

# INFORMATION AND COMMUNICATION TECHNOLOGY

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# INFORMATION AND COMMUNICATION TECHNOLOGY

2012

The Académie universitaire Louvain (AL) is a university consortium composed of the following three academic institutions: University of Namur (FUNDP), University faculties of Saint-Louis, Brussels (FUSL) and Université catholique de Louvain (UCL).

In this particular case, this brochure «ICT» has been prepared by the Research Administration Departments of the FUNDP and the UCL only, with the valuable help of a peer review committee composed of:

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# Foreword

In 1982, the title of “Man of the Year”, delivered by Time magazine has not been awarded to a person but to a machine: the computer. Slightly later on, the computer manufacturer Sun promoted the idea that “the network was the computer”. Nowadays, we are used to terms like “pervasive computing”, “ubiquitous computing”, “cloud computing”, and “ambient intelligence”, to cite a few. These are just several indications that information technologies are everywhere in our life. One can even further claim that without these technologies, our modern societies could not function properly. In fact, would it be imaginable to live or even to survive without mobile phones, access to the internet, sophisticated machines at hospitals and electronic payments?

In this context, this brochure presents the research conducted on information and communication technologies inside the “Académie universitaire Louvain”, by the Université catholique de Louvain and the University of Namur. As will be appreciated by the reader, the brochure does not focus only on the technologies themselves but also encompasses work on its impact on society. In doing so, we follow the humanistic approach of the two universities which aims at not only developing science but also at being concerned with its role in our everyday life. As a result, our research has generated many spin-off companies and has created strong links with regional technological centers, such as Multitel and Cetic, with industrial clusters, like Infopole and Twist, as well as with many research laboratories in the world.

The brochure is structured in 13 chapters and tackles various domains, such as society and law, human computer interaction, bioinformatics, micro and nano-technologies<sup>1</sup>, applied electromagnetism, electronic circuits, signal and image processing, networks, cryptography, security, control, optimization, large graphs, high-performance computing, machine learning, artificial intelligence, natural language processing, software engineering, programming, formal methods, databases and information systems. This multitude of research activities demonstrates a strong, dynamic and international presence of the “Académie universitaire Louvain” in the field of information and communication technologies. As such, the aim of this booklet is to provide the reader with an up-to-date view of this expertise and will undoubtedly ease its transfer to industry and society.

Jean-Marie Jacquet  
Chairman of the Peer-review Committee

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<sup>1</sup> Detailed in the brochure “Nanotechnologies 2011”.



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# Cellular and wireless access networks

## SENIOR SCIENTIST:

▶ Laurent SCHUMACHER

## Research Field and Subjects

The research unit investigates the impact of cellular (3G/HSPA - 4G/LTE) and wireless (WiMAX) access networks on IP traffic. This involves the characterisation of the traffic flows and the modelling of the system behaviour, in order to build up vanilla test beds emulating radio-based access networks in line with standardisation (both in Control and Data/User Planes).

The availability of such test beds enables the evaluation of the Quality of Experience of end-user applications when offered through a radio-based connection.

The research unit has also gathered expertise in characterising the end-user performance of such access networks.

## Representative References

- ▶ SCHUMACHER L., GOMAND G., TOMA G., Performance Evaluation of Indoor Internet Access over a Test LTE Mini-Network, WPMC'11 – Wireless Personal Multimedia Communications, **2011**.
- ▶ TOMA G., SCHUMACHER L., Offering Streaming Rate Adaptation to Common Media Players, ICME 2011 – Workshop on Hot Topics in Multimedia Delivery (HotMD), **2011**.
- ▶ TOMA G., SCHUMACHER L., Measuring the QoE of Streaming Sessions, SCVT'08 – Symposium on Communications and Vehicular Technology in the Benelux, **2008**.
- ▶ VANDERPYPEN J., SCHUMACHER L., Multistream Proportional Fair Packet Scheduling in HSDPA, SCVT'08 – Symposium on Communications and Vehicular Technology in the Benelux, **2008**.

## Funding

F.R.S.-FNRS, European (FP6), Wallonie.

## Partnership

- ▶ Université catholique de Louvain, Louvain-la-Neuve (Belgium)
- ▶ Università Federico II, Naples (Italy)
- ▶ Aalborg University, Aalborg (Denmark)

## Main Equipment

- ▶ Three computing nodes part of the worldwide PlanetLab testbed
- ▶ A WiMAX access point with IBPT experimental licence

## Products and Services

Characterisation and performance analysis of cellular and wireless access networks

## KEYWORDS

HSPA  
LTE  
WiMAX  
Testbed  
Emulation

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# SIP-based Communication Networks and Services

## SENIOR SCIENTIST:

▶ Laurent SCHUMACHER

## Research Field and Subjects

SIP, whose acronym stands for Session Initiation Protocol, is a signalisation protocol enabling the establishment, the configuration, the update and the closing of communication sessions like voice calls, instant messaging, videoconferencing, etc. SIP is the lingua franca of nowadays communicating applications.

As of today, SIP is natively used in a communication framework called IP Multimedia Subsystem (IMS). Originally, IMS has been developed within cellular network standardisation to ease the design and deployment of new value-added services. IMS helps to overcome the proprietary, vertically integrated service paradigm that has slowed down innovation in the Telco world for so many years. It aims at enabling a web-like service development (i.e. download and play) on communication terminals.

SIP and IMS are very elegant solutions to deploy new IP-based telecommunication services. Thanks to numerous Requests For Comments (RFC), their standard description is quite detailed, but deployments quickly reveal significant shortcomings. Among them, one finds scalability, flow regulation and interoperability.

Investigation of scalability in the orders of magnitude that really matter, typically thousands of nodes and more, cannot be performed with a dedicated computer per node. Virtualisation enables to reach this goal by emulating the behaviour of a significant number of competing nodes on a single computer.

To investigate interoperability, one should build an ecosystem populated with implementations from several vendors. Without aiming at reproducing such a rich ecosystem as Fokus Open IMS Playground, the research unit valorises existing contacts with industrial partners to gather implementations of their products in a single environment and to interface them with complementary open source systems.

## Representative References

- ▶ ROLY A., SCHUMACHER L., SIP Overload Control Testbed: Design, Building and Validation Tests, CCNC'11 – Consumer Communications and Networking Conference, **2011**.
- ▶ WAUTHY J.-F., SCHUMACHER L., Implementation and Performance of a P2PSIP Distributed Proxy/Registrar, NGMAST'07 – International Conference on Next Generation Mobile Applications, Services and Technologies, **2007**.
- ▶ GAMBY S., SCHUMACHER L., RAMAEKERS J., Securisation of SIP Presence notifications thanks to the Belgian electronic identity card, NGMAST'07 – International Conference on Next Generation Mobile Applications, Services and Technologies, **2007**.

## Funding

F.R.S.-FNRS, Wallonie.

## Partnership

FTW - Forschungszentrum Telekom-munikation Wien, Vienne (Autriche)

## Main Equipment

Three computing nodes part of the worldwide PlanetLab testbed

**KEYWORDS**

SIP  
IMS  
Overload  
Testbed

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# Internet protocols

## SENIOR SCIENTIST:

▶ Olivier BONAVENTURE

## Research Field and Subjects

During the last twenty years, the Internet evolved from a research network that was only used by universities to become a global and pervasive network. The Internet is built upon the TCP/IP protocol suite. This protocol suite is not static. New protocols or extensions to the existing ones are developed, tested and, for the most successful ones, standardized and deployed in the global Internet.

The main challenge in this R&D activity is to propose new protocols or extensions that encounter problems that cannot be solved by using existing protocols. The IP networking lab within the ICTEAM Institute has accumulated a lot of experience in designing, improving and implementing protocols, notably in the network and transport layers of the TCP/IP suite. The lab participates in all activities related to new Internet protocols. These activities start with the design of new Internet protocols, but also include the development of models to analyze the performance of a particular protocol or the development of open-source reference implementations. The lab also actively participates to standardization of protocols within the Internet Engineering Task Force (IETF) and maintains strong cooperations with vendors of network equipment and network operators.

In the transport layer, recent significant research results include an active participation in the specification of Multipath TCP and the development of the first reference implementation in the Linux kernel. In the network layer, the lab has a recognised expertise in the development and tuning of routing protocols. It has also actively contributed to the development of the IPv6 host-based multihoming solution (shim6) and the Locator/Identifier Separation Protocol (LISP).

## Representative References

- ▶ BONAVENTURE O., Computer Networking: Principles, Protocols and Practice, **2011**.
- ▶ BARRÉ S., PAASCH C. and BONAVENTURE O., MultiPath TCP: From Theory to Practice. IFIP Networking, Valencia, May **2011**.

- ▶ IANNONE L., SAUCEZ D. and BONAVENTURE O., Implementing the Locator/ID Separation Protocol: Design and Experience. Computer Networks, 55(4):948-958, March **2011**.
- ▶ BARRÉ S., RONAN J. and BONAVENTURE O., Implementation and evaluation of the Shim6 protocol in the Linux kernel. Computer Communications, **2011**.
- ▶ RAICIU C., BARRÉ S., PLUNTKE C., GREENHALGH A., WISCHIK D. and HANDLEY M., Improving datacenter performance and robustness with multipath TCP. SIGCOMM 2011, Toronto, Canada, August **2011**.
- ▶ VAN DEN SCHRIECK V., FRANCOIS P. and BONAVENTURE O., BGP Add-Paths: The Scaling/Performance Tradeoffs. IEEE Journal on Selected Areas in Communications, 28(8):1299 - 1307, October **2010**.
- ▶ BONAVENTURE O., FILSFILS C. and FRANCOIS P., Achieving Sub-50 Milliseconds Recovery Upon BGP Peering Link Failures. IEEE/ACM Transactions on Networking, 15(5):1123 - 1135, October **2007**.
- ▶ FRANCOIS P. and BONAVENTURE O., Avoiding transient loops during the convergence of link-state routing protocols. IEEE/ACM Transactions on Networking, 15(6):1280-1932, December **2007**.

## Awards

INFOCOM 2007 best paper award

## Funding

The work on Internet protocols has been funded by the EC in several FP7 projects, but also by F.R.S.-FNRS, FRIA, Wallonie and also directly by industry.

## Partnership

- ▶ Cisco Systems
- ▶ Google
- ▶ University College London
- ▶ Université de Liège



## **Products and Services**

UCL researchers have contributed to various open-source implementations including:

Linshim6 : <http://inl.info.ucl.ac.be/linshim6>

MPTCP Linux : <http://inl.info.ucl.ac.be/mptcp>

OpenLISP : <http://www.openlisp.org>

## **KEYWORDS**

Network Architecture and Design  
Network Protocols

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<http://www.uclouvain.be/icteam>

# Management and operation of IP networks

## SENIOR SCIENTIST:

▶ Olivier BONAVENTURE

## Research Field and Subjects

During the last decade the Internet Protocol (IP), sometimes associated with MultiProtocol Label Switching (MPLS), became the de-facto standard protocol to carry any type of data in enterprise and service provider networks. IP is now used to support Internet services, but also voice, video, gaming, and various types of applications that depend on computing and storage resources in datacenter. Despite their importance, many IP networks are still managed and configured manually. This is not optimum and frequently causes problems that affect all users of the network. Large networks cannot continue to be managed and configured manually. They must be controlled by a specialised software that interacts with all the networking equipments.

This research activity develops algorithms and techniques that enable network management platforms to better control the operation of the network. Traffic engineering is an example of the benefits of using software to configure the network. Based on measurements collected in the network, another expertise that has been developed within this activity is an optimisation algorithm. This algorithm determines the best network configuration that meets the performance objectives of the network. A second example is the utilisation of software engineering techniques to produce network configurations whose properties are known and that can be validated before being installed inside the network. A third example is the development of innovative techniques to enable a network to be reconfigured without causing traffic disruptions and losing packets. Another example is the support of Openflow on networking equipment from various vendors. This will clearly lead to new network management and operation techniques. These techniques are also taught in the advanced networking courses at UCL to encourage students to automate their network management and operations problems by using appropriate software.

## Representative References

- ▶ VANBEVER L., VISSICCHIO S., PELSSER C., FRANCOIS P. and BONAVENTURE O., Seamless Network-Wide IGP Migrations. Proceedings of the 2011 ACM SIGCOMM Conference, Toronto, Canada, Aug. **2011**.
- ▶ TRONG VIET Ho, DEVILLE Y., BONAVENTURE O. and FRANCOIS P., Traffic Engineering for Multiple Spanning Tree Protocol in Large Data Centers. ITC 2011 23rd International Teletraffic Congress, San Francisco, USA, September **2011**.
- ▶ LEROY D. and BONAVENTURE O., Preparing network configurations for IPv6 renumbering. International Journal of Network Management, Wiley InterScience, 19(5):415-426, Sept-Oct **2009**.
- ▶ VANBEVER L., PARDOEN G. and BONAVENTURE O., Towards validated network configurations with NCGuard. Proc. of Internet Network Management Workshop 2008, pages 1-6, Orlando, USA, October **2008**.
- ▶ FRANÇOIS P., SHAND M. and BONAVENTURE O., Disruption-free topology reconfiguration in OSPF Networks. IEEE INFOCOM, Anchorage, USA, May **2007**.
- ▶ FRANCOIS P., COSTE P.-A., DECRAENE B. and BONAVENTURE O., Avoiding disruptions during maintenance operations on BGP sessions. IEEE Transactions on Network and Service Management, 4(3):1-11, **2007**.

## Awards

INFOCOM 2007 best paper award

## Funding

This research has been funded by the EC in several FP7 projects, but also by F.R.S.-FNRS, FRIA, Wallonie and also directly by industry.

## Partnership

- ▶ France Telecom
- ▶ Alcatel-Lucent
- ▶ Internet Initiative Japan
- ▶ University of Roma Tre
- ▶ Université de Liège

## Products and Services

Various software tools have been developed to model, traffic engineer and configure networks, e.g.:

- ▶ NCGuard: Network Configuration Safeguard, <http://inl.info.ucl.ac.be/>
- ▶ C-BGP simulator, <http://c-bgp.sourceforge.net/>
- ▶ TOTEM traffic engineering toolbox, <http://totem.info.ucl.ac.be>

## KEYWORDS

Network Operations  
Network management  
Network monitoring

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# Signal processing and Information theory for Wired Communications (DSL and PLC)

## SENIOR SCIENTISTS:

- ▶ Jérôme LOUVEAUX
- ▶ Luc VANDENDORPE

## Research Field and Subjects

Wired communications have become rather popular with the advent of DSL technologies. These technologies will still evolve in the future while other technologies are being considered, like the powerline communications (PLC). While solutions exist for both DSL and PLC, there is room for further optimisation, like coordination, fair resource allocation among users, adaptability, etc.

– Fair multiuser resource allocation: information theory  
DSL and PLC can be looked at in the framework of multiple access, broadcast and interference channels. An important issue when several users communicate simultaneously is the fair resource allocation among users. Different fairness criteria can be defined, which lead to different solutions, bit rates, etc. In the framework of cross layer design, research is conducted in this area.

– Signal coordination and crosstalk cancellation  
Crosstalk has become one of the main sources of degradation for DSL communications. However, the lines that are contained in a common bundle and that interfere with each other are also often handled by the same equipment at the central office. Signal processing on the signals sent over the different lines is thus possible to compensate or pre-compensate the interference. Research focuses on methods to obtain the required accurate channel estimates in order to perform these compensations, as well as ways to limit the complexity of the overall system.

– Spectrum management  
Smart usage of the spectrum among the users is another way to decrease the impact of crosstalk on DSL systems. Several optimisation methods are investigated in this context, focusing on solutions with limited complexity.

## Representative References

▶ LOUVEAUX J., VAN DER VEEN A.-J., "Adaptive precoding for downstream crosstalk precancellation in DSL systems using sign-error feedback", *IEEE Trans. On Signal Processing*, vol. 58, No. 6, pp. 3173-3179, June **2010**.

- ▶ GUENACH M., LOUVEAUX J., VANDENDORPE L., WHITING P., MAES J., PEETERS M., "On signal-to-noise ratio assisted crosstalk channel estimation in downstream DSL systems", *IEEE Trans. On Signal Processing*, vol. 58, No. 4, pp. 2327-2338, April **2010**.
- ▶ LOUVEAUX J., KALAKECH A., GUENACH M., MAES J., PEETERS M., VANDENDORPE L., "An SNR-assisted crosstalk channel estimation technique", International Conference on Communications (ICC'09), Dresden, Germany, June **2009**, 5 pp.
- ▶ KALAKECH A., LOUVEAUX J., and VANDENDORPE L., "Enhancement of the iterative spectrum balancing algorithm for power allocation in DSL systems", IEEE Global Telecommunications Conference, GLOBECOM 2008, New Orleans, USA, pp. 1-5, November **2008**.
- ▶ SARTENAER T., LOUVEAUX J. and VANDENDORPE L., "Balanced capacity of wireline multiuser channels with individual power constraints", *IEEE Trans. on Communications*, vol. 56, No., pp.925-936, 6, June **2008**.
- ▶ DEVILLERS B., LOUVEAUX J. and VANDENDORPE L., "Bit and power allocation for goodput optimization in coded parallel subchannels with ARQ", *IEEE Trans. on Signal Processing*, vol. 56, No. 8, August **2008**, pp. 3652-3661
- ▶ LOUVEAUX J. and VAN DER VEEN A.-J., "Error sign feedback as an alternative to pilots for the tracking of FEXT transfer functions in downstream VDSL", *EURASIP Journal on Applied Signal Processing (Special issue on Advanced Signal Processing Techniques for Digital Subscriber Lines)*, **2006**.

## Patents

- ▶ "Determining channel matrices by correlated transmissions to different channels", US patent US2008/010058.
- ▶ "Multiband detector", patent CN1224291, 1999.
- ▶ "Method and arrangement to determine a clock timing error in a multi-carrier transmission system", US patent US200215007
- ▶ "Optimised bit allocation adapted for VDSL", US patent US2003130824, 2003.

## Awards

- ▶ Siemens 2002 biennial Award from the Belgian NSF (Information and Communications technologies), J. Louveaux, F. Deryck, L. Vandendorpe;
- ▶ Alcatel Bell 2005 Award to T. Sartenaer and J. Louveaux for the work on "Transmission over powerline communications" directed by L. Vandendorpe;
- ▶ IEEE Fellow 2006 (L. Vandendorpe)

## Partnership

- ▶ Stanford University, USA
- ▶ Delft Technical University
- ▶ Alcatel
- ▶ Research Contracts from Wallonie, IWT, Alcatel, Broadcom.

## Products and Services

DSL-PLC oriented signal processing toolbox

## Main Equipment

- ▶ Digital sampling oscilloscope (16 GHz analog bandwidth, 80 GSa/s – 2 channels)
- ▶ HP Signal generator (10 MHz BW), up to 2.4 GHz

## KEYWORDS

Wired communications  
Spectrum management  
Signal processing  
Multiuser systems  
Detection estimation

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# Satellite Communications

## SENIOR SCIENTISTS:

- ▶ Claude OESTGES
- ▶ Danielle VANHOENACKER-JANVIER

## Research Field and Subjects

### – Models of turbulent atmosphere

The team has maintained for 20 years a well-established position in modelling tropospheric scintillation on earth-satellite links. Emphasis is put on the analysis and modelling of the random amplitude variations of microwave signals based on ESA's satellite Olympus beacon measurements. A statistical method using radiosonde data has been developed to predict scintillation effects on slant paths. The outputs of the Numerical Weather Prediction models are envisaged to provide inputs to the software that simulates the propagation through the turbulent troposphere. A similar model is developed to calculate the radar backscattering of wake vortices detection.

### – Rain and Ice Depolarisation Modelling

The focus is on electromagnetic modelling of rain and ice depolarisation, and on comparison with measured time series and long-term statistics.

### – Link performance prediction for the land mobile satellite (LMS) channel

A variety of specific prediction methods for personal satellite communication networks have been applied, starting from a physical description of tropospheric and surface environmental mechanisms. Furthermore, an improved method has been developed to extract the parameters of a two-state Markov model for LMS channel. Having the parameters, time series can be generated for system simulation.

### – Implementation and improvement of ITU-R models for interferences and coordination area

This activity has just started in the framework of an ESA contract on the development of a software that predicts the effects of the troposphere, the ionosphere, the environment and interferences on communication systems (RAPIDS II software).

## Representative References

- ▶ LEMORTON J., FABBRO V., KOUROGIORGAS C., BOUCHARD P., ROGERS D., LUINI L., RIVA C., VANHOENACKER-JANVIER D., LACOSTE F., BRATEN L., CASTANET L., Review of prediction methods for low-elevation aerospace systems and new achievements, EUCAP 2011, pp. 3393–3397, **2011**.
- ▶ MONTENEGRO-VILLACIEROS B., OESTGES C., PEREZ-FONTAN F., PRIETO-CERDEIRA R., HEYN T., EBERLEIN E., VANHOENACKER-JANVIER D., Stationarity study of Land Mobile Satellite channel in view of developing a time series generator, EuCAP 2011, pp. 3739–3741, **2011**.
- ▶ VANHOENACKER-JANVIER D., OESTGES C., MONTENEGRO-VILLACIEROS B., VAN MALDEREN R., DE BACKER H., Scintillation prediction using improved pre-processed radiosounding data, EuCAP 2009, pp. 3849–3851, **2009**.
- ▶ LEMORTON J., CASTANET L., BLARZINO G., CARRIE G., VANHOENACKER-JANVIER D., MONTENEGRO-VILLACIEROS B., WENDLAND D., MARTELLUCCI A., Global Archive of propagation measurements for satellite communication systems, EuCAP 2009, pp. 3623–3627, **2009**.
- ▶ PARABONI A., OESTGES C., MARTELLUCCI A., Experimental assessment of atmospheric depolarization at Ka and V band based on Olympus and Italsat propagation campaigns, EuCAP 2006, **2006**.

## Awards

1999-2000 IEE Marconi Premium Award (C. Oestges, D. Vanhoenacker *et al.*)

## **Funding**

- ▶ 5 ESA contracts
- ▶ Thales Air System (SESAR JU, FP7)

## **Partnership**

- ▶ IRM, Belgium
- ▶ ONERA-CERT, France
- ▶ Univ. of Vigo, Portugal
- ▶ UNIK, Norway
- ▶ DLR
- ▶ Politecnico de Milano, Italy

Participation in

- ▶ COST 0802 Action (co-chair)
- ▶ Network of Experts in Propagation

## **Products and Services**

- ▶ Olympus experiment database at 12.5, 20 and 30 GHz (including scintillation and depolarisation data)
- ▶ Development of a new version of RAPIDS II

## **KEYWORDS**

Satellite communications  
Tropospheric scintillation  
Tropospheric depolarisation  
Earth-satellite channel modelling  
Radar backscattering of wake vortex

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# Wireless Communications

## SENIOR SCIENTISTS:

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- ▶ Claude OESTGES
- ▶ Luc VANDENDORPE
- ▶ Christophe CRAEYE

## Research Field and Subjects

Wireless communications have become a very exciting area with the success of GSM, UMTS, WiFi and sensor networks. Even if some maturity has been reached, new challenges are still to be faced, such as the support of higher bit rates and throughput, the increase of mobility, the interoperability of different technologies and the miniaturisation of components. On top of current systems with known topologies, new paradigms are also currently explored such as cross-layer design, relaying and cooperative strategies, and cognitive radio.

### – Advanced Tranceiver Design

Multi-cell communications are an emerging concept which offers many degrees of freedom. Attention is paid to centralise and distribute coder and decoders across cells, robust against channel uncertainties.

### – Wireless Channel Characterisation

This activity deals with the measurement and the modelling of wireless transmissions, including cellular, vehicular and body-area networks, with a particular focus on multi-link aspects (multi-node, multi-cell).

### – Multi-Link MIMO Communication Systems

The research projects in multi-link Multiple-Input Multiple-Output (MIMO) communications cover channel modelling and measurements, together with the development of space-time signalling techniques that exploit the spectral efficiency advantage of spatial multiplexing and the robustness of eigen-beamforming.

### – OFDM(A) Communications Systems

OFDMA is the current technology considered for many new standards. Research focuses on resource (bit, power, carrier) allocation strategies for multiuser OFDMA, possibly including cognitive setups.

### – Cooperative communications

Cooperation is a new paradigm that receives a lot of attention in the aim to increase coverage. Different strategies are investigated in P2P and multiuser scenarios, including for OFDM

based systems. Game theory is one of the frameworks which is exploited to optimise coalition formation.

### – Ultra-Wide Band

Research on Ultra-Wide Band (UWB) focuses on the channel modelling and on the communication techniques, such as time-reversal and accurate localisation via advanced signal processing.

### – Body-Centric Communications

Channel models and algorithms are developed for body-centric applications, including healthcare and motion capture systems.

### – Antenna technology

Numerical simulation of antennas and antenna arrays (narrow-band and ultra-wideband). Design and characterisation of such antennas. Near field imaging and beamforming networks – see A8.

## Representative References

- ▶ LIU L., KESHMIRI F., CRAEYE C., DE DONCKER P. and OESTGES C., An analytical modeling of polarized time-variant on-body propagation channels with dynamic body scattering, *EURASIP Journal on Wireless Communications and Networking*, 12 p., March **2011**.
- ▶ OESTGES C., CZINK N., BANDEMER B., CASTIGLIONE P., KALTENBERGER F., PAULRAJ A., Experimental characterization and modeling of outdoor-to-indoor and indoor-to-indoor distributed channels, *IEEE Trans. Veh. Tech.*, vol. 57, No. 5, pp. 2253–2265, June **2010**.
- ▶ RENAUDIN O., KOLMONEN V.-M., VAINIKAINEN P., OESTGES C., Non-stationary narrowband MIMO inter-vehicle channel characterization in the 5 GHz band, *IEEE Trans. Veh. Tech.*, vol. 57, No. 4, pp. 2007–2015, April **2010**.
- ▶ CHALISE B. K., VANDENDORPE L., MIMO Relay design for multipoint-to-multipoint communications with imperfect channel state information, *IEEE Transactions on Signal Processing*, vol. 57, No. 7, pp. 2785–2796, July **2009**.
- ▶ DEVILLERS B., LOUVEAUX J. and VANDENDORPE L., About the diversity in cyclic prefixed single-carrier systems (invited paper), *Physical Communication*, vol. 1, No. 4, pp. 266–276, December **2008**.



- ▶ HERZET C., NOELS N., LOTTICI V., WYMEERSCH H., LUISE M., MOENECLAËY M., VANDENDORPE L., Code-Aided Turbo Synchronization (invited paper), *Proceedings of the IEEE*, vol. 95, No. 6, pp. 1255 – 1271, June **2007**.
- ▶ OESTGES C., CLERCKX B., *MIMO wireless communications: from real-world propagation to space-time code design*, Academic Press: Oxford, **2007**.
- ▶ WAUTELET X., HERZET C., DEJONGHE A., LOUVEAUX J. and VANDENDORPE L., Comparison of EM- Based Algorithms for MIMO Channel Estimation, *IEEE Transactions on Communications*, vol. 55, No. 1, pp. 216 – 226, January **2007**.

## Awards

- ▶ IEEE Fellow 2006 (L. Vandendorpe)
- ▶ 2004 IEEE Vehicular Technology Society Neal Shepherd Award (C. Oestges)
- ▶ NEWCOM++ (NoE) best Journal Paper Award 2011
- ▶ Best Vehicular Technology Conference Paper Award Fall 2011
- ▶ Best NEWCOM (NoE) Journal Paper Award 2006
- ▶ 1999-2000 IEE Marconi Premium Award (C. Oestges *et al.*)

## Partnerships

- ▶ Stanford University, USA
- ▶ Eurecom Institute, France
- ▶ Supelec, France
- ▶ FTW, Austria
- ▶ University Roma Tre
- ▶ University di Pisa
- ▶ Technical University of Munich

Participation in

- ▶ NEWCOM++ Network of Excellence in Wireless Communications
- ▶ COST IC1004 and IC902 Actions

Research Contracts from Wallonie and the EU.

## Products and Services

Measurement campaigns (see Main Equipments).

## Main Equipments

- ▶ Vector Network Analyzers (40 MHz-110 GHz)
- ▶ Wideband Channel Sounders (80 MHz @ 1.9 GHz, 200 MHz @ 3.8 GHz)
- ▶ Digital Sampling Oscilloscope (16 GHz true analog bandwidth, 80 GSa/s sample rate - 2 channels or 40 GSa/s sample rate - 4 channels)

## KEYWORDS

Wireless communications  
 Transceiver design  
 Adaptive signal processing  
 (MIMO) Multiple-Input Multiple-Output  
 Cooperative communications  
 Cognitive radio  
 Propagation  
 Ultra-Wide Band (UWB)

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# Antenna technology

## SENIOR SCIENTISTS:

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- ▶ Danielle VANHOENACKER-JANVIER
- ▶ Isabelle HUYNEN
- ▶ Jean-Pierre RASKIN

## Research Field and Subjects

Antenna technology is getting extremely diverse, since wireless communications are becoming ubiquitous and since antennas are being used for various detection functionalities. In those different applications, the expected properties of the antenna hardware widely vary and their integration constraints become more and more stringent. This calls for new materials, new front-end electronics, new analysis techniques, and new fabrication and testing technologies. Over the last decade, important developments have taken place at UCL in these complementary areas.

### – Wideband antenna arrays

Wideband antenna arrays have been developed for three main applications: radio-astronomy with focal-plane arrays ground-penetrating radar and near-field imaging. Fast analysis methods have also been devised for extremely large non-regular arrays, like those envisaged for the Square-Kilometer Array telescope. In all cases, the effects of mutual coupling are duly taken into account.

### – Metamaterial antennas

Beam steering using frequency-tunable metamaterial antennas has been realised in planar technology. A special transmission line is formed to operate as a compact leaky-wave antenna. The direction of the main beam is controlled by frequency of the feeding source, enabling backward to forward scanning. Metamaterials have also been designed for the collimation of MRI images away from the high static-field zone.

### – RFID antennas and arrays

Low-profile RFID antennas have been designed, especially for on-metal applications. Localisation of passive RFID tags with the help of phased arrays has been realised, as well as the interpretation of the received signals.

### – Centimeter-wave planar antenna arrays

Antenna arrays have been developed for radar traffic control with digital beamforming, in the 24 GHz ISM band. The design of the array relies on accelerated analysis techniques, based on an integral-equation approach.

### – Beamforming front-ends

Multi-frequency front-ends comprising filters, low-noise amplifiers, mixers and data acquisition blocks have been developed for direction-finding and intrusion detection. Specific attention has been given to low-cost production, ease of calibration and integration.

### – Body-Area Network antennas

Compact antennas have been developed for point-to-point communication along the human body. They are based on the excitation of surface waves propagating along the body-air interface.

### – Micro-machining for antennas

Use of micromachining technique to build up efficient millimeter-waves planar antenna in silicon technology. The etching of air cavities underneath the planar antenna greatly reduces the electromagnetic crosstalk between antenna arrays.

## Representative References

- ▶ VIRONE G., SARKIS R., CRAEYE C., ADDAMO G., PEREVINI O., "Gridded Vivaldi antenna feed system for the Northern Cross radio telescope," Special Issue of the IEEE Trans. Antennas Propagat. on Next-generation radio telescopes, vol. 59, pp. 1963 – 1971, June **2011**.
- ▶ GONZALEZ D., CRAEYE C., "Interpolatory Macro Basis Functions Analysis of non-periodic arrays," IEEE Trans. Antennas Propagat., vol. 59, pp. 3117-3122, Aug. **2011**.
- ▶ CRAEYE C. and GONZALEZ-OVEJERO D., "A review on array mutual coupling analysis", Radio Science, 46, RS2012, April **2011**.
- ▶ EGGERMONT S., HUYNEN I., "Leaky Wave Radiation Phenomena in Metamaterial Transmission Line based on Complementary Split Ring Resonators", Microwave and Optical Technology Letters, vol. 53, No. 9, pp. 2025–2029, September **2011**.
- ▶ BHATTACHARYA A., SARKIS R., HISLOP G., LAMBOT S., CRAEYE C., "Modeling of an ultra-wideband antenna array devoted to near-field imaging," Proc. Loughborough Antennas Propagat. Conf., Loughborough, UK, Nov. **2010**.

- ▶ FORT A., KESHMIRI F., ROQUETA G., CRAEYE C., OESTGES, "A body area propagation model derived from fundamental principles: analytical study and comparison with measurements", *IEEE Trans. Antennas Propagat.*, vol. 58, pp. 503-514, Feb. **2010**.
- ▶ RADU X., GARRAY D., CRAEYE C., "Toward a wire-medium endoscope for MRI imaging", *Metamaterials Journal*, pp. 90-99, Oct **2009**.

### Partnerships

- ▶ University of Cambridge
- ▶ University of Siena
- ▶ University of Sevilla
- ▶ Thalès Communication, Colombes
- ▶ University of Bordeaux
- ▶ Aalto University
- ▶ Royal Military Academy of Belgium

Research Contracts from Wallonie and the EU.

### Products and Services

Antenna measurements, realisation of customised antennas for specific applications.

### Main Equipments

- ▶ Various coaxial setups, on-wafer probe stations and Vector Network Analyzers configurations for multi-port (up to 4 accesses) multi-parametric characterisation of devices
- ▶ Anechoic chamber for electromagnetic testing of materials, devices and sensors
- ▶ Broadband antennas and arrays
- ▶ Channel sounders
- ▶ RF hardware for wireless and ultra-wideband communications between sensors

see *full catalog list at*:

<http://www.uclouvain.be/welcome>

The WELCOME facility is a state-of-the-art technological platform providing multidisciplinary tools in the field of electrical and electromagnetic characterisation.

### KEYWORDS

Antenna Arrays  
Mutual coupling  
Wireless communications  
Detection and sensing  
Metamaterials

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# Software Evolution

## SENIOR SCIENTISTS:

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- ▶ Angela LOZANO

## Research Field and Subjects

Software systems have a natural tendency to require evolution throughout their life-time, due to a variety of reasons like changing requirements, adoption of new technology, software maintenance and bug fixing, use of the software beyond its original goals, new insights, etc. However, evolving software is not straightforward, amongst others because important knowledge about the systems (architectural and design decisions, for example) tends to get lost over time.

The RELEASeD research group investigates mechanisms, tools, formalisms, languages and methodologies to support object-oriented software developers during software maintenance and evolution. In particular, it focuses on techniques to support:

- ▶ *Source code mining*: To discover evolution opportunities, for example program regularities that could be transformed into higher-level abstractions, or irregularities that should be corrected.
- ▶ *Co-evolution of source code and its structural regularities*: To detect or avoid inconsistencies between program source code and higher-level design regularities, and resolve such inconsistencies when they are discovered, by proposing (semi-) automated correction strategies.
- ▶ The group also works on the analysis of implementation choices (such as code clones) and their impact on evolution.

To test its ideas the team develops prototypes that can analyse open-source software projects, but we are open to test them on large-scale industrial cases as well, as we did in the past with our research on intensional views (Intensive tool).

## Representative References

- ▶ CASTRO S., DE ROOVER C., KELLENS A., LOZANO A., MENS K., D'HONDT T., Diagnosing and Correcting Design Inconsistencies in Source Code with Logical Abduction. Elsevier Journal on Science of Computer Programming (SCICO), 76(12), pp. 1113–1129, **2011**.

- ▶ LOZANO A., KELLENS A., MENS K., AREVALO G., Mining Source Code for Structural Regularities. Working Conference on Reverse Engineering 2010, pp. 22–31. IEEE Computer Society, **2010**.
- ▶ LOZANO A., WERMELINGER M., Tracking clones' imprint. Proceedings of the 4rd International Workshop on Software Clones: IEEE Computer Society, **2010**.
- ▶ CASTRO S., BRICHAU J., MENS K., Diagnosis and Semi-Automatic Correction of Detected Design Inconsistencies in Source Code. Proceedings of IWST'09, 11 pages. ACM, **2009**.
- ▶ BRICHAU J., MENS K., KELLENS A., Enforcing Structural Regularities in Source Code using Intensive. International Conference on Automated Software Engineering 2008, pp. 471–472. IEEE Computer Society Press, **2008**.
- ▶ MENS K., TOURWE T., Evolution Issues in Aspect-Oriented Programming. Chapter in book "Software Evolution", pp. 197–224. Springer, **2008**. ISBN 978-3-540-76439-7.
- ▶ KELLENS A., MENS K., TONELLA P., A Survey of Automated Code-Level Aspect Mining Techniques. Transactions on Aspect-Oriented Software Development (TAOSD), vol. IV, pp. 143–162. Springer-Verlag, LNCS 4640, **2007**.

## Awards

- ▶ Third Prize of the Technology Innovation Awards 2005 of the European Smalltalk User Group, awarded to Andy Kellens, Frédéric Pluquet and Kim Mens for their development of Intensive (the Intensional Views Environment).

## Funding

- ▶ Centre de Recherche en Adaptabilité Logicielle. FRFC-FNRS research collaboration between UMONS, FUNDP and UCL, funded by the Fonds de la Recherche Fondamentale Collective (FRFC-FNRS).
- ▶ MoVES: Fundamental Issues in Software Engineering: Modelling, Verification and Evolution of Software. IAP project P6/39, funded by the Belgian Science Policy (BELSPO).

## Partnership

- ▶ Vrije Universiteit Brussel, Software Languages Lab
- ▶ The Open University, Computing Department, UK

## Products and Services

- ▶ The Intensive tool helps software developers to verify conformance of a software system's source code to structural regularities like architectural and design rules, and coding conventions.
- ▶ HEAL is a prototype tool to help software developers diagnose and correct violations of inconsistencies with respect to structural source code regularities in source code, by inferring corrective actions from the design rules themselves and the code over which these rules are verified.
- ▶ Proof-of-concept implementation, in Smalltalk, of a variety of source code mining tools such as Mendel and Clairvoyant.

## KEYWORDS

Object-oriented programming  
Logic programming  
Programmer workbench  
Maintainability  
Restructuring, reverse engineering, and reengineering  
Development tools  
Object-oriented languages  
Software maintenance

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[www.info.ucl.ac.be/~alozano/clairvoyant.html](http://www.info.ucl.ac.be/~alozano/clairvoyant.html)  
<http://released.info.ucl.ac.be>  
[moves.vub.ac.be](http://moves.vub.ac.be)  
[www.evolumons.be/FRFC](http://www.evolumons.be/FRFC)

# Context-Sensitive Software

## SENIOR SCIENTISTS:

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- ▶ Sebastián GONZALEZ

## Research Field and Subjects

Today, software has become truly omnipresent. People are being assisted proactively by software-intensive systems in their daily activities, at home, at work and underway, through computing devices offering intuitive interaction modalities. However, software technology is lagging behind to develop such software-intensive systems efficiently. The usefulness and quality of delivered services could be improved considerably if devices were able to adapt their behaviour according to sensed changes in their surrounding environment, both at the physical and logical levels. This interplay between context-awareness and dynamic software adaptability is a key to the construction of applications that are smart with respect to user needs. The novel paradigm of context-oriented software development investigates software technologies that enable the development of such highly dynamic and context-sensitive applications.

In particular, with its research on the Ambience programming language, and derivative implementations in programming languages commonly used in industry, UCL's RELEASeD research group contributes to the emerging research area of context-oriented programming, by studying:

- ▶ the conception of adequate programming abstractions for developing context-sensitive software;
- ▶ the implementation of such abstractions in established programming languages like Objective-C, Java, Smalltalk, Ruby, Javascript;
- ▶ application domains and scenarios that could benefit from such context-oriented technology;
- ▶ the validation of this technology through realistic case studies;
- ▶ tools, techniques and methodologies to support the development of context-sensitive software applications.

## Representative References

- ▶ GONZALEZ S., CARDOZO N., MENS K., CADIZ A., LIBBRECHT J.-C., GOFFAUX J., Subjective-C: Bringing Context to Mobile Platform Programming. Lecture Notes in Computer Science 6563, Springer Verlag, pp. 246–265, **2011**.

- ▶ BAINOMUGISHA E., CÁDIZ A., COSTANZA P., DE MEUTER W., GONZÁLEZ S., MENS K., VALLEJOS J., VAN CUTSEM T., Language Engineering for Mobile Software. Chapter of Handbook of Research on Mobile Software Engineering: Design, Implementation and Emergent Applications, **2011**. ISBN 978-1615206551.

- ▶ VALLEJOS J., GONZALEZ S., COSTANZA P., DE MEUTER W., D'HONDT T., MENS K., Predicated Generic Functions: Enabling Context-Dependent Method Dispatch. Lecture Notes in Computer Science 6144, Springer-Verlag, **2010**.

- ▶ GONZALEZ S., MENS K., CADIZ A., Context-Oriented Programming with the Ambient Object System. Journal of Universal Computer Science, 14(20):3307–3332, **2008**.

- ▶ GONZALEZ S., Programming in Ambience: Gearing Up for Dynamic Adaptation to Context. PhD Thesis. Département d'Ingénierie Informatique, Université catholique de Louvain, October **2008**.

- ▶ GONZALEZ S., MENS K., HEYMANS P., Highly Dynamic Behaviour Adaptability through Prototypes with Subjective Multimethods. In Proceedings of the 2007 symposium on Dynamic Languages – Companion of the 22nd Annual ACM SIGPLAN Conference on Object-Oriented Programming, System, Languages and Applications (OOPSLA), pp. 77–88, October **2007**.

## Funding

- ▶ VariBru: Variability in Software-Intensive Product Development. ICT Impulse Program. Brussels Institute for Research and Innovation (INNOVIRIS).

- ▶ MoVES: Fundamental Issues in Software Engineering: Modelling, Verification and Evolution of Software. IAP project P6/39, funded by the Belgian Science Policy (BELSPO).

## Partnership

Vrije Universiteit Brussel, Software Languages Lab

## Products and Services

- ▶ *Ambience* is a proof-of-concept language for context-oriented programming, inspired primarily on Slate, Self, Smalltalk and Lisp.
- ▶ *Subjective-C* is a proof-of-concept language extension of Objective-C for context-oriented programming on Apple's iOS platform.
- ▶ Proof-of-concept implementations of languages, languages extensions or context-oriented frameworks for languages like Java, Smalltalk, Ruby and Javascript; yet other languages may be studied in the future.

## KEYWORDS

Emerging technologies  
Ubiquitous computing  
Mobile environment  
Programming paradigms  
Pervasive computing

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<http://moves.vub.ac.be>

# Software Variability

## SENIOR SCIENTISTS:

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- ▶ Angela LOZANO
- ▶ Sebastián GONZALEZ

## Research Field and Subjects

Driven by customers that are increasingly cost-conscious and demanding, software-intensive product builders (i.e. companies building a product with an important software component) have to become customer intimate and compete on the basis of giving customers exactly what they need. Customer intimacy and mass customisation are therefore business strategies adopted by a growing number of companies. This forces such companies to face several variability challenges with respect to managing all the variants of their products.

