Project "TESUN-83486178370409 finanziamento dipartimenti di eccellenza CAP. 1694 TIT. 232 ART. 6"

DIGEP - POLITECNICO DI TORINO

SECOND YEAR REPORT

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This document is split into four main sections. The first section provides the research activity carried out in 2019 and some relevant results/achievements. The second section sketches the relevant entries of the project budget at the end of year 2019. The third section provides indications on the year 2020 activity.

1 Research activity

As indicated in the project presentation, the aim of the research activity of DIGEP is to cope with the fundamental theme of man-machine interaction/integration, intermingling three complementary disciplinary areas, namely, the Technological Perspective, the Management Perspective, and the Economic and Legal Perspective. Below are itemized the main themes under the various perspectives.

Technological Perspective

A. 3D modelling and simulation;
B. Design and simulation of new processes and systems;
C. Collaborative robots;
D. Additive production;
E. Factory logistics;
F. Quality and measurements;
G. Sustainability.

Management Perspective

H_1. Technological change, productivity growth and competitive dynamics;

H_2. Technological change, managerial tensions and technology transfer challenges and ecosystems for SMEs;

H_3. Technological change, skills and work design;

H_4. Technological change, entrepreneurship and scientific method;

I. Algorithms and their influence on decision making processes;

L. Algorithms for complex production systems and supply chain.

Economic and Legal Perspective

M. Economical Perspective;
N. Legal Perspective.

Within the technological perspective, as indicated above, the research is “declined” into seven disciplines, each of which encompasses several research and experimentation activities, to be carried out in seven dedicated technological laboratories.

Many of the above-mentioned laboratories will be incorporated into the premises of the "MInd4Lab" general laboratory, which is still undergoing radical refurbishment. Unfortunately, due to some unforeseen circumstances (e.g., remediation of asbestos and other pollutants), the refurbishment works of the building "Fabbricato Area Sud - Part 1" have been slowed down by several months. These works will hopefully be completed by spring 2020. In the meantime, however, many purchases of equipment/instruments for research have been performed and some of the instruments have been temporarily installed and used in other premises. On the other hand, the refurbishment of the premises located in the “Palazzina Corso Trento 21” – which can be seen as an “appendix” of the Mind4Lab, dedicated to research activities based on “lighter” and portable instrumentation – has been completed.

The opening of the “Palazzina Corso Trento 21” took place in conjunction with the so-called “Festival of Technology” (in Italian “Festival della Tecnologia”), an initiative conceived and promoted by the Politecnico di Torino in the period 7-10 November 2019, to bring society closer to the world of science, technology and research (https://www.festivaltecnologia.it). In this initiative, several demonstration activities related to the research of the project of interest have been organized. The large audience of all backgrounds and ages has decreed the success of the initiative and – in some ways – helped to publicize the activities of the project itself.

The website of Project "TESUN-83486178370409 finanziamento dipartimenti di eccellenza CAP. 1694 TIT. 232 ART. 6" is available at:

http://www.digep.polito.it/focus/dipartimento_di_eccellenza

1.1 Technological Perspective

Below is a detailed description of the progress of research activities for the year 2019 under the technological perspective, with reference to the related seven dedicated laboratories. For each of these activities, references to any relevant scientific publication produced during the year of interest are also given.

A – 3D modelling and simulation

With reference to human-machine interaction, a very interesting topic – although still little debated in the scientific literature – is that of the psycho-physical impact on the human subjects involved. In fact, it is well known that working closely together with robots/machines can trigger emotional reactions of different types and entities (e.g., discomfort, fear, uncertainty, etc.). Recognizing and interpreting these emotions correctly could be useful to improve the quality and effectiveness of the interaction itself.

Regarding human-machine interaction issues, the research activities have been focused on the adoption of three-dimensional modelling, digitization, simulation and advanced digital visualization.

A particular attention has been given to 3D face analysis [A1, A2, A3] and specifically to the study of human facial expression recognition [A4], to understand and quantify the user's engagement in order to design new innovative products, in a product life cycle logic. This approach is called Emotional Design and is aimed at developing products and environments which also respond to the inner needs of the customer [A5]. To achieve the above goal, human perception has been studied from the computational, neuroscientific, behavioural and psychological perspectives, in order to improve the methods of facial expressions recognition starting from the concept of "mental representation" of the human face [A6]. Deep convolutional neural networks have been adopted for conceiving a methodology of automatic categorization of Paul Ekman's six basic emotions, obtaining an accuracy that matches the state-of-the-art one [A7]. Then, a tailored method has been designed for emotional engagement classification, developed for users interacting with online platforms, including virtual reality environments [A8], and during specific interviews to potential customers [A9], with the aid of 3D sensors (depth cameras) for the real-time acquisition and processing of facial data. These methodologies rely on James A. Russell's theoretical "circumplex model of affect", which locates all emotions on a cartesian plane with the degree of positivity on the *x*-axis and activation degree on the *y*-axis.

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B – Design and simulation of new processes and systems

The description of the research activities carried out in this field is divided into three parts, described individually in the following sub-sections.

B.1 Product and process design

Industry 4.0 entails deep interactions between humans and machines during all phases of the product lifecycle, from its conception to production and from usage to disposal, while requiring the integration of the many enabling technologies. All this requires the development of new tools, which may enable Product Life Cycle management, Model Based Enterprise, and the definition of CAD Cloud-based strategies within an extended enterprise. Furthermore, the radical and potentially disruptive nature of technological innovations requires a tight interaction between the world of "technical" product development and the formulation of

innovation strategy. This allows both to clearly identify the strategic potential of new technology and to make sure that product and service development operations are run in coherence with strategy. This broad effort has led to the following activity streams.

1. At the higher level of inquiry, state of the art analysis of the impact of scientific research on enterprise and human resources management, business model and technology has been performed [B1]. Moreover, a detailed study on the interconnections between innovation strategy and product development processes has been carried out [B2], also in view of supporting decisions in the 'fluid' phase of the technological lifecycle [B3]. This analysis has also been carried out by investigating the variability of the implementation of the Industry 4.0 paradigm in operational processes, and across several Countries, according to their degree of industrialisation (e.g. mature Countries as Italy and France and emerging ones, such as Uzbekistan and Brazil).
2. Delving deeper into processes and activities impacted by Industry 4.0, research has been carried out on explicit explanation models of interactions between human operator, e.g., designer, manager, worker, etc., and the enabling competence level for a proper exploitation of innovative technologies. A specific focus has been dedicated to research on product development processes, which has been carried out at different levels, ranging from the entire enterprise [B4] and all the way to individual design activities, which have been studied by using next-generation protocol analysis methods based on neurophysiological signals [B5].
3. This activity stream has looked into methods and frameworks to model and evaluate new digital technologies, e.g. Gap Analysis, Business Model Canvas, Balanced Scorecard, Benefit Evaluation Grid, to assess risk and resilience of innovative solutions, also in collaboration with ENSAM (École Nationale Supérieure d'Arts et Métiers) – ParisTech. The impact of data-driven methods on product development processes has been studied both conceptually [B6] and under the specific application of Lifecycle Costing [B7].
4. Design and production departments are scarcely integrated in manufacturing companies. This fact, especially for companies with a highly customized production, is very critical, since the collaboration between the two departments is essential to reduce the trial-and-errors cycles to design new products and process. It is therefore necessary to collect data from the shop floor, especially the ones related to anomalies or critical situations, and make them at disposal to be used to improve the design of the next products and processes. A research was developed to design a knowledge based system to digitalize and collect

data regarding anomalies at the shop floor, and to integrate them with data coming from the design phase, in order to reduce the time for finalizing a new product [B8, B9].

B.2 Laboratory research

The IoT (Internet of Things) section of the Mind4Lab laboratory does not have a physical location yet. Nevertheless, some preliminary experiments dealing with the exploitation of IoT devices for the intelligent monitoring of operating systems have been carried out in the last months [B10, B11, B12].

The experimental activities related to the laboratory research will be summarised in an operational document, which is still under preparation. Such report will also highlight the benefits provided by innovative interactive didactics in the academic course "Engineering tools for industry 4.0".

