Information and Communication Technologies Institute

Carnegie Mellon | PORTUGAL

AN INTERNATIONAL PARTNERSHIP

ICTI PORTUGAL

AN INNOVATION AGENDA FOR RESEARCH, TECHNOLOGY AND GRADUATE EDUCATION

2009-2011

FCT Fundação para a Ciência e a Tecnologia

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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CONTENTS

OUR MISSION

THE MISSION OF THE CARNEGIE MELLON|PORTUGAL PROGRAM IS TO CREATE NEW KNOWLEDGE IN KEY FOCUSED AREAS OF INFORMATION AND COMMUNICATIONS TECHNOLOGIES BY MEANS OF CUTTING-EDGE RESEARCH, WORLD-CLASS GRADUATE EDUCATION AND A CLOSE CONNECTION WITH THE PORTUGUESE INDUSTRY, THUS PLACING PORTUGAL AT THE FOREFRONT OF SCIENCE AND INNOVATION.

EXECUTIVE SUMMARY

By connecting major universities, research institutions and high-tech companies in Portugal, with schools, research centers and institutes at Carnegie Mellon University, and by focusing on key strategic areas of information and communications technologies, where Carnegie Mellon and Portugal can gain comparative advantages, the Carnegie Mellon | Portugal Program holds the promise of a decisive impact on the scientific culture and the innovation potential of the educational and research system in Portugal.

Since the initial kick off in October 2006, partners in Portugal and at Carnegie Mellon have succeeded in developing six dual degree PhD programs, launching four dual Professional Master's programs, and beginning a number of collaborative research efforts, in which industry and academia join forces to create new scientific knowledge and solve real-life engineering problems.

After the initial exploratory phase, the Program now enters a second phase that shall be characterized by strong scientific leadership towards coherence, consolidation and sustainability. The purpose of this strategic document is to identify the challenges and opportunities that are before us and set an ambitious agenda for future efforts. In its final form, it will gather the contributions of a large number of experts from various scientific and business communities. Ultimately, we seek to bring the Carnegie Mellon | Portugal program to maturity in all its facets, including excellence in research, outstanding education and training, successful technology exchange with the Portuguese industry, and effective integration of the Portuguese partners in key global innovation networks.

During the next few years this international partnership is likely to evolve beyond what was envisioned at its early stages, as successful aspects are strengthened and weaknesses eliminated. Joint initiatives that are successful will continue to thrive, others will be replaced by different models that better serve our goals. Experimentation is the operative word, both in research and in education. Irrespective of the format of future activities we envision the following legacy:

• A legion of highly qualified individuals with relevant international experience and proven leadership qualities;

• Adoption, adaptation, dissemination, and consolidation of the best practices that make Carnegie Mellon a world-leading hub for research and innovation;

• Innovation networks in key focused areas of ICT, which signal a closer and profitable connection among universities, research centers and companies;

• Implementation of mechanisms and routine practices for brainstorming, exchanging ideas, attaining technical depth, publishing in top scientific periodicals, protecting of intellectual property and developing products with the industry;

• Professional management of educational activities, including the international recruiting of students, researchers and faculty, as well as the development of world-class collaborative graduate degrees;

• A culture of innovation and entrepreneurship in which class projects, master theses and doctoral dissertations are routinely targeted towards technical depth with strong impact in the real world;

• Significant increases of Portugal's comparative advantage within the ICT sector and new opportunities for Carnegie Mellon to extend its global presence.

PARTNERS

Long-term partnerships have been initiated by the following institutions.

Portugal	
Universities	Universidade de Aveiro (UA)
Faculties and Schools	Universidade do Algarve (UALG)
	Universidade da Beira Interior (UBI)
	Universidade de Coimbra (UC)
	Universidade Católica Portuguesa (UCP)
	Universidade de Lisboa (UL)
	Universidade da Madeira (UMa)
	Universidade do Minho (UM)
	Universidade Nova de Lisboa (UNL)
	Universidade do Porto (UP)
	Universidade Técnica de Lisboa (UTL)
	Escola de Engenharia da Universidade do Minho (EEUM)
	Faculdade de Ciências Económicas e Empresarias (FCEE/UCP)
	Faculdade de Ciências e Tecnologia da Universidade de Coimbra (FCTUC)
	Faculdade de Ciências da Universidade de Lisboa (FCUL)
	Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa (FCTUNL)
	Faculdade de Engenharia da Universidade do Porto (FEUP)
	Instituto Superior de Engenharia do Porto (ISEP)
	Instituto Superior Técnico (IST/UTL)

Associate Laboratories and Research Units	Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento (INESC-ID) Instituto de Engenharia de Sistemas e Computadores do Porto (INESC Porto) Instituto de Sistemas e Robótica Laboratório Associado (ISR LA) Instituto de Telecomunicações (IT) CISTER/Instituto Superior de Engenharia do Porto
Applied Research Institute	Instituto de Soldadura e Qualidade (ISQ)
Government Agencies	Fundação para a Computação Científica Nacional (FCCN) Agência para a Sociedade do Conhecimento (UMIC)

Carnegie Mellon University	
Colleges	Carnegie Institute of Technology, the College of Engineering at Carnegie Mellon (CIT) Heinz College (Heinz) Humanities and Social Sciences College (H&SS) Mellon College of Science (MCS) School of Computer Science (SCS) Tepper School of Business (Tepper)
Reserch Centers and Institutes	Carnegie Mellon Electricity Industry Center (CEIC) Center for Sensed Critical Infrastructures Research (CenSCIR, ICES, CIT) Cyber Security Lab (Cylab)

	Center for Technology Transfer and Enterprise Creation (CTTEC) ILab Institute of Complex Engineered Systems (ICES) Industrial Technology Research Institute (ITRILab) Language Technologies Institute (LTI)

Industry	
Affiliates	Portugal Telecom Nokia Siemens Networks Novabase

01 OUR CHALLENGES

At the dawn of a new decade, with a deep financial crisis that casts some doubt over the ruling economic model, growing concerns about environmental sustainability and citizens who aspire to better quality of life, security and social cohesion, a number of important challenges offer numerous opportunities for research and innovation:

- **Leadership in Times of Economic Uncertainty:** As the world struggles through a recession by the current economic crisis, lack of confidence of investors and entrepreneurs leads to the loss of jobs and of innovation ability even at companies that were key players in their respective fields and major exporters in the global arena. Fewer jobs for highly skilled engineers could lead to a rise in immigration and the deterioration of the human substrate over which Portugal can build a knowledge based economy.

- **Generational and Social Gaps:** With one of the lowest birth rates in Europe, the Portuguese are ageing at a fast pace. Beyond the generational divide that cuts through technical savvy, cultural interests and job qualifications, there exists a social divide that unless compensated may lead to a societal fringe whose members do not have access to state-of-the-art information and communication technologies and are not equipped to take part in a globalized economy of networked talent.

- **Constrained Natural Resources:** It is now very clear that the way the world produces and consumes our natural resources is not sustainable. From the search for alternative energy sources to the design of power-efficient homes, vehicles and industries, the convergence of communication, computation and control systems may hold the key towards smarter living.

