RESEARCH TOPIC AND ABSTRACT RESEARCH OF POST DOC/RESEARCH FELLOWS (DIEE)

FELLOWS RESEARCH (Art. 22 L. 240/2010)

-Start of activities in 2025:

Bingol Gulnaziye

Research Topic:

Integration of Estimated Emotions into the Human Cyberdigital Twin System and Testing.

Abstract:

The research addresses the development of Human Cyber Twin (HCT) technology for collaborative environments in Virtual Reality (VR). This digital representation captures both static user attributes (age, gender, preferences) and dynamic states (emotions, facial expressions, body movements, and perceived quality scores), with the goal of enabling human-centered immersive communication systems. Through a systematic experimental methodology, the researcher analyzes how technical parameters, avatar representations, and social dynamics interact within collaborative VR contexts. The experimental framework involves 40 participants engaged in structured tasks in VR, aiming to establish correlations between network performance, avatar expressiveness, and perceived quality across multiple dimensions. The work develops multimodal data processing techniques that integrate facial expression analysis (based on 70 distinct action units), voice signal processing for emotional marker identification, and body movement analysis. These data streams, combined through fusion algorithms, enable a comprehensive assessment of user states during immersive interactions. The researcher implements machine learning architectures to predict Quality of Experience (QoE) based on multimodal inputs, creating models that relate technical parameters to subjective quality evaluations.

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Statistical validation revealed significant relationships between network conditions and perceived quality and showed how increased avatar expressiveness can mitigate the negative effects of technical issues. The research contributes both to the theoretical understanding of human perception in virtual environments and to the practical development of immersive systems capable of recognizing and responding to emotional states. The resulting multimodal dataset and predictive algorithms represent an advancement of HCT technology across various user-oriented application domains.

Concas Mattia

Research Topic:

Fabrication of Flexible Electronic Sensors Based on Organic Field-Effect Transistor Structures.

Abstract:

As the title suggests, the research project focuses on the fabrication of organic field-effect transistors (OFETs) with a dual-gate structure on flexible and ultraflexible substrates, to be used as sensors for detecting mechanical quantities such as force, pressure, temperature, and strain. The fabrication of these devices will rely on large-area techniques such as photolithography or inkjet printing, and the use of green and potentially biocompatible materials, with the aim of producing low-cost and easily manufacturable devices. Building on previous doctoral work, in which the dielectric material used was Parylene C—a plastic deposited via vapor phase deposition—the project will investigate alternative dielectric materials that can be deposited using faster yet equally effective techniques. Once the deposition process for these new dielectrics is optimized, it will allow for faster and more cost-effective device fabrication, as the involved processes will require lower energy consumption compared to current manufacturing standards. However, this optimization cannot overlook the compatibility between dielectric and semiconductor materials. In cases where both are soluble in the same solvents, depositing the dielectric directly onto the semiconductor may damage the active layer of the device, degrading its performance or

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rendering it unusable. Therefore, the research will also focus on finding the right balance between device performance and the materials used.

Cheshfar Mohammad

Research Topic:

Automation of Reconfigurable FPGA Accelerator Design through MLIR HLS.

Abstract:

Hardware accelerators are used to ensure high performance and computational efficiency. The use of FPGA technology enables the deployment of reconfigurable accelerators, offering greater flexibility but also increasing the complexity of translating software applications into specialized hardware. As part of the MYRTUS project (Multi-layer 360° dYnamic orchestrion and interopeRable design environmenT for compute-contInUum Systems), the research grant aims to develop a design flow that, starting from high-level (dataflow) specifications of the target application, is capable of generating a hardware accelerator for FPGAs. The design flow will involve extending the MDC tool, developed at the University of Cagliari, to leverage the MLIR intermediate representation. This will enable the reuse of existing optimizations within the MLIR framework and ensure interoperability of newly developed optimizations with other tools that adopt the same representation.

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Lai Maria Elena

Research Topic:

Study and Development of Wearable Systems for Monitoring Stereotypies in Rett Syndrome.

Abstract:

The activity takes place within the STOPme project — Supporting Termination Of stereotyPies in patients with RETT syndrome by advanced ambient intelligence. The project aims to develop an intelligent wearable system for multimodal monitoring and modulation of stereotypies in Rett syndrome. The system involves the combined use of wearable sensors to acquire physiological and motor signals, alongside vibroactuators designed to provide targeted interventions aimed at conditioning patients to interrupt stereotypical behaviors. A key part of the work involves data acquisition and annotation, focusing on recording signals from magneto-inertial measurement units (MIMUs) that track upper limb movements useful for characterizing motor stereotypies, as well as from a medical device that measures biopotentials and respiratory parameters. The core objective is to create annotated datasets necessary for training and validating artificial intelligence models capable of automatically recognizing motor and respiratory stereotypies, thereby enabling timely and adaptive responses in both clinical and home settings.

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Palladino Alessia

Research Topic:

Browsering the Legal Maze of HEAT: Legal Aspects of Immersive Technologies.

