources reinforcements;

Demonstrate the feasibility of the use of biodegradable polymers in automotive interiors;

Better understand the behavior of biodegradable polymers fostering their applications in automotive components;

To develop manufacturing solutions to produce an innovative eco-door module;

Interior door trim made in composites based in renewable resources

Creativity and innovation in product design and services

Leaders for Technical Industries PhD
IST-UTL
Background: **MSc Engineering Physics, University of Lisbon, Portugal;**
Degree Industrial Engineering, FCT-UNL, Portugal
Portugal
Starting Year: **2007 / 2008**
Supervisors: **JProf. Arlindo Silva (IST-UTL), Prof. Elsa Henriques (IST-UTL)**
Research team: **A. Silva, E. Henriques, C. Magee**

Pedro Marques

Objectives

The objective of this research is to create a better understanding of the framework of creativity, with special attention to the way in which the engineer's mind processes the information available to make engineering decisions. A model of information processing and creativity is being established to explain how an engineer responsible for product development will foster creativity within his team and stay within the time schedules imposed.

Work plan

Task 1 – Defining a set of criteria for the specialization or generalization loops

Task 2 – Determining the role of stage gates in a more fuzzy development

Task 3 – Relating creativity and product architecture

Task 4 – Establishing a methodology for the validation of the proposed model

Task 5 – Implementing the methodology for validation

Results

Establishment of a framework for rational thinking that fosters creativity. Detailed definition of what kind of framework for the mind must be assumed for people at various stages of product development.
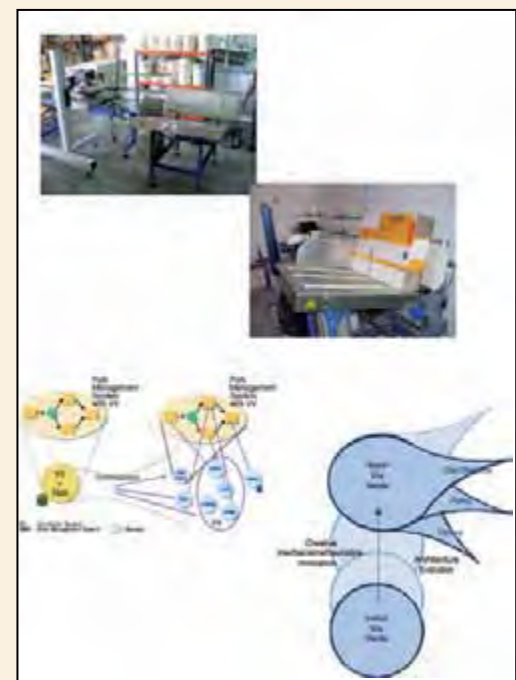
Influence of Variability on Assembly Systems

Leaders for Technical Industries PhD
IST-UTL
Background: **MSc. Mechanical Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Elsa Henriques (IST-UTL), Paulo Peças (IST-UTL),**
Stan Gershwin (MIT), Guilherme Silva (UMinho)
Research team: **V.Chu, A.T. Pereira, A. Pimentel, M. Santos**

Raquel Folgado

Objectives

The assembly process is a fundamental process in most of our common commodities, and this is no different in the automobiles we drive. All of these functional components had to go through several production processes to be at our disposal inside an automobile, namely intricate assembly processes since these components are made of a high number of small scale parts working together to deliver a kinematic function. Assembly systems performance is also influenced by both exogenous factors and endogenous sources of variability to the system itself. Depending on the type of assembly system, there will be different variability sources influencing the system behavior as well as different impacts. In this research project it's proposed to study and characterize the variability sources present in assembly systems in an automotive industry setting, and to develop new strategies of managing the addressed sources of variability in order to mitigate its effects.

Results

In a real industrial setting the task times are basically never deterministic, unless in the case of simple manual tasks or highly reliable automated stations. This is not the case in assembly systems where most of the operations are carried out manually and these operations have a significant number of assembly steps. Both factory observations and previous studied studies indicate that the variability of manual processing time is considerable.

Preliminary results show that are several phenomena affecting the time performance of a manual operation, which are being further investigated.

Work plan

Phase 1 – Alignment with Industrial Setting
Phase 2 – Problem Definition and System Boundaries
Phase 3 – Assembly Systems Characterization
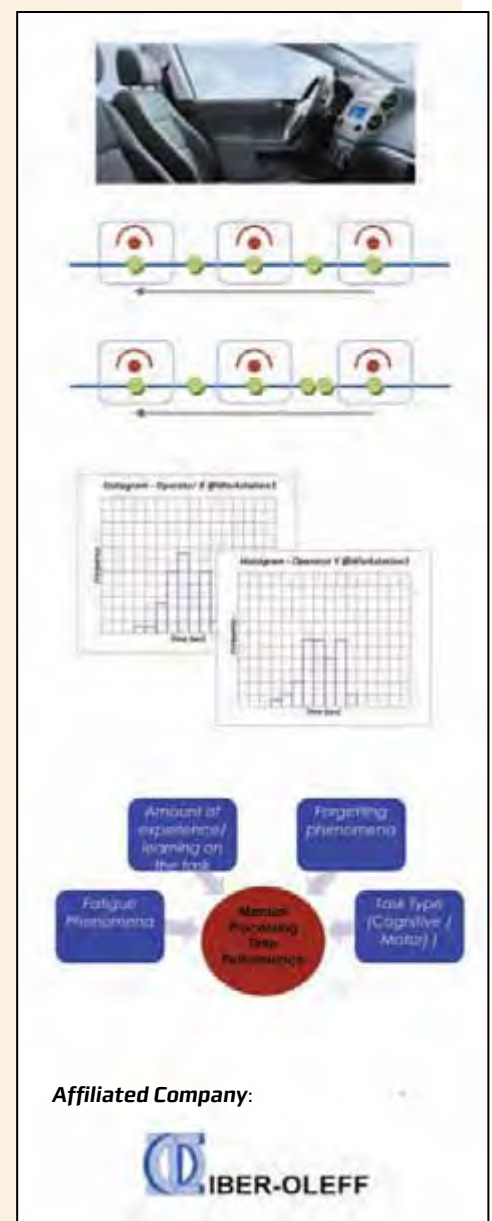**Phase 4** – Definition of Endogenous and Exogenous Factors of Influence
Phase 5 – Endogenous Sources of Variability Characterization
Phase 6 – Develop Methodology to Manage Main Sources of Variability

Affiliated Company:

IBER-OLEFF

An expert decision support system for concurrent development of RIM plastic parts

Leaders for Technical Industries PhD
FEUP
Background: **Bsc. Industrial Engineering.**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Ricardo Santos (FEUP), Madalena Dias (FEUP),**
Richard Roth (MIT)
Research team: **Ricardo Santos (FEUP), Madalena Dias (FEUP),**
José Carlos Lopes (FEUP, Fluidinova), António Pontes (UMinho),
Richard Roth (MIT), Randolph Kirchain (MIT)

Ricardo Torcato

Objectives

The main aim of this research is to identify and organize the knowledge required in the development process of RIM (Reaction Injection Molding, fig. 1) parts at the early product development stage, specifically the material selection, mold design and the process planning for mold making and molding operation. This work will assess if an Expert System, a computer program that uses knowledge and inference procedures to model the RIM development process, provides the necessary insight into metrics such as development lead time and manufacturing costs to deal with the decision makings required in that stage.

Results

An expert decision support system will be developed for implementation in a company, consisting of:
▶ A framework providing a generic decision making model for describing the entire product concept development process of RIM parts with emphasis on the concept development and evaluation stage.
▶ A prototype expert system which is capable of generating the RIM mold design features, mold making process plan, production molding plan, estimated mold making lead time, and cost estimates of the RIM mold and production molding.

Work plan

Future work is planned as follows:
▶ Structure and formalize the downstream processes and procedures of developing product design concepts of RIM plastic parts, including the mold design and the process planning of mold manufacture and molding operations. – Mostly finished.
▶ Recognize and define the dimensions of knowledge required in the concurrent product concept development process of RIM parts (fig. 2).
▶ Establish an implementation framework, the methodologies and procedures, of an ES which helps dealing with concurrent concept development decision makings at the early design and development stage of RIM plastic parts.
▶ Develop a PBCM capable of receiving the technical inputs from the ES and sending the economical outputs to the ES.
▶ Develop a prototype ES to test the validity of the implementation framework.
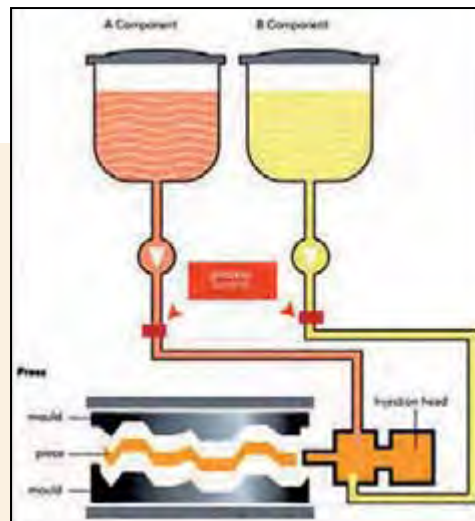
Fig. 1. – RIM scheme
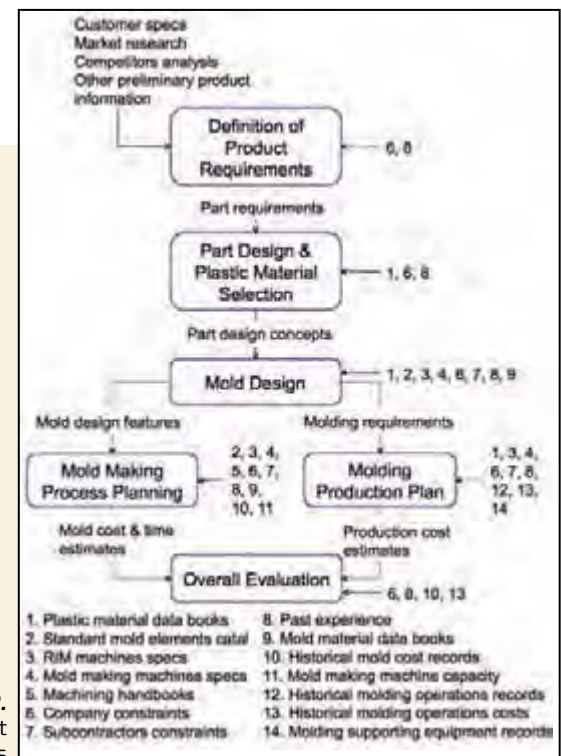
Fig. 2. – Concurrent concept development process of RIM parts

Flexible information technologies for complex supply chain networks

Leaders for Technical Industries PhD
FEUP
Background: **MSc., University of Aveiro, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Américo Azevedo (FEUP), José Crespo Carvalho (ISCTE),**
David Simchi-Levi (MIT)

Ricardo Almeida

Objectives

In the last decade, the markets were faced with the need to deal with a new trend for total customization associated with a significant increase in the complexity of the products and an uncertainty demand. Firms have sought to apply new business models and re-structure their internal processes to ensure greater flexibility in developing services and products. The emergence of **networks of organizations** (called "virtual organizations" - VOs) enabled an effective response to these new market challenges, however, placed the company on new organizational, cultural and technological challenges.

Sharing the same concerns, **this study aims** to:

▶ Assess the **degree of dependence** of virtual organizations in technological systems;

▶ Evaluate how they **affect or facilitate the desired flexibility** on these organizations;

▶ Analyze which kind of **technological architecture** should exist for communication, between different information systems, to become fluid and consistent and ensure transparency between business processes, promoting an effective cooperation between organizations.

Early studies already have shown that there is no standard architecture for managing virtual networks of enterprises. As a result of the work is expected to present a **model architecture** that enables technology to be applied to several information systems, with a view to facilitating communication between businesses companies.

Work plan

The **first phase** relevant current concepts and trends from information gathered by a deep research on bibliographic source, scientific papers, published doctoral thesis.


The **second phase** intends to:

▶ Gather information from **personal interviews** with key-users from companies (directly) integrated on virtual networks, from several business types.

▶ Study the **current information technology infrastructures** existing at the IT market, as well as a comparison of the most used information systems, their major advantages and restrictions, in order to measure a quality level of recognition to support this business networks.

▶ Resume the existing **standards and data models** used on communication procedures.

Finally, the **third phase** will consider the design of a **new technological infrastructure model** that would guarantee a successful integration of network partners. The main idea is to promote an easily integration of a new node on the network enhancing a dynamic collaboration.

Results

At the moment, it's has been studied the collaborative platforms and decision support tools already presented on the IT market, to response to the needs of these business communities. The next step is to study the standards and frameworks for enterprise systems integration. It is expected that this research work can have a major impact, for the next years, for the business community in Portugal. Portuguese companies have not fully adhered to the concept of business networks, because of restrictions still find the level of trust and systems integration. However, they are aware that they need to choose this path in order to effectively address the emerging markets.
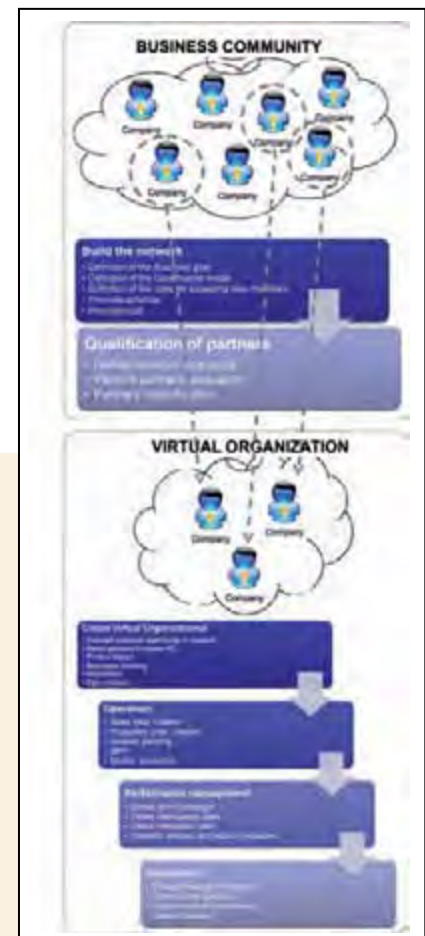
Designing the travel experience

Leaders for Technical Industries PhD
FEUP
Background: **MSc. Industrial Engineering and Management, FEUP, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Lia Patrício (FEUP), Renato Natal (FEUP),**
Chris Magee (MIT), Arlindo Silva (IST-UTL)
Research team: **Rui Carreira, Lia Patrício, Renato Natal,**
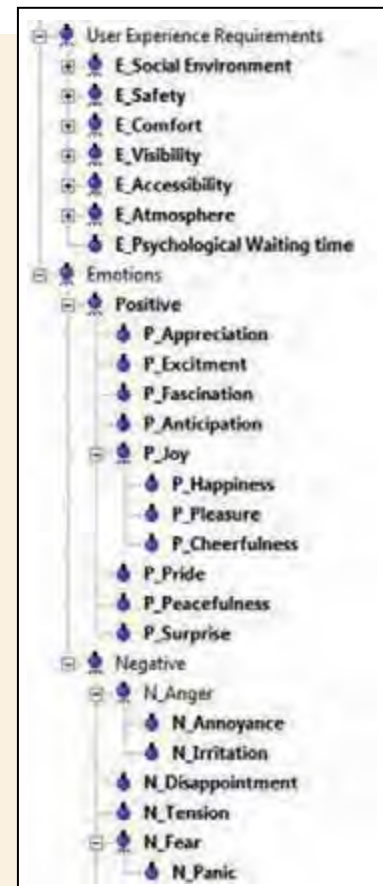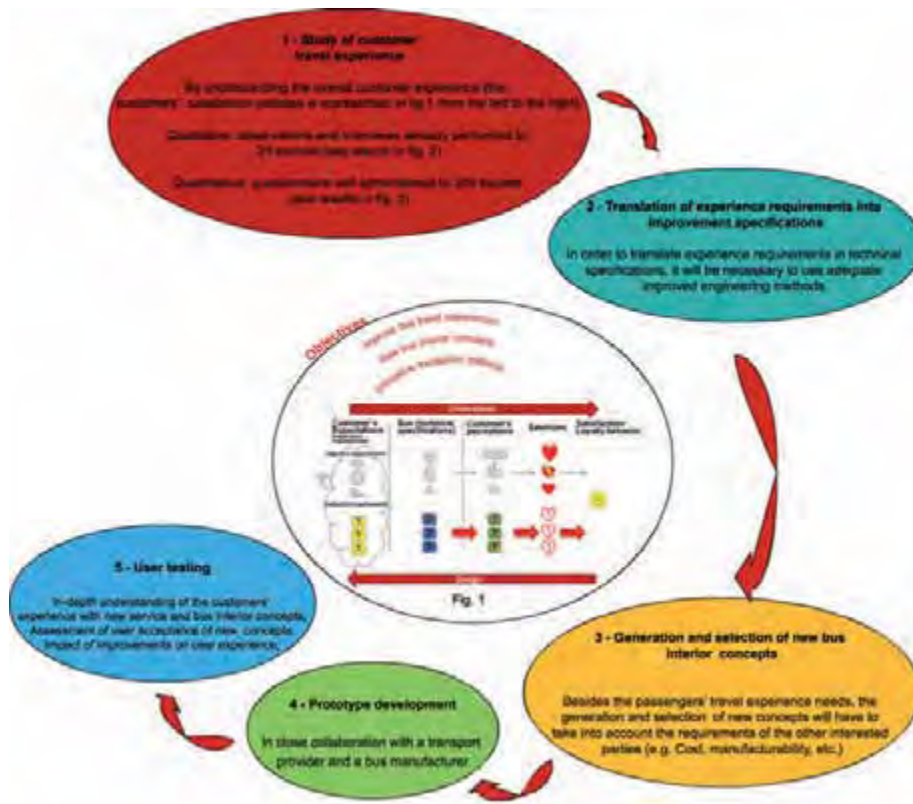**Chris Magee, Arlindo Silva**

Rui Carreira

Fig. 1

Fig. 2.

Results

Based on the qualitative study with passengers, involving interviews and observations, the main User Experience Requirements and Emotions associated with the travel experience are the ones listed in Fig. 2.

People reveal a global satisfaction with the transportation service, and expect that new vehicles will reinforce the positive emotional aspects, and eliminate the negative ones.

Taking in consideration the qualitative conclusions, it was developed a questionnaire to perform a quantitative analysis of the passengers' Requirements and Emotions.

After performing Exploratory Factor Analysis, there are 7 factors that were considered statistically significant (see Fig. 3).

Factor	Cronbach's Alpha
1-Seat Comfort	.793
2-Clean interior space	.713
3-Calm and quick trips	.765
4-Easy accessibility awareness	.780
5-Information	.802
6-Social environment	.774
7-Safety	.639

Fig. 3.

Light-duty vehicles energy and emissions "eco-score" considering total life cycle analysis and different end-users

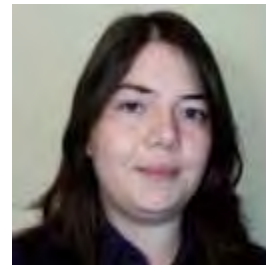**Leaders for Technical Industries PhD**
IST-UTL
Background: **MSc in Mechatronic Engineering, Instituto Superior de Transportes e Comunicações, MIT Portugal the Advanced Studies Program**
Starting Year: **2009 / 2010**
Supervisors: **Carla Silva(IST-UTL), João Afonso (UMinho) , Luís Reis (IST-UTL)**
Research team: **DTEA – IDMEC / IST-UTL**

Sara Marques

Objectives

A major concern nowadays is energy management.

The development of this work aims the eco-scoring of energy and CO2 emissions of light duty vehicles considering several technologies (internal combustion engine vehicles, fuel cell vehicles, pure electric vehicles, hybrid vehicles, plug-in hybrid vehicles) and different end users (urban, highway, mix driving and driving frequency).

It is main objective of this work to fulfill the gap created by the actual labeling methods for vehicles, which is not prepared for new vehicle technologies (e.g. electric and hybrid).

Work plan

The main tasks of the project are defined by:

-Review of the state of the art with focus in technologies, legislation, life cycle studies, labeling and smart connection to the grid.

-Assessment of the optimization model for possible technology, end user profile and connection to the grid combinations, having as parameters CO2 emissions and energy consumption considering total life cycle.

 -Efficiency bands definition.

 -Development of a label prototype adequate to all vehicle technologies.

Results

From this research, the following outcomes are expected:

- Vehicle efficiency per end user profile calculation formula (energy consumption / CO2 emissions)
-Efficiency bands
-Comparison between technology efficiency per end user profile
-New label design considering vehicle total life cycle
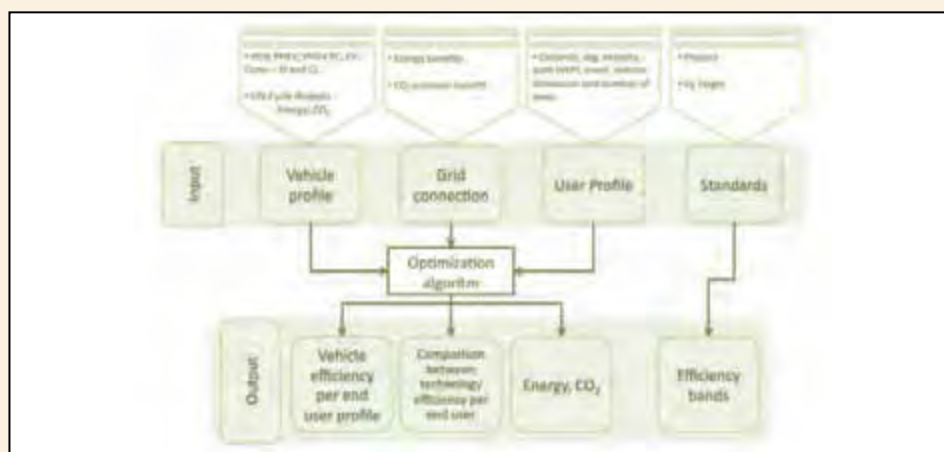
New Design Concepts for Aeronautical Applications by Friction Stir Welding

Leaders for Technical Industries PhD
FEUP
Background: **MSc Mechanical Engineering, FEUP, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Paulo M.S.T. de Castro (FEUP); Pedro Vilaça (IST-UTL),**
**Thomas Eagar (MIT), Jorge dos Santos (GKSS)**

Sérgio Tavares

Objectives

A multidisciplinary approach for the infusion in aeronautics of friction stir welding (FSW), an emerging technology, is the focus of this PhD.

This joining technology allows the production of leaner structures for airframes, reducing the global weight and manufacturing costs while ensuring structural integrity. Furthermore to the new concepts development, implications related to structural integrity, non-destructive inspections, cost evaluation and design for X analyses are the object of current research.
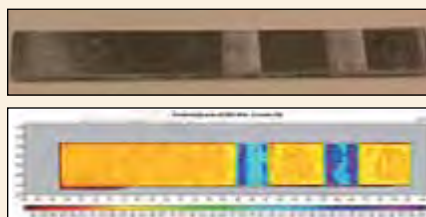
Work plan
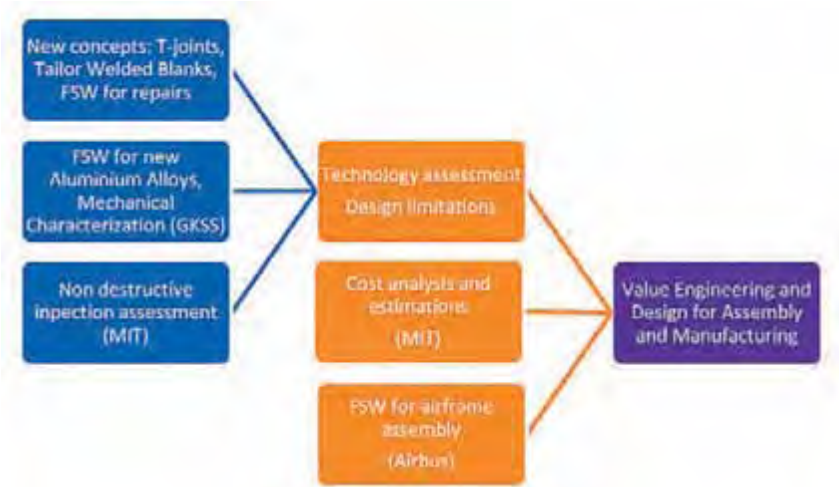
Results

New joining technologies as friction stir welding may improve transport system structures. The present work indicates that these structures can achieve high structural integrity, and compete with those manufactured using classical joining processes, as riveting in aeronautical structures.
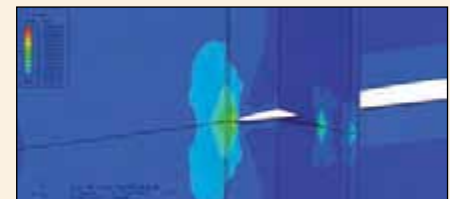
Results concerning the mechanical characterization of new aluminum alloys and new joining concepts were obtained through this research. In addition, non-destructive techniques were assessed and their limitations in these processes were detailed. These results, interrelated with cost analyses, allowed an improved understanding of the capabilities and limitations of an emerging joining process in aeronautics using design for assembly and manufacture concepts.
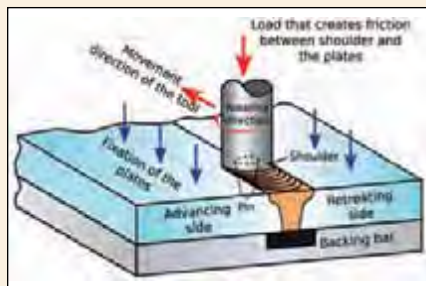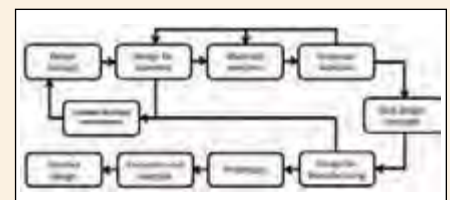

Fig. 1. Friction Stir Welding (FSW) process.

Fig. 2. Fracture mechanics analysis of FSW stiffened panels.

Fig. 3. Non destructive techniques, investigation with Meandering Winding Magnetometer®.

Fig. 4. Process selection and development in aeronautical context using design for manufacture and assembly approaches.

The Impact of Competitive Learning on Technology Choice in Electric Vehicle Battery Assembly

Leaders for Technical Industries PhD
MIT
Supervisors: **Randolph Kirchain (MIT)**,
Charles Fine (MIT), **Richard Roth (MIT)**

Thomas Rand-Nash

Objectives

Characterize the conditions under which multiple, interactive learning effects change technology choice decisions about:

- Which assembly technologies to choose
- When to introduce these technologies
- How to allocate finite financial resources among the resulting technology portfolio

## Work plan

Problem Characterization:
- Identify assembly processes exhibiting cost reductions over time via learning
- Identify technology basket for each process

Quantitative Modeling:
- Cost model to capture initial technology costs
- Learning model to capture cost evolution over time and interactive learning effects
- Ramp-up/penetration model to determine annual capacity
- Formal mathematical representation of models and interactions

Analysis:
- Characterize the impacts of competing learning on technology costs over time
- Characterize the conditions under which these impacts alter technology choice strategy
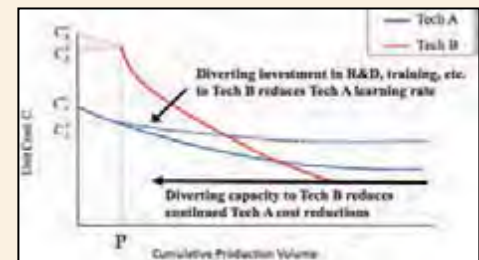
**Fig. 1.** Types of Learning Considered and The Impacts of Competitive Learning

Fig. 2. Cost Models Convolve Many Independent Learning Drivers Into Aggregate Learning Curves for Each Technology
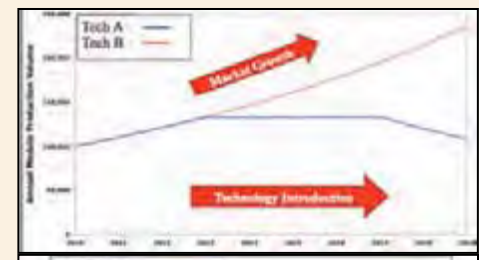
Results

- Interactive learning highlights several novel and subtle tradeoffs which impact decision making
- Further work is needed to fully characterize the impacts of these tradeoffs
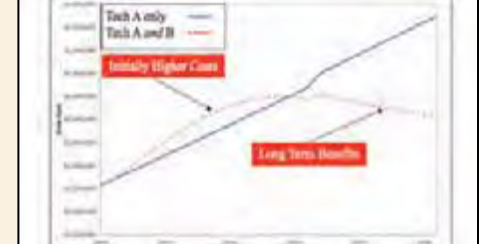
Fig. 3. Capital Investment and Ramp-Up Strategy Models Characterize How Far "Down The Learning Curve" Each Technology Progresses.

Sustainable Energy Systems

World Carbon Responsibility

Sustainable Energy Systems PhD
IST-UTL
Background: **Bsc., Applied Plant Biology, FCUL, Portugal; MSc. International Management, ISCTE, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisor: **Tiago Domingos (IST-UTL), João Rodrigues (IST-UTL)**

Alexandra Marques

Objectives

This work aims to provide quantification of the CO2 emissions embodied in the circular flow of an economy and better knowledge of the drivers of anthropogenic related CO2 emissions. Making available a new vision on an agent's responsibility on climate change based upon the framework developed by Rodrigues et al. (2005).

Work plan

This work is based on multi-regional input-output (MRIO) analysis. It started with the thorough analysis and discussion of the data provided by GTAP 6 database. Presently a MRIO table is being built with the latest available GTAP database. Future work comprises the analysis of the information provided by the MRIO table, understanding the drivers of indirect emissions, and study the application of this information in climate change policy.

Fig. 1 – Downstream emissions embodied in the payment for exports and in the payment for imports for six world regions (in Mt of CO2).

Fig.2 – Downstream emissions embodied in trade between Developed Economies, Fossil Fuel Exporters, Asia and the Rest of the world (in Mt of CO2).

Results

Here we show the emissions embodied in the payments for primary factors of production of goods internationally traded between world regions (Fig.1):

- Developed Economies and Fossil Fuel Exporters are net receivers of downstream emissions, Asia is a net sender. These regions contribute to 80% of the downstream emissions embodied in international trade (Fig.2).

- Developed Economies receive downstream emissions mainly via the payments for their manufactured products exports. Fossil fuel exporters receive downstream emissions mainly via the payments for fossil fuels. Asia sends downstream emissions mainly through payments of imported fossil fuels (Fig.3).

