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Physics of information and communication technologies



Une école de l'IMT

Non-linéarités optiques dans les lasers à boîtes quantiques pour les communications à haut-débit

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Résumé :

L'évolution actuelle des systèmes de communications optiques est telle que la circulation d'information n'est plus exclusivement limitée par les liens longues distances transocéaniques ou par les réseaux cœurs. De nombreuses applications courtes distances comme les réseaux d'accès où les débits des systèmes amenant la fibre chez l'abonné doivent être maximisés et les connexions internes et externes des centres de données transportent un trafic de données important produit en partie par les applications de type « Big Data ».

Les critères imposés par ces nouvelles architectures notamment en termes de coût et consommation énergétique doivent être pris en compte en particulier par le déploiement de nouveaux composants d'extrémités. Grâce au très fort confinement des porteurs, les lasers à boîtes quantiques constituent une classe d'oscillateurs présentant des caractéristiques remarquables notamment en termes de courant de seuil et de stabilité thermique.

En particulier, l'application d'une perturbation optique externe permet d'exploiter les non-linéarités optiques des boîtes quantiques pour la réalisation de convertisseurs en longueur d'onde performants ou de transmetteurs à haut-débit fonctionnant sans isolateur optique. Ce dernier point est particulièrement critique dans les réseaux courtes distances où l'utilisation de sources modulées directement reste une solution technologique importante.

Ce travail de thèse réalisé sur des structures lasers à base d'Arséniure de Gallium (GaAs) et de Phosphore d'Indium (InP) montre la possibilité d'améliorer l'efficacité de conversion non-linéaire par injection optique et de générer de nombreuses dynamiques dans des oscillateurs rétroactionnés et émettant sur différents états quantiques.

Par ailleurs, le déploiement massif des systèmes cohérents mais également la conception des futures horloges atomiques sur puces nécessite l'utilisation de sources optiques à faible largeur de raie et ce afin de limiter la sensibilité de la réception au bruit de phase du transmetteur et de l'oscillateur local et induire un taux d'erreur binaire important. La conception de laser à faible largeur spectrale constitue un autre objectif de ce travail thèse. Les avantages de la technologie boîtes quantiques ont été mis à profit pour d'atteindre une largeur spectrale de 160 kHz (100 kHz en présence de rétroaction optique) ce qui est de première importance pour les applications susmentionnées.

Mots clés : lasers à semiconducteur, boîtes quantiques, mélange à quatre ondes, rétroaction optique, injection optique, dynamique non-linéaire, largeur de raie, communications optiques.

Publications / Patents:

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Start: 01/11/2013 End: 23/12/2016

Abstract:

The advent of sensitive interfaces is promising prospects to the human-machine interaction. We propose a new concept of sensitive flexible surface. Its aim is to study the interaction between electrical signal and resistive and dielectric environment of the support in order to realize an acquisition system providing machine readable information.

The technological base is a waveguide on flexible substrate on which the touch creates a reflection at the input port. We have developed a location method as an alternative to the time domain reflectometry (TDR). It is named Harmonic Detection and Location (HDL) and it allows using a narrow band, around 100 MHz, low complexity acquisition system.

The concept has been approved using measures on flexible and rigid sensitive surfaces connected to a vector network analyzer (VNA) used as reference. A compact acquisition system based on a Wheatstone bridge associated to a phase detector has been developed. For this purpose, errors characterization and identification work has been done. Electromagnetic interactions between the finger and the waveguide, waveguide imperfections, substrate nature and acquisition system errors' impact have been studied.

This knowledge has provided the possibility to co-develop the hardware and the detection algorithm to demonstrate location accuracy below 2cm. Fundamental principles of this work provide the possibility of realizing simple connection, conformable, large surface interfaces in order of one to several square meters with a low cost acquisition system.

In the next step, signal processing will explore opportunities to acquire advanced 3D mode studying the possible integration of these objects within an innovative man-machine interface. Any 3D object could become tactile.

Keywords: *Sensitive surface, large surface, flexible, waveguide, harmonic method, reflectometry, Wheatstone bridge, phase detection, vector network analyzer (VNA), flexible substrate, human-machine interaction.*

Publications:

- [1] Nissem Selmene, Muriel Muller, Sylvain Blayac, Ghalid Abib, "Système de détection compact pour dalle tactile monoport"; JNM 2015, Bordeaux.
- [2] Nissem Selmene, Sylvain Blayac, Muriel Muller, Ghalid Abib, "Innovative Large Area Touch Sensor: Design and Tests of a Compact Acquisition System"; IEEE Sensors Applications Symposium (SAS) 2016, April Catania, Italia.
- [3] Nissem Selmene, Sylvain Blayac, Muriel Muller, Ghalid Abib, "Compact acquisition system for a large area monoport tactile surface", IEEE, Microwave, Radar and Wireless Communications (MIKON), 2016, June, Krakow, Poland.
- [4] Nissem Selmene, Sylvain Blayac, Muriel Muller, Ghalid Abib, "Compact acquisition system for a large area monoport tactile surface", Journal of Electrical Engineering, ISSN 2328-2223. (proposed)

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Start: 30/09/2014, End: 30/09/2017

Abstract:

There are a number of biological plausibility issues with current artificial neural networks, regarding the reliability of the components involved. Given the intrinsic inability of neurons and synapses to achieve high precision as units, the plausibility of deep learning models or other types of artificial neural networks with precise floating point weights are put into question. Neural clique networks, which are associative memories and the focus of our research team, mitigate this problem thanks to their error-correcting properties. The first objective of the thesis was establishing a noise model in the brain and studying its impact on the behavior of neural clique networks or architectures composed of them. The second objective is using neural clique networks to achieve more high-level tasks.

As such, in the first year, we modeled noise. We took into account noise from synaptic failures, as well as interferences from other neurons in the brain not relevant to the task. Synaptic noise could be generalized as a binomial noise for the communication between any two neurons, and interferences as the sum of two Poisson distributions, aka a Skellam distribution, which forms an additive (possibly negative) noise. We also showed that if this noise model is used between different layers of a binary neural network or between different networks altogether, it could be simplified and reduced to insertions and erasures.

Then, we study long distance communications between multiple neural clique networks. We show that simple biological rules can lead to an efficient connection scheme between two neural networks in the brain. We further show that despite the noise model, perfect transference of data over time can be achieved. This opens the way to plausible architectures based on neural clique networks. We propose a scalable architecture where data between multiple networks can be associated using hubs, establishing a plausible model for memory in the brain. We also show such architectures being used to recursively store sequences of arbitrary data in the brain, using a process seeming natural to humans as well as compressing correlated data. Finally, we are currently studying how architectures of neural clique networks can be used in learning algorithms or processes.

Keywords: biologically plausible neural networks, neural cliques, neural communication

Publications / Patents:

Neural clique networks in an unreliable environment Elliott Coyac, Vincent Gripon, Charlotte Langlais, Claude Berrou, 1st International Conference on Math. NeuroSciences, ICMNS 2015, Jun. 2015

Consolidated Hebbian learning and parsimonious energy consumption, resulting in large capacity associative memories Elliott Coyac, Vincent Gripon, Charlotte Langlais, Claude Berrou, , 1st International Conference on Math. NeuroSciences, ICMNS 2015, Jun. 2015

Impact du bruit synaptique sur les performances des réseaux de cliques neurales Elliott Coyac, Vincent Gripon, Charlotte Langlais, GretsI 2015, Sept. 2015

Distributed Coding and Synaptic Pruning Elliott Coyac, Vincent Gripon, Charlotte Langlais, Claude Berrou, ISTC 2016, Sept. 2016

Performance of Neural Clique Networks Subject to Synaptic Noise Elliott Coyac, Vincent Gripon, Charlotte Langlais, Claude Berrou, COGNITIVE 2017, Feb. 2017

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Start: 01/10/2014 End: 30/09/2017

Abstract:

Since amplitude, phase, frequency, polarization have already been used in the actual deployed systems that can achieve a maximum capacity of 100 Terabis/s, space-division multiplexing (SDM) has been suggested as the last degree of freedom in optical transmissions in order to cope with the increasing demand of more capacity. Spatial division multiplexing can be realized through multimode fibers or multicore fibers. Propagation through multimode fiber is limited by the differential mode group delay (DMGD) caused by the different velocities of spatial modes, this can be mitigated using multiple-input multiple-output (MIMO) techniques already known in wireless communications. Moreover signals propagating in multimode fibers are affected by a non-unitary coupling known as mode dependent loss (MDL) arising from fiber imperfections and optical components.

The purpose of our research work is to mitigate mode dependent loss in SDM transmission systems. For this aim, we investigate modern MIMO coding/decoding techniques and propose new solutions suitable to the optical channel. In the first part of our work, we have investigated the channel capacity through average and outage capacity studies and proposed statistical channel state information to increase both capacities. After that, we proposed an optical solution based deterministic mode scrambling to improve the quality of the transmission. lastly, we proved that a selection of only a small number of modes in a fiber supporting a high number of modes gives better performances than using fibers supporting the propagation of only small number of modes.

In the second part of our work, we investigated MIMO DSP techniques based space-time coding and forward error correction. We proved through numerical simulations that these techniques are very efficient for MDL mitigation. Moreover, we derived an error probability upper bound for space-time (ST) coded systems that yield a design criterion for codes suitable for the optical channel.

In the near future, we are looking forward to lead experimental studies to investigate the benefits of ST coding in real transmission taking into account different channel impairments. The experimental validation of the propagation through multimode fiber requires an important number of equipment (e.g for a two mode transmission, eight MZM modulators are needed to generate signals for the two modes and two coherent detectors are needed at the receiver for coherent detection). Our future experiments will be done in collaboration with the IRCICA laboratory of University of Lille.

Key words: Space-Time coding (ST), mode dependent loss (MDL), channel state information (CSI), Digital signal processing (DSP), Multiple-Input Multiple-Output (MIMO).