- **Administrative Inefficiencies:** Although much has been accomplished in recent years towards a more efficient public administration, new technological and organizational solutions are needed to bring government and judiciary up to the state-of-the-art and closer to the people thus providing citizens with excellent services and added value for their contributions.

- **Security and Privacy:** With an increased awareness of the threat of global terrorism, the need for countermeasures against digital theft and fraud, and the abundance of surveillance equipment and sensitive databases, the delicate balance between protecting society and guaranteeing individual liberties is a challenge in itself. Technology and policy must come together to ensure that Portugal meets this balance to the benefit of its citizens.

- **Renewing Education:** Now that Portugal has successfully revised its curricula in the spirit of the Bologna Declaration, the next important step is to enhance the quality of university education, in particular at the graduate level. On the one

hand universities must ensure that the third cycle (PhD) exposes students to the frontiers of knowledge in their respective fields, on the other hand educational offerings must be expanded towards international experience and top training for young talents and professionals who wish to embark in life-long learning and problem solving in technical fields.

- **Changing Economic Model**: It is clear that the economic development model of the future is based in knowledge, innovation and entrepreneurship. This is especially relevant for Portugal that, until recently, has had an undue reliance in low wages as the prevailing approach towards international competitiveness. Accelerating the transition towards the new economic model and leveraging national capabilities and opportunities is thus of critical urgency .

The Carnegie Mellon | Portugal Program aims to meet these challenges by promoting a culture of innovation and collaboration which connects the university and the industry, sparks creativity, generates new solutions for real-world problems and helps build a more balanced and sustainable society.

02 OUR STRATEGY

In view of the current challenges, we believe that rather than re-booting the current economic system or embarking on a protectionist path, leaders around the world must re-connect and work towards the growth of global innovation networks, capable of providing robust and sustainable solutions for our common future. In this context, information and communication technologies have no doubt a key role to play, not only because they remove both geographic and cultural barriers, but also because they are the basic building blocks in the search for technical solutions that ensure a more intelligent use of the resources of our planet (e.g. smart grids, vehicular networks, precision agriculture, etc.) and of the talents of our people (workflow software, social networks, personalized contents, etc.).

Any increase of competitive advantage both for Portugal and Carnegie Mellon is necessarily tied to our ability to lead this search in focused areas where we can leverage technological innovation.

It is therefore only natural that innovative research is at the heart of all initiatives within the Carnegie Mellon | Portugal Program. A major goal of the partnership is to identify the key focused areas in ICT that offer opportunities for high-impact collaborative research in cooperation with Carnegie Mellon, while ensuring that Portugal's competitive advantage is leveraged through the formation of industrial and academic consortia capable of meeting the challenges of the next economic model. The key challenge is to define targeted research endeavors, where the partnership

with Carnegie Mellon can be leveraged to achieve high international impact and wide industrial applicability.

To boost relevant research and provide opportunities for innovation towards world-class graduate education, the program supports dual degree PhD programs designed to train the most talented young researchers in the context of thriving research collaborations between faculty at Carnegie Mellon and in Portugal, while offering post-doctoral positions to attract bright minds for a scientific career in Portugal. We aim to foster cooperation among Portuguese universities to further promote the excellence, international visibility and attractiveness of research and graduate education in our country. Professional master programs aim at qualifying skilled personnel for high-tech industries in ICT. The dual degree programs are part of an internationalization strategy that builds on Carnegie Mellon's excellent reputation and explores Portugal's location in Europe and the special relations with Africa and Brazil.

Since scientists and entrepreneurs alike usually have more ideas at hand than they can reasonably solve with the time and the resources that are available to them, the Carnegie Mellon | Portugal Program consequently aims at focusing their efforts around common objectives, thus aggregating the critical mass and providing incentives for emerging innovation networks to focus on those problems that have strategic value towards higher comparative advantage for all partners.

03 OUR INSTRUMENTS

COMPETITIVE RESEARCH GRANTS

The Carnegie Mellon Portugal Program, through the Portuguese Foundation for Science and Technology (FCT) funds a number of innovative research projects, which are selected by means of open calls and independent evaluation by international experts. Each proposal must include at least two research institutions in Portugal, one research group at Carnegie Mellon and one Portuguese company. A financial commitment from the industrial partner is expected, which can take many forms from direct funding to man power or prototyping. Research projects typically involve faculty members, researchers, and PhD students. It is desired that they also result in research opportunities for undergraduates, both as a tool for recruiting talent and as a means of promoting the scientific culture of our society. Beyond traditional measures of success, such as scientific and technological significance of results, quality and number of publications, patents, degrees conferred, and number of students, post-doctoral and other young researchers involved, the impact of projects will be measured also by the successful deployment of research prototypes and the adoption of new services by

leading companies and by building successful partnerships between industry and academia.

PHD AND POST-DOC FELLOWSHIPS

High-potential young researchers can apply to a number of PhD and Post-Doc fellowships, which are awarded by FCT on a yearly basis in the various key focused areas of the Carnegie Mellon | Portugal Program. PhD Students are enrolled in the Carnegie Mellon | Portugal dual degree programs as outlined in Section 06 Training the Best.

SENIOR RESEARCHER POSITIONS

In the spirit of the Ciência 2007 and Ciência 2008 programs, which were designed to bring up to one thousand researchers with a PhD to the Portuguese scientific community, the Carnegie Mellon | Portugal program enables the participating institutions to recruit and hire experienced international researchers, who will strengthen the existing critical mass in key focused areas of ICT, where Portugal can have a comparative advantage.

RESEARCH CHAIRS

Through close cooperation with industry and a policy of matching funds, FCT provides universities with endowed chairs aimed at attracting leading scientists from around the world. As in the case of senior research positions, the Carnegie Mellon | Portugal program shall assist the institutions by training their professional recruiters and raising the international awareness of the available opportunities.

INSTITUTIONAL SEED FUNDING

To jump start the collaboration with Carnegie Mellon, FCT signed a number of program oriented contracts, which provided the participating institutions with the means to set up the dual degree programs, to recruit new students and faculty, to promote exploratory visits to the United States and to initiate the first collaborative research projects. As the program progresses funding will be made available essentially through competitive calls.

DUAL DEGREE PHD | PROFESSIONAL MASTER | COURSES | EXCHANGE PROGRAMS

Consortia of Portuguese universities cooperate with Carnegie Mellon to offer world-class graduate programs, where PhD students and professionals from the industry are trained partly in Portugal and partly in the United States, develop research projects under co-supervision by faculty on both sides of the Atlantic, and receive a degree both from a Portuguese institution and from Carnegie Mellon. In addition, students in

other graduate programs and faculty members of participating institutions have the opportunity to spend time at Carnegie Mellon's labs and departments, where they are exposed to the best practices of a vibrant interdisciplinary research environment. Simultaneously, the Program promotes both short and longer visits of Carnegie Mellon faculty of Portuguese institutions to give lectures, teach advanced courses and intensify the research collaboration. Summer Academies are designed to bring together the academic and industrial communities in Portugal.