This approach allows the quantification of emissions associated with the generation of added value, and we conclude that the Developed Economies and Fossil Fuel Exporters are the regions whose wealth generation is more heavily dependent on carbon emissions.
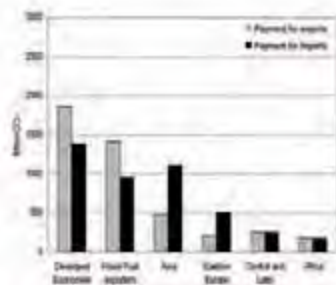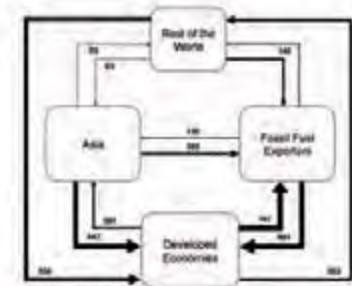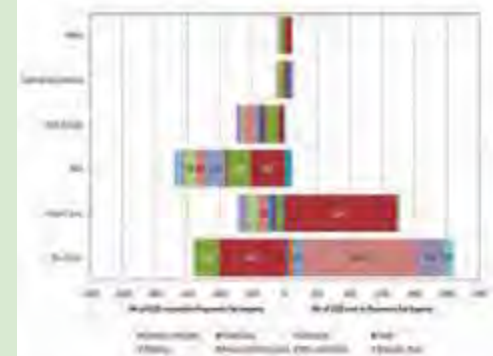

Fig.3 – Balance, by sector, of downstream emissions embodied in the payment for exports (negative number) and in the payment for imports (positive numbers) for six world regions (in Mt of CO2).

Life Cycle Optimization Model for Integrated Cogeneration & Solar Systems

Sustainable Energy Systems PhDFEUP
University of Coimbra
Background: **BSc Industrial Engineering, Azad University, Iran; MBA, University of Glasgow, UK**
Iran
Starting Year: **2008 / 2009**
Supervisors: **Fausto Freire and Carlos Henggeler Antunes (UC)**

Amir Safaei

Objectives

Energy consumption in the building sector consists more than 40 percent of the global energy consumption. Distributed energy generation is discussed to replace the conventional centralized energy systems in buildings. In this context, cogeneration systems and solar technologies (PV, thermal) offer an opportunity to meet the building energy demand from more sustainable sources. The objective of this research is to:

Develop a modeling framework to optimize the building energy performance by integrating cogeneration, solar and utility systems by considering the life cycle environmental impacts and economical implications to meet the electrical, heating, and cooling demand.

Work plan

Environmental life cycle assessment (LCA): is the investigation and evaluation of the environmental impacts of a given product or service caused or necessitated by its existence. LCA covers direct and indirect emissions as well as other burdens from full energy system. Life-Cycle Cost Analysis (LCCA): An Economic Evaluation method that takes into account all costs of acquiring, owning, and disposing of a building energy system.
Optimization methods: Dynamic multi-objective optimization modeling
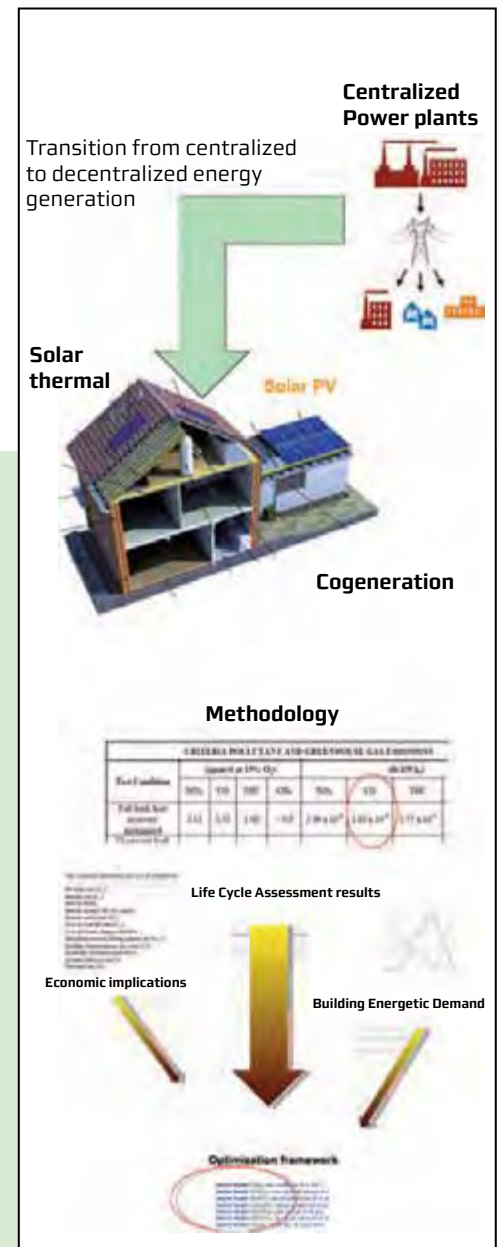
Results

Development of a life cycle optimization modelling framework for combined cogeneration, solar and conventional building energy systems, considering both economic and environmental objectives
Evaluating the ecological and economical combination of solar and cogeneration systems to address the office buildings energy demands
Com o apoio / with support of: LOGOTIPOS
Optimizing the Environmental/economical performance of such energy systems by employing multi-objective optimization techniques;
Exploring the conditions of the improvement of such a system for standalone applications;
Assessing the tradeoffs between implementing cost-effective operation versus strategies that could result in lower environmental impacts.

Transition from centralized to decentralized energy generation

Centralized Power plants

Solar thermal

Solar PV

Cogeneration

Methodology

Life Cycle Assessment results

Economic implications

Building Energetic Demand

Optimization framework

The Influence of Urban Dynamics on Economic Growth: Impact on energy consumption

Sustainable Energy Systems PhD

IST-UTL

Background: **MSc. Physics Engineering, IST-UTL, Portugal**

Portugal

Starting Year: **2007 / 2008**

Supervisors: **Tiago Domingos (IST-UTL);, John Fernandez (MIT)**

Ana Gonçalves

Objectives

Study in which way is urbanization beneficial to a region/country, in terms of economic growth and energy use. This implies: understand the trends of urbanization and create projections of it for the future and create a model that describes the dynamics between city size and its development

Work plan

This work will be divided into three main parts:

Make an econometric study to find what influences urbanization and in which way. Usage of a time-series method with a data set of more than 100 countries.

Use a macroeconomic model with the inputs of labor (L), capital (K) and energy use (U) applied to cities in which the variables will be influenced by the city size (total population).

Create a single dynamic model of economic growth and energy consumption in a country using the two parts mentioned above

Results

In the analysis made to study the relation between urbanization and economic growth (measured through GDP) was modeled using the following equation:

The results in fig. 1 show us a clear difference between more and less developed countries. In the first, the parameters are more concentrated. However there is not a clear pattern in this results leading us to further analysis which will include the time dependency.

To validate the use of empirical works found in the literature to the portuguese context the relations found were tested with portuguese data for different years. Zipf's law results (table I) show that the law holds for the latest years, but only if we don't consider the 5 largest cities. Urban scaling laws (table II) have also been verified with R2 around 0,8 and 0,9.
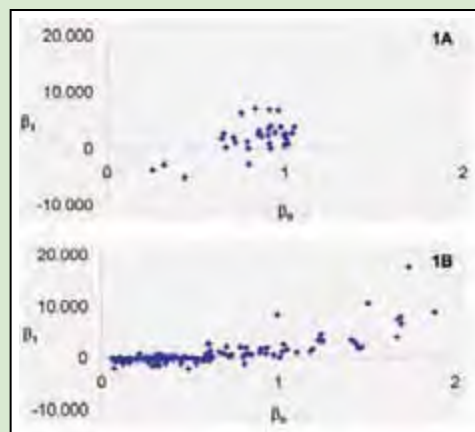
$$Urb = \frac{\eta_0 GDP}{\eta + GDP}$$

Fig.1 – Parameters obtained in the study for A. more developed countries; B. less developed countries

Table I – Coefficients of the Pareto distribution for Portugal

Year		
1991	1,20	1,11
1993	1,20	1,10
1995	1,19	1,09
1997	1,18	1,08
1999	1,17	1,07
2001	1,16	1,06
2003	1,16	1,05
2005	1,15	1,04
2007	1,14	1,03
2009	1,14	1,02

Table II – Electricity and revenue elasticities of urban scaling laws for Portugal

Year	energy	income
1994	1,16	N.d.
1995	1,16	N.d.
1996	1,16	N.d.
1997	1,15	N.d.
1998	1,15	N.d.
1999	1,15	N.d.
2000	1,14	N.d.
2001	1,13	N.d.
2002	1,12	N.d.
2003	1,12	N.d.
2004	1,12	1,12
2005	1,12	1,13
2006	1,13	1,13
2007	1,13	1,13

Methodology for energy sustainability assessment and planning at the local level

Sustainable Energy Systems PhD

FEUP

Background: **Msc. in Land Use and Environmental Planning,**

Bsc. Environmental Engineering FCTUNL, Portugal

Portugal

Starting Year: **2007 / 2008**

Supervisor: **Vítor Leal, (FEUP)**

Research team: **Filipa Carlos, Gustavo Souza, Maria Kapsalaki, Pedro Silva, Reza Fazeli**

Ana Neves

Objectives

1 ▶ To identify a set of local energy sustainability indicators and to develop methods for computing the indicators;

2 ▶ To develop an energy planning decision support methodology based on the combination of energy modelling with multi-criteria evaluation that will deliver to the local decision-maker the best set of technical actions to be implemented in order to achieve the objectives defined..

Work plan

The PhD work plan encompasses the following tasks:

1 ▶ Identification of relevant information and characterization of the state of the art;

2 ▶ Identification of the relevant energy-related indicators for sustainability and development of methods to compute the indicators;

3 ▶ Structuring of the decision problem, including the identification of the objectives and the evaluation criteria, and the analysis and selection of the energy management actions;

4 ▶ Evaluation of the impacts of the actions in terms of each of the evaluation criteria;

5 ▶ Structuring the decision support methodology for local sustainable energy planning, through the combination of energy modelling with multi-criteria evaluation;

6 ▶ Application of the methodology to case studies;

7 ▶ Writing the thesis.

Table 1 – The local energy sustainability indicators.

State Indicators

GHG emissions from energy use, per capita and per unit of GDP, and by sector
Primary energy use per capita
Final energy use per sector
Ratio of local renewables production to local consumption of energy and electricity
Industrial energy intensity
Agricultural energy intensity
Service/commercial energy intensity
Household energy intensity
Transport energy intensity
Public transit ridership
Emissions of air pollutants from road transport activities
Renewable energy share in energy and electricity
Share of household income spent on fuel and electricity
Ratio of green energy jobs to population

Policy Indicators

Locally available finance schemes for energy efficiency and renewable energy
Awareness raising campaigns on energy issues
Public participation in energy-related policy-making
Local Authority advice and assistance to the citizens on energy issues

Figure 1 – The disaggregated actions that were aggregated into meta-actions and will be included in the methodology.

Results

Achieved: **Framework of local sustainability indicators** (table 1) → through a literature review and testing with local authorities (Porto, AREANATejo and City of Boston);**Technical actions for local energy planning** (figure 1)→ through an extended literature review
Ongoing: **Structuring of the decision problem: definition of objectives covering the sustainable development dimensions (economic, environmental and social), evaluation criteria and actions** → definition through extended literature review.
Expected: **The decision support methodology for local sustainable energy planning and its application to case studies.**

Thermal energy storage control for space heating systems based on ground source heat pump

Sustainable Energy Systems PhD
University of Coimbra
Background: **M.Sc., Systems and Automation, University of Coimbra**
Portugal
Starting Year: **2007 / 2008**
Supervisor: **Aníbal Traça de Almeida, Manuel Carlos Gameiro (UC)**
Research team: **V.Chu, A.T. Pereira, A. Pimentel, M. Santos**

Anabela Carvalho

Objectives

ANALYZE THE FEASIBILITY AND OPTIMIZE THE IMPLEMENTATION OF A LATENT HEAT STORAGE SYSTEM (LHS) COUPLED TO A GROUND SOURCE HEAT PUMP (GSHP) IN AN EXISTING BUILDING IN COIMBRA AND EVALUATE THEIR POTENTIAL FOR BETTER MANAGEMENT OF THE LOAD PROFILE AND LARGE-SCALE INTEGRATION OF INTERMITTENT RENEWABLE ENERGY SOURCES.

Work plan

TO CARRY OUT THIS RESEARCH WORK, THE FOLLOWING TASKS WILL BE DEVELOPED:

▶ - COMPARATIVE ANALYSIS OF PCM TECHNOLOGIES
▶ - DEVELOPMENT OF A MATHEMATICAL MODEL OF THE STORAGE SYSTEM COUPLED TO A GSHP AND ITS VALIDATION;
▶ - DEVELOPMENT OF A MONITORING AND CONTROL SYSTEM AND DEFINITION THE ALGORITHM CONTROL IN A DYNAMIC ELECTRICITY PRICING CONTEXT;
▶ - DESIGN OF THE STORAGE UNIT TAKING INTO ACCOUNT THE CHARACTERISTICS OF THE SELECTED PHASE CHANGE MATERIAL, DEFINITION OF THE THERMAL REQUIREMENTS OF THE BUILDING AND THE VARIATION IN ELECTRICITY PRICES;
▶ - EXPERIMENTAL TESTS AND MONITORING DURING THE HEATING PERIOD TO OPTIMIZE THE OPERATION SYSTEM AND EVALUATE SYSTEM PERFORMANCE;
▶ - TECHNO-ECONOMIC FEASIBILITY ANALYSIS OF THE SYSTEM AND ASSESSMENT OF ITS POTENTIAL FOR THE INTEGRATION OF INTERMITTENT RENEWABLE ENERGY SOURCES.

Results

IT IS EXPECTED THAT THE COMBINATION OF THESE TECHNOLOGIES WILL BE A HIGHLY EFFICIENT SOLUTION FOR SPACE CONDITIONING WITH HIGH POTENTIAL APPLICATION IN BUILDINGS IN PORTUGAL REDUCING THE USE OF FOSSIL FUELS.
THIS WILL ALSO CONTRIBUTE TO THE INTEGRATION OF INTERMITTENT RENEWABLE ENERGY, STORING THIS ENERGY WHEN PRODUCED TO BE CONSUMED WHEN NECESSARY, THEREBY CONTRIBUTING TO A HIGHER ELECTRIC SYSTEM EFFICIENCY.

Study of a new solar cell technology to boost photovoltaic penetration in the energy market

Sustainable Energy Systems PhD
FCUL
Background: **MSc, Physics and Technology Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisor: **João Serra [FCUL]**

André Augusto

Objectives

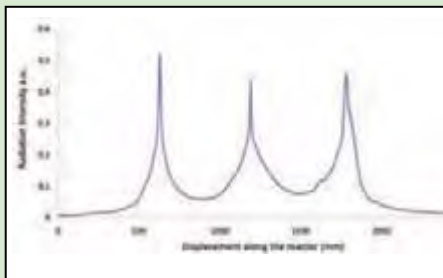The sun is the biggest energy source available on Earth.

The main factor against photovoltaic systems dissemination is cost!

The development of low cost photovoltaic technologies can dramatically boost the penetration of photovoltaics in the energy generation mix.

Work plan

1. Design and manufacturing the reactor ✓
2. Computational fluid dynamics (CFD) analysis of the gas flow inside the reactor (convection flow cells) ✓
3. Ribbon production and recrystallization ✓ ✗
4. Ribbon characterization ✗ (collaboration with Buonassisi Group from MIT)
5. Production of solar cells with the ribbons ✗
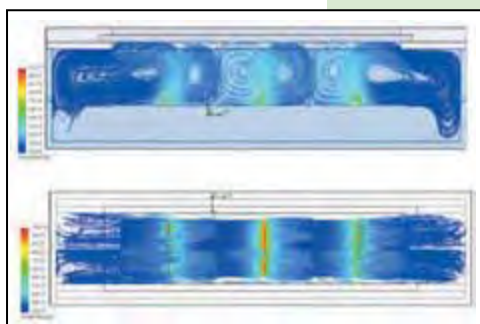6. Perform a life cycle analysis of the SDS process. ✗

Results

Intensity profile in the CVD setup

The SDS Process

Deposition by CVD

substrate

Separation

as-grown nanocrystalline Si ribbon

ZMR

multicrystalline Si ribbon
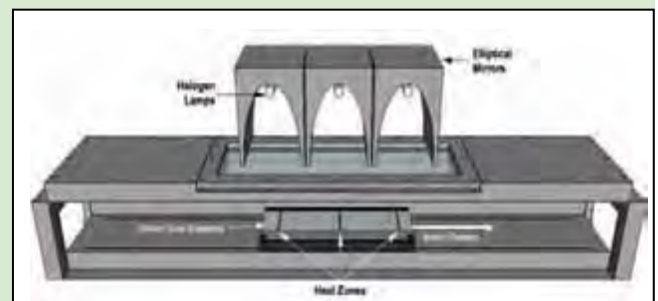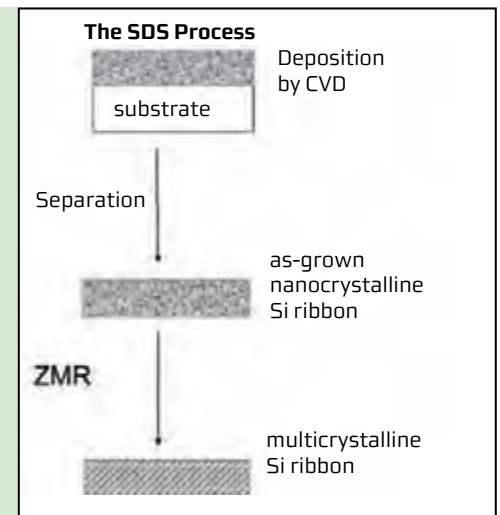
The SDS setup

CFD simulations

Ribbon growth

Supply and Demand Dynamics in Energy Systems Modeling

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc., Technological Physics Engineering, IST-UTL**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Paulo Ferrão (IST-UTL), Carlos Silva (IST-UTL)**
Research team: **V.Chu, A.T. Pereira, A. Pimentel, M. Santos**

André Pina

Objectives

The main objective of this work is to include resource and demand dynamics (such as the ones shown in Fig. 1) in long- and medium-term energy models in order to increase the robustness of the solutions proposed by these models. This will have an impact on investment decisions of new generation capacity and the design of energy policies (energy efficiency, electric vehicles, others).

Work plan

The main task is the development of a new integrated modeling framework that is capable of capturing energy supply and demand dynamics for medium/long-term evolution scenarios of energy systems. This implies working on two temporal scales:

▶ Medium/long-term for the evolution of energy demand, energy policies and investment in new generation capacity;

▶ Short-term for analyzing the match (or mismatch) between supply and demand with high temporal resolution (hourly or less).

TIMES models of São Miguel and Flores have been built to analyze the investment in new generation capacity in those islands for different electricity demand scenarios. A MATLAB model is currently being developed to deal with the short-term dynamics of energy storage systems, electric vehicles and electrification scenarios.

Results

The methodology combining the medium- and short-term approaches (Fig. 2) was tested for São Miguel to analyze the investment in new generation capacity. The comparison with the results obtained when using just the TIMES model showed that by using just a medium/long-term model the penetration of renewable electricity can be overestimated (Fig.3 and Fig. 4). This can lead to early investments that might end up being not economically optimal, or even viable.
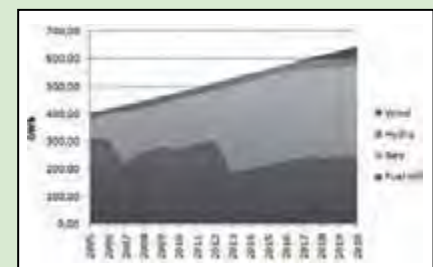
The use of this combined approach can then reduce the risk of new investments and promote a clear understanding of the real impact of new energy policies.
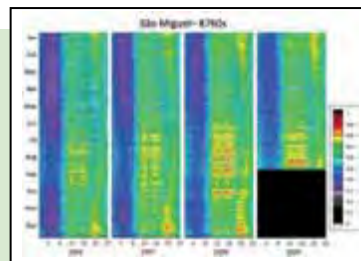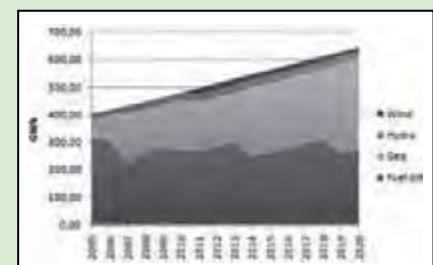

Fig. 1. Electricity demand variation in São Miguel
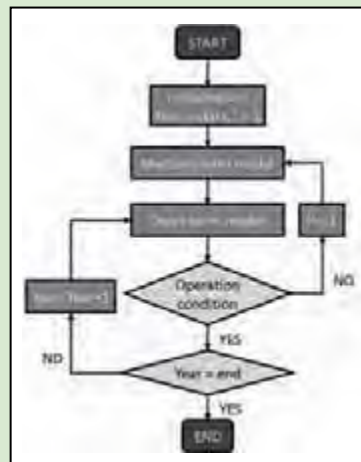
Fig. 2. Integrated modeling framework

Fig. 3. Fig 3: Electricity production scenario using TIMES

Fig. 4. Electricity production scenario using the developed framework

Smart Grids – Electricity Networks of the Future

Sustainable Energy Systems PhD
IST-UTL
Background: **Electrical Engineering**
Portugal
Starting Year: **2009 / 2010**
Supervisor: **João Costa Freire (IST-UTL)**

**António Abreu**

Objectives

Developing algorithms and innovative technical solutions to reduce primary energy consumption through lower power losses of electrical transmission and
distribution systems.

Work plan

Recent experiments shown that current Reactive Power Compensation Methods are not suitable for Sustainable Energy Systems. Therefore, a New Efficiency Definition is required, when considering reactive components in the Electrical Transmission System. This paper presents a new theory, attending to the Power Losses along the distribution process, regarding the minimum of the Input Power Flow and the lowest CO_2 emissions indicators. Also, two special mathematical methods are presented. These methods were designed to solve the Optimization Problem and to find the best solution which provides less losses and the minimum of the Natural Resources consumption.

Results

A new mathematic definition of efficiency is proposed, regarding the Sustainable Energy concept. Also, a Predictor-Corrector Abacus was developed and a Optimization Theorem for High Power /High Voltage Power Lines was created. Algorithms for AVAC Systems were improved and a Prototype of a Reactive Power Injected was invented.
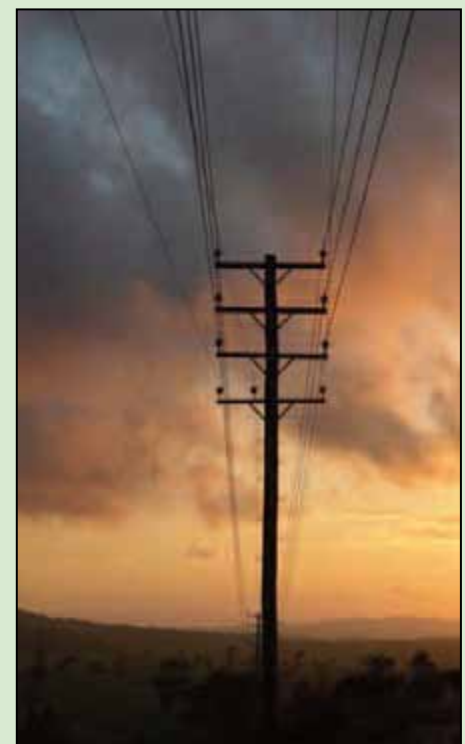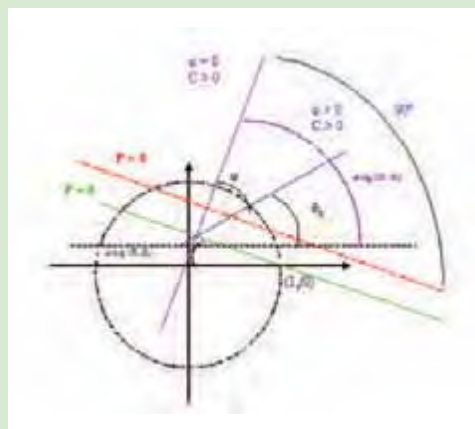
Defining new control and management solutions for security assessment and preventive control in transmission grids with large scale integration of wind generation

Sustainable Energy Systems PhD
FEUP
Background: **MSc Electrical Engineering, FEUP, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **João Peças Lopes and Manuel Matos (FEUP)**

António Santos

Introduction:

In case of low voltages due to short-circuits in the electrical grids, large number of Wind Farms can be disconnected from the grid. This power unbalance may lead to overloads in transmission lines, with load curtailment or even collapse in some areas. These problems reach great importance since wind power is having an important role in electricity production.

Objectives

The main objective of this thesis is to develop a tool that can assess the risk of losing wind generation due to short circuits in the Portuguese electrical network. The impact of those short circuits will be evaluated at different buses where can be connected wind generators with or without Fault Ride Through [FRT] capability.

With the results provided after those simulations, System Operators will develop preventive control solutions (wind generation curtailment, increase of reserve levels, scheduling, generation re-dispatch, etc.) in order to avoid disturbances in the network.
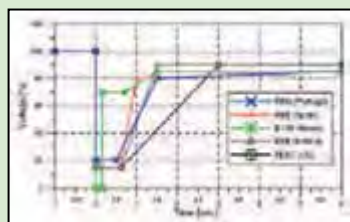
Results

In figure 1, it's possible to analyze the impact of a short circuit in a determined bus. The voltage will drop below 0,8 pu at all neighboring buses after the short circuit simulation (figure 2). One of those buses have wind farms connected and this voltage drop will active their minimum voltage protection. In this case, the disturbance will disconnect around 215 MW of wind power generation.

After one more short circuit simulation in another bus (figure 3), the voltage after the fault at a wind farm bus was above the minimum voltage protection (defined as 0,8 pu) (figure 4). Regarding this result, and if a short circuit occur in the related bus, the System Operator could keep connected the wind farm avoiding the loss of 56 MW of wind power generation. The results provided from this simulation tool will increase the security of electrical systems with large amount of wind generators.
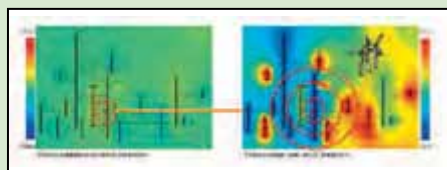
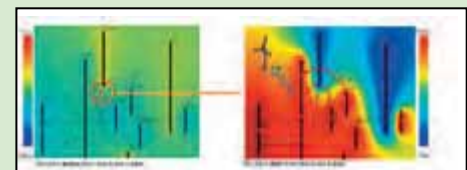**Portuguese installed Wind Power**

Fault Ride Through capability:

Simulation results:

Fig.1 Short circuit simulation with the loss of large wind power generation

Fig.2 Voltages drops after short circuit simulation

Fig.3 Short circuit simulation without the loss of wind power generation

Fig.4 Voltages drops after short circuit simulation

An Integrated Assessment Methodology applied to Brazilian bioethanol case

Sustainable Energy Systems PhD
University of Coimbra
Background: **MSc. Economics, Faculty of Economics, University of Coimbra, Portugal**
Starting Year: **2008 / 2009**
Supervisor: **Fausto Freire and Carlos Henggeler Antunes (UC)**

Ariovaldo Carvalho

Objectives

The purpose of this PhD thesis is to apply an Integrated Assessment Methodology to the Brazilian bioethanol case, making use of a systemic combination of multi-objective optimization and uncertainty/robustness analysis over the supply chain of this product. The aim is to assess the trade-offs among economic, social, energetic and environmental objectives in the overall bioethanol system in a prospective way capable of producing sound recommendations to planners while dealing with the sources of uncertainty associated with this system.

Work plan

Construct an economic-social-environmental-energetic interval multi-objective macro model for the Brazilian economy considering current and prospective scenarios;
Construct an interval multi-objective micro model over the Life Cycle (LC) of the Brazilian bioethanol system, considering economic, social, environmental and energetic aspects for current and prospective scenarios;
Integrate both previous models through a hybrid approach to assess the life cycle of Greenhouse Gas (GHG) emissions, fossil energy requirements, employment and economic costs accounting for uncertainty and variability.

Expected Outcomes

Generate feasible ranges for the LC GHG emissions and fossil energy requirements from the combination of different technologies, scenarios and conditions of the Brazilian bioethanol system;
Identify the best compromise solutions for maximization of the energy balance, economic and employment levels, as well as minimize the GHG emissions;
An integrated assessment of the use of bioethanol in Portugal replacing gasoline in the transportation sector..
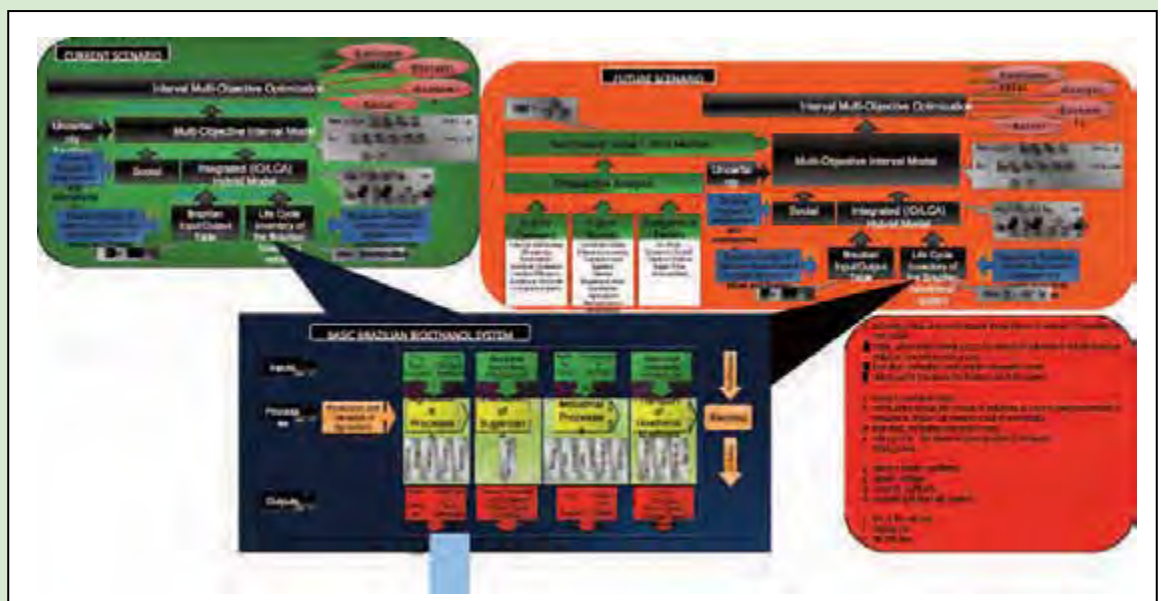
Economic, Energy and Environmental Impacts of Plug-in vehicles in the Electric Utility Systems

Sustainable Energy Systems PhD

IST-UTL

Background: **Master in Business Administration, Faculty of Economics, UNL, Portugal**

Starting Year: **2007 / 2008**

Supervisors: **: Tiago Farias (IST-UTL), Jorge Esteves (ISEL)**

Cristina Camus

Objectives

To study the impacts of the introduction of electric vehicles on the Portuguese electric system in terms of
Primary energy needs, for transportation and electricity sectors
Local and global emissions impacts
Energy costs and wholesale and retail prices of electricity

Work plan

The simulation methodology used encompasses the following main steps (Fig.1):
Study today's electric system characteristics and establish scenarios for expected evolution of electricity production mix.
Analyse the different mobility patterns and energy needs to establish the energy requirements for plug-in vehicles
Analyse the electricity market behaviour with a market simulator and generate a supply curve per technology for expected power installed.
Evaluate Electric vehicles penetration scenarios/ recharging profiles in the electric power system in terms of energy efficiency gains, environmental advantages accounts (local and global emissions) and economic impacts (Fig. 2).
Two case studies - the Portugal Mainland and St Miguel Island in Azores

Results

Preliminary results confirm that:

mass introduction of Plug-In vehicles in an electric system with more than 50% of renewable sources show reductions in energy consumption, fossil fuels use and CO_2 emissions of the transportation and electricity production sectors together up to 13%, 21% and 17% respectively for a scenario of 3 Million EVs for 2020 relatively of BAU scenario for 2020 (Fig. 3).