Publications:

- E-M. Amhoud; E. Awwad; G. Rekaya Ben-Othman; Y. Jaouen. "Mode selection and larger set equalization for mode-multiplexed fiber transmission systems" OFC, March 2015.
- E-M. Amhoud; Y. Jaouen; G. Rekaya Ben-Othman. "Capacity Enhancement of Space-Division Multiplexed Systems by using Statistical Channel State Information" ACP, November 2015.
- E-M. Amhoud et al., "Design criterion of space-time codes for SDM optical systems," In the Proceedings of the International Conference on Telecommunications, May 2016.
- E-M. Amhoud, Y. Jaouen , G. Rekaya Ben-Othman. "Optimal Mode Scrambling for Mode-Multiplexed Optical Fiber Transmission Systems," SppCom, 2016
- E-M. Amhoud, Y. Jaouen , G. Rekaya Ben-Othman. "Joint Space-Time Coding and FEC for MDL Mitigation in Few-Mode Fiber Systems," SppCom, 2016

Network architectures and management



Efficient Management of Electric Vehicle Systems with Self-Interested Actors

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Start: 01/09/2013 End: 30/08/2016

Abstract:

Electric Vehicles (EVs), as their penetration increases, are not only challenging the sustainability of the power grid, but also stimulating and promoting its upgrading. Indeed, EVs can actively reinforce the development of the Smart Grid if their charging processes are properly coordinated through two-way communications, possibly benefiting all types of actors. Because grid systems involve a large number of actors with nonaligned objectives, we focus on the economic and incentive aspects, where each actor behaves in its own interest. We indeed believe that the market structure will directly impact the actors' behaviors, and as a result the total benefits that the presence of EVs can earn the society, hence the need for a careful design.

The thesis first provides an overview of economic models considering unidirectional energy flows, but also bidirectional energy flows, i.e., with EVs temporarily providing energy to the grid. We describe and compare the main approaches, summarize the requirements on the supporting communication systems, and propose a classification to highlight the most important results and lacks.

We propose to use the recharging processes of EVs to provide regulation to the grid by varying the instantaneous recharging power. We provide an economic analysis of the incentives at play, including the EV owners point of view (longer recharging durations and impact on battery lifetime versus cheaper energy) and the aggregator point of view (revenues from recharging versus regulation gains). In particular, we analyze the range of regulation rewards such that offering a regulation-oriented recharging benefits both EV owners and the aggregator. After that, we split the monopolistic aggregator into two competing entities. We model a non-cooperative game between them and examine the outcomes at the Nash equilibrium, in terms of user welfare, station revenue and electricity prices. As expected, competing stations offer users with lower prices than the monopolistic revenue-maximizing aggregator do. Furthermore, the amount of regulation service increases significantly than that in the monopolistic case.

Considering the possibility of discharging, we propose an approach close to Vehicle-to-Grid, where EVs can give back some energy from their batteries during peak times. But we also use EVs as energy transporters, by taking their energy where it is consumed. A typical example is a shopping mall with energy needs, benefiting from customers coming and going to alleviate its grid-based consumption, while EV owners make profits by reselling energy bought at off-peak periods. Based on a simple model for EV mobility, energy storage, and electricity pricing, we quantify the reduction in energy costs for the EV-supported system, and investigate the conditions for this scenario to be viable.

Keywords: Smart Grid; Electric Vehicle, Electricity Pricing; Non-cooperative games

Saving Energy of Mobile terminal by Offloading Applications in Mobile Cloud Computing Environment

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Start: 16/09/2013 End: 15/09/2016

Abstract:

Both theoretical and experimental evidence are presented in this thesis for a new proposed mobile application offloading algorithm, which can enhance user's quality of experience and save battery energy. Today, mobile devices are unable to accommodate most of the computing demand as long as they may be constrained by certain technical limits such as the battery capacity or computational performance. To cope with this problem, application offloading enables mobile devices to execute tasks remotely in the cloud for energy conservation or performance gains.

Typical set of three applications with low, medium and high stringent response times (virus scanning, chess game and speech recognition) were considered running specific computation capacities in the analytical model. Data gathered during several hours simulation campaigns shows that MAO algorithm may save significant amount of energy, and, more interestingly, the curves were exhibited based on QoE satisfaction whatever its position context. Analytical fitting functions for this behavior are provided and motivated. The circumstances are discussed under which these functions can be exploited, with the aim of finding an optimal solution while reducing radio and cloud resources when offloading applications to remote servers. These fitting formulas are potentially more exploitable by cloud providers whenever they decide to deploy applications servers.

Via experiments done in collaboration with IMPACT mobile computing Lab in Arizona, it is shown that the experimental implementation is indeed validating the developed theoretical model for an example of application of speech to text conversion for Android mobile devices. Experiment results and data showed that the proposed offloading algorithm could significantly reduce computational time and battery energy consumption.

Besides analytical and experimental evidence, the optimal placement of application servers is also studied. For WDM-PONs networks, as frequently viewed as the most promising candidate for FMC infrastructures, a joint BBU/application server's optimization may be theoretically justified. Here, the mutualization of BBU farms and cloud servers is analyzed, subject to wavelength assignment, QoS requirements and latency. It is shown that, for realistic network configurations with a range up to 40 kilometers between the OLT and the most distant ONU, the optimal surrogates placement can be at the OLT.

Keywords: Cloudlets, mobile applications' offloading, Passive Optical Networks (PONs)

Publications/ Patents:

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2. A. Ellouze and M. Gagnaire, "Mobile Application's Offloading: an opportunity towards Mobile Cloud Computing," ICACON 2015, Budapest-Hungary, May. 21-23 2015.
3. A. Ellouze and M. Gagnaire, "Toward an optimized servers placement for mobile applications offloading", 15th IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB), Montreal-Canada, 4-7 October 2015.
4. A. Ellouze, M. Gagnaire, "A novel application offloading algorithm and an optimized application servers placement for mobile Cloud computing", International Journal of Handheld Computing Research (IJHCR), November 2015.



Wireless Node Cooperation. The Nearest Neighbour Model.

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Start: 01/10/2014 End: 30/09/2017

Abstract:

The problem of base station cooperation has recently been set within the framework of Stochastic Geometry. Existing works consider that a user dynamically chooses the set of stations that cooperate for his/her service [1]. Being this assumption difficult to be applied, it is suggested to for groups in a static way [2]. The static clusters are defined in a way that is neither systematic nor optimal. A static and performance-optimal clustering procedure should minimize information exchange and infrastructure between base stations.

For the above problem, we propose a grouping method based on the Nearest Neighbor Model [3]. For this, two new point processes are defined from the dependent thinning of a stationary point process. For a Poisson point process, structural characteristics for the two processes are provided, such as average proportion, repulsion/attraction, and Palm measures [4]. We analyze an approximation to the first model that mimics the cluster structure of the base stations, using the superposition of two Poisson point processes. This approach provides explicit and numerically tractable formulas, to evaluate the coverage probability [5]. To group base stations considering as well the needs of the network, we redefine the singles and pairs with the hyperbolic metric. When the atoms are distributed as Poisson point process, it is possible to make an interference analysis.

The results of the analysis constitute a novel toolbox towards the performance evaluation of networks with static cooperation. It applies to different performance measures related to the so called Signal-to-Interference-and-Noise-Ratio (SINR), such as coverage probability, throughput or delay.

Keywords: Stochastic geometry, Poisson Point Process, Node grouping.

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- [3] Nearest neighbor and hard sphere models in continuum percolation. O. Häggström and R. Meester. Random Struct. Alg., 9:295-315,1996.
- [4] Analyzing Interference from Static Cellular Cooperation, using the Nearest Neighbor Model, A.Giovanidis, L.D Álvarez Corrales, and L. Decreusefond. In: WIOPT-SPASWIN 2015, Mumbai, India.
- [5] Analysis of Static Cellular Cooperation between Mutually Nearest Neighboring Nodes, L.D. Álvarez, and P. Martins. In Globecom 2016, Washington, D.C.

Publications / Patents:

Analyzing Interference from Static Cellular Cooperation, using the Nearest Neighbor Model, A.Giovanidis, L.D Álvarez Corrales, and L. Decreusefond. In: WIOPT-SPASWIN 2015, Mumbai, India.

Analysis of Static Cellular Cooperation between Mutually Nearest Neighboring Nodes, L.D. Álvarez, and P. Martins. In Globecom 2016, Washington, D.C.

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Start: 01/10/2016 End: 30/09/2019

Abstract:

The thesis is an in depth study on the use of finite state models for the effective multi criteria optimization and testing of virtual networks, and in particular SDN (Software Defined Networks) controllers, their components and related modules. After non-functional optimization, effective testing with respect to functional requirements has to be performed to ensure coherence and make sure that both functional and non-functional requirements are met. In this thesis, formal models, and in particular Finite State Models will be used to develop a global approach for optimization and testing applied to various SDN controller components.

The use of finite state models (non-classical) is foreseen. Neither automata nor finite state machines can be considered when (request/response) timeouts and other context variables need to be taken into account. Thus, novel approaches for optimization and testing for (hierarchical) Timed and Extended machines (and their compositions) have to be elaborated.

The efficiency of the proposed techniques will be estimated theoretically and practically, namely the complexity of related problems will be theoretically investigated and experimental evaluation will be performed.

Keywords : Virtual networks, SDN, finite state/transition models

Publications / Patents:

On using finite state models for optimizing and testing SDN controller components A. BERRIRI, N. KUSHIK, D. ZEGLACHE Russian Physics Journal (August, 2016).T.59, #8/2. pp. 5-7 (published)

Architectures And Engineering Of Software Systems And Digital Services

Designing services on network of Connected Objects Approach by Formal Methods

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Start: 16/09/2013 End: 16/04/2017

Abstract:

This thesis is motivated by the emergence of the *Internet of Things* and the increasing number of connected objects within the next decade. Our work is part of a strategic focus on the co-evolution between human and machine conducted at the institute Mines-Télécom. The number of devices will increase as well as their complexity for the users and the designers.