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C – Collaborative robots

As part of the research on the exploitation of collaborative robots in production, important interventions on the robot units available in the laboratory have been carried out or are nearing completion. Furthermore, the “virtualization” of the laboratory robots has been completed, creating a digital model of the robotic workstations present in the laboratory [C1-C4].

The following subsections deal specifically with: (1) procurement of new research equipment and (2) hardware/software adaptations to existing equipment, in order to integrate it into the research activities of the project.

C.1 Procurement of new research equipment

On September 2019, it was started the purchase procedure of two collaborative robots to be mounted on a single work bench with arm synchronization. These two robots are equipped with a force sensor integrated on the wrist [C5]. The robots are also equipped with the following interchangeable tools [C6-C7]:

- a haptic gripper capable of lifting loads equal to the robot's load capacity;
- a carrier with a limitation of the force applied to the tip, which can be obtained by adjustable springs;
- a screwdriver with a settable torque within a range of 5-20 Nm.

The robots will be programmed offline by means of a dedicated computer, equipped with a high-performance graphics card. This computer has already been ordered and delivered.

C.2 Hardware/software adaptations to existing equipment

The robots already present in the premises of the DIGEP department, i.e., a Universal Robots UR3 robotic arm and a MiR mobile robot, were assembled together by means of a mechanical, electrical and electronic prototype interface [C8]. Specifically, the robotic arm that is mounted above the mobile robot is powered by the batteries of the mobile robot, through an inverter, and communicates with the PCs of the laboratory by means of the wi-fi router of the mobile robot.

The COMAU robot, already present in the DIGEP department, was not updated; thus, it was digitally reconstructed on the V-Rep robotics simulation platform. The UR3 robot and the MiR robot are already present in the V-Rep platform library. The UR3 robot was digitally reconstructed to be simulated on the Matlab Simscape Multibody program. Digital simulation allowed the integration of the robot with a series of applications developed on Matlab, e.g., (1) the computer vision system and (2) the finite state automaton for managing contacts with human beings, implemented with Matlab Stateflow. Furthermore, the artificial intelligence system, based on a reinforcement learning control, is currently under development on Matlab Reinforcement Learning Toolbox, which will allow a smart control of UR3 robot through task-based programming.

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D – Additive production

During the year 2019, the research activities concerned three interconnected activity streams, which are illustrated separately in the following subsections.

D.1 Directed Energy Deposition (DED) of metal powder with laser beam

An experimental campaign was conducted in order (1) to deeply investigate the DED process and (2) to prove the robustness of the numerical model developed during the first year of the project. The experimental analysis was performed at two different levels: deposition of single tracks and deposition of cubic samples. As regards the deposition of single tracks, the relationships between the process parameters and the morphology of the deposited track were identified by means of statistical tools. Subsequently, the process was studied at a macroscale level and cubic samples were produced. This experimental campaign allowed to identify a process-parameter window in which the process is stable [D1]. The fabricated cubes were fully characterized, and specifically the effects of the process parameters on surface roughness and residual stresses were evaluated.

A new numerical model was formulated to describe and simulate the DED process for advanced scanning strategies. Especially, the innovative adoption of the advanced laser-scanning strategy, already used in welding process, was studied for implementation in an Additive Manufacturing (AM) process. The aim of this study was to model and simulate this new scanning strategy on single track deposition, by creating an analytical model that predicts the characteristics of the deposited track. The model was validated on experimental linear deposition tracks and finally compared with the traditional scanning strategy, in terms of the main process parameters [D2].

Based on the acquired knowledge on the process, the requirements and specifications for the DED system to be installed in the Mind4Lab were defined. At the present, the purchasing procedure is still ongoing.

D.2 Automation in metal AM production

The digitalization and the technological innovation have allowed the creation of automized processes, as customers are demanding new, high-quality and cheaper products within shorter periods of time. The two main drivers of the change for the industrial production are

Technology and Innovation. Typically, AM produces high value-added products and requires a new set of skills and technologies. This also depends on the fact that AM is not an actual conventional industrial technology suitable to mass production and wide assembly lines. Therefore, to build a reliable AM system of production, it is necessary to combine the new technologies with the innovation of, not only final products, but also the relevant manufacturing processes. Despite the challenges, the fact remains that AM is a versatile set of technologies that can support the industrial companies in their pursuit of the strategic imperatives of (1) performance, (2) growth, and (3) innovation.

Some scenarios of metal AM production lines were analysed, with different levels of automation according to the production rates this led to identifying suitable layouts and machines to adopt. The whole AM cycle was considered to account for raw material handling, pre-processing, AM production, and post-processing operations. Some preliminary outcomes deal with an initial suggestion of the best solutions for metal laser-powder processes that allow companies to reduce the environmental impact and to optimize the trade-off between production time and cost.

D.3 Fabrication of plastic parts by photo-polymerisation

In any manufacturing process, there are several factors for which the final product exhibits dimensional and shape deviations from its ideal nominal geometry. For this reason, engineers generally indicate the admissible tolerance interval for the critical dimensions on the blueprint of the product. Unlike traditional manufacturing processes, no tools, molds or dies are needed for additive manufacturing (AM), and a single machine can produce infinite different shapes. An AM part is built layerwise in a single manufacturing step and is often net shaped. In most cases, no finishing operation is applied to change the dimensions of the product, apart from a reduction of the superficial roughness through sandblasting or polishing. Knowing the dimensional tolerance of AM processes in advance is therefore of fundamental importance, but little information is currently available in the literature. A benchmarking analysis of different AM systems, including those for photopolymers, is under development. The dimensional accuracy of the machines to be compared is defined using the ISO IT grades of a reference artefact [D3].

Beyond the dimensional accuracy, another aspect that is under consideration is the user-perceived quality of the 3D printed parts. An Aesthetics Quality Index (AQI) has been defined for the evaluation of the aesthetic quality of 3D printed parts, according to user's perception. A replica of a specific reference part containing those defects with higher

probability of occurrence was constructed. This replica was printed with different printers for polymers and then evaluated by several users. The AQI measure and the reference part seem user-friendly providing a useful design-aid for an immediate understanding of the feasibility of a specific design feature, in a framework of user interactivity [D4, D5].

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E – Factory logistics

The factory-logistics part of the project aims at integrating a factory with the downstream and upstream phases of a supply chain, within the Factory 4.0 context. This integration can be obtained by coordinating the operations and using the information concerned with the production phases of the materials and the flow of the individual moved parts. The physical and IT modelling of the flows will be reproduced in the laboratory, through dedicated work areas (present in other areas of the laboratory), which are interconnected through an automatic transport system. The transport system is composed of two Automated Guided Vehicles (AGV) able to carry up to 150 kg of material via physical interfaces, with a conveyor that will serve as input/output to an Automated Storage and Retrieval System (AS/RS), which is in turn equipped with a load system with shuttle carriers. In the AS/RS, each storage level is serviced by one transfer car, travelling in dual command operation. The shuttle system will be able to provide a throughput of around 450/500 totes per hour.

A reading of data relating to objects in motion through systems of RFID (Radio-Frequency Identification) detection will be also implemented. In this sense, a RFID gate including two UHF (Ultra-High Frequency) antennas and one UHF Long Range Reader will be adopted. Then, workbenches will be installed close to the storage system, in order to reproduce two typical activities carried out in warehouses, i.e., (1) light assembly of components and (2) order kitting of finished products. Figure E.1 sketches the plant logistics area, including the storage system with the automated transport system and the workbenches.