Off-peak recharge level the consumption profile and leads to an increase in the wholesale prices at the valley hours, while competing with low priced demand bids. These facts could offer good opportunities for base load technologies.

Fig. 1 - Simulation methodology. Main inputs, intermediate data and main outputs
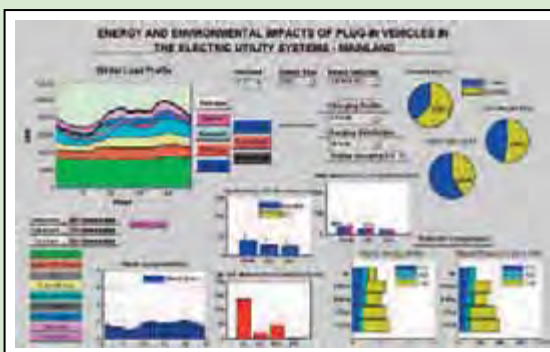
Fig. 2 - Example of an "on line" output for Portugal – mainland, with a scenario of 1M EVs and an off-peak recharge profile for year 2020
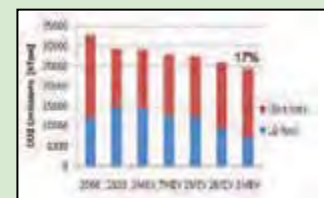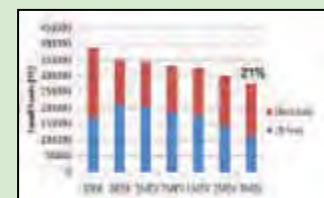
Fig. 3 - Impacts in primary energy consumption, fossil fuels use and CO_2 emissions reductions for 2020 with different scenarios of EVs penetration.

The Energy Box: Locally Automated Control of Residential Energy Usage

Sustainable Energy Systems PhD
MIT
Supervisors: **Richard Larson (MIT), Jim Kirtley (MIT), Steve Graves, (MIT**
Research team: **Woei Ling Leow (MIT), Joana Abreu (IST),**
Carlos Alberto Henggeler de Carvalho Antunes (UC), and others

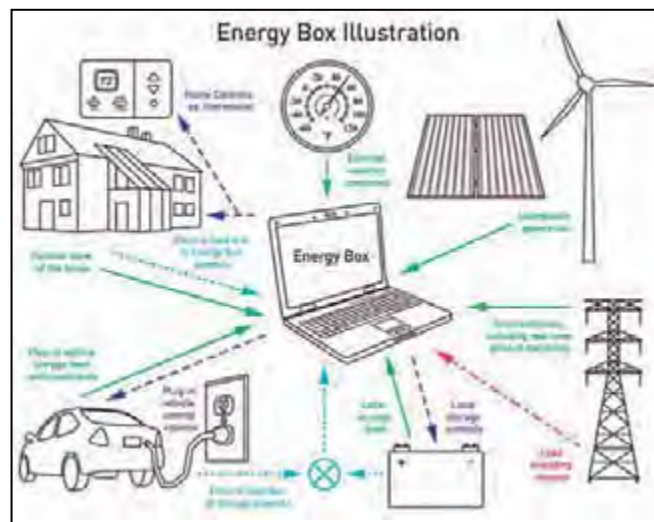**Daniel Livengood**

Objectives

Create a single-home energy management system simulation to test benefits of coordinated control of electric appliances under uncertainties of weather-dependent distributed generation and time-varying electricity prices while balancing homeowners' desired comfort and cost preferences

Beyond the PhD: how will the aggregation of large numbers of automated residential energy management systems affect the electric grid? (part of Energy Box v2.0 below)

Work plan

Energy Box beta - Completed an initial simulation to test hypothesis of coordinated control improving decision-making under uncertainty (initial results in table below)

Energy Box v1.0 - Currently building a more detailed Energy Box model that compares coordinated control of appliances under uncertainty via paired and sequential decision-making methods. This model is in the final stages of development and testing, with results pending.

Energy Box v2.0 - The 'Learning and Adaptive' Energy Box will be developed in collaboration with others on the Research Team listed above through the FCT-funded Energy Box project

Energy Box Illustration

Results

Energy Box beta - See the table and the paper referenced below

Energy Box v1.0 - Full results are coming soon and will be presented at the dissertation defense of Daniel Livengood (date to be determined)

Corresponding paper:

Livengood and Larson: The Energy Box: Locally Automated Optimal Control of Residential Electricity Usage Service Science 1(1), pp. 1-16, © 2009 SSG

	Individual versus Coordinated Control of controllable thermostat, electricity storage, and wind turbine	Total Cost ($)	Cost Reduction Compared with Baseline	Number of Hours in tolerably cool indoor temperature range	Number of Hours in comfortable indoor temperature range	Number of Hours in tolerably warm indoor temperature range	Percent of wind energy used
Uncontrolled		182	-	12	708	-	n/a
Individual Control		120	34%	5	618	97	38%
Coordinated Control		120	34%	13	641	66	59%

Analyzing Urban Resource Consumption

Sustainable Energy Systems PhD
IST-UTL
Background: **Bsc. in Physics, Swiss Federal Institute of Technology (ETH Zurich), Switzerland**
Switzerland
Starting Year: **2008 / 2009**
Supervisors: **Paulo Ferrão (IST-UTL), John Fernandez (MIT), Inês Azevedo (CMU)**

Daniel Wiesmann

Objectives

Parallel to the exponential growth of the worldwide population, many other quantifiable aspects of the human condition have also changed dramatically over the last century. Two important aspects of that change are the increase in resource consumption and the increase in urbanization. My main interests are to study the relationship that connects both of these phenomena. To design sustainable futures in an increasingly urbanized world, understanding the drivers of resource consumption in urban areas is crucial.

The goal of my PhD is to assess resource consumption in urban areas from different perspectives in a series of studies. The methods used are a combination of statistics, spatial analysis and for outreach also geovisualization. Some example of visualizations are shown in Figures 1-3.

Work plan

After successfully completing the first year of classes at IST in 2009, I spent a year as a visiting student at MIT. During that time I worked on a number of projects, amongst which there are an econometric study of electricity consumption in Portuguese households and a land cover model of San José in Costa Rica. In the next phase of my research, I will participate in the ResiSt Project at IST, studying the resilience of Lisbon in terms of resource flows.

Results

Residential Electricity Consumption in Portugal

An econometric study of electricity consumption in Portuguese households has already been completed and a paper has been submitted to a journal. In the paper we studied the relationship of dwelling and household characteristics and electricity consumption in Portuguese households. The dwelling characteristics were found to have significant influence on residential electricity consumption, as can be seen in Table 1.

Land Cover Change Induced Greenhouse Gas Emissions in Costa Rica

Together with researchers at MIT and the University of Costa Rica, a land cover change analysis for the metropolitan area of San José has been developed. The model was developed using multinomial logistic regression. The resulting map is shown in Figure 2. These results will be used to calculate land cover change induced greenhouse gas emissions for the metropolitan area of San José.

Fig 1: Visualization of data of global cities

Fig 2: Land cover map of San José in Costa Rica

Table 1: Estimated coefficients from econometric models

Fig 2: Perspective on 3D model of Lisbon in Google Earth

Quantifying Resource Flows in Cities

Sustainable Energy Systems PhD
MIT Building Technology
Supervisor: **John Fernandez (MIT)**
Research team: **Daniel Wiesmann, Karen Welling**

David Quinn

Objectives

To developing standardized methodologies for analyzing cities:

➢ using script based approaches for analyzing spatial data

➢ packaging scripts as plugins for GIS (ArcGIS and QGIS)

➢ visualizing results in dynamic interactive tools

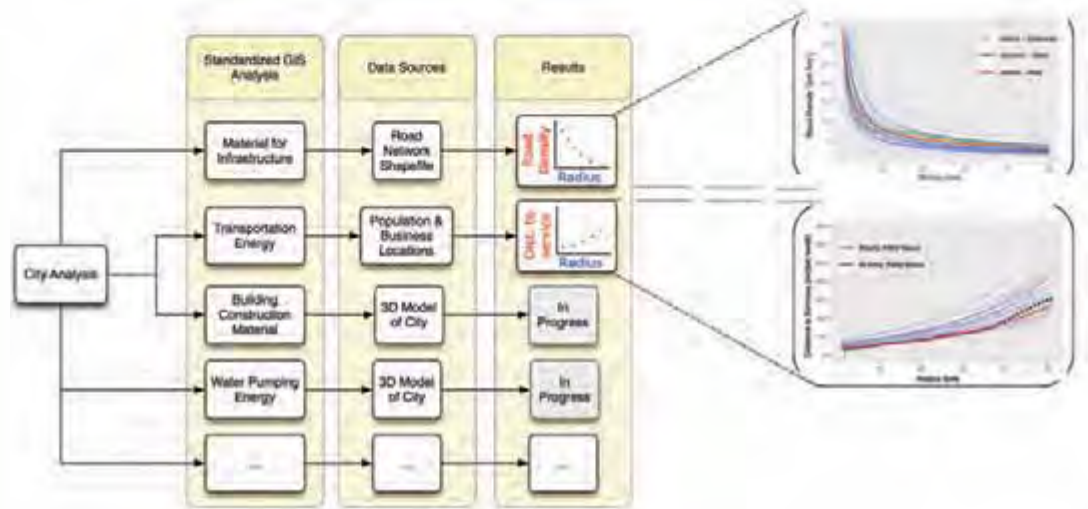## Work plan

Develop analysis script

Make plugin for repeatable analysis

Visualize results dynamically

Results

Integrated Communication Systems for Large Scale Distributed Energy Resources and V2G

Sustainable Energy Systems PhD
FEUP
Background: **MSc. Electrical and Computer Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Peças Lopes (FEUP), José Ruela (FEUP)**

David Rua

Objectives

The main objective of this thesis is to enable the integration of Distributed Energy Resources (DER) and Electric Vehicles accounting for their information flow requirements, ensuring a sustainable deployment in current and future visions of the electric industry.

Work plan

▶ Characterization and modeling of the integration of EVs and large scale distributed energy resources in the electric network and understanding the roles and scenarios under which they are likely to operate.

▶ Framing of DERs and EVs from the point of view of standards, defining a uniform approach towards their integration. Ex. IEC, IEEE, EPRI, ISO, etc.

▶ Identification and characterization of the information flows involving DERs and EVs under the operational requirements of the electric network.

▶ Derive a functional specification for the communications system according to the characterization of the whole system, including the electric system behavior and the control of the system.

▶ Simulation of the functional model specified including the electric system behavior and the control of the system, using existing and custom tailored tools.

Results

▶ Characterization of DER and EV integration under different operating scenarios.

▶ Applicable standardized technologies and solutions.

▶ Communications architecture for control and monitoring of microgrids.

▶ Impact assessment of communications performance in monitoring and control activities in microgrids.
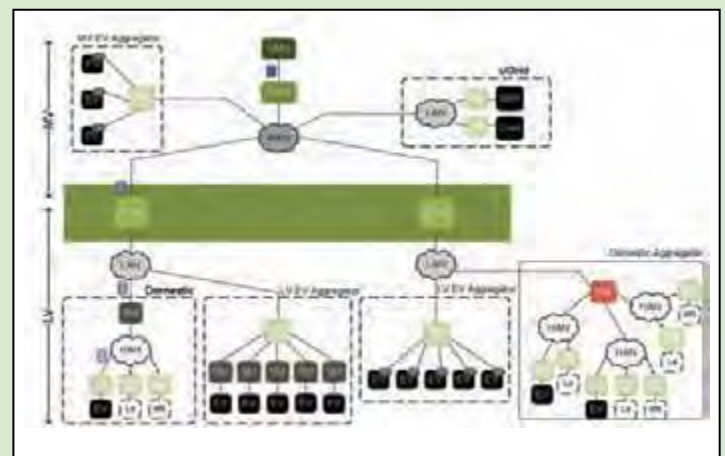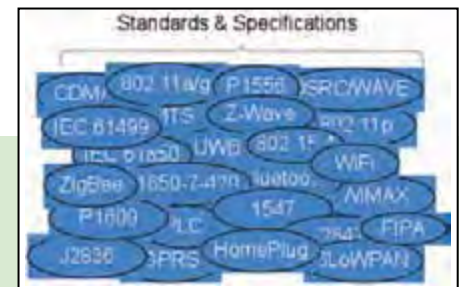
Sustainable demand and supply for heating and electricity in residential buildings on Corvo, Azores

Sustainable Energy Systems PhD
FCUL
Background: **MSc. Environmental and Energy Engineering, Faculty of Sciences, University of Lisbon, Portugal**
Portugal
Starting Year: **2009 / 2010**
Supervisor: **António Vallera [FCUL]**

Diana Neves

Objectives

- Study the improvement of living standards and of sustainability of this specific and isolated micro-community

- Make a demand and supply energy analysis taking into account the abundance of local renewable energy resources

- Make a contribution for a sustainability and welfare action plan to be applied to Corvo to help fixing the population

- Possible extrapolation of the methodology to other micro-communities

Work plan

I - Get to know Corvo:
- Domestic habits, economic indicators, weather conditions, type of construction, present means of energy supply, etc.
- Obtain and improve data on renewable sources in Corvo

II - Analyze the patterns of heating and electricity demand and which parameters most influence them → create a dynamic model

III - Review literature on energy solutions for isolated micro-communities and propose ways to rationalize the demand → see viability of district heating and test demand side management

IV - Optimize the energy mix, by increasing renewable energies and low carbon technologies share (on season and daily basis)

Control Strategies for Smart Distribution Grids under Emergency Operation using Agent-based Technology

Sustainable Energy Systems PhD
IST-UTL
Background: **Msc. in Electrical Engineering,**
Federal University of Santa Catarina, Brazil
Brazil
Starting Year: **2008 / 2009**
Supervisor: **João Peças Lopes (FEUP)**
Research team: **INESC Porto**

Diego Issicaba

Objectives

Development of decentralized control solutions necessary to meet a grid with self-healing capabilities taking advantage of the large scale integration of Distributed Energy Resources (DERs) and Electric Vehicles (EVs).

↳ The control solutions will be utilized to create an **agent-based architecture** tuned for Smart Grid applications.

Work plan

▶ Characterization and modeling of DERs and EVs under different operating scenarios (scope and roles).
▶ Development of decentralized self-healing control strategies considering the large scale integration of DERs and EVs.
▶ Design of an agent-based system using the control strategies — agents are assigned to grid entities & components.
▶ Implementation of an agent-based simulation platform to evaluate the control strategies as well as the benefits of integrating active DERs and EVs into the distribution grids operation.
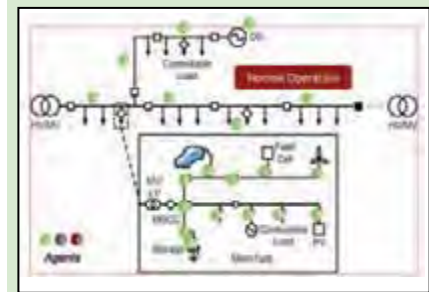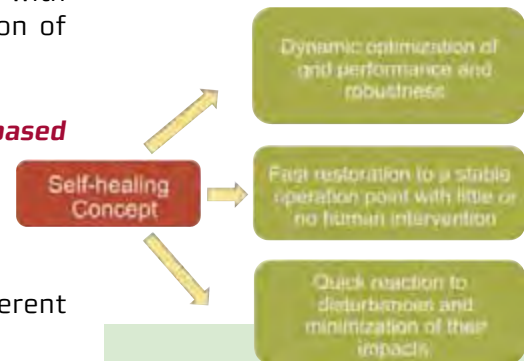
Results

▶ Power systems: Agent-based control strategies to tackle islanding protection, frequency control, restoration and black start.

▶ Engineering: Control architecture tuned for Smart Grid applications.

▶ Tangible product: A simulation platform where decentralized active control schemes can be evaluated.

Patterns of Innovation and Entrepreneurism in the Modern Energy Sector

Sustainable Energy Systems PhD
University of Coimbra
Background: **B.Sc. Computer Engineering, University of Alberta, Canada;**
Masters in Business Administration (MBA), Queen's University, Canada;
Postgraduate Certificate in Environmental Management,
University of Toronto
Canada
Starting Year: **2009 / 2010**
Supervisors: **Pedro Saraiva, Marco Seabra dos Reis (UC)**

**Donald Scott**

Objectives

The Renewable Energy industry is characterized by slow innovation and low rates of adoption in comparison to other, similar industries. This research intends to perform a comparative analysis of the structure, role and interactions of entrepreneurs and institutions, and patterns of innovation between the modern energy sector and other more-established technology-based sectors such as telecommunications and biotechnology. .

Work plan

The study will be based on a combination of quantitative and qualitative analysis, leaning heavily on research streams in diffusion research, entrepreneurism, and the theories and studies developed in the area of Systems of Innovation. A structural comparison of the three industries and a quantitative analysis of indicators of innovation within those industries will be followed by a bibliometric analysis of the key functions within selected sub-sectors, and finally an illustrative case study of firms exhibiting some of the more effective patterns of innovation within the renewable energy industry.

Results

The expected results of this work will be the determination of patterns of innovation in the renewable energy industry, with similarities and differences to those exhibited in other industries. The study intends to present those learnings in the form of a set of recommendations to policy makers and managers that can be used to accelerate the development and commercialization of innovation in this field.to establish a 2D FS sensor array.
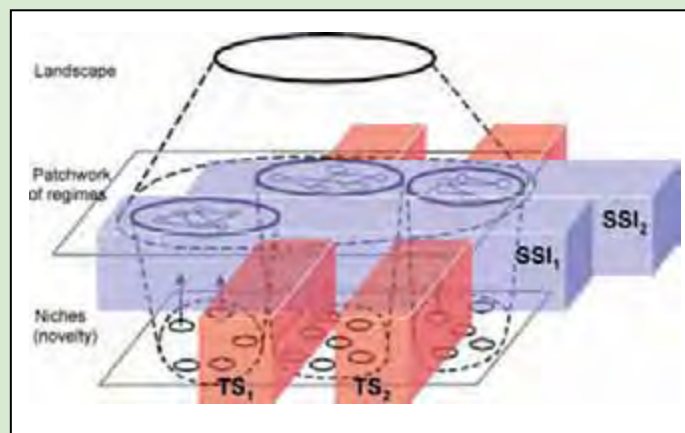
Interrelation between Technological and Sectoral Systems of Innovation Approaches

(Markhard & Truffer)
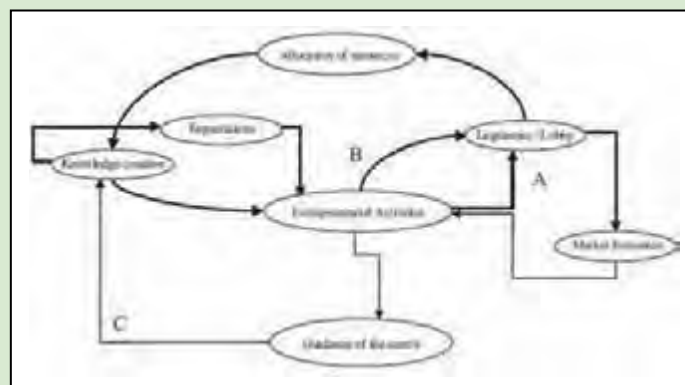
Typical functional interaction within a System of Innovation

(Hekkert, Suurs, Negro, Kuhlmann & Smits)

Multi-Objective Optimization approach for building retrofit strategies

Sustainable Energy Systems PhD
University of Coimbra
Background: **MSc. in Energy Systems Engineering, 2008,**
at K.N. Toosi University, Tehran, Iran.
Iran
Starting Year: **2008 / 2009**
Supervisors: **M.C. Gameiro da Silva,**
L.C. Dias and C. H. Antunes (University of Coimbra)

**Ehsan Asadi**

Building energy facts

- Building sector accounts for about 40% of the total final energy consumption in the EU.
- 29% of total energy consumption in Portugal is due to building sector.
- About 60% electricity in Portugal is consumed in building sector.
- Recently approved National Action Plan for Energy Efficiency.
- Portugal modernization program for improvements of public school buildings.

Objectives

- To provide stakeholders sound information to support the definition of intervention measures aimed at minimizing energy use in the building in a cost effective manner, while satisfying the occupant/owner needs.
- To design and develop Decision Support System based on Multi-Objective optimization tool.

Work plan

I. Selection, characterization and simulation of case studies.
II. Design space definition identifies the appropriate set of alternative measures that are available for the improvement of energy efficiency and indoor environmental quality.
III. Decision model formulation of objective functions
IV. Retrofit Decision Support System

Develop the model and the DSS prototype in MATLAB;
Explore the method application to identify the strengths and weakness of the approach in a real-world setting;
Recommend the best retrofit action package according to the DMs preferences.

2006 Electricity Consumption by Sector in Portugal
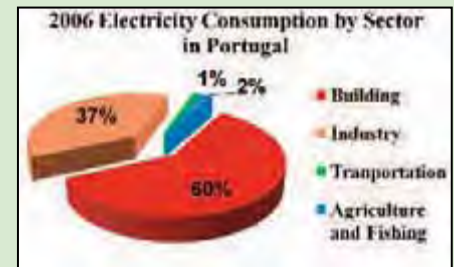
Dom Dinis Secondary School, Photography: Fernando Guerra e Sérgio Guerra

Expected Result

Results

Problem formulation
Objectives:
Z1 = Heating + Cooling + Lighting Energy
Z2 = Retrofit Cost
Example of decision variables

Variable	Description	Units	Lower Bound	Upper Bound
X1	Window type	Single, Double, Triple	0	2
X2	Window Coating	Clear, Low-e	0	1
X3	U-Value	W/m²K	1	7

Next Steps
Develop Indoor comfort objective function;
Incorporate all the more representative retrofit technologies.

Courtesy to C. Brown's work

Extended Life Cycle Assessment of biodiesel from vegetable oils

Sustainable Energy Systems PhD
University of Coimbra
Background: **MSc in Energy and Environmental Management, University of Aveiro, Portugal; Graduate in Environmental Engineering, Agrarian Polytechnic School of Coimbra, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **Fausto Freire (UC)**
Research team: **Fausto Freire (PI), Carlos Henggeler Antunes, Luis Dias**

Érica Castanheira

Objectives
✔ Model and assess the overall environmental impacts of complex and multi-functional biodiesel systems using a life cycle approach.
✔ Extend the standard Life Cycle Assessment (LCA) methodology to address local aspects (e.g., soil and water pollution) associated with land use and land use change (LUC).
✔ Calculation of the overall environmental impacts of biodiesel (from palm oil and soybean) and comparison with fossil diesel displaced.
✔ Integrate multi-criteria decision analysis (MCDA) within the LCA framework to support decision making.
✔ Identify the major sources of uncertainty and quantify the robustness of environmental assessment results.

Work in progress

1. A review of LCA studies on palm oil biodiesel.
2. A life cycle modeling and inventory of palm oil biodiesel (Figure).
3. Scenario analysis to investigate alternative LUC cases, N-fertilizers and multi-functionality approaches within the LCA framework.
4. Assessment of Global warming potential and other environmental impact categories.
5. The Directive 2009/28/EC on the promotion of the use of energy from renewable sources and the Commission Decision on guidelines for the calculation of land carbon stocks have been adopted for GHG emissions calculations (Figure).
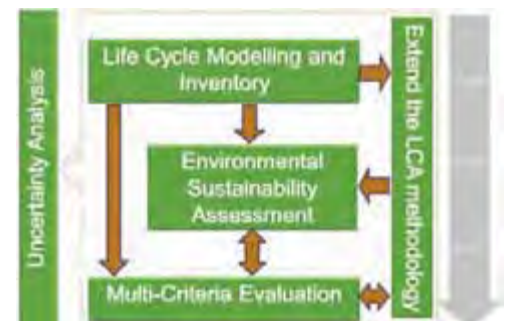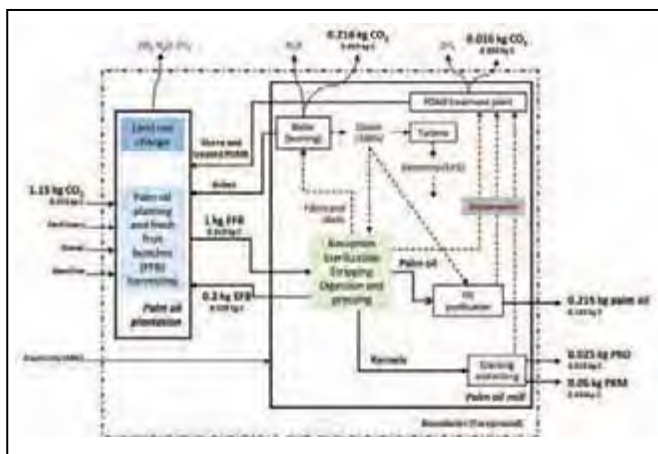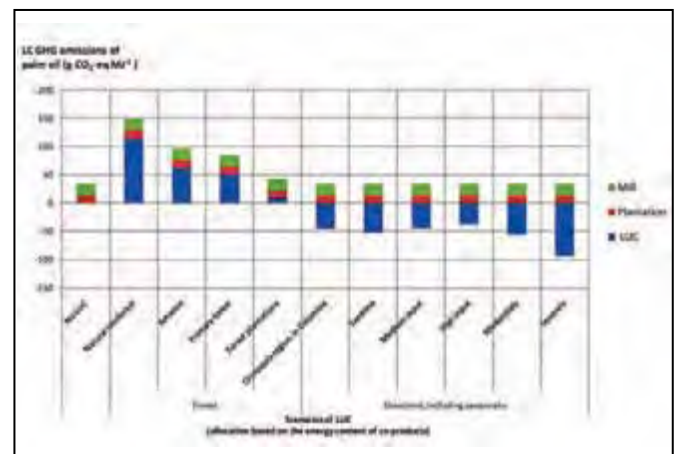
Future work
1. The life cycle modeling of biodiesel from soybean is the next step.

Work plan

Palm oil production chain and system boundaries

LC GHG emissions of palm oil

Comparison of Building Design Scenarios Through Performance Simulation and Optimization Techniques

Sustainable Energy Systems PhD
University of Coimbra
Background: **Lic. Architecture, FAUTL, Portugal; Postgraduate certificates in Urban Design (ISCTE) and in Occupational Safety and Hygiene (ESTG/IPVC), Portugal**

Starting Year: **2009 / 2010**
Supervisors: **Prof. Jan Hensen (University of Technology Eindhoven – UT/e) and Prof. Adélio Gaspar (UC)**

**Eugénio Rodrigues**

Objectives

The motivation to carry the forgoing research is to assist architects into support their decision-making based on energy efficiency when facing the need to choose between different design variations. For this it would be carried out the development of a prototype interface tool to compare these variations. Mathematical algorithms will be implemented in a specific engine prototype to allow the user, in the interface prototype, to generate for each scenario an optimal version of it.

Work plan

The methodology to carry out the research will be to survey the architectural practice trough inquiries, literature review on architectural design process and optimization algorithms, compare different performance-based simulation engines and see which one is more suitable according to the optimization algorithms and information to provide, elaborate the system architecture according to interoperability and language code, validate the mathematical algorithms implemented and the usability of the prototype interface tool, and test interface prototype usability.

Results

Architects methodologies are heuristic and empirical by nature and they have the need to compare different design scenarios. Current tools do comparison of design reference variation or single-zone of high detailed constructive solutions. In the early design stage, architects have more doubts then certainties. Understanding how different design solutions can be compared and how can they be communicated to the practitioners is something still to comprise by researchers. This project thesis proposal tries to fill this void.
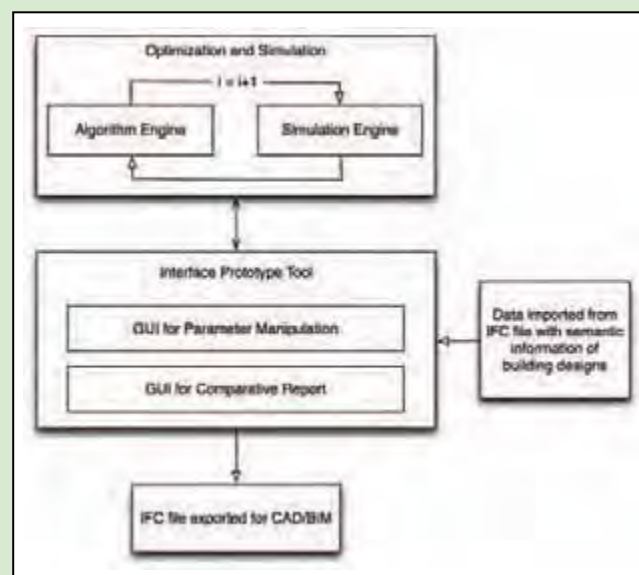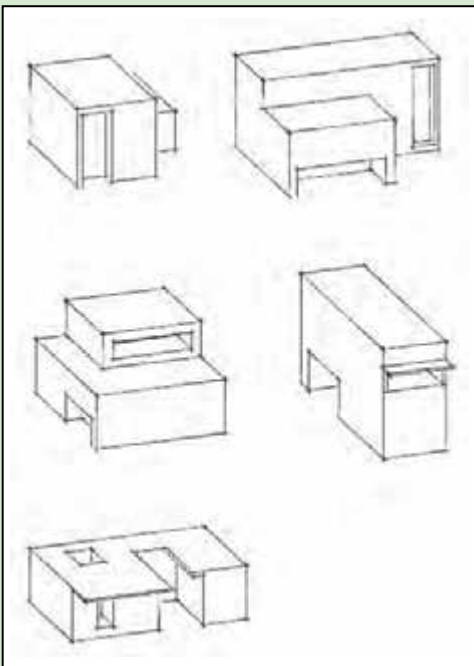
Development of photovoltaic systems with concentration

Sustainable Energy Systems PhD
FEUP
Background:**MSc. Physics Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisors: **Miguel Centeno Brito (FCUL), Gianfranco Sorasio (WS Energia)**

Filipa Reis

Objectives

Understand the sustainability challenges of renewable energy systems.

Build a receiver with high efficient silicon cells to integrate in a low concentration photovoltaic prototype.

Assess and design an optimal configuration to significantly reduce the PV electricity cost/kWh.

Work plan

Extensive literature review of low concentration photovoltaic systems.
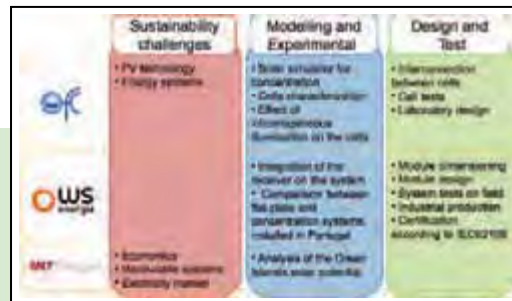Atmospheric data analysis; modelling of thermal, electrical, mechanical and optical parameters; and experimental tests.
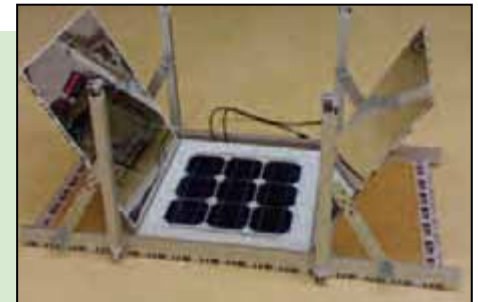Prototype design, installation, monitoring, certification and industrial implementation.