Our research motivation is to study the design of automatic services for connected object management. Services and objects then need to have features and capabilities that will allow automation and adaptability for user needs and variability of profiles.

Our approach consisted in first studying new modalities of interaction as we described in the article "*Sensemaking in the autonomic smart-home, UbiComp '14 Adjunct*". Then we defined an architecture for managing group of objects. In this architecture we identified sensor, effector, service and human-computer interface. Following this work we have designed and implemented a remote control which allows spatial control of connected objects, "Supervision: Spatial Control of Connected Objects in a smart-home, CHI'EA 2015", this work was conducted in collaboration with the Human Computer Interaction laboratory of Telecom ParisTech.

We think that it is interesting to consider the human-machine interactions in a context of pervasive technologies so we worked with a research team in psychological and ergonomic fields. Our research goal was to think about the possible solutions to include the human-factor in automatic control-loops of connected objects. This collaboration led us to study the acceptability of new technologies by humans and to write an article about the possibility of using automation processes to manage collective resources in smart living spaces "*Modéliser la gestion collective de ressources dans un quartier intelligent : complémentarité des approches de la psychologie ergonomique et de l'informatique autonome, ARPEGES 2015*".

The past year our work has been oriented toward designing a set of tool and a methodology to design and simulate services over network of connected objects by using the language SDL(Specification and Description Language) for designing and MSC(Message Sequence Chart) for checking simulations. Using formal methods for describing allows us to simulate the behaviors of complex environments with many connected objects. With this formalization we could work on the definition of communication protocols among connected objects, services and users.

In a future work we would like to build User Graphical Interface to design services and manage connected objects. We also plan on designing a protocol for automatic verification of service description consistency.

Keywords: Connected Objects, formal language, Human-Computer Interactions, Ubiquitous computing

Publications / Patents:

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Start: 01/10/2013 End: 30/09/2016

Abstract:

More and more organizations are adopting cloud-based Process-Aware Information Systems (PAIS) to manage and execute processes in the cloud as an environment to optimally share and deploy their applications. This is especially true for large organizations having branches operating in different regions with a considerable amount of similar processes. Such organizations need to support many variants of the same process due to their branches' local culture, regulations, etc. However, developing new process variant from scratch is error-prone and time consuming. Motivated by the "Design by Reuse" paradigm, branches may collaborate to develop new process variants by learning from their similar processes. These processes are often heterogeneous which prevent an easy and dynamic interoperability between different branches.

A process variant is an adjustment of a process model in order to flexibly adapt to specific needs. Many researches in both academics and industry are aiming to facilitate the design of process variants. Several approaches have been developed to assist process designers by searching for similar business process models or using reference models. However, these approaches are cumbersome, time-consuming and error-prone. Likewise, such approaches recommend entire process models which are not handy for process designers who need to adjust a specific part of a process model. In fact, process designers can better develop process variants having an approach that recommends a well-selected set of activities from a process model, referred to as process fragment. Large organizations with multiple branches execute BP variants in the cloud as environment to optimally deploy and share common resources. However, these cloud resources may be described using different cloud resources description standards which prevent the interoperability between different branches.

In this thesis, we address the above shortcomings by proposing an ontology-based approach to semantically populate a common knowledge base of processes and cloud resources and thus enable interoperability between organization's branches. We construct our knowledge base built by extending existing ontologies. We thereafter propose an approach to mine such knowledge base to assist the development of BP variants. Furthermore, we adopt a genetic algorithm to optimally allocate cloud resources to BPs. To validate our approach, we develop two proof of concepts and perform experiments on real datasets. Experimental results show that our approach is feasible and accurate in real use-cases.

Key words: Business process models, process mining, cloud resource allocation, business process fragments, ontology, knowledge base.

Publications:

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2. [Karn Yongsiriwit](#), Mohamed Sellami, Walid Gaaloul, A Semantic Framework Supporting Business Process Variability Using Event Logs, 13th International Conference on Services Computing, IEEE SCC 2016, San Francisco, USA, June 27 - July 2, 2016.
3. [Karn Yongsiriwit](#), Mohamed Sellami, Walid Gaaloul, A Semantic Framework Supporting Cloud Resource Descriptions Interoperability, 9th International Conference on Cloud Computing, IEEE CLOUD 2016, San Francisco, USA, June 27 - July 2, 2016.
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A MDE Approach To Build Secure Information Systems

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Start: 01/10/2013 End: 30/09/2016

Abstract:

Information systems (IS) play a crucial role in our society and are at the heart of most organizations. Therefore, the security of information systems constitutes a major issue and significant efforts are being made to enforce their access by defining adequate security policies and ensuring their correct deployment on a given technological infrastructure. To this aim, the different abstraction development layers should be strongly linked to guarantee that the security aspects are correctly maintained from the users requirement specification phase until their implementation.

In the beginning of this century, Model Driven Security (MDS) has been proposed as a solution that permits to reconcile these abstraction layers by transforming abstract models into a given target technology. Nevertheless although promising, this approach is rarely applied in practice. The main reasons for that are as follows. There is a lack of publicly available tools supporting MDS. Moreover, the approach must cope with dynamic constraints that refer to previous or/and future states of the system. This thesis aims at providing a complete formal approach, based on MDS methodology, to build secure information systems. The main contributions of this thesis are:

- Definition of a metamodel that permits to cope with both functional and security aspects of an IS, this corresponds to the Platform Independent Model (PIM) that also includes dynamic properties;
- Definition of translation rules to generate a formal B specification from the PIM model in order to reason on the formal specification and prove different properties;
- Definition of a proved refinement process to generate a database-like implementation based on the AOP paradigm;
- Development of an automatic tool to support the complete proposed approach.

Keywords: MDE approach, security policies, information systems, AOP paradigm

Publications :

Amel Mammar, Thi Mai Nguyen, Régine Lalaeau. **Formal Development of a Secure Access Control Filter**, IEEE High Assurance Systems Engineering Symposium (HASE 2016).

Thi Mai Nguyen, Amel Mammar, Regine Laleau, Samir Hameg: **A tool for the generation of a secure access control filter**. IEEE International Conference on Research Challenges in Information Science (RCIS 2016)

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Start: 01/10/2014 End: 31/09/2017

Abstract:

A complex system is defined as a set of distributed entities that have certain autonomy. The structure of a complex system is inherently in dynamic evolution due to its increasing size. The continuous growth of the complexity and the size of these systems make their design and management one of the most tedious tasks. Therefore, it becomes compulsory to enforce the autonomy of the entities that compose these systems with the principals of Autonomic Computing.

The introduction of Autonomic Computing implies the usage of autonomic loops that manage a set of resources. Their main role is to adapt the associated resources to the dynamic of their environment. Currently, each autonomic loop is solely responsible for the resources it manages. Decision making in an autonomic loop is performed independently of the other loops in the system. This independence can cause problems of inconsistency, concurrency, conflicts, etc.

Therefore, it is necessary to establish collaboration between the different autonomic loops that act in a complex system. This will enable different loops to exchange the necessary information to have an overview on the system state and to take reconfiguration decisions in an effective manner. In order to achieve this collaboration, we propose a generic framework for autonomic loops as well as mechanisms adopted in complex systems to evolve our autonomic loops infrastructure. This has for aim taking into account the information exchange between the different autonomic loops in the decision making mechanism and considering the cost of this collaboration.

Keywords: Complex Systems, Autonomic Management, Collaboration.

Publications / Patents:

Collaborative Autonomic Management of Distributed Component-based Applications Nabila Belhaj, Imen Ben Lahmar, Mohamed Mohamed, Djamel Belaïd 23rd International Conference on Cooperative Information Systems, CoopIS, On The Move to Meaningful Internet Systems, OTM Oct 2015 vol. 9415 pp. 3-18 State: published

Collaborative Autonomic Container for the Management of Component-based Applications Nabila Belhaj, Imen Ben Lahmar, Mohamed Mohamed, Djamel Belaïd 24th IEEE International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises, WETICE Aug 2015 pp. 41-43 State: published

Contextual integration of heterogeneous data in an open and opportunistic smart environment: application to humanoid robots

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Start: 02/10/2014 End: 02/10/2017

Abstract:

This thesis addresses the challenges induced by the contextual integration of heterogeneous data in an open and opportunistic smart environment for decision making. This is applied to a humanoid robot operating indoor: typically a service robot helping an elder in his/her everyday life. The robot shall be autonomous and mobile, and shall be able to reason and learn from what it perceives. The idea is to handle a mobile object (i.e. smartphone or robot) interacting with its environment. The environment is enhanced with communicating objects, mobile or not, that provide services.

The aim is to propose a mediation system sensitive to the context, in other words, it must discover dynamically and opportunistically surrounding objects and choose which one are to use according to objectives or needs.

Smart devices connect and disconnect over the moves of the embedded mediation system or of the objects themselves. Furthermore, as the environment evolves over time, context awareness is a major challenge. For example, the robot must be aware of the movement of the user or the changes of luminosity in order to interact with the devices needs and to provide proper services to the user. In the state of art, the consideration of the smart environment, in particular with robots, is not commonly addressed: for instance, context awareness in planning approaches is often neglected, and most situation awareness techniques do not support opportunism.

The thesis follows three steps matching layers of a simplified architecture: perception, cognition, action. At first, the action layer is addressed through a novel planning approach that is able to handle context changes and to smartly use the available devices. In everyday life environment, it is to expect that some generated plans could not reach the target goal, due to an unexpected obstacle or a mechanical issue. Our second objective is to reason, to analyze through cognition and to overcome these blocking situations. Finally, as sensors data are heterogeneous, uncertain and have various acquisition mode, we aim to provide a perception layer tackling these issues and capable of handling any kind of sensors.