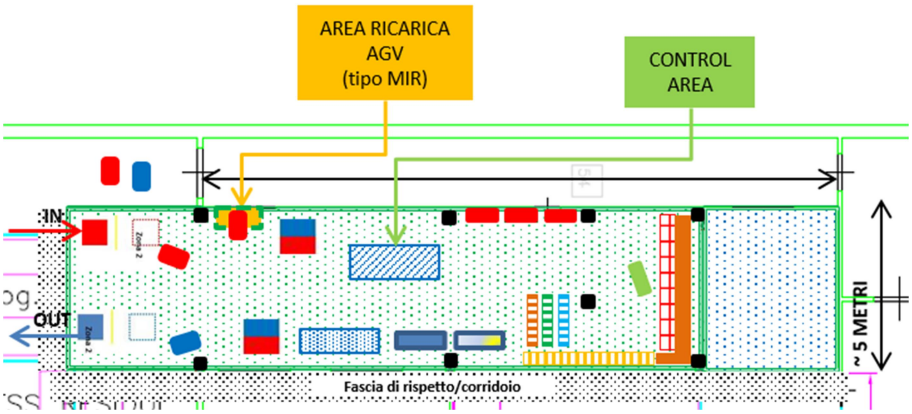

Figure E.1. Overview of the Factory-Logistics area within the MInd4Lab laboratory

Operations of the storage system are simulated via a simulation tool, which is able to couple the existing physical flow, in order to carry out laboratory experiments in a virtual environment. The simulation model is currently under development and will require validation from the physical warehouse. Such simulation will pave the way for further integration between physical and virtual environments, so as to achieve a Digital Twin of the warehouse process. The chosen simulation software is Anylogic, i.e., a multi-method simulation software that allows to define the physical boundaries and components of the area with embedded objects and classes (i.e., conveyor belt, AGV, etc.) as well as design the material flows, via discrete-event modelling method. For now, input data are: (1) the speed of the conveyor belt and the AGVs, (2) the order rate for materials in/out of the area, and (3) the size of the area and its main components. The integration with other factory areas will take place progressively.

Regarding the future, the final goal is identifying the most critical aspects of the material-handling and production stages, by comparing situations with and without the use of automatic and/or interfaced systems. By configuring archetypal production processes, we will define methods for reading and detecting data on products, tracking methods and their processing, taking also account of the downstream production phases. The activity will be

carried out in parallel between physical simulation and IT, in order to compare multiple scenarios at the same time.

The possibility of integration with simulated upstream and downstream flows will also be assessed to understand the potential impact on the whole supply chain. This is a step forward in the direction of treating unknown demand processes, which have to be estimated both in terms of process type and parameter values [E1].

Finally, the plant logistics area of the Factory 4.0 requires a full integration between the different parts, which cannot work alone *in vitro*. Hence, due to the fact that the renovation works of the devoted area (within the Mind4Lab) are not still completed, we could not proceed with the purchase of equipment and materials. In 2020, we will concentrate on purchasing the components of the plant logistics area, starting from two AGVs, the shuttle based AS/RS, the RFID gate and two workbenches. Additionally, we plan to install a Warehouse Management System (WMS) in collaboration with the provider of AS/RS – i.e., a software able to plan and schedule all the activities taking place in the plant logistics area – and a middleware software connecting all physical and informational flows. On the experimental side, we will first validate the simulation tool by operating the plant logistics in automated and manual mode, and, afterward, experiment with different calibration of the afore-mentioned parameters. Moreover, different warehouse configurations will be tested; in particular, we will model/reproduce (1) a factory warehouse handling finished/unfinished product for final assembly and (2) a distribution warehouse for finished products and order kitting for distribution to the final customer.

Another research carry out in this domain is the proposal of a method capable to support both an easy initial configuration of the warehouse system, and an easy reconfiguration of warehousing operations based on the current state of the manufacturing process. The proposed approach is based on discrete-event simulation and it is applied to an Autonomous Vehicle Storage and Retrieval Systems (AVS/RS), one of the most recent and promising automation technologies for warehouses [E2]. Another crucial point is the estimation of the energy necessary to perform the warehouse activities. A research is proposed to define an analytical model to evaluate the energy consumption of an AVS/RS [E3].

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F – Quality and measurements

The increasingly close interaction between man and machine makes it possible to carry out productions with a higher and higher degree of customization, in a customer-driven perspective. On the other hand, the need to guarantee the quality of the products and verify their conformity with specifications is still current. This makes Quality verification/measurement operations increasingly challenging and complex.

During the year 2019, research activity was mainly focused on the advanced methods for technological surface characterisation, which were addressed both from the metrological and application perspective. Techniques for mechanical characterisation were considered as Instrumented Indentation Testing, which allows thorough mechanical characterisation of the surfaces on different scales, by means of a semi-destructive test. Surface topography characterisation was also considered [F1-F4].

F.1 Deliverables

- Metrology for Instrumented Indentation test: influence factors to measurement uncertainty and studies on calibration procedures.
- Metrology for Surface topography characterisation: metrological characteristics evaluation of a point autofocus instrument.
- Application of instrumented indentation test and surface topography characterisation for investigating influence factors of manufacturing processes (e.g., additive manufacturing) and subsequent process optimisation in terms of surface characteristics.
- Development of statistical models (1) to predict defects occurring in the optimised process, (2) to assess the effectiveness and total cost of inspection strategies, and (3) to provide inspection designers with a tool to support early phases of inspection design. Application to manufacturing processes and highly customised assembly processes [F5, F6].
- Development of multi-scale and multi-sensor characterisation methods to characterise materials and processes [F7-F9].

F.2 Next steps

- Development of methods to enrich the mechanical characterisation from instrumented indentation test and reduce indentation exploiting Electrical Contact Resistance method.
- Development of Surface topography-based method for tribological test characterisation, to reduce measurement uncertainty.
- Metrology for surface topography characterisation: participation to the CIRP (The International Academy for Production Engineering) sponsored inter-laboratory comparison of the noise characteristics.
- Improvement of statistical models to predict defects in short-run productions by further detailing the statistics.

F.3 Infrastructures

The laboratory of quality and technological surface characterisation was put in operation. The following items were purchased:

- Instrumented indentation testing platform STeP6 by Anton Paar for the nano (NHT3) and micro range with micro-scratch capability (MCT3);
- Macro-scale Instrumented indentation tester AXIOTEK ISRHU09;
- Coherence Scanning Interferometry Zygo New9000;
- Software license for surface topography analysis: Digital Surf MountainsMap.

The laboratory has been fully equipped and placed in a temporary location where it is operational, while the renovation works and the installation of a metrological cell are being completed. Regarding the future, it will be considered purchasing optional moduli to extend characterisation capabilities [F10, F11].

F.4 Strategies for project sustainability

The research was conducted establishing strong collaboration relationship with both academic and industrial partners:

- Ultraprecision Surfaces Group (Prof. D.A. Lucca) – Oklahoma State University (OK, USA);
- Manufacturing Metrology Team (Prof. R.K. Leach) – University of Nottingham (UK);
- Department of Material Science – DISAT (Prof. P. Fino) – Politecnico di Torino (ITA);
- STAM – Science and Technology in Advanced Manufacturing Team (Prof. R. Lupoi) – Trinity College Dublin (IRL);

- CRF (Centro Ricerche FIAT) and FCA, Turin (ITA);
- TriTech – Anton Paar, Graz (AUT).

F.5 Dissemination of results

Result dissemination entailed publication on scientific journals and participation to scientific conferences (see the following reference list) and public educational events, such as the "Festival of Technology" above mentioned.

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G – Sustainability

Sustainability is an increasingly important issue in all areas, including human-machine interaction within innovative technological processes. In the research developed during the year 2019, life cycle-based methodologies – accounting for the main factors of influence on the economic and environmental impact for the production of metal components – were investigated. In particular, decision-support tools for identifying the most sustainable manufacturing route (subtractive versus Additive Manufacturing-based approaches) were presented for different scenarios, aiming to contribute to the debate concerning the environmental impact characterization of Additive-Manufacturing (AM) processes [G1].

It is worth underlying that AM, which includes different technologies, allows free-form parts to be produced flexibly by selectively depositing material, layer after layer. Among the various AM processes, metal wire deposition (MWD), which uses a metal wire melted by a high-energy source as feedstock, was found to be suitable for the manufacturing of low-complexity, medium-to-large components at relatively high deposition rates. Some industrial applications were identified, despite the quality of the as-deposited surfaces, which usually require further finishing operations [G2]. In particular, an energetic comparison between the Wire Arc Additive Manufacturing (WAAM) process and a traditional machining-from-bulk solution, to produce a steel blade, was presented. Experimental measurements and environmental databases were used to quantify the primary energy demand at each stage of the life cycle. The results revealed that, for the analyzed case study, an integrated additive (WAAM)-subtractive manufacturing route enables significant material and primary energy savings with respect to traditionally applied approaches [G3]. In addition, a structured modelling framework to assess whether WAAM could successfully substitute machining processes – with respect to costs, manufacturing times, energy demand and carbon footprint – was also developed [G4].