Results

We performed an analysis of accelerated modules degradation rates of standard PV modules when integrated in a V-trough concentration system (Fig.2).

Fig.1 – Framework of the research describing involvement of institutions.

Fig.1 –Fig.2 – Small-scale prototype of DoubleSun® technology. With adjustable position of the mirrors to vary the concentration between 1x and 1.9x.

The tests (summarized in the table below) where performed according to the concentration qualification standard IEC62108.

	Outdoor exposure	Off-axes beam	UV exposure
Goal	• Determine the ability of the module to withstand exposure to outdoors. • Find power degradation (that may be undetectable in lab) by cumulative outdoor effects.	• Evaluate that no part of the module could be damaged by concentrated solar radiation during conditions of misalignment or malfunctioning.	• Reveal possible premature failures of physical and electrical integrity due to limited UV exposure.
Results	✓ Imperceptible physical changes. ✓ Power degradation of 1.7% < 5%.	✓ Preliminary tests on the 2-axis tracking system revealed that the protection system had responded to forced misalignments.	✓ Imperceptible physical changes. ✓ Drop of I_{sc} suggesting mirrors degradation within the limits of the norm.

Impact of V2G systems in grid operation and expansion

Sustainable Energy Systems PhD
FEUP
Background: **Lic, Physics, Electrical Engineering (Renewable Energies) Post-Graduation, University of Porto**
Portugal
Starting Year: **2007 / 2008**
Supervisor: **João Peças Lopes (FEUP)**
Research team: **J. A. Peças Lopes, M. A. Matos and P. M. Rocha Almeida.**

Filipe Soares

Objectives

The main objectives of this thesis are to assess the impacts in the Portuguese power system provoked by the increase in electricity demand due to EV, as well as the environmental benefits associated, and to develop new grid management strategies, involving smart charging and exploiting the V2G concept, aiming to minimize the investment needs to safely accommodate EV in the grid.

Results

1. If a dumb charging approach is used, networks can handle the penetration of EV up to 10%, without any kind of reinforcements;
2. Multiple tariff policies slightly improve the integration capability of current electricity networks;
3. The smart charging approach developed, using the aggregator capability to manage EV charging, proved to be the most effective one, as by applying it EV deployment capability increases to roughly 50%;
4. The adoption of a smart charging strategy avoids a substantial increase in the peak load, resulting in improved voltage profiles, more homogeneous congestion levels and lower losses and GHG emissions.

Work plan

- Characterize scenarios, taking into account the type of vehicles, their owners' behaviour, the traffic patterns and the increase in renewables installed capacity;
- Analyse EV impacts on the power system and on the environment, through steady-state power flows, and develop smart charging strategies to tackle the problems identified;
- Develop a conceptual framework for EV integration into electric power systems;
- To tackle the uncertainties problem related with where and when EV will charge, a Monte Carlo simulation method is being developed to obtain average values and confidence intervals for buses voltages, branch congestion levels, energy losses and GHG emissions;
- A Markov chain to simulate the drivers' behaviour along one day is being prepared to be included in the Monte Carlo algorithm;
- Calculate investment needs to safely accommodate EV in the power system, as well as an evaluation of the additional costs needed to implement smart charging strategies, coupled with smart metering solutions..

Fig. 1. Technical management and market operation framework for EV integration into electric power systems.

Fig. 2. Markov chain to simulate the drivers' behaviour

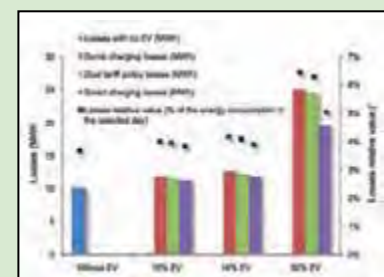**Fig. 3.** Load diagram for a scenario with 50% of EV

Fig. 4. Losses absolute (bars), referred to the left vertical axis, and their value relative to the overall energy consumption (crosses), referred to the right vertical axis.

A smart home energy storage for a renewable energy consumption

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc., Mechanical Engineering, ISEL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisor: **Carlos Cardeira (IST-UTL), João Calado (IST/ISEL),**
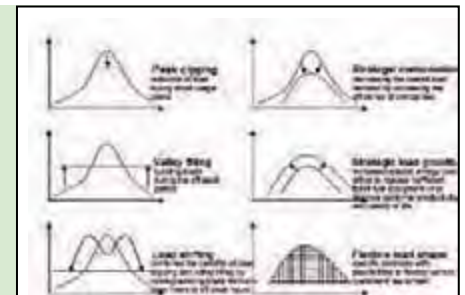**Leon Glisckman (MIT)**

Filipe Rodrigues

Objectives

This research will provide a clever driver for: Energy demand; Feedback on energy consumption; Load management and Smart Energy Storage. The result of the work carried out will allow developing a solution for energy storage to make the load balance of electric energy, anticipate and defer the energy consumption (See Figure 1). This project, will be based on an intelligent energy management system of power use and energy storage without compromising the human comfort (See Figure 2).

Fig. 1: A driver for electricity demand"

Work plan

The work carried out aims to define the best Artificial Neural Network (ANN) architecture and best training algorithm in order to achieve a robust model to be used in forecasting daily energy consumption in a typical household. It was observed that a feed-forward ANN could provide a good performance. After testing several training algorithms, the back-propagation Levenberg-Marquardt achieved best performance (See Figure 3). The performance of the model achieved has been measured using three different parameters: SSE, stands for sum of square error, MSE, stands for mean squared error; and R2, stands for fraction of variance. The results show that the ANN approach is a reliable model for forecasting household daily energy consumption.


Fig. 2: Our Approach "A Smart Home Driver

Fig. 3: The performance of the network trained using six different learning algorithms

Results

During the current studies, to obtain a model able to predict daily household energy consumption, ANNs have been used. From the total of 1488 data sets, 50% were used for training, while the other 50% were used for testing. To obtain the desired model, the Levenberg-Marquardt learning algorithm was used and the best results were obtained for a network having 20 hidden neurons, 16 neurons in the input layer and 1 neuron in the output layer (See Figure 4). Thus, based on the model obtained, the energy consumption forecast is quite rigorous (R2 and MSE reach values near or equal to 1) compared with consumption measured and recorded in each household. For each network, fraction of variance (R2) and mean squared error (MSE) values were calculated and compared, in order to assess the achieved models robustness based on different ANNs architectures.
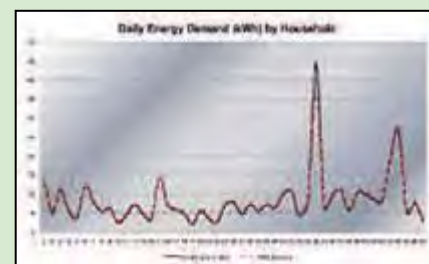
Fig. 3: Comparison of daily consumption – ANN forecast

Intelligent Multicellular Grids

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc. Industrial Management and Engineering, IST-UTL, Portugal**
Starting Year: **2008 / 2009**
Supervisors: **Christos Ioakimidis (IST-UTL)**
Research team: **Jorge Borges, Filipe Sim-Sim, Luís Oliveira**

Filipe Sim-Sim

Objectives

To research and design a new model of control and associated algorithms to be used in a electrical system composed of multiple interconnected microgrids with extremely high dependence on Renewable and Distributed energy sources (RER) and with high electric vehicle (EV) penetration.

Model Description

The control model focus is on maximizing the usage of Renewable Source in its peaks, adjusting controllable Demand to the predicted Renewable Supply, through Numerical Weather Predictions (NWP – See Fig. 1), and therefore minimizing the usage of other storage devices than the Electric Vehicles present in the local Microgrid.

The model is based on the assumption that appliances or some sort of controllable Demand Loads are available. Using the NWP for the local RER the model, it is then possible to calculate a schedule that allows a match between the forecasted RER peak supply and the controllable demand. (see Fig. 2) This will constitute the Local (Microgrid) Solution.

The set of all of the Microgrid Solutions can then be inserted in the Multi-Grid (network of Microgrids) Controller Algorithm and adjusted so that energy can be scheduled to be imported or exported aiming to reduce the total cost of the Multigrid Energy usage.

Wind Power Prediction Accuracy
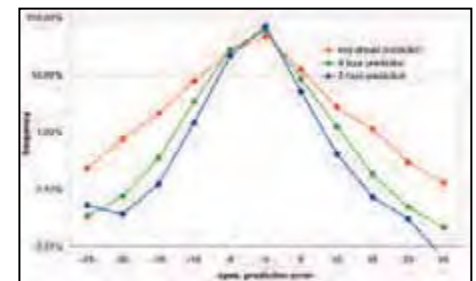
Fig. 1 - Frequency distribution of prediction error.

The figure shows the frequency distribution of the prediction errors of the day ahead prediction in comparison to the 4-hour and 2-hour short-term forecast". Predictions of wind power production in the short term and up to a day are quite accurate and with a high degree of certain.

From: *"Application of Wind Power prediction tools for Power System Operations", Rohrig, K.; Lange, B.; IEEE Power Engineering Society General Meeting, 2006*

Load Scheduling

Fig. 1 - Supply Peak Matching by scheduling of Controllable Loads

Work plan

First Year:	Introductory Research to areas of focus. (undergoing)
Second Year:	Basic prototyping of working model.
Third Year:	Model perfection and application to Azores Case Study

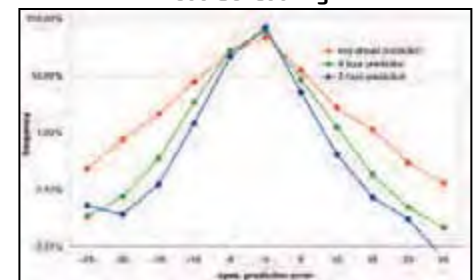# *Decentralized Energy Production for a Sustainable Built Environment*

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc., Civil Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Paulo Ferrão (IST-UTL), Ana Póvoa (IST-UTL),**
Chris Marnay (LBNL)
Research team: **Michael Staedler (LBNL), Gonçalo Mendes (IST)**

Gonçalo Cardoso

Objectives

- Assess the potential of integrating decentralized energy production technologies into (Portuguese) buildings focusing on multiple technology integration, economic and environmental benefits, deployment scales, tariff schemes and policies (Fig. 1).
- Improve existing modelling tools by adding support to additional technologies and stochastic variables

Work plan

The methodology used encompasses the following main steps

- Software development: Re-write DER-CAM in order to support new technologies and uncertainty. Latest work included generalization of fuel related equations in order to allow bio-fuels or any other generic fuel. Follow up will focus on the addition of wind turbines and stochastic variables.
- Model and analyse representative Portuguese buildings (case study). Latest work included multiple building types (multi-residential, small office, large office and museum) in order to access the impact of bio-diesel in the adoption of CHP units (Fig. 2 and 3).

Results

Latest results on the use of bio-fuel fired CHP units in the Portuguese building sector indicate that there is potential for CO_2 emission savings, although economic incentives are required in order to make it competitive with other fuels (eg. natural gas) (Fig. 3). Also, solar panels, either photovoltaic or solar thermal, provide better overall results. Bio-fuel fired units may be of use whenever roof space becomes a constraint.
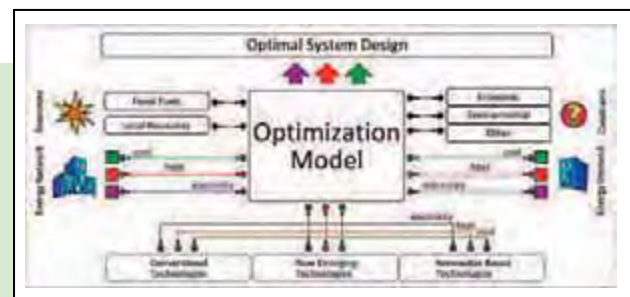
Fig 1.
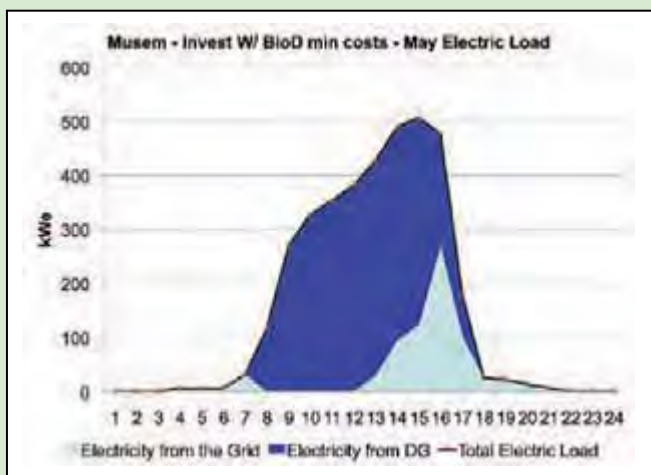
Fig 2.
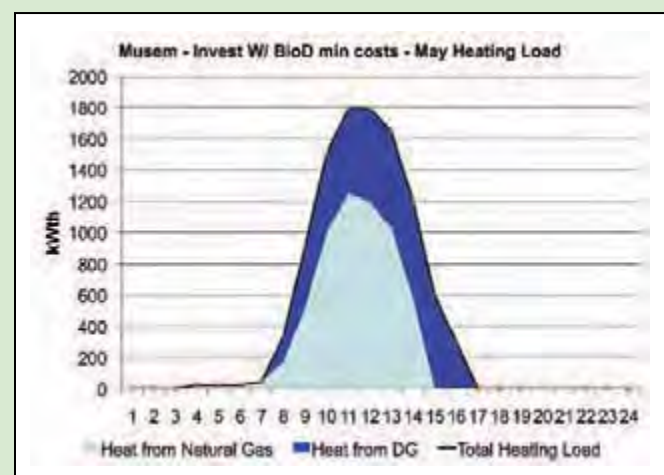
Fig 3.

Towards the Sustainable Planning of Microgrid Systems

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc. Environmental Engineering, FCT-UNL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **Christos Ioakimidis (IST-UTL)**
Research team: **Christos Ioakimidis, Gonçalo Mendes,**
Filipe Sim-Sim

Gonçalo Mendes

Objectives

To develop a reliable approach for incorporating the full-spectrum
concepts of **Sustainability** and **Systems Thinking** in the deployment of
Distributed Generators (DG) in forms of small scale microgrids, through:

1. Developing an environmental and social components for an existing customer
adoption exclusively economical algorithm (**MILP - DER-CAM**)

1. Introducing life-cycle vision into the algorithm

Work plan

The methodology used encompasses the following main steps:

Tasks	Achievement
1. Literature review on DG sitting and sizing optimization problem and methods (MILP, GIS, etc..), Industrial Ecology and LCA	✓
2. Case-study (SÃ£o Miguel, the Azores) data gathering (resource data, tariff structure, load profiles, etc..)	**80%**
3. Viable site selection and GIS mapping of local constraints	**50%**
4. Exploring the model and the algorithm through multiple runs and acessing the source (Guest internship at LBNL -" Fall 2010)	**20%**
5. Algorithm expansion (on objective function and on LCA logics)	**2011**

Introducing **social impacts**

$$\min Sf = \min[w_1(ef) + w_2(ef) + w_3(sf)](w_1 + w_2 + w_3 = 1)$$

To improve via:
Introducing **LCA impacts – AVOIDING A NAIVE APPROACH TO SUSTAINABILITY**
Adding other realistic impacts: Noise disturbance, other GHG, SO, CO, etc..

EXISTING INPUT

INPUT TO INTRODUCE
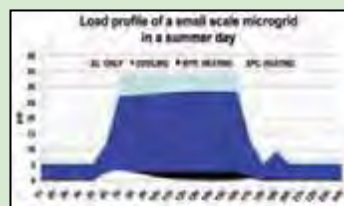
Adapted from LBNL

Results

Preliminary test results for a **residential minigrid** suggest good potential for investment
on 35kW of PV technology, able to generate on-site 90% of the electricity resulting in
35% reduction on base case Total Energy Costs (TEC)

Small microgrid composed of two low-rise residential buildings and a medium-sized restaurant

Adapted from LBNL

Selection of the most efficient physical measures for the development of Energy Efficiency Action Plans in a multi-criteria environment

Sustainable Energy Systems PhD, FEUP

Background: **Lic., Electrical Engineering, State University of Rio de Janeiro, Brasil**

Starting Year: **2007 / 2008**

Supervisor: **Vítor Leal and Eduardo de Oliveira Fernandes (FEUP)**

Research team: **Ana Neves, Filipa Carlos, Maria Kapsalaki, Pedro Silva, Reza Fazeli**

Gustavo Souza

Objectives

Development of a methodology and a tool which helps the decision process of choosing among **energy demand-side alternatives** in the definition of **energy-efficiency** (EE) plans.

Results

The application of the model to Portugal enabled the identification of the most important end-uses and energy carriers in each of the four sectors covered by the model (domestic, services, industry and transports).

Figure 1 illustrates the energy use breakdown for the services sector.

The end-uses add-up 41 in all sectors and are characterized by 177 technologies, where opportunities on energy efficiency improvement due to technological upgrade of equipments and infrastructure can be quantified and compared, as shown in Figures 2 and 3.
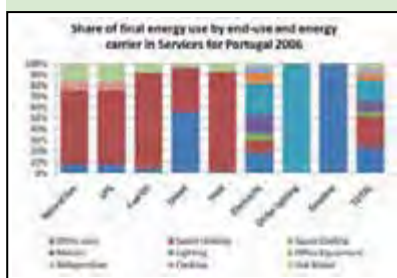
Work plan

- **Review of the energy planning models** and how they deal with the **energy demand structure**
- Build an **appropriate demand structure (model)** to apply measures
- **Identification of possible EE measures;**
- Finding methods to **quantify EE measures;**
- Apply identified methods to **estimate future energy demand;**
- **Select criteria and build the appraisal process** for the EE alternatives;
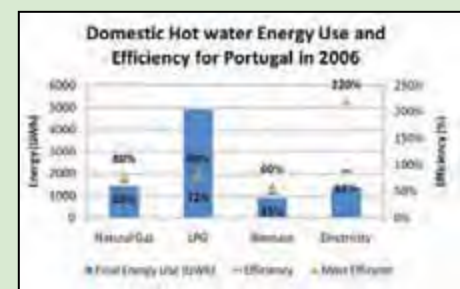- **Build a planning decision support tool** based on the previous steps and test it in a case study.

Fig. 1.

Paper Industry - Motors by power range in KW for Portugal in 2006

Fig. 2.

Domestic Hot water Energy Use and Efficiency for Portugal in 2006
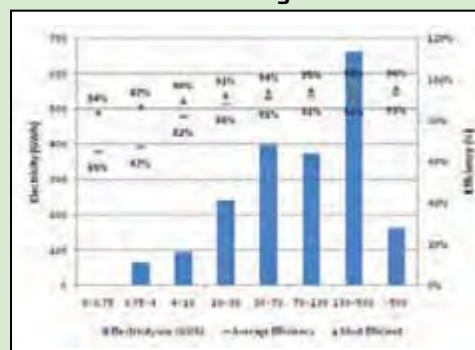
Fig. 3.

EXTENDED LIFE CYCLE ASSESSMENT TO IMPROVE RESIDENTIAL BUILDINGS OVERALL PERFORMANCE

Sustainable Energy Systems PhD
University of Coimbra
Background: **Lic. Architecture, University of Porto, Portugal;**
Master in Energy for Sustainability, University of Coimbra, Portugal
Portugal
Starting Year: **2009 / 2010**
Supervisor: **Fausto Freire, Adélio Gaspar (University of Coimbra)**

Helena Monteiro

Objectives

i) To assess and support improvements at project level to reach new energy and environmental life cycle (LC) enhanced residential buildings

ii) To develop a novel extended LC approach considering energy, environmental impacts and costs of residential buildings towards more sustainable solutions for different Portuguese climatic regions

Work plan

The following methods will be used:

LCA methodology – to assess LC energy and environmental impacts, quantifying the trade-offs between alternative building solutions and the various LC phases.

Energy building simulation tool – to calculate operational energy considering different Portuguese climatic conditions.
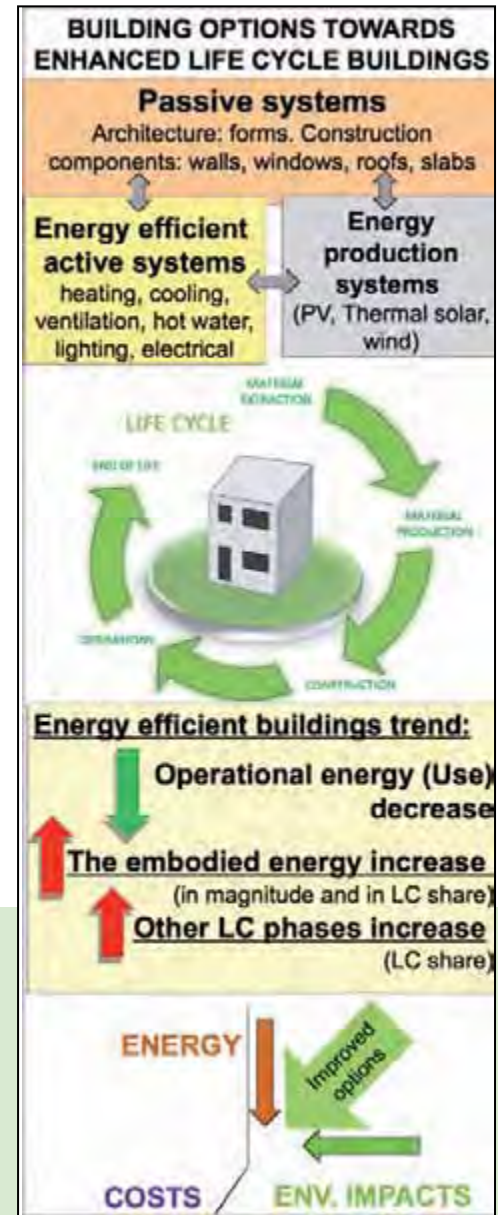
Life Cycle Costing – to assess economic costs (from investment to operations, maintenance and end of life) and to support decision making.

Multi-criteria Decision Analysis and trade-offs analysis – to identify a range of preferable solutions to improve residential buildings performance.

Results

The research will contribute to assess and select optimal improvement options for residential buildings within the Portuguese context towards a very low energy house concept.

Results shall give insights about a range of LC preferable solutions for each climatic region, which so far have not been done for Portugal. This research is directed to support building stakeholders (user community, architects and building designers) and policy makers.

BUILDING OPTIONS TOWARDS ENHANCED LIFE CYCLE BUILDINGS

Passive systems
Architecture: forms. Construction components: walls, windows, roofs, slabs

Energy efficient active systems
heating, cooling, ventilation, hot water, lighting, electrical

Energy production systems
(PV, Thermal solar, wind)

LIFE CYCLE

Energy efficient buildings trend:

Operational energy (Use) decrease

The embodied energy increase (in magnitude and in LC share)

Other LC phases increase (LC share)

ENERGY

Improved options

COSTS / ENV. IMPACTS

Exploring energy saving potential in existing buildings with energy management and control systems

Sustainable Energy Systems PhD
University of Coimbra
Background: **MSc., Electrical and Computer Engineering, University of Trás-os-Montes and Alto Douro, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **António Manuel de Oliveira Gomes Martins, Adélio Rodrigues Gaspar (UC)**

Hermano Bernardo

Objectives

The main goal of the proposed study is quantifying the energy savings potential of improving and retrofitting the Building Energy Management and Control Systems (BEMCS) in commercial and institutional existing buildings, identifying the main risk factors related to BEMCS malfunctions

Table 1 - Building control system functionality classifications

Building Control Functionality Classification	Examples
Plant Control	Room temperature control, boiler sequencing
Plant Maintenance	Fault reporting/alarming, filter conditioning monitoring, equipment "real-time" monitoring
Energy Saving	HVAC/lighting scheduling, demand limitation, free cooling
Recording	Energy metering, energy use monitoring (e.g., gas, electric, oil)

Work plan

In order to achieve the main objectives, it will be required to define a sample of buildings to study. After the selection of the case-studies their analysis through surveys will be done to measure the energy consumptions and comfort conditions.

To improve the installed BEMCS it will be necessary to search a set of retrofitting measures and develop some control strategies. It will be required to do the energy simulation of selected case studies, creating building models in existing building energy simulation tools, with system and control parameterization, which must be adequately calibrated and validated. Then, some experiments will be carried on a real BEMCS to demonstrate how the overall performance of building energy management systems can be improved.

After the analysis of the case-studies, it is necessary to do a statistical treatment of collected data oriented to the prediction of the energy savings potential associated to the optimization and changing of some control strategies in existing BEMCS, identifying factors that can contribute for technical dysfunctions of BEMCS and causes for the human behavioral reactions to this kind of systems.

Fig. 1 - Surveyed prevalence and usage rates for selected BEMCS functions.

Results

It is expected that the results obtained lead to a methodological contribution on demonstrating to decision makers and building managers the energy savings potential of retrofitting existing automation and control systems in buildings, applying the most cost-efficient control strategies and refurbishment measures.
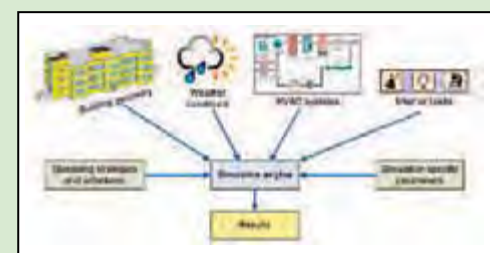

Fig. 2 - General data flow of simulation engines

Generation Coordinationin Complex Systems with Stochastic Reservoirs

Sustainable Energy Systems PhD
FEUP
Background: **Bsc. Faculty of Electrical Engineering and Computing,**
University of Zagreb, Croatia
Croatia
Starting Year: **2008 / 2009**
Supervisor: **Vladimiro Miranda (FEUP)**
Research team: **INESC Porto Power Systems Unit**

Hrvoje Keko

Position of generation coordination in electric power system: Spatial and temporal resolution of the problem

Objectives

Determine and evaluate practices for management of *generation operational schedules* in an electric power system with a diverse generation portfolio including hydro, wind, other renewables and storage capabilities including *electric vehicles.*

The analysis of energy storage and retrieval strategies should include classic pumped hydro storage and volatile/uncertain forms of dispersed storage such as batteries – denoted globally as a *stochastic reservoir.*

Work plan

Development a stochastic reservoir concept: model of energy storage based on granular contributions of individual smaller storages
▶ capacity and energy stored have strong spatial and temporal dependence
▶ primary function of stored energy external to the electric power system i.e. fleet of EV batteries connected to the grid via vehicle-to-grid
▶focusing on representative stochastic models that keep tractability of a highly granular and uncertain reality

Determining a suitable method for short term operation planning
▶correctly representing volatilities and spatial/temporal relations of renewable energy production
▶allowing implementation of diverse policies embedded and implemented in operational decisions - minimization of production costs is not the only possible objective function

Introducing stochastic storage into generation coordination
▶ considerable scale - small individual contributions and large numbers
▶ primary function is not to serve the power system
▶granular constraints
▶coordination with volatilities from storages and volatilities from energy sources
▶use city traffic simulations to extrapolate patterns

Implementation plan of PhD thesis development

Using a systematic evaluation scheme to evaluate granular coordination decisions in an aggregated form
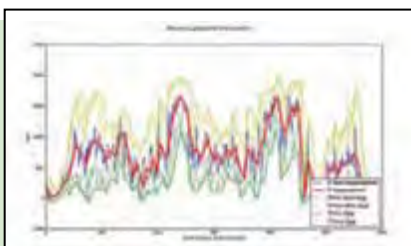▶cost models focus only on very short term operational costs, however impacts of granular decisions only visible on a larger time scale
▶actual impacts of a temporal stream of daily decisions visible on yearly scale
▶using an adequate scheme for evaluation of coordination policiesdetection platform with proper data analysing system.

Handling of wind power plant time series

Results

▶ New generation coordination method suitable for today's electric power system including wind power generation, hydro storage and mass storage in electric car batteries.
▶ Mathematical model capable of dealing with uncertainties stemming from volatile forms of production and volatile storage.
▶ Algorithmic procedure for efficient generation of operational schedules in such environment.
▶ Computer application allowing technology transfer to industry
▶ Assessment of the cumulative impact of operational decisions.

Energy efficiency and demand response in the residential sector
Sustainable Urban Energy Systems
Uncovering the Potential for Demand Response in the
Residential Sector

Sustainable Energy Systems PhD
IST-UTL
Background: **BSc. in Environmental Engineering, FCT-UNL, Portugal;**
MSc., Geographical Information Systems, Leeds University, United Kingdom
Portugal
Starting Year: **2007 / 2008**
Supervisors: **J. Vasconcelos (IST-UTL) D. Marks (MIT) P. Ferrão (IST-UTL)**

Joana Abreu

Objectives

Estimate the impact of feedback and social pressure in the way the experiment recruits use electricity. Evaluate the potential of the domestic clients to responsive demand (balancing, shifting and curtailment – differential frequency events)

Work plan

I. Experimental Design.
II. Experiment Implementation: 12 homes, 10 controls; Electronic metering, interface and Google Power Meter. Stratified sampling of recruits (employees of Oeiras Municipality).
III. Multivariate analysis of loads. Activity modeling and segmentation.
IV. Analysis of response post-treatment . Causal inference analysis.
V. Interpretation of results. Recommendations for the design of responsive demand programs that look to aggregate residential demand.

Results

Understanding of the challenges behind the implementation of electronic metering devices; estimation of errors due to communication failure or equipment malfunction. Identification of behavioral impacts on the good functioning of equipments.

