Doctoral School in Materials, Mechatronics and Systems Engineering

Research subjects proposed for the 40th cycle – first call

A mandatory attachment of the application is **a description of the research project (**max. 4 pages**).**
The research project proposal must contain: i) a title, ii) an introduction to the problem with reference to the state of the art, iii) a clear description of the aim and the content of the research, iv) an estimation of the time sequence of the intended activities, v) literature references.

The project's topic must be included within the Doctorate's fields of interest, **preferably** on one of the following research subjects. **Important!** The candidate's choice to compete also for the reserved scholarships implies a preference on his/her part for the awarding of that specific scholarship over the free ones.

Suggested research topics for free scholarships, funded by UNITN:

Title: Development of design methods for compensating sintering deformation in Metal Binder Jetting additive manufacturing
Reference persons: I. Cristofolini, M. Zago

Metal Binder jetting (MBJ) is an additive manufacturing technology with strong potential for manufacturing small-medium batches in different fields – consumer goods, medical, automotive, aviation, and aerospace. However, its widespread adoption is currently limited by the challenge of controlling product accuracy during sintering. Anisotropic shrinkage and shape distortion negatively affect product quality, and they cannot be avoided by tuning the process parameters. To overcome these issues, robust compensation strategies are required to redesign the printed geometries. Products reshaping is enabled by the free-form design of additive manufacturing processes. However, the effectiveness of the compensation is strictly related to the accurate prediction of shape changes during sintering.
This research project focuses on the experimental and numerical investigation of the dimensional change during sintering of MBJ products. The project aims to develop models capable of predicting the sintering deformation. Skorokhod and Olevsky's viscous sintering model will be adopted. Additionally, the model will be modified to consider anisotropic shrinkage. The origin of anisotropy will also be investigated in correlation to printing parameters, microstructure, and sintering mechanisms. Furthermore, FEM simulations will be compared with the sintered products to validate the modelling procedure.
The candidates must be highly motivated, have an aptitude for teamwork, and be ready to learn simulation and conduct experimental activities. A background in product design, finite element modeling, and physical metallurgy is strongly recommended, though not strictly required.

Title: Development of advanced 3D silicon radiation detectors
Reference person: G.-F. Dalla Betta

This activity aims at developing novel radiation sensors with three-dimensional electrodes (either columnar- or trench-shaped) deep etched within the silicon substrate to offer outstanding features in terms of radiation tolerance and high speed at low power consumption. Several INFN and EU funded projects are presently running in Trento on this topic, mainly aimed at High Energy Physics applications (e.g., the upgrades of ATLAS, CMS and LHCb experiments at LHC). The PhD research program, to be carried out within the framework of these projects, will be focused on the design, TCAD simulation, and experimental characterization of prototypes, both in laboratory and in beam tests also in collaboration with Italian and foreign research partner institutions.

Title: Measurement and monitoring systems for smart grids
Reference persons: D. Macii, D. Petri

The research activity aims at developing and implementing high-accuracy measurement technques to improve observability, efficiency and resilence of smart distribution systems and smart grids in general. Depending on the Ph.D. candidate's personal interests and educational background, the research work can be focused either on the study of digital signal processing techniques to be implemented on a stand-alone measurement instrument (e.g., Phasor Measurement Units or the emerging Synchronous Waveform Measurement Units), or on novel data fusion algorithms conceived to process as well as to extract useful information from multi-rate and heterogenous measurement data collected over a geographic area. In the former case, special attention shall be devoted to the integration of the propsoed measurement technique into equipment already deployed on the grid, such as the smart power converters commonly connected with PV generators or battery energy storage systems. In the latter case, the use of single-objective or multi-objective optimization techniques is envisioned to find a suitable trade-off between metrological needs and cost requirements.