Key words:

Ambient intelligence / Robotic / Reasoning

Publications / Patents:

- *Nathan Ramoly, Amel Bouzeghoub & Béatrice Finance*, Context-aware Planning by Refinement for Personal Robots in Smart Homes, 7th International Symposium on Robotics, 2016, state: published
- *Amina Jarraya, Nathan Ramoly, Amel Bouzeghoub, Khedija Arour, Amel Borgi and Béatrice Finance*, A Fuzzy Semantic CEP Model for Situation Identification in Smart Homes, 22nd European Conference on Artificial Intelligence, 2016, state: published
- *Amina Jarraya, Nathan Ramoly, Amel Bouzeghoub, Khedija Arour, Amel Borgi and Béatrice Finance*, FSCEP: a new model for Context Perception in Smart Homes, 24th International Conference on COOPerative Information Systems, 2016, state: published



Bringing transparency to personalized services through statistical inference

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Start: 01/10/2015 End: 30/09/2018

Abstract:

Personalized services are online services that use information about their users to offer to each user a service that is more adapted to the individual. With the proliferation of personal data over the Internet, personalized services have become omnipresent in our daily life, including for instance all services offering recommendations. Although this data-based personalization has increased the utility of services for users and for service providers, in the recent years, the gravity of the privacy concerns has increased considerably.

In fact, much of the privacy concern is due to a lack of transparency of personalized services: users do not know what information is known about them and how it is used. Moreover, users do not know how their information can be leveraged, even by third-parties and augment possible privacy leaks.

The goal of this PhD is to develop tools and statistical inference methods to bring transparency back by allowing users to infer what information is known about them, what can become known about them additionally, and by allowing users to control it. Throughout the project, we use social computing systems and targeted advertising as the main usecases of personalized service.

Keywords: Transparency, personalized services, targeted advertisement, statistical inference, data analytics, privacy, social computing systems

Publications / Patents:

Athanasios Andreou, Oana Goga, Patrick Loiseau and Krishna Gummadi. Identity vs. Attribute Disclosure Risks for Users with Multiple Social Profiles, 2016. (Preprint.)

Content, knowledge,interactions

Statistics of local descriptors for change detection, texture analysis and synthesis

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Start: 16/01/2014 End: 15/05/2017

Abstract

Important tasks in image analysis require indexing schemes that are invariant to both radiometric and geometric changes. These include texture recognition, remote sensing terrain identification or change detection, to name but a few. Using the statistics of local descriptors (such as SIFT descriptors) is a very efficient way to achieve such indexing schemes. In most of the literature, only the marginals of descriptors are used, therefore neglecting both their spatial distribution and their interactions.

The purpose of this thesis is to investigate the modeling of spatial distributions as well as dependency properties of local descriptors in this context. We first tackle two analysis tasks, texture recognition and change detection, and then consider the problem of texture synthesis.

1) Texture recognition.

Two of the most powerful indexing tools for recognizing texture images are bag-of-words of SIFT features, and statistics of local morphological attributes. We have proposed an improvement of these approaches relying on co-occurrences of local descriptors. We also developed an indexing methodology relying on the so-called Ripley K-function.

2) Unsupervised change detection.

In a second part of the thesis, we have developed a complete pipeline permitting to detect changes between high resolution remote sensing images, possibly acquired by different sensors and with different angles, and without co-registration. The approach relies on local descriptor statistics and a *contrario* methods. The only existing methods permitting such a task necessitate the knowledge or computing of a terrain model, while our approach only needs two images. The efficiency of the method is demonstrated both with known satellite acquisitions and arbitrary images from Google Earth.

3) Texture synthesis

Very recently, a breakthrough has been achieved for the automatic synthesis of texture images from an example, by using Convolutional Neural Networks (CNN). The idea is to impose statistics of the linear responses of the CNN, in a way similar to what is classically done with wavelet-based texture synthesis. While achieving impressive results, these approaches fail in the presence of low frequency contents (e.g. brick wall, tiling, checkerboards, etc.). In this last part of the thesis, we model the synthesis as a constrained optimization problem, with constraints conditioning both the Fourier spectrum and statistical features learned by CNNs. In contrast with existing methods, the presented method inherits from previous CNN approaches the ability to depict local structures and fine scale details, and at the same time yields coherent large scale structures, even in the case of quasi-periodic images. This is done at no extra computational cost. Synthesis experiments on various images show a clear improvement compared to a recent state-of-the art method relying on CNN constraints only.

Keywords (choose 3 key words max): Local descriptors, texture, change detection

Publications / Patents:

[1]. Texture synthesis by using convolutional neural networks and spectrum constraint, G. Liu, Y. Gousseau and G.-S. Xia, ICPR2016.

[2]. Unsupervised change detection in multi-sensor high resolution satellite images, G. Liu, J. Delon, Y. Gousseau and F. Tupin, Eusipco2016. Journal version in advanced preparation.

[3]. Shape co-occurrence patterns for texture classification, G.Liu, G.-S. Xia, ICPR2014. Journal version in advanced preparation



Une école de l'IMT

Local features for RGBD image matching under viewpoint changes

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Start: 01/10/2013 End: 07/11/2016

Abstract:

In the last five-to-ten years, 3D acquisition has emerged in many practical areas thanks to new technologies that enable a massive generation of texture+depth (RGBD) visual content, including infrared sensors Microsoft Kinect, Asus Xtion, Intel RealSense, Google Tango, laser 3D scanners (LIDARs). The increasing availability of this enriched visual modality, combining both photometric and geometric information about the observed scene, opens up new horizons for different classic problems in vision, robotics and multimedia. In this thesis, we address the task of establishing local visual correspondences in images, which is a basic task that numerous higher-level problems are settled with. The local correspondences are commonly found through local visual features. While these have been exhaustively studied for traditional images, little work has been done so far for the case of RGBD content.

This thesis begins with a study of the invariance of existing local feature extraction techniques to different visual deformations. It is known that the traditional photometric local features that do not rely on any kind of geometrical information may be robust to various in-plane transformations, but are highly sensible to perspective distortions caused by viewpoint changes and local 3D transformations of the surface. Yet, those visual deformations are widely present in real-world applications. Based on this insight, we attempt to eliminate this vulnerability in the case of texture+depth input, by properly embedding the complementary geometrical information into the first two stages of the feature extraction process: repeatable interesting point detection and distinctive local descriptor computation.

With this objective, we contribute with several new approaches of keypoint detection and descriptor extraction, that preserve the conventional degree of keypoint covariance and descriptor invariance to in-plane visual deformations, but aim at improved stability to out-of-plane (3D) transformations in comparison to existing texture-only and texture+depth local features. In order to assess the performance of the proposed approaches, we revisit a classic feature repeatability and discriminability evaluation procedure, taking into account the extended modality of the input. Along with this, we conduct experiments using application-level scenarios on RGBD datasets acquired with Kinect sensors. The results show the advantages of the new proposed RGBD local features in terms of stability under viewpoint changes.

Keywords: RGBD, texture+depth, keypoint, local image descriptor, local feature.

Publications / Patents:



Community detection in complex networks

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Start: 01/10/2015 – End: 31/12/2018

Abstract:

Community detection has been receiving a great attention from the world of scientists in many disciplines due to its broad range of application. Some application fields such as detecting groups of similar users in social networks, identifying communities of malicious web domains in network security, discovering plausible candidates for biological modules in protein-protein interaction networks, etc., are worth to be mentioned. Provided that a network can be modeled as a graph, i.e. a set of vertices representing objects interconnected by edges representing relationships between these objects, multiple community detection methods can be applied to extract hidden community structures.

As the notion of structural community varies according to specific contexts, depending on which kind of network is considered and in which kind of application, one might need to decompose a network into clusters that possess specific features with different desired modular structures. However, there is actually no guidance that can help analysts to choose the most appropriate methods for their specific requirements about structural features. This thesis aims to survey existing community detection methods' functionalities in such a way that can assist analysts to find methods that best correspond to their requirements about community structure.

In order to achieve this task, we firstly describe the notions of community structure that could be interesting for different contexts and conduct exhaustive experimentations on various datasets in order to verify the existence of these structures [1]. Then, we analyze communities identified by different methods to extract common structural characteristics produced by each method and match each one with a similar predefined notion of community.

As a whole, we expect to help analysts with a meaningful guideline to choose appropriate community detection methods for their applications, or at least, when no definitive conclusion can be determined, with a meaningful description of potential solutions.

Keywords: Community detection, complex network

Publication:

[1] Vinh-Loc Dao, Cécile Bothorel, Philippe Lenca: Community structures evaluation in complex networks: A descriptive approach, in NetSciX-2017. (Accepted for publishing in the Proceedings in Complexity series by Springer Nature).



Geometry & Statistics of Self-Similarity in Natural Images. Applications to Inverse Problems in Imaging

Géométrie & Statistique de l'Auto-similarité des Images Naturelles
applications à la Résolution de Problèmes Inverses

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Start: 05/10/2015 End: 4/10/2018

Abstract:

The topic of this thesis is twofold:

1. We propose to develop and implement a general theoretical framework for modeling self-similarity in natural images, including and extending recent works in the field.

2. We propose to apply this theoretical framework to the solution of inverse problems in computational photography.

During the first year of this thesis we addressed two theoretical issues and an application on image denoising, namely

A. Image patches model

We formalize an statistical approach to the regularization of inverse problems in imaging via Gaussian Mixture Models (GMM) for natural image patches. We add a dimensional model on the GMM in order to properly solve the issue induced by the “curse of dimensionality”. This work yields an image denoising algorithm that seems to reach the state-of-the-art performance. This work will be submitted for publication shortly.

B. Global image denoising

In this work, we focus on the global denoising framework recently introduced by Talebi & Milanfar (2014) and analyze the asymptotic behavior of its RMSE (root mean squared error) restoration performance when the image size tends to infinity.

We introduce precise conditions both on the image and the global filter to ensure and quantify this convergence. We also discuss open issues concerning the most challenging aspect, namely optimal choice of basis. This part of the work was submitted for a poster presentation at the international conference SIAM IS16 and we also submitted a paper in JMIV.