Daily or intra-daily periodicity depending on the characteristics of the families. Identification of cyclic equipments and main components of the load.
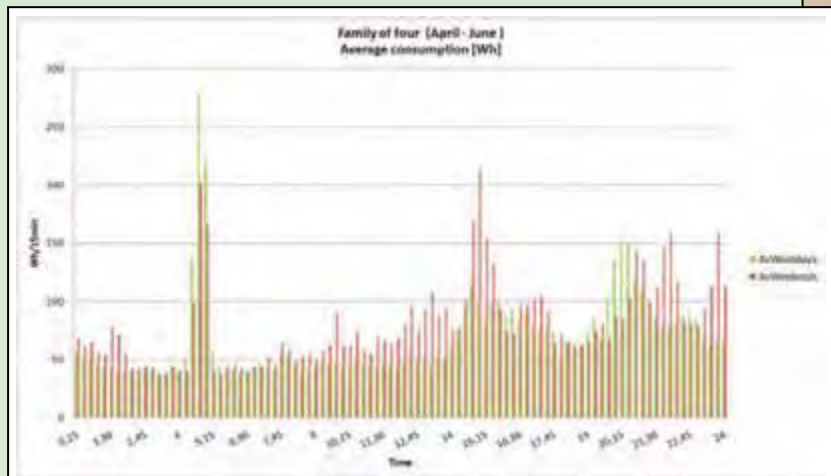
Business model to Electric Vehicles Fast Charging Stations

Sustainable Energy Systems PhD
IST-UTL
Background: **Bsc. Electrical Engineering, ISEL, Portugal**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Christos Ioakimidis (IST-UTL), Steven Connors (MIT)**
Research team: **C.Ioakimidis, A. Pina, F. Sim Sim, J. Borges, L. Oliveira**
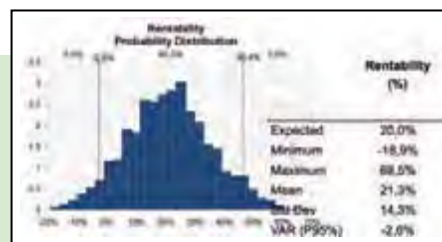
Jorge Borges

Objectives

- Develop a Business Model that can study the economic viability of Fast Charging Stations
- Estimate the Fast charging price for consumers at the station and compare it with the residential charging and fuel prices at gas stations
- Simulate different scenarios of electric vehicles demand for fast charging and electricity market price and analyse the risk for investors

Fig. 1 - EV charging processes

Work plan

This work studies and evaluates the Fast charging station as part of the EV ongoing charge process that intend to perform similar to a commercial gasoline service station. It was developed a business model that calculate the station Net Present Value (NPV) over a 20 year period, simulating the Fast charging price for drivers at the station, that is compared with the house night charging and with the internal combustion engine (ICE) fuel (diesel and gasoline) at the Gas stations, for the Portuguese case. The developed model simulate the electricity price based on the MIBEL, through a methodology that uses a non-dimensional hourly curve for one year, created from historical market data, and the yearly average market price estimation for the analysis period. To analyse the risk for investors, it was used a Monte Carlo simulation that calculates the NPV and rentability probability distributions and the correspondent Value at Risk (VAR).

Results

The model simulated a fast charging price at the station of 0,194 €/kWh, which provides 17% profits (NPV over a 20 year period, Fig. 2) and 20% rentability for station stakeholders. This price is almost 3 times higher than charging the EV at home during night (off peak hours) but it is 38% lower than refuel a diesel ICE vehicle and 66% lower than a gasoline ICE vehicle (table 1). To analyse the risk for investors, it was used a Monte Carlo simulation that calculated the NPV and rentability probability distributions (Fig. 3). The VAR (Value at Risk) of the NPV (Profit) represents 2% of the investments, which indicates a low risk project for this model assumptions.

Fig. 2 - Fast Charging Station Net Present Value

	EV charging		ICE fuel at Gas Station	
	Home (at night)	Fast Chrg. St.	Diesel	Gasoline
Vehicle consumption	0,150 kWh/km	0,150	0,044 l/km	0,066
Charging/Fuel Price	0,066 €/kWh	0,194	1,060 €/l	1,305
Price per km	0,010 €/km	0,029	0,047	0,086
40 km travel cost	0,40 €	1,16 €	1,87 €	3,45 €

Table 1 – Price comparison between EV charging and ICE vehicle refuel

Fig. 3 - Rentability Probability Distribution

Impact assessment of Micro-Grids and Multi Micro-Grids

Sustainable Energy Systems PhD
FEUP
Background: **Bsc. Power Systems, Faculty of Electrical Engineering of the "Ss. Cyril and Methodius" University, Skopje, Republic of Macedonia**
Republic of Macedonia
Starting Year: **2007 / 2008**
Supervisor: **João A. Peças Lopes and Manuel A. Matos (FEUP)**
Research team: **J. A. Peças Lopes, M. A. Matos**

Julija Vasiljevska

Objectives

- Methodology development for evaluation of the benefits one can get by large scale integration of micro-generation (µG) together with controllable loads under the Micro-Grid (MG) and Multi Micro-Grid (MMG) concepts;

- Address the relation between benefits and costs resulting from the MG and MMG concepts deployment;

- Identification of different incentive mechanisms and remuneration schemes for the Distribution System Operator (DSO), µG owners and loads to be involved in the MG and MMG concepts deployment.

Work plan

- Adoption of different control strategies at different distribution network levels under the MG and MMG concepts (Figure 1 and Figure 2), as a potential way to facilitate integration of higher levels of µG into the distribution networks, assumed to be operated in real market environment;

- Analysis of real study cases (typical Portuguese distribution networks) and scenarios regarding the expected annual load growth and electricity market prices;

- Addressing a cost / benefits relation related with the MG and MMG concepts deployment using Multi Criteria Decision Aid techniques for capturing different decision maker's preference structures.analysing system.

Figure 1. MG level control structure

Figure 2. MMG hierarchical control scheme

Results

- Control strategies for optimal µG production and load level settings under MMG active control and management to account for technical constraints resolution in so called, stressed Medium Voltage operating conditions;

- Assessment of costs and benefits attributed to different stakeholders (decision makers) involved in the MG and MMG concepts deployment exploiting different installation costs sharing mechanisms;

- Creation of new regulatory approaches for DSO to accept MG and MMG concepts by defining adequate µG and responsive demand remuneration schemes.
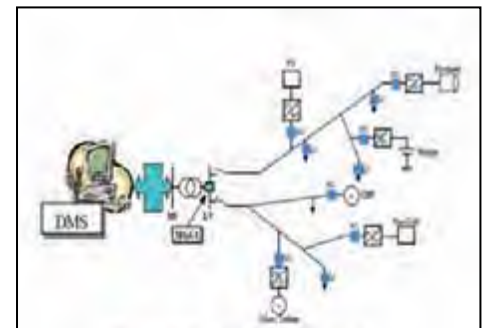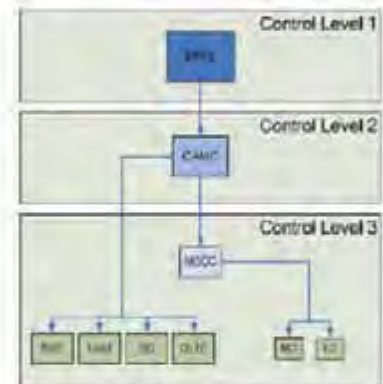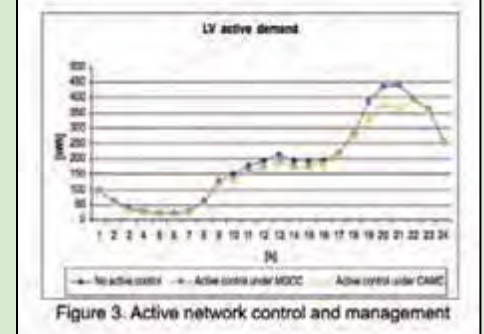

Figure 3. Active network control and management

Economical Evaluation of Emerging Biofuel Technologies: The Microalgae Case Study

Sustainable Energy Systems PhD
University of Coimbra
Background: **Master and Bachelor degrees in Management / Universidade Federal do Rio Grande do Sul (UFRGS), Brazil**
Brazil
Starting Year: **2009 / 2010**
Supervisor: **Patrícia Pereira da Silva (UC)**

Lauro Ribeiro

Objectives

The proposed study aims to analyze the market and development of emerging biofuels technologies with an emphasis upon cultivating microalgae and assess the economic and technological factors that could be critical to the success of this technology.

Work plan

The purpose of this study is to verify who are the key players in this emerging market, analyze the present economical and political situation, evaluate possible opportunities and weaknesses and forecast ways to enhance the economic viability of large-scale microalgae biofuel industries and compare this emerging technology with other technologies that can replace our oil consumption.

The study aims to make the intersection of three major areas of knowledge: the Economic Policies to handle the deregulation of the energy industry (with analysis of the incentives, regulatory constraints and price signals coming from the Power Exchange), with processes of technological diffusion and economical evaluation / performance analysis of companies within this market.

Results

Technological advances in cultivation and extraction of oil from microalgae are scientifically well known, and should continue to move forward in the coming years with increasing investment in R&D in this area. However, with the emergence of several new private companies in this sector, it is evident the need of a study of the economics of cultivation of microalgae and the ability to produce biofuel in an economically viable manner. This study could help, not only private algae biofuel companies so that they could decide on what product mix to explore, but would help governments when deciding what policies to adopt to enhance this technology.

Fig. 1. Three categories to be studied in the algal biofuels market.

Fig. 2. Valcent Products, Inc. (USA) closed microalgae cultivation system.

Fig. 3. Solix Algae Biofuel Plant (USA).

Urban Metabolism: Modeling Consumers Material Flows

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc in Engineering Design, Instituto Superior Técnico (IST-UTL), Portugal**
Starting Year: **2007 / 2008**
Supervisor: **Paulo Ferrão (IST-UTL) & John Fernandez (MIT)**
Research team: **S. Niza, D. Wiesmann and D. Quinn**

Leonardo Rosado

Objectives

Within the Urban Metabolism framework it is intended to provide information that enables Municipal agents to test the efficiency of different types of policies towards "urban sustainability" from a systems perspective, such as: changing consumption patterns; changing lifespan of selected products in order to modify consumption; and stimulating reuse of products that are still functional and recycling of materials of non functional products, avoiding final deposition and waste to energy recovery.

Work plan

DESCRIPTION of the SYSTEM:

- MFA for the Lisbon Metropolitan Area;
- Description of Key Variables for products: material composition & lifespan
- EIOLCA model for the household consumption of products;
- Identification of the potential for Recycling of products;
- Integration of the different models in a common platform: System Dynamics has the global framework to understand relationships
- Estimation of the spatial location of consumer goods

ACTION upon the SYSTEM:

- Analysis of the changes in the system if key variables are changed;
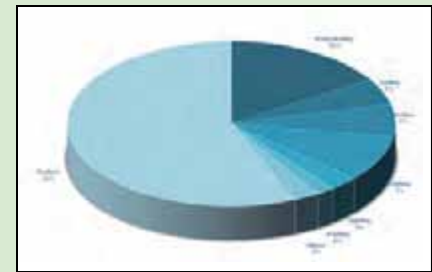- Identification of the location and timing of different types of waste

Fig. 1.

Fig. 2.

Fig. 3.

Results

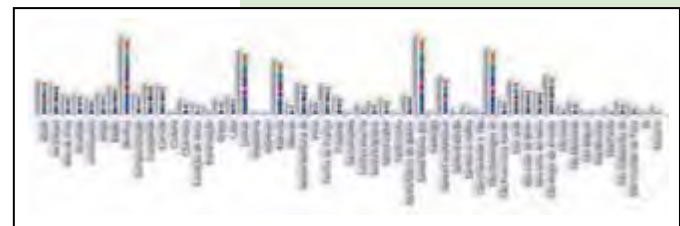**Preliminary results on aspects of the global model EIOLCA model**

With this model it was possible to identify the clear relevance of the embodied energy in the global consumption of energy in households, more than 50%, of the energy needed, see Figure 1. And also to distribute the embodied energy by Freguesia of the Lisbon city (see Figure 2).
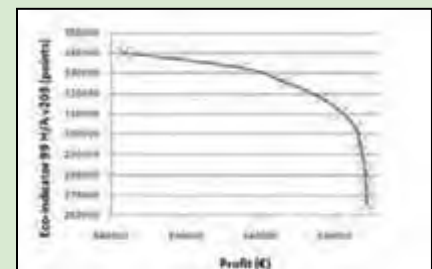
Recycling potential of waste products

Waste from Electric and Electronic Equipment economic valuation of materials and environmental impacts mitigation, in order to define priorities of recycling, using a Linear programming (see Figure 3).

Optimization of Large Scale Power System Problems with New Tools

Sustainable Energy Systems PhD
FEUP
Background: **MSc, Electrical Engineering, FEUP, Portugal**
Starting Year: **2008 / 2009**
Supervisor: **Vladimiro Miranda (FEUP)**

Leonel Carvalho

Objectives

- To explore **new computational trends** in order to better represent the flexible models contained in large scale problems, such as **Power System Reliability Assessment**

- To evaluate the **impact** of the **integration** of **renewable power sources, dispersed generation** and **electric mobility** in Power System Reliability

- To explore the use of **Computational Intelligence** algorithms to diminish the computational effort of the Reliability Assessment tools

Work plan

- Establishment of a solid **state-of-the-art** of the **tools** used for **Reliability Assessment** and of the **Computational Intelligence** algorithms
- Development of a **Chronological Monte Carlo Simulation** algorithm (depicted in figure 1), in Java™ programming language, capable of estimating the **reliability indices** for **each transmission network delivery node**
- Development of **models** that can accurately represent the **chronological** and **stochastic behavior** of **renewable power sources**, of **dispersed generation** and of **electric vehicles**
- Evaluate the **impact** on the system's **reliability** of the **integration** of **renewable power sources**, of **dispersed generation** and of **electric vehicles** into the **generating portfolio**
- Studying the possibility of **diminishing** the **computational effort** of some stages of the Monte Carlo Chronological Simulation with **Computational Intelligence** algorithms

Results

- The Monte Carlo Chronological Simulation algorithm, which allows the representation of the maximum integration of renewable and dispersed generation, is in its final test stage

- A simulation for one year of operation of the IEEE RTS 79 power system including 6 hydro generators and 7 wind farms was successfully performed

Fig. 1.
Flow Chart of the Chronological Monte Carlo Simulation algorithm with emphasis on the state evaluation stage
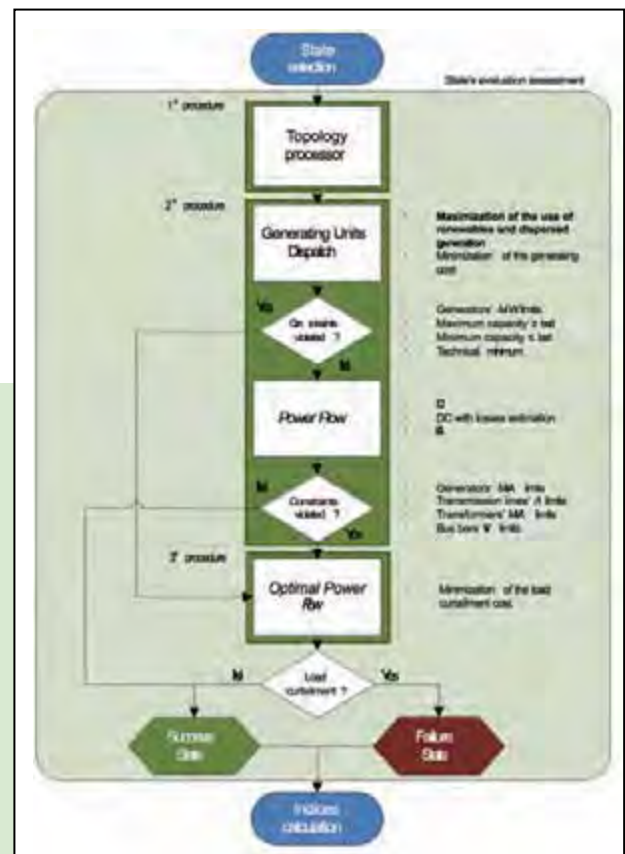
Strategies for the Design of Carbon Neutral Buildings

Sustainable Energy Systems PhD
FEUP
Background: **Degree in Physics, Master of Science in Environmental Physics,**
National and Kapodistrian University of Athens (NKUA)
Greece
Starting Year: **2007 / 2008**
Supervisor: **Vitor Leal (FEUP), Mat Santamouris (NKUA)**
Research team: **Ana Neves, Filipa Carlos, Gustavo Haydt, Manuel Silva,**
Pedro Silva, Reza Fazeli

Maria Kapsalaki

Objectives

- The identification of the parameters that influence Net Zero Energy Building (NZEB) design and performance (Fig.1)
- The development of a calculation tool that based on design parameters and geographical location, determines the energy needs and flows, sizes the appropriate local offset equipments and performs a life cycle economic analysis
- The use of that tool in order to investigate what are the most adequate approaches (insulation levels, type of glazing, type of ventilation, heating & cooling equipment, etc) for the design of residential NZEB buildings in different geographical zones of Europe
- The assessment of the potential influence of the local climate and the endogenous energy resources in the optimal design of a NZEB

Fig. 1

Work plan

- Literature review and comparative analysis of already existing net zero energy homes
- Climate Scenarios and Design Alternatives Structure for the conduction of Building energy simulation in order to identify the energy needs of typical residential buildings in different climate contexts
- Drafting of a calculation methodology for the thermal energy needs and the respective local offset equipments for the analysis & optimization tool, based on HDD and CDD method of the RCCTE
- Completion of the technical tool (software) to identify offset solutions as function of the building design with the help of MATLAB
- Gathering of information on the cost of technologies and assessment of an economic analysis to identify the more cost-effective design strategies in different climates through the development of an optimization algorithm
- Assessment of the trade-off point between energy efficiency to decrease the demand and the integration of renewable energy technologies to offset the consumption

Fig. 2 e 3

Fig. 3 e 4

Results

- Local climate is already influencing the design choices; the results confirm that the design of NZEBs is climate specific (Fig.2 &3)
- The envelope design options should be climate specific; improving the insulation of the envelope and enhancing the glazed area of the windows as well as reducing the infiltration rate minimizes the heating and cooling needs of a building; however some measures are only significant in some climates (Fig.3 &4)
- The design tool validation (Fig.5 & 6) and interface (Fig.7)
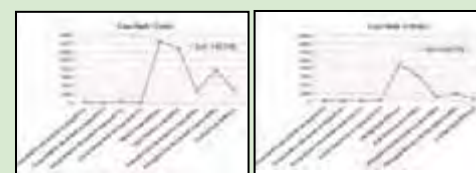

Fig. 7

Fig. 5 e 6

Corporate Reporting Towards Sustainability

Sustainable Energy Systems PhD
FEUP
Background: **MSc. Economics, Faculty of Economics, University of Porto, Portugal**
Starting Year: **2007 / 2008**
Supervisors: **Eduardo Oliveira Fernandes (FEUP), Isabel Soares (FEUP)**

Marta Mota

Objectives

The purpose of the research is to contribute towards a comprehensive and universal corporate sustainability reporting for the promotion of sustainable development at corporate level.
The main goal is the development of a new structure for Sustainability Corporate Reports (SR) to overcome the limitations found in this type of reporting, specifically applied to the energy sector.

Work plan

The first part of the work (market analyses) is dedicated to:

- Check the status of the market position before responsible corporate behavior, through the volatility analyses of shares prices.
- Identify the information relevant for the sector, through the analyses of environmental, social and economic events reported on magazines and newspapers.
- Identify current contents of sustainability reports from the sample.

On the second part (report improvement), in possession of the information that characterizes the baseline, the opportunities of improvement of SR´s are identified. Some potential issues, that the market is not yet valuing properly, are also weighted to consider on the development of a new methodological proposal for reporting on sustainability.

Results

Proposal of a new synthetic structure for Sustainability Reports. This structure considers the relevant information identified for the sector and for the market, organized on a set of indicators that reflect all the corporation activities interconnected, providing a genuine and holistic image about its performance.
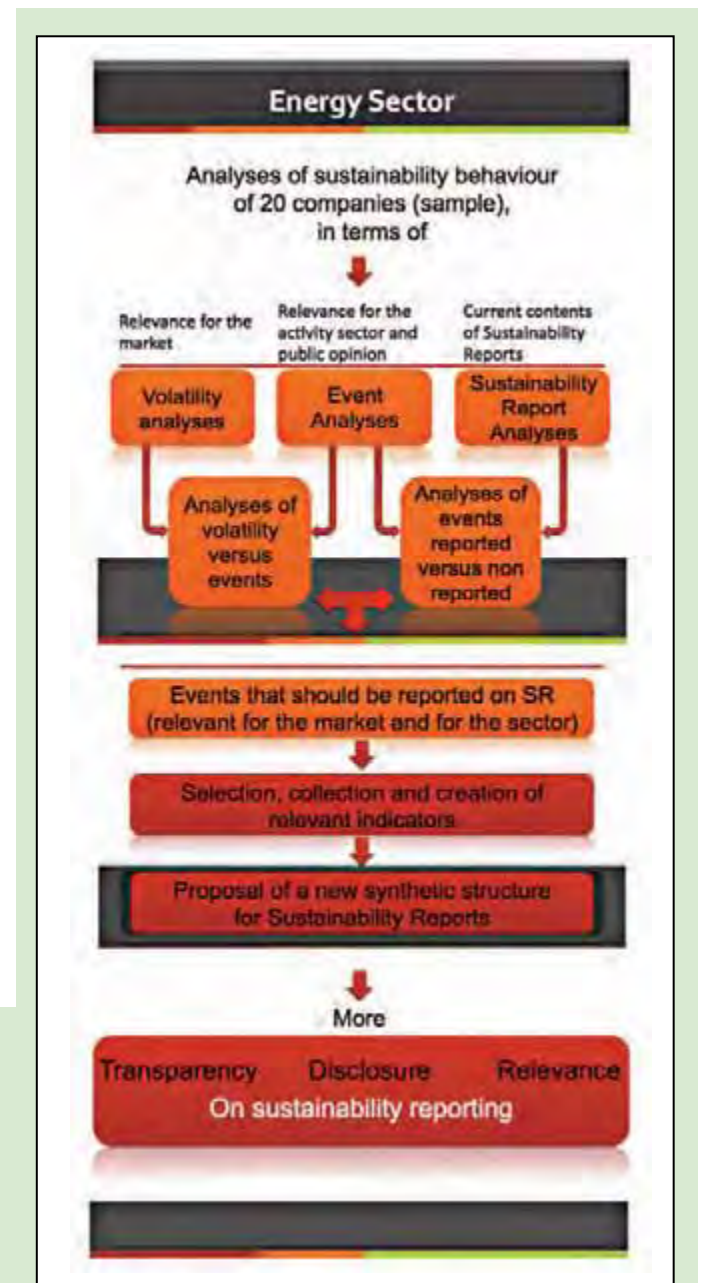
Sustainable Data Centers

Sustainable Energy Systems PhD
IST
Background: **Post-Graduation in Telecommunications Management (ISEG)**
Bsc. Electrical Engineering (IST-UTL), Portugal
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Carlos Silva (IST), Luis Dias (FEUC)**
MIT Portugal Associeted Research Project.

Miguel Covas

Objectives

The mains goals of the PhD is to characterize the main Data Centers in Portugal, develop a tool to analyze and support the Decision Making for a Sustainable Data Center and an indicator for the Sustainability of Data Centers. The work will identify the best regions in Portugal to develop a Sustainable Data Center.
Key Words: Sustainable Approach; Multicriteria Analysis; Site Selection; Geographic Information Systems; Data Center (DC

Work plan

Assessment of the main Data Centers in Portugal taking into account energy efficiency, power consumption, location, areas, among other criteria. A tool should be developed to analyze and support the decision making for a sustainable DC, considering that the location decision process is often time consuming and complex, involving considerations of both objective and subjective location factors. Identify best regions in Portugal to develop a Sustainable Data Center using geographic information systems and multicriteria analysis (ELECTRE TRI). Develop an indicator for the Sustainability of Data Centers using: energy efficiency; greenhouse gases emissions; water consumption; renewable energies.

Results

Most Data Centers in Portugal are located in urban or suburban areas, particularly nearby Lisbon. Typically DC's are installed in office buildings, only a small proportion has a dedicated building, and do not use renewable energy. About half of the DC's surveyed have electric power between 0.5 and 5 MW.

From the 4.050 parishes in Portugal, it was possible to identify 62 that are potentially suitable to develop a Sustainable Data Center (represents 1,5% of the total Portuguese parishes). Geographically, these potential regions are at north of Lisbon and near the coastline (where there is a higher number of hours per year with average temperatures below 21 ºC.

117

Schools:
the system beyond the building

Sustainable Energy Systems PhD
IST-UTL
Background: **Lic. Mechanical Engineering, MSc. in Energy, IST-UTL**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **Carlos Augusto Santos Silva (IST-UTL)**
Research team: **Carlos Silva, Nuno Clímaco, Joana Abreu, Nuno Santos**

Nuno Santos

Objectives

Definition of an effective energy education of children that can trigger a group of growingly sustainable behaviors that will surpass well beyond the school limits (especially the outer links from school to home).

Enlarge the scope of the initial project by introducing the transport modes (of both people and goods) for and from the school building.

Study the school as an energy system and, further, the energy system beyond the school

Work plan

a) gathering and over-viewing of diverse programs already deployed in the world - compare and to distinguish the programs' area of focus, expectations and strategy to achieve them. Finding every "pros and cons" of each program; compare individual results, showing the programs' strengths and weaknesses.

b) taking advantage of Vergílio Ferreira secondary school's retrofit to evaluate practical options regarding energy spending, auditing the "old" school building and its last years' energy bills and face it with the "new" school. Apply the same methodology within the detailed outer school energy system (homes of socially segmented people that somehow interlink to the school), both before and after a set of experiments/activities along the school's educational program.

c) develop a more complete program to Portuguese schools, adapting the best features of every other program to the Portuguese specificities (bearing in mind the local culture and infrastructures, and reviewing policies when needed), strongly integrating the view of the school as an energy system.

Results

Forecast the school system capacity to reduce its overall energy consumption, checking the "spillover effect" of students' activeness in the energy fields.

Check the additional effects of turning a school into "carbon neutral" through electricity micro generation and solar water heating.

Validate additional studies for sustainable transport, to benefit NZES as a more holistic research project (SUES + Green Islands + Transports)

Perform a conscious and holistic approach to the subject of energy in schools, serving both as a pro-active and a monitoring instrument, setting guidelines to achieve these expected results.

Evaluation of the impact of new vehicle and fuel technologies in the Portuguese road transportation sector

Sustainable Energy Systems PhD
IST
Background:**MSc. in Chemistry, IST**
Portugal
Starting Year: **2007 / 2008**
Supervisors: **Tiago Farias (IST), Carla Silva (IST), John Heywood (MIT)**

Patrícia Baptista

Objectives

This research is focused on the Portuguese road transportation sector and aims at evaluating the impacts in terms of energy consumption and CO_2 emissions of introducing new vehicle technology and energy sources.

Work plan

The main task for this work is to develop a fleet model tool for Portugal, named PATTS (Projections of Alternative Technologies in Transportation Software) capable of generating scenarios, by forecasting and backcasting, assessing the scale and timing of the impact of introducing new vehicle technologies (such as hybrid electric vehicles, plug-in hybrid electric vehicles, electric vehicles and fuel cell vehicles) and energy sources (such as biofuels, electricity and hydrogen) in the Portuguese road transportation sector. A life-cycle analysis LCA (TTW + WTT + CTG) is included.

In order to model the fleet evolution along time, the vehicle stock and the fleet kilometers travelled evolution are combined with the vehicles' fuel consumptions (according to the technology/fuel configuration) and emissions, so that the total fleet energy consumption and emissions are estimated for the total fleet along time.

Results

If no alternative solutions are adopted, the total life-cycle energy consumption and CO_2 emissions will continue to increase until 2050 having as reference the energy consumption in 2009. These impacts can be reduced if different vehicle technology and energy source scenarios are implemented.

Preliminary results confirm that the introduction of alternative technologies takes a longtime to achieve considerable shares of the total global fleet, due to the delay caused by the slow fleet turnover

PATTS simulation tool
Projections for Alternative Transportation Technologies Software

Scenarios and Results

Different vehicle technology and energy source scenarios can be evaluated:

To obtain their LCA energy consumption and CO_2 emissions impacts:
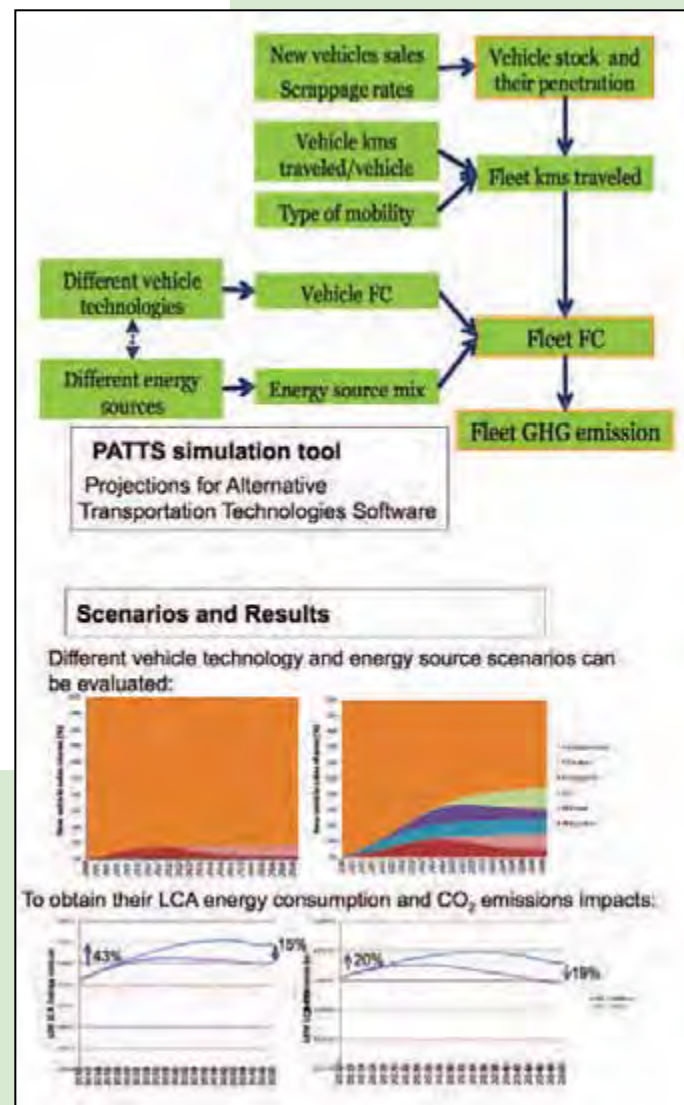
Energy Efficiency Monitoring and Management to Promote Sustainable Behaviors

Sustainable Energy Systems PhD

IST-UTL

Background: **Master, Systems, Decision and Control, IST-UTL, Portugal**

Starting Year: **2009 / 2010**

Supervisor: **Pedro Lima [IST-UTL]**

Pedro Fazenda

Buildings in Portugal
- 30% of the Final Energy
- 35% of the Primary Energy
- 60% of the Electricity

Smart Buildings

The term assumes a functional approach and is normally associated with the **integration** and **automation** of Systems and functions to operate in ways that provide a responsive, effective and supportive environment, within which organizations can meet their performance objectives.

Objectives

This PhD is focused on using and developing tools for the Artificial Intelligence community that can be applied in Smart Buildings. The idea is to use these tools to manage building resources to achieve efficiency and minimum waste, while still promoting a comfortable environment and social satisfaction with the working and living spaces.

With increasingly sophisticated demand for comfortable environments and requirements for increased occupant control of such environments, a Smart Building will integrate the many systems that are part of the building and will act towards minimizing energy misusage and operating costs by manipulating available parameters, within an optimization space compliant with the comfort of the users of the building

Examples:

- A Building Management System (BMS) learns that the HVAC of a room can be shut off 30 minutes before launch hour, and connected 10 minutes before the user comes back from launch. Most of the times he does not notice it...;
- The BMS learns how to regulate illumination, without bothering its tenants;
- A BMS verifies if it can save energy by operating the elevators in a certain way;
- A BMS tries to sensibilize users to save energy, by promoting sustainable behaviors;
- A BMS detects that some spaces are very inefficient in terms of energy use, when compared to other similar spaces of the building, or even, other similar spaces in other buildings!

Work plan

The focus of the PhD thesis will start by including aspects of knowledge representation for the domain of intelligent energy systems, using description logics, and machine learning with planning under uncertainty. The work plan includes controlling several building variables like, e.g., lighting and the heating, ventilation and air conditioning system (HVAC). This can include the creation of new algorithms to accomplish the proposed objectives while dealing with the complexity of the domain, partial observable environments and limited actuation capabilities.