04 PROMOTING WORLD-CLASS RESEARCH

Since its inception the Carnegie Mellon | Portugal has strived to identify the key focused areas of ICT where Portuguese universities and companies can become world leaders in high-impact research and innovative products and services. In collaboration with colleagues at Carnegie Mellon and partners from the local industry, the scientific community has been engaged in a broad discussion, which deepened the perception of the need for a clear focus and allowed a number of relevant topics to emerge in a bottom-up fashion.

KEY STRATEGIC AREAS

NEXT GENERATION NETWORKS FOR TRUSTED HIGH-QUALITY SERVICES

As many of the world's communication and computation infrastructures expand, connect and evolve into one pervasive mesh of heterogeneous devices, we witness large investments to bring fiber directly to most homes and the fast convergence of large-scale data processing facilities, ultra-portable computers, intelligent vehicles, safety and health-care systems, energy-aware technologies and peer-to-peer architectures. Network operators, equipment manufacturers and government regulators are now confronted with ever changing system architectures, traffic demands, and costumer expectations with respect to quality of experience, brought now to new levels for example by high-definition television over IP. Not satisfied by simply acquiring information from centralized servers, many of today's users want to upload their own content and share it with the world. Likewise, businesses are becoming increasingly global with teams collaborating across continents and time zones, requiring massive data transfers and high-speed connections for multimedia communication. The high-performance networks of the future must provide their customers with unhindered access to the world wide web of people and things, which must be available at all places and in all moments, automatically and without delays, irrespective of the underlying optical, cable or wireless infrastructure, yet automatically adapting to and taking optimal advantage of the available features of the access device.

MAIN TECHNICAL CHALLENGES:

- **Design and Integration of Future Internet Technologies:** Seamless communication and service continuity over the emergent global network requires innovative technologies, which can be integrated, optimized and operated with ease over multiple domains, from the physical communications channel up to the services and applications as seen by the user. This includes an all fiber infrastructure capable of carrying massive traffic across the network to individual homes and businesses, as well as an array of wireless gateways that enable mobile services and reliable connectivity in dense and volatile environments. The finite amount of wireless spectrum asks for dynamic resource allocation based on new hardware and software for flexible radio. It is important to investigate how novel lower layer techniques ranging from cognitive radio to multiple-antenna systems and cooperative communications (e.g. relaying, beam forming, and network coding) can be leveraged by the communications protocols at higher layers of the system architecture to provide the necessary throughput and robustness guarantees. Mesh networks, home networks and vehicular networks will complement the cellular infrastructure in ways that are yet to be explored, with users roaming from one network to another seamlessly or even tuning simultaneously to multiple access points for higher rates and efficiency. Decisions on the best radio access technology selection may be based on context awareness and localization. The selfishness of users and devices that compete for common network resources can be taken into account based on game-theoretic models and the search for equilibrium. Increasingly the network will interact more and more with the physical world through wireless enabled objects, also known as the Internet of Things, which are likely to change traffic patterns and alter services and applications thus justifying the development of new architectures and protocols.
- **Security, Privacy and Trust:** The growth of the ICT sector is strongly dependent on the level of confidence with which the average costumer is willing to carry out electronic transactions over the network. It is not sufficient for the infrastructure, protocols and services to be secure, their level of security must be obvious to anyone wishing to use them. This includes the correct usage of enabling technologies for security like cryptography, protection against spoofing attacks on wireless and cable links, active measures against identity theft by means of phishing, virtual machines to isolate malware, trust primitives for software updates, traitor tracing for peer-to-peer content, intrusion detection, and other defense mechanisms capable of adapting to the constant surge of new attacks and vulnerabilities. Electronic IDs can be included in the effort towards implementing reliable identity management. Security should not be an add-on to existing communication protocols and

services, but rather be a primary concern in the design of new information and communication technologies.

- **Applied Machine Learning for Traffic analysis and Efficient Network Management:** Peer-to-peer communication and social networking are only two examples of recent developments that are fundamentally changing how information and data packets flow within a large-scale communications network. By collecting and compressing massive quantities of data on network traffic and employing tailored machine learning and data mining techniques, it should be possible to characterize, at least partially, the resulting patterns of network usage. A natural step could be to investigate how root-cause analysis can predict demands, anticipate problems, reduce congestion and combat failures. The key is to understand how the decisions made by a myriad of devices based on local rules and partial information impacts the emergent behavior of large-scale networks as a whole.
- **Network Assessment and Evaluation:** How customers value the services provided by high-performance networks is ultimately determined by the levels of satisfaction they reach during their interaction with the various systems. Standard metrics such as packet loss rates or transmission delay are clearly insufficient to capture the end user's satisfaction, which is closely tied to human perception and our ability to process intelligible speech or tolerate certain classes of visual artifacts. Consequently there is need for research on testing methodologies and measurable criteria by which networks can be assessed and compared. More adequate metrics should be incorporated into the optimization and planning that governs the interaction between different operators and user terminals. The objective must be to maximize network efficiency whilst minimizing the effort of each network entity and guaranteeing a prescribed level of quality of experience. Multimedia services should be context-aware and adapt to the conditions of the network and the terminal of the user. Network virtualization, with large pools of networked physical machines that can host tens of thousands of virtual machines and services, emerges as a possible tool to provide differentiated services requirement specific methods for management and assessment.
- **Regulating, Charging and Billing:** With the paradigm shifting from connection oriented traffic to distributed systems with constant roaming among multiple service providers, it is not yet clear how governments should regulate the telecommunications sector and how businesses can charge for their services in a fair and effective manner without incurring excessive management overhead. Economic trends are pointing towards a fragmented market, in which communication services are often offered by autonomous service providers who are independent of the customer management, access network provision and core network management entities. Load balancing techniques must also

be revisited to account for new modes of communication in which users are as much service providers as service recipients. Ultimately, we must seek ways for the network infrastructure and its protocol stack to provide the means to track individual users without compromising their privacy, measure their contributions and their benefits, and produce a billing scheme that ensures the economic viability of successful services.

OPPORTUNITIES FOR CARNEGIE MELLON / COMPETITIVE ADVANTAGES FOR PORTUGAL:

Portuguese universities have a number of research groups who are actively involved in European projects in the area of Future Internet, including the networks of excellence Euro-NF and NewCom++. As countries and companies join efforts to envision the network of the future, Portugal cannot afford to be left behind on pooling its resources towards contributing to these developments in key areas where universities and companies have a competitive advantage.

As the largest operator in the country, Portugal Telecom (PT) is naturally a key player in this endeavor and a major contributor to the Carnegie Mellon | Portugal Program. PT engineers have started collaborating with Cylab at Carnegie Mellon to enhance their capabilities to model, mine, monitor and manage the quality of service, dependability and security of key components of their IP infrastructure. Another important work stream focused on improving PT's portal *Sapo*'s anti-phishing security mechanisms. The research community in Portugal has a great deal to contribute to this effort, with expertise ranging from complex event processing, system's modeling and machine learning to protocol engineering and integration of heterogeneous networks. Several departments have strong labs in the development of hardware and electronics, with important contributions involving measurement and real-world experimentation. Larger companies such as Nokia Siemens Networks, but also small and medium enterprises, such as NDrive (see box), can benefit from the synergies among researchers in hardware and software to develop new products that incorporate the latest developments in cooperative transmission, secure networking and self-configuration, among others.

