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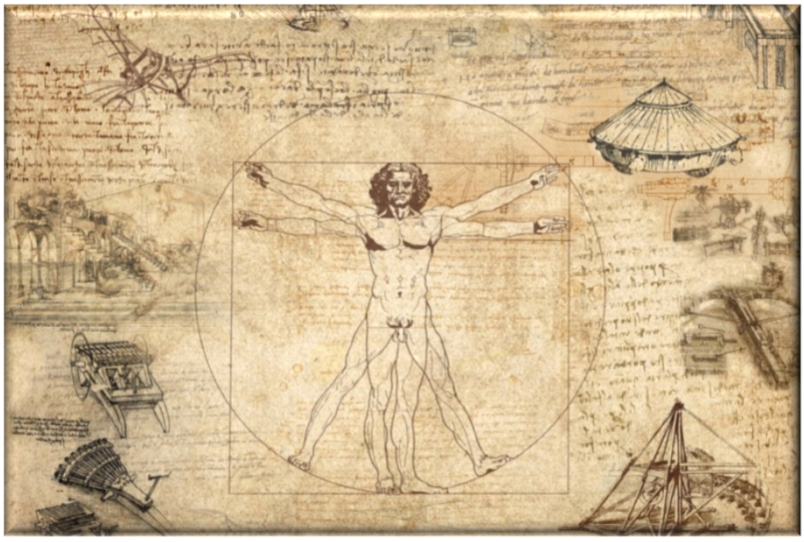
PON RICERCA E INNOVAZIONE 2014 - 2020

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

Scuola di Scienze e Tecnologie

Science and Industry for Environment, Health and Digital Society Technologies

WORKSHOP: Industrial PhD day @ UNIBA - 26 June 2019



Abstracts

PhD Programmes in:
Chemical and Molecular Sciences
Computer Sciences and Mathematics
Geosciences
Physics

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Advisory Committee

Maria Francesca
Costabile Domenico Di
Bari Giuseppe Iaselli
Massimo Moretti
Luisa Torsi

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Science and Industry for Environment, Health and Digital Society Technologies

Industrial PhD Day @ UNIBA – 26th June 2019

In Italy, from 2013 (D.M. 8th February 2013 n. 45), companies with specific skills in Research and Development activities participate to the 3rd level of education, cooperating with the university system on specific Industrial PhD Programmes. The Ministry of Education, University and Research (MIUR) finances additional PhD Scholarships with the National Operational Program "Research and Innovation" Founds (PONRI 2014-2020). The purpose of the workshop "Science and Industry for Environment, Health and Digital Society Technologies" is to review the experience of the industrial doctorate and to further strengthen the collaboration between the Bari University and companies of the Apulian territory.

The industrial researches of the *Scuola di Scienze e Tecnologie* of the Bari University involve 22 PhD students and 16 companies. The active Industrial PhD projects cover many topics in the field of Chemistry, Computer Science and Mathematics, Geosciences and Physics and have been shown during the Workshop "Industrial PhD Day @ Uniba" (26th June 2019) as oral or poster presentations. The contributions of the Industrial PhD students are the object of this proceedings volume.

Coordinators of the PhD Programmes:
Maria F. Costabile - *Computer Science and Mathematics*;
Giuseppe Iaselli – *Physics*;
Massimo Moretti – *Geosciences*;
Luisa Torsi - *Chemical and Molecular Sciences*.

President of the "Scuola di Scienze e Tecnologie"
Domenico Di Bari

Chemical and Molecular Sciences

Nano-TiO_2 based photocatalyst for water application (XXXIII)
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Academic Tutor: A. Agostiano - angela.agostiano@uniba.it
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Synthesis of N-Functionalised Aryl and (Hetero) Aryl Compounds via Ligand-Free Copper-Catalysed Ullmann-Type Cross Coupling Reactions in Deep Eutectic Solvents (XXXIII)
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Self-powered bioelectronic disposable sensor for HIV-1 p24 single molecule detection (BioElSens&Fuel) (XXXIV)
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Plasma deposition of antibacterial nano-capsules on decellularized biologic scaffolds for Tissue Engineering (XXXII)
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Deposition of photocatalytic thin films by atmospheric pressure cold plasma processes for the sustainable degradation of industrial wastes (XXXII)
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Nano-TiO_2 based photocatalyst for water application

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The interest of the scientific community towards the Advanced Oxidation Processes (AOPs) for wastewater decontamination has had an exponential increase. AOPs are convenient innovative alternatives to conventional wastewater treatment processes, (Truppi et al. 2017) that include a set of water treatment strategies as UV, UV-H_2O_2 and UV-O_3, and semiconductor assisted photocatalysis aim at accomplishing the complete mineralization of organic pollutants (i.e. their conversion in safe end products such as O_2, H_2O, N_2 and mineral acids). Among AOPs, TiO_2 assisted photocatalysis has recently emerged as a promising water treatment method, because it can be integrated in water treatment processes as biological water treatment plants. In particular, nanosized TiO_2 demonstrated improved performances with respect to its bulk counterpart, thanks to its extremely high surface-to-volume ratio which can greatly increases the density of active sites available for adsorption and catalysis. In addition, the size-dependent band gap of nanosized semiconductors allows tuning the red-ox potentials to achieve selective photochemical reactions. Nevertheless, dispersed nanocatalysts presents significant technological drawbacks related to the catalyst recovery, (Petronella et al. 2013). In the present work, we investigated two different deposition approaches, namely doctor blade method and a purposely developed dip coating procedure (here referred to as "inverted dip coating"), to coat TiO_2 NPs on different surfaces, namely glass and stainless-steel mesh. To this end, a batch of TiO_2 NPs was synthesized by suitably modifying a reported approach, specifically selected for its scalability (Ancora, Borsa, and Cassar 2009). The obtained product was characterized by UV-Vis absorption spectroscopy, X-ray diffraction analysis and TEM microscopy. Successively, TiO_2 NPs were deposited by applying the two proposed approaches onto glass slides respectively, used as a model support, prior to deposition onto final substrates to be integrated into photoreactor. In particular, TiO_2NPs-based coatings were obtained by means of the doctor blade technique and the *inverted dip coatin*g method, from isopropanol suspensions of TiO_2 NPs, at a concentration of 6,5%, 13% and 26% by weight, respectively. The morphology of the resulting coatings was investigated by SEM analysis and allowed to detect significant differences between the coatings fabricated by using the two deposition techniques. The films resulting from the application of the *doctor blade* method appear inhomogeneous with presence of superficial cracks. On the contrary, more homogeneous coatings, without cracks were obtained by using the *inverted dip coating* method. The photocatalytic activity of the prepared coating was assessed by monitoring the decolouration of a model target molecule, Methylene Blue (MB), in aqueous solution under UV light irradiation. The extent of adsorption of the dye onto the coatings in the dark was also evaluated in order to estimate the actual photocatalytic performance. The inverted dip coating was found to be the most versatile deposition method for real applications. The TiO_2 NPs were then deposited on stainless-steel mesh by using isopropanol suspensions at 6,5% and 13%. TiO_2 NPs content. Also, the films deposited onto the stainless steel meshes were thoroughly investigated by SEM microscopy and by measuring their photoactivity. Therefore, considering both the photocatalytic performance and the quality of the films, the coatings obtained by inverted dip coating method at 13% TiO_2 NPs contents onto stainless steel mesh result to be the most promising for real applications.