The mitigation and prevention of environmental impacts is still a challenge for most companies, especially for small and medium-sized enterprises (SMEs). Companies are making significant efforts to develop sustainable methodologies, as a result of consumer pressure or for government enforcement reasons. However, there is still a lack of concrete initiatives implemented at SME level. A conceptual framework that may be used to examine to what extent SMEs understand the eco-efficiency concept and implement sustainability strategies was presented, with reference to four specific factors: (1) availability of an environmental management system, (2) environmental knowledge, (3) organizational culture,

and (4) environmental monitoring and control. The limitations and research gaps in the specific context were analyzed, and a conceptual agenda that allows the eco-efficiency implementation to be assessed was proposed [G5]. Future activities will be focused on the extension of these methodologies to the circular economy scenario, aiming to develop decision-making tools, to promote a sustainable change in the current manufacturing context.

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1.2 Management Perspective

H – Technological change

The managerial perspective on the relationship between technological change (due to digitization and to the Fourth Industrial Revolution) has been developed around the research trajectories illustrated below.

H_1 - Technological change, productivity growth and competitive dynamics.

This research trajectory is taking into consideration the impact that the technological change due to digitalization and investments in Information Systems (IS) have on competitive dynamics and on value creation. This research trajectory finds its motivation in the multifaceted and evolving role that IS can assume in organizations– i.e., the automation of existing processes (i.e., the elimination of routine work), "informate" processes (i.e., automating the way data and information are collected, processed and used to support managerial decision-making), and the transformation of the value proposition and the features of the product or the service. In front of such broad and complex role of digital technologies, we still know little about whether the value generated by IS investments essentially generates economic growth at an aggregated level, due to its potential of transforming products, services and values chains and of using information better and faster, or whether it enables a reduction in labor input, due to its automation potential. This gray area in what we know about the IS value has important implications on the way IS investments can generate value for society as a whole.

In a study developed on this research trajectory [H1], it has been theorized and tested which value component – either economic (output) growth or input reduction – prevails, by analysing, at the industry level, the effects that IS investments have on labor productivity. The results on 231 three-digit industries in Italy, between 2008-2016, show that IS investments affect labour productivity growth. However, such an effect has different drivers, depending on the type of industry. IS investments in the information goods sector lead to output growth, while they lead to a reduction in both labor input and the output (value added) in other sectors. Also, another study [H2] has shown that higher investments in IS have led to greater competitive divides and higher market concentration at the industry level.

Two studies in the hospitality industry [H3, H4] have allowed to go more in depth on the reasons why digitalization can be accompanied by limited value capture, as they showed that

in an increased digitalized and online business environment firms develop new types of resource dependence from online intermediaries [H4]. Also, online intermediaries increase the threats of substitute products (e.g. the supply of accommodations that are alternative to hotels) [H3].

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H_2 - Technological change, managerial tensions and technology transfer challenges and ecosystems for SMEs

Technological change and the Fourth Industrial Revolution poses new challenges and opportunities of radical and continuous innovation to Small and Medium-sized enterprises. Such opportunities are still poorly understood and explored in light of the peculiarities that SMEs show in reference to their integration if international supply chains, to the characteristics of their domestic and international markets, and their capacity to interact with universities and scientific actors to absorb innovative knowledge.

Such research trajectory have been aimed at exploring the antecedents and the impact of technology adoption initiatives in SMEs and their implications for the managerial approaches. The empirical settings have been developed by both capitalizing established institutional relationships of the Department in the local regional ecosystem (with the local Chambers of Commerce and with the local employer associations such as Confindustria Piemonte and Unione Industriale Torino) and by developing new partnerships at the international level with leading universities. In thin vein, a research group in the Department has launched a survey on the automotive supply chain at the international level that replicates and adapts a research developed by Case Western University and New York University. This survey is aimed at exploring how digitalization change approaches in Human Resource Management, Industrial Relations in SMEs and value creation and capture. The idea is that in the moment operations

on the shop floor and new product development processes become increasingly data-driven through investments in connected and smart machineries and software, the higher the portion of the value that is captured by a tier of system integrators and technology vendors, or simply by OEMs (that act as large customers of small and medium-sized suppliers). However, such approach can be contrasted by having a model of HRM and work design that requires high involvement of line employees in data analysis and continuous improvement. The survey is in process, is based on multi respondent approach (involving the HR director, the plant director, and the sales director). At the Italian level 78 firms have answered the complete questionnaire. The target is to arrive at a sample of 130 firms in April 2020. The delivery of the first working papers has been programmed for Fall 2020. Papers will be submitted to the international conferences of scientific association like Academy of Management, Strategic Management Society, DRUID, EGOS.

The other studies have explored how Industry 4.0 investments and R&D strategies are conducted by enterprises and have been based on periodic survey initiatives launched by the local Chamber of Commerce in Turin. The studies have identified different patterns of Industry 4.0 adoption depending on the type of linkages that SMEs develop with universities or with suppliers and customers [H5]. The studies have also identified a managerial tension (i.e. trade-off) between internationalization and innovation that is mitigated when SMEs develop more structured partnerships with technical universities and research centers [H6].

Within this research line, another study conducted in the Department is aimed at obtaining a better understanding of the role played by universities in the technological development and specialization of the ecosystems in which they are located [H7]. Both quantitative and qualitative approaches have been applied and have taken advantage of collaborations with the European Commission and 20 European technical universities belonging to the CESAER university network. Results provided evidence of the interplay between the technological specialization of universities and the evolution of the technological trajectories of firms located in Italian NUTS3 regions, allowed to build an original taxonomy of university-region technological evolution processes that leads to the identification of four possible university-region evolution models and reveals substantial heterogeneity in university-region specialization processes. Moreover, further results on the underlying mechanisms of university technology transfer activities allowed identifying different entrepreneurial university models and “best practices” associated with each entrepreneurial university model in the European setting of S&T universities. All in all, this research acknowledged that one-size-fits-all is not the case in this field, but rather that entrepreneurial universities, and

therefore their impact on ecosystems, may take on different forms, depending, among other things, on the organisational resources, the presence of an advanced local innovation ecosystem and a strong industrial system. Other studies [H8, H9] have analysed the topic of innovative and entrepreneurial ecosystems in the empirical settings of Turin.

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H_3 - Technological change, skills and work design

This research trajectory analyses how digitalization (Internet of Things, Big Data and Artificial Intelligence) is changing skills, work design and HRM practices. The empirical setting currently include the electrical sector and cultural heritage, who represent two extreme cases where the phenomenon of technological change is more evident than in other contexts. The research being conducted in the electrical sector capitalizes the mid-term relationships established with the main electrical employer associations in Italy (Elettricità Futura and Utilitalia) and with Enel, one of the largest power generation and utility company in the world. Specifically, the research conducted in 2019 have been built on two steps.

1- Step n. 1. Case study on how smart grid and digitalization change work practices, skills, workplace learning and training methods in the electrical distribution grid. This study has been developed as a longitudinal case study commissioned by Enel to the Department. Enel's intent has been the one to be supported by the department in revising workplace learning, relationship with technical schools and checklists for recruitment of new workers

2- Step n 2 has been an action research based on involving in a challenge-based education initiative two groups of students enrolled in Enel as apprentices[1]. The challenge has been designed by the Department along with Enel and has been based on involving students in designing new mechanisms of monitoring and controlling the electrical grid (transformation substations) through devices based on Internet of Things. This initiative has provided a perspective of observational research through which we could observe how middle skills jobs are required to interiorize and use new digital skills (related to software programming, data management and data analysis linked to inspection and maintenance of the grid) along with the traditional industry-specific jobs. On this initiative the Department has obtained a job for a 32,000 € revenue from Enel.

These two research lines have allowed to build a training development project with EIT Manufacturing, the 7 year research program funded by European Commission and aimed at promoting technology development, education and technology transfer on the fields of digital manufacturing. Specifically, the project has been funded for 123 k€ by EIT Manufacturing, it will be conducted during 2020 with the aim of developing training content for open online courses on the work transformation ignited by digital technologies. The course will target managers and production specialists in the settings of SMEs as well as students.