To advance the state of the art in software variability, the RELEASeD research group at UCL investigates, amongst others:

- Techniques to mine for variability opportunities in program code, in order to gradually transform a software system into a software family;
- Programming languages and abstractions that support run-time variability, in order to write programs that dynamically adapt their behaviour to changing contexts, without added source code complexity.

## Representative References

- ▶ LOZANO A., KELLENS A., MENS K., AREVALO G., Mining Source Code for Structural Regularities. Working Conference on Reverse Engineering 2010, pp. 22–31. IEEE Computer Society, **2010**.
- ▶ LOZANO A., WERMELINGER M., Assessing the Effect of Clones on Changeability. International Conference On Software Maintenance **2008**.
- ▶ GONZALEZ S., Programming in Ambience: Gearing Up for Dynamic Adaptation to Context. PhD Thesis. Département d'Ingénierie Informatique, Université catholique de Louvain, October **2008**.

- ▶ GONZALEZ S., MENS K., HEYMANS P., Highly Dynamic Behaviour Adaptability through Prototypes with Subjective Multimethods. In Proceedings of the 2007 symposium on Dynamic Languages – Companion of the 22nd Annual ACM SIGPLAN Conference on Object-Oriented Programming, System, Languages and Applications (OOPSLA), pp. 77–88, October **2007**.

## Funding

- ▶ VariBru: Variability in Software-Intensive Product Development. ICT Impulse Program. Brussels Institute for Research and Innovation (INNOVIRIS).
- ▶ Centre de Recherche en Adaptabilité Logicielle. FRFC-FNRS research collaboration between UMONS, FUNDP and UCL, funded by the Fonds de la Recherche Fondamentale Collective (FRFC-FNRS).

## Partnership

- ▶ Vrije Universiteit Brussel, Software Languages Lab
- ▶ Facultés Universitaires Notre-Dame de la Paix, PReCISE research center
- ▶ Sirris, Software Engineering and ICT
- ▶ Vrije Universiteit Brussel, Web & Information System Engineering Lab
- ▶ Université Libre de Bruxelles, Computer & Decision Engineering Department

## Products and Services

*Ambience* and *Subjective-C* are proof-of-concept programming languages supporting run-time variability.



**KEYWORDS**

Reusable Software  
Scalability  
Maintainability

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# Programming Languages and Distributed Computing

## SENIOR SCIENTIST:

▶ Peter VAN ROY

## Research Field and Subjects

The Programming Languages and Distributed Computing (PLDC) Research Group has as general theme to increase the expressiveness of programming languages, with a special focus on support for distributed computing. The research is a combination of theory and practice: new concepts are suggested by development needs, which leads both to theoretical results and system building. The research vehicle is often the Mozart Programming System (see [www.mozart-oz.org](http://www.mozart-oz.org)), a full-featured development platform based on the Oz multiparadigm programming language.

The PLDC Research Group has efforts in the following areas:

- Programming languages for intelligent distributed systems
- Computer programming education
- Large-scale distributed systems including peer-to-peer and cloud computing
- Constraint programming
- Human-computer interfaces
- Computer-aided music composition
- Designing and building complex systems

A major theme for PLDC is how to program intelligent distributed systems. The relationship between computing technology and society is transitioning rapidly toward a new form of intimate interaction based on intelligent applications built with a combination of large-scale distributed computing and large-scale machine learning. Computing systems will learn to interact with us at a level much closer to human senses and abilities. For example, real-time audio language translation (using learning to map between phoneme sequences in different languages) and creative problem solving (brute force search tamed by domain knowledge and learning algorithms) are coming soon, in addition to many other abilities not yet clearly imagined. The PLDC Research Group aims to catalyse this transition by building bridges between the different stakeholders: large-scale distributed computing (especially clouds and peer-to-peer), large-scale machine learning, distributed algorithms, programming languages, and many areas of domain knowledge.

## Representative References

- ▶ MELCHIOR J., VANDERDONCKT J. and VAN ROY P., A Model-Based Approach for Distributed User Interfaces, ACM SIGCHI Symposium on Engineering Interactive Computer Systems (EICS 2011), Pisa, Italy, June **2011**.
- ▶ ARDELIUS J. and MEJÍAS B., Modeling the Performance of Ring-Based DHTs in the Presence of Network Address Translators, 11<sup>th</sup> IFIP International Conference on Distributed Applications and Interoperable Systems (DAIS 2011, part of DisCoTec 2011), Reykjavik, Iceland, June **2011**.
- ▶ VAN ROY P., The CTM Approach for Teaching and Learning Programming, Chapter 5 in Horizons in Computer Science Research (ed. Thomas S. Clary), Nova Science Publishers, Inc, Vol. 2, pp. 101-126., Jan. **2011**.
- ▶ MEJÍAS B. and VAN ROY P., Beernet: Building Self-Managing Decentralized Systems with Replicated Transactional Storage, International Journal of Adaptive, Resilient, and Autonomic Systems (IJARAS, 1(3), pp. 1-24), Jul.-Sep. **2010**.
- ▶ VAN ROY P., Programming Paradigms for Dummies: What Every Programmer Should Know, New Computational Paradigms for Computer Music, G. Assayag and A. Gerzso (eds.), IRCAM/Delatour France, June **2009**.
- ▶ VAN ROY P., Overcoming Software Fragility with Interacting Feedback Loops and Reversible Phase Transitions, First International Conference on Visions of Computer Science (BCS08), London, UK, Sep. **2008**.
- ▶ MEJÍAS B. and VAN ROY P., The Relaxed Ring: A Fault-Tolerant Topology for Structured Overlay Networks, Journal of Parallel Processing Letters, 18(3), Sep. **2008**.
- ▶ VAN ROY P. and HARIDI S., *Concepts, Techniques, and Models of Computer Programming*, MIT Press, March **2004** (929 pages). Translations in French, Japanese, Polish, and Spanish.

## Awards

- ▶ In 2011, the company Knowledge Plaza was awarded Belgian Startup of the Year 2011 by the DataNews Awards for Excellence. This company started as a Master's project by Antoine Perdaens and Raphaël Slinckx in the PLDC Research Group (June 2007).

- ▶ In 2011, Boris Mejías and Peter Van Roy received the award for Best Published Journal Article in IJARAS for 2010 (IGI Global Fourth Annual Excellence in Research Journal Awards).
- ▶ In 2009, Boris Mejías received the Best Presentation Award, Doctoral Symposium, XtremOS Summer School, University of Oxford, UK, Sep. 2009.

## Funding

Erasmus Mundus Joint Doctorate (EACEA) (2011-2016, see [www.emjd-dc.eu](http://www.emjd-dc.eu)), European Union (FP5, FP6, FP7), Wallonie, Commercial subcontracting.

## Partnership

- ▶ Distributed Systems Laboratory, Swedish Institute of Computer Science (SICS) (Sweden)
- ▶ Institut de Recherche et Coordination Acoustique/Musique (IRCAM) (France)
- ▶ Department of Microelectronics and Information Technology, Royal Institute of Technology (KTH) (Sweden)
- ▶ Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB) (Germany)
- ▶ Initiative pour la Recherche et Innovation sur le Logiciel Libre (IRILL) et Université Paris Diderot (France)
- ▶ Centre d'Excellence en Technologies d'Information et de Communication (CETIC) (Belgium)
- ▶ Euranova (Belgium)
- ▶ AVISPA Research Group, Pontificia Universidad Javeriana and Universidad del Valle (Colombia)
- ▶ LIP6 Programming Research Group, Université Pierre et Marie Curie (France)
- ▶ Mozart Programming Community (Open-Source Developers and Users)

## Main Equipment

IBM Blade Cluster, departmental LAN clusters, PlanetLab network, cloud infrastructures (Amazon EC2, Rackspace, etc.), mobile computing devices (Android, iPhone/iPad)

## Products and Services

- ▶ Programming languages and platforms for intelligent distributed systems
- ▶ Applications and libraries for large-scale distributed systems
- ▶ Applications and libraries for combinatorial optimisation based on constraint programming
- ▶ Educational material for programming curriculum
- ▶ Advanced tools and libraries for human-computer interfaces

## KEYWORDS

Computer programming  
 Programming languages  
 Constraint programming  
 Large-scale distributed systems  
 Data-intensive computing  
 Peer-to-peer computing  
 Cloud computing  
 Complex systems

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# Coordination and mobile languages

## SENIOR SCIENTISTS:

- ▶ Jean-Marie JACQUET
- ▶ Isabelle LINDEN

## Research Field and Subjects

Coordination languages are recognised as promising to deal with a number of issues in agent-based and component-based software construction where components need to coordinate themselves.

In the FOCUS research group, such a language, called Bach, has been designed. Its main characteristics are the use of a tuple space shared by processes and communication between processes in an asynchronous manner through that space. This is believed to model conveniently current distributed systems like those based on the web or on the cloud computing paradigm.

Various extensions have been studied, for instance to deal with temporal data and conditional access. Recently, mobile and ad hoc networks have been addressed. These are networks that are formed in an opportunistic way by mobile devices that travel from site to site, coming accidentally close enough to one another to communicate. Given that the number of such devices is constantly growing, the design of applications that support this kind of mobility is recognised as an important concern in the current research. In this context, an important aspect is the possibility of manipulating contextual information in a reactive way. In order to be useful in such a setting, the Bach coordination model is being extended to allow for better context management and for probabilistic events integration.

Such coordination languages are studied from different perspectives: semantics, expressiveness issues, programming methodologies, language design and implementation.

## Representative References

- ▶ JACQUET J.-M. and LINDEN I., Fully Abstract Models and Refinements as Tools to Compare Agents in Timed Coordination Languages. *Theoretical Computer Science*, Elsevier, vol. 410 (2-3), pp. 221-253, **2009**.

- ▶ BENIGNI F., BROGI A., BUCHHOLZ J.-L., JACQUET J.-M., LANGE J. and POPESCU R., Secure P2P Programming on Top of Tuple Spaces. *Proceedings of the 17th IEEE International Workshops on Enabling Technologies: Infrastructures for Collaborative Enterprises (WETICE)*, pp. 54-59, **2008**.
- ▶ JACQUET J.-M. and LINDEN I., Coordinating Context-aware Applications in Mobile Ad-hoc Networks. In T. Braun, D. Konstantas, S. Mascolo and M. Wulff (eds), *Proceedings of the first ERCIM workshop on eMobility*, pp. 107-118, **2007**.
- ▶ LINDEN I. and JACQUET J.-M., On the Expressiveness of Timed Coordination via Shared Dataspaces. *Electronic Notes in Theoretical Computer Science*, Elsevier, vol. 180 (2), pp 71-89, **2007**.

## Funding

- ▶ FSR
- ▶ Wallonie

## Partnership

- ▶ University of Pisa, Italy

## KEYWORDS

Coordination  
Component-based systems  
Mobility  
Ad hoc networks

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# Program analysis and verification

## SENIOR SCIENTIST:

▶ Wim VANHOOF

## Research Field and Subjects

Program analysis is the research field comprising the study of techniques that collect useful properties about the behaviour exhibited by a program by analysing (preferably in a completely automatic way) its data- and/or control flow.

In the FOCUS research group, a substantial amount of attention is devoted to the analysis, transformation and verification of programs, in particular for programs written in a declarative language. Since these languages have a simple structure and are usually defined by means of a small but formal semantics, it makes it effectively easier to construct semantics-preserving program transformations and to devise analyses that are both safe (in the sense that the analysis results are a correct approximation of the program's semantics) and precise (i.e. retaining a maximum of useful information). In particular, the following themes are pursued:

- Program analysis for developing concurrent declarative programs, in which the focus is on developing static program analyses for detecting application-level race conditions and granularity control of atomic sections.
- Clone detection and automatic refactoring in declarative programs. Clones in a program refer to program fragments that are redundant in the sense that they implement or share a functionality that is already present in some other program fragment. An analysis has been developed in logic programs to identify the clones whose outputs can be used to automatically drive a number of programs refactoring that aim at removing such redundancy in the program.
- Test data generation for database intensive applications. The idea behind test data generation is to automate the generation of a suitable set of inputs with respect to which a program can be tested. A framework has been developed in the FOCUS research group in order to generate test data that are parameterised with respect to a given coverage criterion. It is currently investigated whether and how the framework can be extended in order to deal with applications whose data is recorded in a relational database.

## Representative References

- ▶ DEMEYER R. and VANHOOF W., Proper Granularity for Atomic Sections in Concurrent Programs. In G. Vidal (ed.) Preproceedings of the 21<sup>st</sup> International Symposium on Logic-based Program Synthesis and Transformation, **2011**.
- ▶ DANDOIS C. and VANHOOF W., *Clones in Logic programs and how to detect them*. In G. Vidal (ed.) Preproceedings of the 21<sup>st</sup> International Symposium on Logic-based Program Synthesis and Transformation, **2011**.
- ▶ DEMEYER R., VAN ASSCHE M., LANGEVINE L. and VANHOOF W., *Declarative Workflows to Efficiently Manage Flexible and Advanced Business Processes*. In Proceedings of the 12<sup>th</sup> International ACM SIGPLAN Symposium on Principles and Practice of Declarative Programming (PPDP) 2010, pp. 209-218, ACM, **2010**.
- ▶ DEGRAVE F., SCHRIJVERS T. and VANHOOF W., *Towards a framework for constraint-based test case generation*. in D. De Schreye (ed). Logic-based Program Analysis and Transformation, LNCS 6037, Springer-Verlag, **2009**.

## Funding

- ▶ Fonds de la Recherche Scientifique (FNRS/FRIA)
- ▶ Fonds Spécial de Recherche (FSR)

## KEYWORDS

Program analysis  
 Program understanding  
 Clone detection  
 Automatic refactoring  
 Test input generation  
 Concurrent program analysis

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# Evolution / Software Product Line Engineering

## SENIOR SCIENTISTS:

- ▶ Patrick HEYMANS
- ▶ Pierre-Yves SCHOBBERNS
- ▶ Gilles PERROUIN

## Research Field and Subjects

Software Product Line Engineering (SPLE) is of interest to any company that develops a line of software products or services that are similar, but also customised for specific clients or market segments. Developing and maintaining efficiently such software families require specific tools and concepts, since the ones of classical software engineering are designed with a single product in mind. For instance, an error detected in one product should be analysed to discover all products affected, and correct the problem for all products at once.

The introduction of SPLE can bring important benefits to software developers. For instance, Hewlett-Packard reported a four-fold increase of development productivity, and a ten-fold decrease of the number of defects. Cummins, Inc., reported a 50-fold reduction of time-to-market. Furthermore, introducing a product line brings commercial advantages and thus higher margins, by targeting customer needs very precisely while offering a large portfolio of products at a reduced cost.

The main tool we propose for managing a product line is Feature Modelling, a technique to explicitly and compactly document features and their legal combinations. Feature models are the basis for efficient variability management, quality assurance and automated product derivation.

## Representative References

- ▶ CLASSEN A., BOUCHER Q. and HEYMANS P., A text-based approach to feature modelling: Syntax and semantics of TVL. In *Science of Computer Programming, Special Issue on Software Evolution, Adaptability and Variability*, 76(12):1130-1143, **2011**.
- ▶ CLASSEN A., HEYMANS P., SCHOBBERNS P.-Y. and LEGAY A., Symbolic model checking of software product lines. In *33rd International Conference on Software Engineering (ICSE 2011)*, Waikiki, Honolulu, Hawaii, Proceedings, pages 321–330. ACM, **2011**.
- ▶ CLASSEN A., HEYMANS P., SCHOBBERNS P.-Y., LEGAY A. and RASKIN J.-F., Model checking lots of systems: Efficient verification of temporal properties in software product lines. In

Proceedings of the 32nd International Conference on Software Engineering (ICSE 2010), Cape Town, South Africa, Proceedings, pages 335–344, ACM, **2010**.

- ▶ HEYMANS P., SCHOBBERNS P.-Y., TRIGAUX J.-Ch., BONTEMPS Y., MATULEVICIUS R., CLASSEN A., Evaluating Formal Properties of Feature Diagram Languages, in *IET Software Journal*, volume 2, issue 3, pp. 281-302, **2008**.
- ▶ SCHOBBERNS P.-Y., HEYMANS P., TRIGAUX J.-Ch. and BONTEMPS Y., Generic semantics of feature diagrams. *Computer Networks*, 51(2):456–479, **2007**.
- ▶ METZGER A., HEYMANS P., POHL K., SCHOBBERNS P.-Y., SAVAL G., Disambiguating the Documentation of Variability in Software Product Lines: A Separation of Concerns, Formalization and Automated Analysis. In *Proceedings of the 15th IEEE International Conference on Requirements Engineering (RE'07)*, pp. 243-253, **2007**.
- ▶ SCHOBBERNS P.-Y., HEYMANS P., TRIGAUX J.-Ch., Feature Diagrams: A Survey and a Formal Semantics. In *Proceedings of the 14th IEEE International Conference on Requirements Engineering (RE'06)*, pages 139-148, **2006**.

## Funding

Wallonie, European Commission, BELSPO, Banque Nationale de Belgique, FEDER, F.R.S.-FNRS

## Partnership

- ▶ Academic: University of Duisburg-Essen, INRIA, University of Waterloo (Canada), University of Sevilla
- ▶ Industry: Océ, Spacebel, CETIC

## Products and Services

- ▶ Training, coaching, consulting
- ▶ Tools (FTS, TVL, FCW)
- ▶ Research transfer projects



**KEYWORDS**

Software Product Lines  
Software Reuse

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# Requirements Engineering

## SENIOR SCIENTISTS:

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- ▶ Pierre-Yves SCHOBBERNS
- ▶ Stéphane FAULKNER
- ▶ Ivan JURETA

## Research Field and Subjects

Requirements Engineering (RE) is concerned with **what** Information Systems should do, and **how well**, rather than **how**, technically, they are implemented. Just like architects draw plans of buildings, requirements engineers draw “plans” of software based on stakeholders’ needs, resources and constraints.

Analyses of project failures have shown that requirements play a central role in project success (above 30%). This is easy to understand, since this is the first step upon which all others depend. The cost of correcting requirements errors increases up to a hundred times as the development proceeds. It is therefore vital, but difficult, to maximise the quality of requirements documents.

Since requirements are where software originates, RE is also a creative discipline. The requirements engineer must act as a facilitator among stakeholders, guiding them to “invent” the right software for them. RE consequently requires an unusual mix of soft and hard skills.

Beyond our general expertise in the RE discipline, the PReCISE Research Centre has gained international recognition in specialties like requirements for software product lines, requirements visualisation, goal-oriented requirements as well as collaboration and creativity techniques for requirements. Our collaborations with industry include certifying trainings, coaching, consulting and research transfer projects in all areas of RE.

## Representative References

- ▶ MAHAUX M., HEYMANS P. and SAVAL G., Discovering Sustainability Requirements: An Experience Report, in Requirements Engineering: Foundation for Software Quality (REFSQ'2011), p. 19–33, **2011**.

- ▶ MAHAUX M., MAIDEN N. A. M. and HEYMANS P., Making it all up: getting on the act to improvise creative requirements, in Proceedings of the 18th IEEE International Requirements Engineering Conference (invited mini-tutorial at RE'10), Sydney, Australia, **2010**.
- ▶ HUBAUX A., ABBASI E. K., CLASSEN A., HEYMANS P., Workflow-driven Product Derivation (Invited Talk), in First International Workshop on Product Line Requirements Engineering and Quality (PLREQ'10), Essen, Germany June 30, **2010**.
- ▶ JURETA I., BORGIDA A., ERNST N., MYLOPOULOS, Techne: Towards a New Generation of Requirements Modeling Languages with Goals, Preferences, and Inconsistency Handling, in Proceedings of the 18th IEEE International Requirements Engineering Conference (RE'10), Sydney, Australia, **2010**.
- ▶ MOODY D., HEYMANS P., MATULEVICIUS R., Visual syntax does matter: improving the cognitive effectiveness of the i\* visual notation, in Requirements Engineering, volume 5, issue 2 (Springer), and in Proceedings of the 17th IEEE International Requirements Engineering Conference (RE'09), Atlanta, Georgia, USA, pp. 171-180 (Best paper award) **2009**.
- ▶ JURETA I., MYLOPOULOS J., FAULKNER S., Analysis of Multi-Party Agreement in Requirements Validation, in Proceedings of the 17th IEEE International Requirements Engineering Conference (RE'09), Atlanta, Georgia, USA **2009**.
- ▶ MAHAUX M. and MAIDEN N. A. M., Theater Improvisers Know the Requirements Game, IEEE software, vol. 25, No. 5, p. 68–69, **2008**.
- ▶ CLASSEN A., HEYMANS P., SCHOBBERNS P.-Y., What's in a Feature? A Requirements Engineering Perspective, in Proceedings of the 11th International Conference on Fundamental Approaches to Software Engineering (FASE'08), collection LNCS, volume 4961, pp. 16-30, **2008**.

## Awards

- Best paper award at 17th IEEE International Conference on Requirements Engineering (RE'09)

## **Funding**

Wallonie, European Commission, BELSPO, Banque Nationale de Belgique, FEDER, F.R.S.-FNRS

## **Partnership**

- ▶ Academia: City University (London), University of Ottawa, University of Toronto, University of Trento
- ▶ Industry: OZemantics, escent, Yellow

## **Products and Services**

- ▶ Certifying training, coaching, consulting

## **KEYWORDS**

Requirements  
Business Analysis  
Software engineering  
Software Product Lines  
Collaboration

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# Real-Time System Verification

## SENIOR SCIENTIST:

► Pierre-Yves SCHOBBERNS

## Research Field and Subjects

Many computer-based systems are critical: their failure could endanger lives or cause huge financial losses. It is therefore worth to submit them to thorough validation and verification. At the PReCISE Research Centre, we consider formal validation by model checking, since this technique is already well accepted in the digital electronic industry due to its high level of automation and its exhaustiveness. Most of these critical systems are real-time: they must react within tight delay constraints. Verification can then be performed by comparing a model of the system (including its real-time aspects) with its implementation. Any mismatch will be reported as a failed test case, e.g. a timed sequence. Introducing model-checking in product development has been reported to strongly increase reliability and decrease testing cost.

## Representative References

- KANG E.-Y., SCHOBBERNS P.-Y., PETTERSSON P., Verifying functional behaviors of automotive products in EAST-ADL2 using UPPAAL-PORT, in 30th International Conference on Computer Safety, Reliability and Security (SAFECOMP), Naples, Italy, Sept 19-21, **2011**.
- CLASSEN A., HEYMANS P., SCHOBBERNS P.-Y., LEGAY A., Symbolic Model Checking of Software Product Lines, in 33rd International Conference on Software Engineering, ICSE 2011, pp. 321-330 May 21-28, **2011**.
- ORTIZ VEGA J., LEGAY A., SCHOBBERNS P.-Y., Distributed Event Clock Automata: Extended abstract, in CIAA 2011, collection LNCS, volume 6807, pp. 250-263, **2011**.
- HUBAUX A., HEYMANS P., SCHOBBERNS P.-Y., ABBASI E. K., DERIDDER D., Supporting Multiple Perspectives in Feature-based Configuration, in Software and Systems Modeling (SoSyM), **2011**.
- BONTEMPS Y., SAVAL G., SCHOBBERNS P.-Y., HEYMANS P., Synthèse de diagrammes d'états par classe à partir de diagrammes de séquence, in Technique et Science Informatiques, **2007**.

## Funding

F.R.S.-FNRS

## Partnership

- SPACEBEL
- Université catholique de Louvain
- Université Libre de Bruxelles
- Université de Liège (ULg)
- University of Aalborg, Denmark

## Products and Services

Consultancy for verification, modelling.

## KEYWORDS

Verification  
Embedded systems  
Real-time, reliability  
Model checking

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# Service Engineering

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- ▶ Philippe THIRAN

## Research Field and Subjects

Achieving increased automation requires open, distributed, service-oriented systems capable of multi-criteria driven, dynamic adaptation for appropriate response to changing operating conditions. A service is a self-describing and self-contained modular application designed to execute a well-delimited task, and that can be described, published, located, and invoked over a network. Services are offered by service providers, that is, organisations that ensure service implementations, advertise service descriptions, and provide related technical and business support.

To interact with the service-oriented system, stakeholders submit service requests. Satisfying a service request usually involves service composition, that is, the identification of appropriate services and their coordinated execution. Responsibility for service composition can either be delegated to humans or to autonomous agents. Service-orientation is an attractive approach to the engineering of complex decentralised information systems. Among the main reasons, one finds the fact that services are designed to be modular and interoperable, that open service-oriented systems are designed to accept entry and participation of previously unknown services, that services can be designed as interfaces to legacy systems, etc. Overall, service-oriented architectures increasingly enable organisations to make their information technology infrastructures (IT) flexible, facilitating for instance IT change management and IT outsourcing.

Engineering service-oriented systems efficiently is a critical concern at present both in research and industry. Key topics studied in the PReCISE Research Centre are:

- Requirements engineering for service-oriented systems
- Ontologies of/for service-oriented systems
- Service-oriented architecture
- Service recommendation, adaptation & composition at run time
- QoS monitoring, reputation assessment
- Cooperation between services (contract & policies between parties ; service substitution and selection)
- Authorisation and trust in service-oriented systems

## Representative References

- ▶ JURETA I., BORGIDA A., ERNST N. E., MYLOPOULOS J., Towards a New Generation of Requirements Modelling Languages with Goals, Preferences, and Inconsistency Handling. *RE*, pp. 115-124, **2010**.
- ▶ KHOSRAVIFAR B., BENTAHAR J., MOAZIN A., THIRAN Ph., Analyzing Communities of Web Services Using Incentives. *International Journal of Web Services Research*, volume 7, issue 3, pages 30-51, **2010**.
- ▶ JURETA I., HERSSSENS C., FAULKNER S., A comprehensive quality model for service-oriented systems. *Software Quality Journal* 17(1), pp. 65-98, **2009**.
- ▶ ACHBANY Y., JURETA I., FAULKNER S., FOUSS S., Continually Learning Optimal Allocations of Services to Tasks. *IEEE T. Services Computing* 1(3), pp. 141-154, **2008**.
- ▶ SUBRAMANIAN S., THIRAN Ph., NARENDRA N.C., MOSTEFAOUI G.K., MAAMAR Z., On the Enhancement of BPEL Engines for Self-Healing Composite Web Services. *Symposium on Applications of and the Internet (SAINT)*, IEEE, pp. 33-39, **2008**.
- ▶ MAAMAR Z., BENSLIMANE J., THIRAN Ph., GHEDIRA Ch., DUSTDAR S., SATTANATHAN S., Towards a Context-based Multi-Type Policy Approach for Web Services Composition, *Data and Knowledge Engineering (DKE)*, volume 62, issue 2, pp. 327-351, **2008**.
- ▶ BENTAHAR J., MAAMAR Z., BENSLIMANE J., THIRAN Ph., An argumentation framework for communities of Web services. *IEEE Intelligent Systems*, volume 22, issue 6, pp. 75-83, **2007**.

## Funding

- ▶ FUNDP
- ▶ Banque Nationale de Belgique
- ▶ Wallonie-Bruxelles International
- ▶ F.R.S.-FNRS
- ▶ EU (FP7)

## Partnership

- ▶ Concordia University, Montréal, Canada
- ▶ University of Lyon 1, France
- ▶ Zayed University, Dubai, UAE
- ▶ Technical University of Vienna, Austria
- ▶ University of Trento, Italy
- ▶ Vodafone Group, Düsseldorf, Germany

## Products and Services

- ▶ Methods for requirements engineering of service-oriented systems
- ▶ Quality criteria for the evaluation of service-oriented systems
- ▶ Assessment of industrial methods and processes for service-oriented systems engineering
- ▶ Training in best practices in, and advanced technologies for service-oriented systems engineering
- ▶ Decision methods for service selection
- ▶ Reputation-driven service recommendation algorithms

## KEYWORDS

Service-oriented computing  
Requirements engineering  
Decision-support  
Service selection  
Service composition  
Reputation  
QoS Monitoring  
Authentication  
Authorisation

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# Communities of Web services

## SENIOR SCIENTIST:

► Philippe THIRAN

## Research Field and Subjects

The W3C defines a Web service as a software system having an interface described in a machine-processing format and designed to support machine-to-machine interactions over a network such as the Internet.

As the number of Web services through the Internet continues to increase, the needs for discovering and engaging these Web services in more complex and complete business solutions are stressed out, leading to very rich settings for market competition.

In this context, the PReCISE research centre proposed, along with partners, the notion of community of Web services to gather Web services having the similar functionalities (e.g., flight booking and travel reservation) in the same “virtual” space permitting to create pockets of expertise.

Using communities offers many advantages that range from facilitating the discovery of Web services since they are all in the same place, to enhancing the composition since Web services can be substituted and tasks can be delegated within the same community, to enforcing the security since the community is in charge of checking the credentials of the members before joining and during their stay in the community and, last but not least, maintaining a “healthy” group of Web services by ejecting from the community those that do not perform as expected or misbehave.

The developments done to bear this notion are around the following questions:

- How to specify and represent communities of Web services with respect to existing W3C standards/specifications?
- How to specify and manage Web services in a community?
- How to make a Web service select the community that suits it better? How to convince a Web service to remain longer in a community? And, how to eject a Web service from a community for misbehavior?
- How to evaluate, establish, and foster trust among the Web services in a community?

To address the aforementioned questions, the researchers studied and validated the appropriateness of empowering Web services with extra capabilities through the use of agents. As such, they abstract Web services and communities as agents that are capable to engage in complex operations such as argumentation (e.g., to convince a Web service join a community), negotiation (e.g., to identify a trade-off between Web services rewards and penalties), and making decisions (e.g., to select the appropriate Web service in response to a user’s request).

## Representative References

- KHOSRAVIFAR B., ALISHASHI M., BENTAHAR J., THIRAN Ph., A Game Theoretic Approach for Analyzing the Efficiency of Web Services in Collaborative Networks. In Proceedings of the 8th IEEE International Conference on Services Computing (SCC 2011), **2011**.
- KHOSRAVIFAR B., BENTAHAR J., MAOZIN A., THIRAN Ph., On the Reputation of Agent-based Web Services. In Proceedings of the Twenty-Fourth AAAI Conference on Artificial Intelligence (AAAI-10), pages 1352–1357, **2010**.
- KHOSRAVIFAR B., BENTAHAR J., MOAZIN A., THIRAN Ph., Analyzing Communities of Web Services Using Incentives. In International Journal of Web Services Research, volume 7, issue 3, pages 30-51, **2010**.
- MAAMAR Z., SUBRAMANIA A., THIRAN Ph., BENSLIMANE D. and BENTAHAR J., An approach to engineer communities of web services - concepts, architecture, operation, and deployment. In International Journal of E-Business Research, volume 5, issue 4, pages 1- 21, **2009**.
- BENTAHAR J., MAAMAR Z., BENSLIMANE J., THIRAN Ph., An argumentation framework for communities of web services. In IEEE Intelligent Systems, volume 22, issue 6, pages 75–83, **2007**.



## **Funding**

- ▶ Banque Nationale de Belgique
- ▶ Wallonie-Bruxelles International

## **Partnership**

- ▶ Concordia University, Montréal, Canada
- ▶ University of Lyon 1, France
- ▶ Zayed University, Dubai, UAE

## **Products and Services**

- ▶ Web communities' infrastructure
- ▶ Web services selection and recommendation (reputation-driven)
- ▶ Web services monitoring

## **KEYWORDS**

Reputation  
QoS  
Cooperative Web Services  
Recommendation  
Agent-based Web Services

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# Information System Evolution

## SENIOR SCIENTISTS:

- ▶ Anthony CLEVE
- ▶ Jean-Luc HAINAUT
- ▶ Pierre-Yves SCHOBENS
- ▶ Patrick HEYMANS

## Research Field and Subjects

An information system is developed to support the business processes of an organisation. Any change in the latter or in the underlying technology requires corresponding changes in the information system.

PRECISE has studied this phenomenon for long and has developed innovative solutions to maintain the quality of information systems in an ever changing world.

In the database realm, three aspects have been addressed. First, the evolution of organisational requirements leads to changes in the database. Second, the inter-organisation reengineering often implies interoperability problems among independent information systems. Third, the technology evolution requires platform migration. These aspects of the phenomenon have been coped with through specific methodologies that are supported by components of the DB-MAIN CASE tools. Wrapper-based architectures have been designed to automatically control the evolution of databases in order to minimise the impact of these changes on the application programs. These results are exploited and maintained by spin-off ReveR. They are applied in several medium-size to large companies.

Information System Evolution can be modelled as the addition of features that can then be combined in many ways.

## Representative References

- ▶ CLEVE A., BROGNEAUX A.-F., HAINAUT J.-L., A Conceptual Approach to Database Applications Evolution, in Proc. of ER'2010, LNCS, pp. 132 - 145, Springer-Verlag, **2010**.
- ▶ CLEVE A., MENS T., HAINAUT J.-L., Data-Intensive System Evolution, IEEE Computer, pp. 110- 112, IEEE CS, 43(8), **2010**.
- ▶ CLEVE A., Program Analysis and Transformation for Data-Intensive System Evolution, PhD Thesis, University of Namur, **2009**.
- ▶ HAINAUT J.-L., CLEVE A., HENRARD J., HICK J.-M., Migration of Legacy Information Systems, in Software Evolution. Mens, T. and Demeyer, S. (Eds), Springer, pp. 107-138, **2008**.
- ▶ HICK J.-M., HAINAUT J.-L., Database application evolution: A transformational approach, Data and Knowledge Engineering, 59(3): pp. 534-558, **2006**.

- ▶ THIRAN P., HAINAUT J.-L., HOUBEN G.-J. and BENSLIMANE D., Wrapper-based evolution of legacy information systems, ACM Trans. Soft. Eng. Methodol., 15(4): pp. 329-359, ACM Press, **2006**.
- ▶ CLEVE A., HAINAUT J.-L., Co-transformations in Database Applications Evolution, in Generative and Transformational Techniques in Software Engineering, Lecture Notes in Computer Science, Volume 4143, pp. 409-421, Springer-Verlag, **2006**.
- ▶ THIRAN P., Legacy database federation. A combined forward-Reverse approach, PhD Thesis, University of Namur, **2003**.

## Awards

Price IBM 2011

## Funding

- ▶ Wallonie
- ▶ FEDER

## Partnership

- ▶ ReveR s.a, Belgium.
- ▶ CWI, Amsterdam.

## Products and Services

- ▶ Methodologies for database migration and evolution
- ▶ DB-MAIN, a programmable data centered CASE platform
- ▶ Software Product Line Methodology

**KEYWORDS**

Database migration  
Database evolution  
CASE tool  
Software Product Lines

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# Security / Identity and Access Management in complex software environments

## SENIOR SCIENTIST:

▶ Jean-Noël COLIN

## Research Field and Subjects

Nowadays, complex software environments are built by assembling and integrating existing components and systems. This integration may happen in a loose or tight manner. It may cross organisation boundaries and may bridge different technologies and technical environments. SOA, web services, widgets, portals are all meant at integrating heterogeneous components.

In such potentially large and complex environments, the questions of user and system authentication, as well as of authorisation, are keys to guarantee secure operation, system integrity as well as stakeholders' satisfaction and trust.

Beyond authentication, user and identity management becomes an issue because in such environments, a system may need to give access to users that do not authenticate and are not managed locally, but by a third party that needs to be trusted. Protocols like SAML, OpenID... provide building blocks that allow one to design higher-level protocols that are able to support such complex scenarios. This is for instance the exact role of the PReCISE Research Centre within the iTEC EUN FP7 project.

Authorisation and access control deal with granting or denying access to resources. The rules that govern the authorisation decisions are often complex. Even after the access has been granted, ensuring only acceptable use of the resources (also known as usage control) requires appropriate measures.

Access control models allow one to formalise access rules, to further reason on those policies, to detect conflict or overlap between rules, for instance. RBAC is a commonly used access control model, but various extensions are also widely spread, depending on the context and requirements, like P-RBAC or OrBAC.

Access and usage control policies need to be expressed in an interoperable way. By taking into account advanced conditions, obligations, and other type of constraints, Rights Expression Languages (RELs) allow one to describe complex policies which are derived from the access control model. XACML or ODRL are widely used standards that provide support for expressing various types of policies. Both need to be profiled according to the actual case, but are generic and extensible enough to be adapted to a wide range of application domains, from digital

resources and media to Electronic Health Record or Social Network Information.

Since a few years, the PReCISE Research Centre is active in the field of Privacy Rights Management (PRM), which is a direct application of this approach to the protection of user's privacy. Main research activities are focusing on privacy-preserving access control in medical data and in mobile environment. Methodological aspects inspired from Privacy by Design are also included in the research spectrum.

## Representative References

▶ BENATS G., BANDARA A., Yu Y., COLIN J. and NUSEIBEH B., PrimAndroid: Privacy Policy Modelling and Analysis for Android Applications. In *Proceedings of the IEEE International Symposium on Policies for Distributed Systems and Networks (POLICY 2011)*, Pisa, pp. 129–132, June 2011.

## Funding

- ▶ EC FP7 Project: iTEC
- ▶ FUNDP Ceruna Doctoral scholarship

## Partnership

- ▶ Vodafone Group, Düsseldorf, DE
- ▶ Open University, Milton Keynes, UK
- ▶ University of Koblenz, DE
- ▶ Réseau Santé Wallon

## Products and Services

- ▶ Development of an open-source toolbox for ODRL policies evaluation and management
- ▶ Infosafe: Certificate in Information Systems Security Management

**KEYWORDS**

Authentication  
Access control  
Rights management  
Privacy  
Rights expression languages

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# Model Driven Engineering / Domain Specific Modelling Languages

## SENIOR SCIENTIST:

▶ Vincent ENGLEBERT

## Research Field and Subjects

Model-driven engineering (MDE) aims at defining modelling languages, methods, and tools suitable for the precise and efficient representation of, and reasoning about, software-intensive systems.

Models, methods and tools together form the so-called software factories that aim at supporting the software engineer and other stakeholders of the system over the entire lifecycle, from requirements elicitation to implementation and maintenance. This support facilitates all system-related tasks and decision-making involved in, among others, transformations, verification, import/export, round trip engineering, visualisation, cooperation, integration, and versioning.

In addition to the software-centric activities, MDE studies domain specific modelling languages (DSML) that are best suited for describing human and business activities in a precise and more efficient manner. Such models can give rise to domain ontologies that can be used to guide the acquisition of information needed for model construction, and this over all projects in a given application domain.

DSML are now regarded as more appropriate for quickly generating quality software with a higher return on investment. For several years, the PReCISE research group develops a tool to quickly define such languages as naturally as possible: metaDONE.

The strengths of this tool are its ability to correlate modelling paradigms and to model as effectively as possible a maximum of aspects of the software, the ability to define arbitrarily complex graphical representations without resorting to programming, and the possibility to extend it by OSGi plugins. MetaDONE can provide a modelling environment tailored to the needs of the enterprise, scalable and completely customisable.

## Representative References

- ▶ KOSHIMA A., ENGLEBERT V., THIRAN P., Distributed collaborative model editing framework for domain specific modeling tools. 6th IEEE International Conference on Global Software Engineering. **2011**.
- ▶ CONSTANTIN C., ENGLEBERT V., THIRAN P., A Reconciliation Framework to Support Cooperative Work with DSML. First International Workshop on Domain Engineering held in conjunction with CAiSE'09 Conference. **2009**.
- ▶ ENGLEBERT V., HEYMANS P., Towards More Extensible MetaCASE Tools. International Conference on Advanced Information Systems Engineering CAISE. pp. 454-468, **2007**.

## Funding

- ▶ FSR
- ▶ PReCISE
- ▶ Banque Nationale de Belgique - BNB

## Partnership

- ▶ France Telecom Bretagne, France
- ▶ University of Ottawa, Canada

## Products and Services

- ▶ MetaDONE: a software factory for domain specific modelling languages.
- ▶ DICOMEF: a distributed collaborative model editing framework (for EMF).

**KEYWORDS**

Domain Specific Modelling Language  
Computer Supported Cooperative Work  
Visual Modelling  
MetaCASE  
Eclipse/EMF

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# Model Driven Engineering / Software Architecture

## SENIOR SCIENTISTS:

- ▶ Vincent ENGLEBERT
- ▶ Anthony CLEVE

## Research Field and Subjects

The PReCISE Research Centre actively contributes to the field of software architecture by developing model-driven engineering approaches, techniques and tools that support architecture design, analysis and evolution.

In support to software system design and evolution, PReCISE has built a transformation-oriented method mixing software architecture, requirement models and infrastructure models in order to design and evolve component-based information systems. This method provides systematic, generic and reusable support for problem-to-solution traceability management and to system architecture composition and evolution. It links implementation alternatives and corresponding architectural models and it provides infrastructure-related constructs that are used to validate the architecture deployment on a given target infrastructure.

PReCISE also addresses the domain of architectural variability analysis with promising results. A reverse engineering approach was developed to enable the automated identification and analysis of the extension points that are inherent to highly (re)configurable software systems. The approach takes as input a system made up of a set plugins, each of which defines an architecture fragment. It then extracts an architectural feature model expressing the commonalities and variabilities that exist between all possible configurations of the system.

## Representative References

- ▶ GILSON F., ENGLEBERT V., Towards handling architecture design, variability and evolution with model transformations. In *Proceedings of the 5th Workshop on Variability Modeling of Software-Intensive Systems (VaMoS '11)*, 39-48, ACM, **2011**.
- ▶ ACHER M., CLEVE A., COLLET P., MERLE P., DUCHIEN L., LAHIRE P., Reverse Engineering Architectural Feature Models. In *Proceedings of the 5th European Conference on Software Architecture (ECSA'11)*, LNCS 6903, 220–235, Springer, **2011**.

- ▶ PARRA C., CLEVE A., BLANC X., DUCHIEN L., Feature-based Composition of Software Architectures, in *Proceedings of the 4th European Conference on Software Architecture (ECSA'10)*, LNCS 6285, 230-245, Springer, **2010**.
- ▶ GILSON F., ENGLEBERT V., MATULEVICIUS R., A Large Scope Transformational Approach for Distributed Architecture Design in Second European conference on Software Architecture (ECSA'08). LNCS 5292. **2008**.