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Synthesis of N-Functionalised Aryl and (Hetero) Aryl Compounds via Ligand-Free Copper-Catalysed Ullmann-Type Cross Coupling Reactions in Deep Eutectic Solvents

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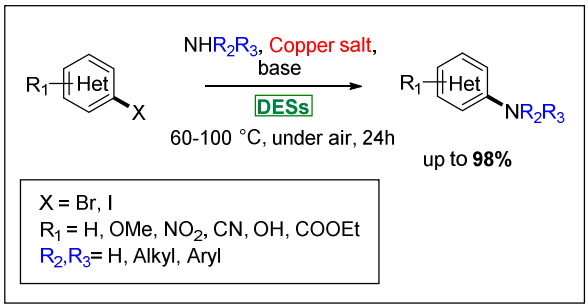
As a result of the rapidly evolving needs of our society (both economic and environmental) since the end of the last century, many efforts are currently being made to replace extensively used hazardous volatile organic solvent (VOCs) in favour of inexpensive, green and bio-renewable reaction media (e.g., water, Deep Eutectic Solvents (DESs)).[1,2] In this contest, of particular relevance are DESs, which are combinations of two or three safe, inexpensive and nature-inspired components able to engage in reciprocal hydrogen-bond interactions to form a eutectic mixture with a melting point much lower than that of the individual components.
Nowadays, there has been a boost in metal-catalysed and metal-mediated organic reactions run in the above-mentioned unconventional solvents.[3,4] Special efforts have especially been made to promote copper-catalysed organic reactions because of the low toxicity and low cost of this metal.[5] Copper-catalysed Ullmann-type cross-coupling reactions allow the synthesis of N-functionalised aryl and (hetero)aryl compounds starting from aryl halides and amines. These reactions are usually carried out in VOCs (e.g., THF, toluene), at high temperature, and in the presence of ligands.[6-8] In this communication, we report an environmentally friendly synthetic methodology for amination of aryl and (hetero)aryl compounds set up in DESs as reaction media. Working under air and moderate heating, and in the absence of ligands, the desired products are straightforwardly isolated from selected eutectic mixtures in up to 98% yield. Scope and limitations are also discussed.



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Self-powered bioelectronic disposable sensor for HIV-1 p24 single molecule detection (BioElSens&Fuel)

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New approaches in immunoassay technologies are receiving increasing attentions through the scientific community. This is due to the need of more sensitive advanced devices, capable of detecting those analytes in low concentration that can be spy for degenerative pathology presence. The so called wide field approach [1] for antigens-biomarker bounding detection is the most promising one, since the single molecule recognition is ensure by the attaching of millions of receptor on a millimetre-size surface, which increase the interaction cross section [2]. This method can be applied to the realization of bio-sensors to be employed for Point-of-care (POC) prompt diagnosis of infections caused by Human Immunodeficiency Virus type-1 (HIV-1). The urge of effective methods for early detection of HIV-1 relies on the significance of the first infection stage, the acute phase [3], in which there is the highest risk of spread, and the infected individual could be treated with a more effective immune response to the virus.
To reach the goal of producing a disposable rapid test, using plastic or paper substrates, a bioelectronic label-free sensors was studied, based on an electrolyte-gated organic field-effect-transistor (EGOFET) [4], implementing the self-powering of the device by means of a paper-based bio-fuel cell (BFC) [5]. The sensor Bio-TFT is specifically made of a thin film transistor whose gate-electrode is functionalized with the specific antibodies of HIV-1 p24 protein (anti-HIV-1 p24), found on the capsid of the virus. The sensing derived from the specific binding of the antibody with its affinity ligand (HIV-1 p24) will be performed in standard physiologic solution as well as in a real serum.
The BFC is powered by glucose and oxygen present in the analyzed serum, and succeeds in consistently and stably delivering the required voltage and current to perform the bio-sensing measurements at a record low concentration of HIV-1 p24 antigen. The proposed self-powered platform could give rise to a ground-breaking progress in the bio-medical device research field, allowing the realization of a disposable diagnostic test made of inexpensive materials compatible with printable techniques.
The fabrication and characterization of the biotically degradable bio-fuel-cell (Bio-FC) has been developed at ICREA of CSIC - IMB-CNM, supervised by Dr. Neus Sabaté; for the subsequent integration of the bio-TFT with the bio-FC in a printable and flexible device, in collaboration with the industrial partner MASMECBiomed (Ing. Pietro Larizza).

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Plasma deposition of antibacterial nano-capsules on decellularized biologic scaffolds for Tissue Engineering

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Coatings consisting in gentamicin-containing nano-capsules have been synthetized by means of an aerosol-assisted atmospheric pressure plasma (AA-APP) deposition process [1,2]. The coatings have been deposited on matrices derived from biologic decellularized tissues, for improving their properties and obtain new products for Tissue Engineering. A Dielectric Barrier Discharge (DBD) plasma source fed with He, ethylene and an aerosol of a gentamicin solution has been used to deposit the coatings. Porcine biological tissues were properly decellularized at TissueGraft s.r.l before being lyophilized and used in the experiments. SEM analyses were carried out to analyze the morphology of the coatings; their chemical composition was investigated by means of XPS, FT-IR and AP-MALDI. The release of gentamicin in water was monitored by means of conductivity analysis. The antimicrobial activity and the cytocompatibility of the coatings have been evaluated. SEM highlighted that, such AA-APP process, leads to a peculiar morphology, namely a coating with the presence of spherical features whose shape, number, and size depend on the plasma discharge parameters. FT-IR spectra, XPS and MALDI-TOF analysis confirm the presence of gentamicin in the coatings. A fast release of gentamicin was observed from coatings obtained in different deposition conditions, in some cases 90 % of the maximum amount of the drug was released in 30 min. The release of gentamicin was modulated through deposition of a diffusion barrier layer deposited from a water/ethylene DBD on top of the coating. The agar diffusion assay against P. aeruginosa and S. Aureus confirmed the antibacterial activity of the released gentamicin: this indicates that the structure modification induced by the plasma concerns only part of the gentamicin load of the coatings and does not compromise the potential of such coatings as drug delivery systems. Cytocompatibility analysis indicated that the coatings do not cause major concerns to eukaryotic cells (Saos-2 cell line) [1]. Gentamicin-containing nano-capsules were then deposited on decellularized scaffolds. SEM has shown that the microstructure of these substrates was not significantly altered by the presence of the coatings. The antibacterial and cytocompatibility of the modified biological scaffolds could be demonstrated in vitro. The results obtained show the potential of the AA-APP process in producing surfaces of biomedical interest as drug-release systems. Gentamicin-containing nano-capsules have been successfully transferred to a biological scaffold.