A second research setting on which the Department has decided to conduct its research on the relationships between digital technologies and digital transformation is cultural heritage [H10, H11]. Specifically, within the Department some scholars are developing (along with Gianvito Lanzolla, dean of the Management Department at Cass Business School) a longitudinal case study on the digital transformation of the Van Gogh Museum in Amsterdam. Such institution represents an extreme case of both external and internal transformation (in both the business and the organizational model).

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H_4 - Technological change, entrepreneurship and scientific method

This line of research aims first at analysing the effects of technological change on entrepreneurship dynamics. The digitalization of economy is indeed favouring the emergence of a new breed of entrepreneurs that, unlike their pre-internet predecessors, can leverage digital technologies, innovation and online communities to support most of the key processes within a company. As a consequence, we are witnessing a peak of initiatives across the globe to foster the acceleration of digital entrepreneurial activity related with the creation and development of "digital start-ups". By relying on an original database - which collects data on the creation of innovative start-ups within the framework of a recent legislations by the Italian government that aim at promoting the creation and the digitalisation of new innovative firms - the research conducted at the Department aims at investigating the relationship between the features of digital ecosystems and the creation of digital start-ups. The research allows identifying new dimensions of the digital ecosystem that may sustain and foster the creation of digital start-ups and, specifically, the influence of digital knowledge spillovers, the digital skill endowment, the digital infrastructure and the integration of digital technologies on the creation of digital start-ups in Italian regions.

Second, this line of research focuses on the relationship between technological change and entrepreneurial decision making. New entrepreneurial firms are important drivers of technological change. Yet, despite several interventions to increase entrepreneurial activity, the rate of failure of new entrepreneurial firms remains high, especially in the new technological domains of the Fourth Industrial Revolution. Moreover, especially in Europe and in Italy, even start-ups that do not fail rarely scale up to become full-fledged new firms in the market. The rate of failure (or the inability to grow) that we currently observe in new firms raises the question of whether managerial actions, and particularly decision-making, can improve the ability of entrepreneurs to adequately screen technological opportunities. In this framework, the research conducted at the Department studies the implications of a scientific approach to entrepreneurial decision making to understand whether such an approach allows early-stage start-ups facing the high risks inherent in new ventures operating in new technological domains. This research is developed in collaboration with the ICRIOS research centre of Bocconi University and adopts a Randomized Control Trials (RCTs) approach with more than 200 entrepreneurs from high-growth start-ups operating in technology sectors [H12, H13, H14].

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I - Algorithms and their influence on decision making processes

The 2019 activity focused mainly on production scheduling and packing problems but was extended also to bi-level and graph problems on a side and to combinatorial design on the other side.

In terms of production scheduling, the so-called no-idle no-wait total completion time flow shop scheduling problem was investigated where machines cannot remain idle and jobs must be processed continuously on the various machines without interruption. This latter requirement occurs, for instance, in metal-processing industries, where delays between operations interfere with the technological process. For this problem a successful matheuristic approach exploiting an ILP formulation based on positional completion times variables structural properties of the problem was provided [I1].

In [I2], the problem of deciding in which sequence to process a given number of circuit boards in a batch oven was efficiently solved by means of column generation. In [I3], a matheuristic approach was proposed for selective disassembling sequencing under sequence-dependent costs.

Exploiting the presence of Prof. V. T'kindt as visiting for 1.5 months, the application of exact exponential-time algorithms for the solution of just-in-time scheduling problems when jobs have symmetric earliness/tardiness weights and share a nonrestrictive common due date was explored in [I4]. Also, preliminary results were obtained in bilevel scheduling on a single machine [I5].

Also, the approximation algorithm for the two identical parallel machines scheduling problem with the objective of minimizing the maximum completion time started in the previous year was eventually completed and published [I6]. Peculiarity of this result is the use of problem independent Linear Programming (LP) modeling for the analysis of related approximation ratios. Finally, solution approaches for lot streaming in flow shop scheduling have been proposed in [I7].

In terms of packing problems and in the quest of bi-level optimization, the work on the Bi-level Knapsack problem with Interdiction Constraints started the previous year was completed and extended. Indeed, it was possible to show that the same algorithmic framework could be applied to the Interval Min-Max Regret Knapsack Problem after providing an alternative bi-level programming reformulation [I8, I9].

The activity dedicated to the application of operations research and artificial intelligence techniques to combinatorial design problems was continued in 2019. The work proposed on the Oberwolfach problem [I10] is currently under submission and preliminary activity on partitioned balanced tournaments design problems was started.

Further activities on graph problems were also provided in [I11] where the so-called maximum happy vertices problem that involves determining a vertex coloring of a graph such that the number of vertices assigned to the same color as all of their neighbors is maximized and in [I12] where a stochastic version of the Critical Node Problem (CNP) with the goal of minimizing the pairwise connectivity of a graph by attacking a subset of its nodes is discussed. Further activities on decision making were also proposed in [I13, I14, I15]

The following other papers [I16, I17, I18] not mentioned above were published in 2019.

In terms of dissemination, the organization of the next MAPSP (Models and Algorithms for Planning and Scheduling Problems) Conference has been attributed to our Department with F. Della Croce as Chair of the Organizing Committee. The Conference will take place on June 13-18 2021 at Oropa Sanctuary (BI), Italy.

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L - Algorithms for complex production systems and supply chain

The research activity of the group focused on (1) the study of complex production systems and development of algorithms for their design and management, and (2) the design of eco-industrial parks to investigate new supply chains that environmental sustainability is fostering. The research on production systems includes both practical aspects and theoretical studies. From a practical point of view, real systems have been studied to design forecasting and planning procedures to help system efficiency (in terms of resource saturation), when mass customization is considered. Tabu-search based meta-heuristics have been developed to find good solutions in reasonable time and they have been applied to a case study from the automotive sector [L1]. Also, the integration of machine and transportation scheduling has been addressed in a textile company, with the aim to understand the economic impact of

adding transportation resources to manage shop floor movements [L2]. Although these studies have been performed starting from industrial cases, the results have the potentiality to be extended to other similar contexts.

From a theoretical point of view, the research on new methodologies to integrate system simulation and optimization (differently from the current state of the art) has been intensified with respect to the previous year. More advanced algorithms to integrated simulation-optimization models have been developed. These algorithms are based on decomposition techniques and they have been studied for the buffer allocation [L3] and the server allocation [L4] problems.

The impact of additive manufacturing on inventories has also been investigated, to understand how these new technologies will prospectively change the structure of supply chains. Preliminary results show that the effectiveness of additive on inventory cost reduction depends on the relationship between additive manufacturing and conventional manufacturing processing and setup times [L5].

Eco-Industrial Parks (EIPs) have been investigated, as they are one of the means to achieve a sustainable development that takes into account both economic gain and environmental aspects. Many contaminations appeared in the literature between eco-industrial parks and supply chains, in the framework of circular economy. The research of the group investigated new factors that can be used for the design of EIPs and their Industrial Symbioses to improve environmental and economic performance of the firms. Specifically, MILP (Mixed-Integer Linear Programming) models have been developed to this purpose [L6].

For the next year, the research activity will continue investigating algorithms to efficiently and effectively solve large simulation-optimization MILP models and other complex production planning problems. Techniques to automatically update digital twins, to guarantee a continuous alignment between production system models and real systems, will also be studied.

About the research on EIPs, the objective for the next year will be twofold: (1) to design solution algorithms for the proposed MILP models; (2) to design a case study to test the proposed models and algorithms.

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1.3 Economic and Legal Perspective

M - Economic perspective

During the second year of the project, the research has been directed to the study of the economic implications of new digital technologies (in particular, the development of artificial intelligence, the deployment of ultra-fast broadband connections, the advance of Industry 4.0, big data, and additive manufacturing) along four main directions: (1) the macroeconomic implications of digital technologies on economic growth and labor market outcomes; (2) the microeconomic effects of new technologies on firms, markets and human behavior and the potential policy interventions to sustain investment and drive social changes; (3) the implications of new digital technologies on consumers' privacy, an issue exacerbated by the possible present-bias of users of these technologies, and on firms' adoption of Industry 4.0 (in general, and lean technologies in particular) paradigm; (4) Additive Manufacturing (AM), notably the constraint faced by firms in adopting the new technology and the effects of the adoption on firm performance.

