PhD Course in Materials, Mechatronics and Systems Engineering

Research subjects proposed for the 41st cycle

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: Biofunctional metamorphic materials: design of natural photo-responsive structures
Reference persons: D. Maniglio, F. Parrino

This research project aims to develop biofunctional metamorphic materials through the design and fabrication of natural-origin structures that are both active and adaptive in response to physical stimuli. The study focuses on the selection and characterization of natural biomaterials combined with light-responsive molecules to engineer smart systems capable of undergoing controlled shape changes. These structures will be fabricated using a digital light projection based microprinter, enabling precise control over geometry and functionality at the microscale. The final goal is to create responsive platforms that can act as cargo systems for the targeted delivery of bioactive substances, such as biomolecules or biopolymer super-assemblies, or even living cells. These systems are expected to show high versatility in biomedical applications, particularly in regenerative medicine, tissue engineering, and drug delivery.

Title: Understanding and improving the anisotropic mechanical behaviour of 3D printed polymers and polymer composites
Reference persons: L. Fambri, A. Pegoretti

The main aim of the project is to investigate both static and dynamic mechanical behaviour of additively manufactured polymers and polymer composites under bi-axial testing conditions. In particular, an extended experimentation will be performed on a model system consisting of both a neat polymer (such as ABS, PLA or PA) and the same polymer reinforced with short carbon fibers. In particular, bi-axial tests will be performed to determine the elastic constants, the fracture strength and toughness and the fatigue life on samples printed under different conditions (temperature, printing angles,….). The obtained data will be used to develop a failure criterion for 3D printed components.
In the second part of the project, strategies will be investigated to improve the mechanical properties of 3D printed polymers and polymer composites exploring the possibilities to promote a repair by external stimuli in case of damage.

Title: The Worker of the Future: digital technologies and artificial intelligence to improve the performances and well-being of industrial and logistic operators
Reference persons: F. Pilati, F. Calabrese

The manufacturing and logistic sectors are affected by the most dramatic trend of the latest years: the aging and shrinking of their workforce. This trend will result in less and older workers, often distinguished by chronic diseases which have to keep pace with a hugely dynamic environment of product mass customization, reduction of lead times and uncertainty of the market demand. This project aims at developing original and disruptive digital technologies to improve the performances and well-being of whatever human operator involved in whichever manufacturing, assembly or logistic process. Innovative wearable sensors will be employed to acquire in real- time valuable information regarding the activities performed and the physical conditions of industrial workers, while executing complex and strenuous tasks. Artificial intelligence algorithms will be employed to mine precious information from the acquired data concerning which are the non-intuitive determinants of under-performing working conditions, predict future hazardous events and automatically suggest solutions to elevate the industrial environment to the next level of the factory of the future, accordingly to the novel Industry 5.0 paradigm.

Scholarships on reserved topics:

Title: A - Reliable Robot Control with Learned Safe Sets
Reference persons: M. Saveriano, A. Del Prete
Funded by: UNITN and Department of Industrial Engineering, project UE HE INVERSE, n. 101136067, CUP E63C23001600006

Safety is often the most important requirement in robotics applications. Nonetheless, learning and control techniques that can provide safety guarantees are still extremely rare for nonlinear systems, such as robot manipulators. The goal of this research is to develop new learning algorithms to efficiently compute safe sets of robotic systems. The learned sets will be used to ensure safety during learning and execution of robotic tasks, providing reliable solutions for real world deployment.

Title: B - Innovative processes for the production of high mechanical performance and durability glass and glass-ceramics
Reference person: V. M. Sglavo
Funded by: UNITN and Department of Industrial Engineering

The goal of the present research project is to study and optimize processes for the realization of glasses and glass-ceramic with improved mechanical performance and chemical durability. Glasses in the soda-lime silicate or soda-magnesia silicate systems will be considered; the glass-ceramics will be produced starting from lithium aluminosilicate glasses. The mechanical reinforcement will be carried out through ion exchange techniques to be carried out in single or multiple steps, eventually alternated also to tailored thermal treatments. The chemical durability of bare and reinforced glasses and glass-ceramics will be evaluated especially in terms of weathering resistance. The ion exchange process will be optimized for the specific material in order to guarantee high mechanical performance (surface damage resistance, strength and reliability) and superior degradation resistance in the environment.