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Deposition of photocatalytic thin films by atmospheric pressure cold plasma processes for the sustainable degradation of industrial wastes

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Thin films deposition by atmospheric pressure cold plasma processes attracts growing interest since it allows the preparation of nanocomposite coatings consisting of an organic or inorganic matrix and inorganic nanoparticles (NPs) at room temperature and atmospheric pressure. [1,2] In this work the atmospheric pressure dielectric barrier discharge (DBD) is fed by helium and aerosol of a dispersion containing preformed NPs (oleate-capped TiO_2 P25) in liquid hydrocarbon precursors (i.e., a mixture of n-octane and 1,7-octadiene).
The process, optimized on different supports: i) borosilicate glass slides (i.e. flat substrates) and ii) polyurethane (PU) foams (i.e. tree-dimensional porous substrates) allows, under appropriate deposition conditions, the preparation of multifunctional nanocomposite coatings since they combine the superhydrophobic behaviour and the photocatalytic properties due to the utilized NPs.
Photocatalytic experiments to evaluate the activity of the photocatalytic thin films are carried out in a small recirculating reactor with a solution containing a model target molecule irradiated by using UV lamp. The degradation kinetics of the organic compound followed by using UV-vis absorption measurements show promising results for the wastewater treatments with different advantages due to the simple recovery and efficient recyclability of the photocatalytic coatings.

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Computer Sciences and Mathematics

Business Process Management (BPM) e Case Management (CM) for Enhanced Care Pathway (XXXIII)
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Models and tools for predictive analysis of Big Data through interactive visual techniques *(XXXII)*
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Business Process Management (BPM) and Case Management (CM) for Enhanced Care Pathway

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The research area of the Phd research is the Business Process Management (BPM) and Case Management (CM) for Enhanced Care Pathway and is located between two of the thematic areas and technological trajectories of interest identified within the SNSI [1], namely "Health, Nutrition and Quality of Life" and "Digital Agenda, Smart Communities, Intelligent Mobility Systems". More specifically, the research can be framed along three main directions:

- ***application***: the research aims to affect the process of innovation of "territorial" health care services making the system more efficient and focussed on patient personal situation and needs (Case Management). In health care, the concept of Integrated Clinical Pathway (ICP) [1] defines a set of heterogeneous services (prevention and public health services, family medicine, services for mental health and addiction, hospice care and different forms of home care), oriented to a progressive de-specialization of the care environment, which require the participation of a multidisciplinary network (Clinical Network) of actors responsible for the provision of hospital services and territorial needs with high levels of professional integration. In practice, clinical paths are designed to organize and put in sequence actions, in a given period of time, all health professionals and territorial structures of reference, regulating the succession of interventions to be operated. From smart community point of view, Integrated Clinical Pathways are "smart" services, highly integrated and aimed at the citizen (the patient), which allow to simplify and improve the quality of life and generate positive social effects on the Community. The paths have another peculiarity: they must be created and developed directly by the various professional figures who will then use them.

- **methodologies**: from a theoretical point of view a path is a process and clinical networks a complex organizational structure. The research subject of the proposal will focus on methods, models and techniques of Business Process Management useful to optimize the modeling, execution, monitoring and analysis of the path in the light of the many research issues that the theme presents: process design, process sharing, process execution, process management.

- **technologies**: from the technological point of view, the research will focus on defining tools, including prototypes, useful to support the methods and techniques proposed during the doctoral program. In particular, reference will be made to tools for process modeling, integration, simulation, enactment and monitoring as well as for the analysis, including visual (Visual Analytics) and, the data collected.
The research is carried out in collaboration with the University of Castilla La Mancha (Spain) – Istituto de Tecnologìas y Sistemas de Informacion, that is involved in the the issues concerning the quality of the software product and the ICT company Openwork that involved in the research for requirements and proof of concept development.

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Models and tools for predictive analysis of Big Data through interactive visual techniques

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Today, analysts increasingly deal with Big Data, which are data collections having high storage, management and analysis requirements, for which traditional database systems are inadequate. An important part of data analysis is predictive analysis. In data science, a prediction is the *estimation of unknown values* that could occur in the future (Provost, 2013). A predictive model provides estimates of future values of the variables characterizing a phenomenon. The increasing use of machine learning models is pushing towards understanding how models are trained and evaluated, in order to discover issues such as possible incorrect correlations, wrong generalizations, model performance leaks, with the aim of avoiding wrong decisions. Different models produce different results on a same dataset; thus, several models should be compared, in order to identify the most suitable one. The selection of the best model is difficult. One reason is that "*predictive modelers often only explore relatively few models when searching for predictive relationships… due to either modeler's preference for, or knowledge of, or expertise in only a few models or the lack of available software that would enable them to explore a wide range of techniques*'' (Kuhn, 2013). Visual Analytics techniques use interactive visualizations to provide the analysts with additional knowledge about the data allowing them to guide the analysis process (Krause, 2014).
This research investigates how Predictive Visual Analytics can support the analyst in the comparison of predictive models and provides a contribution towards creating a software system that enables the analyst to explore and compare a wider range of predictive models using interactive visualizations. Several interactive visualizations have been created, in order to select the model that best fits the data. The visualizations support the tasks of the Keim's Visual Analytics Mantra: "*Analyze first, show the important, zoom, filter and analyze further, details on demand*" (Keim, 2010). System design and development is performed according to the User-Centred Design methodology. The proposed visualizations are applied to various datasets, including the one provided by the Links SpA company.

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Big Data Analytics for Process Improvement in Organizational Development

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Modern information systems that support complex business processes maintain significant amounts (event logs) of process execution data (traces). Process mining techniques are used to analyze data extracted from event logs and provide surprising insights for managers, system developers, auditors and end users. Predictive process monitoring has recently become one of the main enablers of data-driven insights in process mining.

Being able to predict the future behaviour of a business process is an important business capability. In particular, the effectiveness of a managerial decision-making response to variation in the environment may strongly depend on the extent to which it can reduce the impact of uncertainty through prediction.