Title: Innovative logistics and operations for fair and sustainable e-commerce optimization
Reference persons: F. Pilati, M. Brunelli

The e-commerce sector is experiencing a remarkable increase in volume and revenues in the last decades. It has been typically distinguished by strong pressure to reduce costs and increase efficiency as much as possible. Moreover, the common business model proposes very short lead times for order delivery ensuring remarkable service level at low cost for the end customer. These features were enabled stressing the effort of human operators through the entire supply chain, e.g. storing, shipping and delivery, at both warehousing and last mile delivery level. Moreover, the environmental impact of the aforementioned activities was completely not considered, nor assessed.
The latest trend in e-commerce is twofold. From one side novel models and applications arises, at both customer experience and processes levels. Instant grocery delivery, clothes short term rental, super low-cost products shipped from the far east, etc. On the other side novel technologies can be employed to increase the efficiency and sustainability of these processes. Cobot in warehousing for picking activities, automation for product sorting, automated guided vehicle for last mile delivery, drone for parcel distribution, wearable devices and augmented reality for human operators. Secondly, cultural, social and political pressure is put on e-commerce companies to reduce their carbon footprint, safeguard the operator's health and improve their working conditions, all together.
This PhD thesis aim is to develop original and breakthrough optimization models and algorithms to tackle the aforementioned problems in an original way. Multi-objective optimization should contribute to simultaneously tackle multiple KPI, while metaheuristics can provide efficient solution in a limited amount of computational time. Mathematical modelling of the problems tackled will be core, since most of the latest advancement in the sector are driven by private company with no assessment nor evaluation of optimizing alternative solutions compared to the one adopted. Applications to real problems is ensured thanks to collaboration of the research group with them, along with involvement of international research centers for cooperation and improvement considering the latest research advancement.

Title: An LLM-based approach for the analysis and design of business processes
Reference persons: L. Mich, M. Missikoff

The overall objective of this research project is to develop methods and tools supporting the analysis and design of business processes (BP) by using an approach based on LLM. LLMs represent an emerging technology extremely powerful in processing natural language texts and extracting the knowledge represented therein.
The business process analyst typically starts by creating an initial document describing the operational context of the BP and how it takes place in that context. The document is created by interviewing the stakeholders, observing the reality, collecting all the relevant documents, together with the explicit rules and constraints that regulate the actual execution of the BP.

We expect that if we provide the BP analysis report to an LLM, it will be able to ingest the text, extract the relevant knowledge and support the analyst in the subsequent phases of BP design. In particular, we expect that a generative AI system will be able to provide substantial support in extracting the description of the tasks that make up the BP and in producing the workflow diagram of the process.
To accomplish the research objectives, the activities will start with a comparative study of the most advanced LLM systems, such as ChatGPT, Gemini, Claude. Then, a BP analysis method will be selected, and a real-world case study will be identified to start a series of tests.
The expected outcomes of the research will be in the field of Prompt Design and Engineering, an emerging field aimed at supporting the interaction with LLMs to obtain the best results from them. Therefore, we expect that the project will produce a Prompt Engineering method, together with a set of Prompt templates, to be used in the analysis and design of business processes.

Scholarships on reserved topics:

Title: A - Estimation and Control Algorithms for Robots in Shared Environments
Reference person: D. Fontanelli
Funded by: Department of Industrial Engineering, project UE HE MAGICIAN, G.A. n. 101120731, CUP E63C23000730006

The project aims to develop motion control techniques for fixed-base and mobile robotic manipulators for safe interaction and collaboration between robots and humans. The research is inspired by the MAGICIAN project, which involves the presence of humans and robots in the same workspace and their cooperative tasks. In the initial phase, the research will focus on implementing techniques for perceiving the working environment, including humans and their movements in the workspace, using learning and estimation techniques. By leveraging state-of-the-art techniques, desired trajectories will be synthesized using learned predictive models. These trajectories will then be executed on the robot using inherently safe closed-loop control algorithms, such as "energy tank control" or "safe reinforcement learning." The research will thus produce innovative and flexible techniques for the safe application of robots in shared environments that will be applicable well beyond the MAGICIAN project case studies and integrable into the Industry 5.0 paradigm.