Title: C - Modelling/estimation/control of vehicles using model-structured neural networks for simulations and real-time applications
Reference persons: G. P. Rosati Papini, M. Da Lio
Funded by: UNITN and Department of Industrial Engineering, funded with a grant from the Ministry of University and Research under D.D. No. 1236 of 1-08-2023 - Bando FIS 2; project FIS-2023-03684 "Structured neural network framework for modeling and control of autonomous systems - Neu4mes", CUP E53C24003800001

Autonomous vehicles are increasingly being used in various fields, from the automotive industry to mobile robotics. The modeling and estimation of vehicle dynamic behavior are fundamental for the development of advanced control systems and for ensuring the safety and reliability of autonomous operations. However, the complexity in modeling their interactions with the surrounding environment makes it difficult to create accurate and robust models. Model-structured neural networks offer a promising approach to address these challenges by combining physical knowledge with prior knowledge and machine learning techniques. The goal is to develop vehicle models that can be used to predict the future motion of the vehicle given the initial conditions and to estimate states that are not directly measurable. The models will be developed by combining traditional symbolic equations and physical principles with modern approaches based on neural networks, particularly model-structured neural networks. Specifically, these models can be used to learn the dynamic characteristics of the vehicle from experimental and/or simulated data (e.g., CarMaker vs the F1Tenth vehicle) and to develop models, estimators, and controllers for experimental vehicle platforms and simulation environments or driving simulators.

Title: D - Real-time models and optimal control for racing vehicles combining equation-based approaches and model-structured neural networks
Reference persons: F. Biral, E. Bertolazzi, G. P. Rosati Papini
Funded by: UNITN and Department of Industrial Engineering, funded with a grant from the Ministry of University and Research under D.D. No. 1236 of 1-08-2023 - Bando FIS 2; project FIS-2023-03684 "Structured neural network framework for modeling and control of autonomous systems - Neu4mes", CUP E53C24003800001

Accurate modeling, state estimation, and optimal control are essential tools for maximizing the performance of racing vehicles. High-fidelity models provide deep insights into complex vehicle dynamics under extreme conditions, enabling reliable predictions at the limits of grip and stability. Estimation algorithms allow real-time awareness of key states—such as tire forces—even when measurements are noisy or unavailable. Optimal control supports performance optimization, motion planning, and real-time decision-making. Additionally computational speed of models and optimisation algorithms are particularly vital in high-speed racing and autonomous motorsport applications. Conventional equation-based models, grounded in first-principles physics, offer interpretability and robustness across different scenarios but often struggle to accurately capture highly nonlinear phenomena such as transient tire-road interactions or aerodynamic forces, especially in real-time. Purely data-driven approaches, such as black-box neural networks, can model these effects but lack of interpretability, generalization, and require a high computational demand. To bridge this gap, the research proposes a hybrid modeling approach that integrates model-structured neural networks with physical laws and domain knowledge to retain the generalization and interpretability of physics-based methods and gain adaptability of neural networks. Model-structured neural networks are trained on experimental data, while constrained to obey physical principles, ensuring model consistency and efficiency. The same framework can also be extended to enable real-time solutions of optimal control problems, built on top of the developed hybrid models. Validation will be conducted through both high-fidelity simulation and experimental testing using racing vehicles and professional driving simulators.

Title: E - Planning and control of quadrupedal robot locomotion using model-structured neural networks
Reference persons: D. Bortoluzzi, M. De Cecco, G. P. Rosati Papini
Funded by: UNITN and Department of Industrial Engineering, funded with a grant from the Ministry of University and Research under D.D. No. 1236 of 1-08-2023 - Bando FIS 2; project FIS-2023-03684 "Structured neural network framework for modeling and control of autonomous systems - Neu4mes", CUP E53C24003800001

Quadrupedal robotic systems are increasingly being used in a variety of applications as they are more flexible than wheeled vehicles. However, the locomotion of these robots is more complex and requires accurate planning and control algorithms to ensure stability and optimal performance. Moreover, the complexity of their dynamic models, due to the high state dimensionality and the discontinuous contact interactions with the surrounding environment, make it difficult to use standard control and optimization tools for generating locomotion behaviors. State-of-the-art approaches simplify the problem by pre-specifying the contact patterns, at the cost of reducing the range of possible behaviors that the robot can achieve. Model-structured neural networks offer a promising approach to address these challenges by combining prior physical knowledge with machine learning techniques. In this project, we aim to develop locomotion models for quadrupedal robots that can be used to plan and control the robot's movement in real-time. Model-structured neural networks have the potential for efficiently learning robot models with high generalization capabilities. Designing customized network structures can also enable the efficient computation of average system performance over a range of possible motions. These computational tools could unlock the online generation of complex locomotion behaviors without pre-specified contact patterns. The developed planning and control framework will be validated through numerical simulations and experimental tests on a quadrupedal robot.