Recognized as a country of early adopters, whose inhabitants have a strong inclination towards multimedia services and novel communication devices; Portugal has the potential to become a testbed for preliminary assessment of future networking technologies.

Case Study: The DRIVE-IN Project in Vehicular Networks

Principal Investigators (PIs): Michel Ferreira, IT, FCUP and Ozan Tonguz, Carnegie Mellon

The DRIVE-IN project (Distributed Routing and Infotainment through Vehicular Inter-Networking) aims at investigating how vehicle-to-vehicle communication can improve the user experience and the overall efficiency of vehicle and road utilization. Computer scientists from the University of Porto teamed up with communications engineers from the Instituto de Telecomunicações and the University of Aveiro, wireless networking experts from Carnegie Mellon and NDrive (a Portuguese manufacturer of portable navigation devices) to develop innovative technologies and applications for vehicular ad-hoc networks. The project includes a large-scale experimental testbed with 300 vehicles that is funded by NDrive, as well as hardware and software for collaborative navigation.

Case Study: M3 – Modeling, Mining and Monitoring Routing Configurations for Security

PIs: Hyong Kim, Carnegie Mellon; José Alegria, Portugal Telecom

The main goal of this early project was to test and develop Carnegie Mellon's Minerals framework to model, mine/analyze and monitor potential configuration problems in complex IP networks. The first test bed used was PT's International IP Network and it covered a) routing policy analysis, b) BGP community and complexity analysis, c) ACL analysis, and, finally, d) QoS analysis and visualization. Later, different mechanisms were developed to analyze dynamic aspects of the network, like problematic operational patterns. As a follow-up of this initial project, 4 Professional Master of Science theses were developed by PT employees, under the supervision of Prof. Hyong Kim at Carnegie Mellon, Information Networking Institute, covering a) Operational optimization of firewalls in large corporate networks (PROMETHEUS), b) A consolidated QoS management framework (Q-ANDREW), c) Root cause analysis in large and complex networks (ETYMON), and d) BGP routing visualization tool (IP-CONFIG). The first three theses (MSIT-IS) were applied to key parts of PT's large internal corporate network and are being further developed to support the full network. The last thesis (MSIN) was applied to PT's International IP Network.

SOFTWARE ENGINEERING FOR LARGE-SCALE DEPENDABLE SYSTEMS

Software is a key enabler of economic development as it provides the means to store, process and exchange information as varied as catalogs of products, items in a warehouse, positioning of vehicles, market transactions, and energy measurements. To meet the challenges of globalized software development, where thousands of components must be combined to provide the customer with an adequate application or information system, program modules must be engineered to operate in a seamless and reliable way with each other, adapting to unpredictable scenarios, recovering from

unexpected breakdowns and providing simple means to maintain or extend their features and configurations. To satisfy these requirements, software cannot be developed in an ad-hoc fashion. Thus, better software engineering methodologies and tools offering agility and fast delivery emerge as an indispensable tool for developing the information systems of the future.

MAIN TECHNICAL CHALLENGES:

- **Dependable Software Systems:** The development of industrial strength software requires new ways to certify the integrity, the correctness and the inter-operability of different modules and systems, even when such subsystems must operate across large-scale networks, and subject to continuous updates and extensions. This objective can be attained by means of formal methods from computational logic and type theory, which can be used to develop new high-level design and implementation idioms that are intrinsically reliable and extensible, as well as verification tools. Some intervention by human operators is likely to be necessary even in the presence of self-healing, self-adaptive software. Therefore, research should be devoted to identifying critical scenarios in which human oversight and actions are indispensable, leading to novel methodologies for dealing with highly complex software systems.
- **Collaborative Workflow Software:** Many software packages from business applications to multi-player games are now being developed by large teams that are spread out in various parts of the globe. This is possible because workflow software and online collaboration tools allow for a project to be divided into multiple chunks that are sent out to different developers, whose work is then assembled to produce the final product. New infrastructures for distributed software development will provide the fertile ground over which global innovation networks are likely to grow.
- **Software Modules for Global Supply Chains:** Inventory tracking, automatic transactions and consistent distributed databases are some of the key ingredients of modern supply chain management. Software systems for multinational enterprises must enable reliable real-time monitoring of goods and processes, thus ensuring that vital data is freshly available to all key partners and decision makers at all stages of the global supply chain. Research in this direction must rely on the real-world data collected by internationally operating companies. Challenges also include dealing with shared data-sets where parties with conflicting interests recognize the benefits of collaboration, but impose strong bounds on the admissible information flows.
- **Multi-core and Parallel Systems:** The multi-core processor is today a standard building block. It is commonly used in the edge (servers, proxies) and in the core (routers switches using network processors) and it is an appropriate computational substrate for telecommunication workloads because this class of

workloads tends to exhibit large amounts of parallelism. Sharing of the computational capacity of multi-cores contributes heavily to the end-to-end delay that users experience. A comprehensive theory with algorithms for sharing resources and for proving upper bounds on the delay experienced by an individual program does exist, however this theory is arguably not yet well developed for multi-cores. Moreover, it does not take into account the effects of contention for internal buses and switched interconnection networks inside a multi-core. It is now clear that future massive parallel processing will bring concurrency to the center of software engineering concerns. Harvesting the benefits of parallelization will require new programming abstractions and tools for expressing parallel programs at a high level, verifying correctness properties of concurrent code, and efficiently executing code on modern multi-core platforms.

OPPORTUNITIES FOR CARNEGIE MELLON / COMPETITIVE ADVANTAGES FOR PORTUGAL:

Several Portuguese departments and research institutes in the area of computer science have a strong tradition in information systems, software development, formal methods and computation logic. In the recent past this has lead to a number of successful spin-offs such as Novabase, Critical Software and OutSystems, who are key innovators worldwide. The connection between these companies and the universities can be further leveraged by a close cooperation with Carnegie Mellon, whose School of Computer Science is widely recognized to be the best in the world in several key areas.

Case Study: Certified Interfaces for Integrity and Security in Extensible Web-based Applications

PIs: Luis Caires, FCTUNL and Frank Pfenning, SCS, Carnegie Mellon

A collaborative project joining computer scientists at Universidade Nova de Lisboa, Faculdade de Ciências da Universidade de Lisboa and Carnegie Mellon aims at the development of new techniques for enforcing security, integrity, and correctness requirements on distributed extensible web-based applications by introducing novel, semantically rich notions of interface description languages, based on advanced type systems and logics. The company partner is OutSystems, who develops integrated platforms for the delivery and management of web business applications using agile methods.

Case Study: Institute for Software Engineering at University of Coimbra

Leadership: João Gabriel Silva and Paulo Marques, FCTUC and David Garland, SCS, Carnegie Mellon

Capitalizing on their expertise, some of which acquired through faculty exchange with Carnegie Mellon, and the success of their dual degree professional master's program in software engineering (MSE), which was developed in close cooperation with Carnegie Mellon and Portuguese companies like Novabase and Critical Software, the University of Coimbra is working towards the establishment of a new software engineering institute with high impact both nationally and internationally.