Title: B - Active Sensing Algorithms for Collaborative Robots
Reference person: D. Fontanelli
Funded by: UNITN and Department of Industrial Engineering, project UE HE MAGICIAN, G.A. n. 101120731, CUP E63C23000730006

The research objective is primarily aligned with the goals of the EU-funded MAGICIAN project, which aims to develop new solutions with collaborative robots for Industry 5.0. The study aims to conceive active sensing algorithms for the control and trajectory planning of robotic manipulators capable of using sensor measurements to enhance the understanding of objects to be manipulated and their imperfections in an industrial context. The fusion of classical estimation techniques with artificial intelligence-based machine learning algorithms, as well as closed-loop fusion with techniques based on the quality and quantity of collected information (such as barrier functions), will enable the synthesis of flexible and scalable solutions applicable to various contexts, beyond the limits defined by the MAGICIAN project.

Title: C - Numerically efficient reinforcement learning
Reference persons: A. Del Prete, N. Mansard (LAAS-CNRS)
Funded by: UNITN and Department of Industrial Engineering, project UE HE INVERSE, G.A. n. 101136067, CUP E63C23001600006

The project is aimed at working on "Numerically Efficient Reinforcement Learning", with a focus on robotic applications. Reinforcement Learning and Model Predictive Control can both be cast as solutions of an optimal control problem. Despite impressive demonstrations, however, these methods have yet to be fully realized in real-world settings, and scaling beyond the lab is still a challenge. The objective of this project is to study the

algorithmic foundations of these methods to unlock the full potential of constrained optimization and reinforcement learning to train safe, effective policies for dynamic locomotion and manipulation tasks. Our aim is to achieve faster, more accurate convergence, reducing the computational burden and providing strict guarantees on the resulting optimal policy.
The activity will be carried out in collaboration with LAAS-CNRS (Toulouse, France), in the Gepetto team, where the student is expected to spend at least 1 year. Prospective candidates should preferably have a M.Sc. degree in Computer Science or Applied Mathematics. Strong knowledge of mathematics, control theory, robotics or computer vision is desirable.Computer programming, mainly Python, but knowledge of C++ is a plus. Prior courses, knowledge, or practical interest in robotics, machine learning, or numerical optimization is a plus.

Title: D - RESilient hybrid microgrids enabled by COordinated Power Electronic hubs for the GREEN Revolution (RESCOPE4GREEN)
Reference person: E. Tedeschi
Funded by: UNITN and Department of Industrial Engineering, project PNRR M4C2 I1.1 MUR PRIN 2022, Prot. n. P2022W4HFX, CUP E53D23014790001

The focus of the PhD project is the Coordination of Power Electronics Energy Hubs (PE2H) to provide grid services in smart grids. Specifically, the PhD candidate will aim at the coordinated management of various PE2H based on power electronic converters to be connected to traditional three-phase alternating current (ac) networks to allow the interfacing of multiple renewable energy and energy storage systems, electric vehicles and flexible loads, without compromising the stability of the electricity grid and ensuring a more efficient and optimized operation of the power system.
The project will first investigate the capabilities and performance of a single PE2H of appropriate topology in providing ancillary services to the upstream ac network and, possibly, in facilitating the interfacing with portions of direct current (dc) networks. Then, it will focus on the coordination of multiple PE2H to provide, in a coordinated and optimized manner, such support functions to the grid, in order to maintain/increase grid stability margins, reduce losses, improve power quality, and maximize the exploitation of distributed energy resources thereby connected.

Title: E - 3D vision aided Robotic device
Reference person: M. De Cecco
Funded by: UNITN and Robosense

3D vision is a key enabling technology that is revolutionizing different fields ranging from industry to clinics. In industry, just to cite a few examples, automated diagnostics, objects localization for robotics path planning, autonomous driving; in clinics smart robotic devices able to train and enable impaired users' mobility.
The PhD work shall identify a relevant 3D infrastructure (ToF cameras or LIDARS) comprising sensor and elaboration unit (PC or GPU) then focus on the current state of the art in 3D vision, in order to develop and apply such configuration to industrial and/or clinical robotic scenarios. On this ground, the research shall focus on algorithms, measurement techniques and technologies to develop and test in relevant scenarios a robotic prototype.