References :

Talebi, H., & Milanfar, P. (2014). Global Image Denoising. *IEEE Transactions on Image Processing*, 23(2), 755–768.
doi:10.1109/TIP.2013.2293425

Key words:

Image Denoising, Inverse Problems in Imaging, Self-Similarity and Patch-Based Methods

Publications / Patents:

A. Houdard, A. Almansa, J. Delon, “On the Asymptotic Optimality of Global Image Denoising”, *SIAM Conference on Imaging Science*, Albuquerque, NM, USA, May 23-26. Submitted Abstract.

A. Houdard, A. Almansa, J. Delon, “Demystifying the asymptotic behavior of global denoising”, submitted to JMIV

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Start: 01/10/2015 End: 30/09/2018

Abstract:

Modern video players and display devices allow the user to directly act in a video content while watching it. The user can change the position of the camera, zoom inside the video or even interact with objects inside the video. Such video services, which we refer to as Interactive Video, is a major disruption in the multimedia industry: cloud gaming, 360° videos, immersive Virtual Reality (VR), and multi-view videos. The Quality of Experience (QoE) felt by a user watching an interactive video is extremely sensitive to the resolution, the frame rate, and the latency of the video. For instance, to deliver a high-quality 360-degree immersion on head-mounted displayed (HMD) devices, a content provider needs to transmit a 4K resolution video per eye at 100 frames per second with a reaction time lesser than 10 ms. Under those constraints, the streaming of interactive video over the Internet is extremely challenging because of the gap between current Internet connection and the needs of high-quality interactive videos.

The goal of this PhD thesis is to improve the QoE of the streaming of interactive video. I first worked on a cross-layer scheduler to stream low latency Dynamic Adaptive Streaming over HTTP (DASH) videos using the MultiPath TCP (MPTCP) transport protocol.

Then i worked on a lightweight evaluation function to estimate the impact of the loss of a video frame on the distortion generated at the client side. I have also worked on an original proposition of a view-adaptive video streaming architecture to stream 360-degree videos. And finally I defined an optimal model to generate 360-degree video representations with Quality Emphasized Regions (QERs) for Viewport-Adaptive streaming content provider.

Keywords: interactive video, 360° videos, Viewport-Adaptive streaming, multimedia delivery, content provider, cloud gaming

Publications / Patents:

- Cross-Layer Scheduler for Video Streaming over MPTCP, X. Corbillon, R. Aporicio-Pardo, N. Kuhn, G. Texier, G. Simon, ACM MMSys 2016.

State: **published**

- Efficient lightweight video packet filtering for large-scale video data delivery, X. Corbillon, F. Boyrivent, G. Asselin De Williencourt, G. Simon, G. Texier, J. Chakareski, ICME Packet Video Workshops 2016.

State: **published**

- Viewport-Adaptive Navigable 360-Degree Video Delivery, X. Corbillon, A. Devlic, G. Simon, J. Chakareski, ArXiv preprint 1609.08042 2016

State: **published**

- Viewport-Adaptive Navigable 360-Degree Video Delivery, X. Corbillon, A. Devlic, G. Simon, J. Chakareski, IEEE ICC 2017

State: **submitted**

- Optimal 360-Degree Video Representation for Viewport-Adaptive Streaming, X. Corbillon, G. Simon, A. Devlic, J. Chakareski, ACM MMSys 2017

State: **submitted**



Une école de l'IMT

Learning and information transmission for online learning and transfer between domains: use of non-euclidean geometries and Kolmogorov complexity

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Start: 04/01/2016 End: 03/01/2019

Abstract:

The goal is to use continuity and simplicity principles in order to learn from very few samples or from samples in a related domain which would be different from the target domain. These conditions make a merely statistical approach completely inefficient.

This research project is bounded by two limit cases: on the one side, the statistical approaches of automatic learning which are currently growing up due to the amount of available data and to the computing power; on the other side, the structural approaches able to learn from only a few samples. The study is based on two theoretical tools:

- (1) non-euclidean geometry which enables formalizing analogic transport from a source domain to a target domain;
- (2) Kolmogorov complexity which offers a formal framework for both statistical and symbolic induction.

This study is a way to think "out of the box": automatic learning tends to focus on cases where the data are available and thus to neglect the sometimes strategic situations when statistical approach cannot rival human performances. This study could help to address this gap.

Keywords:

Automatic learning, analogy, Kolmogorov complexity

Publications / Patents:

Minimum Description Length Principle applied to Structure Adaptation for Classification under Concept Drift, P.-A. Murena and A. Cornuéjols. In *2016 International Joint Conference on Neural Networks (IJCNN)*, pp. 2842–2849, July 2016

Passive Incremental Learning with the Minimum Description Length Principle, P.-A. Murena, A. Cornuéjols and J.-L. Dessalles. Submitted to IJCNN 2017



Diachronic analysis of diasporic communities through the enrichment of web archives

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Start: 16/11/2015 End: 16/11/2018

Abstract :

Based on, and extending the e-Diasporas Atlas project (1), the present thesis will investigate for the first time a web archives corpus of 10000 sites crawled and captured by the French National Audiovisual Institute during the past 6 years.

The e-Diasporas Atlas project was a pioneer research program in the analysis of on-line activities associated with migrant populations as it helped to reveal diasporic communities through the visualization of migrant websites networks. The timestamp annotations, the wide volume (70 TB) and the thematic coherence of our archives constitute a gold mine for all kind of analysis: from sociology of migration to web's history.

The inspiration of our research is to argue that the structure and contents of web archives can be permeable to the effects of shock and external events, political and social mobilizations, catastrophes, etc. By following those traces and enriching them we will be able to deal with an event and its genesis by restoring it in the dual temporality of the web and the real. Can we detect and understand the web through its transitions and mutations, from the web of blogs to the social web, from laptop's to smartphone's screen?

As the ability to collect, store, and manage data is increasing quickly, our ability to understand it remains constant. In an attempt to gain better understanding of web archives data, the present thesis tends to be consistent with the Exploratory Data Analysis as formalized by Tukey (2). This iterative loop where the maximization of data's insight by extracting important variables goes to the discovery of underlying structures, outliers and anomalies which will help researchers and sociologists extract knowledge by the construction of "maps" and "compass" through web archives.

(1) Dana Diminescu, *e-Diasporas Atlas. Exploration and Cartography of Diasporas on Digital Networks*, 2012

(2) John Tukey, *The Future of Data Analysis*, 1961

Keywords : Diasporas and migrations, web archives, temporal web

Publications:

Deep learning-based continuing robot learning of visual objects and gestures

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Start: 01/10/2015 End: 30/09/2018

Abstract:

While speech robotics is a mature technology, efforts dedicated to vision robotics are still restricted to limited tasks. This might be explained by previous processing power and storage capabilities. Yet gesture recognition is needed for communication with users suffering from speech, hearing or other cognitive impairment. The objective of this thesis is to develop a robust human-machine interaction through gesture interpretation while ensuring a wide acceptability among users. The targeted application is an engine for recognizing sign language in real-life conditions.

The thesis main objectives are :

- Constructing a solid recognition stack from video processing to recognition which implements state of the art methods
- Exploring the resemblance and dissimilarities between voice and gesture recognition
- Experiment continuous and incremental learning for gesture recognition

The thesis ambitions to explore two different aspects of machine learning for gesture recognition:

- Representation learning, a new active statistical learning approach supported by recent breakthrough on deep learning models in several applications of computer vision. Representation learning may help to find compact and sensible encoding of features for the purpose of gesture classification.
- Reinforcement learning for user-specific optimization and label creation for the insertion of new gesture classes.

So far, the work has been focused on the recognition stack which involves :

- the preprocessing of Kinect depth map videos
- a Convolutional Neural Network based feature extraction
- an HMM based sequence recognition

Until recently the hybrid CNN-HMM was the state of the art method for speech recognition. Upcoming experiments will test the CNN-Recurrent Neural Network architecture which allows end-to-end training of the parameters in a more natural way.

Keywords: Sign Language, Computer-Vision, Machine-Learning

Publications:



Incremental learning of affordances using interactive and strategical algorithms

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Start: 01/10/2016 End: 30/09/2019

Abstract:

Nowadays, an assistant robot must be able to plan different actions in order to efficiently perform tasks and transform its environment. Nevertheless, facing the complexity and the diversity of the tasks and situations the robot may encounter, it is impossible to completely pre-program it. At the opposite, it should be given the capacity to learn new tasks all along its life and to adapt to its environment.

Currently, learning algorithms for multitasks have already been developed, based on the human-robot interaction. They allow the motor control of the robot and the control of the environment in order, for a robot, to learn how to move and how to interact with the surroundings. Until now, those algorithms, called interactive and strategical algorithms, have only permit to learn simple tasks, composed of a single action. The question now is how to allow a robot to perform complex tasks and to plan series of actions. This PhD Thesis is focused on improving those algorithm in order to let a robot use this multitask learning to plan complex tasks.

To reach this goal we will combine learning algorithms, using active and incremental approaches and planning methods. As we want our robots to be able to operate in real environment, we will operate on a low level representation of the surroundings, using raw data from sensors (camera, depth sensor...) to construct semantic maps. We will use predictive models for planning and, to improve its decision taking, the robot will simulate the consequences of its various actions in order to pick the best actions to execute.

The algorithms developed during this PhD Thesis will help a robot to navigate in an obstructed environment or to learn affordances from the objects around it.

Keywords : Interactive Learning, Intrinsic motivation, Planning

Publications:



Understanding the affective and stylistic human motion for style transfer and animation

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Start: 01/10/2016 End: 30/09/2019

Abstract:

Understanding human motion is an important issue currently studied in various research fields. Improvements made on that topic can, therefore, benefit different domains such as gaming, human computer interaction, biometry and medical applications.

Human motion can be considered as a combination of two sets of features: action variations – specifying actions like walking, running, punching or jumping, etc. – and stylistic variations – related to emotions, styles or individual characteristics in which those actions are performed. The thesis aims to investigate new approaches to analyze human motion by taking advantage of the recent advancements in acquisition technologies (depth sensors, motion-capture, etc.), and demonstrate its effectiveness in several application domains and contexts.

This thesis also aims to develop an animation system for motion synthesis and control, which takes into consideration the affective and stylistic motion features, and gives the possibility to add various styles or emotions to an existing animation.