CYBER-PHYSICAL SYSTEMS FOR AMBIENT INTELLIGENCE

The convergence of computation, communication, sensing and control capabilities in relatively small devices at very low cost has signaled the advent of so called cyber physical systems, composed by large numbers of independent nodes that take measurements from physical processes and interact with the surrounding environment. These massively distributed systems can have many different applications ranging from the safety monitoring of roads, bridges, buildings, water distribution systems and public transportation systems to the provision of remote healthcare services and support to first responder in emergency scenarios. To face the challenges posed by numerous application scenarios, sensors and actuators must coordinate their efforts to achieve a global behavior that mirrors ambient intelligence, i.e. the ability of cyber-physical systems to use the collected data in a distributed fashion to solve problems in a collaborative way.

MAIN TECHNICAL CHALLENGES

- **Robust Sensor-Actuator Nodes:** The ability of a cyber-physical system to meet the challenge of a particular application clearly depends on the characteristics of individual nodes, which must be small enough to be embedded in the environment, robust enough to survive adverse conditions, tamper-proof to resist malicious attacks, flexible enough to adapt to new conditions or applications, and complex enough to be able to sense, compute and communicate over a typical noisy channel. In particular, new sensing and radio technologies are necessary, which can operate for example inside large buildings or in underground structures.
- **Distributed Sensing and Actuation:** To enable applications to run on cyber-physical systems, signal processing, communication and control algorithms must be re-thought to account for the strong restrictions in terms of power and computational capabilities. The information picked up by heterogeneous sensors must be secured and can be combined with other information about the physical world that is generated by users and made available through the

web (e.g. pictures posts with GPS information). Node mobility, for example through network robot systems, changes the picture once again, forcing cooperative control to work even in the presence of highly volatile channels. Design issues include cooperative localization, navigation, environment perception, map building, task allocation, and task execution.

- **Networked Infrastructures:** As sensor nodes are embedded seamlessly in buildings, water pipes, electrical grids and even inside textile fabric, these resulting cyber-physical systems will be able to collect very large amounts of data, compute the necessary inferences, and make decisions that can increase the life-cycle of these infrastructures, identify possible risks and prevent disruption of service or attacks on their integrity.
- **Middleware for Large-Scale Deployments:** The design of massively distributed applications poses great challenges to the programmer and to developers of programming languages. A top-down design would allow for the system designer to specify the functionalities of the system as a whole, which could then be translated semi-automatically to code that runs on each individual node. These micro-programs and their updates and configurations then have to be spread over the network, which from an operational point of view also requires dedicated middleware and adequate interfaces for the system administrator. Embedded nodes are becoming more and more powerful, but complex to specify and develop. In one hand, new multiprocessor and multi-core technologies are being used for small devices, which allows building more powerful applications, but that imposes new requirements in terms of resource management (CPU, memory, power, etc). On the other hand, applications become more complex to specify, imposing the need for advanced, but more and more reliable, operating systems and programming languages.
- **Scalable Query Processing:** The large number of sensing devices produces an enormous amount of sensor readings and clearly this generates an enormous amount of traffic. Fortunately, application designers are not interested in obtaining every sensor reading but designers are rather interested in answering high-level queries such as “What is the maximum temperature in this area?” or “Is there a person in this room?”. It is therefore typically not necessary to communicate all sensor readings since it is possible to compute answers to such queries inside the network. Novel approaches have been recently proposed that excel one of the main features of CPS: tight coupling of computing and communications with the physical environment and dynamics.

OPPORTUNITIES FOR CARNEGIE MELLON / COMPETITIVE ADVANTAGES FOR PORTUGAL:

Companies like Critical Software, ISA, Siemens, Efacec and BioDevices have been successful at developing technology that combines sensing, computation and

communication for applications as varied as aircraft control, utility monitoring, transportation systems, power networks and automation. In addition, Portugal has been a leader in renewable energy sources, whose outputs must be integrated in the smart grids of the future, supported by state of the art information and communication technologies.

On the other hand engineering schools in Portugal have a tradition of solid education in electronics and communications, which combined with software for real-time applications could yield new technologies for cyber-physical systems with wide applications in homes, offices, factories and other infrastructures.

Case Study: The Vital Responder Project

PIs: João Paulo Cunha, IEETA/UA, Priya Narasimhan, Carnegie Mellon

The goal of the Vital Responder research project is to explore the synergies between innovative wearable technologies, scattered sensor networks, intelligent building technology and precise localization services to provide secure, reliable and effective first-response systems in critical emergency scenarios. The core problem under consideration is to evaluate human stress in real-time under adverse conditions, by means of continuous online vital sign monitoring of first responders. Turning this vision into engineering reality requires significant advances on the several fronts: (a) real-time information gathering of body signals is very hard to achieve in uncontrolled and dangerous environments, (b) GPS based location systems do not work indoors, and (c) inter-disciplinary research between engineers and clinicians on the origins and nature of physiological stress is still at an infant stage. The “silver bullet” is provided by a high-tech company named Bio-Devices, which together with researchers at the University of Aveiro developed a suite of non-intrusive wearable technologies, as inconspicuous as a t-shirt, capable of gathering relevant information about the individual. The next step, which is currently taken in collaboration with researchers at IT, University of Porto and Carnegie Mellon is to view Vital Jackets as nodes of a distributed system that leverages the rich data sets with short-range communication, intelligent building technologies and localization capabilities. Ultimately the team will deploy a prototype infrastructure that enables continuous online monitoring of the collected information. Companies like McLaren Electronics and Petratex are also involved in the project.

HUMAN-CENTRIC COMPUTING

Although much has been accomplished in terms of developing hardware interfaces such as mice or touch screens, as well as software metaphors such as closing windows and opening menus, computers, small and large, are still far from the effortless usability that guarantees customer satisfaction. Users must still learn and adapt to interfaces that are not always intuitive and easy to understand. It is therefore only

natural to ask why it is not the machine who adapts to the human users, e.g. by learning their behaviors, adapting the environment, communicating in natural ways and offering alternatives and decision paths that match human senses and desires. To be successful, research in this area should be carried out in a highly inter-disciplinary fashion, combining elements of engineering with sociology, psychology and the arts.

MAIN TECHNICAL CHALLENGES

- **Context-Aware Services:** Using the inputs from various sources of information, such as sensing equipment and computer vision, applications will be able to infer the values of attributes such as physical location, physiological state, personal history, or daily behavior patterns of users. Ultimately, we aim at ICT for all, including people with special needs that can be accommodated by means of dedicated interfaces. The system should provide location-based user-oriented services that are tailored to a particular situation and a particular user, be it by delivering the right information at the right time or providing the right assistance by means of augmented reality at home or in the office.
- **Next Generation Social Networking:** The advent of Web 2.0 software revealed once again the innate necessity of human beings to share their experiences, tastes and feelings with a community, which can now be widely spread around the world. Beyond the potential for personal enjoyment, social networking promotes business by allowing a faster search for people and opportunities. Understanding how the enabling technologies for social networking, such as collaborative work, content sharing, instant messaging and reputation based systems, can be used to improve all facets of our lives offers large uncovered ground for research.
- **Innovative Language Technologies:** Language and speech are essential towards understanding the innate human ability to think and communicate. Computer aided language learning and speech-to-speech machine translation are only two examples of applications that offer relevant research challenges yet to be met. The solution is sure to require not only machine learning and pattern recognition techniques but also waveform synthesis and voice morphing.
- **Enhanced Human Interaction with Mobile Technology:** Technological advances are embedding more and more powerful computation and communication in both mobile systems and everyday objects, creating a dense ecosystem of increasingly connected smart objects, each capable of performing a complex sets of tasks. But human interaction with these sophisticated systems is limited, based on a paradigm of buttons, dials and on screen widgets borrowed from the world of desktop computing. We must transcend these limiting paradigms and create enriched human interactions in order to make accessible the sophisticated functionality inherent in smart objects.