As an application of predictive analytics in Business Process Management (BPM), business process prediction is mainly concerned with predicting the evolution of running traces based on patterns extracted from a big amount of historical event data. Example use cases include techniques to predict the next activity (and the timestamp of the activity), as well as the completion cycle time until a trace is resolved. Specifically, the prediction of the next activity can be considered to guarantee the higher utilization by acting proactively in anticipation, while the accurate estimate of the remaining cycle time can be used to minimize the deadline violation.

The research will investigate predictive process mining approaches, which will use sophisticated deep learning techniques, in order to support the decision making process of the organization involved in various execution scenarios of a business process.

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Change detection in remote sensing

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Technological innovation in recent years has made available various sources of geospatial data, such as satellite and aerial images, optical, radar and point clouds data, elevation models. The availability of geospatial data is really wide, so that it comes to Big Data in the geospatial field, wanting to show large aggregations of data, whose size and complexity requires more advanced tools, at all stages of the process.

As it is known, many learning techniques have been applied for the detection of anomalies in aerospace images, i.e. for the identification of critical areas on earth. In particular the scientific literature has placed a lot of attention on supervised learning techniques using statistics methods and machine learning. Currently the challenge of research in this area is to be able to capture anomalies with unsupervised learning techniques and in this sense, the aim is to provide new algorithms that perform better than the traditional ones.

This research will try to extract high quality information from the available data. We look for change detection strategy, by using a holistic combination of, numerical and spatio-temporal data mining methods and innovative statistical approaches. The first technique we will analyze is based on “copula”, a multivariate cumulative distribution function for which the marginal probability distribution of each variable is uniform. In quantitative finance, copulas are widely used to describe the dependence between random variables to model and minimize tail risk and portfolio-optimization applications and in this field it has been proved that can be very interesting and innovative in the analysis of the correlation of space-time data. Some preliminary experiments conducted on data provided by Planetek have already given good results. Moreover we will compare these methodologies with the most recent deep learning algorithms that use neural networks in the analysis of outliers and change detection.

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Pattern-Based Business Process Digitalization

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Nowadays, an enormous amount of data is produced in Smart City scenarios, which are characterized by Internet of Things (IoT) systems (including embedded systems, wireless networks, personal devices as smartphones, tablets, wearable objects) widespread across the territory and involving a multitude of actors. These data represent value for business processes, but, in order to respond "in real time" to customers' needs and requirements, new business models must be developed. This implies a transformation of traditional Business Processes (BPs) since the involved IoT systems are not anymore just data sources, but actively take part and interact with the various BPs that have also become cross organizations. However, the digital transformation of BPs, and their subsequent re-engineering, is a complex task that small and medium-sized enterprises often cannot afford. Pattern-based digital transformation of BPs permits to reduce such a complexity by maximizing the reuse in different contexts of well-established solutions to recurring problems [1].
This industrial Phd aims at the definition of methodologies and tools for pattern-based digital transformation of BPs in the context of Smart Communities and Industry 4.0. A critical aspect currently addressed is the representation of the knowledge grasped from the data acquired by IoT devices, since different types of users interact with such data with different goals. In order to transform them in knowledge, data have to be organized in a proper way and meaningfully provided in an IoT application specific for that type of user. The Knowledge Stratification Model is proposed to guide technical experts when developing an IoT application. The model, which organizes the knowledge elements in three layers, aims to identify the data produced by IoT devices and integrate them into BPs, thus making them meaningful for the user. A semantic approach, based on three subsets of ontologies specific for each model layer, is proposed to represent domain knowledge and to solve the technological and user interaction semantic issues characterizing complex and heterogeneous contexts as Smart City [2]. Further technological and semantic issues are introduced by Internet of Everything, which includes user-generated communications (such as citizen's smartphones, wearable devices, etc.) and interactions with networked devices: new BPs must be defined to filter the collected data, register citizens' alerts and include them in the administrative management. This raises important issues related to usability, requiring the use of methodologies and techniques typical of Human-Computer-Interaction such as Human-Centered Design (HCD) [3].

The research is carried out in collaboration with **AQC Lab** at University of Castilla-La Mancha (Spain) and with **Sincon srl**, an ICT company in Taranto. The PhD project includes two research periods to be carried out at the partners' site: 12 months at **Sincon**, during the 1st and 3rd year of the PhD, and 6 months at **AQC Lab** (Spain) in the 2nd year.
Sincon is a system integrator and a provider of Business Process Management and process automation solutions, with an extensive and in-depth knowledge in BPs digital transformation and in the smart community context. SINCON will allow to identify the use cases to experimentally validate the innovations proposed during the research.
AQC Lab is the first accredited laboratory worldwide for Software Product and Data Quality Evaluation conforming to the ISO/IEC 25000 standard. It is directly involved in verifying software quality resulting by using digitalization patterns. AQC Lab will provide the skills related to metrics and measures, the software quality requirements (maintainability, usability, safety, functional adequacy, data quality, etc.) evaluation, and the tools for the assessment.

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Geosciences

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The research activity aims to develop an integrated UAV-UTV system that is able to identify and alert the user to the presence of pollutants distributed by the movements of the sea along the coastline and to send a UTV for a first sampling for the purposes monitoring, definition of the areas involved and planning of remediation interventions.
The system will consist of a UAV (Unmanned Air Vehicle) vehicle with special sensors (camera and thermal camera) able to carry out surveys along the coast and send them to the receiving station for the recognition of pollutants. According to these data, the control station will send a special UTV (Unmanned Terrestrial Vehicle) to collect samples that will be sent to the nearest laboratories for the characterization of the pollutant. The system is designed to detect spills and accumulations of pollutants in coastal areas or possibly land.
The test areas chosen for this research project are located on the Apulian Adriatic coast and on the Ionian coast of Basilicata. They are located in marine protected areas where the potential anthropic impact deriving from presence of pollutants could damage the present ecosystem.
The final product of the activities will therefore be the overall integration of the UAV and the UTV which will ensure: the production of a geo-referenced mapping of the coastal morphology derived from the orthophotogrammatic surveys in the test areas, mapping of the pollutant distribution according to data collected by UAVs with integrated thermal imaging camera, georeferenced mapping of the distribution of samples taken from UTV on indicatio received from the receiving station after the UAV surveys.
The three products together constitute a database in the GIS environment that allows the recognition of the polluting product (to be carried out in the laboratory) to plan the environmental remediation actions.