Title: F - Development of model-structured neural networks for modelling, estimation, and control of autonomous robotic systems, designed for embedded architectures
Reference persons: D. Brunelli, P. Bosetti, G. P. Rosati Papini
Funded by: UNITN and Department of Industrial Engineering, funded with a grant from the Ministry of University and Research under D.D. No. 1236 of 1-08-2023 - Bando FIS 2; project FIS-2023-03684 "Structured neural network framework for modeling and control of autonomous systems - Neu4mes", CUP E53C24003800001

In the context of autonomous robotic systems, artificial intelligence is essential to address many of the challenges related to autonomy, such as navigation, perception, and interaction with the environment. However, data-driven approaches rely on a large amount of data for training and require significant computational power, making them unsuitable for embedded applications. Model-structured neural networks offer an alternative approach, where the structure of the network is designed to incorporate prior knowledge about the physical system being modeled. This approach allows for a reduction in the number of parameters, and the computational cost, and improves model interpretability. The project will focus on designing and implementing model-structured neural networks for modeling, estimating, and controlling autonomous robotic systems, with particular attention to optimization for embedded architectures. The goal is to enable learning and inference on distributed machine learning architectures across ultra-low-power microcontroller nodes to edge computing platforms. This project will investigate how artificial intelligence can reach edge devices, leveraging advances in TinyML in collaboration with model-structured neural networks, for in-sensor processing and federated learning to enable real-time, low-power distributed intelligence. The main tests will be conducted on aerial drones, with the aim of developing control systems, navigation, environmental recognition, and estimation; including the design and deployment of model-structured neural networks on microcontrollers using state-of-the-art platforms.

Title: G - AI-Driven Embedded Monitoring Solutions for Next-Generation Energy Systems

Reference persons: D. Brunelli, D. Macii, D. Petri
Funded by: UNITN and Department of Industrial Engineering

This PhD program explores the development of scalable sensing solutions to monitor and predict power and energy consumption of electrical equipment to improve efficiency and reduce waste. Core themes include non-intrusive load monitoring NILM, intelligent sensing, and self-powered electronics. Emphasis is on AI and deep learning techniques aimed at measuring and estimating consumption, optimizing energy use, forecasting load profiles, detecting power-hungry devices and/or operating conditions from aggregate patterns, while ensuring durable device autonomy through energy harvesting techniques, hardware-software co-design optimization and low-power management strategies.
The research program is expected to combine theory, simulation, and real-world prototyping and aims to improve monitoring infrastructure for classification, anomaly detection, or observability of distribution systems status. The selected PhD candidate is expected to develop algorithmic and signal processing solutions for power or energy profile disaggregation, forecasting, and system optimization, using both real-world datasets and synthetic models. Minimal hardware prototyping and design of embedded systems capable of adaptive power control and efficient data processing, possibly with self-powering capability, can be required to support the validation phase of the developed solutions.
Matlab and Python shall be used for system modeling and simulations as well as to develop and to test the prototype algorithms and to train the deep learning models adopted for classification, disaggregation and forecasting.

Title: H - Production and characterization of metallic materials for the biomedical sector by binder jetting additive manufacturing
Reference persons: M. Pellizzari, C. Menapace
Funded by: UNITN and Department of Industrial Engineering

This research project aims to study the binder jetting process for the additive manufacturing of metallic materials for the biomedical sector. Among additive techniques, binder jetting has interesting potential, does not require vacuum or a protective inert atmosphere, and the grain structure obtained tends to be more equiaxial than that from fusion-based powder bed fusion (PBF) or direct energy deposition (DED) processes. However, the process has not been sufficiently studied compared to other additive manufacturing (AM) processes for metals. In this PhD work, the aim is to investigate some of the aspects inherent to printing and post-processing, such as understanding the powder distribution process, the binder-powder interaction, the dimensional shrinkage of components during sintering, and the heat treatment of steels and/or some selected non-ferrous alloys. The correlation between process parameters, microstructure, and properties will be investigated using different characterization techniques.