Results

Using a MDP to control the HVAC system

Some of the work that has been executed included the use of a Markov Decision Process (MDP) to control the HVAC system in a way that adapts to the behavior of the tenants, while maintaining operation needs to a minimum.

The idea is to reduce the HVAC system operation when the building or space is unoccupied and dynamically explore the heating and cooling set-points that satisfy user comfort, while minimizing the needs for thermal energy. The concepts of reinforcement learning, MDPs and Q-learning agents were studied and applied.

The BMS learns how to keep the temperature just above the tenant's comfort threshold, while he is in the room.
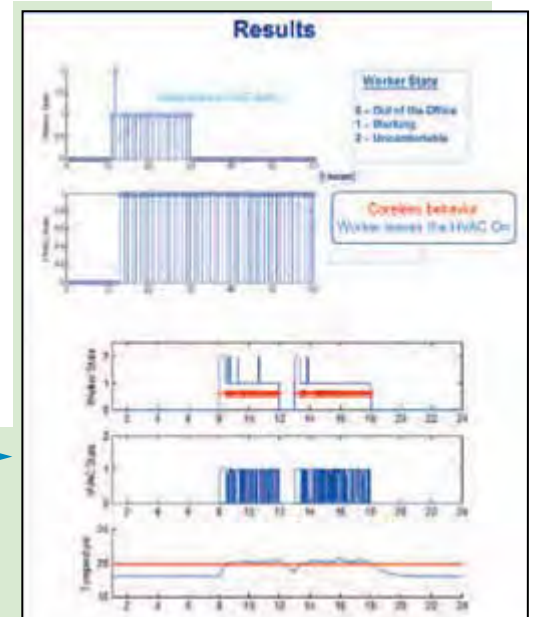
The BMS learns how to keep the temperature just above the tenant's comfort threshold, while he is in the room.

Impact of Vehicle to Grid in the Power System Dynamic Behaviour

Sustainable Energy Systems PhD

Background: **MSc. Electrical Engineering, FEUP, Portugal**

Portugal

Starting Year: **2007 / 2008**

Supervisor: **João Peças Lopes (FEUP)**

Research team: **J. A. Peças Lopes, M. A. Matos, P. M. Rocha Almeida, F. J. Soares, A. M. Moreira da Silva.**

Pedro Almeida

Objectives

The main objectives of this thesis are to prove that the electricity grids operation will benefit from the presence of Vehicle to Grid (V2G) connections and that a larger amount of Intermittent Renewable Energy Sources (IRES) can be integrated into these grids.

Work plan

Characterize and model from the dynamic point of view electricity grids, renewable energy sources and the power electronic interfaces for EV batteries.

Create scenarios representing: a) Microgrids, b) Multi-microgrids, c) Isolated systems d) Interconnected systems.

Define appropriate EV battery control strategies for several grid operating conditions, participating in reserves delivery in c) and d) or decreasing the need for dedicated storage in a) and b). Evaluate the dynamic behaviour of the system when facing different disturbances with the presence of V2G devices.

Evaluate the effectiveness of these control schemes regarding further large scale integration of IRES.

Results

Regarding primary reserve provision in isolated systems:

1. It is possible to verify that this system improved dramatically its dynamic behavior when EV electronic grid interfaces were used for frequency control.
2. Electric vehicles interfaced with the grid in a smart way can increase robustness of operation to power system dynamic behaviour.
3. The presence of a considerable amount of storage capability connected at the distribution level also allows the operation in islanding manner of distribution grids with large amounts of IRES and/or microgeneration units connected to it.

**Regarding secondary reserves provision in interconnected systems:**

1. Improvement of the system robustness of operation.
2. Increase of the system reserve levels that can be effectively mobilized for secondary control use.
3. Increase safe integration of renewable power sources in the system.
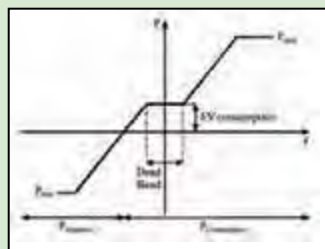
Fig. 1. Droop control mode envisioned for primary reserve delivery in isolated systems and PQ inverter control system
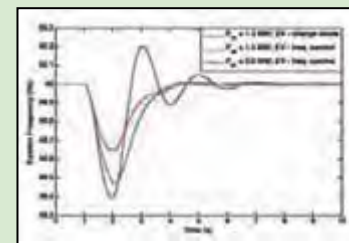
Fig. 2. Isolated system frequency for two EV battery control modes and two levels of wind penetration.
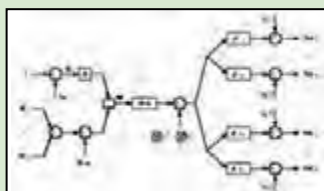
Fig. 3. AGC operation in the presence of EV aggregators.

Fig. 4. Interconnection active power flow Portugal-Spain (Portuguese export value).

	Reserve (MW)	Used Reserve (MW)			Reserve (MW)	Used Reserve (MW)	
		t=2min	t=15min			t=2min	t=15min
Hydro	459	461	461	Hydro	459	192	316
Thermal	590	211	256	Thermal	590	31	74
EV	0	0	0	EV	581	581	581
Total	1049	672	717	Total	1630	804	971

Table 1: Reserve Used Without EV Participating in Secondary Control.

Table 2: Reserve Used With EV Participating in Secondary Control.

Selection of glazing and shading devices for office buildings: criteria and integrated optimization
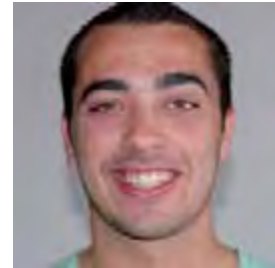
Sustainable Energy Systems PhD
FEUP
Background: **MSc. Mechanical Engineering, FEUP,**
Portugal
Starting Year: **2007 / 2008**
Supervisor: **Vítor Leal (FEUP), Marilyne Andersen (MIT)**
Research team: **Ana Neves, Filipa Carlos, Gustavo Haydt, Maria Kapsalaki, Reza Fazeli**

Pedro Silva

Objectives

This PhD envisages to typify the methods of selecting glazing and shading systems upon the energy consumption for heating, cooling and lighting, considering the dynamic interaction with the building occupants. It shall also use the results to assess the performance of different transparent surfaces at several climates.

Work plan
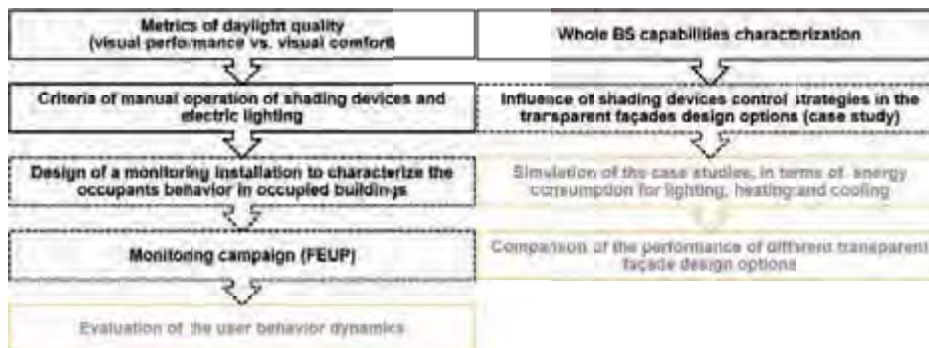
Fig. 1. Monitoring station and characterization of the visual indoor environment

Results

A literature review of the criteria used to evaluate daylighting quality of office buildings and to account for the occupants' behavior related to shadings and lighting provided the support for a post occupancy monitoring procedure definition (fig. 1), aiming the assessment of the visual environment and the identification of behavioral patterns of occupants in the manual actuation of shading devices and electric lights in occupied office buildings (fig.2).

It was characterized the capacities of building simulation software (fig.3) due to the modelling of occupants behavior and it was carried out a case study where it is studied the influence of shading devices control strategies in the transparent façades design options using different behavioral models and considering the overall building energy consumption and occupants visual comfort.
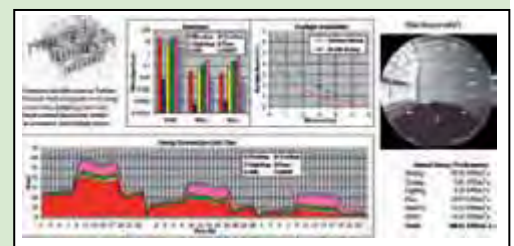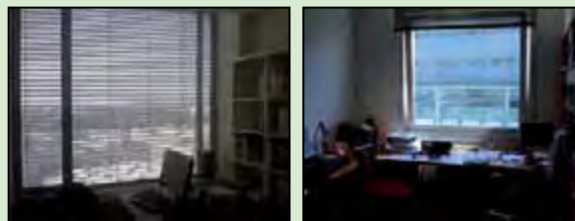

Fig. 2. Selected office buildings for the monitoring campaign

Fig. 3. Modelling capabilities of the BS software (i.e. ESP-r)

Nonlinear Dynamics of Arrays of Wave Energy Converters

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc. Electrical Engineering and Computers, IST-UTL**
Portugal
Starting Year: **2009 / 2010**
Supervisors: **António Falcão, Luís Gato (IST-UTL)**

Pedro Vicente

Objectives

To contribute to the development of wave energy conversion systems (WECs), particularly offshore oscillating bodies, proven to be the most promising. Emphasis is given to the modeling of the wave-device hydrodynamic interaction, operation of the energy absorption mechanism, hydrodynamic interference between devices in arrays and the influence of the moorings system. Different configurations of arrays and moorings are analyzed.

Fig. 1 - Offshore oscillatiiong WECs

Work plan

Initial study of the hydrodynamic modeling (in frequency and time domain, with one or more degrees of freedom) of offshore oscillating WECs and their mooring systems, both for individual devices and arrays.

Consideration given to the (linear and nonlinear) modeling of moorings cables under tension (tight mooring) and in catenary (slack mooring) and their impact on the converter oscillations and energy absorption process.

Selection of specific device of practical interest and business involvement, for a detailed numerical study and more realistic analysis.

Experimental analysis with a model testing at small scale (—1:80) in the wave tank at IST and followed by the scale of —1:35 in the wave tank at FEUP, for validation of the theoretical and numerical modeling results.

Waves generated simulating sea states representing a real wave climate (possibly of the Portuguese pilot zone). An effort will be done for the work to be integrated in solving real problems that appear at the successive stages of development of a floating offshore system.

Fig. 2 - Inter-moored array of WECs.

Fig. 3 - Different array configurations.

Fig. 4 - Array of inter-moored converters.

Results

It was considered that it may be more convenient and economical that an array is moored to bottom only through elements in the periphery, while others are prevented from drifting and colliding by connections to adjacent elements. This configuration has been analyzed, for different type of mooring systems and array configurations. Results indicated the viability of the system. The existence of a nonlinear behavior for slack moorings was observed. The influence of the mooring systems in individual devices with tight moorings was also analyzed with strong non-linear behavior in oscillations being observed.
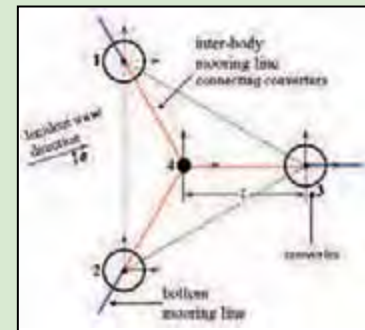

Fig. 5 - Research scope.

Development of a Multi-Criteria evaluation framework for alternative light-duty vehicles technologies

Sustainable Energy Systems PhD
FEUP
Background: **M.Sc. Energy System Engineering, Sharif University of Technology, Iran; B.Sc. Mechanical Engineering, University of Tehran, Iran**
Starting Year: **2008 / 2009**
Supervisors: **Vitor Leal (FEUP), Jorge Pinho Sousa (FEUP)**

Reza Fazeli

Objectives

This thesis aims to develop a methodology to evaluate different evolution pathways in terms of vehicle technologies-fuel pairs, under a multi-criteria decision making (MCDM) approach comprising environmental, economical and social issues.

The MCDM technique will be used both to compare the techology-fuel alternativas as well as the transition processes from the current state to state charactrized by each of those alternatives. System dynamics techniques will be applied in the later.

Work plan

- Identification through literature review, of main alternative fuel technology combinations applicable for light-duty vehicles (LDVs) (figure 1)
- Comprehensive attribute characterization of the different AFV technologies for current and for (expected) future stages.
- Development of a Multi Criteria Analysis model to evaluate the alternatives regarding the adoption of the different technologies. Screening is a process for multiple criteria decision analysis (MCDA) that reduces a large set of alternatives to a smaller set that most likely contains the best choice.
- Application of the methodology to three different geographical contexts (e.g. Portugal, UK and Iran), in order to assess the most adequate technology for each context.
- Tackling the transitional issues related with the adoption of AFVs using system dynamic methodology and evaluating policy impacts

Results

- The attributes which after extensive literature review, were categorized as: (figure 2)

  - Acceptance; which includes two sub-attributes; vehicle's present expenses and vehicle performance.

  - Emissions to Atmosphere; that translate the damage costs resulted from GHG emissions and Air pollution for each alternative.

  - Transition Cost; to compare the alternatives in terms of required investment in infrastructure

  - Risk of Technology Maturity; to compare the readiness level of each technology for operation in actual situation.

  - Security of Supply; Another key issue which recently obtained a lot of attention is the Security of Supply, which composed of three key factors; Energy Security, technological diversification and share of renewable.

- Development of Sequential Screening Methodology to identify a set of best alternative technologies (figure 3)
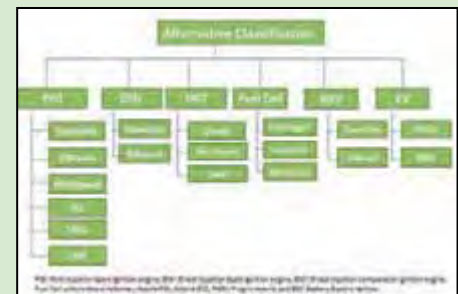

Fig. 1. Alternative fuel-technology combination for light-duty vehicles

Fig. 2. Classification of key attributes for evaluating alternative fuel-technology combination for LDVs
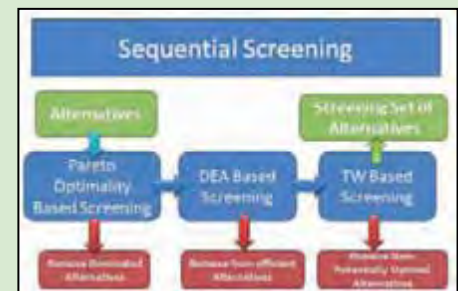

Fig. 3. Figure 3: Sequential Screening methodology to be applied for evaluation of alternatives

Towards Sustainability in Developing Countries

Sustainable Energy Systems PhD
IST-UTL
Background: **MSc Mechanical Engineering, IST-UTL**
Portugal
Starting Year: **2009 / 2010**
Supervisor: **Carlos Silva (IST-UTL)**
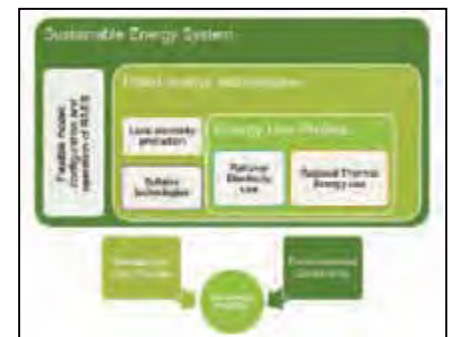

Rita Paleta

Objectives

The research assessments ponder over "Sustainability for a Developing Context", through exploration of passive design, supported with renewable technology to accomplish full development. Integrated in the sustainable built environment research field and energy providing systems, we propose to follow a new branch of study that focuses on discovering new tools to react to the complex issues of a developing country. Understanding the transformation and amelioration processes of human settlements on practical case studies in developing countries, it is crucial as there is a positive prospective for making a difference in this emerging circumstance.

Work plan
'RAES Project' / Rita Paleta

RAES Concept: Remote Autonomous Energy Systems (RAES), in its fully renewable or hybrid configuration (conventional auxiliary production based for example in diesel generators), are becoming a solution to places which, due to the high cost of transmission and distribution, are not connected to the grid until they do not meet certain load demand criteria. Thus, RAES are the most suitable energy infrastructure configuration once asses-sing isolated and distant places. Motivation: in developing countries, there are presently regions where energy supply is far from acceptable, which can compromise socio-economic progress in those places. The World Bank is planning the expansion of financial support for renewable energy and energy efficiency with special attention to those world areas. Methodology: 1) Case-study characterization through a socio-economic and technology indicator system; 2) Technology assessment; 3) Optimization method choice.

Towards Sustainability in Developing Countries

Sustainable Energy Systems PhD
IST
Background: **DLic. Architecture Design, FA-UTL, Portugal; Master in Advanced Architecture, UPC-IaaC, Portugal**
Portugal
Starting Year: **2009 / 2010**
Supervisors: **Manuel Arriaga Brito Correia Guedes (IST-UTL);**
Vallentyne Vinod Niranjan Kishore (TERI University);
**Chhaya Neelkanthray Hariprasad (School of Architecture, CEPT, Ahmedabad)**

Vasco Portugal

Objectives

The research assessments ponder over "Sustainability for a Developing Context", through exploration of passive design, supported with renewable technology to accomplish full development. Integrated in the sustainable built environment research field and energy providing systems, we propose to follow a new branch of study that focuses on discovering new tools to react to the complex issues of a developing country. Understanding the transformation and amelioration processes of human settlements on practical case studies in developing countries, it is crucial as there is a positive prospective for making a difference in this emerging circumstance.

Work plan
'Sustainability for a Developing Context' / Vasco Portugal

The main argument is that this research is crucial to generate new effective self sufficient-energy systems and evaluate the complexity to integrate energy producing/saving features in the slums building design processes. Part of this study focus on what I consider to be an essential critique of the present concept of the sustainable strategies, ignoring the building magnitude trough microgeneration and design as important elements in assessing energy, particularly in a developing environment where it becomes a powerful tool for alleviating poverty and reducing inequality. Methodology: Setting up settlement diagnoses following a set of determined study criteria. Analysis tools would be agreed upon each particular case, achieving a concept shaped into a prototype built and tested in Pune (India) with the support of the Vigyan Ashram Institute and collaboration of the MIT Fabrication Laboratory in Pabal.
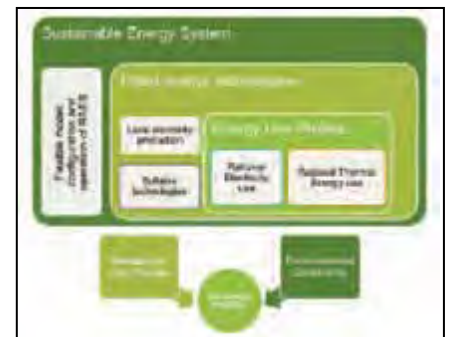
Development of offshore heaving two-body wave energy converters

Sustainable Energy Systems PhD

IST

Background: **MSc. Mechanical Engineering, IST, Portugal**

Portugal

Starting Year: **2007 / 2010**

Supervisors: **Luís Gato (IST), António Falcão (IST)**

Research team: **Miguel Lopes (IST), João Henriques (IST)**

Rui Gomes

Objectives

This PhD aims to contribute to the development of scientific and technical capabilities in the field of wave energy utilization, especially in offshore oscillating-body and oscillating water column (OWC) systems.

This work will compare the dynamics and power extraction of these two types of devices by means of numerical modeling and physical model testing in a wave tank.

Work plan

The PhD is focused on two types of devices dynamically comparable:
• IPS wave power buoy (Fig. 1);
• Floating oscillating water column (Fig. 2).

The work plan comprises the following phases:
• Optimization of the geometry of both type of devices based on numerical simulation;
• Control studies, optimization of the power take-off equipment and influence of mooring forces;
• Construction and testing of a physical model in a wave tank;
• Economic assessment of the selected device.

Fig. 1 - Three-dimensional representation of the IPS wave power buoy and electromagnetic brake to simulate the power take-off unit in a 1:35 scale model.

Fig. 2 - Floating OWC 1:35 scale model during preliminary tests.

Results

The geometry optimization of the IPS wave power buoy was made using a genetic algorithm (Fig. 3). Two maxima in the power extraction are observed. The maximum corresponding to a smaller device offer a better option for construction.
Numerical simulations proved the dynamic similarity between the IPS and the floating OWC. The floater highly influences the hydrodynamics of the devices. Additional inertia is given by the mass of water enclosed inside the tube.
Physical model testing at the irregular-wave tank (28mx12m) of FEUP will take place in 2010.

Fig. 3 - Optimization results of the IPS buoy geometry (Gomes et al., 2010). The graph represents the power extracted versus the volume of the device.

Transportation Systems

Development of Railway Track Degradation Model for Maintenance Optimization on HSR

Transportation Systems PhD
FEUP
Background:**Bsc. Engineering, University of Lampung, Indonesia;**
MSc Management Economics and Industrial Engineering, Politecnico di Milano,
Italy
Starting Year: **2008 / 2009**
Supervisors: **Raimundo Delgado, Rui Calçada (FEUP)**
Research team: **Raimundo Delgado, Rui Calçada, A. Cristina, C. Vale (FEUP);**
P. Teixeira, P. Ferreira, R.Santos (IST); Luis de Picado Santos, A. Ferreira,
D. Leal (FCTUC)

Abdur Berawi

Objectives

Identification on the key influencing parameters that may have great impact on the track degradation model.
Track Degradation Model based on the analysis of degradation pattern shown by track quality index as well as the frequency spectrum of track irregularities.
System Dynamic for Cost effective maintenance strategies

Work plan

Bibliographical research.
Revision and systematization of normative aspects related to track degradation model.
Analysis on degradation models based on the evolution of track quality indices and track irregularity frequency spectrum
Calibration and validation of the adopted methodologies by comparing analytical solution with the result presented in the case study.
Development of Track Degradation Models
Creation of System Dynamic for cost effective maintenance strategies.

Results

Berawi, A.R., Delgado, R., Calçada, R., Vale, C. (2009) Development of Railway Track Degradation Model for Maintenance Optimization on HSR. Proceding of the 11th International Conference On Quality In Research (QIR) 2009, Indonesia , 3-6 August, ISSN 114-1284.
Berawi, A.R., Delgado, R., Calçada, R., Vale, C. (2010). A Study on the Methodology for Evaluating Track Quality Condition. International Journal of Technology, University of Indonesia" (on submitted).
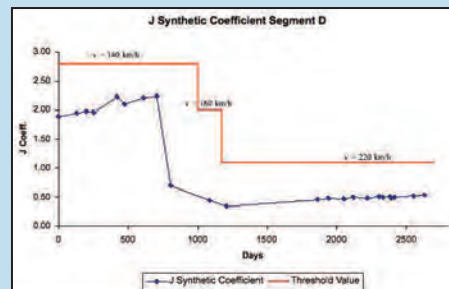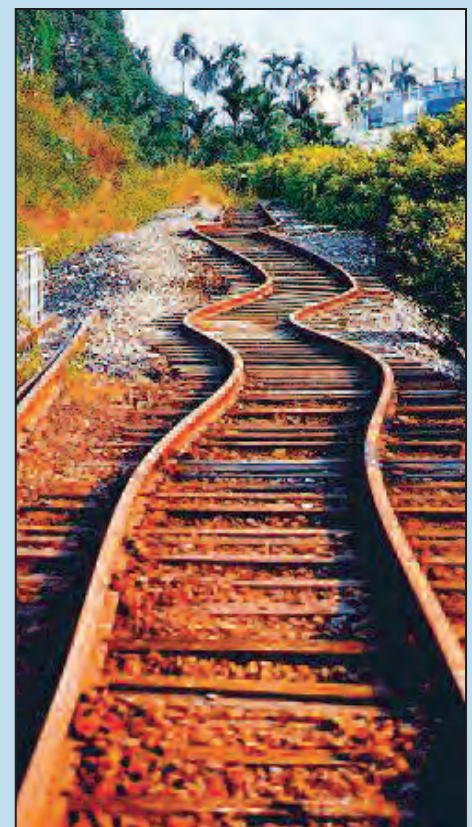
A) Track evolution by using J Synthetic
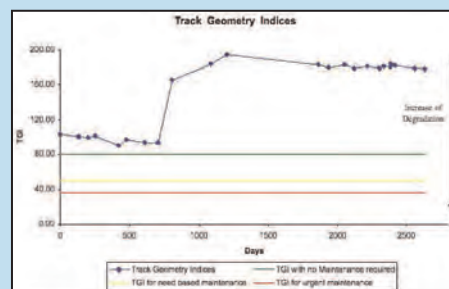
B) Track Evolution by using TGI
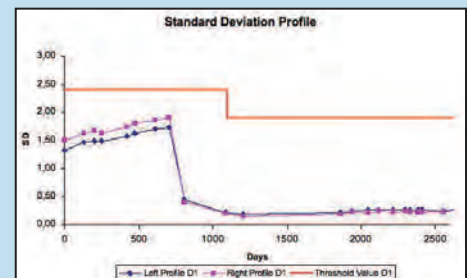
C) Track Evolution by using European Standard

Air Transportation for effective and efficient service to small remote communities: Policy options under regulatory reforms

Transportation Systems PhD

FEUP

Background: **Diploma in Civil Engineering (Urban Planning Transportation and Management), IST-UTL, Portugal; Postgraduate studies in Management (Marketing), ISCTE, Portugal**

Starting Year: **2007 / 2008**

Supervisors: **Álvaro Costa (FEUP) and Richard de Neufville (MIT)**

Research team: **V.Chu, A.T. Pereira, A. Pimentel, M. Santos**

Alda Metrass Mendes

Objectives

Governments are expected to ensure cohesion of their territories by sustaining accessibility to all regions, including small and or remote communities. In cases where alternative transportation links are scarce or unavailable, air service becomes essential. Typically, governments' role in serving these centers was facilitated through regulatory provisions. The paradigm shift launched by liberalization of the airline industry, and caused by loosening of control over markets, questions the traditional mechanisms for ensuring equitable air accessibility. As the result, nations worldwide now face the challenge: effective and efficient sustainability of air service to small communities under regulatory reforms and conditions. The circumstances provide incentives for air transportation policy design deployment and intervention worldwide.

This research project aims to promote and bring depth to the worldwide debate on regulatory reforms of air transportation policies for small remote communities. The primary goal is to inform and assist policymakers in their decisions. This will be accomplished through a case-based cross-national comparison analysis of the deregulation experiences of several countries.

Work plan

The research will consist of three elements: (A) the development of a mixed (quantitative and qualitative) approach to evaluate the performance of policy mechanisms for provision of air service to small communities, (B) a policy analysis that evaluates the impacts of different design options, using the product of the first part, (C) an inference process that will use the results of (B) to formulate recommendations for designs under different circumstances, taking into account the similarities and variations in regulatory, institutional and economic realities.

Results

The ultimate goal is to provide feedback and formulate recommendations for policy decision-making, though there is also much to be done with respect to best practices in terms of the tools used in their assessment. Another aspect that also requires attention is the multi-national comparability and use of multiple case-studies. Furthermore, devising best-practices that account for country specificities is a challenging task. This research has expected contributions in all of these areas.

Fig. 1. Research procedure: three levels of analysis (PE and CBCN). The circles represent the nations in the study.
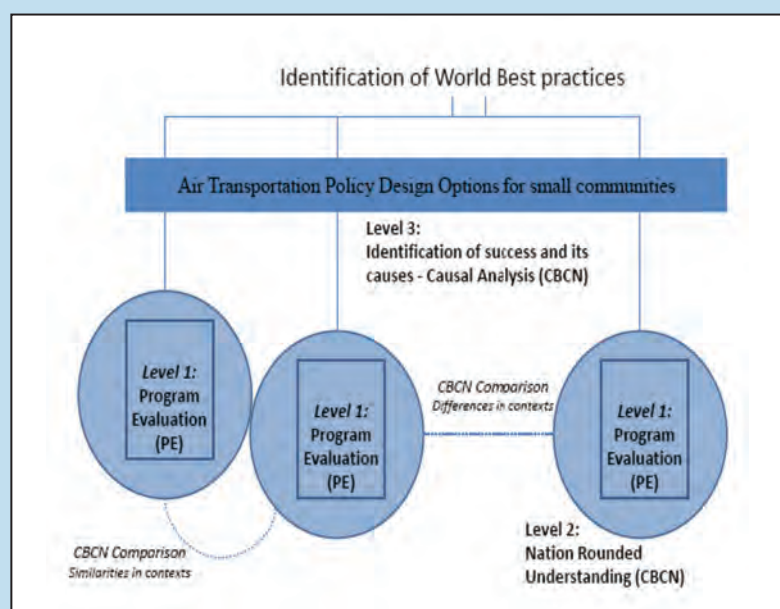
Risk Assessment and Management for High-Speed Rail Systems based on Scenario Description under Uncertainty

Transportation Systems PhD
IST-UTL
Background: **MSc Civil Engineering, FCTUC, Portugal**
Starting Year: **2008 / 2009**
Supervisors: **Paulo Coelho, Maria da Conceição Cunha (FCTUC)**
Research team: **A. Costa, P. Coelho, M. Cunha, H. Einstein**

Ana Costa

Objectives

-Develop decision aid tools for high-speed rail systems.
-Integrate various aspects of risk analysis and management (Figure 1).
-Consider different possible scenarios under uncertainty.

Work plan

The methodology used encompasses the following main steps:
-Carrying out a comprehensive characterization of geotechnical, seismic and hydrological risks, including their effects and mitigation measures;
-Establishing the technical alternatives that may be considered in the construction;
-Defining future scenarios for project lifetime;
-Applying available and designing innovative tools that may be used for current practice in decision-making.

Results

On completion of the research, decision aid tools based on robust optimization techniques will be proposed. These will enable the consideration of risk through scenario descriptions of uncertainty.