## Funding

Banque Nationale de Belgique - BNB

## Partnership

- ▶ INRIA Lille
- ▶ University of Nice Sophia-Antipolis

## KEYWORDS

Architecture description language  
 Model transformation  
 Architecture variability management  
 Architecture composition  
 Deployment  
 Architecture design rationale  
 Middleware & services  
 Component-based software engineering

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# Formal Analysis and Verification of Computer Systems

## SENIOR SCIENTIST:

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## Research Field and Subjects

Computer programs continue to invade every inch of individuals, enterprises and societies. They keep getting more complex and interdependent. Just like building bridges or rockets, building dependable programs demands sound engineering principles grounded in rigorous mathematical foundations. The goal of the Louvain Verification Lab (LVL) is to invent and improve rigorous techniques for developing, analysing, transforming and synthesising models of programs and computing systems.

The Louvain Verification Lab (LVL) is a research team in the ICTEAM institute at Université catholique de Louvain. LVL investigates principles, tools and applications of formal analysis and verification of computer systems. LVL was officially created in 2010, but members of the team have been active in this field at UCL since 2004.

The research at LVL mainly revolves around the automated verification technique known as model checking, under different views and directions. As typical for such automated software engineering disciplines, the work combines devising new methods and algorithms, implementing these algorithms into actual software tools, and assessing and validating them on actual case studies and applications. Formalisms and languages used to represent systems and their properties are also studied, with connections to logic and automata theory.

More specifically, fields of interest of LVL researchers include symbolic and bounded model-checking, verification of human-computer interaction, generation of enriched verification explanations, verification of concurrent systems and partial-order reduction, structural coverage criteria for specifications, temporal and epistemic logics, analysis of observability and diagnosis, and verification of autonomous and intelligent systems.

## Representative References

- ▶ COMBEFIS S., GIANNAKOPOULOU D., PECHEUR C. and FEARY M., A Formal Framework for Design and Analysis of Human-Machine Interaction. 2011 IEEE International Conference on Systems, Man, and Cybernetics, IEEE, **2011**.
- ▶ VANDER MEULEN J. and PECHEUR C., Combining Partial Order Reduction and Symbolic Model Checking to verify LTL properties. M. Bobaru, K. Havelund, G. Holzmann, and R. Joshi, eds, Nasa Formal Methods 2011, Volume 6617 of LNCS, Springer Verlag, **2011**.
- ▶ PECHEUR C., RAIMONDI F. and BRAT G., A Formal Analysis of Requirements-Based Testing. ACM, ed, 2009 International Conference on Software Testing and Analysis (ISSTA), Chicago, IL, **2009**.
- ▶ COMBEFIS S. and PECHEUR C., A Bisimulation-Based Approach to the Analysis of Human-Computer Interaction. Proceedings of ACM SIGCHI Symposium on Engineering Interactive Computing Systems (EICS 2009), Pittsburgh, PA, **2009**.
- ▶ VANDER MEULEN J. and PECHEUR C., Combining Partial Order Reduction with Bounded Model Checking. Communicating Process Architectures 2009 - WoTUG-32, Volume 67 of Concurrent Systems Engineering Series, IOS Press, **2009**.
- ▶ LOMUSCIO A., PECHEUR C. and RAIMONDI F., Automatic Verification of Knowledge and Time with NuSMV. 20th International Joint Conference on Artificial Intelligence (IJCAI-07), Hyderabad, India, **2007**.

## Funding

- ▶ CE-IQS: Centre d'Ingénierie et Qualité des Systèmes (FEDER, Wallonie / EU), 2009–2014.
- ▶ MoVES: Fundamental issues in software engineering: Modeling, Verification and Evolution of Software. Inter-University Attraction Pole (Belgium Federal Govt), 2007–2011.

## Partnership

- ▶ NASA Ames Research Center (USA)
- ▶ Middlesex University (UK)
- ▶ Fondazione Bruno Kessler (Italy)
- ▶ CETIC (Belgium)
- ▶ FUNDP, KUL, UA, ULB, ULg, UMon, VUB.

## Products and Services

LVL is always looking for opportunities for scientific and industrial collaborations. In particular, pilot studies in applying innovative methods to real-life industrial applications provide an excellent opportunity to assess and demonstrate benefits and identify new challenges.

## KEYWORDS

Software/Program Verification  
Formal methods  
Model checking  
Reliability  
Design Tools and Techniques  
Models of Computation  
Logics of programs

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# Model-Driven Requirements Engineering

## SENIOR SCIENTIST:

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## Research Field and Subjects

Requirements engineering (RE) is concerned with the elicitation of the objectives to be achieved by the system-to-be, the operationalization of such objectives into specifications of requirements and assumptions, the assignment of responsibilities for those specifications to agents such as humans, devices and software, and the evolution of such requirements over time and across system families. Getting high-quality requirements is difficult and critical. Poor requirements were recurrently recognized to be the major cause of system failures.

The UCL group in Louvain-la-Neuve has pioneered a systematic, goal-oriented approach to requirements engineering for high-assurance systems. The target of this approach is a complete, consistent, adequate, and structured set of software requirements and environment assumptions.

The approach is model-based, and partly relies on the use of formal methods *when and where needed* to support RE-specific tasks such as goal refinement, goal operationalization, risk analysis, conflict management, and synthesis of behaviour models.

The software tools supporting this approach include model animators, model checkers against goals and domain properties, deductive verifiers, and inductive model synthesizers from scenario examples.

Current research efforts aim at expanding this approach in a number of directions including:

- The analysis and enactment of models of safety-critical medical processes (such as those involved in, e.g., cancer therapies).
- The modelling and analysis of probabilistic goals and risks.
- The combination of model checking and property learning for automated generation of risk conditions and model transformations resolving these.

## Representative References

▶ VAN LAMSWEEERDE A., *Requirements Engineering: From System Goals to UML Models to Software Specifications*. J. Wiley & Sons, 682p., **2009**.

▶ VAN LAMSWEEERDE A., Reasoning About Alternative Requirements Options. In *Conceptual Modeling: Foundations and Applications*, A. Borgida, V. Chaudhri, P. Giorgini, E. Yu (Eds.), Springer-Verlag LNCS 5600, 380-397, **2009**.

▶ DAMAS C., LAMBEAU B., ROUCOUX F., VAN LAMSWEEERDE A., Analyzing Critical Process Models through Behavior Model Synthesis, *Proc. ICSE'2009: 31th International Conference on Software Engineering*, Vancouver, May 16-24, **2009**.

▶ VAN LAMSWEEERDE A., Requirements Engineering: From Craft to Discipline. *Proc. FSE'2008: 16th ACM Sigsoft Intl. Symposium on the Foundations of Software Engineering*, Atlanta, November **2008**.

▶ DUPONT P., DAMAS C., LAMBEAU B., VAN LAMSWEEERDE A., The QSM Algorithm and its Application to Software Behavior Model Induction. *Applied Artificial Intelligence*, Vol. 22, 77-115, **2008**.

▶ VAN LAMSWEEERDE A., Engineering Requirements for System Reliability and Security. In *Software System Reliability and Security*, M. Broy, J. Grunbauer and C.A.R. Hoare (eds.), NATO Security through Science Series - D: Information and Communication Security, Vol. 9. IOS Press, 196-238, **2007**.

▶ PONSARD C., MASSONET P., MOLDEREZ, J.F. RIFAUT A., VAN LAMSWEEERDE A., Early Verification and Validation of Mission-Critical Systems, *Formal Methods in System Design*, Vol. 30, No. 3, Springer, 233-247, **2007**.

## Awards

- ▶ ACM Sigsoft Outstanding Research Award, 2008.
- ▶ IEEE Most Influential Paper Award, International Requirements Engineering Conference, 2011.
- ▶ ACM Sigsoft Distinguished Service Award.
- ▶ ACM Fellow.
- ▶ SWIFT Award.

## **Funding**

- ▶ F.R.S.-FNRS
- ▶ European
- ▶ Wallonie
- ▶ Fédération Wallonie - Bruxelles (ARC)
- ▶ IAP

## **Partnership**

- ▶ Imperial College London (UK).
- ▶ University College London (UK).
- ▶ University of Oregon (USA).

## **KEYWORDS**

Model-driven software engineering  
Goal-oriented requirements engineering  
Software specification  
Risk analysis  
Model synthesis  
Model checking  
Inductive learning from examples

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# Multi-Agent Systems Architectures

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## Research Field and Subjects

Agent-Oriented is emerging as a powerful new paradigm in computing. Concepts and techniques from the agent paradigm could well be the foundations for the next generation of mainstream information systems, which we might term "active computing".

Information systems architectures have become the backbone of all kinds of organisations today. In almost every sector - manufacturing, education, health care, government, and businesses large and small - information systems are relied upon for everyday work, communication, information gathering, and decision-making. Yet, the inflexibilities in current technologies and methods have also resulted in poor performance, incompatibilities, and obstacles to change. As many organisations are reinventing themselves to meet the challenges of global competition and e-commerce, there is increasing pressure to develop and deploy new technologies that are flexible, robust, and responsive to rapid and unexpected change.

Agent concepts hold great promise for responding to the new realities of active information systems. They offer higher level abstractions and mechanisms which address issues such as knowledge representation and reasoning, communication, coordination, cooperation among heterogeneous and autonomous parties, perception, commitments, goals, beliefs, intentions, etc. On the one hand, the concrete implementation of these concepts can lead to advanced functionalities, e.g., in inference-based query answering, transaction control, adaptive workflows, brokering and integration of disparate information sources, and automated communication processes. On the other hand, their rich representational capabilities allow for more faithful and flexible treatments of complex organisational processes, leading to more effective requirements analysis and architectural and detailed design.

The research work focuses on how agent concepts and techniques will contribute to the meeting of information systems architectures with today and tomorrow needs, especially in the context of service-oriented architectures and web services development.

## Representative References

- ▶ KIV S., WAUTELET Y., KOLP M., "A Multi-Agent Architectural Pattern for Wrapping Off-the-Shelf Components". In KES-AMSTA 2011, 5th KES Int. Conf. on Agent and Multi-Agent Systems: Technologies and Applications, Manchester, UK, LNCS 6682, pp. 321-331 June 29 - July 1, **2011**.
- ▶ MOURATIDIS H., FAULKNER S., KOLP M. and GIORGINI P., "A Secure Architectural Description Language for BDI Multi-Agent Systems". In *International Journal of Web Intelligence and Agent Systems (WIAS)*, 8(1) pp. 99-122, **2010**.
- ▶ NGUYEN T., KOLP M. and PENSERINI L., "A Development Framework for Component-Based Agent-Oriented Business Services". In *International Journal of Agent Software Engineering (IJAOSE)*, 3 (2/3), pp. 328-367 Inderscience, **2009**.
- ▶ KOLP M., HENDERSEN-SELLERS B., MOURATIDIS H., GARCIA A. and GHOZE A. (Eds.), *Agent Oriented Information Systems IX*, Springer, 231 pages, ISBN: 978-3-540-77989-6, Germany, **2008**.

## Partnership

- ▶ University of Toronto, Department of Computer Science
- ▶ University of Trento, Department of Information and Communication Technology
- ▶ Valencia University of Technology, Department of Computer Science
- ▶ University of Utrecht, Department of Computer Science
- ▶ Federal University of Pernambuco, Department of Computer Science
- ▶ Center for Scientific and Technological Research - ITC-IRST

## Products and Services

- Agent-oriented modelling and design methods
- Models and architectures for agent-oriented/active information systems
- Novel information system technologies based on software agents
- Agent-based requirements engineering
- Agent-oriented approaches to data integration
- Agent orientation and e-services
- Agent orientation in web information systems
- Agent-oriented enterprise and business process modelling
- Agent communication languages for business communication
- Ontologies and agents
- Agent orientation and human computer interaction
- DesCARTES Agent Oriented CASE Tool
- SkwyRL framework for Agent Architectural Design
- Consultancy
- Expertise
- Executive education

## KEYWORDS

Architectural Patterns  
Software Design  
Design Patterns  
Multi-agent systems  
Intelligent Systems

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# Software Quality – Software Measurement

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## Research Field and Subjects

As any engineering discipline, software specification, development, operation, and maintenance require the application of disciplined and quantifiable approaches. This implies a systematic control of the quality for all the *products* being involved as well as the *processes* being followed.

As any management discipline, software management implies also such a systematic control of the quality for all the products and processes being involved. Moreover, it implies the integration of quality management of systems within the global quality management process of the organisation.

Software Quality involves four levels of study: The Quality Management level where criteria are defined at the business level according to a customer-centric approach; The Software Process level where focus is put on software process modelling, evaluation and improvement; The Software Product level where focus is put on the definition of quality indicators for the different software products and their relationships; And the Software measurement level where metrics and measuring methods are defined.

PRECISE actively contributes to Software Quality research community following several axis:

- At the management level: Quality criteria are defined on the basis of customers' specification limits. Control of those criteria is performed in order to guarantee the stability of business processes. When processes are stable, opportunities of improvement can be studied through typical quality tools: Pareto analysis, cause-effect diagrams, why-why analysis, etc. Also, some expertise in software certification have been developed, namely in the aeronautic domain (DoD-178B).

- At the Process level : the establishment of a Software Process Model dedicated to Small & Medium Enterprises on basis of the adaptation of classical software process models like CMMi. The OWPL is used as basis to the current development of an ISO standard for SME (ISO-29110).

- At the product and the measurement levels: the development of a generic framework (MoCQA) allowing to build particular quality model for any specific uses on basis of a meta-model integrating different standards.

- On this base, several specific quality models have been designed: the model "Qualoos" for open source systems; the

model "Doca" for documentation assessment. A Bayesian belief networks based model for web site evaluations is also being investigated.

## Representative References

- ▶ VAUCHER S., MOULART A., SAHRAOUI H. and HABRA N., Automated Evaluation of Web Site Navigability: an Empirical Validation of Multi-level Quality Models, in Journal of Software Maintenance and Evolution: Research and Practice, special issue, **2011**.
- ▶ VANDERROSE B., HABRA N. and KAMSEU F., Towards a Model-Centric Quality Assessment, in Proceedings of the 20th International Workshop on Software Measurement (IWSM **2010**).
- ▶ MATULEVICIUS R., HABRA N. and KAMSEU F., Validity of the Documentation Availability Model: Experimental Definition of Quality Interpretation, in Proceedings of The 22nd International Conference on Advanced Information Systems Engineering (CAISE'10), pp. 236-250, **2010**.
- ▶ HABRA N., ABRAN A., LOPEZ MARTIN M.A. & SELLAMI A., A Framework for the Design and Verification of Software Measurement Methods, in Journal of Systems & Software, volume 81, issue 5, pp. 633-648, **2007**.
- ▶ HABRA N., ALEXANDRE S., DESHARNAIS J.M., LAPORTE C. and RENAULT A., Initiating software process improvement in very small enterprises: Experience with a light assessment tool, in Information & Software Technology, volume 50, issue 7-8, pp. 763-771, **2007**.

## Funding

- ▶ Wallonie
- ▶ EC



## Partnership

- ▶ Université de Montréal
- ▶ Ecole Polytechnique de Montréal
- ▶ CETIC

## Products and Services

- ▶ MoCQA: Generic Quality Framework
- ▶ OWPL: Process Model for SME
- ▶ DOCA: Quality Model for Documentation
- ▶ QuaLOSS: Quality Model for Open Source Systems

## KEYWORDS

Software Quality  
Software Measurement  
Software Process Improvement  
Certification  
Standards  
Empirical Software Engineering

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# Intelligent Decision Support Systems

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## Research Field and Subjects

Decision support systems are information systems designed to support all the phases of a user's decision making process. They have many applications in the society in many domains. Some systems propose tools with visual and data research facilities, but they leave the intelligence of the decision in the hands of deciders. Other systems embody artificial intelligence techniques to propose advices that would typically be offered by experts.

Two intelligent decision support systems have been developed inside the Focus research group. On the one hand, the ExpeSurf system answers the problem of conceiving novel products in metallurgy by planning various surface treatments. This allows one to obtain a set of required properties while taking into account incompatibilities, environment constraints and production costs. On the other hand, the SEPlanS system has been conceived to help tax consultants, company revisers, patrimonial advisers of banks or solicitors to plan the inheritance of a contractor, in particular, allowing them to explore the various alternatives offered by the Belgian legislation and the European one.

Since 2010, a new project, called BEM (i.e., Business Event Manager) aims to develop a new IT approach in order to manage unexpected events in the context of logistics workflow management. The framework supporting this approach will associate an intelligent engine with a traditional workflow engine.

## Representative References

- ▶ LINDEN I., JACQUET J.-M., STAIU O., OSPINA G., Experts Collaboration for Wealth and Estate Planning Using the SEPlanS Platform, in P. Zaraté and F. Dargam, Collaboration in Real Environments, Lecture Notes in Business Information Processing, **2012**.
- ▶ DERBALI M., A Framework Proposal for Intelligent Management of Unexpected exceptions in workflow, in Proceedings of the On The Move Academy, pp. 3-10, **2011**.

- ▶ BAUDOUX C., DEGRANDCOURT C., AILINCA G., D'ANS P., DEGREZ M., WATHELET D., BARTHELEMY F., ANCIAUX J., OSPINA G., JACQUET J.-M., An Expert Software for Multi-layer Coatings Design in Surface Engineering. Material Science Forum, vol. 595-598, 2008, pp. 583-591.

## Funding

Wallonie: Winnomat, Wist 2 and plan Marshall.

## Partnership

- ▶ Université libre de Bruxelles, Prof. M. Degrez
- ▶ UCL- Mons, Prof. P. Jaillot and D. Helbois
- ▶ NSI IT Software and Services
- ▶ Cetic - Centre d'Excellence en Technologies de l'Information et de la Communication
- ▶ Smolinfo
- ▶ Trendy Foods Belgium

## Products and Services

- ▶ The ExpeSurf software system
- ▶ The SEPlanS software system
- ▶ The BEM inference engine

## KEYWORDS

Decision support system  
Artificial Intelligence

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# Information Management, Knowledge Extraction and Business Intelligence

## SENIOR SCIENTIST:

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## Research Field and Subjects

Nowadays, companies do not lack information: data are used and stored at any stages of the production process. Nevertheless, retrieving useful knowledge among them is a daily challenge.

For several years, various tools and methodologies have been developed to support the process of knowledge extraction out of huge amount of data. Data mining and OLAP (*online analytical processing*) analysis are probably the most well known among them. More recently, Business Intelligence aims to provide processes to transform data into knowledge at any decision level, from the most operational to the most strategic ones. This perspective involves, on the one hand, very technical aspects as data extraction, cleaning and storage, optimisation of search and analysis algorithm. On the other hand, it has a significant impact on the management policies in particular by the fact that many indicators become available.

The information management team of the management department has interest in both aspects. It focuses on their use for decision-making, mainly in the particular context of Small and Medium-sized Enterprises (SME).

## Representative References

- DETHIER G., Analyse et Evaluation des Solutions de Business Intelligence à Destination des PME wallonnes, master thesis FUNDP, **2011**.
- LIU S., MOIZER J., SUBRAMANIAM P., LEAT M., LINDEN I., Decision Support for ERP-based Production Management: a Business Intelligence Perspective, in Proceedings of the 15th IFIP WG 8.3 International Conference on Decision Support Systems, **2010**.

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## KEYWORDS

Information Management  
Knowledge Extraction  
Business Intelligence  
Data mining  
Social Network Analysis

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# Web Information Systems and Technologies

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- ▶ Philippe THIRAN

## Research Field and Subjects

The Web has changed the way information is accessed and shared. For example, many companies now depend on the Web for directly selling their products to their customers, or for developing distributed business-to-business processes inside or across the company.

Besides the Web's core technology (HTML and HTTP), new Web technologies have emerged like:

- XML technologies for extracting, transporting, searching and transforming Web data;
- Web services for interoperable interactions between machines;
- Semantic Web for creating a Web with a meaning so that machines can understand it.

Web Information Systems (WIS) use these Web technologies to retrieve information from data sources and deliver them to the users. Due to their complex requirements, the design of WIS is not a trivial task. Design methods provide guidelines for the building of WIS so that the complexity of this process can be handled. These methods rely on models that specify different aspects of WIS design like data integration, application interaction, navigation structure, user interface, user interaction, presentation personalisation, etc.

The main aspects studied in the PReCISE research centre, include:

- Integration of the huge amount of information already available (mainly in relational databases) on the Web ;
- Web presentation generation (including Web information adaptation to device capabilities and user preferences) ;
- Web application interactions (including Web service selection and composition).

## Representative References

- ▶ AL-JABARI M., MARISSA M., THIRAN Ph., Context-Aware Interaction Approach to Handle Users Local Contexts in Web 2.0. International Conference on Web Engineering, LNCS, Springer, pp. 248-262, **2010**.
- ▶ NARENDRA C.N., BADR Y., THIRAN Ph., MAAMAR Z., Towards a Unified Approach for Business Process Modeling Using Context-Based Artifacts and Web Services. IEEE SCC, IEEE Computer Press, pp. 332-339, **2009**.
- ▶ AL-JABARI M., MARISSA M., THIRAN Ph., Towards Web Usability: Providing Web Contents According to the Readers Contexts, International Conference in User Modeling, Adaptation and Personalization (UMAP), LNCS, Springer, pp. 467-473, **2009**.
- ▶ BENSLIMANE S.M., BENSLIMANE D., MALKI M., MAAMAR Z., THIRAN Ph., Ontology Development for the Semantic Web: an HTML Form-Based Reverse Engineering Approach. Journal on Web Engineering, Rinton Press, 6(2), pp. 143-164, **2007**.
- ▶ CHAMPIN P-A., HOUBEN G-J., THIRAN Ph., Cross: An OWL Wrapper for Reasoning on Relational Databases, Conceptual Modelling conference (ER), LNCS, Springer, pp. 502-517, **2007**.
- ▶ ESTIEVENART F., MEURISE J-R., Extraction de données sur Internet avec Retroweb, in Extraction et gestion des connaissances (EGC'07), Revue des Nouvelles Technologies de l'Information, Volume E-9, pages 181-182, **2007**.

## Funding

- ▶ Wallonie
- ▶ UNESCO

## Partnership

- ▶ Technical University of Delft, The Netherlands
- ▶ Technical University of Eindhoven, The Netherlands
- ▶ University of Lyon 1, France
- ▶ IBM Research Lab, Bangalore, India
- ▶ Zayed University, Dubai, UEA
- ▶ CETIC

## Products and Services

- ▶ Techniques and tools for generating and adapting Web presentations
- ▶ Techniques and tools for composing Web services
- ▶ Techniques and tools for extracting data from the Web
- ▶ Techniques and tools for integrating existing data on the Web
- ▶ Training in Web technologies

## KEYWORDS

Semantic Web  
Personalisation  
Adaptation  
User context  
Web services  
Web presentation

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# E-Health Information Systems

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- ▶ Jean-Noël COLIN
- ▶ Anne-France BROGNEAUX

## Research Field and Subjects

PRReCISE (research centre in information system engineering) has developed a holistic approach to e-Health information systems (HIS).

A comprehensive healthcare model has been elaborated to cover the main requirements of most e-Health IS. It includes four core subsystems, namely healthcare processes, information, resources and organisation. It also includes five transverse aspects: instances, time, privacy/access control, evolution and specialisation. A metadata repository has been developed to store and process clinical care paths for cancer and diabetes and to serve as an interoperability platform for assisted home care control. This ontological approach also serves as a basis for more specialised models, e.g. in mammology, pneumology, molecular pathogen identification, prosthetics, emergency medicine, etc. These models are enriched with probabilistic reasoning rules reflecting the latest medical evidence, to assist diagnostic and guidelines engineering.

## Representative References

- ▶ HAINAUT J.-L., BROGNEAUX A.-F., CLEVE A., Healthcare Information System Modeling, Chapter in I. M. Miranda & M. M. Cruz-Cunha (Ed.), Handbook of Research on ICTs for Healthcare and Social Services: Developments and Applications, **2012**.
- ▶ HAINAUT J.-L., BROGNEAUX A.-F., CLEVE A., Base de modèles pour les itinéraires de soins, Rapport technique, projet GISELE, **2010**.
- ▶ GEMO M., KIEFFER S., GOUZE A., LAWSON L., MACQ B., NIANG M., SCHOBBERNS P.-Y., MAZY G., DEBANDE B., FARSI S. M., An Intuitive Annotation Toolbox for Open-source Imaging Diagnosis, in Proc. IST-Africa, May **2007**.
- ▶ PETIT M., ROUSSEAU A., LOBET-MARIS C., SCHOBBERNS P.-Y., La rédaction du Cahier des Charges : Pour une méthodologie pluridisciplinaire et participative d'élicitation des exigences: Chapitre 3, in Urgence aux urgences, Presses Universitaires de Namur, Collection Les organisations : gestion, méthodes, cas. **2004**.

- ▶ LOBET-MARIS C., PETIT M., ROUSSEAU A., SCHOBBERNS P.-Y., Analyse organisationnelle et ingénierie des exigences : préalables à l'informatisation des services des urgences, in ARTHUR - Manuel d'informatisation des urgences hospitalières, Presses universitaires de Louvain, pp. 13-53, **2003**.

## Funding

- ▶ Wallonie
- ▶ FEDER

## Partnership

- ▶ CETIC
- ▶ Institut NARILIS
- ▶ CRIDS
- ▶ Réseau Santé Wallon
- ▶ ICTeam, UCL
- ▶ Cliniques Universitaires St-Luc, UCL
- ▶ Cliniques de Mont-Godinne, UCL
- ▶ Polymedis S.A.
- ▶ Palantiris
- ▶ IBA

## Products and Services

- ▶ General customisable healthcare model and portable healthcare metadata repository
- ▶ Requirements Engineering Methodology for e-Health



**KEYWORDS**

Healthcare model  
Workflow model  
Metadata repository  
Information privacy  
Medical guidelines  
Medical ontology  
Computer-assisted diagnostic  
Medical image annotation

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# Special Purpose Database Engineering

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- ▶ Frédéric VESENTINI
- ▶ Anne-France BROGNEAUX

## Research Field and Subjects

Design methods for standard databases that support OLTP (Online transaction processing) systems have been studied and applied for decades. However, these approaches fall short when coping with non standard databases. PReCISE has invested in the study of three special purpose databases, namely active, temporal and statistics databases. For each of them, it has developed models, design methodologies and tools.

In the active database domain, the emphasis has been on specifying complex conceptual integrity constraints, and on generating SQL code for controlling these constraints. In particular, rules have been developed for extending the expressiveness of relational databases to existence constraints, redundancies and complete inheritance constraints in SQL2. Specific DB-MAIN components have been developed for automatic code generation.

All information systems include temporal or historical data. However, modelling and managing these data pose complex theoretical and practical problems. Comprehensive conceptual, logical and physical models have been elaborated, including transaction, valid and bitemporal dimensions. A CASE tool, based on DB-MAIN, has been developed to specify and generate active databases managing all the temporal dimensions.

Huge resources have been devoted to the development of methods and tools to feed a statistics data warehouse with data from heterogeneous sources, included poorly written paper documents. Special attention is paid to the evolution of dimensions (add/remove/change dimensions and dimension values). The tool also includes a user-friendly web-based query interface. These results have been successfully applied to penal and economic statistics in several Belgian administrations.

## Representative References

- ▶ DETIENNE V., VESENTINI F., HAINAUT J.-L., Entreposage et exploitation de documents multidimensionnels évolutifs : le cas des tableaux statistiques, in Document Numérique, numéro spécial Entreposage de documents et données semi-structurées, Hermès, **2007**.

- ▶ ROUSSEAU X., VESENTINI F., DETIENNE V., Le projet Quetelet.net dans l'histoire de la statistique judiciaire belge, in Christiaensen, S., Rousseau, X., Vesentini, F. (Eds), Rencontre entre criminologie et histoire. Maintien de l'ordre, Justice et Politique criminelle en Belgique, Academia Press, **2005**.
- ▶ BROGNEAUX A.-F., HAINAUT J.-L., Active Databases. Rapport final du projet Active Databases, 265 p., **2003**.
- ▶ HAINAUT J.-L., DETIENNE V., Introduction pratique aux bases de données temporelles, 116 p., novembre **2002**.
- ▶ DETIENNE V., HAINAUT J.-L., Understanding, Developing, Processing Temporal Databases. Rapport final du projet TimeStamp, 974 p., **2002**.
- ▶ DETIENNE V., HAINAUT J.-L., CASE Tool Support for Temporal Database Design, in Proc. of ER'01, LNCS 2224, pp. 208-224, Springer-Verlag, **2001**.

## Funding

- ▶ Wallonie
- ▶ BELSPO

## Partnership

- ▶ ReveR s.a.
- ▶ CHDJ, UCL
- ▶ CETIC

## Products and Services

- ▶ Methodologies and tools for active database design
- ▶ Methodologies and tools for temporal database design
- ▶ Quetelet.net, a data warehouse management environment

**KEYWORDS**

Database design  
Active database  
Temporal migration  
Statistics database  
Data warehouse  
Data dematerialisation  
CASE tool

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# Database Reverse Engineering

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## Research Field and Subjects

Most activities related to a database require a complete, precise and up to date documentation, notably its conceptual schema that describes in detail the semantics of the database structures. This is the case of application programming and of database maintenance, migration, evolution and integration to mention a few. Unfortunately, such documentation is most often missing. To allow the processes mentioned above to be performed efficiently, this documentation should be rebuilt from various information sources, a process called *database reverse engineering*.

The PReCISE Data Engineering group has been developing for two decades a comprehensive database reverse engineering methodology supported by the DB-MAIN CASE environment. Many schema constructs are not explicitly declared in the database DDL, so that special techniques have been designed to extract this implicit information from schemas, database contents, program source code and user interface, among others. New application architectures, such as web-based applications, require dynamic analysis techniques.

These techniques and tools are quite general and have been used to recover the documentation of a wide variety of data structures, e.g., legacy databases, plain files, relational databases, object-relational databases, Java classes and XML documents.

The results of this research are exploited, maintained and continuously extended by spin-off ReveR.

## Representative References

- ▶ CLEVE A., MEURISSE J.-R., HAINAUT J.-L., Database Semantics Recovery through Analysis of Dynamic SQL Statements, in Journal of Data Semantics, Vol. XV, pages 130-157, LNCS no 6720, Springer, **2011**.
- ▶ HAINAUT J.-L., Conceptual interpretation of foreign keys, Technical report, 60 pages, May **2010**.
- ▶ HAINAUT J.-L., HENRARD J., ENGLEBERT V., ROLAND D., HICK J.-M., Database Reverse Engineering, in Encyclopedia of Database Systems, Liu, L. and Özsu, T. (Eds), Springer-Verlag, **2009**.

- ▶ HAINAUT J.-L., Legacy and Future of Database Reverse Engineering, Keynote, Proceedings of the 16th Working Conference on Reverse Engineering, (WCRE'09), IEEE Computer Society, **2009**.

- ▶ CLEVE A., HENRARD J. and HAINAUT J.-L., Data Reverse Engineering using System Dependency Graphs, in Proceedings of the 13th Working Conference on Reverse Engineering (WCRE'06), pp. 157-166, IEEE Computer Society, **2006**.

- ▶ THIRAN P., ESTIEVENART F., HAINAUT J.-L. and HOUBEN G.-J., A Generic Framework for Extracting XML Data from Legacy Databases, Journal of Web Engineering, 4(3): pp. 205-223, Rinton Press, **2005**.

- ▶ HENRARD J., Program comprehension in database reverse engineering, PhD Thesis, University of Namur, **2003**.

- ▶ HAINAUT J.-L., Introduction to Database Reverse Engineering, Technical report, 140 p., **2002**.

## Funding

Wallonie

## Partnership

ReveR s.a.

## Products and Services

- ▶ Database reverse engineering methodologies for most data models
- ▶ DB-MAIN, a programmable data centered CASE platform

**KEYWORDS**

Data engineering  
Database reverse engineering  
Program code analysis  
Transformational techniques  
CASE tool

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# Database Design

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## Research Field and Subjects

Data are at the core of modern information systems, so that their quality is critical for all the components of these systems. Poorly designed databases inevitably lead to costly maintenance and evolution of application programs. Though widely described for decades, database design methods still deserve further development. Indeed, modern databases bring new challenges for which current methods appear too weak.

Understanding and solving these challenges in a disciplined way, well beyond the simplistic approaches described in most textbooks, are among the main goals of the activities of the Data Engineering group of PreCISE. It has developed generic database analysis and design methodologies, based on the transformational techniques that can be specialised to fit different data models and development contexts. In particular, it has developed solid techniques and methods for the following core processes: user-driven requirement acquisition and validation, schema integration, schema normalisation, schema quality evaluation and improvement, correct and complete conceptual schema translation into DBMS DDL. In addition, they are supported by the DB-MAIN CASE tool.

These results are exploited and maintained by ReVeR, a spin-off of PreCISE. These processes as well as their underlying concepts are described in detail in a book [HAINAUT, 2012] which is intended to student and professional audience.

## Representative References

- ▶ HAINAUT J.-L., *Bases de données - Concepts, utilisation et développement*, 2e Edition, 1300 pages, Dunod, **2012**.
- ▶ RAMDOYAL R., HAINAUT J.-L., Involving End-users in Database Design – The RAINBOW Approach, in International Journal on Computer Science and Information Systems, IADIS Publish., **2011**.
- ▶ LEMAITRE J., HAINAUT J.-L., Quality evaluation and improvement framework for database schemas - Using defect taxonomies, in Proc. of CAiSE'11, LNCS, pages 536-550, Springer-Verlag, **2011**.

- ▶ RAMDOYAL R., Reverse Engineering User-Drawn Form-based Interfaces for Interactive Database Conceptual Analysis, PhD Thesis, University of Namur, October **2010**.
- ▶ LEMAITRE J. and HAINAUT J.-L., Transformation-based Framework for the Evaluation and Improvement of Database Schemas, in Proc. of CAiSE'10, LNCS, pp. 317-331, Springer-Verlag, **2010**.
- ▶ CLEVE A., BROGNEAUX A.-F., HAINAUT J.-L., A Conceptual Approach to Database Applications Evolution, in Proc. of ER'2010, LNCS 6412, pp. 132 - 145, Springer-Verlag, **2010**.

## Funding

Wallonie

## Partnership

ReVeR s.a.

## Products and Services

- ▶ Methodologies for database design and evaluation
- ▶ DB-MAIN, a programmable data centered CASE platform
- ▶ A comprehensive textbook in Database design [HAINAUT, 2012]
- ▶ Training modules in Database design

**KEYWORDS**

Database engineering  
Database quality  
Database design  
Transformational techniques  
CASE tool

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# Business IT Alignment

## SENIOR SCIENTISTS:

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- ▶ Michaël PETIT

## Research Field and Subjects

Business IT-Alignment (BITA) is the set of activities ensuring that the investments in IT as well as its usage are consistent with the organisation's business strategy, and effectively serves the organization's business strategic objectives. This alignment requires that the IT projects, infrastructure and applications are defined and implemented by taking into account the business strategy. Furthermore, it also views IT as a support to define and enable new business models and innovate at the business level. IT subsumes software, hardware and all other necessary information infrastructure in the broad sense (including e.g. management of IT capabilities, services and projects). BITA relies on the premise that IT is valuable only to the extent that it enables an organisation to meet its business goals.

The BITA research seeks to elaborate and evaluate reference models, techniques and methodologies that help to identify, capture, visualise and analyse and improve:

- Business strategies, business models and business motivations;
- Organisational infrastructures (including business processes, IT projects, IT infrastructures and services...);
- Correspondence and alignment between both.

The research in this field includes results on:

- Understanding of strategic conditions favouring the success of ICT projects (Critical success factors for alignment);
- Understanding the impact that ICT tools can offer in the management of innovation and knowledge;
- Aligning organisational responsibilities and enterprise governance rules and constraints with ICT access control policies;
- Aligning enterprise strategies with IT support for business rules;
- Using goal models to represent and align enterprise strategies with business and value models;
- Defining rich languages and ontologies for describing enterprise strategies;
- Project program and portfolio management and benefits management.

## Representative References

- ▶ FELTUS Ch., PETIT M., DUBOIS E., ReMoLa: Responsibility Model Language to Align Access Rights with Business Process Requirements. Proceeding of the Fifth IEEE International Conference on Research Challenges in Information Science (IEEE RCIS 2011), Gosier, Guadeloupe, French West Indies, IEEE, ISBN 9-78142-448-67, Colette Rolland, Martine Collard (editors), pp. 107–112, **2011**.
- ▶ GIANNOULIS C., PETIT M., ZDRAVKOVIC J., Modeling Competition-driven Business Strategy for Business IT Alignment. In Advanced Information Systems Engineering Workshops, Proc. of the 6th International Workshop on BUSInness/IT ALignment and Interoperability (BUSITAL 2011) Held on 20th June 2011 in conjunction with CAiSE'2011 (20-24 June 2011) London, UK, Camille Salinesi and Oscar Pastor (editors), Lecture Notes in Business Information Processing (LNBIP), Springer, Vol. 83, pp. 16–28, **2011**.
- ▶ GIANNOULIS C., PETIT M., ZDRAVKOVIC J., Towards a Unified Business Strategy Language: A Meta-model of Strategy Maps. In The Practice of Enterprise Modeling, Proc. of the Third IFIP WG 8.1 Working Conference, PoEM 2010, Delft, The Netherlands, November 9-10, **2010**.
- ▶ VAN BOMMEL P., HOPPENBROUWERS S., OVERBEEK S., PROPER E. and BARJIS J. (editors), Lecture Notes in Business Information Processing (LNBIP), Springer Vol. 68, p. 205 – 216, **2010**.
- ▶ BAÄ NA S., ANSIAS P.-Y., PETIT M., CASTIAUX A., Strategic Business/IT Alignment using Goal Models, Proceedings of BUSITAL, **2008**.
- ▶ CASTIAUX A., Knowledge building in innovation networks: the impact of collaborative tools, Proceedings 7th European Conference on Knowledge Management, Budapest, September **2006**.



## **Funding**

Public Research Centre Henri Tudor, Luxemburg

## **Partnership**

- ▶ Public Research Centre Henri Tudor, Luxemburg
- ▶ Department of Computer and Systems Sciences (DSV), Stockholm University, Sweden
- ▶ Faculté des Hautes Etudes Commerciales (HEC), Université de Lausanne, Suisse
- ▶ Faculty of Information, University of Toronto, Canada

## **Products and Services**

- ▶ Expertise in strategy and business model definition and representation
- ▶ Expertise in alignment evaluation and improvement

## **KEYWORDS**

Business-IT alignment  
Critical success factors  
Strategy  
IT architecture  
Knowledge management  
Business Modelling  
Languages  
Governance  
Responsibility

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# Business Modelling

## SENIOR SCIENTISTS:

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## Research Field and Subjects

Business Modelling is concerned with analysing and understanding the organisational context within which a software system will eventually function. It proposes organisational patterns motivated by organisational theories intended to facilitate the construction of business software models such as use cases models and is concerned with the evaluation of the patterns using desirable qualities or non functional requirements.

Since the origins of civilisation, people have been designing, participating in, and sharing the burdens and rewards of organisations. The early organisations were primarily military or governmental in nature. In the *Art of War*, Sun Tzu describes the need for hierarchical structure, communications, and strategy. In the *Politics*, Aristotle wrote of governmental administration and its association with culture. To the would-be-leader, Machiavelli advocated in the *Prince* power over morality. The roots of organisational theories, then, can be traced to antiquity, including thinkers from around the world who studied alternative organisational structures. Such structures consist of stakeholders - individuals, groups, physical or social systems - that coordinate and interact with each other to achieve common goals. Today, organisational structures are primarily studied by two disciplines: *Organisation Theory*, that describes the structure and design of an organisation and *Strategic Alliances* that model the strategic collaborations of independent organisational stakeholders who have agreed to pursue a set of agreed upon business goals.

Both disciplines aim to identify and study organisational patterns. These are not just modelling abstractions or structures, rather they can be seen, felt, handled, and operated upon. They have a manifest form and lie in the objective domain of reality as part of the concrete world. A pattern, however, is not solely a set of execution behaviours. Rather, it exists in various forms at every stage of crystallisation (e.g., specification), and at every level of granularity in the organisation. The more manifest is its representation, the more the pattern emerges and becomes recognizable - whether at a high or low level of granularity.

At the lowest level of granularity, Business modelling proposed information patterns and service patterns that represent the “nitty-gritty” of business that an organisation must deal with on a day-to-day basis. When we move to an upper level, we find business patterns - the mix of products and markets that flow from organisational styles. The highest level of granularity is the organisational styles that address the mix of socio-technical context and organisational constructs: they are manifestation of organisation invariants, layers of organisational constructs, organisation molecules, and complex arrangements of molecules, the collection of which constitutes organisational structures.

Many organisational styles are fully formed patterns with definite characteristics. In contrast, many other organisational styles are not very explicit, that is, not easily specified, operationalised, and measured.

## Representative References

- ▶ HOANG T.T.H., KOLP M., “Goal, Soft-goal and Quality Requirement”. In J. Filipe, J. Cordeiro (Eds.): ICEIS 2010 - Proceedings of the 12th International Conference on Enterprise Information Systems, Volume 3, Funchal, Portugal, pp. 13-22 June **2010**.
- ▶ HOANG T.T.H., “Quality-aware agent-oriented information-system development” PhD thesis, Louvain School of Management, Université catholique de Louvain, December, **2010**.
- ▶ CASTRO J., KOLP M., LIU L., PERINI A., “Dealing with Complexity Using Conceptual Models Based on Tropos”. In A. Borgida, V. K. Chaudhri, P. Giorgini, E. S. K. Yu (Eds.): Conceptual Modeling: Foundations and Applications. LNCS 5600 Springer, pp. 335-362, **2009**.
- ▶ KOLP M., FAULKNER S. and WAUTELET Y., “Multi-Agent Patterns for Organizational Analysis”, In A. Gunasekaran (Ed.), *Global Implications of Modern Enterprise Information Systems: Technologies and Applications*, IGI Publishing, Chap. VI, **2008**.

- ▶ KOLP M., TUNG DO T. and FAULKNER S., "Social-Centric Development of Multi-Agent Architectures". In *Journal of Organizational Computing and Electronic Commerce (JOCEC)*, 18(2):150-175, Taylor and Francis, **2008**.
- ▶ KOLP M. and FAULKNER S., "Patterns for Organizational Modeling". In *International Journal of Enterprise Information Systems (IJEIS)*, 3(3):1-22, Idea Group, **2007**.