Title: I - Development of CMOS pixel sensors for radiation imaging in space, medical diagnostics and High-Energy Physics applications
Reference persons: L. Pancheri, G. Dalla Betta, R. Iuppa
Funded by: UNITN and Department of Physics, project SPACE IT UP! Contratto ASI n.2024-5-E.0 CUP Master n. I53D24000060005, ASI SPACE IT UP SPOKE 4, CUP n. E63C24000530003

Silicon pixelated radiation detectors are crucial in applications like space radiation monitors, medical imaging (e.g. TAC, PET and SPECT), and charged particle tracking and timing in High Energy Physics (HEP) experiments. The goal of this research activity is the development of novel CMOS-integrated sensors for space, medical and HEP applications. The co-integration of arrays of detectors with low-noise, low-power or high-speed readout circuits will enable the creation of a new class of devices with State-of-the-art performance for innovative radiation imaging systems. In addition, high timing resolution at reduced power consumption can be obtained exploiting linear-mode avalanche signal amplification. Integrated detectors will be designed using TCAD simulations tuned with the foundry process parameters, fabricated in commercial CMOS processes and validated through extensive experimental laboratory characterization, in close collaboration with partner research institutions.

Title: J - Damage analysis of thick-walled ductile cast iron castings under complex loading and severe environmental conditions

Reference persons: V. Fontanari, M. Benedetti

Funded by: UNITN and Fonderie Ariotti S.p.A.

The mechanical behaviour of ductile cast iron components is significantly influenced by the cooling rate during production, which is directly related to the component's wall thickness. Slower cooling rates typically result in a coarser microstructure, larger graphite nodules, a lower nodule count, possible graphite degeneration, microporosity and hard precipitates at grain boundary and consequently reduced mechanical properties, such as tensile strength, UTS, elongation at break, hardness, and fatigue resistance. Additionally, large cast iron components are often subjected to complex static and dynamic loading conditions, frequently operating in harsh environments. The formation of cracks in such components is unacceptable and must be prevented through careful design. Despite extensive research on this ferrous alloy, several aspects remain insufficiently explored. One such area is the impact of overloads, which can induce local yielding, thereby affecting both static and fatigue performance. Even in the absence of complete yielding, overloads can influence the fatigue life of components, highlighting the need for accurate damage accumulation models in the design phase. Raw surfaces are typically less durable than machined surfaces, and innovative solutions may enhance the mechanical performance of raw surfaces. Additionally, rapid deformations or impacts can influence the damaging mechanisms in cast iron, making it crucial to understand the material's response under these conditions.

Title: K - New concepts of electrostatic energy harvesters based on electroactive materials

Reference person: G. Moretti

Funded by: UNITN and Department of Industrial Engineering, project UE HE ERC flEAP, CUP E63C24001590006

The quest for sustainable power is accelerating the development of energy harvesting technologies spanning different power scales, from small-scale harvesting for portable electronics, to large-scale harvesting from currently untapped sources of renewable energy, like ocean waves. Electrostatic generators based on electroactive polymers are increasingly regarded as a highly promising technology, offering modularity and scalability, and performing effectively in conditions where traditional electromagnetic machines struggle. This PhD position, offered in the framework of ERC Starting Grant project flEAP, will explore new concepts of energy harvesters based on combinations of dielectric polymers and fluids. The successful candidate will analyse new concepts of dielectric fluid generators, develop models and control algorithms to evaluate their performance in applications, and design experimental validations campaigns.

Title: L - Electro-mechanical design and characterisation of high-performance electrostatic actuators
Reference person: G. Moretti
Funded by: UNITN and Department of Industrial Engineering, project UE HE ERC flEAP, CUP E63C24001590006

Actuators are among the most critical components in robotic systems, and their evolution towards compact, flexible and resilient designs is essential to enable future mechatronic devices to operate in unconventional environments or under extreme working conditions. This PhD position, offered in the framework of ERC Starting Grant project flEAP, aims to explore new concepts of high-performance actuators based on an electrostatic working principle, combining electroactive polymers and dielectric fluids. The successful candidate will develop methodologies and experimental setups to characterise actuators using dielectric fluids (liquids and gases) and will contribute to the development of proof-of-concept applications for ground-based and space applications.