1) As for the first area, a book offering an analysis of the development of a capitalist economy, in which technological innovation is its main determinant, has been written [M1]. The main goal is to examine the possible future evolution consequent to the dissemination of new information and communication technologies (ICT), including recent developments in artificial intelligence (AI) and robotics. The adopted method of analysis is that of the general equilibrium of the economic system. The models have their roots in the classic economics of Smith, Ricardo and Marx and employ the medium-long term input-output schemes of Leontief and Sraffa.

2) As for the microeconomic effects of new technologies on firms, markets and human behavior and the potential policy interventions to sustain investment and drive social changes, several outcomes have been prepared.

The first one is a comprehensive survey of the growing literature on Artificial Intelligence, and of its implications on markets and society [M2], with a focus on the role of intelligent machines and algorithms on economic growth, employment, firms' organization and consumers' behavior, evidencing the main policy implications. A second survey [M3] is on the impact of ultra-fast (fiber based) broadband technologies on growth, unemployment, firm creation and the interplay of those investment with policy interventions by Policymakers (national regulators and the Government). The paper is based on a keynote speech held by

Carlo Cambini at the *European International Telecommunication Society* – Trento (Italy), August 2018. Furthermore, the policy intervention in terms of access prices or joint-ventures to sustain investment on fiber technologies has been analyzed (M4 and M5), by using a game theoretic model of coverage and incorporate the new legal prescriptions defined in the recent European Electronic Communication Code (Directive n. 2018/1972). In the first paper the Authors investigate on how to modify access regulation to support new infrastructure investment in presence of demand uncertainty, while in the second one the role of joint-ventures (or co-investment) could help to expand network coverage that is currently consider the main policy target at European Union. Contributions M6 and M7 are based on an original dataset on ultra-fast broadband deployment in Italy for the period 2013-2018 at municipal level provided within a joint project with Telecom Italia Lab, the research center of Telecom Italia Mobile (TIM Spa). In the first paper, by complementing the data with local data on firms provided by local Chambers of Commerce, the authors study how the new fiber based infrastructure affect the establishment of local firms and its heterogeneous effects over industry, sectors, and geographical location. In the second one, using data provided by the Ministry of Education (MIUR) on INVALSI Test, the Authors study how the use of new digital connections affect reading and math proficiency of primary school students, by focusing on the Generation Z, i.e. the cohort of children that use digital technology since a young age and are comfortable with the Internet and social media. Finally, the relationship between investment in 4IR technologies and firm-level performance (labour productivity, total factor productivity and accounting profitability) has been analyzed (M8) by using a panel of 1,396 large and medium-sized OECD firms (2009-2014) which have filed patents in the 4IR domain at the EPO in the period 1985-2014. The paper finds a positive association between the stock of 4IR patents and firm-level performance, but not profitability. The effect is stronger in companies investing in 4IR technologies after the mid-2000s, in companies that have shown less continuity in patenting and in firms whose patents combine different technological domains associated with 4IR and have a stronger content of downstream applicability, hence closer to the market.

3) As for the implications of new digital technologies on consumers' privacy, the potential effects of regulation over the use of data by a monopolistic platform has been analyzed by means of a theoretical model (M9). The model assumes that platform's profit mainly originates from the sale of data that users freely and excessively provide due to their myopia on costs related to the loss of privacy. The paper studies which policy intervention may be

useful to restore social welfare by contracting over the quantity of data released to advertisers. However, in the presence of myopic users, optimal regulation entails a larger production of data by users with a high present-bias. On this topic, we recall, the economic research group organized – together with the Law research group – a workshop at the Politecnico on December 13th, 2018, entitled "Dati, Mercato e Tecnologie nell'era dell'Artifical Intelligence" with policy makers (members of the privacy, communications and transport national authorities) and academics.

4) As for AM, the survey on the adoption of the new technology in the Italian orthopaedic prostheses industry has been extended, leading to the result that AM technology adoption leads to an improvement of performances in the medium but not in the short run (M10). This result can be explained in the light of the very specific skills required to use AM technologies, so that adopters need time to efficiently use the new equipment. Furthermore, a new survey on AM adoption by dental offices. By using a sample of dentists in the Torino area, a deep knowledge of the advantages of the new technology has emerged. However, the adoption is still scant, mostly due to the high cost of intra-oral scanners, necessary to perform 3D printing and whose industry is characterized by low competitive level (M11).

References

[M1] Ravazzi P., Abrardi L. "Crescita economica e prospettive del capitalismo. Gli effetti delle tecnologie digitali", Carocci ed., 2019;

[M2] Abrardi L., Cambini C., Rondi L. "Artificial Intelligence, Firms and Consumer Behavior: a Survey", 2019, submitted;

[M3] Abrardi L., Cambini C. "Ultra-Fast Broadband Investment and Adoption: A survey", Telecommunications Policy, 43(3), 183-198, 2019

[M4] Bourreau M., Cambini C., Hoernig S., Volgelsang I. "Fiber Investment and Access under Uncertainty: Long-Term Contracts, Risk Premia, and Access Options", 2019a, submitted;

[M5] Bourreau M., Cambini C., Hoernig S., Volgelsang I. "Co-investment, Uncertainty, and Opportunism: Ex-Ante and Ex-Post Remedies" 2019b, submitted;

[M6] Cambini C., Sabatino L. "Fast Internet and Firm Creation: Evidence from Italy", 2019, mimeo;

[M7] Cambini C., Sabatino L., Zaccagni S., "Friend or Foe? The Effect of Super Fast Broadband on Student Performance", 2019, mimeo;

[M8] Benassi M., Grinza E., Rentocchini F., Rondi L., "Going Revolutionary: The Impact of 4IR Technology Development on Firm Performance", 2019, mimeo;

[M9] Abrardi L., Cambini C. "Carpe data: Regulating the market of personal information with present-biased users", 2019, mimeo;

[M10] Benfratello L., Serio F. "AM adoption in the Italian orthopaedic prostheses industry and its effect on firm performance and employment", 2019, mimeo;

[M11] Benfratello L., Conte S., "Additive Manufacturing adoption in Dental Practices: state of the art and future perspectives", 2019, mimeo;

N - Legal perspective

Following the main guidelines of this project related to data-driven society and the new era of machines, during the second year, legal research focused mainly on AI, including artificial intelligence-based services for IoT devices, and 3D printing.

In the field of AI and IoT, our research benefited from the synergy with H2020 Virt-EU project (2016-19), whose legal unit is led by the Politecnico and coordinated by Prof. Mantelero.

In this context, the research in the second year of this project focused on four main areas: (1) impact assessment for large-scale data intensive systems, (2) AI regulation, (3) data ethics, (4) 3D printing and Roboadvisory.

N_1 - Impact assessment for large-scale data-intensive systems

Prof. Mantelero and Dr. Esposito have conducted background research and developed an initial prototype of a new model of impact assessment to include human rights, ethical and social issues in the design of IoT devices and AI services (see [N1, N2, N3]). This model represented a novel approach in dealing with data and technology devices, as existing experience and legal requirements focused primarily on data protection issues.

The results of this research were presented at the following international conferences:

- [Belgium] CPDP2019 Computers, Privacy and Data Protection conference, January, 30, 2019, conference panel organised by Politecnico di Torino on "Values and Ethics in Innovation for Responsible Technology in Europe" (Chair: Eleni Kosta, Tilburg Institute for Law; Moderator: Alessandro Mantelero, POLITO; Speakers: Irina Shklovski – ITU, Alison Powell, LSE, Christian D'Cunha, European Data Protection Supervisor, Javier Ruiz Diaz – ORG, Annelie Berner - CIID)
- [Switzerland] Expert workshop on the right to privacy in the digital age
  OHCHR, International expert workshop, Geneva, United Nations, February 19-20, 2018
  Presentation: Mantelero. New and emerging issues: The collective dimension of data protection and the tools to safeguard it (Privacy, Ethical and Social Impact Assessment)

- [Italy] L'entrata in vigore del Regolamento (UE) 2016/679: la riforma alla prova della prassi in Italia e in Spagna, International conference, University of Pisa, Pisa, June 8-9, 2018.