OPPORTUNITIES FOR CARNEGIE MELLON / COMPETITIVE ADVANTAGES FOR PORTUGAL:

The citizens of Portugal are well known for their appetency for television, smart phones, portable computers and other gadgets. By nurturing a center of excellence for human computer interaction and empowering local companies with cutting-edge product development oriented towards ultimate usability, Portugal can become a living laboratory for a more humane relationship with new technologies. Novel interfaces will allow an ageing population and people with disabilities to keep up with the information age. The same applies to citizens with lower levels of education, thus providing a means for a more inclusive society.

Case Study: Sinais - Sustainable Interaction with social Networks, context Awareness and Innovative Services

PIs: Nuno Nunes, LabUse, UMa, and Anind K. Dey, Carnegie Mellon

The Sinais project is lead by researchers at the University of Madeira and Carnegie Mellon in partnership with ISA, Zon and Electricidade da Madeira, among others. It addresses environmental sustainability by questioning the seductive vision of "wellbeing" afforded, enabled and encouraged by industrialization; a vision based on personal ownership and mass consumption. The project is situated in the multi-disciplinary field of Human-Computer Interaction (HCI) and has three major foci: (i) the use of sensors and machine learning to monitor and make sense of human behavior; (ii) the application of motivational theory to intentionally influence people's behavior; and (iii) the use of a design mode of inquiry to address "wicked problems," such as sustainability. The practical work takes place in two key areas of human activity: resource use in the home and transportation. A major theme throughout the project is the use of social networking services as an enabling technology. The results of the project will be integrated into the open-innovation model provided by the Madeira Living Lab that enables companies, researchers and users to co-create user-centric services and products as active partners in the research, development and innovation (RD&I) cycle.

Case Study: Madeira Interactive Technologies Institute (Madeira-ITI)

Leadership: Nuno Nunes, UMa

A new institute for interactive technologies was recently created at the University of Madeira, which draws from the success of the dual degree professional master's program in human computer interaction (MHCI). The close relationship with Carnegie

Mellon and various companies helped the University of Madeira to recruit top faculty and students from all over the world. The institute shall function as an autonomous academic department with the goal of sustaining a long-term collaboration with related institutes at Carnegie Mellon.

PUBLIC POLICY & ENTREPRENEURSHIP DYNAMICS IN NEW INFORMATION AND COMMUNICATION TECHNOLOGIES

As exciting as scientific research often is, there is a long way to go from the first fundamental results to products and companies that bring comparative advantages to the economy of a region or a country like Portugal. Understanding how to bridge this gap and boost the latent innovation processes is a science in itself, in which the establishment of public policies and the governance and support of innovation and entrepreneurship processes ought to be guided by in-depth studies of, among others, regional aspects, technology issues, and the professional and personal path of entrepreneurs and innovators.

MAIN RESEARCH CHALLENGES

- **Global Innovation Networks:** From software development to product engineering, many of today's creative processes that generate intellectual property and innovative products are based on a global supply chain of talents. Many questions remain unanswered such as how these global innovation networks emerge, how they are energized by the synergies among universities and companies, how labor is divided among different peers, how the revenues of each partner can be ensured in a fair manner and how these networks can be sustained over long periods of time in an increasingly profitable fashion.

- **High Growth Technology Based Entrepreneurship:** Entrepreneurship is now seen as a critical driver of innovation and economic development. As a response, many countries, including Portugal, have enacted policies to foster entrepreneurial activity. However, only a small number of fast-growing new firms, typically with a strong knowledge base, account for the majority of job creation, while most are born small and remain small during their life spans. Thus, it is vital to improve our understanding of the critical factors that lead an entrepreneurial venture to have the desired high growth path, including the origin and experience of the founders and other leading employees, the access and characteristics of the capital structure and the expansion paths.

- **ICT Enabled Service and User Innovation**: The use of advanced ICTs for delivering services is forcing us to revisit many of our assumptions behind service management. In addition, there is great interest in understanding how innovation in ICT-enabled services can be used to differentiate and enhance commercial relationships. One of such dimensions is to explore the role of 'users' be sources for new offerings in the service sector. What are the operational antecedents that influence new service development, including software and processes support? To what extent does service innovation

influence business performance? To what extent are users sources of new services? And what are the managerial and policy implications?

- **Impact of Regulation on Competing Technologies:** The ICT sector is highly dynamic with new technologies emerging at increasing rates and conflicting interests of operators, manufacturers and costumers affecting the competition among different infrastructures, products and services. Regulation can have a decisive role in determining which competitors ultimately survive and succeed. Without a thorough understanding of this impact, regulation can hinder innovation rather than promote an environment where the best fit for individual and societal needs can be attained.

- **Segmented Regulation for Next Generation Networks (NGNs):** NGNs promise to deliver triple-play directly to end-users through high-speed connections in the last mile. However, the regulatory context under which such investments develop has a significant bearing on the attractiveness and promptness of carriers to deploy NGNs. It has been suggested that no single regulatory framework is correct under all circumstances. Rather, regulatory agencies must identify specific geographic sub-regions within each country and the appropriate regime in each region. One thus needs to study the determinants of segmentation and how they map to the appropriate requirements for wholesale offers of unbundled network elements.

- **Policies for Universal Service Provisioning:** The primary goal of universal service policy is to make telecommunications services widely available at affordable costs. Previous attempts at deploying such a policy have been largely criticized both in the US and in the EU. While reverse auctions provide an attractive way to elicit the true costs to reach remote underserved areas, one must study how they can complement specific projects to connect all schools, hospitals and local libraries with broadband.

OPPORTUNITIES FOR CARNEGIE MELLON / COMPETITIVE ADVANTAGES FOR PORTUGAL:

The spectacular growth of the ICTs sector and its shift of value towards IP-based innovative services and applications, supported by high-speed communication networks that now provide hard QoS guarantees, raise a number of challenges as to which business models are sustainable and which adaptive regulatory actions improve welfare. However, there is still little knowledge about the impact of all these intricate complex decisions on the dynamic structure of the industry. The current structure of the telecom industry in Portugal, due to the separation of cable from the incumbent

and the fierce competition in the mobile sector, provides a unique testbed to study a number of issues that can inform worldwide telecom policy making.

Information and Communication Technologies is an area where Portugal has been able to affirm some of its more innovative and successful ventures. For example, over 40% of the COTEC Network of innovative SMEs are active in the area of Information and Communication Technologies, often delivering new services. Thus, building on this success, learning from it and understanding how to further leverage ICT based innovation in the national context is critical for the growth and development of Portugal. The highly dynamic software sector and large multinational offer particularly relevant case studies that can be further utilized to grasp the yet uncovered potential of the Portuguese economy.