#### **KEYWORDS**

Organisational Patterns  
 Requirements engineering  
 Business Modelling  
 Use Case Models  
 Non Functional Requirements  
 Information Modelling  
 Conceptual Modelling

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- ▶ University of Utrecht, Department of Computer Science
- ▶ Federal University of Pernambuco, Department of Computer Science

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<http://www.isys.ucl.ac.be/descartes>

#### **Products and Services**

- ▶ DesCARTES Organisational Modelling CASE Tool (Tropos project)
- ▶ SkwyRL framework for Organisational Modelling
- ▶ Consultancy
- ▶ Expertise
- ▶ Executive education

# E-Business Applications

## SENIOR SCIENTISTS:

- ▶ Manuel KOLP
- ▶ Yves WAUTELET

## Research Field and Subjects

E-business is a term used to describe businesses run on the Internet, or utilising Internet technologies to improve the productivity or profitability of a business. In a more general sense, the term may be used to describe any form of electronic business - that is to say, any business which utilises a computer. This usage is somewhat archaic, however, and in most contexts e-business refers exclusively to Internet businesses.

The most common implementation of e-business is as an additional, or in some cases primary, storefront. By selling products and services online, an e-business is able to reach a much wider consumer base than any traditional brick-and-mortar store could ever hope for. This function of e-business is referred to as e-commerce, and the terms are occasionally used interchangeably.

An e-business may also use the Internet to acquire wholesale products or supplies for in-house production. This facet of e-business is sometimes referred to as e-procurement, and may offer businesses the opportunity to cut their costs dramatically. Even many e-businesses which operate without an electronic storefront now use e-procurement as a way to better track and manage their purchasing.

In addition to buying and selling products, e-business may also handle other traditional business aspects. The use of electronic chat as a form of technical and customer support is an excellent example of this. An e-business which uses chat to supplement its traditional phone support finds a system which saves incredible amounts of time while providing opportunities unavailable through traditional support. By using virtual computer systems, for example, technical support operators can remotely access a customer's computer and assist them in correcting a problem. And with the download of a small program, all pertinent information about the hardware and software specifications for a user's computer may be relayed to the support operator directly, without having to walk a customer through personally collecting the data.

Using email and private websites as a method for dispensing internal memos and white sheets is another use of the Internet by e-business. Rather than producing time-intensive and costly

physical copies for each employee, a central server or email list can serve as an efficient method for distributing necessary information.

In the past few years, virtually all businesses have become, to some degree or another, an e-business. The pervasiveness of Internet technology, readily available solutions, and the repeatedly demonstrated benefits of electronic technology have made e-business the obvious path. This trend continues with new technologies, such as Internet-enabled cell phones and PDAs, and the trend of e-business saturation will most likely continue for some time.

## Representative References

- ▶ TRAN V., KOLP M., VANDERDONCKT J., WAUTELET Y., "Using Task and Data Models for User Interface Declarative Generation". In J. Filipe, J. Cordeiro (Eds.): ICEIS 2010 - Proceedings of the 12th International Conference on Enterprise Information Systems, Volume 5, Funchal, Portugal, pp. 155-160, June **2010**.
- ▶ KIV S., WAUTELET Y., KOLP M., "A Process for Cots-selection and Mismatches Handling - A Goal-driven Approach". In ICAART 2010, Proceedings of the International Conference on Agents and Artificial Intelligence, Valencia, Spain, pp. 98-106, January **2010**.
- ▶ WAUTELET Y., ACHBANY Y., LANGE J.C., KOLP M., "A Process for Developing Adaptable and Open Service Systems: Application in Supply Chain Management". In J. Filipe, J. Cordeiro (Eds.): Enterprise Information Systems. Lecture Notes in Business Information Processing, Springer, pp. 564-576, **2009**.
- ▶ NGUYEN T., KOLP M. and PENSERINI L., "A Development Framework for Component-Based Agent-Oriented Business Services". In *International Journal of Agent Software Engineering (IJAOSE)*, 3 (2/3), pp. 328-367 Inderscience, **2009**.
- ▶ DEHOUSSE S., FAULKNER S., GIORGINI P., KOLP M. and MOURATIDIS H., "Reasoning about Willingness in Networks of Agent". In *Software Engineering for Large Multi-Agent Systems (SELMAS)*, (5):56-70, LNCS 5467, Springer, **2007**.
- ▶ NGUYEN T., *A Methodological Framework for Developing and Composing Business Services*, PhD Thesis, Louvain School of Management, UCLouvain, **2007**.

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- ▶ University of Ancona, Department of Computer Science
- ▶ SONACA S.A.

## **Products and Services**

- ▶ Web recommendation system
- ▶ E-business solutions
- ▶ E-business patterns
- ▶ Web services
- ▶ Agent-oriented services

## **KEYWORDS**

E-Business  
Customer relationship Management  
E-Commerce  
Web services  
Recommendation Systems  
Business to Business

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# Digital circuits and systems

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- ▶ François-Xavier STANDAERT
- ▶ David BOL

## Research Field and Subjects

• Low-power digital electronics. At the Microelectronics Laboratory, a wide expertise has been gained at each design level from device to system, e.g.:

– Ultra-low-voltage devices and circuits have been studied for high energy efficiency in applications such as biomedical and wireless sensor nodes. A strong focus was set on achieving high reliability and increased speed performances. Both test structures (ring oscillators) and logic blocks (AES coprocessor) were demonstrated in nm-CMOS technologies.

– Ultra-low-leakage logic and memories were proposed based on UCL patented building blocks to achieve up to 1000x stand-by power reduction.

– Dynamic current-mode logic styles were intensively analysed and new ones (Low-Swing Current-Mode Logic, Dynamic Differential Swing-Limited Logic) were designed for several low-power applications.

– Novel full adder architectures: special logic styles like branch-based logic and pass-gate allowed the implementation of hybrid high-performance low-power full adders. Moreover, a special multi-value signed-digit full adder using Ultra-Low-Power diodes was designed and other versions using dynamic current-mode logic styles are under development.

– Asynchronous logic based on new completion techniques is under research for easy implementation in both ASIC and FPGA EDA tool flows.

– Low-power microcontrollers: thanks to the extensive use of low power state-of-the-art techniques at gate and architectural levels, a low-power 80C51 microcontroller was designed. Both a high temperature and a deep-submicron version were manufactured to meet wide-range industry standards. Moreover, a microcontroller System-on-Chip based on an MSP430 has been manufactured in nm-CMOS technology with ultra-low-voltage operation for record low power consumption.

• FPGAs (Field Programmable Gates Arrays). The research focuses on cryptography, image processing and hardware security:

– Cryptography: research on cryptographic implementations has been a permanent activity at UCL. Different works have investigated the hardware performances of various algorithms (DES, AES, RSA ...). In particular, the UCL Crypto Group has

recently designed the first compact implementation of the new hash standard finalists SHA3. The impact of technology scaling on low power constraints has also been analysed.

– Image processing: thanks to collaborations with the image processing lab of UCL, the first FPGA publications of JPEG2000 decoder and fingerprinting inserter were achieved. The laboratory continues investigations on such topics combined with cryptography, in order to meet the future Digital Cinema requirements.

– Hardware security: UCL is a long standing leader in the analysis of physical security for cryptographic devices. Published works include theoretical tools and models for the fair evaluation of physical security as well as concrete analysis and proposals of countermeasures against side-channel and fault attacks.

• Microprocessor design and advanced computer architecture. The topics are in the scope of signal processing, embedded systems and general-purpose processors:

– RISC architectures: the basic high performance processor architecture is well studied, simulated and used as baseline architecture.

– Systolic and DSP architectures: such architectures were developed for high performances signal processing and reconfigurable applications. Several optimised applications were validated such as image compression or wavelet transforms.

– Superscalar processors: evolutions of this general-purpose architecture have been proposed. In particular, a further parallelism extraction by a multithreaded execution model has been developed and validated.

– Parallel architectures: researches are carried out on instruction-level parallel architectures such as EPIC (Explicit Parallel Instruction Computing) or VLIW architectures for intensive computation in embedded systems. Coarse grain parallelism and reprogrammable hardware by RISC ISA are also studied in the field of FPGA embedded applications.

## Representative References

- ▶ BOL D. et al., A 25MHz 7 $\mu$ W/MHz Ultra-Low-Voltage Microcontroller SoC in 65nm LP/GP CMOS for Low-Carbon Wireless Sensor Nodes), in IEEE Int. Solid-State Circuits Conf. (ISSCC), 2p., **2012**.

- ▶ KERCKHOF S., DURVAUX F., VEYRAT-CHARVILLON N., REGAZZONI F., MEURICE DE DORMALE G., STANDAERT F.-X., *Low Cost FPGA Implementations of the SHA-3 Finalists*, in the proceedings of CARDIS 2011, Lecture Notes in Computer Science, vol 7079, pp. 115-132, Leuven, Belgium, September **2011**, Springer.
- ▶ HOCQUET C., KAMEL D., REGAZZONI F., LEGAT J.-D., FLANDRE D., BOL D., STANDAERT F.-X., *Harvesting the potential of nano-CMOS for lightweight cryptography: An ultra-low-voltage 65 nm AES coprocessor for passive RFID tags*, accepted for Springer J. Cryptographic Engineering, vol. 1, No. 1, pp. 79-89, **2011**.
- ▶ BOL D., *Robust and energy-efficient ultra-low-voltage circuit design under timing constraints in 65/45nm CMOS (invited)*, in MDPI J. Low-Power Electronics and Applications, vol. 1, No. 1, pp. 1-19, **2011**.
- ▶ RENAULD M., STANDAERT F.-X., VEYRAT-CHARVILLON N., KAMEL D., FLANDRE D., *A Formal Study of Power Variability Issues and Side-Channel Attacks for Nanoscale Devices*, in the proceedings of Eurocrypt 2011, Lecture Notes in Computer Science, vol 6632, pp. 109-128, Tallinn, Estonia, May **2011**, Springer.
- ▶ STANDAERT F.-X., MALKIN T.G., YUNG M., *A Unified Framework for the Analysis of Side-Channel Key Recovery Attacks*, in the proceedings of Eurocrypt 2009, Lecture Notes in Computer Science, vol 5479, pp 443-461, Cologne, Germany, Springer, April **2009**.
- ▶ BOL D., AMBROISE R., FLANDRE D., LEGAT J.D., *Interests and Limitations of Technology Scaling for Subthreshold Logic*, IEEE TRANSACTIONS ON VERY LARGE SCALE INTEGRATION (VLSI) SYSTEMS, 17 (10): 1508-1519, **2009**.
- ▶ LEVACQ D., DESSARD V., FLANDRE D., *Low leakage SOICMOS static memory cell with ultra-low power diode*, IEEE Journal Of Solid-State Circuits, 42 (3): 689-702, **2007**.

## Patents

- ▶ *Low Swing Current Mode Logic Style*. Provisional US patent application n° 60/571,383 filed on 14th May 2004.
- ▶ *Ultra Low Power Analog Basic Blocks*. International PCT/EP01/15023 filed on 17/12/2001.
- ▶ *ULP basic blocks and their uses*. "Continuation in Part" filed in USA on June 23rd 2003 under reference no. 10/602,016.
- ▶ *Ultra-low-power circuit*, dépôt européen 30.04.2007, Pub. No.: US 2009/0273356 A1 (43), Nov. 5, 2009.

## Partnerships

- ▶ EUROSOI: SOI technology, EU Network, FP6 (CISSOID, Philips, VTT, SOITEC...).
- ▶ RECOPS: Euclid Eurofinder consortium investigating reconfigurable architectures.
- ▶ CEA-Leti, ST Micro, INGP, ISEP, ENST, Dolphin Integration, France.
- ▶ nSilitation, IMEC, Belgium.
- ▶ CSEM, Switzerland.

## Products and Services

- ▶ Digital or mixed-signals ASIC design
- ▶ Real-time systems
- ▶ FPGA Development
- ▶ Rapid prototyping
- ▶ Dedicated parallel architectures

## Main Equipment

- ▶ Latest FPGA boards from Xilinx and Altera.
- ▶ Software tools: Eldo, Modelsim, SimpleScalar, SystemC (Simulation); ISE, Symplify Pro, Synopsys and Encounter (Synthesis); Cadence and Synopsys work suite (Design); EDK (Embedded).

## KEYWORDS

Computer architecture  
 Digital circuits  
 Digital systems  
 FPGA  
 DSP  
 Low-power  
 Parallel architecture  
 System-on-chip

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# Wireless autonomous smart sensor networks

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## Research Field and Subjects

A new domain fastly emerges from the general and continuous trend to incorporate ever more electronic functions in any system, from cars, planes or buildings to biomedical or consumer products. This new domain is more loosely defined by the inclusive association of such often-heard catchphrases as “pervasive/ubiquitous computing”, “things that think”, “ambient intelligence”, “internet of things”... It is then best characterized by a stronger and richer coupling between the physical world and the information/communication world. This trend will be characterized by the deployment of a wide diversity of networks of autonomous microsystems, combining miniaturised sensors of electrical, physical, mechanical, chemical or biological data, with signal processing and wireless communication. Considering the immense application reservoir, sensor networks are under considerable interest and expansion in the R&D and industrial communities.

The main challenge in this R&D orientation is not so much the individual device in itself, for which extreme performances are generally not required, except for the ultra-low electrical power consumption, but it much more lies in the full system miniaturisation, from energy sources to antennas. The new research directions therefore evolve from pure MOS transistor scaling to the incorporation of new functions (sensors, MEMS, energy scavengers...) on the silicon chips, in addition to the CMOS circuitry, embedded software, communication, antennas, channel modelling and security issues. With these regards to new materials, Silicon-on-insulator (SOI) technology has already demonstrated promising compatibility and performance properties for the co-integration of such new functions with high-quality MOS circuits, at the wafer level. The SOI substrates indeed intrinsically allow one to combine all its well-known circuit advantages, of huge interest for the targeted applications (i.e. micropower consumption, harsh temperature or radiation environment resistance, RF operation...), with high-performance sensors and MEMS free of the parasitics due to the bulk Si substrate or to off-chip connections.

The UCL group dedicated to foster “innovation in wireless sensors networks” gathers many researchers in Electrical Engineering

(i.e. Microelectronics, Telecommunications and Microwaves) of the Institute ICTEAM (Information Communication Technologies, Electronics and Applied Mathematics).

## Representative References

- ▶ LIU L., KESHMIRI F., CRAEYE C., DE DONCKER P. and OESTGES C., An analytical modeling of polarized time-variant on-body propagation channels with dynamic body scattering, *EURASIP Journal on Wireless Communications and Networking (special issue: Towards the Connected Body: Advances in Body Communications)*, 12 p., March **2011**.
- ▶ HOCQUET C., KAMELD., REGAZZONIF., LEGAT J.-D., FLANDRE D., BOL D. and STANDAERT F.-X., “Harvesting the potential of nano-CMOS for lightweight cryptography: An ultra-low-voltage 65 nm AES coprocessor for passive RFID tags”, *Springer J. Cryptographic Engineering*, vol. 1, no. 1, pp. 79-89, **2011**.
- ▶ ANDRÉ N., DRUART S., GÉRARD P., PAMPIN R., MORENO-HAGELSIEB L., KEZAI T., FRANCIS L.A., FLANDRE D., RASKIN J.-P., “Miniaturized wireless sensing system for real-time breath activity recording”, *IEEE Sensors Journal*, 10 (1), pp. 178-184, **2010**.
- ▶ MALLAT A., GERARD P., DROUGUET M., KESHMIRI F., OESTGES C., CRAEYE C., FLANDRE D., VANDENDORPE L., “Testbed for IR-UWB based ranging and positioning: Experimental performance and comparison to CRLBs”, *Wireless Pervasive Computing (ISWPC)*, 5th IEEE International Symposium on; Modena, Italy, 5-7 May 2010, pp. 163–168, **2010**.
- ▶ BOULKENAFET H., KEZAI T., GÉRARD P., FLANDRE D., “Networking Strategies for Structural Health Monitoring with Autonomous sensors”, *Caneus Workshop (International Collaborative Aerospace Development of Micro Nanotechnologies: From Concepts to Systems, NASA Ames Research Center, California, USA)*, 1-6 March **2009**.

## Patents

“Network Architecture For Wirelessly Interfacing Sensors At Ultra Low Power”, Pub. No.: WO/2009/092771, International Application No.: PCT/EP2009/050734, Publication Date: 30.07.2009, International Filing Date: 22.01.2009



## Partnership

- ▶ IEMN, Lille, France.
- ▶ IMEC, Leuven, Belgium.
- ▶ CEA-LETI, France
- ▶ CETIC, Belgium
- ▶ EADS, France and Germany

▶ Partners in EU Networks of Excellence, FP6, FP7 and “Guardian Angels” Flagship projects, as well as projects from Wallonie (the so-called Pôles de compétitivité...).

## Products and Services

Design, simulation, fabrication and characterisation of integrated sensors, MEMS/NEMS, electronic circuits and communication systems.

## Main Equipments

- ▶ Unique research- and service-oriented infrastructures in Wallonie:
  - WINFAB clean rooms (1000 m<sup>2</sup>) with all key micro-nano-fabrication technologies.
  - WELCOME for electrical and communication measurements.
- ▶ Simulation and programming platforms (ADS, FPGA, DSP, Cadence, Mentor...)

## KEYWORDS

Communication  
Electromagnetics  
MEMS/NEMS  
Sensors  
Micro-nano-electronics  
Networks  
Security

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# Green electronics: SOI technology and ultra-low-power design

## SENIOR SCIENTISTS:

- ▶ David BOL
- ▶ Denis FLANDRE
- ▶ Jean-Didier LEGAT

## Research Field and Subjects

The reduction of our energy consumption is a global challenge, which has to be dealt with by all industry sectors in a common effort. In the sector of electronics and integrated circuits (ICs), the green electronics trend features two aspects: greening THE electronics and greening BY electronics. The microelectronics laboratory of UCL has been carrying out key research activities in both fields.

### Greening THE electronics

The research focuses on lowering energy consumption of electronic devices through:

- Development of Silicon-on-Insulator (SOI) technology;
- SOI circuit design: featuring best-in-class patented circuit blocks to achieve smart power management. Those blocks allow drastic reduction of stand-by power consumption, which is due to leakage current in nanoscale CMOS processes.

### Greening BY electronics

The team has a strong expertise with breakthrough patents in ultra-low-power design of both analogue and digital functions towards energy-autonomous systems. The design aims at minimising both active energy and stand-by power, targeting all level of abstractions from technology development and circuit design to system integration. These energy-autonomous systems can then be used either to efficiently manage our energy consumption (building heating or cooling, electricity production and delivery, transportation) or to improve healthcare and human security.

## Representative References

- ▶ BOL D., DE VOS J., HOCQUET C., BOTMAN F., DURVAUX F., BOYD S., FLANDRE D. and LEGAT J.-D., "A 25MHz Sub-1mm<sup>2</sup> 7μW/MHz Ultra-Low-Voltage Microcontroller SoC in 65nm LP/GP CMOS for Low-Carbon Wireless Sensor Nodes", *IEEE Int. Solid-State Circuits Conf.*, Vol. 55 (1), pp. 490-491, 2p., **2012**.
- ▶ BOL D., "Robust and energy-efficient ultra-low-voltage circuit design under timing constraints in 65/45nm CMOS" (invited), in *MDPI J. Low-Power Electronics and Applications*, vol. 1, no. 1, pp. 1-19, **2011**.

- ▶ BOL D., BOYD S. and DORNFELD D., "Application-aware LCA of semiconductors: life-cycle energy of microprocessors from high-Performance 32nm CPU to ultra-low-power 130nm MCU", In *Proc. IEEE International Symposium on Sustainable Systems and Technologies*, 6p., **2011**.
- ▶ GOSSET G., BOL D., POLLISSARD-QUATREMÈRE G., RUE B. and FLANDRE D., "Disruptive ultra-low-power SOI CMOS circuits towards μW medical sensor implants", in *Proc. IEEE International SOI Conference*, 2p., **2010**.
- ▶ BOL D., FLANDRE D. and LEGAT J.-D., "Nanometer MOSFET effects on the minimum-energy point of sub-45nm subthreshold logic—Mitigation at technology and circuit levels", in *ACM Trans. Design Automation of Electronic Syst.*, vol. 16, no. 1, pp. 2-26, **2010**.
- ▶ BOL D., AMBROISE R., FLANDRE D. and LEGAT J.D., *Interests and limitations of technology scaling for subthreshold logic*. *IEEE Trans. VLSI Systems* 17 (10), 1508-1519, **2009**.
- ▶ BOL D., DE VOS J., FLANDRE D. and LEGAT J.D., *Ultra-low-power high-noise-margin logic with undoped FD SOI devices*. *IEEE Int. SOI Conf.*, **2009**.
- ▶ BOL D., DE VOS J., FLANDRE D. and LEGAT J.D., *Building ultra-low-power high-temperature digital circuits in standard high-performance SOI technology*. *Solid-State Electronics* 52 (12), 1939-1945, **2008**.
- ▶ GOSSET G., RUE B. and FLANDRE D., *Very high efficiency 13.56 MHz RFID input stage voltage multipliers based on ultra-low power MOS diodes*. *IEEE Int. Conf. RFID*, 134-140, **2008**.
- ▶ LEVACQ D., DESSARD V. and FLANDRE D., *Low leakage SOI CMOS static memory cell with ultra-low power diode*. *IEEE J. Solid-State Circuits* 42 (3), 689-702, **2007**.

## Patents

- ▶ Ultra-low power basic blocks and their uses, PCT/EP01/15023, European patent, 17/12/2001.
- ▶ Ultra-low power basic blocks and their uses, US2004/0026760, US patent, 12/02/2004.
- ▶ Ultra-low-power circuit, EP2008/055239, European patent PCT, 29/04/2008.
- ▶ Network architecture for wirelessly interfacing sensors at ultra low power, EP2009/050734, European patent PCT, 22/01/2009.

## Awards

- ▶ Best paper award from the IEEE Int. Conf. Computer Design 2008 to D. BOL et al. for *Analysis and minimization of practical energy in 45nm subthreshold logic circuits*.
- ▶ Best poster award from the IEEE Int. SOI Conf. 2008 to D. BOL et al. for *Sub-45nm fully-depleted SOI CMOS subthreshold logic for ultra-low-power applications*.

## Funding

- ▶ Wallonie
- ▶ EU
- ▶ F.R.S.-FNRS

## Partnerships

- ▶ Collaboration with major international industrial (e.g. IBM, TSMC, AMD, ST-M) and academic actors in SOI technologies and circuits, through the SOI consortium (SOI Simply Greener initiative)
- ▶ Participation to European strategic consortia (AENEAS/ENIAC, SINANO/NANOSIL) defining research directions in nanoelectronics
- ▶ Partnership within research projects with European R&D companies in nanoelectronics

## Main Equipment

- ▶ 1000 m<sup>2</sup> clean room facilities (WINFAB) with major CMOS/MEMS processing equipments
- ▶ Mainstream EDA tools and design kits from major external CMOS foundries
- ▶ 400 m<sup>2</sup> characterisation and test facilities (WELCOME) for nanoelectronics components from devices to systems

## Products and Services

- ▶ SOI CMOS and MEMS processing
- ▶ Characterisation of nanoelectronics devices
- ▶ Ultra-low-power circuit design expertise
- ▶ Launch of various spin-off companies

## KEYWORDS

Micro-nano-electronics  
Integrated circuits  
Ultra-low power  
Energy consumption  
Circuit design  
CMOS process  
Power management  
Sensors

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# Software based hardening against radiation

## SENIOR SCIENTIST:

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## Research Field and Subjects

Radiations induce transient errors in electronic systems such as computers. Protecting computers against radiation effects is very important in satellites, launchers and other spacecrafts. With the increasing miniaturisation of computer components, protection against radiations is becoming critical also in airplanes and increasingly on the ground too.

The traditional approach to radiation hardening is hardware hardening by using less sensitive technologies, redundant circuits and so on.

This approach is too expensive for many applications.

A few other researchers are working on software hardening by detecting and correcting some errors in software. They usually work by program transformation.

The chosen approach is to consider transient errors as "normal" events, and to design software in such a way that these errors do not produce any effect. To achieve this, a few simple hardware hardened circuits are needed and the software must be designed according to some very strict rules, as a sequence of atomic operations that are either performed entirely and without error or restarted. In this approach, all kinds of malfunctions are taken into account, from computational errors to processors running mad.

This approach is possible because these radiation-induced transient faults are rare at the time rate of modern processors, so that only single errors must be considered during the processing of one atomic operation.

Simulation and a proof of concept hardware system, in which all thinkable kinds of errors were injected, showed the soundness of the approach. The systems performed their job flawlessly in spite of the transient errors that were injected.

The limitation of the approach is that it is only applicable to specifically designed programs.

## Representative References

► LESAGE L., MEJIAS B., LOBELLE M., A software based approach to eliminate all SEU effects from mission critical programs, G-2 RADECS 2011 Sevilla Septembre 19/23 2011.

## Funding

► Wallonie, Skywin « Marshall Plan » program, Telecom and S@T projects.  
 ► European Space Agency

## Partnership

► Thales-Alenia-Space-ETCA  
 ► Tima laboratory, Grenoble Institute of Technology

## KEYWORDS

Fault tolerance  
 Checkpoint-restart  
 High availability  
 Design concept  
 Software architecture  
 Embedded systems

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# Classification, analysis and clustering of graphs and networks

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- ▶ Julien HENDRICKX
- ▶ Raphaël JUNGERS
- ▶ Yurii NESTEROV
- ▶ Paul VAN DOOREN

## Research Field and Subjects

This research focuses on some of the most recent and fundamental computational challenges occurring in large networks. It concentrates on questions related to the classification, visualisation, and stochastic analysis of large networks. Theoretical and practical aspects of topics such as data-mining of text documents, web-searching, analysis of telephone, traffic and electricity networks, hierarchical reduction of large scale networks, and analysis of dynamical properties of large networks, are being studied.

Large networks are everywhere: telephone networks, the world-wide web, databases such as electronic dictionaries, power distribution networks, micro electro-mechanical systems, are all large networks with sometimes up to billions of nodes. Other examples include biological, social and financial networks, networks in the brain, transportation, gas and electricity networks, etc.

The computing power and storage capacity have increased so much in the last few decades that, today, they allow one to store and process such vast networks. It is now possible to cluster large networks by their connection pattern, to evaluate the fragility of a network when faced to an external event, to identify more relevant nodes, to verify connectivity patterns, to evaluate how fast a disease spreads in a population by human contact, or a virus on a computer network, etc. Simulation, optimisation, classification, information retrieval and representation of networks of up to millions of edges or nodes have all recently become possible.

Several algorithms have been developed. They have essentially a linear complexity, are quite efficient for large sparse graphs and scale well with the dimension of the graph. These algorithms approximate the solution of a variety of problems related to the classification, analysis and clustering of graphs and networks.

## Representative References

- ▶ DELVENNE J.-C., YALIRAKI S., BARAHONA M., Stability of Graph Communities Across Time Scales, Proceedings of the National Academy of Sciences of the United States of America, vol.107, pp.12755-12760, **2010**.

- ▶ DE KERCHOVE C., VAN DOOREN P., Iterative Filtering in Reputation Systems, SIAM Journal of Matrix Analysis and its Applications, vol.31(4), pp.1812-1834, **2010**.
- ▶ JUNGERS R., The Joint Spectral Radius: Theory and Applications, Springer-Verlag, Lecture Notes in Control and Information Sciences, **2009**.
- ▶ BLONDEL V., NESTEROV Yu., Polynomial-time computation of the joint spectral radius for some sets of nonnegative matrices. SIAM J. Matrix Anal. Appl., Vol. 31(3), 865-876, **2009**.
- ▶ ABSIL P.-A., MAHONY R., SEPULCHRE R., Optimization Algorithms on Matrix Manifolds. Princeton University Press, **2008**.
- ▶ FRAIKIN C., NESTEROV Yu. and VAN DOOREN P., Optimizing the coupling between two isometric projections of matrices. SIAM Journal Matrix Anal. Appl., 30(1):324-345, **2008**.
- ▶ HENDRICKX J., FIDAN B., YU C., ANDERSON B.D.O., BLONDEL V., Formation Reorganization by Primitive Operations on Directed Graphs, IEEE Transactions on Automatic Control, 53(4):968-97, **2008**.
- ▶ YU C., HENDRICKX J. M., FIDAN B., ANDERSON B.D.O., BLONDEL V.D., Three and higher dimensional autonomous formations: rigidity, persistence and structural persistence. Automatica, 43(3):387-402, **2007**.

## Awards

- ▶ SIAM George Dantzig Prize, 2000
- ▶ SIAM Control and System Theory Prize, 2001
- ▶ IEEE Antonio Ruberti Prize 2005
- ▶ IEEE Fellow 2006, SIAM Fellow 2009

## Partnership

- ▶ Belgian Interuniversity Attraction Poles (PAI) on Dynamical Systems, Control and Optimization
- ▶ UCL Concerted Research Action (ARC) on Information Retrieval in Time Evolving Networks
- ▶ European FP7 program EULER (Experimental UpdateLess Evolutive Routing)

**KEYWORDS**

Clustering  
Convex optimisation  
Data mining  
Information retrieval  
Large-scale graphs  
Networks

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# Graphs and network algorithms for mobile telecommunication

## SENIOR SCIENTISTS:

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- ▶ Paul VAN DOOREN

## Research Field and Subjects

Mobile telephone companies often have millions of customers that are connected to each other through their calls. These large networks are difficult to handle, optimise or even draw. Such tasks become much easier if one possesses a hierarchical or reduced-size representation of the network which describes well the influence of the smaller scale behaviour.

How can such a simpler representation be found and how can the network size be reduced while still keeping some key features of the network? Several basic properties of a moderate size network are easy to analyse or can sometimes be recognised by mere visual inspection. This is very difficult for networks of millions of vertices.

In hierarchical representation, one tries to represent the network in a more compact form by identifying substructures which can be used to analyse properties of the system or to represent it in a more compact form. A simple example of this is a large network of computer connections that contains local area networks as lower level substructures. One could also associate substructures with circles of friends in a social network such as groups of people that often call each other during a particular period of time. Identifying such substructures are combinatorial complexity problems that have to be solved using heuristics that exploit all the network properties at hand.

Another important problem is that of identifying leaders in social networks. They can be thought of as those people that will propagate the acquisition of a particular feature or contract related to mobile telephone communications. This is very similar to ranking web-pages in Google, finding authorities in a hyperlinked environment, retrieving information from a database, or identifying synonyms in a dictionary. We have developed a general framework to identify similar nodes in two arbitrary graphs. We are using this framework in order to find leaders in the graph of telephone calls using mobile telecommunication. Algorithms computing such leaders have a linear complexity and use modifications of the power method, which is quite efficient for large sparse graphs and scales well with the dimension of the graph.

## Products and Services

Service provided to several telephone companies for network analysis

## Representative References

- ▶ BLONDEL V., KRINGS, THOMAS I., Regions and borders of mobile telephony in Belgium and in the Brussels Metropolitan zone, *Brussels Studies*, vol. 42, **2010**.
- ▶ BLONDEL V. D., GUILLAUME J.-L., LAMBIOTTE R., LEFEBVRE E., Fast unfolding of communities in large networks, *Journal Statistical Mechanics: Theory and Experiment*, **2008**.
- ▶ HO N.-D., VAN DOOREN P., BLONDEL V.D., Descent methods for nonnegative matrix factorization. in *Numerical Linear Algebra in Signals, Systems and Control*, Lecture Notes in Engineering, Springer Verlag, **2008**.
- ▶ DE KERCHOVE C., NINOVE L., VAN DOOREN P., Influence of the outlinks of a page on its PageRank, *Linear Algebra and its Applications*, vol. 429, P. 5-6, pp.1254-1276, **2008**.
- ▶ BLONDEL V., GUILLAUME J.-L., HENDRICKX J., DE KERCHOVE C., LAMBIOTTE R., Local leaders in random networks, *Physical Review E*, vol. 77, P. 036114, **2008**.
- ▶ LAMBIOTTE R., BLONDEL V., DE KERCHOVE C., HUENS E., PRIEUR C., SMOREDA Z., VAN DOOREN P., Geographical dispersal of mobile communication networks, *Physica A: Statistical Mechanics and its Applications*, No. 387, pp. 5317-5325, **2008**.

## Awards

- ▶ SIAM Control and System Theory Prize, 2001
- ▶ IEEE Antonio Ruberti Prize 2005
- ▶ IEEE Fellow 2006, SIAM Fellow 2009



## **Partnership**

- ▶ UCL Concerted Research Action (ARC) on Information Retrieval in Time Evolving Networks
- ▶ European FP7 program EULER (Experimental UpdateLess Evolutive Routing)
- ▶ MIT Medialab

## **KEYWORDS**

Circle of friends  
Data mining  
Large-scale graphs  
Mobile telephone communication  
Networks  
Social networks

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# Space and time in large-scale social networks

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## Research Field and Subjects

Traditional methods of social science, such as typically small-scale questionnaire-based approaches, increasingly get replaced by automated methods of data collection, which allow for completely different scales of analysis. This change of paradigm is driven by the emergence of pervasive technologies filling databases with information about our day-to-day life, in particular information about our friendship relations (e.g. Facebook) and physical location (e.g. Foursquare). The combination of these two factors offers a groundbreaking opportunity to understand and exploit the spatial properties of the social networks arising among online users, but also a potential window on real human socio-spatial and temporal behavior.

The size and complex nature of the data require the development of new algorithms in order to help users to navigate and find relevant information in large-scale networks. The design of efficient algorithms relies on the identification of regularities and patterns in the observed systems, and on the development of mathematical models for the flows (of ideas, people, information, etc.) that take place on the network. Our current area of interest is the development of algorithms for spatially-embedded and temporal networks, and the uncovering of simple mechanisms explaining observations made in empirical systems, for instance:

- Mobile phone networks in order to explore how homophily and geography affect the network architecture.
- Online Location-based Social Networks in order to investigate the interplay between physical space and social network topology.
- Large-scale online games, in order to explore the multi-dimensional nature of social interactions and, in particular, the organisation and dynamics of conflict.
- Facebook as a window to observe the psychological profile of online users and to identify which personality traits predict online popularity and migration.

## Representative References

- ▶ QUERCIA D., LAMBIOTTE R., KOSINSKI M., STILLWELL D. and CROWCROFT J., The Personality of Popular Facebook Users. Proceedings of the ACM Conference on Computer Supported Cooperative Work, **2012**.
- ▶ SCELLATO S., LAMBIOTTE R., MASCOLO C. and NOULAS A., Socio-spatial Properties of Online Location-based Social Networks. Proceedings of the International AAAI Conference on Weblogs and Social Media, **2011**.
- ▶ NOULAS A., SCELLATO S., LAMBIOTTE R., PONTIL M. and MASCOLO C., A tale of many cities: universal patterns in human urban mobility. arxiv:1108.5355, **2011**.
- ▶ EXPERT P., EVANS T.S., BLONDEL V.D. and LAMBIOTTE R., Uncovering space-independent communities in spatial networks. PNAS 108, 7663-7668, **2011**.
- ▶ SZELL M., LAMBIOTTE R. and THURNER S., Trade, Conflict and Sentiments: Multi-relational Organization of Large-scale Social Networks. PNAS 107, 13636-13641, **2010**.
- ▶ LAMBIOTTE R., BLONDEL V.D., DE KERCHOVE C., HUENS E., PRIEUR C., SMOREDA Z. and VAN DOOREN P., A gravity model for the geographical dispersal of mobile communication networks. Physica A 387, 5317-5325, **2008**.
- ▶ BLONDEL V.D., GUILLAUME J.-L., LAMBIOTTE R. and LEFEBVRE E., Fast unfolding of communities in large networks. J. Stat. Mech., P10008, **2008**.

## Partnership

- ▶ Research group on large graphs and networks, Université catholique de Louvain, Belgium
- ▶ Computer Lab, University of Cambridge, UK
- ▶ Research group on Complexity and Networks, Imperial College London, UK
- ▶ IceLab, Umeå University, Sweden
- ▶ BECS, Aalto University, Finland

**KEYWORDS**

Large-scale Networks  
Mobility  
Social networks  
Space and time

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# Multi-modal freight transport network modelling

## SENIOR SCIENTISTS:

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## Research Field and Subjects

Most transports are analysing networks from a “link” point of view rather than from a “node” point of view. Even if some of them deal to some extent with the different operations performed at the nodes, i.e. loading /unloading, transshipment or simple transit, their output still targets mainly transport flows on the networks.

The NODUS software package, which implements the “virtual network” methodology developed at UCL Mons, aims at filling that need: it is a G.I.S. based software designed for analysing multi-modal, multi-means and inter-modal freight transportation with all their interface operations. It is written in Java and is completely open and flexible through the embedded scripting language. Moreover, it implements a detailed analytical structure that allows an easy set-up of all kinds of parameters.

NODUS has been mainly used for analysing minimum cost solutions to transportation flows over extensive international networks. Actually, the initial motivation was to develop a tool for evaluating the economic impacts of new transport infrastructures and policies, as cost savings constitute an important element. The software can also estimate various direct impacts which can be linked to transport operations, like energy consumption, labour cost or external costs of pollution and congestion.

During the recent years, it has also been used to determine the optimal locations for inter-modal container terminals or to estimate the impact of climate change on waterborne transport on the Rhine river.

The latest refinements of the “virtual networks” methodology makes it possible to explicitly take railway services (lines, frequencies and stops) in the multi-modal networks.

## Representative References

- ▶ JONKEREN O., JOURQUIN B. and RIETVELD P., Modal-split effects of climate change: The effect of low water levels on the competitive position of inland waterway transport in the river Rhine area, *Transportation Research A*, doi: 10.1016/j.tra.2009.01.004, **2009**.
- ▶ LIMBOURG S. and JOURQUIN B., Optimal rail-road container terminal locations on the European network, *Transportation Research E*, vol. 45, pp 551-563, **2009**.
- ▶ MACHARIS C., PEKIN E., CARIS A. and JOURQUIN B., A decision support system for intermodal transport policy, 154 pages, VUBPress, **2008**.
- ▶ JOURQUIN B. and LIMBOURG S., Equilibrium Traffic Assignment on Large Virtual Networks, Implementation issues and limits for Multi-Modal Freight Transport, *European Journal of Transport and Infrastructure Research*, vol. 6, n° 3, pp. 205-228, **2006**.

## Patents

Nodus is a trademark of ASBL Facultés Universitaires Catholiques de Mons (now UCL Mons) under the registration number 0787446

## Funding

- ▶ Belspo
- ▶ Wallonie
- ▶ EC Framework programs

## Products and Services

- ▶ Nodus software package
- ▶ Digitised maps

**KEYWORDS**

Transport networks  
Assignment  
GIS  
Multi-modal

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# Sparse Signal Reconstructions for Optical Imaging

## SENIOR SCIENTISTS:

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- ▶ Laurent JACQUES
- ▶ Christophe DE VLEESCHOUWER
- ▶ Alain CORNET
- ▶ Benoît MACQ

## Research Field and Subjects

These last ten years, a real revolution has occurred in the way optical sensors are designed. The advent of increased computing capabilities, together with recent numerical developments in the field of image processing, sparse signal representations and convex optimisation, have helped breaking the secular "Nyquist" sampling prescription as well as some physical limitations. "Observing" is not anymore synonym of rendering directly a human readable image. More efficient imaging systems are now possible by deeply integrating sensor design and image reconstruction algorithms for processing the raw sensor data. Following this principle, two UCL teams have merged their expertise in order to develop innovative optical systems. The advantages of this collaboration are twofold. First, existing optical instruments stimulate the development of new reconstruction algorithms in order to improve their performance. Second, new optical instruments are designed following the capabilities of the processing algorithms.

The first research team is expert in the development of non-destructive optical characterisation methods that take advantage of the capability of light to interfere with itself.

The second research team develops image processing and reconstruction algorithms for inverse problem solving. Similarly to the recent field of "Compressed Sensing", these techniques are stabilized by assuming "sparse" image models where a few fundamental basis elements (e.g., wavelets) approximate these objects.

As a first achievement of their work, these two research teams have successfully applied their developments to Optical Deflectometry for the accurate imaging of transparent materials, like bundles of optical fibres or multifocal intraocular lens. Their framework finds future extensions in various fields, such as fast X-Ray imaging, Confocal Microscopy in biology and hyperspectral imaging.

## Representative References

- ▶ JACQUES L., GONZALEZ A., FOUMOUO E. and ANTOINE P., "Refractive index map reconstruction in optical deflectometry using total-variation regularization", in "Wavelets and Sparsity

XIV", SPIE Optical Engineering and Applications, San Diego, CA, USA, 21-25 August **2011**.

- ▶ GONZALEZ A., JACQUES L., FOUMOUO E. and ANTOINE P., "Primal-Dual TV Reconstruction in Refractive Deflectometry", SPARS11 Workshop (Edinburgh, Scotland, UK - June 27-30, **2011**).

- ▶ JACQUES L., HAMMOND D. K. and FADILI M. J., "Dequantizing Compressed Sensing: When Oversampling and Non-Gaussian Constraints Combine", IEEE Transactions on Information Theory, Vol. 57(1), pp. 559-571, **2011**.

- ▶ BEGHUIN D., DEWANDEL J.-L., JOANNES L., FOUMOUO E. and ANTOINE Ph., "Optical deflection tomography with phase-shifting Schlieren", Opt. Lett., 43 (22), 3745, **2010**.

- ▶ JACQUES L. and DE VLEESCHOUWER C., "A Geometrical Study of Matching Pursuit Parametrization", Signal Processing, IEEE Transactions on [see also Acoustics, Speech, and Signal Processing, IEEE Transactions on, Vol. 56(7), pp. 2835-2848], **2008**.

## Funding

- ▶ Wallonie, SPW WIST 3, DETROIT
- ▶ BELSPO Tournesol Grant, F.R.S.-FNRS research Funding

## Partnership

- ▶ Industrial collaboration with Lambda-X (Nivelles, Belgium)
- ▶ Université Aix-Marseille 2 / ESIL, CPPM France
- ▶ Swiss Federal Institute of Technology (EPFL), Switzerland.

## Main Equipment

- ▶ Optical instrumentation: Pulsed and Continuous Wave Lasers, Spectrometers, Fast Detectors and Cameras...