  Presentation: Esposito. L'impatto del trattamento su diritti e libertà alla luce della giurisprudenza delle autorità garanti italiana e spagnola
- [Austria] The 13th International IFIP Summer School on Privacy and Identity Management – Fairness, accountability and transparency in the age of big data, 20-24 August 2018, AIT Austrian Institute of Technology, Vienna, Austria (summer school co-sponsored by Virt-EU).

  Presentation: Mantelero. Risk assessment in personal data processing: from DPIA to a broader perspective

References

[N1] Mantelero, A., Big Data and Data Protection. In González Fuster, G., Rosamunde Van Brakel, R., De Hert, P., eds). Privacy and Data Protection Law: Values, Norms and Global Politics, Edward Elgar Publishing, scheduled early 2020)

[N2] Mantelero, A. 2019. La privacy all'epoca dei Big Data. In Cuffaro, V., D'orazio, R., Ricciuto, V., eds). I dati personali nel diritto europeo. (Torino: Giappichelli, 2019) [ISBN/EAN 978-88-921-1274-2]

[N3] Mantelero, A., Esposito. M.S. From the Council of Europe's Guidelines to an Evidence-based Human Rights Impact Assessment tool: The European Way to AI (forthcoming, 2020)

N_2 - AI regulation

The ongoing research on AI regulation concerns the future scenario of an international human rights-based AI regulation [N4]. This research has been conducted by Prof. Mantelero and is also related to his appointment as the scientific expert on AI and data protection of the Council of Europe.

In addition, in 2019, the Politecnico di Torino held a series of conferences on "Technology, regulation and society: a series of lectures on AI (scientific coordinator: Prof. Mantelero) with national and international speakers, including policy makers, regulators, corporations, academics and experts:

- December 13 – Data, Market and Technology in the AI Era

  Alessandra Pierucci| Council of Europe

  Francesco Pizzetti| LUISS Guido Carli, Former Head of the Italian Data Protection Authority

Antonio Nicita| Autorità per le Garanzie nelle Comunicazioni
Andrea Camanzi| Autorità di Regolazione dei Trasporti

- February 21 – IoT / Innovation: Data ethics, regulation and responsible design
  Irina Shklovski| IT University of Copenhagen
  Andrea Di Salvo | Politecnico di Torino
  Ruggero Castagnola | Accurat
  Alison Powell| London School of Economics and Political Science
  Matteo Magnani | Uppsala University
  Luca Rossi | IT University Copenhagen
  Silvia Chiusano | SmartData@PoliTO Center
  Alessandro Mantelero | Politecnico di Torino
  Javier Ruiz | Open Rights Group

- May 13 – Algorithms and Business Automation
  Anna Colaps | European Data Protection Supervisor
  Sara Agnello| Legal Counsel FCA
  Stefano Leucci| Data Protection Officer FCA Bank

Conference presentations:

- [Italy] Italian Data Protection Authority – EU REC-DATA-2016 T4Data Project, International conference "Rising to the Challenge: A Look at Data Protection and Beyond", Roma, November 15, 2019
  Presentation (invited speaker): Mantelero. Artificial Intelligence: Challenges, Uncertainties, and Possible Remedies

- [Belgium] Celebratory conference - 30 years CiTiP (CIR/ICRI), KU Leuven, Leuven, October 4, 2019
  Presentation (invited speaker): Mantelero. Regulating AI: The Council of Europe's Guidelines on Artificial Intelligence and Data Protection

- [Italy] European Union Agency for Cybersecurity Annual Privacy Forum 2019, Rome, June 13-14, 2019

Presentation (invited speaker): Mantelero. Artificial intelligence and inferred identities: Towards a New Paradigm

- [Northern Ireland] British and Irish Law Education and Technology Association Annual Conference, Queen's University, Belfast, April 16-17, 2019
  Presentation: Mantelero. Regulating data processing in the Age of AI

References

[N4] Mantelero, A. 2019. Artificial Intelligence and Data Protection: Challenges and Possible Remedies. Council of Europe, Directorate General of Human Rights and Rule of Law. Strasbourg.

N_3 - Data ethics

This is the most interdisciplinary field among those investigated in 2019. Our research has focused on the values that underpin legal decisions, in the field of data-intensive products/services, to identify the ethical and social values that should be boost the so-called Forth Industrial Revolution.

This research has better defined the boundaries of the legal, ethical and social values and the understanding of the existing relationship between these different realms. As recently demonstrated in the ongoing debate on AI and ethics, there is a certain degree of confusion and overlap between ethical and legal guidance in the regulatory debate [N5]. In this context, the analysis carried out by Prof. Mantelero and Dr. Esposito has contributed to identifying the different issues and values concerning both law and ethics, without confusing these realms.

Conference presentations:

- [Finland] MyData 2019 Conference, Helsinki, September 25-27, 2019
  Presentation (invited speaker): Mantelero. Regulating AI: Law & Ethics
- [Northern Ireland] British and Irish Law Education and Technology Association Annual Conference, Queen's University, Belfast, April 16-17, 2019
  Presentation: Esposito. Human rights and technology development in the jurisprudence of data protection authorities

References

[N5] Mantelero, A. 2018. Ciudadanía y gobernanza digital entre política, ética y derecho. In: Quadra Salcedo T. Piñar Mañas J. L. Sociedad Digital y Derecho. vol. Sociedad Digital y Derecho, Boletín Oficial del Estado, ISBN: 978-84-340-2483-0

N_4 - 3D Printing and Roboadvisory

3D printing and intellectual property rights (IPRs) with a view to analyze the impact of self-production on the existing legal framework, especially on the EU-copyright law. Different elements of the 3D printing process may form a point at which copyright subsistence occurs: the code of the 3D printing design file; the design contained within the file and the physical object to be printed. Despite harmonizing measures, there are still many divergences in different European jurisdictions; and only under Italian IP law the CAD file may be protected as «*progetto di lavoro dell'ingegneria*» (see [N6, N7, N8). The research carried out by Dr. Rivaro also benefitted from the synergy with the ongoing VAMP (Valutazione multidisciplinare delle performance tecnologiche e di sostenibilità di differenti sistemi di fabbricazione Additiva per la realizzazione di componenti in materiali Metallici e Polimerici) project, directed by Paolo Priarone.

Analysis of robo-advisory and regulatory implications: recent technological evolutions are radically reshaping investment consultancy services globally, towards a growing degree of automatization. The research conducted by Prof. Rainelli aims at providing an overview of the overall risks and benefits linked to the use of artificial intelligence in financial advice and the regulatory implications of such transformation (in cooperation with domestic and international regulators).

Conference presentations:

- [Italy] X Convegno nazionale dell'Associazione italiana dei professori universitari di diritto commerciale "Orizzonti del diritto commerciale", L'evoluzione tecnologica e il diritto commerciale, Roma, February 22-23, 2019
  Presentation: Rivaro. Field: 3D printing and intellectual property rights

- [Italy] Seminar with Commissione Nazionale per le Società e la Borsa (CONSOB) – Automated Financial Consulting or robo-advice (la consulenza finanziaria automatizzata o «robo-advice»), Roma, December 12, 2019
  Speaker-coordinator Paolo Rainelli

References

[N6] Rivaro, R. 2019. Stampa tridimensionale e diritti di proprietà intellettuale. Riflessioni sulla proteggibilità del disegno CAD 3D. Riv. dir. ind., 226 – 252.

[N7] Rivaro, R. Analysis of the impact of 3D-printing on EU and Italian patent, design and trademarks law (forthcoming).