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Development, experimentation and validation of treatments, with consolidants and nanostructured protectives, on stones of historical and artistic value

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The aim of this research it is to study the degradation of stone materials and experiment with innovative nanostructured products in the field of cultural heritage conservation.
The research starts from the analysis of the degradation processes of Apulian natural stone materials, through chemical and petrographic characterization (es. XRPD, XRF, SEM-EDS) and the experimentation of different accelerated aging tests on ornamental stones, like saline solution treatments, high temperature heat treatments, thermal shocks and SO2 treatments in the presence of humidity, thermal cycles through cycles of freezing-thawing simulating environmental thermal conditions of the stone material, through the use of climatic chambers (EN 12370: 2001, UNI EN 13919: 2004, UNI EN 14066: 2013). After each cycle of artificial aging, changes in appearance will be noted and the chemical and physical properties have been measured so as to compare the differences between fresh and processed samples. The analysis of the scanning electron microscope (SEM-EDS) will be performed before and after each application of nanostructured coating to evaluate changes in surface morphology of the samples. Through experimental treatments in the laboratory and accelerated aging tests on rock specimens, it is possible to observe and study the response of materials in order to know indirectly the ongoing degradation processes. Based on the type of degradation found on the different lithotypes studied, nanostructured conservative treatments will be tested. The project therefore aims to relate the effectiveness of treatments and their durability over time with various natural stone substrates in the different levels of alteration, in order to contribute to the improvement of products, where necessary, and to the define specific application protocols. Recent work on important international journals makes clear the high degree of innovation of this type of research and the high prospective in the field of cultural heritage conservation.

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BERMA – Beach ERosion Mechanism Analysis: a study of sedimentary dynamic with a multidisciplinary approach along the Apulian coast (Southern Italy)

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This study focuses on the processes influencing the mechanisms of erosion, transport and sedimentation in coastal areas characterized by sandy beaches in order to analyse the sedimentary dynamic with a multidisciplinary approach. The Apulia area is a leading region in the seaside tourism sector, by offering a great variability of coastal landscapes with a widely acclaimed concentration of tourism on sandy beaches. Two beaches have been chosen as representative examples of Ionian (Porto Cesareo, Lecce) and Adriatic (Torre Guaceto, Brindisi) sandy coastal sectors. Both areas are part of Protected Marine Reserves with stunning emerged and submerged landscapes. The application of a multidisciplinary approach consists of gathering and testing different techniques. The use of the Terrestrial Laser Scanner (LST) will allow analysing the emerged beach environment in superficial and geomorphological terms by constructing three-dimensional terrain models and evaluating beach slopes. The thickness of the emerged beach will be quantified with georadar investigations, whereas a Multibeam procedure will determine different relief forms and the bathymetry of the sea floor. Lastly, the Sub Bottom Profiler technique will be applied to measure the thickness and the sediment volumes that are involved in the coastal dynamic. By a sedimentological point of view, the beaches have been monitored by measuring all possible physical data, using classical and modern techniques.

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UAV (Unmanned Aerial Vehicles) and UTV (Unmanned Terrestrial Vehicles) Multi-Sensorial System for Paroxysmal Events Monitoring

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The project is a collaboration between the University of Bari, Niteko S.r.l. and the Geographische Institut of the University of Mainz. The aim of the project is to create a new methodology, based on new technologies, to study highly risky environments generated by paroxysmal events such as landslides and earthquakes. A new approach is needed to overcome difficulties which affect traditional techniques, such as large areas or highly risky environments investigation, bad points of observation, and overcoming limits due to field conformation and study area accessibility, which makes the traditional techniques more expensive, time consuming and less accurate.

The project is based on the use of UAV (Unmanned Aerial Vehicles) and UTV (Unmanned Terrestrial Vehicles) platforms. The research will consist in building, interfacing and calibrating the sensors-platforms system, and it will be carried on developing specific methodologies to collect and process photogrammetric, thermal (Forward Looking Infrared) and laser (Mobile Laser Scanning) data. Niteko S.r.l. will collaborate in the mechanical, electronic and robotic development of the UTV platform. The Natural Hazard Research and Geoarchaeology Laboratory of the Geographische Institut of the University of Mainz will collaborate in testing the system in a different geomorphological context.

The expected result is the development of a new multisensorial remote sensing system, based on the cost-effectiveness and time-efficiency of new technologies, to safely evaluate the stability of natural and anthropic landscape elements affected by paroxysmal events, which would represent a useful and safe tool for the ordinary monitoring activities and for the post-event emergency management.

MICIA - Coastal flooding modeling and sea level changes vulnerability

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MICIA-project was developed in the research carried out by Spin Off Environmental Surveys S.r.l of University of Bari "Aldo Moro" and aims to model the coastal flooding, on GIS environment, and to evaluate the coast vulnerability due sea level changes up to 2100.
In recent years, a great interest has been given to Mediterranean coasts behavior in relation to the shoreline migration in both horizontal and vertical components, as consequence of local sedimentary budget (i.e.: Aucelli et al., 2009; Sabatier et al., 2009) or to the sea level rise (i.e.:Brunel & Sabatier, 2009; Antonioli et al., 2017; Aucelli et al., 2017), in combination with coastal flooding due to storm and tsunami events.
In the last two centuries has been observed that the sea level rises are the highest recorded in the last 3000 years (Rahmstorf S., 2007; IPCC, 2013).
Altimeter radar and tide gauge show an increase of 1.7 millimeters in the 20th century and 3.2 millimeters in the last two decades on a global scale while the sea level in the Mediterranean has increased by 1.8 millimeters over the last 2-3 centuries and it is currently accelerating (Lambeck et al., 2009; Anzidei et al., 2014).
To get a useful tool to highlight these themes, this project aims to develop:
ì – a software prototype to obtain submersion maps by sea level rise and the adaptive response of coastal systems in high-definition with reference to different projections (IPCC 2013, Rahmstorf and Mediterranean model);
ìì – a software prototype to obtain flood maps as assumed from the model developed respect to the new scenarios of the shoreline trend and new coastal systems;
ìììì – a software prototype to obtain flood maps of impact of exceptional floods with reference to known events with respect to the new scenarios of the shoreline development and the new coastal systems.

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Advanced analysis and integration of remote sensing and in situ data for a flood monitoring system

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The project fits the strong need to manage and minimize flood risk through the integration of data and the application of advanced technologies.
Flood events are investigated with geomorphological analysis, satellite remote sensing and hydrodynamic modeling in order to exploit the potential of different and complementary sources of information to improve the forecast of the inundation. The study of the alluvial event is thus inserted into a wider analytical procedure, by considering the event as an expression of multiple factors and environmental and anthropic conditioning. The description of fluvial dynamics and morphological modifications through indices and parameters allows to measure temporal effects of flood events in order to delineate the evolution of the river and to elaborate the future trend. The possibility to detect flood extent by satellite observation with an increasing amount of data at different functionality (optical and radar sensors, various bands and polarizations) and increasingly higher frequency consents to explore the alluvial phenomenon by taking advantage of high spatial resolution of satellite imagery. The combination of these data with models, which simulate hydraulic dynamics and estimate water levels by using temporal series of *in situ* data and derived parameters, reduces the approximation of the prevision by getting better flood hazard map, the main instrument for flood monitoring.
The study applies complex techniques of data analysis and sophisticated tools of computation:

- digital image processing to extract information from satellite imagery (through platform and software such as SNAP-ESA);
- area mapping to elaborate maps of geomorphological indices and to obtain flood maps (through GIS platform);
- statistical methods to define probability scenarios (through software of calculus such as Matlab);
- hydrodynamic modeling to derive flood hazard maps (through software such as Lisflood-FP, Camaflood, etc.).