Keywords: 3D motion analysis, character animation, style transfer

Publications:

Security of digital systems and services

Experimental implementation of multipartite entanglement

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Start: 01/10/2014 End: 30/09/2017

Abstract:

Entanglement is one of the most important resources for quantum information; in particular, it is necessary for quantum communication protocols such as quantum key distribution, quantum teleportation, and entanglement swapping. To be useful for future quantum communication networks, entangled photons need to be distributed to a large number of parties.

In our lab, we have developed entangled photon pair sources based on the spontaneous parametric down conversion (SPDC) process. Photon pairs are generated at 1558 nm in a periodically poled lithium niobate crystal, and polarisation entanglement is produced through a Michelson interferometer. Maximally entangled states, also called Bell states of the type $|\phi^+\rangle = \frac{1}{\sqrt{2}}(|HH\rangle + |VV\rangle)$, where H and V denote horizontal and vertical polarization, can be obtained. The large bandwidth of the created photon pairs allows to split the pairs and to distribute them using commercial telecom wavelength division demultiplexers. With this technique, we experimentally demonstrated the distribution of entanglement to 8 user pairs in a quantum network environment, certified by the violation of the Bell inequality in each case ⁽¹⁾. We also examined the effect of the demultiplexer characteristics on the quality of the distributed entanglement and performed our experiment over an attenuation corresponding to 20 kilometers of optical fiber. Thanks to a collaboration with the MPQ group in Paris 7, this method was also used for a quantum key distribution experiment, with a semiconductor based source ⁽²⁾.

Our next goal is to generate multipartite entangled states, such as, for instance the so-called Greenberg-Horne-Zeilinger state, written as $|\text{GHZ}\rangle = \frac{1}{\sqrt{N}}(|HH\dots H\rangle + |VV\dots V\rangle)$ for N entangled particles. These states are required for advanced quantum information protocols. To obtain the GHZ state for 4 photons we plan to perform a 'fusion' operation between two entangled-photon sources using regular optical components (polarizing beam splitters etc). These four photon states will be detected thanks to coincidences between pairs from two different pair sources. The observation of these events requires very high stability of the experiments and long integration times. Alternatively, we can use hyper-entanglement, which means that we exploit several degrees of freedom of the photons, for instance, polarization and path. This reduces the required resources for multipartite entanglement. The different schemes of the experiments currently underway will be presented on the poster.

Keywords: Entanglement, quantum communications

Publications / Patents:

- (1) Multi-user distribution of polarization entangled photon pairs, J.Trapateau, J.Ghalbouni, A.Orieux, E. Diamanti and I.Zaquine J.Appl.Phys. 118, 143106 (2015)
- (2) « Multi-user quantum key distribution with entangled photons from an AlGaAs chip » Quantum Science and Technology 1, (2016)

E-Health



Platform for automated monitoring of physiological signals in emergency medicine by sequential detection and discrimination of changes with unknown distributions

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Telecom Bretagne / Signal and Communication / LabSTICC -TOMS

Université de Bretagne Occidentale / CHU Brest / LaTIM

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Start: 01/10/2013 End: 30/09/2016

Abstract:

The quality of emergency care and resuscitation requires automated devices for anomaly detection and discrimination for the purpose of monitoring the evolution of various physiological signals. This thesis aims at developing robust, simple and noninvasive methods and tools for real-time monitoring of patients' cardiorespiratory activities and predicting critical cases.

Heart rate (HR) and respiratory rate (RR) can be estimated and tracked from the photoplethysmograph (PPG) which is a representation of the signal resulting from the pulse oximetry measure.

Having an accurate estimation of HR and RR relies on the quality of the PPG signals, which is very sensitive to noise artefact induced by the subject movement and the measurement conditions.

So, two major challenges are addressed: Reducing artifacts and robust estimation of heart rate and respiratory rate. To reduce the effect of artefacts, we propose a new method for detection and rejection of contaminated pulses based on an adaptive comparison of the pulses morphology. Then, we use Random Distortion Testing for hypothesis testing [1]. Heart rate matches with the inverse of the PPG peak to peak distance. To achieve this, moving average method combined to Fourier Transform is used to detect peaks. To estimate respiratory rate, we use Fourier analysis combined with statistical methods to detect respiratory and frequency peaks at the corresponding respiratory band range.

To validate these algorithms, we use different databases. Firstly, the Capnabase database, which is an online database that we use to compare results with other studies. Secondly, to validate the universality of the methods in real conditions, we collaborate with CHU Brest which provides us with the ReaStock database. ReaStock contains physiological signal records of patients in intensive care, with references and annotations about patient's cases.

Keywords: photoplethysmograph, artefact detection, respiratory rate estimation.

Publications:

[1] S. Cherif, D. Pastor, Q. T. Nguyen, and E. L'Her, "Detection of artifacts on photoplethysmography signals using random distortion testing" in Engineering in Medicine and Biology Society (EMBC), 2016 38th Annual International Conference of the IEEE, Aug. 2016.

Source localization for functional brain imaging with M/EEG

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Start: 19/01/2015 End: 31/12/2017

Abstract :

Magnetoencephalography (MEG) and Electroencephalography (EEG) allow for non-invasive analysis of functional brain imaging with high temporal and good spatial resolution. For a given magnetic-electric field outside the head, there are an infinite number of electrical current distributions that could have created it. This means that the M/EEG inverse problem is ill-posed, having many solutions to the single problem. This constrains us to make assumptions about how the brain might work. For example one might assume that many electrical sources are active across the cortical sheet at any time point (MNE [1]). During my PhD, we have been interested in the assumption of having sparse source space, i.e. only few sources are activated in some time windows.

As it was already presented in [2], MxNE promotes spatially focal sources with smooth temporal estimates over the whole window of interest by assuming stationary sources during that time interval. However, this only holds for short time-windows; to overcome this limitation, [3] proposed to use the mixed norm regularization on the time-frequency analysis, in order to capture the non-stationarity and transient nature of brain signals. We then asked the question of what kind of dictionary we should use for the time-frequency decomposition? [3] was taking STFT of the signal by fixing the size of the time window and the overlapping parameter; however, it turned out to be difficult to capture the sources when they produce a mixture of slow waves and sharp transient in the signals.

Hence, we proposed the use of a combination of dictionaries to capture all the different waveforms in the signal. This work has been published in PRNI IEEE conference last summer [4]. In parallel, Daniel Strohmeier was working on another improvement of these source localization methods by looking at the amplitude bias compensation. This issue is mainly due to the $l1$ prior, where the high sparsity of the solution comes with a strong amplitude bias. This is compensated by postprocessing the obtained source waveforms in MxNE/TF-MxNE.

Following on this, they have proposed to use a non-convex optimization problem by introducing $l_{0.5}$ quasi-norm, which still promotes sparsity yet with much less amplitude bias. The issue is that optimization is harder for such non-convex problems. To do so, they have proposed an iterative strategy inspired by reweighted schemes previously proposed in machine learning: It is the iterative reweighted mixed-norm. This work has been accepted to the IEEE journal TMI [5]. I've been contributing to this work by implementing the RAP-MUSIC algorithm [6], which is another way to find focal sources by decomposing the covariance data to a signal and noise subspace, and then compute the sub-correlation to find the best sources.

The difficulty of all the proposed inverse problem solvers is their need to tune one or several hyper-parameters. This makes the validation of the methods with many datasets difficult. The actual project is then to estimate hyper-parameters automatically. Our approach is based on hierarchical Bayesian models for which we compute maximum-a-posteriori estimates jointly for the sources and the hyper-parameters. We already have some results and a draft to be submitted to EUSIPCO in February 2017.

[1] Hämmäläinen, M.S., and Ilmoniemi, R.J. *Medical & biological engineering & computing* (1994) 32:35-42. [2] Gramfort, A., et al. *Physics in medicine and biology* (2012) 57:1937. [3] Gramfort, A., et al. *NeuroImage* (2013) 70:410-422. [4] Bekhti, Y., et al. *PRNI* (2016). [5] Strohmeier, D., Bekhti, Y., Haueisen, J., Gramfort, A. (2016) *IEEE TMI* 35(10): 2218-2228. [6] Mosher, J.C., and Leahy, R.M. *Signal Processing, IEEE Transactions on* (1999) 47:332-340.

Keywords: M/EEG, Inverse problem, Optimization

Publications / Patents:

- Strohmeier, D., Bekhti, Y., Haueisen, J., Gramfort, A. (2016), *IEEE TMI* 35(10):2218-2228.
- Bekhti, Y., et al. M/EEG source localization with multi-scale time-frequency dictionaries. PRNI (2016)



Une école de l'IMT

Automatic Handwriting Analysis on Digital Tablets for Pathology Detection and Therapeutic Monitoring

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Start: 01/09/2015 End: 31/08/2018

Abstract:

This thesis aims at characterizing through on-line handwriting the psychomotor dysfunctioning due to neurodegenerative disease. It is carried out in collaboration with the Geriatrics Service of Broca Hospital (APHP-Broca) in Paris. Our goal is to develop statistical tools for automatic detection of Alzheimer's disease and Mild Cognitive Impairment based on the kinematics and spatial characteristics of handwriting.

We have this far completed the state-of-the-art and defined the protocol for data collection. Data collection is in progress at Broca Hospital on volunteer persons with Mild Cognitive Impairment (MCI), Alzheimer's disease (AD) and Healthy Controls (HC) who agree to participate in the study. A Total of 144 individuals aged over 60 years have participated in the present study. Among these, 29 are AD, 87 are MCI and 28 are HC. All participants had to copy an imposed text and did other graphic tasks. In this analysis only the imposed text is used.