[N8] Rivaro, R. Monitoring of developments on the automated consulting and ongoing dialogue with regulators in the context of consultations/hearings (forthcoming)

1.4 Achievements

- The paper “A. Cestana, E. Pastore, A. Alfieri, A. Matta. Reducing Resupply Time with Additive Manufacturing in Spare Part Supply Chain. Proceedings of the 9th IFAC Conference on Manufacturing Modelling, Management and Control (MIM 2019), Berlin, Germany, 2019. IFAC PapersOnLine 52-13 (2019) 577–582” was one of the 21 recipients of the Commended Paper Award from the IFAC MIM 2019 conference.
- The work “Multi-sensor data fusion for the characterisation of laser cladded cermet coatings” by Giacomo Maculotti, Nicola Senin, Olusola Oyelola, Maurizio Galetto, Adam Clare and Richard Leach, presented at the 19th International conference of the European society for precision engineering and nanotechnology (EUSPEN) in Bilbao in June 2019. The paper was awarded with an Oral session Keynote presentation (the speaker was Giacomo Maculotti) and allowed Giacomo Maculotti to be awarded with the Heidenhain Scholarship Award 2019.
- In February 2019, with his "Make your toothbrush real!" project, Prof. Paolo Minetola obtained the third place in the "Make it Real" challenge promoted by the Stratasys company in collaboration with the GrabCAD platform (https://grabcad.com/challenges/make-it-real). The competition required to design and present a product that could be reproduced with high realism and fidelity using a Stratasys J750 industrial 3D printer. The challenge required to exploit the potential of the Stratasys J750 system by combining several materials with variable shore values, textures, transparency, and/or full-vivid colors to enable realism in a single print. Minetola's project was selected from over two hundred projects by a jury made up of four experts with the following motivation: "his model exploits the ability of the J750 system to make some parts rigid, while others are soft and flexible" (https://grabcad.com/challenges/make-it-real/results).
- F. Della Croce has been keynote speaker at ICORES2019, the 8th International Conference on Operations Research and Enterprise Systems that took place in Prague, Czech Republic, on February 19-21, 2019.
- F. Della Croce has been plenary speaker at ISS2019, International Symposium on Scheduling that took place in Matsue, Japan, on July 5-7, 2019.

1.5 Further dissemination

The foreseen so-called DIGEP lunch seminars took place in 2019.

14-2-2019
X. Shi
The Placement Design of New Street Furniture Based on Behavior-environment Studies: the Case of Turin

21-3-2019
G. Maculotti
Comparison of standard and unconventional methods for form characterisation of technological surfaces

30-10-2019
N. Dagnes
3D Human Face Analysis for recognition applications and motion capture

27-11-2019
E. Blanco
Models to support Operational Excellence in project management and assembly Process design.

2 Update on project budget at December 2019

The Table below sketches in a nutshell the actual expenses and related 2018-2019 budget compared to the planned ones.

PLANNED VS ACTUAL BUDGET 2018-2019

Relevant entry	**Planned 2018-2019 costs/grants/positions**	**Actual 2018-2019 costs/grants/positions**
Equipment and infrastructures	**1500 Keuros** (total of 2875 KEuros)	**670 KEuros**
Acquisition of Associate and Assistant professors	**4 Associate Professor positions** (total of 4 in the project) **2 RTD-B positions** (total of 2 in the project) **4 RTD-A positions** (total of 8 in the project) 1 Technologist position (total of 1 in the project)	**4 Associate Professor positions** (Mantelero, Montagna, Russo Spena, Salmi) **2 RTD-B positions** (Calignano. Salassa) **1 RTD-A position** (Grinza)
Post-doc fellowships	**6 fellowships** (total of 12 in the project)	**7 fellowships** (Altavilla, Battaglia, Nebbia, Pastore, Pesce, Sabatino, Zenezini)
PhD fellowships	**3 fellowships** (total of 6 in the project)	**6 fellowships** (Catalano, D'Amico, Faveto, Fontana, Gervasi, Nonnis) (1 additional foreseen in 2020)
Visiting professors	**3 Visiting Professor positions** (total of 6 in the project)	**1 Visiting Professor position** (T'kindt)

As we can see, the total expenses in equipment and infrastructures is well below planning due to the unforeseen circumstances mentioned above. The foreseen associate professor positions and RTD-B positions have all been filled, while only 1 RTD-A position has been filled. We expect to fill most of the remaining RTD-A positions in 2020 (each RTD-A position has a duration of 3 years). As for the post-doc fellowships, we are slightly overbudget having assigned 7 postdoc fellowships instead of 6, but we will need simply to be under planning in the period 2020-2022. As for the PhD fellowships, we decided to anticipate them (6 fellowships instead of 3) so that all PhD fellowships (expected duration 3 years) could indeed end their activity within the end of year 2022. Besides, a last additional fellowship is expected to be assigned in 2020 using some available extrafunding from other entries. Indeed,

as the number of visiting professors is currently under budget, this is one of the possible entry to be adjusted correspondingly. Overall, apart from the entry related to equipment and infrastructures whose under expenditure is justified by unforeseen circumstances, the actual budget is reasonably in line with the planned one.

3 Activity for the incoming year 2020

With respect to the Technological Perspective, in addition to what has already indicated above, a significant portion of the activities planned for the year 2020 will be focused on the acquisition and implementation of instrumentation and the refurbishment of laboratory infrastructures. These preparatory activities will make possible future experimental activities of various kinds, both within and outside the project of interest.

Below are some of the most relevant activities for the immediate future:

- With reference to *3D modelling and simulation*, it will be started setting up the new "light" laboratory at the "Palazzina Corso Trento 21" and preparing the experimental activities, using the new equipment.
- With reference to *Collaborative robots*, it is planned to complete some purchases (still in progress) and to prepare some preliminary experimental activities, inside the "Fabbricato Area Sud - Part 1".
- With reference to *Factory logistics*, the research will focus on the identification of the most critical aspects of the material-handling and production, with and without the use of automatic and/or interfaced systems.
- With reference to *Quality and measurements*, an air-conditioned metrology cabin, of about 50 m^2, will be built. This new facility will accommodate multiple high-precision measuring instruments, such as Coordinate Measuring Machines (CMMs) or latest-generation micro/nano-indentation machines. These instruments in fact need to work under strictly controlled temperature and humidity conditions, so as to guarantee high levels of precision/accuracy of measurement.

Within the Management Perspective, on the trajectory related to the linkages between industry performance and investments in information systems and digitalization, future research will tackle the question whether investments lead to wage compression. This question assumes interest in the moment current research conducted in the project has shown that investments in information systems had led to a reduction in employment. Moreover, this question assumes interest due to the general debate on whether and how technological change is complementary or replace labour. This interest paves the way for research that uses a qualitative approach to explore how the digitalization brought by IoT, big data and other

technologies affects the demand of labour for middle skills job position. The extension of the research made in collaboration with ENEL will allow to explore such relationship.
Research on Industry 4.0 in SMEs will follow a qualitative approach and will tackle the issue of exploring the extent to which certain operational and knowledge-intensive processes like manufacturing and new product engineering are codifiable in software and into approaches and tools like digital twins. This research assumes interest given the fact that operational processes and customer relationships entail a high degree of tacit and idiosyncratic knowledge that can be hardly codified.
Research on cultural heritage will follow the trajectory of a qualitative and observational research and will analyse the co-evolution between strategy and organizational design in the Van Gogh Museum. Extension to other cases can be considered in order to have theoretical replicability.
For the algorithmic point of view, we plan to prosecute the activity 2019 and focus on further bilevel optimization problems to cope with and to study the integration of machine learning technologies into optimization methods for machine scheduling and resource allocation problems. Also, we expect to further enforce the interaction between the research groups working on themes I (Algorithms and their influence on decision making processes) and L (Algorithms for complex production systems and supply chain)..

With respect to the Economic and Legal Perspectives, the aim is to further analyze some of the topics studied during the first two years and start analysing a couple of new ones.
As for ultra-fast broadband deployment, the two ongoing analyses will be hopefully concluded. Likewise, the analysis of the effects on AM adoption in the orthopaedic prostheses industry will be concluded whereas the study on the adoption in the Dental industry will be extended by using a much larger sample.
Two additional topics which will be addressed are the effect of Industry 4.0 technologies on firm location choices, in order to assess whether these technologies induce the so-called back-shoring phenomenon as alleged by recent governmental programs and the study of how big data affect market competition,
On the legal perspective, the most relevant activities foreseen for the year 2020 are the following

- Analysis of national and international soft law and hard law instruments on AI regulation, focusing on their potential impact on the development of AI and its industrial application.

- Further development of the ongoing research in the field of data ethics and its interplay with private law in the field of data-intensive products/services and AI-based machines.
- Analysis of the impact of 3D-printing on EU and Italian patent, design and trademarks law.
- Monitoring of developments on the automated consulting and ongoing dialogue with regulators in the context of consultations/hearings.