The development of an innovative data assimilation methodology as a monitoring system (valid on a global scale) is thus the final target of the research which contributes to propose and realize services (products, tools, apps) usable by a large user base of the society for the flood monitoring and landscape planning activities.
The project involves a great work team, composed by researchers of Earth and Geoenvironmental Sciences Department (University of Bari, Italy), Istituto per il Rilevamento Elettromagnetico dell'Ambiente (CNR of Bari, Italy), Luxembourg Institute of Science and Technologies (Luxembourg), Planetek-Italia company (Bari, Italy).

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A gamma-ray imaging camera for ambient radioactivity detection

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The aim of this thesis is to build a camera for gamma-ray imaging based on the coded mask technique widely used in astrophysics. An already existing prototype of the camera is made by 16 CsI scintillators doped with Tl (3x3x10 cm_3). Each scintillator is coupled with optical grease to a Photo-Multiplier Tube (PMT) supplied by a Cockcroft-Walton voltage multiplier (HV3020CN). The signals produced is acquired and analyzed with a CAEN digitizer (V1725). The scintillators are arranged as a 4x4 matrix and packaged in a metallic frame. The coding element is a 7x7 mask composed by transparent and opaque tiles (PVC and tungsten 3x3x1 cm_3) to encode a point source image and decode it through a reconstruction algorithm. We tested the system with some different radioactive sources placed at a distance of about 40 cm from the mask. We will present the results obtained in terms of the angular resolution on the position of the source and of the energy resolution measured with the scintillators.
Gamma imaging is a technique to detect the position and the shape of gamma-ray emitting sources, and it is very useful in many fields of nuclear physics. As an example, in medical sciences it is a very important diagnostic tool for scintigraphy, while in security and environmental fields is used to monitor the radioactivity and face the illegal radioisotopes trades.
Inorganic scintillators equipped with photon detectors (e.g. photomultiplier tubes) are among the most common devices for gamma-ray detection. The main goal of this work is to proof the concept of a camera able to reconstruct both the position and the spectrum of a radioactive gamma source.
Many experiments in astrophysics also adopt scintillators to detect high energy photons from the outer space.
As an example, the INTEGRAL satellite (INTErnational Gamma Ray Astrophysics Laboratory) launched in 2002 by ESA and currently on orbit. It is aimed to detect X-rays and gamma-rays from Galactic and extra-galactic objects (Supernovae, neutron stars, black holes, Gamma ray burst, etc.). The satellite is equipped with 4 detection instruments (IBIS, SPI, JEM-X, and OMC) working simultaneously [1]. IBIS (Imager On-Board the INTEGRAL Satellite) can reconstruct the images of the sources with an angular resolution of 3 mrad in the MeV energy range, thanks to a coded mask made with 95x95 square tiles [2]. The JEM-X module uses the coded mask too, in the range between 3 and 35 keV with a spatial angular resolution of 0.9 mrad.
One of the main intents of this work is to design an instrument portable, compact, light, quick and always ready for in-situ and real-time measurements.
We build a prototype camera to make gamma-ray imaging exploiting the coded mask technique and tested it with a ^{60}Co source.
We developed a toy Monte Carlo model to reconstruct the source position and estimate the angular resolution.
The experimental results are slightly worse than the one expected from the toy model, but the position reconstruction proved to be reliable.
In fact, the prototype camera is able to detect a gamma-ray source with low activity with a spatial resolution of about 20 mrad, corresponding to 2 cm for a source at 1 m from the mask.
With the digitizer was possible to calculate the resolution for some different radioisotopes.
This is a very powerful method to detect and identify different gamma-ray sources (between 100 KeV and 3 MeV) in very different environments as an airport or contaminated factory or a large open field thanks to the portability and to the possibility to make real-time analysis with low power consumption. Further studies will allow improvements in the energy resolution and the identification algorithms, e.g. using machine learning and neural networks.

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Satellite Image Processing by means of Deep Learning Techniques for Environmental Monitoring

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The research activity developed deals with image and signal processing techniques applied to earth observation domain and involve the industrial partners Planetek Hellas and Distretto Tecnologico Aerospaziale (DTA scarl). The task of the current activity is to develop procedures of automatic classification of remote sensing images for image understanding and supporting decision making. The classification procedures developed during the activity rely on machine learning (Random Forest, Support Vector Machines, Multi-layer perceptrons, kmeans and knn) and deep learning techniques (like Deep Convolutional AutoEncoders).
The current activity has adressed three issues, namely, the automatic detection of clouds in Sentinel-2 satellite images, the automatic detection of built-up areas in very high resolution optical satellite images from WorldView 3 mission and, the monitoring of sewage system using PSInSAR data from Sentinel-1 mission.
Concerning the automatic detection of clouds in Sentinel-2 images, the classification procedure has been built by means of machine learning models trained on a public available labeled dataset (curated by Hollstein et al., 2016). The developed procedure is single-scene, pixel-based and context-unaware, i.e. it classifies the single pixels relying on their spectral signatures without any information about spatial or temporal context. The best performance has been achieved by random forest both concerning classification skill and computational resources required. The cloud detection procedure relying on random forest has been tested on an independent labeled dataset (curated by Baetens et al., 2019) and has been compared to the current state-of-the-art cloud detection software. The performance of our cloud-detection procedures is similar to the current state-of-the-art but require less computational resources if compared with multi-temporal cloud detection approaches.
For what concerns the automatic detection of building in optical very high resolution images, context-unaware machine learning techniques and convolutional neural networks for semantic segmentation were implemented. Comparison between these approaches have been performed by training and validating models on very high resolution RGB images from WorldView 3 mission, using layers information of Open Street Map as ground truth. The performance achieved were not satisfying as high quality ground truth labels lack. Moreover, it seems that traditional machine learning techniques are unable to classify building as they ignore textural and contextual high level information. Against with this context, convolutional neural network for semantic segmentation are promising.
Finally, an automatic procedure for monitoring a sewage system using PSInSAR data was developed. The procedure is aimed at detecting critical regions of the sewage system by means of time series of subsidence of neighboring persistent scatterers (PSs) inferred by PSInSAR processing of a time series of Sentinel-1 images. More precisely, the developed procedure relies on three steps. First, a model is built by feeding a kmeans algorithm with the PSInSAR data in order to classify each PS according to its kinematics. Then, each point of the sewage system is classified by means of a k nearest neighbor algorithm fed with spatial coordinate and class membership from kmeans of each PS. Finally, adjacent points having different class membership are labeled as critical.