**KEYWORDS**

Signal analysis, synthesis, and processing  
Inverse problems  
Optics

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# Video signal analysis

## SENIOR SCIENTISTS:

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- ▶ Benoît MACQ

## Research Field and Subjects

The Image and Signal Processing (ISP) group of UCL has been conducting research in video analysis for more than 15 years in the context of surveillance applications ([www.acic.eu](http://www.acic.eu)), immersive human-computer interfaces ([www.alterface.com](http://www.alterface.com)), and autonomous production of personalised video event summaries ([www.keemotion.com](http://www.keemotion.com)). The group has been the coordinator of EDCINE FP6-2005-IST-41, proposal n°38454, related to enhanced digital cinema, and of IST-FP6 SIMILAR, a large Network of Excellence dealing with multimodal interfaces. More recently, the group did initiate and coordinate the European FP7 APIDIS as well as the WIST2 WALCOMO and WIST3 SPORTIC projects of Wallonie. The last two were dedicated to distributed and dynamic sensing for autonomous content production, and to the creation of content supporting interactive and personalised access, respectively. All the projects were positively received by the scientific and industrial community (e.g. see [www.apidis.org](http://www.apidis.org) for numerous publications and press releases). Furthermore, they appeared to be significant milestones towards the emergence of automatic content production products ([www.keemotion.com](http://www.keemotion.com)). Interestingly, the object detection and tracking technologies, but also the image reconstruction algorithms considered in surveillance and sport analysis contexts, are now being considered to be extended to the biological and medical domain, e.g. to track moving cells or to reconstruct panoramic views in cytoscopy.

## Representative References

- ▶ DESCAMPE A., DE VLEESCHOUWER C., VANDERGHEYNST P. and MACQ B., Scalable Feature Extraction for Coarse-to-Fine JPEG 2000 Image Classification, *IEEE Transactions on Image Processing*, Volume 20, Issue 9, pp. 2636 - 2649, Sept. **2011**.
- ▶ FAN CHEN, DELANNAY D., DE VLEESCHOUWER C. and PARISOT P., Multi-sensored vision for autonomous production of personalized video summary, in Book "Computer Vision for Multimedia Applications: Methods and Solutions" (Edited by Jinjun Wang, Jian Cheng, and Shuqiang Jiang), IGI Global, ISBN-10: 160960024X, September **2010**.

- ▶ FAN CHEN and DE VLEESCHOUWER C., Personalized Production of Basketball Videos from Multi-sensored Data under Limited Display Resolution, *Computer Vision and Image Understanding*, Special Issue on "Multi-camera and Multi-modal Sensor Fusion", 114, 6,667-680, **2010**.
- ▶ DE VLEESCHOUWER C., CAVALLARO A., FROSSARD P., XU L.-Q., TU P., *Multicamera Information Processing: Acquisition, Collaboration, Interpretation, and Production*. Editorial of special issue in *EURASIP Journal on Image and Video Processing*, p. 1-2. doi: 10.1155/2010/560927, November **2010**.
- ▶ DELANNAY D., DANHIER N. and DE VLEESCHOUWER C., Detection and Recognition of Sports(wo)men from Multiple Views, *Third ACM/IEEE International Conference on Distributed Smart Cameras*, Como, Italy, September **2009**.

## Patent

Systems and methods for the autonomous production of videos from multi-sensored data, GB PSP Patent Application GB0907870.0 (Priority date: 2009-05-07).

## Funding

- ▶ Europe: FP5, FP6, FP7 APIDIS and SV3D
- ▶ Wallonie: WIST2 WALCOMO, WIST3 SPORTIC
- ▶ Belgian NFS

## Partnership

- ▶ Academic: EPFL, QMUL, UPC, UPF.
- ▶ Industrial: Mediapro, Alcatel-Lucent, ACIC.
- ▶ Part of international consortia (FP7 projects)



## **Main Equipment**

- ▶ Distributed network of cameras
- ▶ Motorised PTZ cameras

## **Products and Services**

- ▶ [www.keemotion.com](http://www.keemotion.com)
- ▶ [www.alterface.com](http://www.alterface.com)
- ▶ [www.acic.eu](http://www.acic.eu)

## **KEYWORDS**

Segmentation  
Detection  
Tracking  
Graph-based clustering  
Particle filters  
Multitier processing  
PTZ control

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[www.apidis.org](http://www.apidis.org)  
[www.fp7-sv3d.com](http://www.fp7-sv3d.com)

# Stereo Image Compression

## SENIOR SCIENTISTS:

- ▶ Rony DARAZI
- ▶ Christophe DE VLEESCHOUWER
- ▶ Benoît MACQ

## Research Field and Subjects

Reproducing a natural and real scene as we see in the real world everyday is more and more popular. Stereoscopic and multi-view techniques are used to this end. However, the fact that more information is displayed requires supporting technologies such as digital compression to ensure the storage and transmission of the sequences. Exploiting the binocular dependency allows one to achieve higher compression ratios.

In this work, the researchers focus on designing a lossless-to-lossy transform that reduces the inter- and intra-image redundancy in the stereo pair. This is done within a predictive framework that can be extended to JPEG2000.

This approach is inspired by the Lifting Scheme (LS). Aiming to reduce the residual error, the team has first designed an optimised filter for inter prediction, i.e. a local spatial filtering is incorporated after disparity compensation. Second, a directional inter prediction is investigated. The predictor is adapted by exploiting local orientation information that denotes the optimal way of prediction for each pixel. Finally, a residual LS is proposed to fit with the particularities of the transformed residue tuned by the disparity map.

## Representative References

- ▶ KUMAR K.C. A., DARAZI R., MACQ B., Optimal optical flow based disparity map estimation for lossless stereo image coding. In Visual Information Processing and Communication II. in Proc. Electronic Imaging 2011, IS&T/SPIE **2011**.
- ▶ DARAZI R., GOUZE A., MACQ B., Adaptive Lifting Scheme-based method for joint coding 3D-stereo images with luminance correction and optimized prediction. In Acoustics, Speech and Signal Processing, ICASSP. IEEE International Conference on, 917-920, **2009**.

## Funding

- ▶ ARC-CRYPTOMARK - Wallonie
- ▶ BCRYPT - Belspo

## Partnership

- ▶ COSIC-KULeuven

## KEYWORDS

Stereo Image  
Wavelet transform  
Directional prediction  
Disparity map  
JPEG2000

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# Digital 2D, 3D and Stereo Image Watermarking

## SENIOR SCIENTISTS:

- ▶ Rony DARAZI
- ▶ Benoît MACQ

## Research Field and Subjects

The wide distribution of Digital Media is more and more suffering from the lack of content protection. Digital Watermarking is a widely proposed solution to identify and prove the ownership of digital data. It is mostly used to detect malicious tampering of a digital data and to track illegal copies of copyrighted material. Part of the research work is related to the design of a watermarking scheme for 2D, 3D stereo image, which can be integrated in the DCinema decoding pathway. The team has developed an adaptive exhibition watermarking method during the decoding phase. This method is QIM-based and is designed to fit in the JPEG2000 decoding pipeline. Based on the properties of the wavelets related to the human visual system, it defines a pixel-wise masking vector that will tune the watermarking scheme by taking into consideration a number of constraints. An extension of the 2D exhibition-watermarking scheme is applied to stereo images. A disparity guided watermarking technique with an improved perceptual mask is extended to fit with the particularities of stereo.

Another related topic is digital watermarking for 3D objects. Perceptual properties are not immensely studied in 3D watermarking. The research team defines a perceptual model based on the curvature and the roughness of the 3D mesh. This perceptual mask is used to modulate the watermarking method. Another work focuses on two state-of-the-art techniques which offer different and complementary advantages, namely the QIM-based 3D watermarking and the feature point-based watermarking synchronization. The idea is to combine these two techniques in such a way that the new watermarking scheme would benefit from their advantages and compensate for their respective fragilities. These researches show that robustness against cropping and other common attacks is achieved, provided that at least one feature point as well as its corresponding local neighbourhood is retrieved.

## Representative References

- ▶ DARAZI R., MONTANOLA M., WENG L., PRENEEL B., MACQ B., Disparity Guided Exhibition Watermarking for 3D Stereo Images. In Security and Privacy in e-Societies, SECES. ACM First International Workshop on, pages 1-8, **2011**.
- ▶ MONTANOLA M., DARAZI R., GIARD J., RONDAO P., MACQ B., Using feature point-based extraction for STDM 3D-mesh watermarking that withstands the cropping attack. In Media Forensics and Security IS&T/SPIE, in Proc. Electronic Imaging, **2011**.
- ▶ DARAZI R., HU R., MACQ B., Applying Spread Transform Dither Modulation for 3D-mesh watermarking by using perceptual models, Acoustics Speech and Signal Processing (ICASSP), IEEE International Conference on, pp.1742-1745, **2010**.
- ▶ DARAZI R., CALLAU P., MACQ B., Secure and HVS-adaptive exhibition Spread Transform Dither Modulation watermarking for Digital Cinema. In Information Forensics and Security, WIFS. First IEEE International Workshop on, 1-5, **2009**.

## Awards

Best paper award, 2nd price by the Digital Watermarking Alliance (DWA) and the IS&T/SPIE International Conference on Media Forensics and Security XII 2009.

## Funding

- ▶ ARC-CRYPTOMARK - Wallonie
- ▶ BCRYPT - Belspo
- ▶ TRACEA - Wallonie

**KEYWORDS**

Exhibition watermarking  
Blind  
3D mesh  
QIM  
Disparity map  
Stereo Image  
JPEG2000

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# Information Security

## SENIOR SCIENTIST:

▶ Gildas AVOINE

## Research Field and Subjects

Information security is mostly addressed by the Information Security Group (in French: Groupe Sécurité de l'Information - GSI) launched at the UCL in 2008. With background from computer science, electronics, and mathematics, the members of the GSI address many aspects of information security, including applied cryptography.

The competences and activities in terms of information security concern the following topics.

– **Security analysis of IT solutions:** the activities consist in analysing the *design* of IT solutions, especially the ones that are devoted to data confidentiality and user authentication (for example: ticketing applications, public transportation, data storage, medical applications, and anti-counterfeiting solutions). Advises and help can also be provided for the design of secure distributed architectures.

– **Security analysis of RFID solutions:** the UCL is world-wide known for its competences in the field of RFID security and privacy, including (but not limited to) authentication, user privacy, relay attacks, and pseudo-random generators. The UCL maintains the RFID Security and Privacy Lounge, a scientific portal created in 2004 that references more than 600 research papers in the domain and that counts 800 members registered to the mailing list: <http://www.avoine.net/rfid/>

– **Cryptanalytic time-memory trade-offs:** these techniques are essentially used to break the security of IT systems, for example to recover passwords and cryptographic keys. The GSI is able to adapt this technique to specific problems and pre-compute suited tables, including tables in various languages.

Beyond their academic activities, the researchers who belong to the information security group are also concerned by industrial needs and provide training, consulting, and auditing. They are also involved in industrial partnerships through research projects.

## Representative References

- ▶ AVOINE G., BINGOL M., KARDAS S., LAURADOUX C., MARTIN B., A Framework for Analyzing RFID Distance Bounding Protocols. *Journal of Computer Security - Special Issue on RFID System Security*, 19(2):289-317, **2011**.
- ▶ AVOINE G., KIM C.H., RFID Distance Bounding Protocols with Mixed Challenges. *Journal of IEEE Transactions on Wireless Communications*. 10(5):1618-1626, **2011**.
- ▶ AVOINE G., CARPENT X., MARTIN B., Strong Authentication and Strong Integrity (SASI) is not that Strong. In *Workshop on RFID Security - RFIDSec'10*, Turkey, **2010**.
- ▶ AVOINE G., JUNOD P., OECHSLIN Ph., Sécurité informatique - Cours et exercices corrigés, Seconde édition (304 pages). Vuibert, Paris, France, **2010**.
- ▶ AVOINE G., LAURADOUX C., MARTIN T., When compromised readers meet RFID. In *Workshop on RFID Security - RFIDSec'09*, Belgium, **2009**.
- ▶ AVOINE G., JUNOD P., OECHSLIN Ph., Characterization and improvement of time-memory trade-off based on perfect tables. *ACM Transactions on Information and System Security - TISSEC*, 11(4), **2008**.

## Awards

Apple Research & Technology Support (ARTS): Gildas AVOINE.

## Funding

F.R.S.-FNRS, Wallonie.

## Partnership

- ▶ INRIA Rhône-Alpes (France)
- ▶ EPFL (Switzerland)
- ▶ TÜBITAK UEKAE (Turkey)
- ▶ Rovira i Virgili University (Spain)
- ▶ ParisTech (France)

### **Products and Services**

- ▶ Consultancy in information security
- ▶ Privacy audit of IT solutions
- ▶ Design & analysis of access control systems
- ▶ Training on RFID security and privacy

### **KEYWORDS**

Security  
Cryptographic protocols  
Radio frequency identification (RFID)  
Contactless  
Proximity check  
Time-memory trade-off

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# Physical Security

## SENIOR SCIENTIST:

▶ François-Xavier STANDAERT

## Research Field and Subjects

When a security device runs, its physical behaviour may leak information regarding the operations being performed and the data being manipulated, including secret keys.

Physical attacks, or hardware attacks, aim at breaking a cryptographic device by taking advantage of this information. Physical attacks are typically divided in 3 categories, depending on whether they work by:

- observing the physical memory or data buses of the devices, e.g. using an electronic microscope (**probing attacks**);
- tampering with the device during execution in order to induce errors, in such a way that the erroneous output will leak information about the secret parameters (**fault induction attacks**);
- exploiting information related to the physical behaviour of the device, such as running time, power consumption, or emitted electromagnetic radiations (**side-channel attacks**).

Since their discovery in the 90's, physical attacks have been taken very seriously by the industry, as they may prove very practical in hampering the security of devices such as smart cards or security tokens. This topic has triggered a lot of research, both at the fundamental and applied level.

A recent related topic is the concept of **physically unclonable functions**, or **PUFs**. A PUF is a function embedded in a physical structure that consists of many random characteristics originating from uncontrollable process variations during manufacturing. PUFs are considered unclonable because it is extremely difficult to reproduce the random characteristics in another device. Among other applications, PUFs are a promising tool for secure key storage, whereby the key becomes an integral part of the device's structure: the device can reconstruct the key when needed by probing its physical structure, but this key cannot easily be read by an external observer.

The UCL Crypto Group has been a pioneer in the study of these fields since their first appearance in the literature. The Crypto Group has been involved in most relevant international projects in the field (e.g. European projects SCARD, G3CARD, INSPIRED, ECRYPT, ECRYPT II). Throughout the year, the group has acquired an internationally acknowledged expertise in these fields, with more than 50 publications in international journals and conferences.

## Representative References

- ▶ MEDWED M., STANDAERT F.-X., *Extractors Against Side-Channel Attacks: Weak or Strong?*, in the proceedings of CHES 2011, Lecture Notes in Computer Science, vol. 6917, pp. 256-272, Nara, Japan, September **2011**, Springer. - Extended version in the Journal of Cryptographic Engineering, vol. 1, num 3, pp. 231-241, Springer.
- ▶ ARMKNECHT F., MAES R., SADEGHI A.-R., STANDAERT F.-X., WACHSMANN C., *A Formalization of the Security Features of Physical Functions*, in the proceedings of the IEEE Symposium on Security and Privacy, pp 397-412, Oakland, California, USA, May **2011**.
- ▶ VEYRAT-CHARVILLON N., STANDAERT F.-X., *Generic Side-Channel Distinguishers: Improvements and Limitations*, in the proceedings of Crypto 2011, Lecture Notes in Computer Science, vol 6841, pp 354-372, Santa Barbara, California, USA, August **2011**, Springer.
- ▶ YU Y., STANDAERT F.-X., PEREIRA O. and YUNG M., *Practical leakage-resilient pseudorandom generators*, Proceedings of the 17th ACM conference on Computer and communications security, pages 141–151, ACM, October **2010**.
- ▶ STANDAERT F.-X., MALKIN T.G., YUNG M., *A Unified Framework for the Analysis of Side-Channel Key Recovery Attacks*, in the proceedings of Eurocrypt 2009, Lecture Notes in Computer Science, vol 5479, pp 443-461, Cologne, Germany, April **2009**, Springer.

## Awards

François-Xavier Standaert received the following awards:

- ▶ EDAA Outstanding dissertation award, 2004
- ▶ European Research Council (ERC) Starting Grant for project CRASH: development of concrete basements for the next generation of cryptographic algorithms and their implementation



## Funding

- ▶ Europe: TAMPRES, CRASH, B-CCENTRE
- ▶ Belgium: BCRYPT
- ▶ Wallonie: MIPSs, TRACEA, SCEPTIC, NANOTIC

## Partnership

- ▶ Member of the networks:
  1. ECRYPT II European Network of Excellence in Cryptology
  2. LSEC information security cluster
  3. MUSICS and GRASCOMP graduate schools
  4. Research Community “Veilige ICT”, Fonds Wetenschappelijk Onderzoek, Flanders
- ▶ Academia: Columbia University, INRIA, Massachusetts Institute of Technology, IAIK, ETH Zurich...
- ▶ Industry: Orange France Telecom R&D, ST Microelectronics, NXP, Thales...

## Main Equipment

In order to analyse the power consumption of enciphering devices, the group has built a test bench made of a large bandwidth oscilloscope Tektronix TDS7104, clock generators TaborElectronics WW1072 and Agilent 33250A and a customised board to plug the device in. The power supplies and clock can be finely controlled, and glitches can be inserted in those to check the chip fault-resistance. We also record its electro-magnetic radiations as an image of the local currents flowing in the silicium die, with near-field emission probes Rohde&Schwarz HZ15.

## Products and Services

- ▶ Introductory to advanced training in physical security
- ▶ Security evaluation and advice

## KEYWORDS

Cryptography  
Physical security  
Side-channel  
Cryptanalysis  
Physically unclonable functions  
PUF

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# Secure protocols

## SENIOR SCIENTIST:

▶ Olivier PEREIRA

## Research Field and Subjects

In numerous contexts, different entities need to communicate in order to realise a task jointly. This might be for accessing specific portions of a database, being granted access to some resources, negotiating a business arrangement, or running an election.

However, this communication needs to provide some security guarantees. These guarantees can relate to external parties (pirates, competitors...) or to communication participants (accountability, minimal disclosure, resilience to disasters...).

It is the purpose of cryptographic protocols to specify how such communications can be conducted in order to achieve the expected task while offering appropriate security guarantees.

The UCL Crypto group developed a thorough expertise in the precise modelling, design and analysis of cryptographic protocols. A precise model is needed to express the guarantees that we want a cryptographic protocol to offer. Cryptographic protocols can then be designed in such a way that the targeted task can be achieved while preserving the expected security properties and taking into account the operational requirements like efficiency and usability. Eventually, the UCL Crypto Group builds security proofs that allow one to identify the specific assumptions under which the designed cryptographic protocols offer the properties defined in the model.

## Representative References

- ▶ BERNHARD D., CORTIER V., PEREIRA O., SMYTH B. and WARINSCHI B., Adapting Helios for provable ballot privacy, In Vijay Atluri, Claudia Diaz, editor(s), Computer Security – ESORICS 2011, Lecture Notes in Computer Science, Springer, Sept. **2011**.
- ▶ PALMIERI P. and PEREIRA O., Secure Two-Party Computation Over a Z-Channel, In X. Boyen and X. Chen, editor(s), ProvSec 2011, Volume 6980 of Lecture Notes in Computer Science (LNCS), pages 3-15, Springer, October **2011**.

- ▶ DELAUNE S., KREMER S. and PEREIRA O., Simulation based security in the applied pi calculus, In R. Kannan and K. Kumar, editor(s), Foundations of Software Technology and Theoretical Computer Science – FSTTCS 2009, Leibniz International Proceedings in Informatics, December **2009**.
- ▶ GAJEK S., MANULIS M., PEREIRA O., SADEGHI A.-R. and SCHWENK J., Universally Composable Security Analysis of TLS, 2nd International Conference on Provable Security (ProvSec 2008), Volume 5324 of LNCS, pages 313-327, Springer, October **2008**.

## Awards

Best paper award: Workshop on Trustworthy Elections, Usenix, August 2009

## Funding

- ▶ Europe: B-CENTRE
- ▶ Belgium: BCRYPT
- ▶ Wallonie: CAMUS, SEE
- ▶ Fédération Wallonie-Bruxelles: ARC-SCOOP

## Partnership

- ▶ Member of the networks:
  1. ECRYPT II European Network of Excellence in Cryptology
  2. LSEC information security cluster
  3. MUSICS and GRASCOMP graduate schools
  4. Research Community "Veilige ICT", Fonds Wetenschappelijk Onderzoek, Flanders
- ▶ Academia: Columbia University, INRIA, Massachusetts Institute of Technology...
- ▶ Industry: Orange France Telecom R&D...

### **Products and Services**

- ▶ Secure protocol definition and specification
- ▶ Security evaluation and advice

### **KEYWORDS**

Security  
Protocols  
Cryptography

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# Optimisation: modelling and algorithms

## SENIOR SCIENTISTS:

- ▶ Pierre-Antoine ABSIL
- ▶ François GLINEUR
- ▶ Yurii NESTEROV
- ▶ Mathieu VAN VYVE

## Research Field and Subjects

An important objective of Operations Research consists in modelling real life-situations in order to identify the best decisions to be taken.

Optimisation plays a central role in this context. Indeed, possible decisions can often be represented by a set of numerical variables, possibly restricted by some constraints. The sought decisions are then found as those that minimise or maximise a given numerical criterion, function of the decision variables.

Optimisation modelling and algorithmic techniques can be applied in many different domains (management, engineering, economics) and to various types of problems (resource allocation, choice of design parameters, scheduling).

Efficiency of the computation of an optimal solution heavily depends on the type of problem that is to be solved (linear vs. nonlinear, continuous vs. discrete, stochastic vs. deterministic), its size and the algorithms used.

The research concentrates on two distinct areas. On the one hand, integer programming problems, which allow the use of discrete variables to model choices between a finite set of possible decisions, are notoriously difficult and call for very specific methods. On the other hand, the convex optimisation and the Riemannian optimisation are two specific classes of continuous nonlinear problems that admit much more efficient dedicated algorithms than general methods.

In each case, the focus is on solving larger and larger problems, thus allowing the modelling of more and more realistic situations with greater and greater detail.

Recent progress with this respect is impressive. For example, linear optimisation problems that might have taken a month to solve fifteen years ago are now routinely solved in a few seconds on a desktop machine. It has been estimated that a factor of roughly three orders of magnitude in this speedup is due to algorithmic improvements and development of new methods, while another factor of three orders of magnitude is due to the evolution of computer hardware.

## Representative References

- ▶ CONSTANTINO M., MILLER A.J. and VAN VYVE M., Mixing MIR Inequalities with Two Divisible Coefficients, *Mathematical Programming A*, Vol. 123, no. 2, pp. 451-483, **2010**.
- ▶ DEVOLDER O., GLINEUR F., NESTEROV Y., Solving Infinite-dimensional Optimization Problems by Polynomial Approximation, 2010, pp. 37-46 in: M. DIEHL, F. GLINEUR, E. JARLEBRING, W. MICHIELS (editors), *Recent Advances in Optimization and its Applications in Engineering*, Springer, 535 pp, **2010**.
- ▶ CHARES R., GLINEUR F., An interior-point method for the single-facility location problem with mixed norms using a conic formulation, *Mathematical Methods of Operations Research*, Vol. 68, pp.383-405, **2008**.
- ▶ ABSIL P.-A., MAHONY R., SEPULCHRE R., Optimization Algorithms on Matrix Manifolds, Princeton University Press, 240 pp, **2008**.
- ▶ ABSIL P.-A., BAKER C. G., GALLIVAN K. A., Trust-region methods on Riemannian manifolds, *Foundations of Computational Mathematics* 7(3), pp. 303-330, **2007**.
- ▶ NESTEROV Y., Smoothing Technique and its Applications in Semidefinite Optimization, *Mathematical Programming*, Vol. 110, no. 2, pp. 245-259, **2007**.
- ▶ VAN VYVE M., Algorithms for single-item lot-sizing problems with constant batch size, *Mathematics of Operations Research*, Vol. 32, no. 3, pp. 594-613, **2007**.

## Awards

John von Neumann Theory Prize 2009 (INFORMS society): Yurii NESTEROV

## Funding

- ▶ F.R.S.-FNRS
- ▶ Wallonie
- ▶ Fédération Wallonie Bruxelles (ARC)
- ▶ Belgian Interuniversity Attraction Poles (P6/04 DYSCO, P6/07)

## Partnership

- ▶ Institute for Multidisciplinary Research in Quantitative Modelling and Analysis (IMMAQ)
- ▶ Centre for Operations Research and Econometrics (CORE)
- ▶ Institute of Information and Communication Technologies, Electronics and Applied Mathematics (ICTEAM)

## Products and Services

Consultancy and collaboration with various industrial partners

## KEYWORDS

Optimisation  
Operations research  
Mathematical programming  
Convex optimisation  
Discrete optimisation  
Riemannian optimisation  
Mixed integer programming  
Production planning

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# Multi-agent systems

## SENIOR SCIENTISTS:

- ▶ Julien HENDRICKX
- ▶ Raphaël JUNGERS
- ▶ Jean-Charles DELVENNE

## Research Field and Subjects

Birds or planes flying in formation, sensors sharing measurements, robots seeking to establish a rendez-vous, simple processors collaborating for a complex computation. These are a few situations where a large number of agents communicate and evolve in order to achieve a global goal.

In the last decade, a large number of studies have been devoted to understand these complex mathematical problems and phenomena, among which:

- Emergence of collective behaviours,
- Communication strategies for rendez-vous problems,
- Detection and localisation of autonomous agents,
- Decentralised computation by autonomous processors,
- Decentralised stabilisation of interconnected systems.

The team provides their expertise in analysis, design, and optimisation of these complex systems. Their contribution goes from the mathematical modelisation toward software implementation, and customer support.

## Representative References

- ▶ HENDRICKX J.M., OLSHEVSKY A., TSITSIKLIS J.N., Distributed anonymous discrete function computation, *IEEE Transactions on Automatic Control*, 56:2276-2289, **2011**.
- ▶ JUNGERS R.M. and BLONDEL Vincent, Observable graphs. *Discrete Applied Mathematics*, 159: 981–989, **2011**.
- ▶ LANGBORT C. and DELVENNE J.-Ch., Distributed Design Methods for Linear Quadratic Control and Their Limitations. *IEEE Transactions on Automatic Control*, 55 (9), pp. 2085-2093, **2010**.
- ▶ DELVENNE J.-Ch., CARLI R. and ZAMPIERI S., Optimal strategies in the average consensus problem. *System and Control Letters*, 58 (10-11), pp. 759-765, **2009**.
- ▶ HENDRICKX J.M., ANDERSON B.D.O., DELVENNE J.-Ch. and BLONDEL V.D., Directed graphs for the analysis of rigidity and persistence in autonomous agents systems, *International journal of robust and nonlinear control*, 17:960-981, **2007**.

## Awards

- ▶ IBM Belgium award 2006, 2009
- ▶ EECI award 2008
- ▶ Alcatel-Lucent-Bell award 2008

## Funding

- ▶ PAI (Pôle d'attraction interuniversitaire) DYSCO
- ▶ F.R.S.-FNRS

## Partnership

- ▶ MIT
- ▶ KTH
- ▶ LIP6

## Products and Services

- ▶ Trainees
- ▶ Analysis and design of algorithmic solutions for multi-agents infrastructure
- ▶ Software implementation and long-term care

**KEYWORDS**

Autonomous agent localisation  
Consensus  
Distributed computing  
Large graph analysis and design

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# Modelling, analysis and control of distributed parameter systems

## SENIOR SCIENTIST:

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## Research Field and Subjects

The field of distributed parameter systems (DPS) is an established area of research in automatic control engineering and applied mathematics which traces its roots back to the sixties. The specific feature of DPS is their distributed nature: in order to adequately describe such systems one needs to use partial differential equation (PDE) models. The department of Mathematics of the University of Namur has developed a well recognized expertise in this field and in control and system theory at large. Specific topics of expertise include mathematical techniques of input-output dynamical system modelling, feedback system theory, Linear-Quadratic (LQ) optimal control and spectral factorisation. Modelling, analysis and design applications include the heat diffusion, the vibrating string and chemical and biochemical tubular reactors.

A central issue in process engineering is the analysis and design of control laws for systems that are modelled by nonlinear partial differential equations, and more particularly by convection-diffusion-reaction operators with boundary measurement and control. The goal is to design efficient tools in order to synthesise robust feedback control laws for applications in engineering. A specific topic of interest is the study of the LQ-optimal boundary control problem for the class of Sturm-Liouville systems, with a view to apply the results to convection-diffusion-reaction systems with mass action kinetics.

Invariant dynamical systems are dynamical systems for which every state trajectory that starts from a given physically admissible subset of the state space remains in this subset for all time. Since the whole state is usually unavailable from measurements, one typically uses feedback of the estimated state in order to control such systems (e.g. to stabilise them around some equilibria of interest). A fundamental problem is the analysis and the design of nonlinear state estimators for invariant semi-linear distributed parameter systems, and the development of numerical methods for the synthesis of such estimators.

## Representative References

- ▶ FAVACHE A., DOCHAIN D., WINKIN J., Power-shaping control: Writing the system dynamics into the Brayton-Moser form, *Systems & Control Letters*, vol. 60, 618-624, **2011**.
- ▶ BEAUTHIER Ch., WINKIN J., LQ-optimal control of positive linear systems, *Optimal Control Applications and Methods*, vol. 31, 547-566, **2010**.
- ▶ PRIEUR Ch., WINKIN J., BASTIN G., Robust boundary control of systems of conservation laws, *Mathematics of Control, Signals & Systems (MCSS)*, vol. 20, 173-197, **2008**.
- ▶ DRAMÉ A.K., DOCHAIN D., WINKIN J., Asymptotic behaviour and stability for solutions of a biochemical reactor distributed parameter model, *IEEE Transactions on Automatic Control*, Vol. 53, No. 1, 412-416, **2008**.
- ▶ AKSIKAS I., WINKIN J., DOCHAIN D., Optimal LQ-feedback regulation of a nonisothermal plug flow reactor model by spectral factorization, *IEEE Transactions on Automatic Control*, Vol. 52, No. 7, 1179-1193, **2007**.

## Partnership

- ▶ Département d'Ingénierie Mathématique, Institut ICTEAM, et CESAME, Université catholique de Louvain
- ▶ Faculté des Sciences, Université Chouaib Doukkali, El Jadida, et Ecole Supérieure de Technologie de Safi, Maroc
- ▶ Gipsa-lab, CNRS, Université Joseph Fourier, Grenoble, France
- ▶ Département de Contrôle, Faculté Polytechnique, Université de Mons
- ▶ Department of Chemical and Materials Engineering, University of Alberta, Canada
- ▶ Bergische Universität Wuppertal, Germany
- ▶ School of Mathematics, University of Leeds, UK
- ▶ Faculty of Mathematical Sciences, University of Twente, Netherlands



**KEYWORDS**

Automatic Control  
Dynamical systems  
Distributed parameter systems  
Feedback control  
State estimator  
Optimisation  
Process engineering

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# Process Modelling, Monitoring, Control and Real-Time Optimisation

## SENIOR SCIENTIST:

▶ Denis DOCHAIN

## Research Field and Subjects

### Research Field

The main area of expertise is related to the mathematical modelling of the dynamics of reaction systems, the analysis of the model properties, and the design and application of model-based monitoring, control and real-time optimisation tools. The notion of reaction systems covers a large class of dynamical systems where the matter transformation plays a central role, as in particular in chemical and biological systems. Applications fields cover more specifically the food, pharmaceutical, polymer, nanomaterials, metallurgical and pulp & paper industries, the environment (solid waste, wastewater and water treatment), but also plant growth.

The need for appropriate monitoring and control tools in order to optimise the on-line operation of environmental and ecological systems is obvious. Yet the development of such tools has to handle typically two key issues. The first one is related to the difficulty to model in a reliable way the complex dynamics, including those of the chemical/biological/microbial systems. The second difficulty lies in the absence of cheap and/or reliable on-line sensors for the key system variables. These issues are in the core of the expertise developed over the last 25 years.

Well accepted trends in the industry require plants that comply with safety and environmental requirements in a sustainable way. Besides, in the specific context of biological systems, issues like protection against contamination and coexistence of different micro-organisms are important issues in the biotechnology industry today. This implies on one hand the integrated use of environmental processes within the industrial plant, and on the other hand the development of appropriate techniques to handle coexistence or prevent contamination.

### Research Approach

The developed approaches are largely based on mass (and energy) balance models. One of the underlying ideas is to incorporate the knowledge about the process dynamics (e.g. basically, the reaction network and the material balances) as well as (microbial) ecology concepts in monitoring and control algorithms. Moreover, the latter are able to deal with process uncertainties (in particular on the reaction kinetics) by the introduction of an adaptation scheme. New research trends

involve the link between irreversible thermodynamics and system theory as a tool to design control strategies that are closer to the physics of the reaction systems.

### Developed research methods

The monitoring and control strategies are applied to stirred tank reactors (dynamics described by ordinary differential equations) as well as to processes whose dynamics are described by partial differential equations (e.g. plug flow reactors, fixed or fluidised bed reactors or settlers as well as population balance based models for processes with size-distributed particles or age-distributed cells). Besides, the complexity of the dynamics of the biological systems is also handled by considering possibly complex metabolic networks as well as microbial ecology to emphasise the interactions between the different, possibly competing, species. Monitoring is related in particular to the design of software sensors that are based on the available knowledge on the process dynamics and the limited number of process variables measured on-line in order to reconstruct on-line the values of the unmeasured key process variables. A special attention is also given to the design and implementation of real-time optimisation methods via adaptive extremum seeking control techniques that allow the process to reach a priori unknown optimal operating points, trajectories or profiles. Applications in this field also involve the biomedical field via an on-line optimisation strategy for drug delivery.

### Representative References

- ▶ RAPAPORT A. and DOCHAIN D., Minimal time control of fed-batch processes with growth functions having several maxima. *IEEE Transactions on Automatic Control*, to appear, **2011**.
- ▶ FAVACHE A. and DOCHAIN D., Power-shaping of reaction systems : the CSTR case study. *Automatica.*, 46 (11), 1877-1883, **2010**.
- ▶ DOCHAIN D., PERRIER M. and GUAY M., Extremum Seeking Control and its Application to Process and Reaction Systems: A Survey. *Mathematics and Computers in Simulation*, Special Issue, 82 (3), 369-380 **2010**.
- ▶ DOCHAIN D., *Bioprocess Control*. ISTE, London, **2008**.

▶ HARMAND J., RAPAPORT A., DOCHAIN D. and LOBRY C.,  
Microbial ecology and bioprocess control : opportunities and  
challenges. *Journal of Process Control*, 18, 865-875, **2008**.

### **Funding**

- ▶ European Commission
- ▶ Wallonie
- ▶ Private companies

### **Partnership**

- ▶ Industrial partnership: Nanocyl, Drever, Solvay, GSK, Total, GalvaPower, Dow Corning, Puratos, Lilly
- ▶ EC projects: CAFÉ ("Computer-Aided Food Engineering" EOLI ("Efficient Operation of Urban Wastewater Treatment Plants"), TELEMAC ("TELE-Monitoring and Advanced teleControl of high yield wastewater treatment plants"), AMOCO ("Advanced Monitoring and Control for Improved Stable Operation of Wood Processing Waste Water Treatment Plants"), CPC ("Chemical Process Control")
- ▶ ESA project: MELISSA (Higher Plant Compartment)
- ▶ PAI-IUAP network DYSCO

### **Products and Services**

- ▶ Dynamical models
- ▶ Software sensors
- ▶ Control algorithms
- ▶ Real-Time Optimisation tools

### **KEYWORDS**

Modelling  
Monitoring  
Software sensor  
Control, real-time optimisation  
Population balance  
Metabolic network  
Microbial ecology

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# Cognitive Consequences of Technology

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- ▶ Thierry DE SMEDT
- ▶ Pierre FASTREZ
- ▶ Philippe VERHAEGEN

## Research Field and Subjects

By making new kinds of representations and new ways of interacting with people and with the available information, ICT support their users' cognitive activity in novel ways. The research team observes and analyses the practices related to the uses of ICT in order to assess how the formal properties of digital media shape the activity they support.

Specific research questions include:

- how users develop a particular mental model of the environment they interact with;
- how this model of the environment influences their interaction with it, as well as the knowledge they construct through this interaction;
- how interactive digital environments may foster the development of specific skills;
- how users are taken into account during design process.

Recent empirical research undertaken by our team has focused on:

- metaphor as a means of structuring hypermedia user interfaces and information architecture;
- the interaction between spatial abilities and hypermedia in information retrieval tasks;
- interactive narratives as a means of constructing knowledge;
- the use of persona as a design tool;
- the media literacy competences required by the use of ICT;
- multi-player online role-playing games as an activity developing social competences.

This research finds its foundations in the theoretical tenets of cognitive semiotics, a discipline that emerged at the cross-roads of semiotics and cognitive science, and aims at understanding the interactions between representational media and cognitive activity. The investigation methods involve quasi-experimentations and cognitive ethnography.

## Representative References

- ▶ PHILIPPETTE T., Jeux vidéo en ligne : les groupes d'affinité au service des compétences. *Recherches en Communication*, 34 (under press). **2011**.
- ▶ BROUWERS A., La représentation mentale de l'espace hypertextuel, *Proceedings of H2PTM'2011 – Hypertext & Hypermedia, Products, Tools & Methods* (Université Paul Verlaine-Metz). **2011**.
- ▶ COLLARD A.-S., Un modèle de la prise en compte de l'utilisateur dans le processus de conception d'un dispositif de communication interactif : le cas du persona. *Proceedings of Dispositifs techniques de communication humaine: transformations du lien et nouveaux lieux sociaux* (Namur, Belgique). **2010**.
- ▶ COLLARD A.-S. and FASTREZ P., (2010). A Model of the Role of Conceptual Metaphors in Hypermedia Comprehension. *Proceedings of CICOM: Communication, Cognition and Media* (Braga, Portugal), 241-255. **2009**.
- ▶ CAMPION B., Effet d'un récit non-linéaire sur la construction d'un modèle mental de situation. Dans I. Saleh, S. Leleu-Merviel, Y. Jeanneret, L. Massou, & N. Bouhai (Éd.), *H2PTM'09. Rétrospective et perspective 1989-2009* (p. 87-100). Paris: Hermès. **2009**.
- ▶ FASTREZ P., CAMPION B. & COLLARD A.-S., Le tri de cartes. Une méthode d'investigation des catégories mentales au service de l'architecture de l'information. *Document Numérique*, 12(2), 23-45. **2009**.
- ▶ FASTREZ P. (2008), A longitudinal Perspective on the Relationship between Hypermedia Structure and Comprehension. *Proceedings of the Workshop on Cognition and the Web* (p. 147-151). Granada: Universidad de Granada. **2008**.
- ▶ FASTREZ P. & HAUÉ J.-B., Designing and evaluating driver support systems with the user in mind. *Int J Hum-Comput St*, 66(3), 125-131. **2008**.

## Funding

- ▶ F.R.S.-FNRS
- ▶ FRFC
- ▶ FSR (UCLouvain)
- ▶ European (MEDIA Programme)

## Partnership

- ▶ Laboratoire Travail et Cognition, Université de Toulouse II – Le Mirail (France)
- ▶ COST action “European Research Network on Learning to Write Effectively”
- ▶ TECFA, Université de Genève (Switzerland)
- ▶ Laboratoire Communication, Information, Médias, Université de Paris III (France)
- ▶ Centre de Recherche Images Cultures et Cognitions, Université de Paris I (France)
- ▶ DCOG HCI Lab, University of California, San Diego (USA)

## Main Equipment

- ▶ Data collection and analysis workstations for subject experiments involving the use of multimedia products;
- ▶ Dedicated software for data collection and quantitative/qualitative analysis of user activity.

## Products and Services

- ▶ The research finds applications in the realm of user-centered design and evaluation of multimedia educational applications.

## KEYWORDS

User-centred design (UCD)  
Usability testing  
User interfaces  
Hypertext/hypermedia  
Hypertext navigation and maps  
Computer-assisted instruction  
Games  
Literacy

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# Interfaces for disabled

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## Research Field and Subjects

The research field is User Experience. In particular, the research focuses on the user-centred design and the usability evaluation of interfaces for persons with a disability. The design process involves analysis, elaboration of mock-up, focus-group, and compliance with guidelines. The testing can involve several techniques such as heuristic evaluation, user study, lab-test, and/or field-test.

### *Making ICT accessible to older adults*

“Do I have to press the big button labeled spacebar to separate two words?” This question was the first feedback from a one-year field-test undertaken with novice older adults using a computer. The combination of User-Centered Design, agile development, and field-test was adopted in order to provide the older adults with a better adapted user interface. The purpose to adopt such a combination was to release an easy-to-learn and easy-to-use user interface, so that the older adults would take possession of, and be satisfied with it. The resulting interface supports surfing on Internet, e-mailing, edition of text, and management of photos.

Field-test observation turned out to be a key-success factor, especially because the project addresses the problem of accessibility to ICT for people on the wrong side of the digital divide.

### *Skills and expertise*

- Multimodal interfaces
- User-Centred Design
- Usability and software life-cycle
- Techniques for the elaboration of mock-up
- Evaluation techniques (lab- or field-tests)
- Best practice, Guidelines, and Heuristics
- Data handling, from acquisition to analysis
- Statistics: JMP (SAS Institute)

## Representative References

- ▶ KIEFFER S., SWINE C., MACQ B., Supporting the participation in social life of frail older adults in a one-day clinic. In Proc. IADIS International Conference Interfaces and Human Computer Interaction 2011, Rome, July 24-26, **2011**.
- ▶ KIEFFER S., COYETTE A., VANDERDONCKT J., User interface design by sketching: a complexity analysis of widget representations. In Proc. of 2nd ACM Symposium on Engineering Interactive Computing Systems EICS 2010 (Berlin, 19-23 June 2010), ACM Press, New York, pp. 57-66, **2010**.
- ▶ KIEFFER S., GOUZE A., MONCAREY R., VAN BRUSSEL C., DE WISPELAERE J.-F., KAYSER F., MACQ B., Towards standardized pen-based annotation of breast cancer findings. In Proc. Conference on Human-Computer Interaction (HCI'09), San Diego (CA), July 19-24, **2009**.
- ▶ KIEFFER S., LAWSON J.-Y., MACQ B., User-centered design and fast prototyping of an ambient assisted living solution for elderly people. In Proc. IEEE ITNG 2009, Las Vegas (NV), April 27-29, **2009**.
- ▶ COYETTE A., KIEFFER S., VANDERDONCKT J., Multi-fidelity prototyping of user interfaces. In Proc. IFIP TC13 International Conference on Human-Computer Interaction (INTERACT'07), Rio de Janeiro, Brasil, September 10-14, **2007**, pp. 150-164. Awarded with the Brian Shackel Award.