Title: F - Chipless RFID sensors for ionizing radiation
Reference persons: A. Quaranta, V. Mulloni (FBK)
Funded by: Fondazione Bruno Kessler

The development of low-cost, efficient, printable RFID sensors is a fundamental research domain for Internet of Things (IoT). Chipless RFIDs are a new and emerging technology that removes the silicon chip from the sensor tag, including both the identification and the sensing function in the tag design. A chipless sensor is basically made by one or more RF resonant structures, whose frequency is dependent on the dielectric material covering the metallic resonator.
This PhD position is about the study of chipless RFID technology for the sensing of ionizing radiation. The study will have different combined approaches:
-At material level: study and identify the best polymer formulation for maximising the sensitivity to different types of radiation (x-rays, g-rays)
-At device level: build a sensor prototype with the most promising covering material, for both high-dose and low-dose irradiation. Evaluate its performances, with radiation test and RF measurements, establishing also the suitability for wireless detection.
The work will be in collaboration between DII-Unitn and FBK, with irradiation tests performed at TIFPA or in other Italian INFN labs.

Title: G - Advancing Open-Source Robotics for Cost-Effective Agricultural Digital Twins
Reference persons: D. Fontanelli, M. Vecchio (FBK)
Funded by: Fondazione Bruno Kessler

This scholarship aims to pioneer the development of open-source robotics to create cost-effective agricultural digital twins, bridging the gap between digital and physical farming systems. By leveraging the versatility and accessibility of open-source platforms, it will focus on designing, developing, and implementing robotic systems capable of accurately simulating agricultural environments. These digital twins will enable farmers to predict crop outcomes, optimize resource allocation, and mitigate risks by providing a virtual representation of their fields, thus facilitating informed decision-making processes. Key objectives include the development of scalable and modular robotic platforms that can be customized to suit diverse agricultural needs, the integration of advanced sensors and AI algorithms for real-time data processing and simulation, and the establishment of a framework for the seamless transition between digital twins and their physical counterparts. The project will also explore innovative approaches to reduce costs and improve the accessibility of robotics in agriculture, making cutting-edge technology available to a wider range of users.

Title: H - Novel lead-free actuators based on electroactive ceramics by sustainable processing
Reference person: M. Biesuz
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

The project plans to develop new lead-free electroactive materials by sustainable processing techniques of inorganic compounds. A series of new compositions will be developed and characterized in terms of piezoelectric and dielectric properties. Both traditional non-centrosymmetric and novel centrosymmetric piezoceramics will be considered. Specifically, the effect of complex solid solutions and engineered point defect chemistry on the electromechanical properties will be investigated.
The materials will be synthetized by wet chemical methods and the powders will be consolidated by novel sintering processes, including low-temperature sintering processes. The project will assess the feasibility of integrating piezoceramics films on flexible substrates such as kapton or other organic materials. Prototypes of devices like artificial muscles or transducers for the development of ultrasound medical imaging instrumentation will be considered. These transducers, connected to an appropriate electronic system, can be mounted on robotic manipulators working in actuation mode.

The activity will involve a wide spectrum of experimental activity ranging from the materials synthesis, processing, structural, microstructural and dielectric/piezoelectric characterizations. The project lies at the borders between materials science and devices engineering.

Title: I - Advanced Digital Sensors and Energy Harvesting with 3D Printed Electronics on Flexible Surfaces and Textiles
Reference person: D. Brunelli
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

Self-powered electronic sensors, 3D printed or made of "textiles" i.e., in the form of fabrics or on flexible elements that allow the incorporation of electronic components such as batteries, sensors, actuators, and microcontrollers will be studied. The use of e-textiles is different from the wearable computers (wearable devices) we know because the emphasis is on seamless integration of the flexible covering material with electronic elements such as microcontrollers, sensors and actuators. Furthermore, e-textiles and 3D-printed electronics do not necessarily have to be wearable; for example, they could be used as coverings for exoskeletons and robots.
It is precisely this latter scenario where a final demonstrator will be developed, namely to realize a sensor in a flexible system that is self-powered because it has energy harvesting and for the sensing part of robots. Sustainability is emphasized by the system itself, which does not affect the robot's power consumption because this part of the electronics is self-powered.