We started analyzing the acquired data through statistical methods of the state-of-the-art, mostly based on descriptive statistics. Then, new features have been proposed and compared to the most popular in terms of their discrimination capabilities between the three groups (AD, MCI, and HC). Those features are based on kinematic, dynamic and complexity of the pen trajectory. We have a first set of 46 features; to keep only features that are very significant in terms of discrimination; we applied a selection of candidate features based on mutual information. These selected features are used in an Agglomerative Hierarchical Clustering (AHC) and this clustering retrieved 2 main clusters which have the following distributions of samples:

- The 1st cluster has most of Alzheimer's disease patients (AD) and a set of persons with Mild Cognitive Impairment (MCI);
- The 2nd cluster has a major part of Healthy controls persons (HC) and another set of persons with Mild Cognitive Impairment (MCI).

Thus, we isolated two opposed groups, the first one contains AD and MCI who are closed to AD and the second group contains HC and MCI who are closed to HC.

These preliminary results have been presented in [1].

For the next step we will improve this study and analyze in more details other graphic tasks. After that we will start the longitudinal study which will allow us to predict persons with MCI who will probably change into AD, and we will determine the features that are the best predictors of AD.

Keywords: digital tablet, handwriting, Alzheimer, clustering, mutual information

Publications / Patents:

[1] C. Kahindo, M.A. El-Yacoubi, S. Garcia-Salicetti, V.Cristancho-Lacroix, H. Kerhervé, Anne-Sophie Rigaud, "Identification de Marqueurs de la Maladie d'Alzheimer à travers l'Écriture manuscrite acquise sur Tablette graphique", Journée Nationale de l'Internet des Objets, Nokia Paris-Saclay, France, 2016.

Voice and neuroimaging correlate study in predisposed subjects to Parkinson's disease: diagnosis and prognosis.

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Start: 01/10/2015 End: 01/10/2018

Abstract:

Vocal impairments are one of the earliest disrupted modalities in Parkinson's disease (PD). These alterations of speech are mainly characterized as hypokinetic dysarthria, and are found in 90% of patients with PD [1]. Some vocal impairments are even present up to 5 years before the clinical diagnosis [2], [3]. Detection of PD based on voice records is possible, and several researchers are currently working on PD telediagnosis based on vocal tests via mobile phones (Parkinson Voice Initiative). This will make the diagnosis quicker, cheaper and much more accessible. Unfortunately this will not allow a diagnosis earlier than it is currently done with the motor tests, because those teams will build their diagnostic tools from vocal records of patients who are already diagnosed. And the clinical diagnoses are done when there are motor manifestations, which occur after the loss of 70% of dopaminergic neurons [4].

The main goal of our study is to detect PD during the prodromal stage, in order that patients could have a treatment as soon as possible, to better slow down the disease's progression, and one day to stop the disease's progression (when such treatment exists). We also would like to be able to predict the evolution and the severity of the PD that people may develop (to adapt the treatment). To reach that goal we are looking for early diagnostic and prognostic markers in the voice of predisposed subjects to PD. We are analyzing the vocal changes in predisposed subjects to Parkinson disease (with REM Behavior Disorders) and in subjects diagnosed recently as parkinsonian, in comparison with healthy subjects. The subjects are recruited within ICEBERG protocol at the Institut du Cerveau et de la Moelle in Paris. We ask them to do simple vocal tasks during which their voice is recorded. We are analyzing phonation, articulation, prosody and rhythm. We are adapting and improving techniques used in previous researches on parkinsonian voice combined with techniques used in speaker recognition. The recordings are done once a year at the laboratory and once a month via phone calls, during several years, to see the evolution. This should allow us, after comparison of the vocal parameters and the clinical data, to find early diagnostic and prognostic markers. And finally to create a simple early automatic diagnostic tool, based upon voice recordings at the doctor's, or even via phone calls.

The other aim of our project is to understand the changes in anatomical and functional networks at the very beginning of Parkinson's disease. To reach that goal, we will record neural activities of the same subjects with fMRI at resting state and during vocal tasks. We will analyze the differences between the groups (healthy, predisposed and parkinsonian), and compare the neuroimaging data with the vocal data, in order to better understand the neural networks alterations at the very beginning of PD.

To conclude the overall goal of our project is to understand the changes in anatomical and functional networks at the very beginning of Parkinson's disease, and to establish a simple procedure for early diagnosis and prognosis via voice recordings.

[1] J. R. Orozco-Arroyave, J. D. Arias-Londoño, J. F. Vargas-Bonilla, M. C. Gonzalez-Rátiva, et E. Nöth, « New Spanish Speech Corpus Database for the Analysis of People Suffering from Parkinson's Disease », in Proceedings of the Ninth International Conference on Language Resources and Evaluation (LREC'14), Reykjavik, Iceland, 2014.[2] B. T. Harel, M. S. Cannizzaro, H. Cohen, N. Reilly, et P. J. Snyder, « Acoustic characteristics of Parkinsonian speech: a potential biomarker of early disease progression and treatment », Journal of Neurolinguistics, vol. 17, no 6, p. 439 453, nov. 2004.

[3] J. Ruzs, J. Hlavnička, T. Tykalová, J. Bušková, O. Ulmanová, E. Růžicka, et K. Šonka, « Quantitative assessment of motor speech abnormalities in idiopathic rapid eye movement sleep behaviour disorder », Sleep Medicine, sept. 2015.

[4] M. C. Rodríguez-Oroz, M. Jahanshahi, P. Krack, I. Litvan, R. Macias, E. Bezard, et J. A. Obeso, « Initial clinical manifestations of Parkinson's disease: features and pathophysiological mechanisms », The Lancet Neurology, vol. 8, no 12, p. 1128 1139, déc. 2009.

Keywords: Parkinson, voice, fMRI



Integrated Sensors of Volatile Organic Compounds by impedancemetry for disease diagnosis

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Start: 01/10/2016 End: 2019

Abstract:

The aim of this thesis is to design an electronic nose capable of detecting and classifying volatile organic compounds (VOCs) in exhaled breath and thus it will be possible to have a non-invasive method of diagnosis at early stages of the diseases.

Exhaled breath contains hundreds of compounds and some of them are related to different diseases. Nevertheless, a disease is hardly linked with just one compound but with a multiplicity of changes in the composition of breath. For example, diabetes can be detected with the level of acetone in exhaled breath only, but lung cancer modifies the concentration of dozens of VOCs. Moreover, most of them are at very low concentrations (part per billion). Optical spectroscopic methods can achieve these kinds of measurement but they are bulky.

Having a handheld device that can be easily used by a doctor require simpler methods, like using nonspecific sensors array. The principle is to use sensors which are sensitive to several compounds but not in the same way, and thus attribute a pattern response to a disease. The sensitive surface of the sensors is made of intrinsically conducting polymers called polyaniline, developed at Mines de Douai. They are promising to detect VOCs at a very low concentration. In contact of certain compounds, the electrical impedance of the polyaniline increases due to its deprotonation. With different methods of synthesizing and doping, we can have enough sensors with different sensitivities.

The first step is to recover the response of every sensor and secondly use the right algorithm of classification. It must present the best ratio efficiency/complexity in order to be integrated in a low consumption device. At the end of the thesis, it is expected to have a prototype which has the electronic interface of measurement, the stage of classification of an array of sensors based on polyaniline and that can be tested in a controlled environment.

Keywords : Integrated sensors, Impedance measurement, Early diagnosis

Publications:

Digital Society

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Start: 01/10/2013

Abstract :

In this dissertation we study the social construction of crowdfunding platforms in France. This study is based on interviews with funders and employees of platforms, project owners, political actors within ministries and public administrations, and observations of meetings of a professional association of platforms.

We try to understand how the market of crowdfunding emerges in France. After replacing the development of platforms in the context of traditional financing models, we show that the government has recognized this mode of financing as being able to finance the economy of the country. As a result specific legal standards are created for the platforms to encourage their development.

We study how different notions such as protection of the funders, liberalization and regulation of markets are translated in interaction with the different stakeholders. Then, we study how platforms as marketplaces involve project owners and funders on their platforms. We show that the platforms are commercial judging devices, which provide knowledge for future funders to form their judgment.

The platforms select and standardize crowdfunding campaigns. Thus, platforms appear as economic and political constructions.

Keywords: crowdfunding, market, regulation



Characterization of the good team and leadership to produce good knowledge, the case of Virtual communities.

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Start: 01/11/2014 End: 31/10/2017

Abstract:

People are using the Internet to collaborate and create in ways never before possible. They are geographically distributed, sometimes located in countries on opposite ends of the world, yet technology helps them find each other and connect. Here communities aiming at producing a certain kind of knowledge are viewed as central in the generation of new, innovative knowledge, because the organizations increasingly rely on virtual teams to produce knowledge and also because of the "open-innovation" relationships they create with these online communities. In this context, the prevalence of Wikipedia as the largest free and open access online encyclopedia attracts thousands of volunteer contributors and tens of millions of article views every day. A core question is how this online epistemic community produces a high quality knowledge as outcome dealing with dispersion on a variety of dimensions.

This online creative collaboration is challenging our basic assumptions about factors that contribute to produce more successful projects and to create a high quality knowledge. These points go beyond the simple case of open online communities: the management of those virtual teams echoes the questions of the collective production of knowledge and of the functioning of the groups producing it.

As a primary contribution of our work we propose a method to forecast the future quality of an online knowledge production community -or online epistemic community- by studying the composition of the group who initiated them (the "core members" of, in this case, an article). First, we set a team building period which is defined as the period of 120 days after article creation in order to construct this "core members" group. Second, we explore the effects on article quality of both group composition and member diversity. Core members' characteristics are learned from their previous behavior. The analysis is based on the French Wikipedia project. Our results show that the most important attributes of initial core member to have a high quality article are average reputation, diversity's contribution, participation, and group size. We also find no significant effects of experience diversity and reputation when we are in the team building period.

As a second contribution, we are interested on self-organizing voluntary teams collaborating online to produce new knowledge. Motivated by this phenomenon, our research investigates how teams are auto-formed and participate to efficient project. We test empirically the impact of past collaborative and social ties on WikiProjects efficiency. We find that project efficiency has a non-linear relationship with existing small world properties and the prior leadership behavior improve the project effectiveness.