Another important opportunity is the fact that Portuguese authorities keep many records about employers and employees among other important datasets, which stand ready to be analyzed by competent researchers. This is especially relevant for the study of entrepreneurship dynamics, as it is possible to know the entire historical path of the entrepreneurs before they start their firms, as well as their collaborators and then follow the evolution and growth path of the new firms. The insights they yield can be of vital importance towards the design of sensible policies to promote the economic recovery of the country.

Case Study: Human Capital, Entrepreneurial Careers and Knowledge Based Entrepreneurship

PIs: Rui Baptista, IST/UTL, Steven Klepper, Carnegie Mellon

One central aspect in the creation and growth of knowledge-based firms is the role played by human capital. Human capital entails the stock of knowledge and skills that reside within individuals and that can be developed over time. This research project focuses on the role played by human capital of founders and employees in the creation and development of knowledge-based firms. In doing so, it examines the main decisions taken by entrepreneurs during their life cycle, and attempts to determine how the interaction between firm and market conditions and the background of these individuals influences these decisions and their outcomes in terms of firm success. The interaction between firm/market factors and individual characteristics can only be studied when data are available linking individuals and firms over time. Such data sets are rare and hard to access. Portugal has one of the most complete matched employer-employee databases: the 'Quadros de Pessoal' (QP) Micro Data set is gathered from mandatory information submitted yearly by Portuguese firms to the Ministry of Social Security and Labor since 1983. This longitudinal dataset can be used

to track the evolution of markets and individual firm performance, as well as individuals' professional and entrepreneurial experiences over time, allowing for the examination of their decisions and behavioral patterns in the labor market.

APPLIED MATHEMATICS

Carnegie Mellon University and the participating Portuguese Institutions have strong groups in Applied Mathematics, and a long history of scientific collaboration. Within this partnership the goals are to explore these existing connections, to encourage the emergence of new synergies, and to enhance the training of a new generation of young researchers well positioned to respond to contemporary scientific and technological challenges that require new fundamental and applied research in Mathematics. Ultimately, we would like to leverage jointly the know-how of mathematicians and engineers to produce high-impact research and innovative technical solutions.

MAIN RESEARCH AREAS

- **Applied Analysis:** This is a broad area of research which includes calculus of variations, partial differential equations, mathematical modeling and its applications. A particularly active research area is imaging and the study of properties of advanced materials.
- **Stochastic Analysis:** Many of the current research topics in this area, ranging from mathematical finance, stochastic control theory, viscosity solutions of Hamilton-Jacobi equations have wide real-world applications. One of the key objectives is to promote initiatives that help bridge the gap between theory and practice.

OPPORTUNITIES FOR CARNEGIE MELLON / COMPETITIVE ADVANTAGES FOR PORTUGAL:

The Universities in Portugal have strong groups in Applied Mathematics that would greatly benefit from the interaction with Carnegie Mellon. The area of Applied Mathematics is also a key area in the UTAustin | Portugal partnership, and this represents a unique opportunity to create educational, training and research networks between researchers in Portugal and researchers at these two US institutions.

Case Study: Summer School and Workshop on Kinetics and Statistical Methods for Complex Particle Systems

In summer 2009, the Carnegie Mellon|Portugal and the UTAustin|Portugal programs are joining efforts in organizing two important events to attract students and create

new research opportunities. During two weeks in July, a School and a Workshop on **Kinetics and Statistical Methods for Complex Particle Systems** will be held at FCUL in Lisbon. The Summer School has as target audience post-docs and Ph.D. students, whereas the Workshop will have the participation of key researchers on this area, both Portuguese, from Carnegie-Mellon and UTAustin, as well as from other institutions. We believe this event will help Portuguese students and faculty to establish long term research projects between these two universities.

ONGOING PROJECTS

The first call for proposals resulted in eight new projects, in which interdisciplinary teams from two or more Portuguese institutions, Carnegie Mellon and various companies tackle some of the aforementioned research challenges:

Project Title	Teams	Companies
Certified Interfaces for Integrity and Security in Extensible Web-based Applications PIs: L. Caires, F. Pfenning	UNL, FCUL, Carnegie Mellon	OutSystems
Web Security and Privacy: Weaving Together Technological Innovation with Human and Policy Considerations PIs: V. Kostakos, L. Cranor	UMa, IST/UTL, Carnegie Mellon	Portugal Telecom / Sapo
Human Capital, Entrepreneurial Careers and Knowledge Based Entrepreneurship PIs: R. Baptista, S. Klepper	IST/UTL, UCP, ISCTE, Carnegie Mellon	YDreams, Alfama, Critical Software
PT-STAR Speech Translation Advanced Research to and from Portuguese PIs: L. Coheur, A. Black	INESC/ID, FLUL, Carnegie Mellon	
Computer Aided Language Learning (CALL) Reading Practice (REAP.PT) PIs: N. Mamede, M. Eskenazi	INESC/ID, Carnegie Mellon	Porto Editora
DRIVE-IN: Distributed Routing and Infotainment through Vehicular Inter-Networking PIs: M. Ferreira, O. Tonguz	FCUP, IT, Carnegie Mellon	NDrive,
Vital Responder: Monitoring Stress among First Responder Professionals PIs: J. P. Cunha, P. Narasimhan	IEETA/UA,IT, UP, Carnegie Mellon	Biodevices, McLaren, Petratex
SINAIS - Sustainable Interaction with Social Networks, Context Awareness and Innovative Services PIs: N. Nunes, Anind K. Dey	UMa, Carnegie Mellon	Electricidade da Madeira, Horarios do Funchal, Aream, Zon Multimedia, ISA

ROADMAP

2006-2007	Launching of Partnership and Dual Degree Programs with Seed Research
2008	Launching of the First Call for Projects
2009	Strategic Plan for the Program
	SandBox Workshops
	Second Call for Projects / Calls for Human Resources
	First Annual Conference
2010	Graduation Ceremony for Professional Master's Programs
	Project Evaluation
	Second Annual Conference
2011	Plan for Sustainability

05 ATTRACTING TOP TALENT

The success of our research and innovation agenda is critically dependent on our ability to empower the best faculty, research and students in Portugal, while simultaneously attracting some of the best minds who are abroad. This pool of highly talented and driven individuals is part of the legacy envisioned for the CarnegieMellon|Portugal Program.

CARNEGIE MELLON | PORTUGAL FELLOWS

The Program recognizes individuals that contribute to its goals by awarding the honorary title of CarnegieMellon|Portugal Fellow following a yearly review. Carnegie Mellon | Portugal Fellows become agents of change by co-supervising students with

Carnegie Mellon faculty, participating in collaborative research projects and teaching accredited graduate courses in the dual degree programs, among other activities. Naturally, Carnegie Mellon | Portugal Fellows are key contributors to the present strategic document.