Title: M - Development of a framework for the design of model-structured neural networks for estimation, modelling and control of physical systems
Reference person: G. P. Rosati Papini
Funded by: UNITN and Department of Industrial Engineering, funded with a grant from the Ministry of University and Research under D.D. No. 1236 of 1-08-2023 - Bando FIS 2; project FIS-2023-03684 "Structured neural network framework for modeling and control of autonomous systems - Neu4mes", CUP E53C24003800001

The development of advanced autonomous intelligence systems depends on sharing expertise and tools to support the design and deployment of such systems on hardware platforms, ensuring the effectiveness and efficiency of applications in real-world scenarios. In this context, this project aims to develop an open-source framework for the design and implementation of model-structured neural networks that can be used for modeling, estimation, and control of physical systems. These networks base their structure on the physical context to which they are applied and allow users to transfer domain knowledge within them. The framework will be designed to be modular and scalable, allowing users to customize the architectures of neural networks. The framework will specialize in all phases from data collection to network design and training, validation, and deployment; it will also be optimized for execution on embedded platforms, ensuring high performance even in low-power devices. The project will focus on applications in the most critical areas such as autonomous systems, to develop innovative solutions for navigation, perception, and interaction with the environment.

Title: N - Engineered Bio-Derived Hydrogels Tailoring Mechanical and Adhesive Properties as Sustainable Biomedical Technologies
Reference person: A. Tirella
Funded by: Department of Industrial Engineering, CONSORZIO MELINDA Sca, CUP C77B24000000008

An alternative to reduce the economic and environmental impact of food processing waste is the valorization of derived by-products for biomedical applications. For example, pectins are interesting polysaccharides extracted from apples used to formulate hydrogels with viscoelastic properties compatible with tissue regeneration. This project will use and modify natural polymers, such as pectins extracted from apples and alginates extracted from brown algae, to formulate engineered flexible hydrogels for regenerative medicine applications. The hydrogels will be engineered to control both the mechanical properties and the adhesion capacity to specific surfaces and manufactured as patches or protective layers with ability to protect from external contaminants and regenerate tissue lesions (e.g. wound dressings, cardiac patches). Cutting across the themes of advanced materials, healthcare technologies, sustainable manufacturing and manufacturing the future, the natural-derived technologies will have immediate usage for a variety of healthcare applications, such as controlled drug delivery systems or engineered in vitro models.

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

The project is aimed at the research and development of advanced Human-Aware Motion Planning algorithms for robotic systems operating in close collaboration with humans. The project aims to create motion planning solutions and safe control algorithms that take into account the presence, intentions, and comfort of human operators, while ensuring operational efficiency, safety, and compliance with ergonomic constraints. The research activity is part of the collaborative robotics and smart factory domains within the MAGICIAN project, with applications focused on advanced manufacturing and adaptable to various contexts. It involves both the theoretical development of algorithms and their experimental validation on real robotic platforms. The research objectives include the definition and development of predictive models of human behavior in shared environments, management of interactions (including elements of machine learning), and validation in realistic collaborative scenarios (e.g., assembly, inspection, handling).

Title: P - Reliability of machine learning accelerators for robotic and space applications
Reference persons: P. Rech, F. Vella (DISI)
Funded by: Department of Information Engineering and Computer Science, project UE EDF RA - ARCHYTAS, n. 101167870; CUP E63C24002180006

The space market is growing more than any other market and, in the near future, we foresee an increasing interest in robotics and autonomous vehicles for space applications. By relying on machine learning and artificial intelligence we can sharply reduce the cost of sending and receiving signals to the satellite or rover and increase safety by automatizing critical actions such as docking or debris detection. Despite the unquestionable benefit, adopting AI in space is extremely challenging. The reduced power budget, the lack of a structured data-set for training, and radiation-induced computational errors are among the challenges we will face in this project. The research will be focused on increasing the efficiency and reliability of machine learning models, considering innovative hardware accelerators and modern techniques to mitigate faults effects. The research will be carried out at the HiCREST laboratory that combines expertise from hardware to programming models, AI, quantum computing, and radiation reliability. During the project, the student will have the opportunity to collaborate with international institutions such as the European Space Agency, Jet Propulsion Laboratory, Los Alamos National Laboratory, and the most prestigious European universities. Moreover, several experiments aimed at measuring the radiation effect on the components will be performed using facilities that simulate the space radioactive environment.