## Awards

- ▶ Session Chair, IHCI'11 conference, 2011
- ▶ Best presentation award, EICS'10, 2010
- ▶ Price VOO, Boostcamp of the Microsoft Innovation Center (MIC) in Mons, 2009
- ▶ Oral presentation to Albert II, King of the Belgians, Inauguration of the MIC, 2009
- ▶ Best paper Award, INTERACT'07, “Brian Shackel Award”, 2007

## **Funding**

- ▶ Wallonie, 1st spin-off convention: 816788
- ▶ Wallonie, "Proof of concept" Funding

## **Partnership**

- ▶ Microsoft Innovation Center
- ▶ Neomytic
- ▶ Wavenet

## **Products and Services**

- ▶ User-centred design for interactive systems
- ▶ Designing and observing the user experience
- ▶ Usability testing

## **KEYWORDS**

Ageing well  
Assistive technology for older adults  
Human-Computer Interaction  
User-centred design (UCD)  
Multimodal interaction  
Usability testing

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# Immersive Virtual Environment

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- ▶ Pierre PHILIPPOT

## Research Field and Subjects

The Immersive Virtual Environment laboratory (IVElab) is a new working infrastructure being set up in the Psychological Sciences Research Institute (IPSY) in order to assist psychologists in their research, therapeutic and educational activities. The laboratory uses virtual reality devices to immerse participants in a 3D virtual environment, in order to confront them with computer controlled situations and observe their reactions.

The main advantage of the virtual reality is that it allows a very flexible control of the situations in which the subjects are immersed, overcoming many of the technical and practical problems that are met with the classical 'in vivo' immersion techniques. The deepness of the immersion may also be much bigger than the commonly used audio/video footages. Furthermore, new possibilities are opened, such as the complete manipulation of the environment and the set up of non-realistic situations.

The laboratory is equipped with motion capture devices in order to capture the actions of the body and the hands of the user. The data from these actions are then fed in the system that uses real-time procedural animation techniques to animate the avatar of the user and to control the behaviour of the virtual entities around the user.

The main research domains that are currently investigated in the laboratory are the etiology and treatment of anxiety, perception and action behaviour, facial perception, and number processing.

- ▶ BADETS A., PESENTI M., Creating number semantics through finger movement perception. *Cognition*. 115, 46-53, **2010**.
- ▶ TYBERGHEIN J., SUNSHINE E., RICHTER F., GIST M., VAN BRUSSEL C., Developing video games and virtual environments with the Crystal Space engine. *Design and Engineering of Game-like Virtual and Multimodal Environments*, **2010**.

## Funding

- ▶ Wallonie
- ▶ Fonds National de la Recherche Scientifique
- ▶ European Regional Development Fund

## Main Equipment

- ▶ Z800 Head Mounted device
- ▶ 5DT data gloves
- ▶ Polhemus Liberty and Liberty Latus

## Representative References

- ▶ DOUILLIEZ C., YZERBYT V., GILBOA-SCHECHTMAN E., PHILIPPOT P., Social anxiety biases the evaluation of facial displays: Evidence from single face and multi-facial stimuli. *Cognition and Emotion*, pp. 1-9, **2011**.
- ▶ HARDWICK R., EDWARDS M.G., Observed reach kinematics modulate executed reach kinematics in prehension. *Quarterly Journal of Experimental Psychology*. 64, 1082-1093, **2011**.
- ▶ PHILIPPOT P., VRIELYNCK N., MULLER V., Cognitive Processing Specificity of Anxious Apprehension: Impact on Distress and Performance during Speech Exposure. *Behavior Therapy*. 41(4): 575-586, **2010**.



**KEYWORDS**

Virtual reality  
Immersive interfaces  
Cognition  
Motion capture  
Procedural animation

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# Engineering of User Interfaces

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- ▶ Juan Manuel GONZALEZ CALLEROS
- ▶ Ricardo TESORIERO

## Research Field and Subjects

Engineering of User Interfaces (UIs) is concerned by the software engineering aspects of interactive systems, primarily their user interfaces. The development life cycle of a user interface starts from requirement engineering until its deployment, evaluation, and maintenance. Any question occurring during this development life cycle from an engineering point of view is relevant.

For this purpose, we rely on a dedicated UI development method that is structured according to three axes:

1. *Models* that capture various aspects of an interactive system through adequate abstractions such as: task, domain, user, platform, environment, abstract UI, concrete UI, context of use, interactor. These models are written in a particular User Interface Description Language (UIDL) having its own notation (User Interface eXtensible Markup Language – [www.usixml.org](http://www.usixml.org)).
2. A *step-wise method* that decomposes the development life cycle into steps and sub-steps, involving relevant models when any, based on model-based design, model driven engineering, and method engineering techniques.
3. A *software support* that provides stakeholders (e.g., designers, developers, end users) with guidance on how to apply the method based on the models.

Topics of interest include multi-device interactive systems, new and emerging modalities (e.g., gesture), entertaining applications (e.g., mobile and ubiquitous games), and design and development methods (e.g., extreme programming). Engineering of user interfaces is also explored according to the following axes:

- *Multi-device user interfaces*: the same UI should be executed seamlessly on one or many different devices, having potentially very heterogeneous interaction capabilities.
- *Multi-user interfaces*: tasks could be carried out by one or multiple users working separately or together, thus posing the need for multi-user interfaces that goes beyond sharing a same user interface across different users.

- *Multi-culturality/linguality*: users speak different languages, but also expect to have their user interface subject to localisation (adaptation with respect to their specific country, culture, language) or globalisation (adaptation to the largest population of users possible). In particular, we handle culturally-aware user interfaces.

- *Multi-organisation user interfaces*: they support tasks, business processes, and workflow that span over multiple users belonging to different groups, entities, or organisations.

- *Multi-context interfaces*: they are supposed to continue to run even if the context of use is changing (the user evolves over time, the platform is changing, and the socio-organisational environment is dynamic). The same task could be expressed in very different ways depending on the constraints imposed by the context of use.

- *Multi-modality*: user interfaces may involve different modalities of interaction (e.g., graphic, vocal, haptic, tactile) either one at a time or simultaneously.

- *Multi-platform user interfaces*: they include user interfaces that could run indifferently on any computing platform, regardless of its operating system, window manager or particular device (e.g., mobile phone, smartphone, tablet, laptop, interactive kiosk, desktop, large screen, wall screen).

User interfaces could vary according to any of these axes, thus also introducing Distributed User Interfaces (DUIs) that could span across these dimensions over time and space.

## Representative References

- ▶ VANDERDONCKT J., Distributed User Interfaces: How to Distribute User Interface Elements across Users, Platforms, and Environments, Proc. of XIth Congreso Internacional de Interacción Persona-Ordenador Interacción'2010 (Valencia, 7-10 September 2010), AIPO, Valencia, pp. 3-14, **2010**.
- ▶ VANDERDONCKT J., Model-Driven Engineering of User Interfaces: Promises, Successes, and Failures, Proc. of 5th Annual Romanian Conf. on Human-Computer Interaction ROCHI'2008 (Iasi, 18-19 September 2008), Matrix ROM, Bucarest, **2008**, pp. 1-10.

## Partnership

- ▶ CETIC, Belgium
- ▶ Defimedia, Belgium
- ▶ Fondation CTIC, Spain
- ▶ Polytechnic University of Valencia, Spain
- ▶ See & Touch, Belgium
- ▶ University of Castilla-La Mancha, Spain
- ▶ University of Grenoble, LIG, France
- ▶ W4, France

## Products and Services

- ▶ UI design: scenario-based design, prototyping, mockup
- ▶ UI development: programming, model-driven engineering of UIs
- ▶ UI evaluation: evaluation with or without users according to sound protocols (e.g., web sites)
- ▶ UI adaptation: adaptation of existing UIs to new contexts of use, new devices or platforms.

## KEYWORDS

Computer-Aided Design of User Interfaces  
Engineering Interactive Computing Systems  
Human-Computer Interaction  
Model-driven engineering  
Software engineering  
User interfaces

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# Automated analysis of foreign language learner writing and speech

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- ▶ Fanny MEUNIER
- ▶ Magali PAQUOT

## Research Field and Subjects

The Centre for English Corpus Linguistics (CECL) has played a pioneering role in the collection and automated analysis of large electronic collections of spoken and/or written language produced by foreign language learners. The CECL has designed a comprehensive error annotation system for both English and French as a foreign language and a range of automated methods that can inform the following applications:

- customisation of web-based learning tools in function of learners' attested difficulties;
- improvement of automatic spell- and grammar-checking tools, automatic scoring tools and speech recognition programs;
- automatic identification of the users' mother tongue (L1) and proficiency level;
- design of customised language tests and pedagogical material.

The associated automated techniques are the following:

- comparisons of word/n-gram lists;
- extraction of over- and underused words/n-grams;
- error annotation and analysis;
- part-of-speech tagging.

## Representative References

- ▶ BESTGEN Y., GRANGER S. & THEWISSEN J., Error patterns and automatic L1 identification. In Jarvis, S. & Crossley, S. (eds.) *Approaching Transfer through Text Classification: Explorations in the Detection-based Approach*. Clevendon: Multilingual Matters, **2011**.
- ▶ BESTGEN Y. & GRANGER S., Categorizing spelling errors to assess L2 writing. *International Journal of Continuing Engineering Education and Life-Long Learning*, 21(2/3): 235-252, **2011**.
- ▶ GILQUIN G., DE COCK S. & GRANGER S., *Louvain International Database of Spoken English Interlanguage. Handbook and CD-ROM*. Louvain-la-Neuve: Presses universitaires de Louvain, **2010**.

- ▶ GRANGER, DAGNEAUX E., MEUNIER F., PAQUOT M., *The International Corpus of Learner English. Handbook and CD-ROM. Version 2*. Louvain-la-Neuve: Presses universitaires de Louvain, **2009**.
- ▶ GRANGER S., Learner Corpora in Foreign Language Education. In Van Deusen-Scholl N. and Hornberger N.H. (eds.) *Encyclopedia of Language and Education*. Volume 4, Springer, 337-351, **2008**.
- ▶ GRANGER S., KRAIF O., PONTON C., ANTONIADIS G. & ZAMPA V., Integrating learner corpora and natural language processing: A crucial step towards reconciling technological sophistication and pedagogical effectiveness. *ReCALL* 19(3): 252-268, **2007**.
- ▶ GILQUIN G., GRANGER S. & PAQUOT M., Learner corpora: the missing link in EAP pedagogy. *Journal of English for Academic Purposes* 6(4): 319-335, **2007**.

## Funding

- ▶ EU
- ▶ F.R.S.-FNRS
- ▶ FSR/UCL
- ▶ Fédération Wallonie-Bruxelles
- ▶ Macmillan Dictionaries Ltd

## Partnership

- ▶ Lancaster University (UK)
- ▶ Ohio University (USA)
- ▶ University of Oslo (Norway)
- ▶ Katholieke Universiteit Leuven (Belgium)

## Products and Services

Corpora:

- ▶ *International Corpus of Learner English* (ICLE): 3.7 million words of English writing produced by learners from 16 mother tongue backgrounds. Wide international network coordinated by the CECL (started in 1990).
- ▶ *Louvain International Database of Spoken English Interlanguage* (LINDSEI): 1 million words of English speech produced by learners from 11 mother tongue backgrounds. Wide international network coordinated by the CECL (ongoing; started in 1995).
- ▶ *French Interlanguage Database* (FRIDA): 300,000 words of French writing produced by learners from a range of mother tongue backgrounds; fully error-tagged.

Services:

- ▶ Design and analysis of learner corpora
- ▶ Automated error analysis
- ▶ Design of corpus-informed pedagogical material and language tests

## KEYWORDS

Foreign language learning/teaching  
Pedagogical materials development  
Error detection and correction  
L1 identification  
Language testing  
Speech recognition

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# Constraint Programming

## SENIOR SCIENTIST:

▶ Yves DEVILLE

## Research Field and Subjects

Constraint Programming (CP) is a powerful paradigm for modelling and solving complex combinatorial (optimisation) problems in area such as planning, scheduling, sequencing, configuration, design and resource allocation. It integrates techniques from artificial intelligence, computer science, operational research and optimisation. CP separates the modelling of the problem from the search for solutions. It offers high level modelling languages based on constraints. CP proposes two complementary search mechanisms. Standard CP is based on systematic tree search coupled with pruning techniques to remove infeasible solutions. Constraint-Based Local Search (CBLS) allows heuristic search based on the exploration of neighbourhoods.

The Constraint Research Group at UCL has a high expertise in Constraint Programming. The group is mainly interested in modelling, consistency techniques, integration of CP and CBLS, constraint languages, heuristic search, graph matching, scheduling, routing problems, development of methods and tools for specific classes of problems, applications in domains such as networking and medical applications.

## Representative References

- ▶ DEVILLE Y., VAN HENTENRYCK P., Domain Consistency with Forbidden Values. 16th International Conference on Principles and Practice of Constraint Programming Lecture Notes in Computer Science, Springer, **2010**.
- ▶ SCHAUS P., VAN HENTENRYCK P., MONETTE J.N., COFFRIN C., MICHEL L., DEVILLE Y., Solving Steel Mill Slab Problems with Constraint-Based Techniques: CP, LNS, and CBLS. Journal of Constraints, 16(2), 125-147, Springer, **2010**.
- ▶ ZAMPELLI S., DEVILLE Y., SOLNON C., Solving Subgraph Isomorphism Problems with Constraint Programming. Journal of Constraints, Volume 15, Number 3, 327-353, Springer, **2009**.
- ▶ MONETTE J.-N., DEVILLE Y., VAN HENTENRYCK P., AEON: Synthesizing Scheduling Algorithms from High-Level Models. INFORMS Computing Society Conference (ICS09), **2009**.

- ▶ SCHAUS P., DEVILLE Y., A Global Constraint for Bin-Packing with Precedences: Application to the Assembly Line Balancing Problem. AAAI-08, Twenty-Third AAAI Conference on Artificial Intelligence, **2008**.

## Funding

- ▶ F.R.S.-FNRS
- ▶ Wallonie
- ▶ EC

## Partnership

- ▶ Brown University, USA
- ▶ IRIDIA, ULB, Belgium
- ▶ Dynadec, USA
- ▶ IBA, Belgium

## KEYWORDS

Artificial Intelligence  
Constraints  
Constraint satisfaction  
Constraint programming  
Constraint languages  
Optimisation

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# Graph Analysis and Web Mining

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- ▶ François FOUSS
- ▶ Alain PIROTTE
- ▶ Marco SAERENS

## Research Field and Subjects

Many approaches in the fields of “Machine Learning” (ML) and “Knowledge Discovery in Databases” (KDD or “Data Mining”), but also in applied statistics and pattern recognition, have gone through the extraction of knowledge from the classical double-entry (objects/variables) tabular data.

These approaches are however cumbersome for many application domains, typically those where the data naturally take the form of graph structures (like the web, molecular structures, social networks, etc.) rather than a tabular format.

New techniques – referred to as “graph mining” or “link analysis” techniques – have recently been investigated to extract useful information directly from those complex data.

For example, web link analysis aims to exploit the graph structure of large networks, such as the web environment, and to rank nodes according to some “centrality” or “importance” score. Some of those techniques are used with success in commercial search engines (e.g., Google).

Another example concerns “collaborative recommendation” within a community of users and given a database of past individual behaviors. In this framework, the database can naturally be viewed as a graph and suitable notions of distance on a graph can be developed to capture adequate measures of proximity between items and users, in order to make recommendations (e.g., for books to purchase, like Amazon does).

Biochemical network analysis forms a third application domain of graph mining techniques. Such networks, describing cellular processes, can be viewed as typed graphs for which dedicated mining tools allow new insights for the biologists. Appropriate distance measures between graph nodes can then be used to extract frequent or relevant subgraphs.

We provide our expertise in graph mining and link analysis techniques. Our contribution goes from theoretical modelling toward implementation in various application areas such as the ones described above.

## Representative References

- ▶ MANTRACH A., VAN ZEEBROECK N., FRANCOIS P., SHIMBO M., BERSINI H. & SAERENS M., “Semi-supervised classification and betweenness computation on large, sparse, directed graphs”. *Pattern Recognition*, 44 (6), pp. 1212-1224, **2011**.
- ▶ FAUST K., DUPONT P., CALLUT J. & VAN HELDEN J., “Pathway discovery in metabolic networks by subgraph extraction”. *Bioinformatics*, Vol. 26, No. 9, pp. 1211-1218, **2010**.
- ▶ MANTRACH A., YEN L., CALLUT J., FRANCOISSE K., SHIMBO M. & SAERENS M., “The sum-over-paths covariance kernel: a novel covariance measure between nodes of a directed graph”. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 32 (6), pp. 1112-1126, **2010**.
- ▶ CALLUT J., FRANCOISSE K., SAERENS M. & DUPONT P., “Semi-supervised classification from discriminative random walks”. *Proceedings of the European Conference on Machine Learning (ECML)*, *Lecture Notes in Computer Science*, Vol. LNAI5211, Springer-Verlag, pp. 162-177, **2008**.
- ▶ YEN L., MANTRACH A., SHIMBO M. & SAERENS M., “A family of dissimilarity measures between nodes generalizing both the shortest-path and the commute-time distances”. *Proceedings of the 14th SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD)*, pp. 785-793, **2008**.
- ▶ FOUSS F., PIROTTE A., RENDERS J.-M. & SAERENS M., “Random-walk computation of similarities between nodes of a graph, with application to collaborative recommendation”. *IEEE Transactions on Knowledge and Data Engineering*, 19 (3), pp. 355-369, **2007**.

## Partnership

- ▶ Xerox Research Center Europe (Dr. Jean-Michel Renders)
- ▶ Université de la Méditerranée, Marseille, France (Prof. J. Van Helden)

## Products and Services

- ▶ Collaborative recommendation (Citobi)
- ▶ Bioinformatics and modelling: from genomes to networks (BioMaGNet)



**KEYWORDS**

Graph analysis  
Link analysis  
Biochemical network analysis  
Collaborative recommendation  
Web mining  
Graph mining

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# Machine learning: feature selection and dimensionality reduction

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- ▶ Michel VERLEYSEN
- ▶ Vincent WERTZ

## Research Field and Subjects

Machine learning deals with the design of computer programs that automatically improve with experience their behaviour or predictive performance. Typical examples include computer programs that learn to detect fraudulent credit card transactions, spam filters, medical diagnosis software, etc. The latter help to predict the status of a patient based on former patient records. The common characteristic of those various applications is essentially the estimation of a mathematical model from past measurements to predict new ones.

In modern data collections, the number of different measurements from the same sample is often very large. For example, the number of frequency bands to be considered in the analysis of a spectrogram, or the number of probes measuring gene expressions, may exceed several thousands, if not millions. Such a large dimensionality, sometimes orders of magnitude larger than the number of available samples, raises specific issues to estimate robust predictive models. In particular, traditional machine learning techniques are often prone to overfit their underlying model: the knowledge extracted from the available sample cannot be generalised.

Feature selection aims at identifying automatically the most relevant measurements for the intended analysis or prediction task. Such a selection limits the risk of overfitting, offers more interpretable models and often reduces the computational cost at prediction time.

Dimensionality reduction goes beyond feature selection: it can discard useless features and combine the relevant ones in a linear or nonlinear fashion. This leads to a new feature space with improved or more desirable properties, such as the possibility to represent the most prominent features of the considered data set, such as clusters or other hidden patterns.

## Representative References

- ▶ ZAKHAROV R., DUPONT P., Ensemble Logistic Regression for Feature Selection, Lecture Notes in Bioinformatics, No. 7036, Springer, pp. 133-144, **2011**.
- ▶ HERNÁNDEZ-LOBATO D., HERNÁNDEZ-LOBATO J.M., HELLEPUTTE T., DUPONT P., Expectation Propagation for Bayesian Multi-task Feature Selection, Lecture Notes in Artificial Intelligence, No. 6321, Springer, pp. 522-537, **2010**.
- ▶ LEE J.A., VERLEYSEN M., Scale-independent quality criteria for dimensionality reduction, Pattern Recognition Letters, Elsevier, Vol. 31, No. 14, pp. 2248-2257, October **2010**.
- ▶ HELLEPUTTE T., DUPONT P., Partially Supervised Feature Selection with Regularized Linear Models, 26th International Conference on Machine Learning, **2009**.
- ▶ HELLEPUTTE T., DUPONT P., Feature Selection by Transfer Learning with Linear Regularized Models, Lecture Notes in Artificial Intelligence, No. 5781, Springer, pp. 533-547, **2009**.
- ▶ ROSSI F., FRANCOIS D., WERTZ V., MEURENS M., VERLEYSEN M., Fast Selection of Spectral Variables with B-Spline Compression, Chemometrics and Intelligent Laboratory Systems, Elsevier, Vol. 86, No. 2 pp. 208-218 (April **2007**).
- ▶ LEE J.A., VERLEYSEN M., Nonlinear dimensionality reduction, Springer, Information Science and Statistics series, 310 pp, **2007**.

## Awards

- ▶ Thibault Helleputte, IBM Belgium / F.R.S.-FNRS Computer Science PhD thesis Award, Stable Feature Selection in Empty Spaces
- ▶ Applications to Gene Profiling and Diagnosis from DNA Microarrays

## **Funding**

Wallonie, Region of Brussels, UCL, FRIA, F.R.S.-FNRS

## **Partnership**

- ▶ Department of Plant Systems Biology, Ghent University, Belgium
- ▶ Université Paris 1 Panthéon Sorbonne, France

## **Main Equipment**

Desktop and grid computers

## **Products and Services**

- ▶ Data analysis case studies and software development
- ▶ Short courses on machine learning and data mining specialised topics

## **KEYWORDS**

Machine learning  
Data analysis  
Dimensionality reduction  
Feature Selection  
Transfer learning  
Multi-task learning

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# From noisy to standard written language – statistical rewrite, correction and alignment methods

## SENIOR SCIENTIST:

▶ Richard BEAUFORT

## Research Field and Subjects

*Standard language is the language subset considered as correct and acceptable, because described and encoded in grammars and dictionaries.*

Actually, there are *many* standards, the standard in use depending on a not so short list of factors: the speaker's level of education and mood, the interlocutor (a friend, a colleague, a stranger, and a well-known figure), the social context (informal or official event), the day time, etc.

Some linguistic phenomena, of course, are always wrong. That is the case, for instance, of a misspelled word (like "*spel*" instead of "*spell*"). But, often, both the correctness and the appropriateness of a linguistic fact depend on whether this one belongs to the standard in use; for instance, "*Dear Sir*" is correct, but this is not the appropriate way of greeting a friend... except if joking!

At CENTAL, the Centre for Natural Language Processing, a significant part of the research focuses on written standards, i.e. standards limited to *texts*. Two points are studied: (1) how to build a model of a given standard? (2) when a form is out of the standard in use, whatever the reason, how to choose the right standard form to replace it?

These questions may be seen as two parts of a *correction problem*. In this case, the solution is often expert-based: a linguist describes the standard and the errors he *knows from experience*, which are often only a subset of all possible deviations.

At CENTAL, these questions are considered as a special kind of the *noisy channel metaphor*. On this basis, the idea is to propose a *statistical representation* of both the standard and the channel's noise: a supervised learning, partially based on automatic strings alignment (edit distance, similarity measure) of clean and noisy data, produces (1) a statistical language model of the standard and (2) a set of weighted rewrite rules modelling the channel's noise and corresponding to mappings from noisy to clean data. Represented and handled using weighted finite-state tools, both the statistical language and the set of weighted rules are used at runtime to *normalise* (i.e. "get rid of the noise from") noisy texts.

Up to now, this framework has been applied to (1) the post-correction of noisy OCR outputs, (2) the normalisation of SMS (converted from the so-called SMS language to a chosen standard), and (3) the correction of dictation exercises (smart comparison of a copy with the original of the dictation, to detect the place of errors and propose a diagnosis of them).

## Representative References

- ▶ BEAUFORT R., ROEKHAUT S., Automation of dictation exercises. A working combination of CALL and NLP. *Computational Linguistics in the Netherlands Journal*, 1:1-20, **2011**.
- ▶ BEAUFORT R., Composition filtrée et marqueurs de règles de réécriture pour une distance d'édition flexible. Application à la correction des mots hors-vocabulaire. *Traitement Automatique des Langues (T.A.L)*, 51(1):11-40, **2010**.
- ▶ BEAUFORT R., ROEKHAUT S., COUGNON L.-A., FAIRON C., A hybrid rule/model-based finite-state framework for normalizing SMS messages. *Proceedings of ACL*, pp. 770-779, **2010**.
- ▶ BEAUFORT R., DISTER A., NAETS H., MACE K., FAIRON C., Recto/Verso. Un système de conversion automatique ancienne/nouvelle orthographe à visée linguistique et didactique. *Proceedings of TALN*, no pages, **2009**.
- ▶ BEAUFORT R., ROEKHAUT S., FAIRON C., Définition d'un système d'alignement SMS/français standard à l'aide d'un filtre de composition. *Proceedings of JADT*, pp. 155-166, **2008**.
- ▶ BEAUFORT R., MANCAS-THILLOU C., A Weighted Finite-State Framework for Correcting Errors in Natural Scene OCR. *Proceedings of ICDAR*, pp. 889-893, **2007**.

## Patent

*A method and a device for normalizing SMS messages.* Date of filing: May 27th 2010. Submission number EP10005506.0. Status: pending.

## Funding

- ▶ Wallonie, Belgium
- ▶ European community

## Partnership

- ▶ University of Mons, Belgium
- ▶ University of Antwerp, Belgium
- ▶ University College Ghent, Belgium
- ▶ FOREM (Walloon public service for employment and training), Charleroi, Belgium
- ▶ University of Lancaster, United Kingdom
- ▶ DFKI (German Research Centre for Artificial Intelligence), Kaiserslautern, Germany

## Products and Services

- ▶ *PlatON*: a spelling-dedicated online platform currently focused on dictation exercises. This platform is twofold: on the one side, teachers create dictations and check students' copies; on the other side, students do dictations prepared by their teacher. The platform automatically corrects students' copies.

<http://www.normalink.com/platon/>

- ▶ *Text-it/Voice-it*: automatic text messages normalisation. Online application.

<http://www.normalink.com/textit/>

- ▶ *Recto/Verso*: automatic system dedicated to the application of the 1990 French spelling rectifications on a text written in standard orthography. Online application.

<http://www.uclouvain.be/recto-verso/>

## KEYWORDS

Normative aspects of written language  
Noisy channel  
Supervised training  
Weighted finite-state tools  
Statistical language models  
Weighted rewrite rules  
Pattern recognition  
Machine learning

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<http://www.uclouvain.be/recto-verso/>

# Statistical methods for the analysis of microarray data

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- ▶ Jean-Luc GALA
- ▶ Benoît MACQ
- ▶ Bertrand BEARZATTO
- ▶ Jérôme AMBROISE
- ▶ Annie ROBERT

## Research Field and Subjects

Over the past few years, the microarray technology has markedly impacted the molecular biology, allowing researchers to measure efficiently the expression level of thousands of genes in a single experiment. Simultaneous measurement of thousands of gene expression levels provides a potential source of knowledge. However, the high throughput and noisy nature of the microarray data remains a serious challenge for statisticians and bio-informaticians. Instead of having a few variables and a large number of observations, microarray data usually deal with thousands of variables (the genes) and only few observations. Furthermore, as microarray experiments contain many steps that are potentially affected by their own individual noise and variation, the data are generally very noisy.

The research focuses on the analysis of signals generated by microarray and more specifically on the data pre-processing. Raw data generated by the scanners must be pre-processed in multiple successive steps that include the correction of saturated spots, the background correction, the transformation and the normalisation. These pre-processing steps have to be defined according to the microarray application (class comparison, class prediction or class discovery). Special attention has also to be paid to the pre-analytic procedure. Recent publications have rightfully pointed out problems of inter-platform and inter-operator variability, largely due to the lack of standardisation and quality control of this critical step.

To comprehend the impact of the pre-analytical and data pre-processing steps, the clinical relevance of the results is assessed in a multidisciplinary research team that includes engineers, biostatisticians, clinicians, and scientists.

## Representative References

- ▶ AMBROISE J., BEARZATTO B., ROBERT A., MACQ B., GALA J.-L., Combining multiple laser scans of spotted microarrays by means of a two-way ANOVA model. *Statistical applications in genetics and molecular biology*, 11(3), Article 8, **2012**.

- ▶ AMBROISE J., BEARZATTO B., GOVAERTS B., ROBERT A., MACQ B., GALA J.-L., Impact of the spotted microarray preprocessing method on fold-change compression and variance stability. *BMC Bioinformatics*, 12:413, **2011**.
- ▶ VAN DER VORST S., DEKAIRELLE A.F., IRENGE I., ROBERT A., HAMOIR M., GALA J.L., Automated cell disruption is a reliable and powerful method to isolate RNA from fresh snap frozen normal or malignant oral mucosa samples. *Clinical Chemistry and Laboratory Medicine*, 47:294-301, **2009**.
- ▶ DEKAIRELLE A.F., VAN DER VORST S., TOMBAL B., GALA J.L., Preservation of RNA for functional analysis of separated alleles in yeast: comparison of snap-frozen and RNALater® solid tissue storage methods. *Clinical Chemistry and Laboratory Medicine*; 45:1283-7, **2007**.

## Funding

Wallonie

## Partnership

NANOTIC – Programme d'excellence de la Wallonie, 2005-2010.

## Main Equipment

A comprehensive set of equipments necessary to perform microarray analysis (spotting and reading) is used by the team. Among these, one finds the Bioanalyser Agilent 2100 used to assess the quality of the RNA, the Axon Genepix used to scan and transfer the results to the computer, or the Arraywrx biochip reader and several spotters (scienion, Sensovation, industrial spotter).

A full equipped Affymetrix platform is available nearby for high density testing. Major equipments on the platform also include a pysequencing machine, an ABI sequencer 3130, a real-time PCR Taqman 7900 and a real-time PCR light cycler Roche 480, and a portable Real-time PCR Agilent technology Stratagene Mx3005P.

## Products and Services

The research intends to provide quality controlled results based on the use of arrays of various density (customised array) within the setting of a core facility.

This intends to provide a technical platform for clinical, preclinical, and discovery research considering that sophisticated and costly analytical procedures cannot be afforded by every clinical or research laboratory with a low scale activity (i.e., dealing with a number of samples per day, per week, or per month).

Indeed, this emerging technology requires a high degree of expertise and expensive equipments.

This core facility will provide all the expertise required for the tests and will carry them out. The type of samples and the choice of array will be discussed with each project leader and results will be provided. On this purpose, industrial contacts and support include ClinEuroDiag (for low density microchips) and Affimetrix (for high density microchips).

## KEYWORDS

Microarray data preprocessing  
Microarray low density & high density  
Customised protein and oligonucleotides chips  
Pharmacogenetics  
Pharmacogenomics  
Signal processing

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# Machine learning for biomedical applications

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- ▶ Pierre DUPONT
- ▶ John A. LEE

## Research Field and Subjects

Machine learning (ML) cross-fertilises applied statistics and computer science, and aims at designing algorithms and methods for the automatic analysis of data. It has provided considerable breakthroughs in many domains, e.g. in medicine (help for diagnosis, prognosis or treatment response prediction), industry (design, predictive maintenance, etc.), and many others.

The use of machine learning in the biomedical domain is widespread, and provides considerable opportunities for improving healthcare assistance, pathology discovery and drug administration. Machine learning aims at analysing large amounts of data, and at providing to specialists important information extracted (in an automatic or semi-automatic way) from these data. This information typically takes the form of a mathematical model estimated from a collection of past patients to predict the status of future patients.

The Machine Learning Group at UCL has recently developed expertise in a number of biomedical application fields, among which:

- The automatic annotation and classification of electrocardiogram waveforms, according to AAMI standards;
- The identification of relevant biomarkers from microarray gene expression data, for cancer treatment response prediction, early diagnosis of arthritis or prognosis of allergy;
- The denoising, deblurring, and segmentation of positron emission tomography images;
- The filtering of nerve recordings;
- More generally, the extraction of relevant information and knowledge from signals and data collected in a medical or biomedical environment, including patient data.

## Representative References

- ▶ DOQUIRE G., DE LANNOY G., FRANCOIS D., VERLEYSEN M., Feature selection for supervised inter-patient heart beat classification. *Computational Intelligence and Neuroscience*, Hindawi Pub. Corp., Vol. 2011, No. 643816, pp. 1-9, doi: 10.1155/2011/643816, **2011**.
- ▶ ABEEL T., HELLEPUTTE T., VAN DE PEER Y., DUPONT P., SAEYS Y., Robust biomarker identification for cancer diagnosis with ensemble feature selection methods, *Bioinformatics*, Vol. 26, No. 3, pp. 392-398, **2010**.
- ▶ DE DECKER A., LEE J.A., VERLEYSEN M., A Principled Approach to Image Denoising with Similarity Kernels Involving Patches. *Neurocomputing*, Elsevier, Vol. 73, No. 7-9, 1199-1209, March **2010**.
- ▶ DE LANNOY G., DE DECKER A., VERLEYSEN M., A Supervised Wavelet Transform Algorithm for R Spike Detection in Noisy ECGs. *Communications in Computer and Information Science*, Vol. 25, pp. 256-264, **2009**.
- ▶ HELLEPUTTE T., DUPONT P., Partially Supervised Feature Selection with Regularized Linear Models, 26th International Conference on Machine Learning (ICML), **2009**.
- ▶ DE LANNOY G., MARTIN J., VERLEYSEN M., DELBEKE J., Filtering Heart Related Activity from Vagus Nerve Recordings in Rats, IFESS 2008, 13th Annual International FES Society Conference, Freiburg (Germany), 21-25 September 2008. *Biomed. Tech.*, Vol. 53, Supp. 1, pp 16-18, **2008**.

## Patent

A Method for Classifying a Cancer Patient as Responder or Non-responder to Immunotherapy, (WO/2010/029174).



## **Awards**

- ▶ Thibault Helleputte, IBM Belgium / F.R.S.-FNRS Computer Science PhD thesis Award, Stable Feature Selection in Empty Spaces Applications to Gene Profiling and Diagnosis from DNA Microarrays

## **Funding**

- ▶ Wallonie
- ▶ Brussels-Capital Region
- ▶ FRIA, F.R.S.-FNRS

## **Partnership**

- ▶ St-Luc Hospital, Brussels
- ▶ Christian de Duve Institute of Cellular Pathology
- ▶ Department of Plant Systems Biology, Ghent University, Belgium

## **Main Equipment**

Desktop and grid computers

## **Products and Services**

- ▶ Data analysis case studies and software development
- ▶ Short courses on machine learning and data mining specialised topics

## **KEYWORDS**

Machine learning  
Data analysis  
Signal processing  
Biomedical data  
Patient records

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# Medical imaging

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- ▶ Vincent NICOLAS
- ▶ Laurent JACQUES
- ▶ Guillaume JANSSENS
- ▶ Jonathan ORBAN DE XIVRY

## Research Field and Subjects

Medical imaging techniques underwent significant improvements in the past decades. That leads to the path towards safer and more individualised treatments by allowing the clinician to take images from multiple modalities and at different time points. As this generates a huge amount of data, automatic tools are needed to help the clinician during (a) the diagnostic, (b) the treatment planning and (c) the treatment delivery. The "Image and Signal Processing" (ISP) group of the ICTEAM institute leads several research projects on these topics.

A platform (MedicalStudio) is under development to help the physician to analyse and annotate images such as mammographies, x-rays of the lungs and of bone infections. A strong focus is set on the interface in order to simplify the human computer interaction. An important research effort has been dedicated to the development of automatic segmentation and registration of multimodal images for radiotherapy planning. The following applications are currently evaluated by physicians: articulated registration methods for compensating different patient positions; atlas to patient non-rigid registration using mutual information; and statistical atlas construction.

Finally, whereas new imaging modalities are ever more available, imaging pathology in the treatment room remains a challenge (for instance in surgery or radiotherapy). Indeed, real time imaging and image analysis techniques are mandatory to guide treatment and improve its precision. Therefore, the ISP group is also leading a project that aims to develop new intra-operative imaging functionalities. This is realised by registering and combining high-quality pre-operative anatomical or functional images (PET, MRI, CT, ...) to images available during treatment such as US, CBCT, optical 3D scanner, open field MRI, ...

## Representative References

- ▶ JANSSENS G., JACQUES L., ORBAN DE XIVRY J., GEETS X., MACQ B., Diffeomorphic Registration of Images with Variable Contrast Enhancement. *Int. J. of Biomed. Imaging*, 2011(1), p. 16, **2011**.
- ▶ KIEFFER S., GOUZE A., MONCAREY R., VAN BRUSSEL C., DE WISPELAERE J-F., KAYSER F., MACQ B., Towards standardized pen-based annotation of breast cancer findings. *Human-Computer Interaction. Interacting in Various Application Domains. Springer-verlag*, p. 524-533, **2009**.
- ▶ JANSSENS G., ORBAN DE XIVRY J., FEKKES S., DEKKER A., MACQ B., LAMBIN P., VAN ELMPT W., Evaluation of nonrigid registration models for interfraction dose accumulation in radiotherapy. *Med. Phys.*, 36(9), p. 4268-76, **2009**.
- ▶ OLSZEWSKI R., VILLAMIL M., TREVISAN D., NEDEL L., FREITAS C., REYCHLER, H., MACQ B., Towards an integrated system for planning and assisting maxillofacial orthognathic surgery. *Computer methods and programs in biomedicine*, 91(1), p. 13-21, **2008**.
- ▶ ORBAN DE XIVRY J., JANSSENS G., BOSMANS G., DE CRAENE M., DEKKER A., BUIJSEN J., VAN BAARDWIJK A., DE RUYSSCHER D., MACQ B., LAMBIN P., Tumour delineation and cumulative dose computation in radiotherapy based on deformable registration of respiratory correlated CT images of lung cancer patients. *Radiother & Oncol.*, Vol. 85, no. 2, p. 232-8 **2007**
- ▶ DU BOIS D'AISCHE A., GEETS X., GRÉGOIRE V., DE CRAENE M., MACQ B., WARFIELD S., Estimation of the deformations induced by articulated bodies: Registration of the spinal column. *Biomedical Signal Processing and Control*, 2(1), p. 16-24, **2007**.

## Funding

- ▶ Wallonie
- ▶ F.R.S.-FNRS

## Partnership

- ▶ Clinical: Cliniques St-Luc, Cliniques Mont-Godinne, Maastrro Clinic (NL), Massachussets General Hospital (USA)
- ▶ Academic: UPenn (USA), CREATIS (FR), UCL/MIRO
- ▶ Industrial: IBA, Telemis, Siemens, QRay

## Products and Services

- ▶ General consultancy and expertise in the domain of image processing and user interaction

## KEYWORDS

Image processing  
Registration  
Segmentation  
Annotation  
Interaction  
Atlas construction

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# Impacts of hybrid pedagogical environments on learning and teaching quality

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- ▶ Philippe MERCENIER
- ▶ Frédéric MINNE
- ▶ Denis SMIDTS

## Research Field and Subjects

Ten years ago, the IPM team started the development of a software prototype of what is called today LMS (Learning Management System). Claroline (acronym of Classrooms on line) aimed at promoting pedagogical development, overcoming technical pitfalls and giving teachers the opportunity to focus on the most important goal: students learning.

Today, the development of Claroline goes on in partnership with various departments of UCLouvain (e.g. EPL-ICTM) and with others worldwide institutions gathered in an international not for profit organisation, the Claroline Consortium.

Two main research fields are investigated:

1. User-centred design with concepts like autonomy, simplicity, intuitively and ergonomics based on teachers expectations analysis and users (including students) follow-up.
2. From a pedagogical point of view, and considering that educational institutions are today good laboratories to analyse a wide variety of hybrid configurations, the team developed a real expertise to measure pedagogical impacts of training setups, from computer augmented or knowledge-based traditional lectures to more active or interactive, contextualised environments. These hybrid pedagogical setups are at the intersection between face to face (or standard) education and distance (or continued) training. This invites educational technologists and teachers to reconsider presence and distance learning, initial and continued training, mediatisation of resources and mediation between objects and actors of education and society.

At the European level, the researchers are contributing to the "Collectif Hy-SUP" which is dedicated to the effects and the conditions of impacts of hybrid setups on training and education in higher education. On this basis, the team gets a valuable expertise on distance training and learning, offering now fully distance master degrees. These researches and developments contribute to quality learning and training for multi-sites companies and institutions in a lifelong learning and competences aware world.

## Representative References

- ▶ Collectif Hy-SUP. Vers une typologie des dispositifs hybrides de formation en enseignement supérieur. *Distances et savoirs* 1/2011 (Vol. 9), p. 69-96, **2011**.
- ▶ DOCQ F., LEBRUN M. & SMIDTS D., Analyse des effets de l'enseignement hybride à l'université : détermination de critères et d'indicateurs de valeurs ajoutées. *Revue Internationale des Technologies en Pédagogie Universitaire*, 7,3, p. 48-59, **2010**.
- ▶ LEBRUN M., DOCQ F. et SMIDTS D., Une plateforme Internet pour former les enseignants, *Education et Formation*, revue électronique de l'UMH, [En ligne], n°e-294, mis en ligne en décembre **2010**.
- ▶ LEBRUN M., DOCQ F. & SMIDTS D., Claroline, an Internet Teaching and Learning Platform to Foster Teachers' Professional Development and Improve Teaching Quality : First Approaches. *AACE Journal*, 17(4), 347-362. Chesapeake, VA: AACE, **2009**.
- ▶ DOCQ F., LEBRUN M. & SMIDTS D., A la recherche des effets d'une plate-forme d'enseignement/apprentissage en ligne sur les pratiques pédagogiques d'une université : premières approches, *Revue Internationale des Technologies en Pédagogie Universitaire*, 5,1, p. 45-57, **2008**.
- ▶ LEBRUN M., Quality Towards an Expected Harmony: Pedagogy and Technology Speaking Together About Innovation. *AACE Journal*, 15(2), 115-130. Chesapeake, VA: AACE, **2007**.