Some examples of the undergoing development are shown: the model representation of problem specifics (Figures 2) and results of the tool application in normal operating conditions (Figure 3).
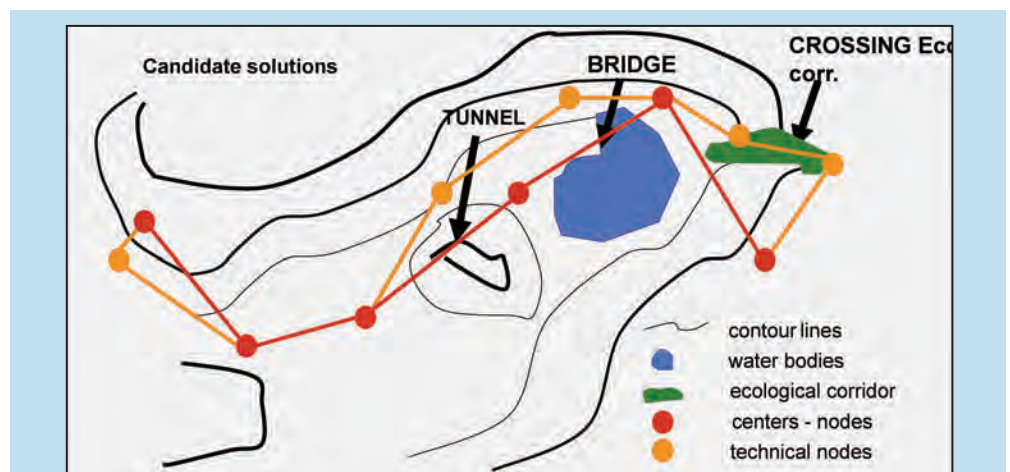
Fig. 1. The figure illustrates the problem idealization, where different characteristics of the configuration may influence the risk level
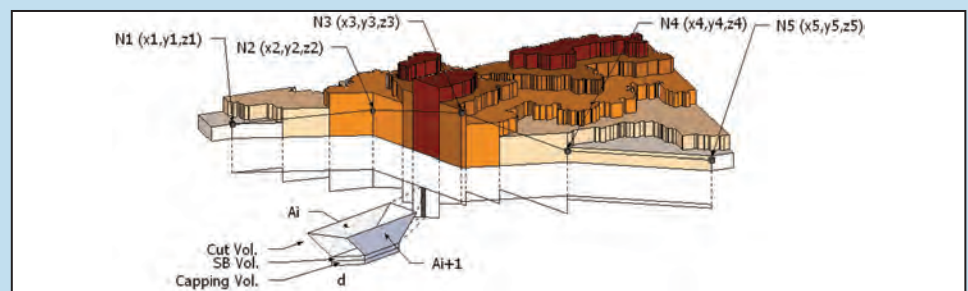
Fig. 2. The figure shows the undergoing development of tools for risk analysis, considering different cross-sections with the ability to compute earthworks' volumes. Earthworks is an important component of a configuration cost.
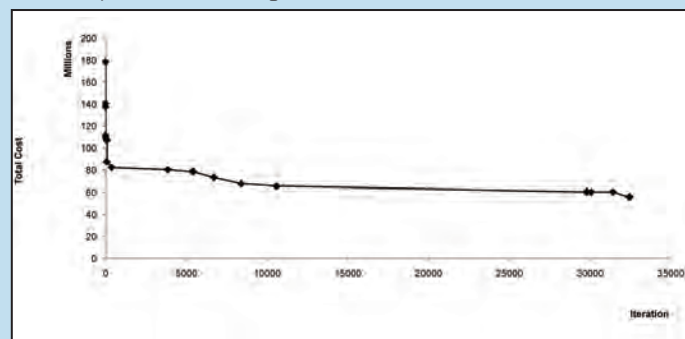
Fig. 3. The figure shows the undergoing development of tools for risk analysis, applied to a synthetic case study in normal operating conditions. The chart represents the evolution of the best configuration found by the tool. It relates the overall cost with the iteration number of the implementation of an optimization algorithm to solve the model.

Business Models in Urban Logistics

Transportation Systems PhD
IST-UTL
Background: **Bsc. MSc, Spatial Planning Engineering, IST-UTL, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **R. Macário (IST)**
Research team: **A. Antunes, J. Ferreira, R. Macário, J. Sussman, J. Viegas, C. Zegras, G. Caiado , M. Diao, T. Dunn, C. Grillo, A. Guevara, W. Li, L. Martinez, S. Melibaeva, L. Rayle, A. Sevtsuk, N. Pinto, M. Santos, M. Spandou , J. Zeferino**

Ana Galelo

Objectives

To understand the urban logistics, namely towards the interrelations and inter-actions among stakeholders.
(Figure 1)
 To establish knowledge on transferability of the Business Models (BM) concept to the urban logistics field. (Figure 2)
 To identify measures that would enable the success of Business Models in Urban Logistics in service exploitation.
To prove that there is potential for private entrepreneurship in the service ex-ploitation domain that can be stimulated by Public policies.

Results

It is expected to develop a package of measures and policies that could enable the success of new Business Models in the Urban Logistics. Since it seems there is potential for private entrepreneurship in the service exploitation domain, it is also envisaged to stimulate this potential through modeling of adequate Pu-blic Transportation Policies.

Work plan

The methodology used encompasses the following main steps:

Understand the interrelations and in-teractions among stakeholders.
- Identify the design patterns and ty-pologies of BM in service exploration. Performance measurement of the current business models in urban lo-gistics (comparative study Paris/Lis-bon).
- Develop the BM approach in the Urban Logistics through theoretical and empirical perspective.
- Modeling institutional measures and policies that will better induce the correct agents' behaviour for service enhancement in urban logistics and investigate their feasibility

LEGEND
- Freight concentration facility outside the city centre
- Urban road/ rail freight distribution centre
- Delivery points (shops, etc.)
- Road/Rail connections
- Last mile delivery

City

Metropolitan area

Fig. 1. Urban Logistics System (Macário et all, 2007)

Business Process

Infrastructure

Business Model

Business Structure

Systems

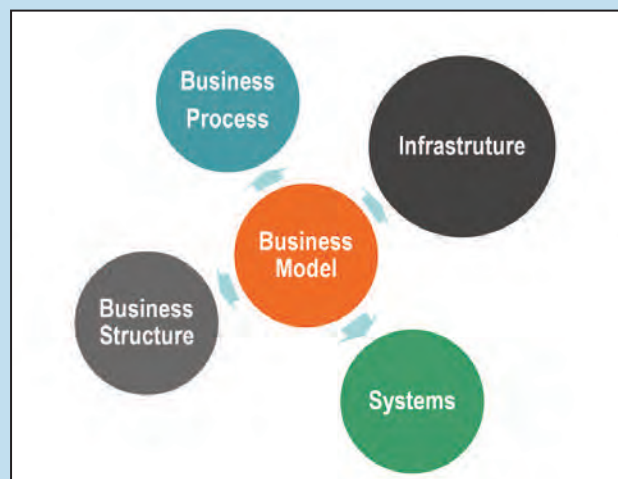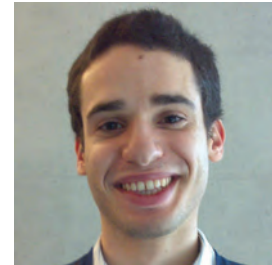*Fig. 2.* Business models transla-tion into four main elements. (Macário et all, 2008)

Rail track degradation models for life-cycle cost modeling

Transportation Systems PhD
IST-UTL
Background: **Msc, Civil Engineering, IST-UTL, Portugal**
Starting Year: **2009 / 2010**
Supervisor: **: Paulo Fonseca Teixeira (IST-UTL)**

António Andrade

Objectives

- Modeling rail track geometry degradation phenomenon and track components degradation;
- Assessing the evolution of uncertainty associated to rail track degradation phenomena throughout rail track life-cycle;
- Assessing the impact of life-cycle uncertainty in the decision-making process regarding maintenance and renewal actions.

Work plan

- Develop rail track degradation models using statistical exploratory analysis with inspection and maintenance data from the Portuguese Infrastructure Manager (REFER);
- Build up a Bayesian framework to assess the evolution of life-cycle uncertainty related to each parameter of each degradation model;
- Incorporate rail track degradation models and the Bayesian framework in a decision support system using a multi-objective optimization perspective.
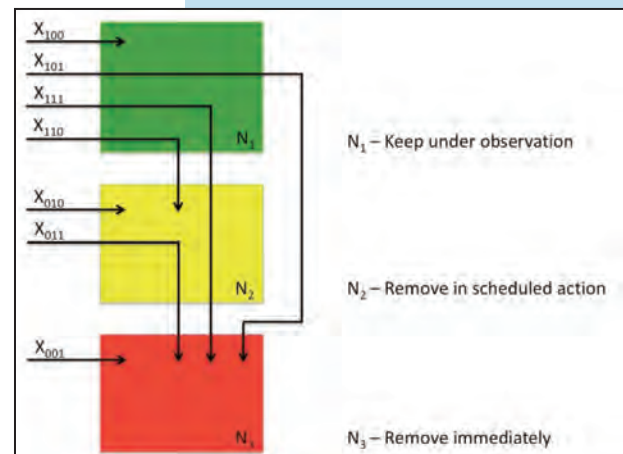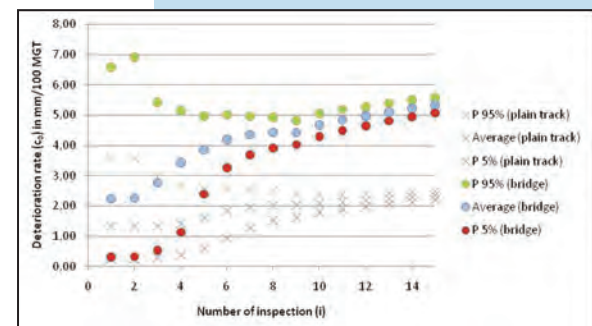
Results

- A decision support system capable of optimizing rail track maintenance and renewal actions from a multi-objective perspective while accounting for the evolution of uncertainty throughout the rail track life-cycle.
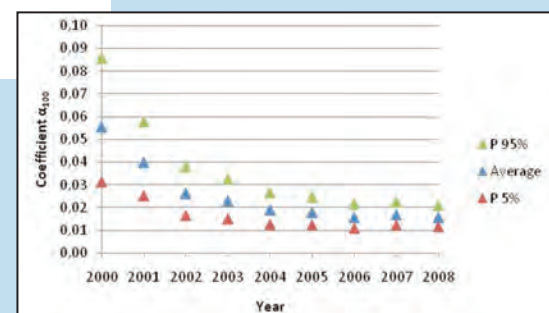
Safety Criteria for the Management of Variable Speed Limits

Transportation Systems PhD
IST-UTL
Background: **Diploma in Civil Engineering (Structural Engineering), MSc. in Transportation, IST, Portugal.**
Starting Year: **2007 / 2008**
Supervisors: **João Cardoso (LNEC), Moshe Ben-Akiva (MIT), and José Viegas (IST)**
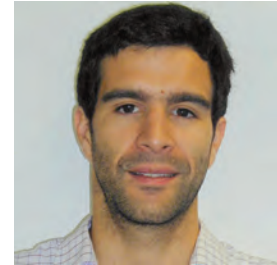
Carlos Azevedo

Objectives

In Intelligent Transportation systems (ITS) evaluation, micro-simulation is increasingly becoming a powerful and essential tool. In the evaluation process, safety analysis is an important step that should be always taken into account. However, the mechanics behind the safety effect of some ITS applications, such as variable speed limits (VSL), are still unknown and classical microsimulation traffic outputs may not be sufficient for an accurate safety analysis. Accident risk estimation is often used as instrument to fulfill this gap, using calibrated simulation output data to evaluate the safety level of a specific site. The main objectives of the proposed research thesis are:

(1) Integrate safety assessment in the state-of-the art traffic micro-simulation tools by developing accident prediction models (APM) for the urban motorway environment.
(2) Identify the safety benefits of Variable Speed Limits systems (VSL) in urban motorways and recommend best strategies for its application.
(3) Understand how ITS affects driver behaviour on urban motorways, and identify which of the related changes may influence road safety.

Work plan

(1) Comprehensive study of APM, driver behaviour modelling and micro simulation, and effect of VSL signs.
(2) Modelling and calibration of a Portuguese urban motorway pilot site in the micro-simulation application MITSIMLab (Fig. 1).
(3) Development of an APM that quantifies accident frequencies on the basis of real-time traffic characteristics and integration with MITSIMLab.
(4) Modelling of the VSL system, definition of control strategies (Fig. 2) and evaluation of their effectiveness in reducing accident risk.
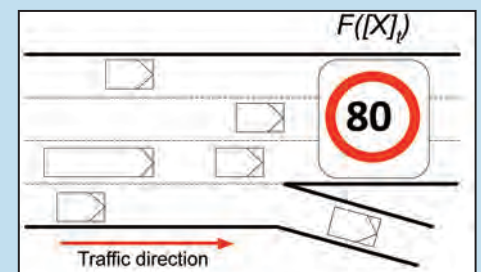(5) Conclusions and recommendations of best strategies in the application of VSL systems in Portuguese urban motorway sites.

Results

The recommendation of best strategies in the application of VSL and a detailed APM for Portuguese urban motorway sites will form the main results of this PhD program.
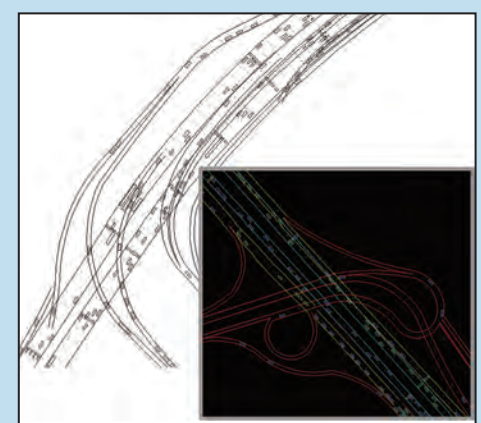
Fig. 1. MITSIMLab screenshots

Fig. 2. VSL schematic modelling

Fig. 3. IVSL implementation in the UK

Emerging Energy and Technology Patterns in Transportation Systems and the Kondratieff Waves Theory – The Case for Air Transportation

Transportation Systems PhD
IST-UTL
Background: **Diploma, Engineering and Industrial Management, IST-UTL, Portugal; MSc, Transportation, IST-UTL, Portugal.**
Starting Year: **2009 / 2010**
Supervisor: **Rosário Macário (IST-UTL)**
Research team: **(IST) Rosário Macário, Vasco Reis, Carlos Marques, Eddy van de Voorde, José Viegas, (FEUP) Jorge Pinho de Sousa, João Claro (FCTUC) António Pais Antunes, (UBI)Jorge Reis Silva, Margarida Vaz, J. Bousson**

Carlos Marques

Objectives

To establish a sound knowledge base on the impact of the economic "Long Waves" on technology and energy patterns in transportation

To design a macro-behaviour system dynamic's model to simulate impacts of fundamental energy, environmental, economic, social, technological and political trends in transportation,

To setup likely "futures" for air transportation across the first half of the XXI century derived from emerging economic, technological , social and business patterns

Work plan

The methodology used encompasses the following main steps:

Undertake a comprehensive state-of-the-art review on the theory of the Kondratieff "Long Cycles", comparing the structure of the first four Kondratieff waves to infer the driving forces and constraints linked to the emergence of a possible fifth Kondratieff wave.

Identification of energy, technology, social and political changes needed to support the requirements of an air transportation system, meeting demanding requirements

Discussion on the crossed implications for the economy in general and the air transportation sector in particular, from a system dynamics perspective, identifying major contextual factors in which the concept of the Long Waves is embedded,

Develop scenarios for energy, technology and business paradigm shift in air transportation, overlaying the predictive context associated to the Long Waves theory in order to discuss the results towards the horizon 2012-2030
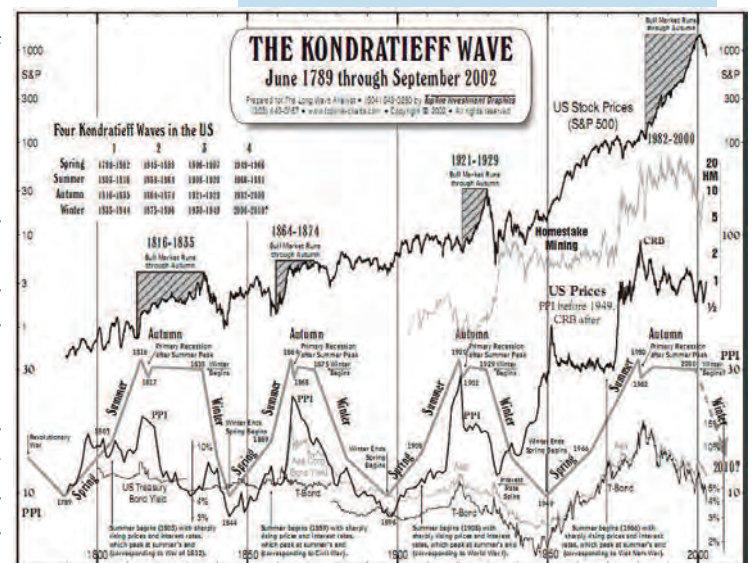
Results

The research is expected to demonstrate that "Long Waves theory" associated to system dynamics' modeling constitutes a sound theoretical predictive approach to determine the context for changing energy, technological and trends and features in transportation across the first half of this century, with a focus on Air Transportation
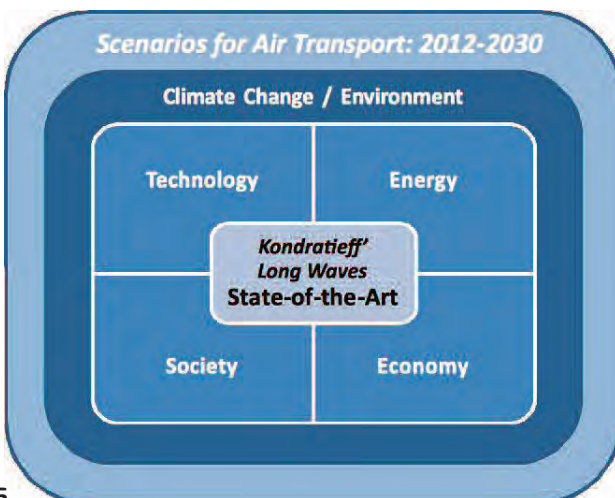
Fighting Parasite Circulation Through Online Parking Space Reservations

Transportation Systems PhD

IST-UTL

Background: **MSc in Computer Engineering, FCTUC, Portugal**

Starting Year: **2007 / 2008**

Supervisor: **João de Abreu e Silva (IST)**

Research team: **J. Viegas, J. de Abreu e Silva, R. Macário, Á. Seco, M. Ben-Akiva, W. Mitchell, J. Sussman, D. Carvalho, R. Arriaga, C. Azevedo, T. P. Dunn, A. Sevtsuk**

Diana Carvalho

Objectives

-To conceive, develop and evaluate a system of online parking space reservations to help fight parasite circulation and therefore contribute to a reduction of congestion levels and its negative impacts (Fig. 1);

-To study its implications on the urban mobility patterns and devise ways of using it as tool for promoting a more sustainable mobility, namely through the promotion of modal transfer and by providing financial compensations to the remaining Mobility System (Fig. 2).

Work plan

The system is being conceived in a way sensible to the policy issues of car use and parking, namely equity and discouragement of further car use:

-frequency of use restrictions and an extra price for the service (conditioning the type of trips eligible – only those highly valued to be made by car);

-availability only in designated parking areas – those with great demand for discretionary travel (Fig. 3), and with good transit alternatives;

-directing with consent users to more external parking lots, providing transit alternatives to their final destination.

Crucial to the accomplishment of the objectives of the system is proper enforcement.

Parasite circulation and parking behavior are to be further studied to more clearly identify areas of intervention and potential gains in performance, as well as the cross-financing mechanisms to apply to the profits generated.

Fig. 1.

Results

We expect that the benefits of improving the efficiency of traffic looking for a parking space, via the mitigation of its wasteful components, as well as the interactions devised with the remaining Mobility System, will be relevant to all elements of it, namely in the reduction of pollutant emissions, fuel consumption and congestion levels, with the consequent time savings for users and increased quality of urban mobility.
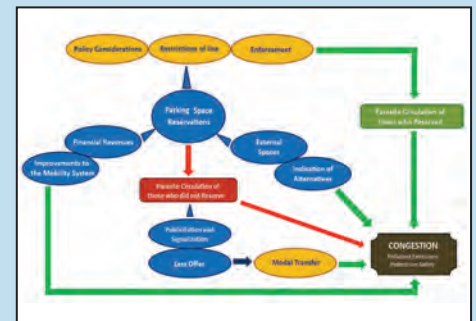

Fig. 2.

Fig. 3.

Goods Traffic on High Speed Railway line Lisbon - Madrid

Transportation Systems PhD
FCTUC
Background: **Diploma and MSc, Civil Engineering, FCTUC, Portugal**
Starting Year: **2008 / 2009**
Supervisor: **Luís Picado-Santos (IST and FCTUC)**
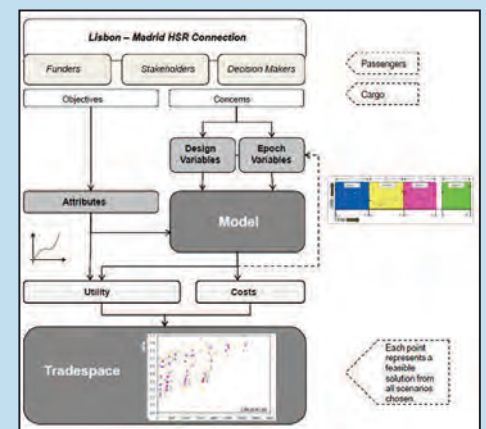Research team: **CIEC - UC**

Diana Leal

Objectives

The introduction of freight-rail services in the Lisbon – Madrid High Speed Rail Line will propose new trade markets and new commercial opportunities. The objective is to estimate the feasibility of having cargo on High Speed Rail Lisbon-Madrid line involving the connection to sea ports located on the south coast of Portugal and to the logistic freight facilities.

Work plan

The main task within this work is to develop a fleet model tool for a Portuguese case-study, capable of generating scenarios to support strategic options on high speed rail line. The study will be based on multi-attribute analysis which aims to evaluate different alternatives within the same transport. This methodology, called MATE – Multi Attribute Tradespace Exploration, has been tried with success to process development for several kinds of products. This method is selected to identify preferable alternatives to the use of the high speed rail line by the establishment of the trade-off between a countable numbers of criteria and thus fully ranked alternatives and approaches usually absent in traditional rank-based methods.

Results

Predictable results based on MATE approach follows the idea of scenarios generation in order to obtain the "Best Value" based in a sensitive analysis. This model includes not only the most properly stakeholders, funds and decision makers of the project, but also the operational and maintenance concerns supported by life cycle analysis. It is expected that this fleet tool to be an efficient support to deal with strategic options in high speed rail investment.

Active Traffic Management of Motorways for Increased Safety, Efficiency and Sustainability

Transportation Systems PhD

FCTUC

Background: **Bsc. Civil Engineering, University of Asmara, Eritrea**

Eritrea

Starting Year: **2008 / 2009**

Supervisor: **Luís Picado-Santos (IST and FCTUC)**

Research team: **Prof. Picado Santos, Prof. José Viegas, Dr. SílviaShrubsall, Filmon G. Habtemichael, and MahdiHajizamani**

Filmon Habtemichael

Objectives

- Managing motorways, and more specifically the lanes of motorways, actively on real-time traffic conditions
- Eliminating and/or regulating speed variations between vehicles within a lane and across lanes so that accident and its severity are reduced
- Accessing driver's and vehicle's competence to handle the real-time traffic conditions, and their management within the motorway network
- Securing sustainability of motorways through increase in safety, better throughput of available motorway space, and reduction in emission

Work plan

- Forecast of traffic demand and compare against infrastructure supply
- Developing models and algorithms for Active Traffic Management (ATM) strategies, e.g. Variable Speed Harmonization, on motorways
- Relating ATM strategies with in-vehicle systems that monitor driver's and vehicle's competence to handle the real-time traffic conditions
- Economic evaluation of the system and preparation of business model for deployment of the system

Results

Expected results include:

- Steady flow of traffic across time and space on the motorway
- Homogenous driving characteristics across drivers on motorways
- Prevention of incompetent drivers from driving on motorways
- Increase in safety and efficiency of motorways while reducing emissions
- Overall sustainability of motorway

Introducing intelligent vehicle into an intelligent infrastructure and monitoring driver competence

Intelligent infrastructure

Intelligent vehicles

Monitoring driver competence
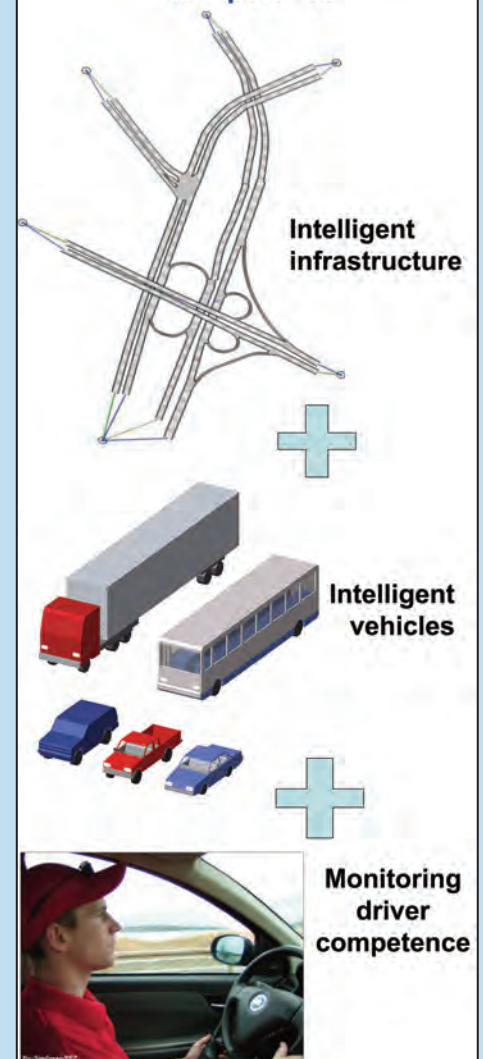
Airport Demand Management
(a hybrid approach)

Transportation Systems PhD
IST-UTL
Background: **Diploma, MSc, Mechanical Engineering, IST-UTL, Portugal; Portugal**
Starting Year: **2009 / 2010**
Supervisor: **Rosário Macário (IST-UTL)**
Research team: **R Macário , JM Viegas, E van de Voorde, V Reis (IST); JP Sousa, J Claro (FEUP); J Silva, K Bousson, M Vaz (UBI)**

Frederico Morgado

Objectives

As air transportation increases, there is a recognized impossibility for physical infrastructure capacity to follow, thus generating the need to adopt demand management procedures under congestion scenarios, namely on assignment of slots to airlines.

Demand management is a solution to mitigate such congestion and aims at diverting flights from peak hours (demand reduction) to other airports or other hours of the day in order to obtain reduction or elimination of delays. This is a highly non-linear problem where a small reduction in demand results in a big reduction in delays experienced by users. Current work lies on both strategic and tactical levels for such task.

The current work takes a hybrid approach, which is a combination of administrative and economic, in order to avoid some of the disadvantages of these options. This approach takes into account that some regulatory and administrative options will have to be present and imposed before any study on the best business model for each specific airport. For example, if slots can be tradable, if auctions are possible, if small operators or general aviation are going to be protected against congestion pricing, how many slots are to be assigned for new entrants, legacy airlines, etc.

As the airport strategy influences demand, a number of indicators related to profit and welfare are expected to render feed-back information in an optimization process to attain the best airport strategy, and to study the influence of the adopted regulation package.

Work plan

A mixed deductive/inductive method will the basis for the thesis as follows:
Evaluate state of the art and airport strategies worldwide;
Model constraints, business models and agents behavior;
Application to case-studies airports;
Develop indicators for change of strategy based on welfare and/or profit.

Results

By the end of the thesis (end target date Oct'2013), it is expected that we have proved that each airport has a unique best strategy in terms of demand management, taking into account the airport characteristics and constraints (in terms of selected business model, regulation and demand) and the desired economic result (maximum profit of airport and/or airlines or maximum welfare).
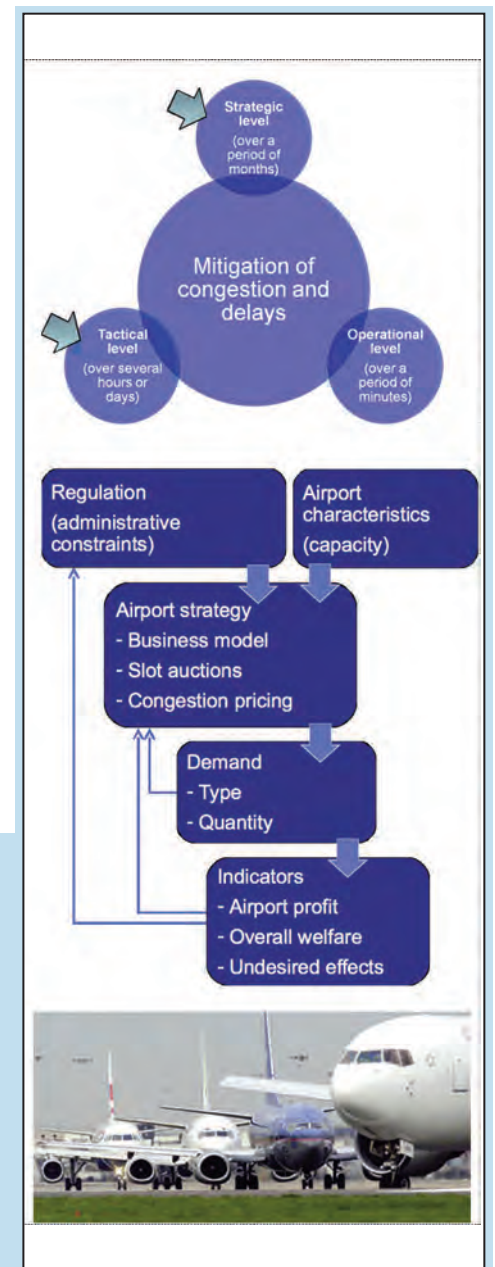
Modelling the Vulnerability of Complex Transport Network Systems: An Application to Seismic Risk in Urban Environment

Transportation Systems PhD
IST-UTL
Background: **Diploma, Spatial Planning Engineering; MSc, Transportation, IST-UTL, Portugal.**
Starting Year: **2008 / 2009**
Supervisor: **Rosário Macário and Carlos Sousa Oliveira (IST-UTL)**
Research team: **A. Antunes, J. Ferreira, R. Macário, J. Sussman, J. Viegas, C. Zegras, G. Caiado, A. Galelo, M. Diao, T. Dunn, C. Grillo, A. Guevara, W. Li, L. Martinez, S. Melibaeva, L. Rayle, A. Sevtsuk, N. Pinto, M. Santos, M. Spandou, J. Zeferino**

Gonçalo Caiado

Objectives

Past experience has shown that earthquake damage to roadway components can severely disrupt traffic flows and impact the economy of the region as well as post earthquake emergency response and recovery actions. The purpose of this dissertation is twofold:
- develop and validate a model to assess urban road network seismic vulnerability, and;
- elaborate seismic risk reduction strategies in urban road networks.

Work plan

The work to be developed will be structured into five main working areas. Firstly, the Overall Context and Research Method will introduce the problem to be addressed. Secondly, the Framework for Assessing Road Network Seismic Vulnerability will develop a method to evaluate road network seismic vulnerability. Afterwards, in Urban Road Network Vulnerability Case Study this method will be validated. Next, in Managing Complexity in Urban Road Network Vulnerability Mitigation, a systematic approach to tackle seismic risk reduction strategies will be developed. Finally, Conclusions and Recommendations will focus on hypothesis demonstration and research evidences.