Title: J - Development of flexible active mechanical metamaterials for autonomous morphing and shape adaptation
Reference person: P. Gallo
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

The proposed project focuses on developing flexible active mechanical metamaterials for autonomous shape-morphing and a high level of shape adaptation. The flexible mechanical metamaterial is realized via additive manufacturing, while the component is activated via shape-morphing electroactive polymers (EAPs). With this unique combination, the aim is for a fully embedded and lightweight integrated solution. The metamaterial is topologically optimized to achieve an anisotropic response (i.e., functionally graded conformal structure), coupled with EAPs, which are now constrained, hence achieving the desired complex configuration when activated. Moreover, particular attention will be devoted to structural integrity, which is often neglected. The project will involve theoretical, experimental activities and simulations, such as topological optimization of mechanical metamaterials, studies on additive manufacturing techniques and the impact of defects and other imperfections on the structural integrity, fatigue or fracture experiments (if relevant), investigation of the physical coupling between substrate and actuators, simulations of the response of the active metamaterials, realization of prototypes and testing, exploring innovative configurations of the EAP materials to obtain more complex morphing. The final aim is the realization of at least one prototype of flexible active metamaterial. The project is developed in collaboration with world-renowned institutions/researchers of USA and Finland.

Title: K - Smart materials integrating embedded optical fiber sensors
Reference person: M. Lobino
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

The project focuses on the study of new type of smart materials (composites, polymer or metallic) with integrated optical fibre sensors, which would allow in situ real-time monitoring of both the manufacturing process and the service life, is highly desirable. Due to their unique characteristics of weight, minimal footprint, high sensitivity to temperature and strain, immunity to electromagnetic interference, possibility to operate in a hazardous

environment and in the presence of electric currents, fibre-optic sensors offer clear unmatched advantages over traditional sensors. However, the interrogation of the fiber sensor is still problematic as it requires expensive cumbersome equipment. We propose to study the integration in integrated optics and develop such interrogators demonstrating a SWAP-C improvement. In particular, Optical Frequency Domain Reflectometry (OFDR) is quite promising as allows to measure the strain and temperature over hundreds of meters with sub-cm resolution. In the context of smart materials. By interrogating an optical component or fiber assembly in reflection, OFDR technology is able to measure and analyze loss and polarization effects spatially, or distributed along the optical path. The Optical Backscatter Reflectometery (OBR) technology measures distributed loss and backscatter with a sampling resolution as low as 1mm, providing an unprecedented level of detail to pinpoint and analyze optical effects in short optical assembly networks that could be embedded in mechanical parts. In particular, by a specific signal processing it is possible to measure strain, temperature distribution and vibrations over the whole extent of the fiber.

Title: L - Design and development of soft robots with multifunctional-material-based artificial muscles
Reference person: G. Moretti
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

As robotics advances towards more sophisticated designs, combining deformable links and the ability to interact softly with their environment, the actuation system remains a crucial aspect in developing integrated soft robots. Smart-material-based artificial muscles (AMs), such as electroactive polymer actuators, offer a highly promising solution due to their significant energy density, low stiffness, and ease of integration into soft structures.
This PhD project aims to develop new concepts of highly-integrated soft robots based on a combination of compliant structures and polymeric AMs.
The successful candidate will 1) explore new principles and materials for multifunctional actuators, with a special focus on electrostatic AMs based on electroactive polymers or multilayer polymer-liquid dielectrics; 2) design and develop prototypes of soft robots with structural components specifically built upon selected AM concepts; 3) study sensorless control approaches (self-sensing) for AM-robot systems.
The PhD project will pursue a multi-disciplinary approach, at the intersection among mechatronics and material science. Specific activities will include: functional material characterisation; physical modelling; investigation of new AM topologies and multi-material actuators; design, development and control of integrated soft robot prototypes.