## Awards

- ▶ In 2007, the Claroline Consortium received the UNESCO prize for the use of ICT in education
- ▶ In 2007, Marcel Lebrun received the Roberval prize for his book « eLearning pour enseigner et apprendre » (Academia-Bruylant, Louvain-la-Neuve)

## Funding

- ▶ European CEE – Tempus, FP7
- ▶ Fédération Wallonie-Bruxelles
- ▶ Wallonie

## Partnership

- ▶ Université Claude Bernard, Lyon I
- ▶ Université Rennes II
- ▶ AWT (Agence Wallonne des Télécommunications)
- ▶ Ecole Centrale de Lyon
- ▶ EMLyon Business School
- ▶ HE Léonard de Vinci - ECAM
- ▶ Université Jean Monnet, Saint-Etienne
- ▶ Université Blaise Pascal, Clermont-Ferrand
- ▶ Université de Montpellier II
- ▶ Université du Luxembourg
- ▶ Université de Genève – Tecfa
- ▶ Universidad de Vigo, Spain
- ▶ Université du Québec à Montréal – Teluq
- ▶ Université du Québec à Rimouski
- ▶ Universidad Católica del Norte, Chile
- ▶ Université Mohamed Premier Oujda, Maroc
- ▶ University of Columbia, School of Law, USA

## Products and Services

- ▶ Development, diffusion and promotion of the Claroline Learning Management System.
- ▶ Hosting, support, customisation and training through the International Claroline Consortium

## KEYWORDS

Education  
Training  
E-Learning  
Competences

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# Ethical governance of information technology

## SENIOR SCIENTISTS:

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- ▶ Stephen RAINEY
- ▶ Laurence MASCLET

## Research Field and Subjects

The Laboratory for Ethical Governance of Information Technology (LEGIT) seeks to address the problem of the conditions for ethical governance of research and development of information technologies. The fundamental aims of the LEGIT are to:

- investigate and determine the conditions and applications of the relationship between ethics, governance, rationality, and technological research and development;
- focus specifically on information and computing technologies research;
- provide a framework for improved governance mechanisms that will identify and address potential ethical issues that arise from new and emerging technologies in the early stages of development.

Based on ethical norms that have been judged as legitimate and valid in specific relation to ICT, the LEGIT seeks to understand the activities through which the society attempts to act and to regulate itself.

The operational base for this research is an international network built around different research projects. These are, in particular, two current European projects on the themes of scientific and technological development, ethics, rationality, and governance. The first one is ETICA (Ethical Issues of Emerging ICT Applications) and the second one is EGAIS (Ethical GovernAnce of emerging technologies).

## Representative References

- ▶ GOUJON Ph., RAINEY St., European project EGAIS: Existing Solutions to the Ethical Governance Problem and Characterization of their Limitations - d. 4.1 **2011**.
- ▶ CARSTEN STAHL B., RAINEY St., GOUJON Ph., How to Address Ethics of Emerging ICTs, **2011**.

- ▶ GOUJON Ph., FLICK C., Ethical Governance for Emerging ICT: Opening Cognitive Framing and Achieving reflexivity in "What Kind of information society? Governance, virtuality, surveillance, sustainability, resilience": 9th IFIP TC9 international conference, HCC9 2010 and 1st IFIP TC11 international conference, CIP 2010 Held as part of WCC 2010, Brisbane Australia, September 2010 Proceeding, ed Springer, pp.98-111, **2010**.
- ▶ GOUJON Ph., FLICK C., Conditions for an effectiveness of ethical reflexivity in ICT-based projects: from theory to practice" in ETHICOMP 2010 The "backwards, forwards and sideways" changes of ICT publisher universitat Rovira i Virgili, pp.230-237, **2010**.
- ▶ GOUJON Ph., Ambient intelligence technology: critical perspective ethical and societal issues, in living and working and learning beyond technology, University of Pavia, Mantua, Italy, 24-26, conference proceedings, pp.334-354, September **2008**.
- ▶ BERLEUR J., BURMEISTER O., DUQUENOY P., GOUJON Ph., GOTTERBARN D., KAIPAINEN K., KIMPPA K., SIX B., WEBER-WULFF D., WHITEHOUSE D., Ethics of Computing Committees: Suggestions for Functions, Form and Structure Eds., On behalf of IFIP-SIG9.2.2: Eds., IFIP Press, Laxenburg- Austria, 32 p., ISBN 9783901882243, **2008**.

## Funding

- ▶ EC Projects:
  - FP6 Project (MIAUCE: multimodal interactions *analysis and exploration of users within a controlled environment*)
  - FP7 Projects (CONSIDER - civil society organizations in designing research governance, ETICA - Ethical Issues of Emerging ICT Applications, EGAIS - The Ethical Governance of Ambient Intelligence in Society)
- ▶ BNB Project: IG3T: transparency, trust and tools

## Partnerships

- ▶ T.EC Solutions Pty Sidney, Australia
- ▶ International Center for Information Ethics (ICIE)
- ▶ Fondation Internet Nouvelle Génération
- ▶ Ecole Normale Supérieure, France
- ▶ Institut Destrée, Belgium
- ▶ European Commission
- ▶ Center for Ethics Technology and Society, ICAM, Lille, France
- ▶ ALERT (Aspects of Law and Ethics Related to Technology), Middlesex University, London, United Kingdom
- ▶ UFR de Philosophie - PARIS 1
- ▶ School of Computing Science, Middlesex University, the Burroughs UK - London
- ▶ VTT Technical Research Laboratory of Finland.
- ▶ Fakultät für Kulturreflexion, Witten, Germany
- ▶ Department of Information Technology, University of Turku, Finland
- ▶ Center for Ethics Technology and Society Institut Catholique d'Arts et Métiers (ICAM), Lille, France
- ▶ Collège International de Philosophie, France
- ▶ CeTIF Università Cattolica del Sacro Cuore (UCSC), Milan, Italy
- ▶ Université de Franche Comté, France
- ▶ Karlsruhe Institute of Technology Germany (KIT), Germany
- ▶ Laboratory for Computing and Social Responsibility, Montfort University, Leicester, UK
- ▶ Delft University of Technology, The Netherlands; TNO-STB Delft, The Netherlands
- ▶ University of Twente, Enschede, The Netherlands
- ▶ Laboratory for Applied Philosophy and Public Ethics (CAPPE), Charles Sturt University, Australia
- ▶ The Castlegate Consultancy, UK

## Products and Services

- ▶ Ethics consultancy for industry, research project government laboratories
- ▶ Ethical expert for the European Commission in charge of the ethical training
- ▶ Organisation of international conferences

## KEYWORDS

Ethics  
Governance  
Information technologies  
Civil society organisation  
Democracy  
Ethical governance  
Responsible research  
Code of conduct

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# Privacy By Design

## SENIOR SCIENTISTS:

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- ▶ Cécile DE TERWANGNE
- ▶ Jean-Marc VAN GYSEGHEM

## Research Field and Subjects

We have entered the society of global media, having millions of eyes peeping in every aspect of citizens life, knowing every habit, every word typed in the network, every relation we maintain... In this pervasive "computing system"-oriented society, the very nature of the privacy is at stake. Nowadays, companies deal with billions of data that could personally identify customers, and the latter have nothing to say in the process.

Responding to the European willingness to answer issues raised by privacy and to reduce the security gaps, the Research Centre in Information, Law and Society (CRIDS) has set up a team to deepen the Privacy by Design and to circumscribe the notion of privacy. The goal within the Privacy by Design project is to achieve an acceptable level of protection for personal data and to enforce this protection in the core design of information systems.

Due to the irreversibility of advanced information technologies, privacy issues and requirements have to be considered at the very beginning of their design. Privacy by Design aims to reinforce the legal framework and the human arrangements in order to ensure people a better protection. It is a way to complete the legal framework which cannot ensure a total protection due to its nature.

As privacy is a concern of the earliest stage of software developments, the studied field applies the concept of pro-activeness. The protection relies on specific technologies that embed privacy and security principles in their source code, but also on a privacy aware management of the infrastructure/network.

The CRIDS project on Privacy by Design focuses on the following main goals:

- explore the contemporary meanings of the notion of "private" and "public";
- propound a democratic balance between security and privacy;
- design a conceptual and methodological frame for Privacy by Design requirements.

## Representative References

- ▶ GRANDJEAN N., CORNELIS M., LOBET-MARIS C., Sociological and ethical Issues in facial recognition systems: Exploring the possibilities for Improved critical assessments of technologies?, in ISM 2008 – Proceedings of the Tenth IEEE International Symposium on Multimedia), 15-17 Dec. 2008. IEEE: p. 602-608, **2008**.
- ▶ LOBET-MARIS C., GRANDJEAN N., CORNELIS M., Human Sciences and System Design - From Expertise to Situated Deliberation, ACM/ICMI 2008 Conference held in Chania (Greece), 20-22nd October **2008**.

## Funding

- ▶ European Union, FP6 – Information Society MIAUCE
- ▶ European Union, FP 7 – Information Society PRACTIS

## Partnership

- ▶ Research Center in Information Systems Engineering (PReCISE) (Belgium)
- ▶ INRIA Grenoble – Rhône-Alpes (France)
- ▶ University of Glasgow (United Kingdom)
- ▶ Visual tools (Spain)
- ▶ University of Amsterdam (The Netherlands)
- ▶ University of Tel Aviv (Israel)
- ▶ University of Lille (France)
- ▶ Middlesex University (United Kingdom)

## Products and Services

- ▶ Privacy Enhanced Technology theory
- ▶ Private and public sphere definition
- ▶ Privacy by Design requirements



**KEYWORDS**

Privacy  
Data protection  
Privacy Enhanced Technology  
Private sphere

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# Telecommunications Regulation

## SENIOR SCIENTISTS:

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- ▶ Jean-Marie CHEFFERT
- ▶ Alexandre DE STREEL

## Research Field and Subjects

Telecommunications (also referred to as electronic communications) cover networks, services and terminal equipment transmitting signals through electromagnetic means (cables, wires, optical fibre, wireless). Telecommunications constitute the backbone of the information society as a whole. A regulation that is efficient, adaptable to technology evolution and applied in a transparent way is thus of crucial importance for the European Union and its Member States as well as for the industry and ultimately for consumers. Such a regulation raises intricate legal, economic and technological issues.

Since the late 1980's, the Research Centre in Information, Law and Society (CRIDS) has addressed a number of challenging topics centred on telecommunications. It works notably on the definition and regulation of markets which are characterised by the presence of incumbent companies having a significant market power. Upon those are imposed remedies aimed at fostering competition, e.g. the obligation to grant access to their networks and other facilities necessary to allow other players to enter the market. Also, the CRIDS' research covers regulation that promotes the deployments of next generation access networks (NGA) using optical fibre and their accessibility. These networks are essential for a very fast internet access. Such issues present a perfect opportunity to address the application of both, sector specific regulation and competition law and the relationship between them.

The conditions for entering the markets are also of crucial importance. The allocation and the regulation of radio spectrum frequencies, which is a limited and valuable resource in a context of rapidly increasing demand for mobile services, are especially studied.

In a context of fast-evolving technologies with high economic relevance, it is important to avoid leaving anyone behind. For this reason, the provision of services of general economic interest (such as the universal service obligations) must be guaranteed in order to prevent or overcome the digital divide to the benefit of less prosperous populations. Consumer protection rules also receive an increasing attention by CRIDS.

Telecommunications regulation is adopted and implemented at both EU and national levels. The issue of the status, activities and principles applicable to regulators is another important aspect of the Unit's expertise. The Belgian repartition of competencies between the federal telecoms and Community media regulators, in the context of the convergence of these technologies, is finally a challenging topic for research, publications, advice and training.

## Representative References

- ▶ DEFRAIGNE Ph., DE STREEL A., Where Should the European Union Intervene to Foster the Internal Market for eComms? *Communications & Strategies* 82: 63-84, **2011**.
- ▶ DE STREEL A., The Regulated conduct defence in antitrust cases. Background paper for the OECD: 36 p., **2011**.
- ▶ DEFREYNE E., Le dividende numérique: contexte et enjeux. *R.D.T.I.* 42: 11-34, **2011**.
- ▶ QUECK R., DE STREEL A., HOU L., JOST J., KOSTA E., The EU regulatory Framework applicable to electronic communications, in GARZANITI L., O'REGAN M. (eds.), *Telecommunications, broadcasting and the internet - EU competition law and regulation*. Sweet & Maxwell: 3-262, **2010**.
- ▶ DE STREEL A., Impacts of EU policy options for revision of the universal service provision. Study for the European Commission, in partnership with Van Dijck Management Consultants: 187 p., **2010**.
- ▶ JOST J., QUECK R., *Communications électroniques et répartition des compétences : chantiers importants en cours*. *R.D.T.I.* 34: 5-27, **2009**.
- ▶ QUECK R., VAN BELLINGHEN M., STEVENS D., VALCKE P., *Droit des communications électroniques - Code thématique*. Larcier: 327 p., **2009**.
- ▶ DE STREEL A., The current and future European regulation of electronic communications: a critical assessment. *Telecommunications Policy* 32 (11): 722-734, **2008**.

## Funding

- ▶ Belgian Institute for Postal services and Telecommunications (BIPT) and other regulators
- ▶ Belgian Federal Public Service Economy, SMEs, Self-employed and Energy
- ▶ Wallonie and Deutschsprachige Gemeinschaft Belgiens
- ▶ Institut pour l'Egalité des Femmes et des Hommes (IEFH)
- ▶ European Commission and European Parliament
- ▶ European Bank for Reconstruction and Development (EBRD)
- ▶ OECD
- ▶ Telecommunications Companies

## Partnership

- ▶ Centre for European Policy Studies (CEPS) (Belgium)
- ▶ Conseil Supérieur de l'Audiovisuel (CSA) (Belgium)
- ▶ Cullen International (Belgium)
- ▶ Florence School of Regulation (Italy)
- ▶ Interdisciplinary Centre for Law & ICT (ICRI) of K.U. Leuven (Belgium)
- ▶ Wissenschaftliches Institut für Infrastruktur und Kommunikationsdienste (WIK) (Germany)

## Products and Services

- ▶ Consultancy and studies providing neutral and independent analysis
- ▶ Preparation of draft laws and regulations
- ▶ Conferences and Seminars
- ▶ Training programmes tailored to individual needs

## KEYWORDS

Electronic communications  
Broadcasting  
Sector Specific Regulation  
Competition Law  
Consumer protection  
Regulatory authorities  
Next Generation Access Networks (NGA)  
Services of General Economic Interest (SGEI)

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# Social Networking Sites

## SENIOR SCIENTISTS:

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- ▶ Claire LOBET-MARIS
- ▶ Jean-Philippe MOINY

## Research Field and Subjects

Today, social networking sites [SNSes] – Facebook, YouTube, LinkedIn, etc. – are a part of the everyday public and private lives of millions of people. These are expanding private territories over the World Wide Web, bringing numerous questions in different scientific disciplines. In other words, they constitute a promising laboratory for interdisciplinarity. In this context, the expertise of the Research Centre in Information, Law and Society (CRIDS) is threefold: sociological, legal and sciences of communication. From the legal perspective, SNSes are studied as a kind of “Cloud Computing” service. The lead researches relate to privacy, data protection, contract law and consumer protection. Taking into account private international law, public international law (applicability of the ECHR) and criminal international law, an ongoing doctoral research is more specifically related to the applicability of privacy and related rights (i.e., notably, data protection and confidentiality of information systems) to international situations.

Social networks also give rise to new social practices. By drawing on these networks, various social groups (e.g., political militants, youth, people with disease, etc.) develop different practices and assign them different meanings and strength. For instance, counseling and prevention services in the psychological field wonder about both the suitability of their presence on those networks, and the risks of using their strength to enhance or create news relationships with their addressees.

In addition, social networks raise questions about the types of social bonds they generate: Do they give rise to new types of social relations or, conversely, do they just reproduce and reinforce existing relationships? Do they allow for socially mixed and diversified publics or, on the contrary, do they lead to individual and social “identity isolation”?

A communication approach will raise the question about the massive recurrence of “rumors” and try to develop tools to understand the risks of breaking the communication framework.

## Representative References

- ▶ KLEIN A., Facebook, quand tu nous tiens..., in PROULX S., *Penser les médias sociaux - Enjeux pour la communication*. PUQ (Presses Universitaires de Québec), **2011**.
- ▶ KLEIN A., PROULX S., *Connections. Communication numérique et lien social*. PUN (Presses Universitaires de Namur): 355 p., **2011**.
- ▶ MOINY J.-P., Facebook au regard des règles européennes concernant la protection des données. *European Journal of Consumer Law*: 235-271, **2010**.
- ▶ MOINY J.-P., *Contracter dans les réseaux sociaux: un geste inadéquat pour contracter sa vie privée - Quelques réflexions en droits belge et américain*. *Revue de la Faculté de droit de l'Université de Liège*: 133-224, **2010**.

## Funding

F.R.S.-FNRS (Research Fellow)

## Partnership

- ▶ DEVOTIC
- ▶ Laboratoire de communication médiatisée par ordinateur (LabCMO) (Canada)
- ▶ Laboratoire Société, environnement et territoire (SET) (France)

## Products and Services

Good use of social networking sites in organisations

**KEYWORDS**

Social Networking Sites  
Cloud computing  
Human Rights  
Consumer protection  
Surveillance  
Democracy  
Sociability  
Social movements

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# Policy and legal issues of the Internet

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- ▶ Yves POULLET
- ▶ Robert QUECK

## Research Field and Subjects

Information and Communications Technologies have a significant legal and policy dimension. These aspects are addressed by members of the Research Centre in Information, Law and Society (CRIDS) for more than 30 years. When computer networks and Internet first unfolded, the primary concern was as how to adapt existing laws to operations carried out on the web, such as e-Commerce, delivery of copyrighted content, communicating. Were contract rules, copyright law, consumer protection, privacy or telecommunications regulations fit for the digital age? Could they simply be applied to this new channel of communication, consumption and entertainment? A primary objective of the research in ICT law is to study the equivalence of the application and enforcement of legal provisions to this new environment.

However, the web and the other digital developments have also generated new opportunities as well as new risks and threats: copyright piracy, failures to comply with privacy and consumers' rights, abuse of monopolies, digital divide and so on. More fundamentally, ICT has begged the question of the extent of the regulation of a worldwide network, both in terms of geography and scope. This raises intricate policy issues where new legal solutions or balances might be required.

Yet, law is not just an obstacle to technology. Policymakers should pay a proper attention to enact regulations that foster the development of a competitive and consumer-friendly digital economy that would be respectful of fundamental freedoms and would bring about full benefits of economic growth for all.

Finally, policy and legal issues increasingly tend to be embedded in emerging technologies, whose design aims at being, for instance, privacy-compliant. That requires an assessment of the technology by legal experts, at the early stage of its design.

Hence, in order to recommend relevant policy choices, the legal research on ICT takes several directions, from the description of applicable laws and the assessment of law compliance of technologies or digital projects, to the prospective thinking about emergent technologies, the challenges they raised and the models they create.

## Representative References

- ▶ JACQUEMIN H. et al., Guide des titulaires de sites Internet. SPF Economie: 220 p., **2011**.
- ▶ MONTERO E. et al., Guide pour les utilisateurs d'Internet. SPF Economie: 250 p., **2011**.
- ▶ POULLET Y., GUTWIRTH S., DE HERT P., LEENES R. (eds.), Computers, privacy and data protection: an element of choice. Springer: 457 p., **2011**.
- ▶ POULLET Y., HENROTTE J.-F., Code du Droit des Technologies de l'Information et de la Communication. Larcier: 1094 p., **2011**.
- ▶ ROUVROY A., HILDEBRANDT M. (eds.), Law, human agency and autonomic computing : the philosophy of law meets the philosophy of technology. Routledge: 227 p., **2011**.
- ▶ POULLET Y., BULLESBACH A., GIJATH S., PRINS C. (eds.), Concise European IT Law. Kluwer: 628 p., **2010**.
- ▶ DUSOLLIER S., DE TERWANGNE C. (eds.), Chronique de jurisprudence en droit des technologies de l'information (2002-2008). R.D.T.I. 35: 175 p., **2009**.
- ▶ QUECK R., VAN BELLINGHEN M., STEVENS D., VALCKE P., Droit des communications électroniques – Code thématique. Larcier: 327 p., **2009**.

## Awards

Y. POULLET is a member of the Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique (2009).

## Funding

- ▶ European Union (FP6, FP7)
- ▶ Belgian Federal Government
- ▶ F.R.S.-FNRS

## **Partnership**

ECLIP: University of Münster (Germany), University of Oslo (Norway), Queen Mary College of London (UK), University of the Balearic Islands (Spain)

## **Products and Services**

- ▶ Policy and legal analysis and recommendations
- ▶ Assessing risks and legal issues of Information technologies, models and scenarios
- ▶ Ensuring the legal compliance of Internet and other ICT projects
- ▶ Practical guide on legal issues and concerns for the Internet users and entrepreneurs
- ▶ Assessing the legal dimension of the design and deployment of technologies

## **KEYWORDS**

Internet policy, law and regulation  
E-Commerce  
Privacy  
Cyberlaw  
Ethics  
Electronic communications  
Copyright  
Piracy

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## E-Health: Legal aspects

### SENIOR SCIENTISTS:

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- ▶ Jean-Marc VAN GYSEGHEM

### Research Field and Subjects

ICT dissemination is part of a new management of healthcare which takes into account both patient's and practitioner's rights – mainly their right to respect for private life. Hospitals and practitioners are setting up telematic networks supporting the exchange of patient's data –within or outside their usual precincts. The Belgian Government created a platform aiming at improving and developing a secure exchange of data in the healthcare sector. In the same time, the privately operated "Walloon Health Network" is growing larger and covers a substantial part of the market. In any case, these platforms have to comply with privacy and data protection requirements which have to be considered for both the patient and the practitioner.

The European Union funds research projects that share resources (including medical databases) with, in view, high-quality healthcare and scientific research. Companies offer new e-Health products and services to practitioners, hospitals, funding agencies and patients. The latter are increasing their hold on the management of their health and on the use made of their data. All these elements raise legal concerns amongst them privacy and data protection issues. Today, those matters are exacerbated by the Web 2.0 and Cloud Computing phenomena.

The work of the Research Centre in Information, Law and Society (CRIDS) in e-Health focuses mainly on the following topics:

- Processing of personal data concerning both patients and practitioners;
- Medical Devices and e-Health Services;
- Electronic Health Records;
- Management of health databases;
- Government's role in the offer of e-Health products and services;
- Patient's rights and duties.

CRIDS possesses a strong expertise in e-Health products and services thanks to its participation to numerous projects:

- European projects: EUROCARDS (1994), TRUSTHEALTH (1996), GEMSS (2002), Research and assistance in the field

of transfers of personal data from Member States to third countries (2003), ACGT (FP6, IP, 2006), SHARE (2006), Legally eHealth (2006)

– Belgian projects: Data Processing for Scientific Purposes, Citizen Legal Protection and Medical Trial, ARTHUR, IRIS 1, 2 & 3, Hospital New Concept, DMMG, ALTEM, WALIBI, Meditel, Walloon Health Network, GSK, etc.

### Representative References

- ▶ HERVEG J., La protection des données du patient à l'hôpital. Kluwer: 110 p., **2009**.
- ▶ VAN GYSEGHEM J.-M., Les patients : usagers ou simples bénéficiaires de droits sur le réseau, in Passager du réseau. Cahiers de l'Institut wallon pour la santé mentale 5: 36-44, **2009**.
- ▶ VAN GYSEGHEM J.-M., eHealth services and directive on electronic commerce 2000/31/EC", in DE CLERCQ E. et al. (eds.), Collaborative Patient Centred eHealth. IOS Press: 57-66, **2008**.
- ▶ HERVEG J. (éd.), La protection des données médicales. Les défis du XXI<sup>e</sup> siècle - The protection of medical data. Challenges of the 21st century. Anthémis: 217 p., **2008**.
- ▶ HERVEG J., Panorama des responsabilités liées aux services et produits de la santé en ligne en droit européen, in DUGUET A.-M., FILIPI I. et HERVEG J (Eds.), Evolution récente des actions en responsabilité médicale en France : comparaison avec l'étranger. Les Etudes Hospitalières: 69-118, **2008**.
- ▶ VAN GYSEGHEM J.-M. et al., The ACGT ethical and legal requirements. ACGT project: 194 p., **2007**.
- ▶ VAN GYSEGHEM J.-M., L'information génétique et le traitement des données à caractère personnel, in DUGUET A.-M., FILIPI I., HERVEG J (éds.), Séminaire d'actualité de droit médical – Dossier médical et données médicales de santé. Etudes Hospitalières: 243-257, **2007**.
- ▶ HERVEG J., La gestion des risques spécifiques aux traitements de données médicales en droit européen, in HERVÉ Chr et al. (éds.), Systèmes de santé et circulation de l'information, Encadrement éthique et juridique. Dalloz: 79-103, **2007**.



## Awards

The Research Report “Legally eHealth” has been designated “Study of the Month” in February 2007 by the European Commission (ICT for Health - Information Society and Media DG) and published in March 2008 by the European Commission

## KEYWORDS

Privacy  
Data protection  
Health law  
E-Health  
Medical Devices  
Health Services

## Funding

- ▶ European Commission (FP6, FP7)
- ▶ Wallonie
- ▶ Fédération Wallonie-Bruxelles
- ▶ Belgian Federal Government
- ▶ Companies

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## Partnership

- ▶ CETIC (Belgium)
- ▶ Université catholique de Louvain, ICTeam (Belgium)
- ▶ Narilis (Belgium)
- ▶ Custodix (Belgium)
- ▶ Centre for Data Protection (Belgium)
- ▶ University of Montreal, CRDP (Canada)
- ▶ IIREB (France – Canada)
- ▶ Paul Sabatier University – Toulouse III, Faculty of Medicine (France)
- ▶ University of Coimbra, Centre de Direito Biomédico (Portugal)
- ▶ University of the West of England, FET (United Kingdom)
- ▶ University of Southampton, The IT Innovation Centre (United Kingdom)
- ▶ European Summer School (21 partners)

## WEB SITE

<http://www.crids.be>

## Products and Services

- ▶ Training
- ▶ Legal Analysis and Support

# E-Archiving and Records Management

## SENIOR SCIENTISTS:

- ▶ Etienne MONTERO
- ▶ Marie DEMOULIN

## Research Field and Subjects

Both public and private sector are concerned by electronic archiving for several reasons: economic, legal or historic value of the data, better management, security, legal obligation...

But a long term preservation of electronic documents remains a challenge. It is indeed crucial to preserve legibility, integrity and authenticity of electronic records, despite the rapid, permanent and unpredictable evolution of technologies (hardware and software) and the fragility of the data medium. These issues must be considered from the creation of the document to its end, i.e. during its complete cycle of life. The digital heritage of information society is at stake.

The problem is not new and great progress has been made in the field of records management. However, substantial efforts are still needed to increase awareness of e-archiving issues and develop appropriate and flexible solutions, from a technical, management and legal point of view.

From a legal perspective, a number of critical questions are identified and addressed by the Research Centre in Information, Law and Society (CRIDS). The first and tricky issue raised by e-Archiving is the legal value of the electronic archive, especially as a means of evidence. The question is important not only for "digital native" documents, but also for scanned ones.

It is also essential to comply with the rules imposed for control or validity purposes, notably in terms of location, duration, medium, authentication or confidentiality, both in private and public sectors. In certain cases, European companies will also have to comply with American e-Discovery rules.

Archiving personal data will also impose duties in terms of privacy. In particular, archiving of e-Mails will raise problems with regard to the secrecy of communications.

E-Archiving is a business in itself. Some companies or administrations would like to recourse to a trusted third party for the archiving of their documents. Such an outsourcing, if allowed by law, also raises questions with regard to the level of

service, contractual duties or reversibility. Moreover, the use of cloud computing to perform secure e-Archiving is controversial and should be carefully examined.

## Representative References

- ▶ DEMOULIN M., Variations sur l'écrit électronique: aspects de droit comparé, in Proceedings of the L. R. Wilson Chair in Information Technology and E-Commerce Law, University of Montreal, Canada, Augustus **2011**.
- ▶ DEMOULIN M., L'archivage électronique et le droit: entre obligations et précautions, in Proceedings of the Conference on the Legal aspects of electronic archiving Namur, Belgium, May **2011**.
- ▶ DEMOULIN M., Quelques aspects juridiques de l'archivage électronique, in Proceedings of the 11th International Days of the Archives, Université catholique de Louvain, Louvain-la-Neuve, Belgium, March **2011**.
- ▶ DEMOULIN M., The legal value of electronic documents: the next steps, in Proceedings of the International conference on Electronic Commerce, Brussels, October **2010**.
- ▶ DEMOULIN M., VAN GYSEGHEM J.-M., L'archivage des courriers électroniques: aspects juridiques, in Proceedings of the workshop on electronic archiving of emails, Namur, Belgium, May **2009**.
- ▶ MONTERO E., Vers un cadre juridique pour les services de confiance? L'expérience belge, in Proceedings of the L. R. Wilson Chair on Confiance et environnements électroniques, University of Montreal, Canada, October **2008**.
- ▶ DEMOULIN M., L'archivage électronique en droit belge, for the 37th Congress of the Archivists Association of Quebec, Quebec, Canada, May **2008**.
- ▶ MONTERO E., DEMOULIN M., COOL Y., MARCHETTI R., Mise en œuvre d'un cadre juridique pour les services de confiance, Report for the Belgian FPS Economy, **2007**.

## **Funding**

- ▶ European (ERDF)
- ▶ Wallonie
- ▶ SPF Economie, P.M.E., Classes moyennes et Energie

## **Partnership**

- ▶ University of Montreal (Canada)
- ▶ States Archives in Belgium
- ▶ FedISA International – Federation of Information Lifecycle Management, Storage and Archiving (France)
- ▶ FedISA Belgium – Belgian Federation of Information Lifecycle Management, Storage and Archiving (Belgium)

## **Products and Services**

- ▶ Organisation of workshops and courses on the legal aspects of e-archiving and records management
- ▶ Study of the legal aspects of an e-archiving project and records management

## **KEYWORDS**

Electronic archiving  
Records management  
Enterprise Content Management (ECM)  
Information Lifecycle Management (ILM)  
E-Signature  
Trusted Third Party  
Cloud computing  
E-Government

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# Copyright and the Internet

## SENIOR SCIENTISTS:

- ▶ Séverine DUSOLLIER
- ▶ Caroline KER
- ▶ Caroline COLIN

## Research Field and Subjects

The digital environment offers new opportunities for creators to achieve and disseminate their works, but it also raises the challenge of the effective protection of their rights. Digital copying of works is easy, fast and inexpensive and dissemination of these copies in the world is done in a few clicks. Technical means, such as streaming or peer-to-peer file-sharing, allow communication of music, movies, software, TV series, e-books, without the consent or remuneration of the authors and producers. Copyright law and enforcement need to adapt to such challenges, particularly to fight what some call a “piracy” widespread. In parallel, copyright-protected works feed the cultural, informational and entertainment content on the Internet. They are now offered in new services (e.g. video-on-demand, social networks, mobile services...) and by new actors (e.g. iTunes, Belgacom TV, YouTube, Google). Fostering the developments of adequate and lawful business models to provide for digital content is also a matter for copyright law, whose territoriality-based rules and practices sometimes raise concern.

The regulatory framework for copyright law (national, European or international) has been profoundly altered in the last 15 years to adapt to the challenges and the threats posed by the digital development and by the increasing piracy on the Internet. This adjustment has raised - and continues to raise - many legal issues, particularly concerning the proper balance of copyright, between protection of the rights of authors and the creation and the safeguarding of a public access to culture and information.

New methods of copyright enforcement have been deployed, such as Digital Rights Management that overrides copyright law in many regards. Private copying and other limitations of copyright are increasingly at stake as they are not guaranteed on the Internet. Copyright might also stand in the way of development of projects with a significant public value such as digital libraries or digital learning.

The fate of creation in the digital age also can not do without a sociological and philosophical approach. Internet revived the debate on the notion of author and work, the status of

information, the conditions for the collective and collaborative creation, and more generally on artistic practices in the information society. Wiki creation, user generated content (born in the Web 2.0), open access and open source creation raise challenging legal and sociological questions.

All these issues are key to research and teaching of the Research Centre in Information, Law and Society (CRIDS) and its Intellectual Property Unit.

## Representative References

- ▶ COLIN C., *Droit d'utilisation des œuvres*. Larcier Coll. CRIDS: 32, 1<sup>ère</sup> édition **2012**.
- ▶ DUSOLLIER S., *DRM at the intersection of copyright law and technology: a case study for regulation*, in *Governance, Regulations and Powers on the Internet*. Cambridge University Press: forthcoming, **2011**.
- ▶ DUSOLLIER S., COLIN C., *Peer-to-peer File-sharing and Copyright: What could be the role of Collective Management*. *Columbia Journal of Law and the Arts*: forthcoming, **2011**.
- ▶ COLIN C., *Registers, Databases and Orphan Works*, in DERCLAYE E. (ed.), *Copyright and Cultural Heritage: Preservation and access to works in a digital world*. Edward Elgar Publishing: 28-50, **2010**.
- ▶ DUSOLLIER S., *The relations between copyright law and consumer's rights from a European perspective*. European Parliament: 39 p., **2010**.
- ▶ DUSOLLIER S., KER C., *Private copy levies and technical protection of copyright: the uneasy accommodation of two conflicting logics*, in E. Derclaye (ed.), *Research handbook on the future of EU copyright*. Edward Elgar: 349-72, **2008**.
- ▶ DUSOLLIER S., *Droit d'auteur et protection des œuvres dans l'univers numérique – Droits et exceptions à la lumière des dispositifs de verrouillage des œuvres*. Larcier: 619 p., **2007** (2<sup>nd</sup> ed.).

## Awards

The CRIDS has been selected by the European Parliament as one of its five experts in copyright law.

## Funding

- ▶ Wallonie
- ▶ European Union (FP6, FP7)
- ▶ Fédération Wallonie-Bruxelles
- ▶ F.R.S.-FNRS
- ▶ FUNDP

## Partnership

- ▶ European thematic network COMMUNIA (Copyright and the public domain) (some 30 countries are represented)
- ▶ European thematic network LAPSI (Legal aspects of public sector information) (some 20 countries are represented)
- ▶ Belgian Council of Intellectual Property
- ▶ Association Littéraire et Artistique Internationale (ALAI) (28 countries are represented)
- ▶ Association for Teaching and Research in Intellectual Property (ATRIP) (some 300 members of various countries)
- ▶ ECLIP: University of Münster (Germany), University of Oslo (Norway), Queen Mary College of London (UK), University of the Balearic Islands (Spain)
- ▶ Creative Commons (Belgium)

## Products and Services

- ▶ Copyright clearance for any digital project (digitisation, on-line provision of content, cloud computing, digital libraries, distance learning, ...)
- ▶ Analysing the application of copyright on the Internet
- ▶ Policy and legal analysis and recommendations in copyright law
- ▶ Assessing the collective management of copyright in Europe
- ▶ Assessing the legal dimension of the design and deployment of digital rights management.

## KEYWORDS

Copyright & Internet  
Peer-to-peer  
Digital Rights Management  
Private copying  
Piracy  
Access to culture  
Authorship  
Digital libraries

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# Legal Aspects of Cloud Computing

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- ▶ Jean-Marc VAN GYSEGHEM
- ▶ Jean-Philippe MOINY

## Research Field and Subjects

With the amazing development of telecommunication technologies and the exponential increase of bandwidth and storage capacities, computing has evolved to a point where isolated machines are not pertinent anymore. Computing is now mainly based upon communication between servers, clients, data centres and networks. The current trend is the mutualisation of resources in order to maximise their allocation and to benefit from economies of scale. It allows the centralisation of machinery, calculation power, memory and software, as well as the supply of such resources amongst clients, according to their constantly actualised needs. These evolutions and tendencies have given birth to a federating but quite blurred concept, namely "Cloud Computing". This model is characterised by the remote use of shared pool of external resources (memory, CPU, software, platforms, virtual machines, data,...), which are at the disposal of the users by on-demand network access on an permanent, adaptable and scalable basis. It offers an easier and cheaper access to the needed computing capabilities, through a certain dispossession of the user.

This new model entails changes of practices and has major consequences from a legal perspective. These issues henceforth constitute an important part of the activities of the Research Centre in Information, Law and Society (CRIDS). First of all, one will note that this more or less systematic externalisation of the computing infrastructures and resources creates a shift towards a system based on service contracts, where the customer is extremely dependent on the cloud and the network providers, permanently relying on these services to drive his business or simply to live his everyday life (e.g., using a social network site). Hosting and processing information in the cloud and its transfer beyond the state's boundaries have also important legal consequences, especially when personal data or confidential data are involved. Sustainability, confidentiality and integrity of the data in the cloud, as well as security of the "network", are crucial issues to be dealt with in a proper and legitimate manner. Cloud computing also creates changes of paradigms and of strategies in the field of intellectual property. The property of data, code and IP rights in and to the cloud are to be carefully analysed. The debates as to how to legally frame interoperability and standardisation are also of particular relevance in the cloud

computing world. Enforcement of law and crime prosecution in the cloud also raise new challenges. The cloud and virtualisation technologies allow the clients to install, configure and use remotely "virtual machines", the location of which could be unknown from users and third parties. When rights, such as IP rights for instance, are violated, or if crimes are committed in such context, it is heavily burdensome to determine the illegitimate acts or actions, to identify the responsible persons and to localise the incriminated data and files.

## Representative References

- ▶ POULLET Y., VAN GYSEGHEM J.-M., MOINY J.-P., GÉRARD J., GAYREL C., Data protection in the clouds, in GUTWIRTH S., POULLET Y., DE HERT P., LEENES R. (eds.), *Computers, privacy and data protection : an element of choice*. Springer: 377-409, **2011**.
- ▶ VAN GYSEGHEM J.-M., *Cloud computing et protection des données à caractère personnel : mise en ménage possible?* R.D.T.I. 42: 35-50, **2011**.
- ▶ POULLET Y., VAN GYSEGHEM J.-M., GÉRARD J., MOINY J.-P., GAYREL C., *Cloud computing and its implications on data protection - discussion paper*. Council of Europe, Project on Cybercrime: 28 p., **2010**.

## Funding

- ▶ Council of Europe
- ▶ European Union
- ▶ IT Companies

## Partnership

- ▶ Queen Mary, University of London (UK)
- ▶ CETIC (Belgium)
- ▶ IT Companies

## Products and Services

- ▶ The CRIDS closely follows the evolution of “cloud computing”, and studies its legal and social implications from different points of view, including data protection, intellectual property protection, liability, computer crimes, contractual practices and other regulatory aspects, and provides studies on the topic.
- ▶ The CRIDS’s team conducts researches and drafts scientific reports and articles on the topic.
- ▶ The CRIDS organises and participates to national and international legal conferences related to the cloud computing technology.
- ▶ The CRIDS has also created a regional think tank gathering experts from different sectors and fields of activity.

## KEYWORDS

Cloud computing  
IT law  
Data protection  
E-Commerce  
Intellectual property  
Contract law  
Service level agreements  
Computer criminality

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# E-Government

## SENIOR SCIENTISTS:

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- ▶ Claire LOBET-MARIS
- ▶ Elise DEGRAVE
- ▶ Marie DEMOULIN

## Research Field and Subjects

The legal issues raised by e-government (e-gov) are manifold. Almost all legal disciplines may be involved, depending on the considered project.

Thus, the online forms for citizens must consider the issues of form, validity and proof. The sharing of software between services raises issues of intellectual property and IT contracts. The development of the eID platforms and the management of access to various databases maintained by the State involve respect for privacy (principles of necessity, proportionality...). The legal framework for authentic sources used by the government also constitutes a major challenge for governments. Finally, the implementation of European legislation on the reuse of information from the public sector (open data) requires adjustments to the federal and regional legal framework. This raises, among others, some issues of intellectual property and personal data protection.

But e-gov raises also sociological and institutional concerns, important to the future of our democracy and the role of the state. The concepts of interoperability and of integration, which are very popular in computer science and are promoted for e-gov, raise wide institutional concerns regarding the roles and responsibilities of the various federated entities. The modernisation of public administration also means the introduction of organisational changes which have to be explored. Finally, the state has a critical role in social cohesion and integration of all. Modernisation and the use of ever more advanced technologies of information can lead to make its access difficult for some citizens, but also to 'govern' increasingly using aggregated data in profiles, models or types both very normative and reductive of the citizens' living experience.

The expertises of the CRIDS regard:

- The legal frame of the e-gov;
- The organisational change management;
- The assessment of ethical, political and sociological impacts of e-government.

## Representative References

- ▶ de TERWANGNE C. et MOINY J.-Ph., « À la croisée de la publicité de l'administration, de la réutilisation des informations du secteur public et de la protection des données : l'exemple de la directive INSPIRE », *C.D.P.K.* n° 2, pp. 121-141., **2010**.
- ▶ de TERWANGNE C., DE ROY D., POULLET Y., « La Convention européenne des droits de l'homme en filigrane de l'administration électronique », *Entre ombres et lumières : cinquante ans d'application de la Convention européenne des droits de l'homme en Belgique*, coll. de la Faculté de droit de l'ULB, Bruxelles, Bruylant, pp. 283-357, **2008**.
- ▶ de TERWANGNE C., « La protection des données à caractère personnel et l'e-gouvernement » in *Défis du droit à la protection de la vie privée - Perspectives du droit européen et nord-américain. Challenges of Privacy and Data Protection Law – Perspectives of European and North American Law*, coll. Cahiers du Centre de Recherches Informatique et Droit, n° 31, Bruxelles, Bruylant, pp. 505-511, **2008**.
- ▶ LOBET-MARIS Cl. et de TERWANGNE C., de l'E-Gouvernement au gouvernement en réseau : questions de recherche pour les sciences sociales, In *Revue Terminal*, Issues 99-100, **2007**.

## Funding

- ▶ Wallonie
- ▶ BELSPO
- ▶ European FP



## Partnership

- ▶ Easi-Wal (Wallonie)
- ▶ CADA (Commission belge d'accès et de réutilisation des documents administratifs)

## Products and Services

- ▶ Legal support for e-gov projects: drafting of legislation, legal assistance for data protection, for issues regarding authentic sources, public archives...
- ▶ Organisational support for e-gov projects: changes management, organisation's analysis, social and ethical requirements.

## KEYWORDS

Simplification  
Modernisation  
Public administration  
Open Data  
Public archives

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# Technology Assessment & Governance

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- ▶ Claire LOBET-MARIS
- ▶ Antoinette ROUVROY

## Research Field and Subjects

The Technology Assessment is a set of methods and techniques to give voice to people in the shaping of the technologies and of the sciences & technologies policies. It aims at driving our technological environment not only with economic and technical criteria, but also on basis of legal, ethical and social concerns. In the field of IT, Technology Assessment is fundamental to the extent that the technologies are shaping our lifestyles, our social interactions and our political organisations. But Technology Assessment is also really critical when considering the irreversibility and the pervasiveness of some emerging information and communication technologies. This is particularly the cases for very critical systems as those related to the surveillance technologies and to the medical ones for which CRIDS has developed a unique expertise in Europe.