Results

The risk reduction strategies to be proposed will include a set of macro and micro scale solutions to be included in: i) specific instruments (such as municipal emergency plans); ii) programs (e.g.: protection of critical mobility assets; enhancement of traffic management capabilities; etc.), as well as; iii) urban planning instruments and policies (such as the Urban Master Plans; other urban plans, or; urban renewal policies).
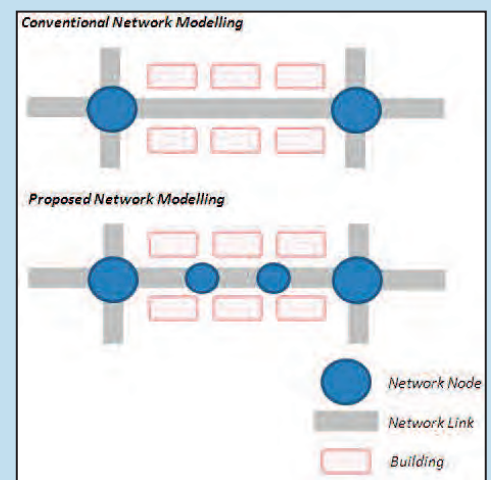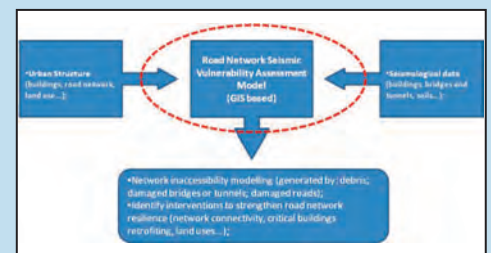
Airline Network Design under Congestion

Transportation Systems PhD
FCTUC
Background: **MSc in Civil Engineering, FCTUC, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **António Pais Antunes (FCTUC), Amedeo Odoni**
and Cynthia Barnhart (MIT)
Research team: **Cynthia Barnhart (MIT), Álvaro Costa (FEUP), Joana Dias**
(FEUC), Rosário Macário (IST)

João Pita

Objectives

Develop models to optimize the design of air traffic networks while maximizing airline profits or minimizing generalized transport costs. Those models can help aeronautical authorities in slot allocation process and airlines in their schedule design and fleet assignment processes. Congestion costs associated with the delays in the system – for passengers and airlines - are included in the model. The airline model also considers airline competition and alliances between airlines.

Work plan

The work plan comprises the following stages: (1) Conceptual design of the air traffic network design models - Oct08/Apr09; (2) Formulation and solving of the air traffic network design models - May09/Apr11; (3) Linkage of the air traffic design models with a delay propagation model - Oct09/Sep10; (4) Real-world applications: European Union air transport system and Portuguese airlines – Oct09/Sep11.

Results

An integrated mix-integer linear schedule design and fleet assignment model was already developed and applied in practice. In the model the objective is to maximize the airline profit while taking into account operational constraints – slots, fleet –, forecast demand, competition, and expected delay times.

Three aspects are new in integrated schedule and fleet assignment models: 1. costs for flights and passengers that miss their connection due to congestion of airports; 2. airline competition by using a piecewise linear approximation of the market share empirical s-curve; 3. airline alliances by allowing passengers to use connected itineraries shared between two airlines.

The model was applied for all week days to a TAP network including 31 airports. Results show that it is possible to increase airline profits (3 to 8%) by changing the schedule of flights. Passenger waiting times increase slightly in the optimized solution but disruption costs are reduced by almost 50%. The total number of flights is reduced between 2% and 5%.
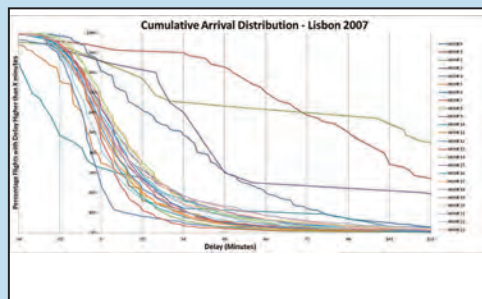
Fig. 1. Arrival Distribution (Lisbon)
The figure shows the arrival distribution in the Lisbon Airport in 2007. This data gives us the probability of having delays higher than a given amount of time

Fig. 2. Summary of Results (Week)
The table summarizes the main results of the application for a week of TAP Portugal operations. Market share, congestion costs and the possibility of changing slots within an hour have great impact in the final results.

Fig. 3. Frequency changes (Friday)
The total number of flights is reduced 2% from 240 to 234. The expected passenger disruption cost decreases from 4.58% to 2.73% of total costs while the passenger waiting time increases 7 minutes. The total delay cost is reduced 2,3% to 8% of the total costs.

Dynamic Data Fusion and Traffic Prediction System

Transportation Systems PhD
IST-UTL
Background: **Diploma, Computer Engineering, FCTUNL, Portugal; MSc, Geographic Information Systems, IST-UTL, Portugal**
Starting Year: **2008 / 2009**
Supervisor: **João Bento (IST), Moshe Ben-Akiva (MIT)**

Jorge Lopes

Objectives

1. To design an innovative framework architecture for the real-time generation of effective anticipatory traffic conditions.
2. To propose an advanced traffic management and information plan based on proactive strategies (see Fig. 1).
3. Evaluation schema to measure and analyze the benefits of real-time information prediction for network operators and for drivers.

Work plan

The PhD work plan is scheduled for a period of three years and focus the following research questions:

1. Automatic traffic surveillance, to proceed with dynamic traffic and mobility data collection, cleaning, fusion, mining and transfer.
2. Traffic and congestion prediction, to evaluate and combine prediction methods to generate effective anticipatory traffic conditions (see Fig. 2).
3. Incident-related congestion prediction, to fine-tune prediction results for unexpected, non-recurrent traffic scenarios.
4. Advanced traffic operations, to implement proactive traffic management strategies to improve network performance.
5. Active traveler information services, to promote route guidance supported by incident warnings and anticipatory delay notifications.

Results

The expected outcome of this research program attempting to create a kind of "transportation time machine" able to collect, evaluate and process real-time traffic and mobility data, to generate and deliver dynamically short and medium-term anticipatory traffic conditions (see Fig. 3). Ultimately, it will enable the traffic management system to use such predictions to adjust control measures and, in some form, to visit and change the transportation system's future.
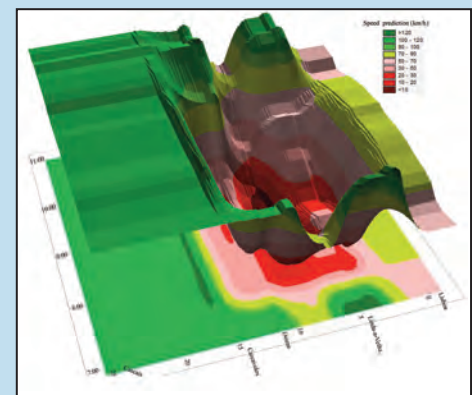

Fig. 1.

Fig. 2.

Fig. 3.

The Emergence of Collaboration in Metropolitan Governance: Two Perspectives from Portugal

Transportation Systems PhD
IST-UTL
Background: **Msc in City Planning, Msc of Science in Transportation**
Supervisors: **Chris Zegras (MIT), Joseph Sussman (MIT)**
Research team: **A. Antunes, J. Ferreira, R. Macário, G. Caiado, T. Dunn, C. Garcia, C. Grillo, A. Guevara, M. Hatzopoulou, S. Jiang, J. S. Lee, W. Li, L. Martinez, N. Pinto, B. Santos, M. Spandou**

Lisa Rayle

Objectives

Recent research on planning and transportation has called for greater coordination between fragmented government agencies. In Portugal, declining urban centers and sprawling suburbs, combined with the absence of a metropolitan planning structure, have heightened the importance of inter-agency collaboration. Many studies point out the barriers to collaboration. But what forces actually contribute to its emergence? In this research I consider two questions:
1. What conditions and factors have led to inter-organizational collaboration in the Portuguese context?
2. What is the potential for a particular scenario-building process to lead to further collaboration among those who participated?

Work plan

The methodology involves two parallel approaches:
1. Interpretive case studies of inter-agency collaboration in Portugal, based on interviews with practioners.
2. A participant survey to measure the effects of interactive scenario-building workshops on Portuguese stakeholders.

Results

The case studies reveal five conditions which appear to contribute to the emergence of collaboration, including existing networks, flexibility in the institutional framework, and a combination of top-down and bottom-up forces. The workshop survey suggests that scenario-building exercises increased the likelihood of the future collaboration among participants to a small degree, primarily by building inter-organizational networks. Recognizing that collaboration is necessary but not sufficient, for better metropolitan-level development, these results suggest ways in which government policy can take advantage of pro-collaboration forces.

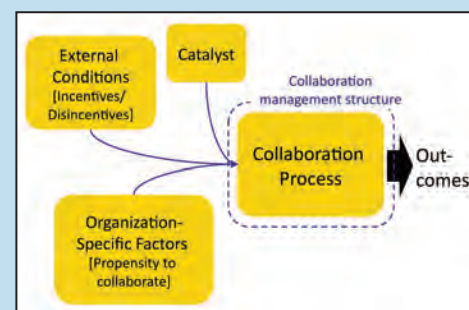**Fig. 1.** Multiple jurisdictions contribute to fragmented metropolitan governance

Fig. 2. Conceptual model of collaboration and its emergence

Fig. 3. Stakeholders engaged in a scenario-building workshop

Institutional Design as a Performance Factor in Urban Mobility Systems

Transportation Systems PhD

IST-UTL

Background: **Diploma, Rural and Surveying Engineering; MSc in Organization, Design and Management of Transport Systems, Aristotle University of Thessaloniki, Greece**

Starting Year: **2008 / 2009**

Supervisor: **Rosário Macário (IST-UTL)**

Research team: **A. Antunes, J. Ferreira, R. Macário, J. Sussman, J. Viegas, C. Zegras, G. Caiado , M. Diao, T. Dunn, A. Galelo, C. Grillo, A. Guevara, W. Li, L. Martinez, S. Melibaeva, L. Rayle, A. Sevtsuk, N. Pinto, M. Spandou**

Maria Spandou

Objectives

DEVELOP A SOUND KNOWLEDGE BASE ON INSTITUTIONAL DESIGN THEORY AND PERFORMANCE MANAGEMENT, FROM AN INTERDISCIPLINARY POINT OF VIEW.

UNDERSTAND AND ASSESS THE DECISION-MAKING MECHANISMS IN THE TRANSPORT POLICY, PLANNING AND OPERATIONS LEVEL, AS WELL AS THE INTERRELATIONS AND INTERACTIONS AMONG STAKEHOLDERS, AND THE VERTICAL CONSISTENCY BETWEEN LEVELS OF DECISION.

IDENTIFY AND ASSESS THE INFLUENCE AND IMPACT OF INSTITUTIONAL DESIGN PARAMETERS OF URBAN MOBILITY SYSTEMS ON THE INDIVIDUAL AND OVERALL SYSTEM PERFORMANCE AND VICE VERSA

PROPOSE INNOVATIVE INSTITUTIONAL AND PERFORMANCE MANAGEMENT FRAMEWORKS FOR A VARIETY OF URBAN MOBILITY SYSTEMS CONFIGURATIONS, AS WELL AS RECOMMENDATIONS FOR BARRIER ALLEVIATION, CONFLICT MANAGEMENT AND DYNAMIC ADAPTATION TO NEW CONDITIONS.

Work plan

IDENTIFY THE INSTITUTIONAL DESIGN PATTERNS AND TYPOLOGIES, STAKEHOLDERS AND DECISION-MAKING PROCESSES IN URBAN MOBILITY SYSTEMS, THROUGH COMPARATIVE QUANTITATIVE AND QUALITATIVE ANALYSIS (MULTI-METHODOLOGICAL APPROACH), FROM A THEORETICAL AND EMPIRICAL PERSPECTIVE.

IDENTIFY AND DEVELOP PERFORMANCE METRICS ON THE BASIS OF DIFFERENT INSTITUTIONAL DESIGN TYPOLOGIES, IN THE STRATEGIC, TACTICAL AND/OR OPERATIONAL LEVEL.

Results

THE RESULTS OF THE DISSERTATION WILL CONSTITUTE A USEFUL TOOL FOR ALL STAKEHOLDERS THAT NEED TO ADDRESS THE ORGANIZATIONAL, FINANCIAL/FUNDING AND PERFORMANCE ISSUES IN AN INTEGRATED WAY, IN ORDER TO ACHIEVE BETTER EFFICIENCY, EFFECTIVENESS AND SUSTAINABLE DEVELOPMENT OF THE URBAN MOBILITY SYSTEM.
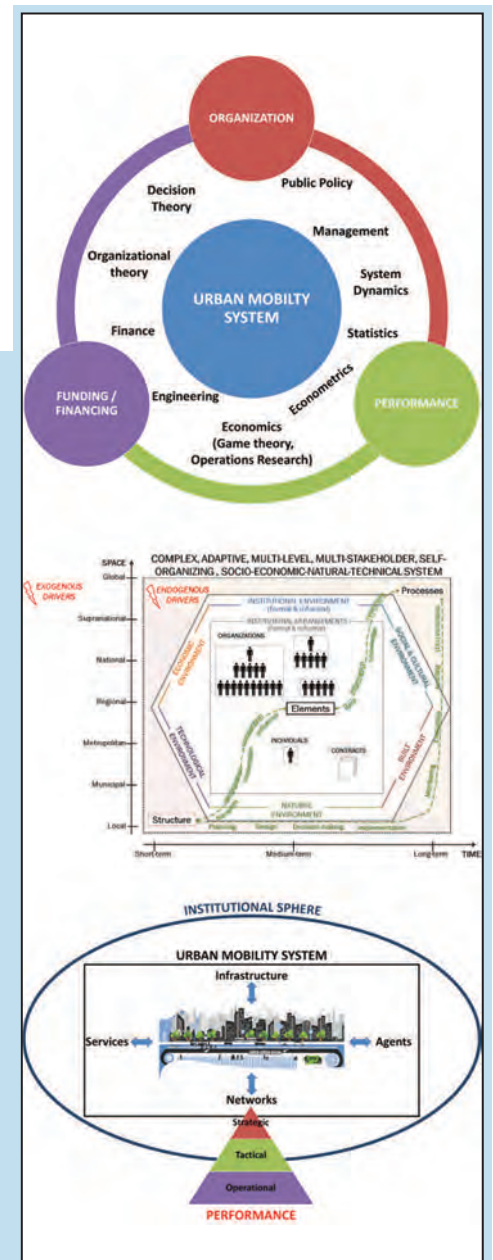
AN INTELLIGENT SYSTEM FOR SUPPORTING DRIVERS BASED ON CAR, ENVIRONMENT AND DRIVING CONDITIONS

Transportation Systems PhD
IST-UTL
Background: **Diploma, Civil Engineering, Iran University of Science and Technology; MSc, Transportation Planning, Imam Khomeini International University ,Iran**
Starting Year: **2009 / 2010**
Supervisor: **Sílvia Costa Shrubsall, José Manuel Viegas, and Ana Paiva (IST-UTL)**
Research team: **J. Viegas (IST), S. Shrubsall (IST), L. Picado Santos (IST), J. Santos (UM), A. Paiva (IST), J. Dias (IST), F. Gherekidan (FCTUC)**

Mohammad Hajizamani

Objectives

The main aim is to reach a significant and lasting reduction in number and severity of accidents and fatalities (Fig.1), by adjusting car dynamics characteristics to the driver's performance and temporary capacities within the current driving conditions (i.e. Intelligent Vehicles) and eliminating main human errors (Fig.2).

Secondary objectives are:
To identify main driver errors and their solutions to avoid some dangerous situations;
To define different possible actions in dangerous situations for the driver;
To contribute to designing a system that can analyze driving situations and take the best decision according to receptions from vehicle, driver and environment;
to assess the impact of inserting intelligent vehicles with different penetration and control degrees;
To develop and evaluate business model;
To identify future applications and research studies

Work plan

Literature Review
The comprehensive literature review will encompass three different research areas: (1) safety, (2) intelligent and communication technologies and (3) software engineering.

Model Routes in Agent-Based program
Several models will be developed for different segments of highway with related specifications. The model will contain vehicles and drivers with different characteristics and physical/psychological conditions. The AnyLogic software has been chosen as the main platform (Fig. 3).

Model Calibration by using case study data
Some segments of Portugal highways are planned to be used for calibrating different variables of the model in an Agent-Based program.

Run the agent-based model with intelligent cars
Calibrated model will be run with different scales of penetration of intelligent cars to assess safety impacts of the system and obtain recommendation for improvements of initially design system based on results studies.

Results

To reduce number and severity of accidents by contributing to improve drivers' behavior and attitudes;
To increase routes' level of service due to reduced accident rates;
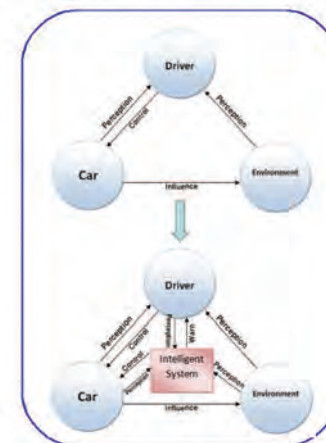To enhance an Agent-Based traffic flow analysis model suitable for road safety studies;
To contribute as a reference for European and international road safety projects;
To publish on several journal and conference papers
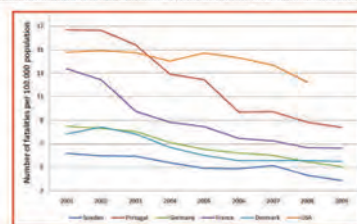
Fig. 1: Number of fatalities in six developed countries in recent years (see Objectives of the PhD)

Fig. 2: Current vs. proposed interaction system between vehicle, driver and environment. Intelligent system will support the driver depending on the environment, the vehicle and the driver himself (see Objectives of the PhD)
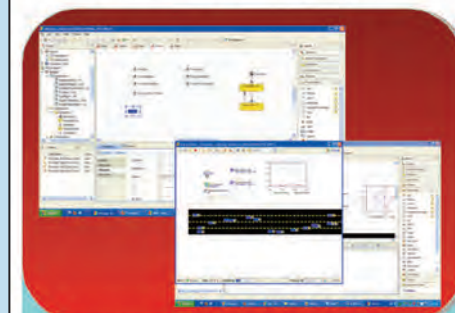
Fig. 3: Screenshots from Agent-Based program (AnyLogic) simulation: a segment of highway was modeled as well as 80 vehicles, of which 20 percent are intelligent (see Work Plan)

Long-term Drivers within Generations in Favor of Sustainable Mobility

Transportation Systems PhD

IST-UTL

Background: **MSc in Logistics, Massachusetts Institute of Technology, USA**

Portugal

Starting Year: **2007 / 2008**

Supervisors: **J. M. Viegas (IST), M. Ben_Akiva (MIT), C. Carvalho (ISPA)**

Research team: **J.M. Viegas, J. Abreu e Silva, R. Macário, A. Pais Antunes, G. Correia, M. Ben-Akiva, W. Mitchell, J. Sussman, P.C. Zegras. C. Choudhury, J. Tavares. R. Arriaga, C. Azevedo, D. Carvalho, L. Martínez, T. P. Dunn, A Sevtsuk, S. Castanheira, L. Yang, S. Xu.**

Rafaela Arriaga

Objectives

This exploratory study is to develop a disaggregate travel behaviour model which directly predicts 65+ years of age traveller's modal switching behaviour due to either a transport service change or an individual ability to drive change

Work plan

First phase: Literature review

Second phase: Survey preparation and launch. Discrete choice modelling, insights from the life course perspective, theory of cohorts, variables from Health Psychology research shall be used to understand the segment of 65+ individual's and both respective mobility needs and preferences in the context of mode choice switching behaviour.

Third phase: Analyses and results

Results

Provide forecast, needs and expectations characterization of current and ageing 65+ individuals and a comparison of three generations of mobility users.

Portuguese Population (2005 – 2050)
Source: analysis, INE data
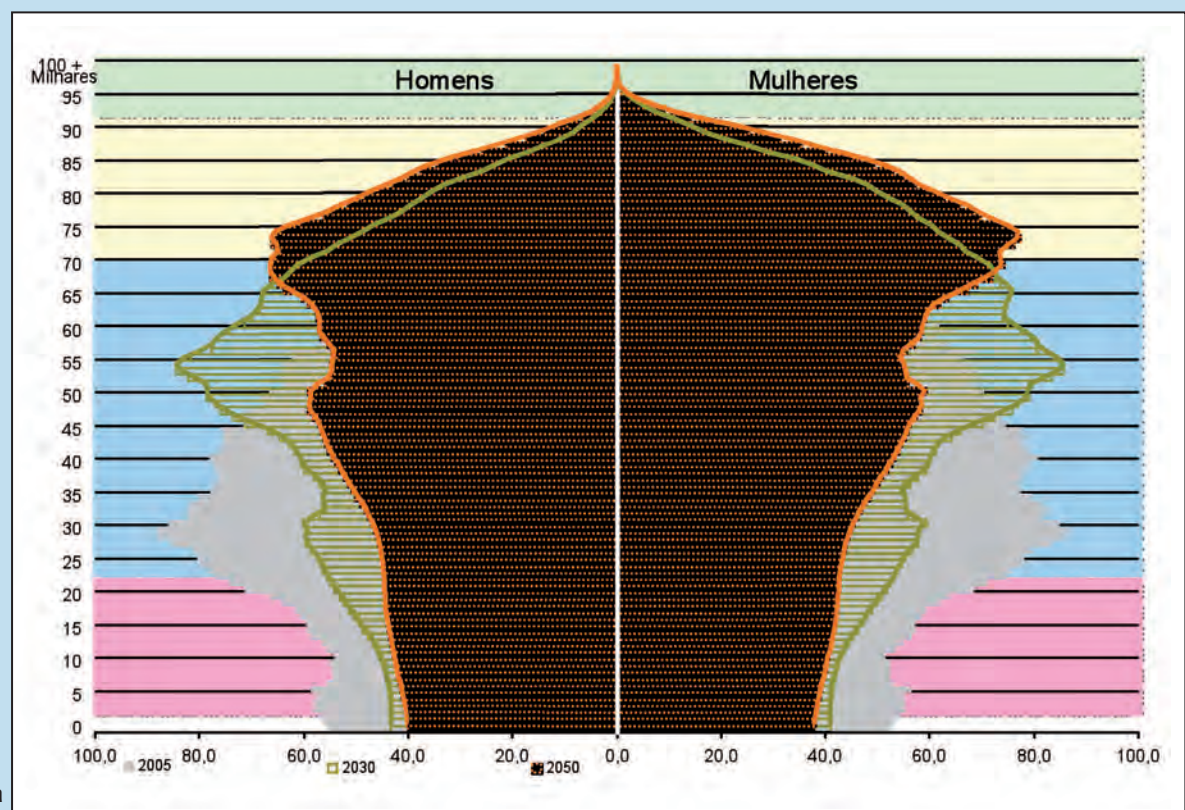
Dynamic Vehicle Routing for Demand Responsive Transportation

Transportation Systems PhD
FEUP
Background: **MSc Computer Engineering, FEUP, Portugal**
Portugal
Starting Year: **2008 / 2009**
Supervisor: **Jorge Pinho de Sousa (FEUP / INESC Porto)**
Teresa Galvão (FEUP)

Rui Gomes

Objectives

Providing quality public transportation is extremely expensive in low demand scenarios. Demand Responsive Transportation (DRT) services are an efficient approach to provide better quality services, with routes and schedules dynamically varying according to demand. They promote social cohesion and environmental sustainability.

The main objective of this research is to develop a general modeling framework and efficient, customizable state-of-the-art multi-objective heuristics for the design and operation of DRT. These heuristics will be embedded in a Decision Support System capable of handling the multiple perspectives of its different stakeholders.

This work is part of a broader research MPP project (CityMotion).

Work plan

After the state-of-the-art, the requirement analysis and the classification and structuring of real problems, we have designed a heuristic approach that constructs a feasible route through a greedy random approach, followed by a local search phase aiming at obtaining an approximation of the Pareto solution set. Preliminary results on randomly generated instances look very promising.

Results

A set of mathematical models and a general framework for characterizing and classifying DRT services

A set of innovative state-of-the-art customizable multi-objective meta-heuristics for designing and operating DRT services

A prototype of a Decision Support System

A synthesis of the results obtained in the case studies, with guidelines for practical application

$$min \sum_{k \in K} \sum_{i \in V} \sum_{j \in V} c_{ij} x_{ij}^k$$

$$min \sum_{k \in K} \sum_{p \in P} (t_{i_p} - e_{i_p}) y_p^k$$

$$min \sum_{k \in K} \sum_{p \in P} (t_{j_p} - t_{i_p}) y_p^k$$

$$max \sum_{k \in K} \sum_{p \in P} y_p^k$$

The Geography of Strategy
An Exploration of Alternative Frameworks for Transportation Infrastructure Strategy Development

Transportation Systems PhD

MIT

Supervisor: **MIT Portugal Associeted Research Project**

Travis Dunn

Objectives

The objective of this research is to improve our understanding of the relationship between the strategic/institutional features of a transportation system and its performance. We characterize the strategy development framework for transportation infrastructure along various dimensions, including the ownership structure (e.g., state-owned, PPP), the type and quantity of revenues generated (e.g., general taxation, user fees), the revenue allocation methods for reinvesting in the infrastructure (e.g., benefit-cost analysis), the degree of integration across transportation modes and other sectors, and the geographic scales of control (see figure 1). By developing a model of the evolution of the Portuguese highway network, we can simulate the performance of the highway transportation system under a wide range of alternatives, in order to determine which frameworks might lead to improvements in performance.

Work plan

105 alternative strategy development frameworks were modeled using an agent-based simulation of the evolution of Portugal's intercity highway network over time and space (see figure 2). By varying the frameworks' dimensions (type of revenue, revenue allocation method, geographic scale of control, etc.), differences emerged among the resulting investment decisions for the network. These investments and networks were evaluated according to 80 performance metrics in order to determine which frameworks lead to desirable outcomes. Each simulation began

with the highway network as it existed in 1995 (see figure 3). Figure 4a shows the results predicted for 2009 of a framework with nationally scaled decision making control, while Figure 4b presents the predicted network in 2009 under municipal control. Figure 4c predicts the characteristics of the network in 2020 under national control.

Results

The simulation and accompanying qualitative analyses yielded many results about the relative performance of various frameworks. Changes in the resource quantity and geographic scale dimensions tend to have the greatest effects: increases in resource quantity predictably result in more spending, more extensive networks, higher speeds, and greater accessibility; larger geographic scales tend to produce similar outcomes. However, these are diminishing returns, as measures of the cost-effectiveness of congestion reduction and speed are better at smaller geographic scales and lower revenue quantities. There is no clear preference for any particular framework across the full range of performance metrics or evaluation scenarios. However, nationally and regionally scaled control tend to result in more robust performance, while general taxation as a revenue source tend to be preferred over user fees (tolls), particularly at the regional and national scale. More generally, these and other results highlight the potential utility of this technique for transportation planners and policy makers to study and understand the influence of strategy development frameworks on infrastructure outcomes.
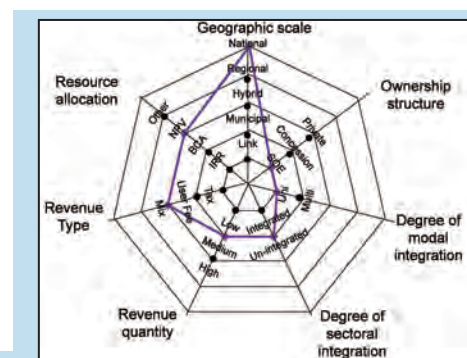

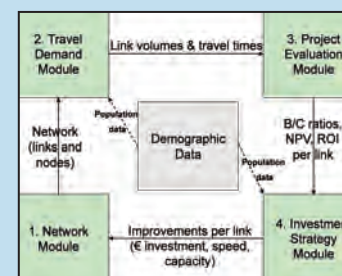**Fig. 1.** Dimensions for characterizing alternative strategy development frameworks

Fig. 2. Simulation model structure

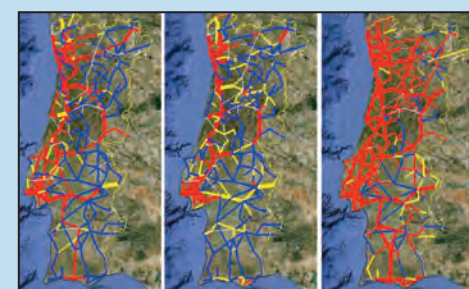**Fig. 3.** IHighway network at start of simulation

Fig. 4. Network at end of simulation (a) in 2009 under national control, (b) in 2009 under municipal control, and (c) in 2020 under national control

OUR INDUSTRY AND INSTITUTIONAL AFFILIATES

Education Affiliates

Alstom
Bento Pedroso / Odebrecht
BRISA
IMTT - Instituto da Mobilidade e Transportes Terrestres
Mota-Engil
RAVE / Refer
Siemens

Industrial and Institutional Affiliates

Alfama, Inc.
Altakitin Corp.
Amorim Industrial Solutions
AREAM – Agência Regional da Energia e Ambiente da Região
   Autónoma da Madeira
ARENA – Agência Regional da Energia e Ambiente da Região
   Autónoma dos Açores
Associação Industrial Portuguesa – Confederação Empresarial
Associação Empresarial de Portugal – Câmara de Comércio
   e Indústria
BANIF – Banco Internacional do Funchal, S.A.
Bioalvo S.A.
Biotecnol, S.A.
Biotempo Lda.
Biotrend – Inovacao e Engenharia em Biotecnologia, S.A.
Cabo TV Madeirense, S.A.
Celoplás – Plásticos para a Indústria, S.A.
Ciência Viva
Cimentos Madeira, Lda.
CIPAN – Companhia Industrial Productora de Antibiótitcos, S.A.
Continental Mabor Indústria de Pneus, S.A.
Crioestaminal – Saúde e Tecnologia, S.A.
Critical Move, S.A.
DEIMOS,S.A.
ECBio – I&D em Biotecnologia, S.A.
EDP, S.A.
EDP Inovação, S.A.
EFACEC, S.A.
Empresa de Electricidade da Madeira, S.A.
FLAD – Fundação Luso-Americana para o Desenvolvimento
Fomentinvest SGPS, S.A.
Fórum de Administradores de Empresas (FAE)
Galp Energia, S.A.
Grupo Bial
Grupo Frulact
GRUPO SOUSA, Investimentos, SGPS, Lda.
Horários Do Funchal – Transportes Públicos, S.A.
Iber-Oleff – Componentes Técnicos de Plásticos, S.A.
Inapal Metal, S.A.
Inapal Plásticos, S.A.
Martifer, S.A.
M. C. Graça, Lda.
Nutroton Energias, S.A.
Ordem Dos Engheneiros
Proforum – Associação Para o Desenvolvimento da Engenharia
REN – Redes Energéticas Nacionais, S.A.
Rolls-Royce plc (UK)
SGC Energia
Simoldes Plásticos, Lda.
Stemmatters, Biotecnologia e Medicina Regenerativa Lda.
Sunviauto, S.A.
TMG Automotive
Unicer Bebidas, S.A.
Universidade dos Açores
VW Autoeuropa

www.mitportugal.org

MIT Portugal

Academic Institutions Providing PhD Degrees in Association

Escola da Engenharia da Universidade do Minho
Faculdade de Ciências da Universidade de Lisboa
Faculdade de Ciências e Tecnologia da Universidade de Coimbra
Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
Faculdade de Economia da Universidade de Coimbra
Faculdade de Engenharia da Universidade do Porto
Instituto Superior de Economia e Gestão da Universidade Técnica de Lisboa
Instituto Superior Técnico da Universidade Técnica de Lisboa

Other Institutions Involved in R&D Activities

Instituto Politécnico de Portalegre
Instituto Politécnico de Setúbal
Instituto Superior de Agronomia da Universidade Técnica de Lisboa
Instituto Superior de Ciência do Trabalho e da Impresa
Universidade de Aveiro
Universidade da Beira Interior
Universidade de Trás-os-Montes e Alto Douro