INTERNATIONAL RECRUITMENT

We aim at facilitating the international recruitment by Portuguese universities and research institutions, based on the following steps:

- Providing training of Portuguese recruiters by experienced international recruiters from Carnegie Mellon;
- Making use of Carnegie Mellon's marketing services, international contacts and extensive alumni network;
- Leveraging the recognition of the Carnegie Mellon brand;
- Joint marketing of the dual degree programs;
- Emphasizing the opportunity of a combined European and American experience throughout the graduate studies.

06 TRAINING THE BEST

Attracting and training the most talented young researchers and professionals is a necessary condition for Portugal to be successfully involved in the global innovation networks that develop breakthrough science and technology.

DUAL DEGREE PHD PROGRAMS

Research in the program is supported by dual degree PhD programs in the general area shown below. Portuguese universities and Carnegie Mellon have worked on cooperation agreements by which students are co-supervised by a faculty member at a Portuguese institution and another faculty member at Carnegie Mellon, thus enabling close research collaborations. Moreover, each graduate who satisfies the requirements of both universities obtains a PhD degree from Portugal and the PhD degree from Carnegie Mellon.

Students typically spend 40% of their time at Carnegie Mellon, where they are immersed in the vibrant culture of a top American university. When returning to their

labs in Portugal, these students bring with them a powerful set of experiences, skills and working habits, which makes them ideal leaders for a renewed culture of change.

Dual Degree PhD Programs		Carnegie Mellon	Portugal	New Students 2007/08	New Students 2008/09
CS	**Computer Science** Co-Directors: L. Caires, F. Silva, F. Pfenning	SCS	FCUL, FCUP, FEUP, FCTUC, UA, UM, IST/UTL, UNL	1	4
ECE	**Electrical and Computer Engineering** Co-Directors: A. Campilho, J. Costeira	ECE	FCUL, FCUP, FEUP, FCTUC, UA, UM, IST/UTL	1	9
EPP	**Engineering and Public Policy** Co-Directors: P. Ferreira and M. Sirbu	EPP	IST/UTL, UCP	1	5
LT	**Language Technologies** Co-Directors: I. Trancoso and Robert	LTI, SCS	IST/UTL	1	2
Math	**Applied Mathematics** Co-Directors: D. Gomes and I. Fonseca	Math	IST/UTL, FCUL, UNL	1	2*
TCE	**Technological Change and Entrepreneurship** Co-Directors: P. Oliveira and F. Veloso	SETChange	IST/UTL, UCP	6	5

* Post-Docs

PROFESSIONAL MS PROGRAMS

Professional MS programs play an important role in establishing a close connection with the Portuguese industry, as they provide top training for the engineering leaders of the industry. These leaders are well poised to become key enablers in bringing innovation from the universities to their companies.

Professional Master Programs		Carnegie Mellon	Portugal	New Students 2007/08	New Students 2008/09
MSIN	**Master in Information Networking** Leadership: R. Aguiar, N. B. Carvalho and D. Tsamitis	INI	UA	7	6
MSE	**Master of Software Engineering** Leadership: P. Marques, J. C.	SCS	FCTUC	4	15

MSIT – IS	**Master in Information Technology – Information Security** Leadership: N. Neves, P.	INI	FCUL	4	12
MHCI	**Master in Human Computer Interaction** Leadership: N. Nunes and D.	IHCI	UMa	3	14

FACULTY EXCHANGE

The Carnegie Mellon | Portugal Program supports faculty exchange programs, in which Portuguese academics can spend at least one term working in research and education at Carnegie Mellon and experience the culture of a top US university. The goal is to accelerate the exchange of best practices through cultural immersion. Carnegie Mellon professors are also given the opportunity to spend some time in Portugal engaging in teaching and research activities with local institutions of higher education and research labs.

07 DRIVINGKNOWLEDGE EXCHANGE

INDUSTRIAL AFFILIATES PROGRAM

The Carnegie Mellon | Portugal Program keeps a very close relationship with the Portuguese industry. Partners companies typically join the industrial affiliates program by which they become members of the program's innovation networks, training their personnel in the various dual degree programs and collaborating in research projects that are targeted towards their strategic needs. Portugal Telecom, Nokia Siemens Networks and Novabase are the main corporate sponsors with sizeable financial commitments. The main benefits, which are open to small and medium enterprises as well, can be summarized as follows:

- Close collaboration with internationally reputed scientists and engineers;
- Specialized training of advanced human resources;
- International partnership with increased visibility;
- Best practices in technological innovation;
- Access to a global network of industrial and academic contacts.

Portugal Telecom, the incumbent telecommunications operator in Portugal, is a key industrial partner and major financial contributor. Nokia Siemens Networks and Novabase have also made their financial commitment since the beginning of the international partnership. Other companies include Alfama, Aream, Biodevices, Critical

Software, Electricidade da Madeira, Horarios do Funchal, ISA, McLaren Electronics, NDrive, OutSystems, Petratex, Porto Editora, YDreams, andZon Multimedia.

SANDBOXMEETINGS AND SUMMER ACADEMY

Innovation within the Carnegie Mellon | Portugal starts with sandbox meetings in which leading academics and emerging talents in various fields meet with company experts and entrepreneurs to identify relevant real-world problems with international scientific value. These meetings take various forms from smaller discussion groups by invitation to special work sessions at the Summer Academy, which combines training for professionals with a doctoral consortium for graduate students.

09 SUSTAINING THE LEGACY

As our international partnership advances, there is one common key priority for all partners: to identify the means for sustaining the positive outcomes of ongoing joint efforts. This includes but is not limited to the following actions:

- **Routines for Sharing Experiences and Best Practices:** As Portuguese institutions move towards closer collaboration through their joint activities with Carnegie Mellon, it is very important to establish standard routines for knowledge sharing based on the experiences with ongoing activities and existing programs. This includes best practices for co-supervision of students, organization and monitoring of educational programs, governance of schools and departments, models for international cooperation, leadership in academics and collaborative research projects, among other aspects.

- **Comprehensive Strategy and Detailed Operational Plans:** Each institution and activity is expected to define and state their strategic objectives and how the partnership with Carnegie Mellon and the Portuguese industry is leveraged towards those ends. The strategic plan drawn from those objectives must state how success is to be achieved and how real outcomes are to be measured. An operational plan must be put in place for each activity outlining the leadership and management timeline, committing to short-term goals and milestones that contribute towards the achievement of the long-term objectives.

- **Accountability:** Every year the program is evaluated by the External Review Committee, which is composed by top international experts who analyze the outcomes of each activity and make detailed recommendations on how to improve the program and converge towards the stated goals. The practice of external evaluation by international peers is a key element in guaranteeing the success and the sustainability of the program.

- **Consortium building:** To attain the necessary critical mass for achieving international impact, universities and research institutes are expected to build long lasting innovation consortia. These consortia can take very different forms, yet they must be entrepreneurial in spirit and sustainable in practice.

- **Cooperation with the Industry:** Sustaining many of the activities of the partnership depends to large extent on the ability of institutions to include the industry in their innovation consortia. This can only be achieved if companies can recognize the value of a close cooperation with the universities and the research institutions. It is thus very important to nurture this relationship up to a point where the benefits for all parts become evident for example through the mobility of highly qualified individuals between academic and industrial environments or established best practices and identifiable innovation outcomes.

LIST OF CONTRIBUTORS (TO BE COMPLETED)

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