The Research Centre in Information, Law and Society (CRIDS) considers Technology Assessment as a set of methods and techniques that improve the democratic deliberation of our future technological environment and therefore their social acceptability.

The expertises of CRIDS are:

- Risks assessment of technological systems;
- Public deliberation of technological choices;
- Delphi survey with experts on prospective scenarios;
- Ethical governance of projects.

## Representative References

- ▶ LOBET-MARIS C., GRANDJEAN N., Le corps ne ment pas. Traversée éthique des technologies de la surveillance, In Gérer & comprendre. Revue des Annales des Mines: Mars **2012**.
- ▶ HILDEBRANDT M., ROUVROY A., A. *Law, Human Agency and Autonomic Computing - Philosophers of Law Meet Philosophers of Technology*. Routledge, **2011**.
- ▶ GRANDJEAN N., CORNELIS M., LOBET-MARIS C., Sociological and ethical Issues in facial recognition systems: Exploring the possibilities for Improved critical assessments of technologies?, in ISM 2008 – Proceedings of the Tenth IEEE International Symposium on Multimedia), 15-17 Dec. 2008. IEEE: p. 602-608, **2008**.
- ▶ ROUVROY A., Privacy, Data Protection, and the Unprecedented Challenges of Ambient Intelligence. *Studies in Ethics, Law, and Technology*, Vol. 2, Iss. 1, Article 3: 1-54, **2008**.

## Funding

- ▶ Wallonie
- ▶ BELSPO
- ▶ Europe FP

## Partnership

- ▶ COST 298 ([cost298.org](http://cost298.org))
- ▶ ESST (European Network in Sciences Society and Technology)
- ▶ Réseau FNRS Sciences Technologie et Société

## Products and Services

- ▶ Methodologies and tools for active technological choices' deliberation
- ▶ Methodologies and tools for DELPHI survey
- ▶ Methodologies and tools for ethical governance of ICT's projects.

## KEYWORDS

Ethics  
Assessment  
Impacts  
Risks  
Democracy  
Deliberation

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# Calcul Intensif et de Stockage de Masse (CISM)

## SENIOR SCIENTISTS:

- ▶ Thomas KEUTGEN
- ▶ Bernard VAN RENTERGHEM
- ▶ Luc SINDIC
- ▶ Damien FRANCOIS

## Research Field and Subjects

CISM is an inter-disciplinary high-performance computing facility. It was created in 2004 by, and for, the scientists engaged in the field of numerical simulations. Since then, CISM has empowered researchers from many distinct areas with the ability to refine models, test theories, and develop algorithms, up to levels which cannot be attained with simple workstations or local servers.

In 2010, the CISM facilities have been used to produce more than 60 high-quality scientific publications in research areas such as climatology, nuclear physics, analytic chemistry, materials engineering, nanotechnologies, theoretical physics, optics, numerical mechanics, and nonparametric statistics. No less than 28 distinct research poles, belonging to 5 universities, use the CISM computing power on a regular basis for their projects.

The CISM facilities allow one to produce and/or process very large amounts of data, but also to apply costly algorithms to more reasonably-sized datasets. Users can rely on a strong and recognised know-how and expertise in parallel programming, optimised libraries, and diverse compilers. The CISM facilities are also equipped with many scientific computing software's, both generalist and highly specialised.

Besides high-performance computing, CISM offers high-performance storage of the data so they can be accessed from the computing facilities and the researcher workstations rapidly, securely, and safely.

## Funding

Fonds de la recherche scientifique (F.R.S.-FNRS)

## Partnership

- ▶ CÉCI: « Consortium des Equipements de Calcul Intensif », supported by the FNRS. CÉCI includes the HPC centres of the universities in Belgian French Community.
- ▶ BEGRID: Belgian GRID Initiative for research BeGrid, coordinated by Belnet.
- ▶ SMCS: Plateforme technologique de Support en Méthodologie et Calcul Statistique of UCL

## Main Equipment

- ▶ The CISM facilities consist mainly of 3 clusters for a total of more than 2100 CPU cores and 18 Tflops peak and nearly 8 TB of RAM:
  - Lemaitre: 256 CPU AMD Opteron 252@2.6 Ghz and 96 CPU Intel Xeon 5520@2.27 GHz, SDR Infiniband low latency interconnect + 8 SMP machines with up to 128 GB of memory.
  - GREEN: 932 CPU Xeon L5420@2.5 GHz, GbE interconnect.
  - HMEM (in collaboration with CÉCI): 816 CPU AMD Opteron 6174@2.2 GHz, up to 512 GB of RAM per node, QDR Infiniband interconnect.
- ▶ A new cluster (in collaboration with CÉCI) containing more than 1000 CPU cores, is planned for the beginning of 2012.
- ▶ The CISM also safely and securely hosts more than 250 TB of data accessible though high-bandwidth networks.
- ▶ All the equipment is located in two computing rooms equipped with water-cooling and air-cooling systems.

## Products and Services

- ▶ Installation, configuration, and optimisation of hardware and software infrastructures for high-performance computing
- ▶ Training regarding all user-related aspects of high-performance computing: code optimisation, parallelisation, optimised libraries, compilers, cluster computing, GPU computing.
- ▶ User support for code optimisation in Fortran, C/C++, Python, and other languages.
- ▶ User support for cluster usage: remote access, scripting, job resource evaluation, etc.
- ▶ Access to fully licensed professional compilers and other commercial scientific software.

## KEYWORDS

High Performance Computing  
Super (very large) computers  
Parallel programming/algorithm  
Distributed file systems / Mass storage  
Batch processing systems  
Numerical algorithms

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# Interuniversity Scientific Computing Facility

## SENIOR SCIENTISTS:

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- ▶ Benoît CHAMPAGNE
- ▶ Olivier DEPARIS
- ▶ Luc HENRARD
- ▶ Philippe LAMBIN
- ▶ Daniel P. VERCAUTEREN
- ▶ Frédéric WAUTELET
- ▶ Johan WOUTERS

## Research Field and Subjects

The interuniversity Scientific Computing Facility was created in 1985 to help Belgian scientists working in the fields of theoretical physics and chemistry to access powerful computing resources in a constructive spirit of know-how sharing. Since that time, the computing resources have roughly doubled every two years, reaching a theoretical performance of 9 Tflops in the current cluster configuration.

The organisation of the centre is still thematic and oriented towards solving problems in computational physics and chemistry, bringing in the simplification of a coherent tool optimised for a focused objective. At the nanoscale, quantum chemistry and numerical solid state physics merge and share common numerical tools.

The iSCF allows us to perform quantum chemistry calculations with growing complexity and sophistication, so that the systems under study today are clearly in the scale range of macromolecules, supramolecules, and nanostructures. On the other end, physics of solid materials extend into the less symmetric cases of structured materials and nanoparticles. Present investigations tackling chromophores, proteins and DNA strands in interaction with drugs, carbon (nano) clusters, nanotubes and (nano)sheets (including graphene), and inorganic mesoporous materials address their structural, thermodynamical, electronic, optical, magnetic, and vibrational properties.

Over recent years, the iSCF project has also included theoretical developments in the field of photonics, as needed for the control of light fluxes in transport, photovoltaic devices, logical devices. In this direction, new methodologies are proposed to address biomimetic materials and plasmonic systems. For example, the reverse engineering of natural structures implies developing large-scale simulations of electromagnetic waves propagation in highly complex structures.

## Representative References

- ▶ LABIDI S.N., KANOUN M.B., DE WERGIFOSSE M. and CHAMPAGNE B., *Theoretical Assessment of New Molecules for Second-Order Non-linear Optics*, Int. J. Quantum Chem. 111, 1583-1595, **2011**.
- ▶ VIGNERON J.P., SIMONIS P., AIELLO A., BAY A., WINDSOR D.M., COLOMER J.F., and RASSART M., *Reverse color sequence in the diffraction of white light by the wing of the male butterfly *Pierella luna* (Nymphalidae: Satyrinae)*, Phys. Rev. E 82, 021903, **2010**.
- ▶ GRESH N., AUDIFFREN N., PIQUEMAL J.P., DE RUYCK J., LEDECQ M. and WOUTERS J., *Analysis of the interactions taking place in the recognition site of a bimetallic Mg(II)-Zn(II) enzyme, isopentenyl diphosphate isomerase: a parallel quantum-chemical and polarizable molecular mechanics study*, J. Phys. Chem. B, 114, 4884-4895, **2010**.
- ▶ VIGNERON J.P. and SIMONIS P., *Structural Colours*, in Jérôme Casas and Stephen J. Simpson, editors: *Advances in Insect Physiology*, Academic Press (Burlington) Vol. 38, pp. 181-218, **2010**.
- ▶ GUTHMULLER J., CECCHETTI F., LIS D., CAUDANO Y., MANI A.A., THIRY P.A., PEREMANS A. and CHAMPAGNE B., *Theoretical simulation of vibrational sum-frequency generation spectra from density functional theory: Application to p-nitrothiophenol and 2,4-dinitroaniline*, ChemPhysChem 10, 2132-2142, **2009**.
- ▶ DEPARIS O., VIGNERON J. P., AGUSTSSON O. and DECROUPEL D., *Optimization of photonics for corrugated thin-film solar cells*, J. Appl. Phys. 106, 094505, **2009**.
- ▶ LEHERTE L. and VERCAUTEREN D.P., *Coarse Point Charge Models For Proteins From Smoothed Molecular Electrostatic Potentials*, J. Chem. Theory Comput., 5, 3279-3298, **2009**.
- ▶ POPOV V.N., HENRARD L. and LAMBIN Ph., *Resonant Raman spectra of graphene with point defects*. Carbon 47,2448-55, **2009**.
- ▶ LIÉGEOIS V., RUUD K., and CHAMPAGNE B., *An analytical derivative procedure for the calculation of vibrational Raman optical activity spectra*, J. Chem. Phys. 127, 204105, **2007**.

## Awards

Triennial Prize of the Belgium Royal Society of Chemistry (2003: Benoît CHAMPAGNE, 2009: Johan WOUTERS)  
In 2009, Luc HENRARD received a 'Special recognition diploma' by the World Cultural Council

## Funding

F.R.S.-FNRS, European (FP6, FP7), Wallonie, Fédération Wallonie-Bruxelles (ARC), IAP 6/27

## Partnership

- ▶ University of Mons (The iSCF is a shared high-performance computing center with UMons)
- ▶ University of California in Santa Barbara (USA)
- ▶ University of Bordeaux (France)
- ▶ University of Sherbrooke (Canada)
- ▶ Osaka University (Japan)
- ▶ KULeuven, UCLouvain, UHasselt, Ugent, ULB
- ▶ Université Pierre et Marie Curie – Paris 6
- ▶ Université Diderot – Paris 7
- ▶ Natural History Museum – London
- ▶ Linköping University (Sweden)
- ▶ University of Stockholm (Sweden)
- ▶ Moscow State University (Russia)

## Main Equipment

iSCF cluster consists of 85 computing nodes for a total of 792 cores with a peak performance of 9 Tflops, 6 interactive nodes from which jobs can be submitted to the job scheduler to run on the nodes and two file servers with about 45 TB of disk space available. There are two main types of compute nodes:

- 58 nodes with 16 or 64 GB of memory, dual Quad-Core Intel Xeon X5460.
- 25 nodes with 36 or 72 GB of memory, dual Six-Core Intel Xeon X5650.

## Products and Services

Elaboration and implementation of methods of theoretical chemistry and physics as well as of optics  
Simulations of structural, electronic, optical, magnetic, and vibrational properties of molecules, supramolecules, clusters, polymers, surfaces, and crystals.

## KEYWORDS

Theoretical and Quantum chemistry  
Theoretical Physics  
Scientific Computing  
Electronic properties  
Optics  
Photonic crystals  
Biophotonics  
Plasmonic

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# Web-based environments for English use in professional and academic settings

## SENIOR SCIENTISTS:

- ▶ Sylviane GRANGER
- ▶ Magali PAQUOT

## Research Field and Subjects

The Centre for English Corpus Linguistics (CECL) specialises in the use of corpora and corpus linguistics techniques to inform needs driven English writing aid tools. Its research expertise covers every aspect of design and production of web-based environments for English use in professional and academic settings, and includes (1) corpus building, (2) extraction of domain-specific terminology, (3) lexicographical analysis of words, (4) warnings against common difficulties and errors and (5) pedagogical materials development (e.g. tailor-made exercises).

The CECL's hallmark lies in the systematic use of corpora, i.e. large databases of texts, to conduct its research. Corpora of expert writing are used to provide detailed lexicographical descriptions of words in terms of meaning, translation, frequency, collocations and recurrent phrases. Learner corpora (i.e. corpora of non-native writing) serve to investigate non-native writers' difficulties. Various automated techniques are used to analyse corpora, e.g. keyword identification, n-gram extraction and collocation analysis.

After a fruitful collaboration with the ILT KULeuven on a University Terminology database, i.e. a French-English-Dutch terminological database of university-related terms (e.g. *coordinated research project, co-supervision agreement*), the CECL is now writing a dictionary of academic vocabulary, i.e. words that are used to structure an academic text (e.g. to introduce a new topic, to sum up or conclude a text). One highly innovative feature of the Louvain English for Academic Purposes Dictionary (LEAD) is its customisability: the content is automatically adapted to users' needs in terms of discipline and mother tongue background (L1). Discipline-based customisation serves to illustrate words in a context that is relevant for the user and provide access to discipline-specific corpora. L1 customisation serves to give feedback on errors and problems that a specific L1 population typically encounters.

## Representative References

- ▶ GRANGER S., Electronic lexicography: From challenge to opportunity. In Granger, S. & Paquot, M. (Eds.) *Electronic Lexicography*. Oxford: Oxford University Press, **2012**.
- ▶ PAQUOT M., Automated customization or how to bring electronic dictionaries closer to their users. In Granger, S. & Paquot, M. (Eds.) *Electronic Lexicography*. Oxford: Oxford University Press, **2012**.
- ▶ GRANGER S. & PAQUOT M., Customising a general EAP dictionary to meet learner needs. In Granger, S. & Paquot, M. (Eds.) *eLexicography in the 21<sup>st</sup> century: New challenges, new applications*. Cahiers du CENTAL 7. Louvain-la-Neuve, Presses universitaires de Louvain, pp. 87-96. **2010**.
- ▶ GRANGER S. & PAQUOT M., The Louvain EAP dictionary. *Proceedings of the XIV Euralex International Congress*, Leeuwarden, The Netherlands, pp. 321-326. **2010**.
- ▶ PAQUOT M. & BESTGEN Y., Distinctive words in academic writing: a comparison of three statistical tests for keyword extraction. In Jucker, A., Schreier, D. & M. Hundt (Eds) *Corpora : Pragmatics and Discourse*. Amsterdam: Rodopi, 247-269, **2009**.
- ▶ GRANGER S. & PAQUOT M., From dictionary to phrasebook? In Bernal, E. and DeCesaris, J. (Eds) *Proceedings of the XIII EURALEX International Congress*, Barcelona, Spain, 1345-1355, **2008**.

## Funding

- ▶ FSR-FNRS
- ▶ Fédération Wallonie-Bruxelles

## Partnership

- ▶ Katholieke Universiteit Leuven, Belgium
- ▶ University of Lancaster, UK



## Products and Services

### Services:

- ▶ Analysis of users' writing needs
- ▶ Extraction of domain-specific terminology
- ▶ Compilation of custom dictionaries
- ▶ Design of localised writing aid environments for professional English

### Products:

- ▶ The Louvain EAP dictionary

## KEYWORDS

Custom dictionary  
English for Specific Purposes  
Localisation  
Needs analysis  
Terminology extraction  
Writing aid  
Pedagogical materials development

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<http://sites-final.uclouvain.be/lexique/lexique.php>

# A world-wide computing grid for LHC data analysis

## SENIOR SCIENTISTS:

- ▶ Giacomo BRUNO
- ▶ Pavel DEMIN
- ▶ Vincent LEMAITRE

## Research Field and Subjects

The Large Hadron Collider (LHC), in operation at the CERN laboratory in Geneva (Switzerland) since November 2009, is designed to produce proton-proton collisions at the unprecedented energy of 14 TeV. UCL physicists are involved in the CMS experiment (Compact Muon Solenoid), which is one of the two main experiments (four in total) that will study the collisions produced by the LHC. The LHC and CMS are expected to be operated for at least 10 years and will allow elementary particles and their fundamental interactions to be studied at the unexplored TeV energy scale.

The amount of data recorded by the LHC experiments in one year corresponds to about  $10^7$  gigabytes. This figure is almost 100 times higher than in previous high-energy physics experiments. Furthermore, it does not include simulation data to be produced in order to compare measurements to theoretical predictions. In addition, the data will have to be re-processed and analysed very frequently by the 2000 physicists of the 200 Institutes worldwide that constitute the CMS Collaboration.

Efficient data processing and analysis of the large amount of LHC data as well as the distributed nature of the Collaboration require a highly powerful and sophisticated distributed computing infrastructure, the Worldwide LHC Computing Grid (WLCG). The WLCG allows transparent use of shared computing resources. UCL is operating a "Tier-2" computing site, which is fully integrated within the WLCG. In 2011 the centre hosted 400 TB of mass storage and 450 CPU cores connected to the internet with a 10 Gb/s dedicated line.

At the Belgian level, the project involves all the Belgian Universities in the CMS Collaboration (UA, UCL, UGent, ULB, UMONS and VUB) with a second computing centre located on the ULB/VUB campus.

## Representative References

- ▶ CMS COLLABORATION. Search for Resonances in the Dilepton Mass Distribution in pp collisions at  $\sqrt{s} = 7$  TeV. JHEP 1105:093, **2011**.
- ▶ CMS COLLABORATION. Search for Heavy Stable Charged Particles in pp collisions at  $\sqrt{s} = 7$  TeV. JHEP 03 024, **2011**.
- ▶ CMS COLLABORATION. First Measurement of the Cross Section for Top-Quark Pair Production in Proton-Proton Collisions at  $\sqrt{s}=7$  TeV. Phys.Lett.B695:424-443, **2011**.
- ▶ CMS COLLABORATION. CMS tracking performance results from early LHC operation. Eur. Phys. J. C 70, 1165, **2010**. <http://hdl.handle.net/2078.1/88706>
- ▶ CMS COLLABORATION, CMS Data Processing Workflows during an Extended Cosmic Ray Run. J. Inst. 5 T03006, **2010**.
- ▶ CMS COLLABORATION. The CMS experiment at the CERN LHC. JINST 3 S08004, **2008**.
- ▶ CMS COLLABORATION. CMS: The computing project. Technical design report, CERN-LHCC-2005-023, **2005**.

## Funding

F.R.S.-FNRS Convention IISN: 4.4.505.05

## Partnership

- ▶ WLCG Collaboration
- ▶ CMS Collaboration

## Main Equipment

The UCL Tier-2 computing center consists of 74 computing nodes for a total of 456 cores with a peak performance of 3500 HEP-SPEC06, 12 file servers with about 400 TB of disk space available. There are 4 main types of computer nodes: 12 nodes with 3 GB of memory and dual Single-Core AMD Opteron 248; 16 nodes with 4 GB of memory dual Dual-Core Intel Xeon 5160; 14 nodes with 16 GB of memory and dual Quad-Core Intel Xeon E5345; 32 nodes with 16 GB of memory and dual Quad-Core Intel Xeon E5420. The center is connected to the WLCG and the internet with a 10 Gb/s dedicated line.

## Products and Services

- ▶ Analysis and storage of the data recorded by the CMS experiment.
- ▶ Simulation of data produced by the CMS experiment.

These services are open to an international collaboration of about 200 research institutes worldwide and are performed thanks to the WLCG software infrastructure.

## KEYWORDS

Particle physics  
LHC  
CMS  
WLCG  
Grid  
Computing  
CERN  
Tier-2

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<http://lcg.web.cern.ch/LCG>  
<http://cms.web.cern.ch>

# UCL Crypto Group

## SENIOR SCIENTISTS:

- ▶ Olivier PEREIRA
- ▶ François-Xavier STANDAERT

## Research Field and Subjects

The UCL Crypto Group gathers 2 full-time professors, 7 post-docs and 12 PhD students with backgrounds from microelectronics, telecommunications, computer science and mathematics. This wide diversity of knowledge allowed the group to develop a strong expertise in cryptography, but also in its applications to various security related issues, including physical attacks and countermeasures (on smart-cards, FPGAs, ASICs), physically unclonable functions (PUFs), efficient implementation of cryptosystems, design and analysis of cryptosystems and protocols, elliptic curves, formal foundations of cryptography, zero-knowledge identification, privacy enhancing technologies, secure multiparty computation, voting systems, etc.

Through its strong commitment to academic research (more than 150 international publications since 2004) and its numerous collaborations with industrial partners, the UCL Crypto Group is intensively involved in the evolution of security technology, including the design of the next generation of smart-cards, sensor network security, election systems, etc.

The UCL Crypto Group also gave rise to several spin-offs: Octalis (2000), K2Crypt (2003) and IntoPix S.A. (2006).

## Representative References

- ▶ BERNHARD D., CORTIER V., PEREIRA O., SMYTH B. and WARINSCHI B., Adapting Helios for provable ballot privacy, In Vijay Atluri, Claudia Diaz, editor(s), Computer Security – ESORICS 2011, Lecture Notes in Computer Science, Springer, Sept. **2011**.
- ▶ ARMKNECHT F., MAES R., SADEGHI A.-R., STANDAERT F.-X., WACHSMANN C., A Formalization of the Security Features of Physical Functions, in the proceedings of the IEEE Symposium on Security and Privacy, pp 397-412, Oakland, California, USA, May **2011**.
- ▶ YU Y., STANDAERT F.-X., PEREIRA O. and YUNG M., Practical leakage-resilient pseudorandom generators, Proceedings of the 17th ACM conference on Computer and communications security, pages 141--151, ACM, October **2010**.

- ▶ DELAUNE S., KREMER S. and PEREIRA O., Simulation based security in the applied pi calculus, In R. Kannan and K. Kumar, editor(s), Foundations of Software Technology and Theoretical Computer Science – FSTTCS 2009, Leibniz International Proceedings in Informatics, December **2009**.
- ▶ STANDAERT F.-X., MALKIN T.G., YUNG M., A Unified Framework for the Analysis of Side-Channel Key Recovery Attacks, in the proceedings of Eurocrypt 2009, Lecture Notes in Computer Science, vol 5479, pp 443-461, Cologne, Germany, Springer, April **2009**.

## Awards

François-Xavier Standaert received the following awards:

- ▶ EDAA Outstanding dissertation award, 2004 (received from the European Design and Automation Association for the best PhD thesis in category “innovative embedded system design”).
- ▶ European Research Council (ERC) Starting Grant for project CRASH: development of concrete basements for the next generation of cryptographic algorithms and their implementation.

Olivier Pereira received the following awards:

- ▶ Best paper award: Ben Adida, Olivier de Marneffe, Olivier Pereira, and Jean-Jacques Quisquater. Electing a University President Using Open-Audit Voting: Analysis of Real-World Use of Helios, In D. Jefferson, J.L. Hall, T. Moran, editor(s), Electronic Voting Technology Workshop/Workshop on Trustworthy Elections, Usenix, August 2009.

## Partnership

Member of the networks:

- ▶ ECRYPT II European Network of Excellence in Cryptology
- ▶ LSEC information security cluster
- ▶ MUSICS and GRASCOMP graduate schools

Academia: Columbia University, INRIA, Massachusetts Institute of Technology, IAIC, ETH Zurich...

Industry: Orange France Telecom R&D, ST Microelectronics, NXP, Thales...

### Funding

- ▶ Europe: TAMPRES, CRASH, B-CENTRE
- ▶ Belgium: BCRYPT
- ▶ Wallonie: MIPSs, CAMUS, SEE, TRACEA, SCEPTIC, NANOTIC
- Fédération Wallonie-Bruxelles: ARC-SCOOP

### Products and Services

- ▶ Cryptosystems and security infrastructure evaluation
- ▶ Security evaluation of integrated circuit against tampering and eavesdropping (side-channel power and electromagnetic attack).
- ▶ Expertise on high throughput and low-cost implementation of processors for asymmetric and symmetric cryptography.
- ▶ Secure multiparty computation protocols
- ▶ Universally verifiable voting systems

### Main Equipment

In order to analyse the power consumption of enciphering devices, the group has built a test bench made of a large bandwidth oscilloscope Tektronix TDS7104, clock generators TaborElectronics WW1072 and Agilent 33250A and a customised board to plug the device in. The power supplies and clock can be finely controlled, and glitches can be inserted in those to check the chip fault-resistance. We also record its electro-magnetic radiations as an image of the local currents flowing in the silicium die, with near-field emission probes Rohde&Schwarz HZ15.

### KEYWORDS

Block ciphers  
Cryptography  
Electronic voting  
FGPA  
Number theory  
PUF  
Privacy-preserving systems  
Secure multiparty computation  
Sensor networks  
Side channel analysis  
Smart card

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# Wallonia Electronics and COmmunications MEasurements

## A facility making a bridge from molecules to signals

### SENIOR SCIENTIST:

▶ Isabelle HUYNEN

### Research Field and Subjects

The WELCOME facility is a state-of-the-art technological platform providing multidisciplinary tools in the field of electrical and electromagnetic characterisation. At WELCOME, over one hundred of researchers from the four corners of the globe perform thousands of hours of experiments per year. They benefit from a powerful range of equipments and an exceptional pool of expertise acquired over more than 40 years at UCL.

Available tools and techniques in the WELCOME facility support various research axes including micro- and nanotechnology (materials and devices), Silicon-on-Insulator technology, RF and microwave circuits, digital systems and VLSI architectures, MEMS/NEMS, cryptography, ultra low-power wireless biometric and biological sensors, molecular electronics, signal propagation and wireless communications between sensors. Extending from molecules to signals, WELCOME offers, through a broadband and unified approach, a wide variety of electrical and electromagnetic measurements techniques, going from the physical behaviour of materials, sensors and devices, to systems architectures and signal propagation between them. The infrastructure goes further bringing together three pillars: research, education, and services to the industry. WELCOME helps to cover all steps of development in electronics and communications, from design to prototyping, including modelling, fabrication, testing and reliability assessment.

The WELCOME facility is also complementary in many aspects to resources and skills available at other UCL technological facilities, such as the WINFAB clean rooms, the Cyclotron Resource Centre, material science and biological labs.

Research in Information and Communications Technologies within WELCOME involves hardware, protocols and channels for wireless and ultra-wideband communications in a free-space, multi-path, secured or anechoic environment (see detailed keyword list).

### Funding

- ▶ EC FP7 program
- ▶ ESF COST actions
- ▶ F.R.S.-FNRS and FRIA
- ▶ IWT
- ▶ FEDER (Project Minatis)
- ▶ PAI
- ▶ Wallonie - DGO6 projects
- ▶ ...

### Partnership

The WELCOME facility is complementary in many aspects to resources and skills available in nearby research centres active in similar fields. This complementary favours fruitful collaborations in the frame of numerous projects funded at the regional and federal level and ensures its international competitiveness.

▶ Belgian collaborations\*: Cenaero, Certech, Cetic, Sirris, Materia Nova, IMEC, KULeuven, Multitel, UGent, University of Liège, ULB/VUB (Brussels), Univ. Mons-Hainaut & FPMS, FUNDP (Namur),

▶ International collaborations: IEMN (FR)...

▶ Industrial collaborations\*:

*in Belgium*: BER, Melexis, nSiltion, CISSOID, IMEC, On Semi Belgium, Thalès Alenia Space Etca, Thalès Communications Belgium, ICOMS, ...

*abroad*: SOITEC (FR), RFMD (USA), ST-Microelectronics (FR), IBM (USA), OKI (J), EADS (FR, DE), Thalès TRT (FR), ...

*\*non exhaustive list*

## Main Equipment

- ▶ Various coaxial setups, on-wafer probe stations and Vector Network Analysers configurations to achieve a multi-port (up to 4 accesses) and multi-parametric characterisation of devices and sensors (IV, CV, temperature-microwave, electro-mechanical, and magneto-electrical sweeps, ...), in small-signal and nonlinear regime, from DC to 110 GHz, in the temperature range 4K-500K.
- ▶ Low current probes, logical analysers, analog waveform and digital pattern generators, digital oscilloscopes, vector signal generators with I/Q or digital modulation for analog/digital circuits and systems-in-package (smart cards, RFIDs, FPGAs) interfacing with sensor measurements
- ▶ Anechoic chamber for electromagnetic testing of materials, devices and sensors
- ▶ Broadband antennas and arrays
- ▶ Channel sounders
- ▶ RF hardware for wireless and ultra-wideband communications between sensors

See *full catalog list* at:

<http://sites.uclouvain.be/welcome/WebBooking/help/facilities.pdf>

## Products and Services

WELCOME already answers needs of industry in Belgium and abroad, in the frame of (sub) contracts and consultancy. With some regulation policy, trainings for R&D engineers from industry are also possible.

## KEYWORDS

Wireless sensors and communications networks  
Ultra-Wide Band (UWB)  
MIMO channels  
Body Area Networks  
Antennas  
Satellite communications  
Signal and image processing  
Digital circuits  
Digital systems  
Security and cryptography  
SOI technology and ultra-low power design  
MEMS/NEMS  
Wideband multi parametric characterisation

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# Decision aid models for Supply Chain and Operations Management

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## Research Field and Subjects

Supply Chain Management (SCM) covers all aspects of production, logistics and supplier relations. It combines operations management, management science and industrial organisation in a systematic attempt to understand, model and support the multi-level organisational behaviour.

The Centre for Supply Chain Management (CESCM) is in particular oriented towards:

- empirical analysis, the economic and systemic modelling of inter-organisational relations,
- the study and development of methodologies and techniques for the decision support systems at all hierarchical levels of the chain
- the study, modelling and optimisation of systems of decentralised or distributed coordination.

CESCM members are closely affiliated with CORE: Centre of Operations Research and Economics.

The centre is currently carrying out several research projects around the theme of shared resources in supply chains. How can containers or re-usable packaging be used efficiently in a network of producers and consumers to increase logistic efficiency? How can investment be managed when the capacity is to be used by several independent agents in order to maximise the global efficiency? How can lot-sizes be optimised in order to take into account the different levels of the supply chain? How is efficiency measured in a decentralised production setting such as a supply chain? How can an energy market be made as efficient as possible? These are examples of questions studied within the framework of shared resources.

## Representative References

- ▶ MELO R. A and WOLSEY L. A., Optimizing production and transportation in a commit-to-delivery business mode. *European Journal of Operational Research*, 203(3), 614-618, **2010**.
- ▶ BRUSSET X. and AGRELL P. J., Supply rent distribution under Bayesian belief when the buyer invests in specific assets. Working Paper LSM 2010/04, **2010**.
- ▶ AGRELL P. J. and KASPERZEC R., Dynamic Joint Investment in Supply Chains under Asymmetric Information. CORE Discussion Paper 2010/85, **2010**.
- ▶ CONSTANTINO M., MILLER A. J. and VAN VYVE M., Mixing MIR inequalities with two divisible coefficients. *Mathematical Programming Series A*, 123(2), 451-483, **2010**.
- ▶ POCHE Y., VAN VYVE M., WOLSEY L., LS-LIB: A library of tools for solving production planning problems, In: *Research Trends in Combinatorial Optimization*, W.J. Cook, L. Lovasz and J. Vygen ed(s), Heidelberg, Springer-Verlag, 317-346, **2009**.
- ▶ TANCREZ J-S., SEMAL P., CHEVALIER P., Histogram based bounds and approximations for production lines, *European Journal of Operational Research*, 197, 1133-1141, **2009**.
- ▶ CHEVALIER P., VAN DEN SCHRIECK J-C., Optimizing the staffing and routing of small size hierarchical call-centers, *Production and Operations Management*, 17(3), 306-319, **2008**.

## Funding

- ▶ Fédération Wallonie-Bruxelles, Action de Recherche Concertée
- ▶ GSK-Biologics chair in strategic sourcing and procurement
- ▶ Johnson&Johnson
- ▶ Idem Papers



## Partnership

- ▶ Lund University
- ▶ Logistics in Wallonia
- ▶ n-Side s.a. (spin-off of research centre)

## Products and Services

- ▶ Development of optimisation or simulation models for logistics and operations within a Supply Chain context
- ▶ Development of performance evaluation methodologies for decentralised systems
- ▶ Development of models (simulation or analytic) for service operations

## KEYWORDS

Supply chain management  
Optimisation  
Production  
Network  
Integer programming  
Decision support systems

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# Molecular Imaging, Radiotherapy, and Oncology

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## Research Field and Subjects

The centre for molecular imaging, radiotherapy, and oncology (MIRO) focuses its research activities on the use of medical imaging for cancer treatment. For this purpose, the centre develops an experimental platform for small animal imaging. This platform comprises a camera for positron emission tomography (PET), a camera for single photon emission computed tomography (SPECT), a camera combining SPECT and X-ray computed tomography, and an autoradiography plate scanner. These imaging devices are backed by an animal house with the necessary equipment for small animal handling, preparation, and anaesthesia, a small animal irradiator, a biology laboratory, and a tracer production unit that covers all steps from the reception of radioisotopes to the delivery of a broad range of certified molecules. Eventually, MIRO also specialises in medical physics applied to imaging and radiotherapy, with a particular focus on Monte Carlo computed simulations. The spectrum of available imaging modalities is completed by a close collaboration with the UCL/REMA research unit (small animal magnetic resonance imaging).

In order to cope with the ever-growing importance of information and communication technologies in modern medical imaging, MIRO continuously extends its expertise in signal and image processing in collaboration with UCL/ICTEAM. MIRO specialises in image segmentation, image registration, and respiratory signal analysis.

For the transition from small animal imaging to clinical studies, MIRO works hand in hand with the Saint-Luc University Hospital and its radiology, radiotherapy, and nuclear medicine departments.

## Representative References

- ▶ CASTADOT P., LEE J.A., GEETS X., GREGOIRE V., Adaptive radiotherapy of head and neck cancers. *Seminars in Radiation Oncology* 20(2): 84-93, **2010**.
- ▶ LEE J.A., Segmentation of positron emission tomography images: Some recommendations for target delineation in radiation oncology. *Radiotherapy and Oncology* 96(3): 302-307, **2010**.

- ▶ GREGOIRE V., LEFEBVRE J.L., LICITRA L., FELIP E. EHNS-ESMO-ESTRO, Guidelines Working Group. Squamous cell carcinoma of the head and neck: EHNS-ESMO-ESTRO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann Oncol. Suppl 5: v184-v186*. **2010**.
- ▶ ORBAN J., CASTADOT P., JANSSENS G., LEE J.A., GEETS X., GREGOIRE V., MACQ B., Evaluation of the radiobiological impact of anatomic modifications during radiation therapy for head and neck cancer: Can we simply summate the dose? *Radiotherapy and Oncology* 96: 131-138. **2010**.
- ▶ DE DECKER A., LEE J.A., FRANÇOIS D., VERLEYSSEN M., A principled approach to image denoising with similarity kernels involving patches. *Neurocomputing* 73(7-9): 1199-1209. **2010**.
- ▶ LEE J.A., GEETS X., GREGOIRE V., BOL A., Edge-preserving filtering of images with low photon counts. *IEEE Trans Pattern Anal Mach Intell* 30(6): 1014-1027. **2008**.
- ▶ GEETS X., LEE J.A., BOL A., LONNEUX M., GREGOIRE V., A gradient-based method for segmenting FDG-PET images: methodology and validation. *European Journal of Nuclear Medicine* 34(9): 1427-1438. **2007**.

## Patents

(1999) European patent n° 99870172.6 "Methods for preparing perfluorinated [<sup>18</sup>F]-radiolabelled nitroimidazole derivatives for cellular hypoxia detection".

## Awards

ESTRO-Varian awards in 2009, 2004, and 1991.

## Funding

- ▶ F.R.S.-FNRS and associated funds
- ▶ Europe
- ▶ Belgian Federal Public Service
- ▶ Wallonie
- ▶ Cancéropôle du Nord-Ouest (France)
- ▶ Belgian Foundation against Cancer
- ▶ Télévie
- ▶ Fonds Joseph Maisin
- ▶ Fondation Saint-Luc

## Partnership

- ▶ Centre Oscar Lambret Lille
- ▶ Katholieke Universiteit Leuven
- ▶ Universiteit Gent
- ▶ University of Wisconsin (Madison, WI)
- ▶ Tomotherapy Inc. (Madison, WI)
- ▶ Ion Beam Applications (Louvain-la-Neuve)

## Main Equipment

- ▶ Small animal PET camera
- ▶ Small animal SPECT camera
- ▶ Radiotracer production facility

## Products and Services

- ▶ Radiotracer production for medical imaging (preclinical & clinical) and industrial applications
- ▶ Modelling of imaging and treatment devices for Monte Carlo simulation
- ▶ Consulting in radiobiology
- ▶ Issuing of international guidelines in radiotherapy and radiobiology

## KEYWORDS

Medical Imaging  
Molecular Imaging  
Radiotherapy  
Oncology  
Radiobiology  
Radiochemistry  
Medical Physics  
Signal and image processing

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## Other research institutes, centres and groups

### 1. CRIDS

The Research Centre on IT, Law and Society has as main objective, the aim of fostering fundamental and applied research in the field of information and communication technologies from legal, technical and socio-economic perspectives. With a team of 46 researchers, CRIDS is developing multi-disciplinary researches in Human Sciences and Computer Science. Information technologies and new communication technologies have a major impact on the way "we exist together" and the way "we act together". In this context, CRIDS explore these changes and the impact on regulation from a technological and legal perspective.

<http://www.crids.eu>

### 2. FOCUS

The Focus research group federates several researchers of the University of Namur interested in the study of the basic paradigms and mathematical foundations of computer science. Building upon the expertise of 7 full time professors and 10 researchers, the group has currently identified two major research axes: on the one hand, declarative languages, and, on the other hand, decision making and performance. Special focus is put on coordination languages, process algebras, semantics, logics, program analysis and verification, probabilistic mathematical problems, uncertainty management, analysis and visualization of model output.

<http://www.fundp.ac.be/en/focus>

### 3. ICTEAM

With more than 40 professors and more than 200 researchers, ICTEAM carries both basic and applied world-class research in various sub domains of Information and Communication Technologies, Electronics and Applied Mathematics.

Several research groups carry out research in the field of:

1. Applied Mathematics
2. Biomedical Engineering
3. Communication Systems and Networks
4. Cryptography and Information Security

5. Dynamical Systems, Control and Optimisation
6. Electronic Circuits and Systems
7. Large Graphs and Networks
8. Machine Learning and Artificial Intelligence
9. Micro and Nano Technologies and Systems
10. Microwave Engineering and Applied Electromagnetism
11. Signal and Image Processing
12. Software Engineering and Programming Systems

<http://www.uclouvain.be/en-icteam.html>

### 4. ILC

The Institute for Language and Communication counts 27 staff members and 60 researchers working in the areas of theoretical and applied linguistics, and communication studies. Several research teams specialise in ICT-related domains:

- Information extraction and retrieval
- Textual databases mining
- Thesaurus generation and construction
- Speech synthesis
- Technology-enhanced language learning
- Multilingual business language analysis
- Linguistic corpus and database construction
- New media use and development (web 2.0)
- Media literacy

<http://www.uclouvain.be/ilc>

### 5. ILSM

The Louvain School of Management Research Institute (ILSM) is devoted to theoretical and applied, empirical and experimental studies of management of private and public organisations, including but not limited to research on internal and external functional management processes that are present in all enterprises and organisations. Since management by itself is characterised by its multiple facets, dynamics and interdependence with resource, process and product development, the science of management requires multiple approaches in terms of functional orientation, research methodology and focus. This is why the Institute mobilises

around 70 faculty members and 100 affiliated researchers from the fields of economics, information system science, operations research, psychology and sociology to address management questions of societal and economic relevance.

<http://www.uclouvain.be/en-ils.html>

## 6. IPM

The IPM, a resource centre for the university teachers.

IPM stands for "Institut de Pédagogie universitaire et des Multimédias" (Institute for Higher Education and Technology). Institute objective is the improvement of the university teaching in a SOTL (Scholarship of Teaching and Learning) perspective. This objective is carried out by university teachers pedagogical training and by offering them a large variety of pedagogical resources. In the same spirit, IPM ensures the coordination, the animation and the diffusion of pedagogical initiatives and promotes them through the FDP (Fonds de Développement Pédagogique, Funds for Pedagogical Development). It covers pedagogical setups development and Learning Outcomes approaches with or without ICT, and also videos-podcasts, multimedias and Internet tools.

IPM coordinates a broad range of activities concerning technological uses for learning and teaching (including eLearning and ODL, Open and Distance Learning), developing so effective expertise and consultancy in this domain. The university gives his support for the development of CLAROLINE, a worldwide known eLearning platform, developed initially within IPM. At an European level, IPM is working inside the "Collectif Hy-SUP" dedicated at the search of effects and conditions of impacts of hybrid pedagogical setups on training and education.

<http://www.uclouvain.be/ipm>

## 7. IRMP

The Institute IRMP is an Institute for research in fundamental mathematics and physics. The Institute is divided into five inter-related components : a center of research on cosmology, general

relativity and fundamental interactions, that is partner of the CMS experiment at the CERN; a center of research in geometry, physics and probability, with works on statistical mechanics and random matrices; a center in fundamental mathematics, analysis, algebra and algebraic topology; the cyclotron resources center with fundamental and applied activities (aeronautics and production of polymers membranes); a research center for space radiations whose activities are related to design of space radiation detectors and analysis of space radiation data.

<http://www.uclouvain.be/irmp>

## 8. NAXYS

Based on a team of 50 researchers, the aim of the NAMur research center for complex sYStems is to study systems composed of interacting parts/agents whose local behavior, resulting from the interactions between them, cannot provide a complete understanding of the global behaviour, i.e. considering the system as a whole, say on a macroscopic scale. At present, the center focuses on the following topics: algorithmic complexity, analysis and data classification, biology and bioinformatics, chemico-physical systems, climate and environment, cosmology and space, financial Systems, mobility and transports, orbital movements and social dynamics.

[www.fundp.ac.be/en/sci/naxys](http://www.fundp.ac.be/en/sci/naxys)

## 9. PRECISE

With 11 faculty members, 30 researchers and 27 research associates, the PReCISE research center conducts research on the engineering and management of advanced information systems. Topics of interest include data engineering, evolution, model-driven engineering, quality and measurement, requirements engineering and business-IT alignment, security and service engineering.

<http://www.fundp.ac.be/en/precise/>

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