Title: Q - Development of Small-Scale Metamaterials for Sensors and Energy Systems
Reference persons: P. Gallo, E. Rustighi, T. Sumigawa (Kyoto University)
Funded by: MUR - Departments of Excellence project “Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)”, CUP E63C22003890001

Our research proposal focuses on the design of small-scale (micro to nano) active metamaterials for energy applications supported by machine learning. The core of the research lies in studying mechanical metamaterials that have specific microtuned internal structures and exhibit multiphysics properties that are not possible with conventional materials. To this aim, we will make use of polymer-based structures with electrodeposited nanocrystalline metal. Moreover, our studies will elucidate the coupling effects between various physical properties and their mechanical characteristics. In developing such materials and devices, it is crucial to consider not only the multiphysics aspects but also mechanical characterization, such as fracture, fatigue, and interface interactions, across both small (in-situ) and large scales. Finally, our proposal puts forward the following challenge: Can we realize atomically tuned metamaterials? The research is developed in collaboration with world-renowned researchers from Japan and USA.

Title: R - Modeling and control of power converters interfacing energy storage systems in industrial smart grids
Reference persons: F. Cecati, L. Zaccarian
Funded by: MUR - Departments of Excellence project “Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)”, CUP E63C22003890001

Power electronics represent the backbone of modern and sustainable smart grids for the efficient and green power supply in modern and future manufacturing industries. Power converters act as a digitally-controllable smart interface between energy storage systems (e.g. batteries, supercapacitors) PhotoVoltaic plants, and the industrial power grid. The accurate modeling, control and coordination among different power converters is fundamental both to ensure sustainable, highly-efficient and green energy supply, but also to ensure the stability of the smart grid, avoiding potential black-outs which would have dramatic consequences on the industrial production. Saturation and wind-up phenomena in power converters have been recognized as a primary cause of converter instability and potential blackouts, and are nowadays a highly-relevant problem both in the scientific and in the industrial community.
This PhD project aims to explore the topics of modeling of power electronics considering switching dynamics, wind-up and saturation phenomena, and system identification in converter-dominated smart grids. The results are expected to be validated also in the laboratory environment.

Title: S - Design and Characterization of CMOS-SiC electronics for the next generation of harsh-environment sensors
Reference persons: L. Pancheri, M. Gandola (FBK)
Funded by: Fondazione Bruno Kessler*

Silicon-based radiation detection systems, composed of both detectors and associated electronics, are widely used across various sectors, including consumer electronics, automotive, industrial processes, medical imaging, and space exploration.However, their performance in high-radiation and high-temperature environments, particularly in medical and space applications, is significantly limited by radiation damage and thermal instability. Silicon Carbide (SiC), already widely used in power electronics and automotive applications, is now emerging as a highly attractive material for harsh environments due to its exceptional radiation hardness and high-temperature tolerance. While SiC technology holds substantial potential to overcome the limitations of conventional silicon-based systems, further research is essential to optimize material quality,refine fabrication techniques, and establish robust manufacturing infrastructures. This research must also include thorough characterization of both detectors and electronic components, as well as the design of fundamental circuits such as amplifiers, comparators, and digital cells, to enable the practical implementation of SiC-based detection systems in advanced applications.The objective of this project is to design and characterize a fully SiC-based CMOS ASIC for radiation applications. The student will work on the characterization of key technological structures, such as transistors and essential analog/mixed-signal circuits, leading to the design of a complete mixed-signal readout chain, while also contributing to the development of a Process Design Kit (PDK).