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Deep Neural Networks for the analysis of Big Data from Earth Observation with GPU on satellite

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In the last few years, there has been a significant growth of Earth Observation missions, due to the increased number of satellites launched into orbit and to the augmented data production capabilities provided by the new sensors in terms of spectral band, resolution and frequency. Unfortunately, this has led to the rise of new problems in the space scenario, since the availability of mass memory storage on payload is still not proportional to the amount of data acquired and a bottleneck effect appears when transmitting data to the ground stations (limited bandwidth). In order to handle the *Big Data* provided by Earth Observation missions, this project aims at speeding-up the image processing on-board and on the ground by developing some Machine Learning algorithms (*Deep Neural Networks*, DNNs) which can be run on dedicated hardware. GPUs (*Graphic Processing Units*) have an optimized architecture for image processing and Deep Learning purpose, but performance (power consumption, energy efficiency, speed-up, …) must be studied before considering to install them on-board the satellites, because of the space scenario major constraints (lack of "always on" power sources mainly). In addition, the GPUs can be configured and programmed directly on-board by means of the CPUs, which can be used for control operations only. On the other hand, DNNs are widely used for several purposes in Data Science and seem to be a very efficient tool to classify images (i.e. land cover and land usage tasks, like detecting buildings, streets, vegetation, sea/lake, crops, …) and to detect changes and anomalies (wildfires, subsidences, avalanches, floods, …). Indeed, Machine Learning techniques allow the satellite to detect novelties and select features in the images, to classify data and to achieve more autonomy in task management, so that they can decide whether to transmit data to the ground or not.

This industrial PhD project is splitted in two part: the first relies on a 12-months period of training at **CERN**, the European Organization for Nuclear Research (Geneva, Switzerland), where the aforementioned technologies will be used in the Particle Physics field, while the second part includes a 12-months period of collaboration with **Planetek Italia** (Bari), a company specialized in Earth Observation related tasks. The activity scheduled at CERN is concerned with learning how to handle the huge amount of data provided by the shower simulations in the *High Granularity Calorimeter* (HGCAL), a new detector which will be integrated in the upcoming upgrade of the CMS experiment, by means of Machine Learning techniques and hybrid computing platforms (CPU + GPU). Deep Neural Networks running on GPUs are going to be used within *CMSSW* (the CMS official software), in order to identify the clusters in the detector, the particle type and its energy from the shower shapes, and to separate particles produced in a p-p collision from the ones produced in another (large pile-up conditions are expected in High-Luminosity LHC). In addition, the training covers the parallelization of the clustering algorithm in HGCAL on GPU (exploiting CUDA programming language), in order to speed-up the code according to the strong requirements of the future Run 3 and Run 4 at LHC, and the eventual integration of fast inference on GPU in CMSSW, by means of the Deep Learning C++ library *NVIDIA TensorRT*, whose performance is very promising for the CMS online analysis.

The activity at Planetek Italia aims at developing Machine Learning algorithms to detect a class of novelties in the images acquired by the satellites and extract important information, in order to reduce the amount of data transmitted to the ground station, since the transmission can be very slow due to the limited bandwidth and being executed only for a limited amount of time along the satellite orbit. The main purpose of the work with the company is to test different models of Deep Neural Network on several GPU architectures, suitable for the installation on-board the satellites, and to study the performance taking into account several aspects of the space scenario. In order to be efficient, the algorithms running on GPUs have to be fast enough as required by each task (i.e. anomaly detection needs more speed than just a normal land classification, since it could be used for a prompt intervention on the ground, i.e. in case of a natural disaster) and to provide a very high accuracy in predictions. In addition, the algorithms will be tested not only on low power GPUs (i.e. *NVIDIA Jetson AGX Xavier*), but also on some of the most powerful GPUs exploited in the *High Performance Computing* (HPC) field (i.e. *NVIDIA Tesla K40* & *NVIDIA Tesla P100* in **ReCaS DataCenter** - Bari), to evaluate the difference in terms of performance and choose which LPGPUs could achieve the best results and are the most efficient in the space scenario.

Development of innovative photoacoustic sensors for industrial and biomedical applications

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The research activity of this industrial PhD is focused on the development of innovative photoacoustic sensors for gas trace detection in industrial and biomedical applications.
Gas trace detection and monitoring are important topics since they find applications in different fields: environmental monitoring, biomarker detection for non-invasive medical diagnosis, industrial process control, toxic gases and explosive precursor detection. The sensors to be developed during the PhD are based on Quartz Enhanced Photoacoustic Spectroscopy (QEPAS). The main strengths of QEPAS sensors like high sensitivity, selectivity, fast response time and compactness, make them suitable for in-situ and real-time monitoring required by industrial and biomedical applications.
QEPAS is an improvement of traditional photoacoustic spectroscopy (PAS). In PAS laser light with wavelength resonant with one of the absorption wavelengths of the target gas is used as excitation source of the gas sample. After the light energy absorption, the gas relaxes to the ground state via molecular collision, generating localized heating in the cell containing the gas. If the light is modulated, the periodic expansions and compressions of the gas generate pressure waves that are detected by a microphone. QEPAS inherits the main merits of PAS: it does not require an optical detector, is wavelength independent, highly sensitive, with a large dynamic range (from few % to part-per-trillion concentration). The key improvement provided by QEPAS is the substitution of the resonant cell and the microphone by high quality-factor quartz tuning forks (QTF), acting as sound waves detectors. The laser light is focused between the QTF prongs, close to the antinode point of one of its the resonance modes and is modulated at the resonance frequency (or one of its subharmonics) of the selected QTF in plane vibrational modes. Thus, the pressure wave excites a resonant vibration of the QTF prongs, and this mechanical deflection is converted to an electrical signal proportional to the stress, thanks to the piezoelectricity of the quartz. The collected electrical signal is proportional to the gas concentration. The acoustic coupling of the QTF with micro-resonator tubes allows the enhancement of the sound wave, and consequently of the photoacoustic signal and the sensor detection limit.
The QEPAS sensors to develop during the PhD target several applications. On one side, a portable sensor for leaks detection will be realized using sulfur hexafluoride (SF_6) as tracer gas, aiming at the quality control of mechatronic systems like diesel injectors and sealing valves. On the other side, a sensor for human breath analysis will be developed to detect ethylene (C_2H_4), which is a volatile organic compound (VOC) present in the exhaled breath and biomarker of inflammatory disease. Prototypes of SF_6 and C_2H_4 sensors have already been demonstrated in the PolySenSe Lab, with detection limits of 50 ppt at 1 s integration time and 10 ppb at 10 s integration time, respectively. Furthermore, a simultaneous dual-gas QEPAS sensor will be developed in order to detect trace gas concentration of the gas target (methane or nitrous oxide), while monitoring the concentration of water vapor, which acts as promoter of the Vibrational-Translational energy relaxation processes; this approach could be used for the human breath sensor, detecting the VOC concentration while monitoring the water vapor in the exhaled breath or for environmental monitoring applications.
The research activity is carried out within the PolySenSe lab in collaboration with the THORLABS GmbH industry in Dachau, Germany and the MASMEC spa in Modugno. Thorlabs is a vertically integrated manufacturer of photonics and optomechanic equipments for research, industrial, medical, and defense applications. Within the PhD project we are collaborating in the development of a compact SF_6 QEPAS sensor, integrating the control, acquisition and signal elaboration electronic, for future commercialization.
Masmec is a company specializing in precision technology, robotics and mechatronics, applied to the automotive and biomedical sectors. Within the PhD project they will collaborate in the implementation of the leak sensor in the production line created for external costumers, and in the realization of the human breath sensor.