As a third step in our model, we will work on the manner members organize their activities. We will study in particular the different kinds of leadership and their effect on article quality.

Keywords: Epistemic community, Knowledge Quality, Team Characteristics, Core member, Diversity, Wikipedia, social relation, prior collaborative networks, self-organizing, auto-formed, quality, teaming, small world, leadership.

Publications

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Start: 05/11/2014 End: 05/11/2017

Abstract:

The digital economy is characterized by business models built around the selling of slots for targeted ads. The value of these slots rises with the audience and the ability of the firm to transform visits into personal data that is then bought and used to design personalized ads. This practice of selling personal data of users to advertising companies has allowed firms to propose free services (Google, Facebook, free news and so on).

To gather personal information about Internet users, websites and firms use tools which allow them to collect browsing data without consent. But Internet users can also voluntarily leave online traces: registration on a website, pictures on social networks, blog posts, comments about a product, tweets and so on. Several reasons can drive an individual to share personal information online, from the possibility to get better prices to feeling part of an online community.

The result of the gathering of these traces is called the digital identity, as it is defined by the links between one person and digital entities. This concept is used to analyze how individuals manage the online disclosure of their personal information. It therefore concentrates on traces left voluntarily by Internet users. The variety of contexts online leads to a variety of disclosure strategies of users regarding their personal information. Digital identities are vital subject for the digital economy as it directly affects the willingness of Internet users to disclose personal information and therefore how firms can derive profit from this data. The reliability of this information is also at stake, given the way non-reliable information can distort the value of the data by misleading firms.

The use of personal data by firms and governments can also create negative externalities for Internet users. Firms can for example be tempted to collect enough data in order to extract the most they can of consumers' surplus. Excessive targeted advertising, spamming, hacking of banking details or identity theft are other examples of negative externalities that can be driven by the use of personal information.

If an important part of Internet users seem indeed to be aware of the existence of practices of data collection by firms and governments, what is made from this data is however mostly characterized by an opacity that can seem deliberate. But the accumulation of articles about state surveillance programs, security breaches or tracking and profiling practices is not without consequence. Internet users seem indeed to become more and more concerned about their privacy online: a survey by the Pew Research Center finds for example that 62% of the interrogated individuals consider online surveillance damaging.

All of this gives more strength to the willingness of Internet users to become empowered by using tools and obfuscation strategies that help them have better control of their online privacy. A Pew Research Center survey estimates that 34% of individuals that are aware of the existence of state surveillance programs have taken obfuscation measures, for example by changing the confidentiality parameters of their social network profiles. Similarly, the number of ad blocking programs installed in the world in 2015 was estimated at 200 million. More and more economical analysis focus on this growing phenomenon that is the use of PETs (privacy enhancing technologies). It might for example make state and firm surveillance harder to implement. Similarly, the growing use of ad blockers impacts greatly the online advertisement industry, which finances a substantial part of online free content such as news websites. These websites now faces great difficulty to combine profit with delivering free content.

This thesis revolves around the question of the management of personal data, that is the strategies designed by consumers in order to consume online and protect their privacy.

Keywords: digital identities, economics, privacy

Economy of privacy and mobile application

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Thesis, supervised by Grazia Cecere and Fabrice Le Guel
Start: 01/10/16 End: 31/09/2019

Abstract:

The Phd thesis in economics aims to study to what extent it is possible to protect individual privacy without compromising the growth and innovation of strategic of ICT sector in France and Europe. It will focus on the following chapters:

- 1) A review of the economics of privacy and regulation and it will tackle technical and economic assessment of the processes by which personal data are collected and exchanged. This part would take advantages of the cooperation with the computer science team. In particular, the cooperation with the two Phd students will permit to explore in detail the impacts of privacy by design in the choice of businesses and consumers.
- 2) We study how data are collected and exploited in the market for smartphone applications.
- 3) We will design a Field experimental design in cooperation with the computer science and analyzing data from experiments set up with computer science. Finally,
- 4) it will identify the policy implications for the regulation of privacy. Each chapter the doctoral thesis will be submitted in ranked journals in economics. And they will be discussed with computer science from the INRIA.

Keywords:

Industrial Organization, Economy of privacy, Mobile applications

Publications:

Workers' Autonomy And Self-Determination In The Wake Of Platform Paradigm

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Start: 01/10/2016

End: 30/09/2019

Abstract:

The research will be focused on the following topics: in the wake of the platform paradigm and new socio-economic models, what are the factors that allow for the self-determination and autonomy of self-employed workers? How to guarantee the welfare and security that would be at least equal to the level of protection of wage laborers? We will seek to formulate a list of criteria, tested using a transdisciplinary approach, in order to outline types of innovative work organizations as compared to the wage labor model. The research will articulate around a critical discussion of the various meanings and interpretations of the concept of autonomy: from the basic principle of the organization of emerging communities of workers such as freelancers, to its rejection as the spine of the social organizations of a State, as well as its conceptual and effective relationship to the demand for independence, both inside and outside work organizations.

Thanks to field work (entrepreneurs, venture laborers, various working platforms, employees of all kind working in companies build on the Fordist pact), we will test assumptions regarding the degree of dependency, the efficiency and fairness of portable rights, as well as the balance between risk and security it is able to provide to those different types of workers. Of interdisciplinary and international scope, the research is linked to works on the conditions of autonomy at work (Alain Supiot, *Beyond Employment*), work for oneself (Michel Lallement, *The Age of Doers*), and will combine ethnographic methods (participatory observation), qualitative and quantitative methods (questionnaires, interviews, observations, etc.) and econometrics, data science, ethno-computational methods and network analysis.

Keywords : Autonomy, work, platform

Publications / Patents:

No publications so far

Information and communication technologies for environmental sustainability

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Start: 01/10/2014 End: 01/10/2017

Abstract:

This PhD subject is conducted in the context of SWOT mission (satellite to be launched in 2021, led by CNES/NASA JPL). The main objective is to recover water elevation with interferometric images acquired by KaRIn (Ka-band Radar Interferometer), SWOT's main instrument. The PhD is dedicated to the automatic extraction of water masks.

Researches have been conducted in two directions: SAR images classification and processing of temporal series of SAR images.

Many works have already been done on image classification. Most of the used techniques have to be adapted when applied to SAR images due to speckle phenomenon. A specific difficulty in the context of SWOT data is the low incidence angle, leading to strong pixel size variations. This induces varying radiometric values inside a class along the range direction. To overcome this difficulty and consider local variations, we proposed two algorithms allowing variable parameters for the different classes in the image. It relies on a local estimation of parameters guided by a quad-tree partitioning of the image in [4] or a dense estimation in a method to be published. The classification is expressed as a Markov Random Field and can be optimized exactly using graphcuts. We also worked on narrow river detection using a two-step approach: the first step detects small segments and is done at the pixel level, while the second uses the detected segments and connects them to retrieve the network. This method allows to find many more narrow rivers than previously used algorithms.

Concerning the exploitation of temporal series of SAR images, we propose a decomposition model adapted to SAR series of images. The high dynamic of SAR images (due to the presence of strong scatterers) makes inefficient direct application of usual regularization techniques (e.g. total variation (TV) based regularization). We propose a decomposition method using both TV as a regularization for the image background, and an L0 pseudo-norm for the strong scatterers which makes it specially adapted for urban areas. Besides this model can be extended to deal with multi-temporal images in different ways. Optimization can be done exactly thanks to graph cut minimization. This work has been presented in [1,3]. Applications of this decomposition model includes scatterers detection and change detection. A new decomposition based on this model has also been developed in [2, 5, 6] allowing for a more robust detection of changes, as they are directly considered in the model.

Keywords: Image processing, SAR, Markov Random Fields, SWOT mission

Publications / Patents:

- [1] Multi-temporal SAR image decomposition into strong scatterers, background, and speckle, Sylvain Lobry, Loic Denis, Florence Tupin, IEEE JSTARS, State: published
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Fast Filtering and Unsupervised Estimation in Switching Markov Models

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Abstract:

Hidden Markov models (HMMs) are statistical models which assume that the observed data Y is generated through a Markov chain X with hidden states. HMMs are especially of interest to deal with big data thanks to their ability to allow fast recursive processing. However, in the case of continuous hidden process exact fast processing are not feasible except some special Gaussian cases, and different approximated methods, like simulation-based methods, must be used. Besides, by adding a third discrete latent process R to continuous pair (X, Y) one arrives to so-called "hidden switching Markov system" in which the triple (X, R, Y) is assumed Markov. The interdependence of processes in the triplet is modeled by a state-space equation depending on system parameters. A common task in such systems is filtering and parameter estimation. Such processing is not feasible in the classic switching models, where (X, R) is Markov and (R, Y) is not, even in simple Gaussian case, and is usually dealt with simulation-based approaches. The present PhD thesis develops alternative and innovative procedures for such challenges. In recent Conditionally Gaussian Observed Markov Switching Models (CGOMSMs, 2011), where the pair (X, R) is not Markov and (R, Y) is, fast optimal processing is feasible in spite of switches. The first direction is approximating the pair (X, Y) from the original model by the marginal distribution of (X, Y) deriving from the CGOMSM, was investigated in [1, 2] during 2015. In 2016, we introduced a novel Switching conditional Gauss-Hermite filter which uses a Gaussian approximation in the state space and the Gauss-Hermite quadrature. This filter allows a fast recursive state estimation and is significantly faster than the classic particle filter. Besides, this filter is deterministic and allows evaluating a quasi-likelihood function related to the observation, and maximizing this function allows an unsupervised estimation of the switching models, what has been demonstrated in [3]. Another direction, that will be investigated during 2017, is approximating the pair (R, Y) from the original model by a triplet Markov chain (TMC), which are triples (U, R, Y) with unobserved discrete factors R and U . This can be done through a discretization of X in the original switching model. An example of discretization of X in a non-Gaussian hidden Markov model, thanks to the Sparse Grid theory, was present in [4] and seems quite promising.

Key words : Switching Markov systems, non-Gaussian systems, nonlinear systems

Publications / Patents:

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