Title: M - Human-centric collaborative manufacturing with industrial cobot for operator well-being in Industry 5.0 era
Reference person: F. Pilati
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

Manufacturing ecosystems are currently facing a dramatic evolution due to customer customization requirements of the ordered product as well as shrinking, aging and outdating of the available workforce. The adoption of collaborative robot (cobots) able to meet the flexibility required by novel production paradigm and to assist and cooperate with human operator is key to succeed on the long term. However, the adoption of such technology in industry so far does not guarantee an increase in productivity, nor an improvement in the human well-being during the execution of manufacturing activities.
This doctoral project aims at developing smart solutions to integrate cobots with human operators to maximize their well-being while ensuring the required productivity in the context of Industry 5.0. Novel human-centric collaborative systems must consider the specific requirements and needs of every human operator for their cooperation with cobots. In particular, the features of the performed tasks assigned to each of them, as well as the peculiar physical conditions are key for a superior human-machine interaction.
To reach this goal this doctoral project will adopt wearable sensors, empowered with artificial intelligence algorithms for an innovative paradigm in human-centric collaborative manufacturing. Physiological data will be

acquired with wearable sensors along with motions of human operator in productive environment through computer vision or similar techniques. Furthermore the interactions of the operators with productive environments will be monitored with different tools and sensors, to assess human-process interactions, e.g. operator movements, interaction with machines, material flow transportations, etc.
Concerning the leveraging of data acquired from such sensors, artificial intelligence algorithms will be developed to mine meaningful data. These algorithms will be empowered with novel labeling approaches to include physical and real constraints in the considered system. This architecture will feed original well-being indicators to be developed to assess quantitatively in a holistic approach the operators physical, physiological and mental load during the execution of the assigned, various and non-repetitive manufacturing tasks.
Finally, the integration of all these components will enable an advance management of the human-cobot interaction, with innovative approaches for tasks assignment, activities scheduling, evolved techniques for cobot to human assistance, also with pre-emptive techniques to anticipate possible risks for the human working conditions.

Title: N - Design, Modeling, and Control with Structured Neural Networks for New Prototypes of Wearable Flexible interfaces
Reference person: G. Rosati Papini
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

Multi-sensory wearable interfaces are becoming increasingly pervasive in applications such as virtual reality, rehabilitation, and assistive devices. The development of all-soft acoustic and vibrotactile actuators and/or sensor, based on soft active materials, can effectively produce lightweight noninvasive wearable solutions, unachievable with traditional technologies. Modelling and controlling multifunctional-material-based user interfaces to achieve performance levels consistent with user applications, however, is a highly complex task that requires innovative approaches. Neural networks represent a promising approach to achieve these goals, but their performance strongly depends on the feasibility of embedding a certain level of physical knowledge of the target system into their structure.
This PhD activity has the aim of developing concepts, models and control strategies for soft multifunctional-material-based user interfaces, leveraging advanced modelling/control tools such as structured neural networks. The successful candidate will initially focus on developing a prototype of a wearable interface based on multifunctional polymeric materials (such as dielectric elastomers) capable of providing users with vibrotactile and acoustic stimuli, or acting as a sensor to measure muscular activity. They will then develop models of the actuator dynamics and user-device interaction, using both physics-based modelling and structured neural networks, comparing the performance and limitations of the two approaches. Finally, the candidate will develop control strategies for the interface, demonstrating the potential benefits of combining neural-based approaches and classical control approaches.

Title: O - Data-driven optimization for the manufacturing of multi-functional natural-based conductive hydrogels for flexible technologies applications
Reference person: A. Tirella
Funded by: MUR – Departments of Excellence project "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP E63C22003890001

Multifunctional hydrogels are promising technological materials to interface with soft, wet, and conductive systems. As coatings, conductive hydrogels can improve the electrical properties of the interface by reducing impedance and increasing the charge injection capacity, as well as possess mechanical properties typical of soft human tissues (e.g., skin). To overcome current issues and advance the manufacturing of electro-mechanical and miniaturized systems, the project integrates materials science knowledge in machine learning/deep learning approaches to optimize the manufacturing of electromechanical prototypes with defined properties (i.e., elastic moduli, conductivity, hydration).

The project uses the advantage for quality control in manufacturing as real-time control, improving accuracy and consistency of inspection and measurements, and overall increasing efficiency and productivity. Thanks to the multidisciplinary nature of the project, the candidate will develop and consolidate knowledge on: the use of circular economy polysaccharides functionalized with conducting polymers; optimization of additive manufacturing technologies for the prototyping of products with precise spatial control over electromechanical properties; development of machine learning and deep-learning techniques, which draw inspiration from the laws of the material sience, to guide synthesis and production procedures to obtain the desired conductive and mechanical characteristics.