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Fs-laser based smart procedures for the fabrication of polymeric Lab on a Chip devices

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A Lab on a Chip (LoC) can be defined as a device in which multiple laboratory techniques are integrated in a chip of few square centimetres. LoCs have tremendous potential for application in various fields of life sciences and chemistry. In particular, in the last years polymer-based LoCs have generated a lot of interest because they are low-cost and disposable devices. Different techniques are achievable for the polymeric LoC production, depending on the target application. The flexibility of ultrafast laser technology and the ability of femtosecond pulses to produce "cold" ablation of the irradiated volume thus avoiding debris and recast layers enables rapid prototyping and high precision micromachining of LoCs devices with complex microfluidic channel networks. In this work, we aim to develop new smart procedures for the microfabrication of polymeric LoCs by exploiting fs-laser technology. Two different approaches are established for the fabrication of polymeric LoCs: (i) direct laser ablation of Polymethyl methacrylate (PMMA) substrate to fabricate the fluidic network; (ii) laser cutting of thin polycarbonate (PC) layers to build a multilayer chip structure. In both cases, the fabrication of prototypes was performed using the TruMicro 5050 Femto Edition laser system delivering 900-fs pulses at a wavelength of 1030 nm. One further fabrication step is the bonding of the laser structured substrates or layers with a cover plate to obtain effectively sealed microchannels. Exploiting the know-how and the laboratory facilities of the industrial partner STMicroelectronics-Lecce, new simple and robust thermally solvent assisted bonding methods were introduced for assembling the polymeric chips. Two procedures are established for PMMA-PMMA and PC-PC bonding, respectively. Furthermore, leakage tests were performed and optimized to assess the reliability of the sealing by injecting a dyed liquid into the channels using a micropump. Based on these results for the LoC fabrication and sealing, the next step will be the fabrication of a prototype of polymeric LoC for DNA extraction and integration of the sensing system to test the device with biological samples.

Research and development of optoacoustic trace gas sensors for industrial, safety and environmental applications

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Demands of trace gas sensing systems from industrial, petrochemical and new medical diagnostic applications are wide-ranging and include emission monitoring and leak detectors, breath analyzers and explosive material sensors. Several chemical and optical techniques have been proposed and the optimum choice depends on the gas species involved, the concentration range, the required spectral resolution, sensitivity, specificity, response time, the operating environment (such as the temperature and interfering species), as well as size and cost. In particular, the detection of hydrocarbons such as methane, ethane, propane or butane is extremely interesting for oil and gas exploration process or for industrial emission/pollution monitoring as well as for environmental analysis. [1]
Photoacoustic Spectroscopy (PAS) is a technique based on an optical absorption process, but differs from common laser absorption spectroscopy based on multipass cells (TDLAS) in the physical phenomenon exploited for detecting the concentration of gas target molecules absorbing the laser light. When light at a specific wavelength is absorbed by the gas sample, the excited molecules will subsequently relax to the ground state either through emission of photons or by means of non-radiative processes. Non-radiative relaxation produces localized heating in the gas, which in turn results in an increase of the local pressure. If the incident light intensity is modulated, the generation of thermal energy in the sample will also be periodic and a pressure wave, i.e., a sound wave, will be produced having the same frequency of the light modulation and detected by microphone, avoiding optical detectors. [1] Quartz-enhanced photoacoustic spectroscopy (QEPAS) represents an upgrade with respect to the PAS technique, because it replace acoustic cell and microphones with a Quartz Tuning Fork (QTF), which acts as a sharply resonant acoustic transducer. The use of QTFs allows detection of weak acoustic excitation and at the same time needs for very small volumes. The laser light is modulated at one of QTF's resonance frequencies and excites the gas molecules between the prongs of the QTF, which amplifies the sound effects thanks to the resonant conditions, and detects the pressure waves at the same time. [1] QEPAS technique doesn't need mirrors or optical detectors, ensure high sensitivity, selectivity in wavelength as well as in acoustic signal and a wide dynamic detection range. Can also work in a wide operative range in pressures and temperatures. For all these reasons, QEPAS sensors show up as the best candidates for leave laboratory to become portable, compact, low noise and high sensitivity gas sensors. As early as during my thesis project, I designed and developed (in collaboration with Thorlabs GmbH and Polysense Group) the first low-noise compact QEPAS-based breath sensor for ethylene detection, presented at SPIE 2018 in San Francisco, California. During my PhD I will continue developing compact QEPAS sensors able to detect (even simultaneously) others important hydrocarbons such as methane, ethane, propane and butane. [2]
Tightening of controls and laws on hazardous material transport and public security makes it necessary to include trace gas sensors inside wagons involved in hazardous gases transport. In this scenario, I will develop a low noise and high sensitivity QEPAS sensor capable to detect hazardous or toxic/pollutant gases such as hydrogen fluoride, sulfur dioxide, carbon disulfide and carbon monoxide. In collaboration with Mer Mec S.p.A. (where I was employed for some months before PhD) I will implement these sensors both on diagnostic trains as well as on ordinary trains.
To conclude, I will design and develop in collaboration with Rice University of Houston, Texas, an ultra-compact, low noise and high sensitivity smart-sensor mounted on drone for detection of carbon dioxide, methane and ethane. This last “On drone QEPAS smart-sensor” have to be able to recognize and follow gradients in gas concentrations, in order to realize a flying gas sensor able to reach locations inaccessible to man.

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