Title: T - Experimental investigation on the performance of flow battery components for low-cost long duration energy storage
Reference persons: M. Fedel, E. G. Macchi (FBK)
Funded by: Fondazione Bruno Kessler, project IPCEI Batterie 2, CUP B62C22000010001*

Redox flow batteries (RFBs) are a promising technology suitable for long-duration energy storage (LDES). In RFBs power and energy are decoupled: the former depends mainly on the size of the cell/stack while the latter on the size tanks containing the redox active species. This feature makes RFBs ideal for economical, large-scale energy storage. However, cost reductions are needed for a widespread diffusion of this technology. The required cost reductions involve two main components of the system: the electrolytes and the stack.
This work will focus on investigating the performances of different key components for redox flow batteries, such as membranes, electrodes and bipolar plates, with a specific focus on RFBs based on low-cost earth-abundant redox active materials (e.g., Zn, Fe, Cu, I, S). The doctoral thesis will start with a screening of the most promising materials for the selected battery chemistries. Then materials will be characterized and tested at cell level (5-10 cm^2) to evaluate the effect on the battery performances. At this stage novel solutions will be devised targeting improved material performances (e.g., material functionalization). During this step an optimization of the electrolytes might be also performed to ensure an optimal matching between anolyte, catholyte and membrane. Finally, the combination of different materials will be evaluated in a larger cell (>100 cm^2) to identify the most promising solutions for cost reductions even considering potential upscaling issues.

Proposed research topic for the positions without scholarship:

Title: Reinforcement Learning Robust to Irreversible Events
Reference persons: M. Saveriano, P. Falco (University of Padova)

Performing reinforcement learning directly on a robot manipulator is challenging and far from being a fully automated process. Indeed, during the learning of manipulation skills, irreversible events like object fallings may occur, preventing the robot from continuing the learning process. The goal of this research project is to develop reactive strategies to predict the occurrence of an irreversible event and to modify the robot behavior to avoid such events. The result will be a robotic system capable of learning manipulation skills in a fully autonomous manner, reducing human intervention and training time.

Title: Low-Cost multi-IMU state estimation on mobile legged robots with flexible surfaces
Reference person: M. Camurri

Exteroceptive sensors in real world scenarios are affected by challenging conditions such as: low light, degenerate geometries, dense fog, sun glare. Instead, IMUs have the unique property of being independent from such conditions, as it is affected only by gravity. However, IMU measurements are affected by noise and bias, especially on low cost devices. Typically, this has been solved by fusing IMU data with exteroceptive sensing, which is expensive and unfeasible in difficult scenarios. However, a new research field emerged recently, as AI have enabled IMU-only state estimation, thanks to the ability neural networks have to learn motion patterns from batches of IMU data. This has been successfully applied to pedestrian tracking using smartphone IMUs, as human gaits are fairly predictable. At the same time, multi-IMU sensor fusion to improve state estimate noise is a more mature research field. The aim of this project is combining these two strands of research (AI-based and multi-IMU state estimation) to estimate the motion of a legged robot from an array of IMUs, as well the joint and link flexibility its legs, unlocking applications that go beyond traditional robotics, such as soft robotics and human rehabilitation.

Title: AI-Driven Robotic Systems for Autonomous Remote Maintenance in the Future Circular Collider
Reference persons: M. Saveriano, M. Di Castro (CERN)

Performing maintenance tasks in hazardous environments poses several unique challenges due to increased safety risks and stringent regulations. These include the need for specialized equipment, robust safety protocols, and compliance with complex regulations. This PhD project aims to develop intelligent robotic systems for the Future Circular Collider (FCC) at CERN, focusing on autonomous remote maintenance in complex and hazardous environments. Leveraging machine learning and reinforcement learning techniques, the research will enable robots to adapt to dynamic conditions, optimize task execution, and make informed decisions without constant human oversight. The integration of these AI methodologies is expected to enhance safety, reduce downtime, and improve the maintainability of large-scale accelerator infrastructures.

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*__Intellectual Property Notice for PhD candidates under the UniTrento-FBK Agreement__**

Please read the following information carefully before submitting your application.

Intellectual Property of Research Results

The intellectual property rights of research results generated by PhD students under scholarships within the UniTrento-FBK Agreement shall belong to FBK.

Transfer of Intellectual Property Rights

FBK will establish agreements with PhD students regarding the transfer of intellectual property rights related to their research results.

Collaboration with UniTrento

If UniTrento academic staff contribute to research results obtained through PhD scholarships funded by FBK, the determination of IP shares will be defined through separate written agreements based on each party's contribution. PhD students are required to collaborate with UniTrento in all necessary activities related to the joint management of IP.