Abstract:

The research activity aims to assess the legal aspects of immersive technologies in the framework of the "Hybrid Extended ReAliTy (HEAT)" Project. In particular, the study focuses first on the analysis of the national and European regulatory context, in order to assess the ethical impact of immersive technologies and identify legal vulnerabilities of HEAT, developing guidelines to address these challenges and supporting the implementation of data management policies and security procedures.

Serreli Luigi

Research Topic:

Social Orchestration of Services Offered by Digital Twins.

Abstract:

The research activity focuses on the study and design of distributed discovery mechanisms and optimal service composition within social IoT networks, leveraging advanced representation models and artificial intelligence techniques. The main objective is to develop approaches capable of comprehensively modeling the behavior, attributes, data, and functionalities offered by network nodes, considered as social entities—that is, able to establish cooperative relationships, trust, and semantic proximity with other nodes. In this context, the researcher will explore service orchestration strategies based on social awareness and analysis of inter-node relationships, aiming to ensure efficient, reliable, and contextually relevant service selection and composition.

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-Start of activities in 2024:

Angioni Daniele

Research Topic:

Incremental Learning Approaches for Robotic Vision and Malware Detection.

Abstract:

The research activity is centered on the development of continual learning algorithms capable of updating machine learning models over time without little to no access to past data. This paradigm is particularly relevant in dynamic environments such as cybersecurity and computer vision, where data distributions evolve and models must adapt incrementally. A major challenge in continual learning is ensuring that model updates do not compromise previously acquired knowledge, a problem known as catastrophic forgetting. In addition, another critical issue is security regression, which occurs when samples that were correctly classified before the update are misclassified afterward. This kind of inconsistency, particularly in security-sensitive applications, is often perceived by users as a decline in performance, even in the presence of overall improvements. Furthermore, existing approaches are not designed to handle inputs from unknown categories, making the model prone to errors when deployed in the real-world. To address this, the research focuses on (i) characterizing novel failure modes, such as security regression, that emerge in continual learning scenarios; (ii) designing regularization strategies to mitigate these; and (iii) enabling models trained incrementally to safely reject or flag unfamiliar inputs encountered during inference.

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Aymerich Enrico

Research Topic:

Real-time heat flux estimation in fusion devices through machine learning techniques

Abstract:

The research activity focuses on the development of machine learning (ML) based tools for the heat flux estimation starting from thermography measurements. ML algorithms are exploited as very powerful tool towards the fast solution of direct and inverse problems related to the heat equation. As an alternative to classical methods (such as FEM or FDM), the ML approach offers reduced computational times, suitable for the strict constraints required for real-time monitoring and control in controlled fusion applications. The activity deals with two main applications. One regards the solution to the direct problem for the real time heat flux reconstruction for Plasma-Facing Components (PFCs) monitoring at Wendelstein 7-X (W7-X). The heat flux reconstruction requires the retrieval of the temperature distribution on the bulk of the tile, starting from the IR camera measurements on the plasma-facing surface. Physics Informed Neural Networks (PINNs) are trained to solve the partial differential equation. The second one concerns the fast power characterization of SPIDER (Source for Production of Ion of Deuterium Extracted from Radio frequency plasma), the negative ion beam source prototype for ITER. The characterization implies the solution of the inverse problem to reconstruct the heat flux on the front side of the calorimeter tile, facing the ion source, by processing the IR cameras measures at the back of the tiles. Neural networks, Deep learning algorithms (such convolutional neural networks) and PINNs are trained to directly solve le inverse problem.

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Balia Riccardo

Research Topic:

. Robust Machine Learning for Out-of-Distribution Sample Detection in Computer Vision.

Abstract:

The research activity focuses on the development of robust methodologies for detecting Out-of-Distribution (OOD) samples within the framework of Continual Learning, a field of increasing relevance for the design of intelligent systems capable of learning incrementally from non-stationary data streams. In such scenarios, the ability to identify inputs that do not belong to the training distribution is essential to ensure the reliability and safety of the model. The project addresses the OOD detection problem through the integration of uncertainty estimation techniques, distance-based metrics in the feature space, and regularization strategies that promote a stable-plastic balance while mitigating catastrophic forgetting. The activity includes the definition of experimental benchmarks and the quantitative evaluation of model performance in dynamic and highly variable environments. The ultimate goal is to contribute to the development of adaptive and trustworthy machine learning systems capable of operating effectively even in the presence of previously unseen data distributions.

Bossi Giuseppe

Research Topic:

Power Electronic Converters for Next-Generation Electrolyzers Powered by Renewable Energy Sources.

Abstract:

The research activity focuses on the development of innovative power electronic converter topologies for supplying next-generation electrolyzers designed for direct hydrogen production from renewable energy sources using seawater. The work will concentrate on the implementation of different converter architectures and on comparative analysis using

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scaled models directly connected to the renewable source.Specifically, the activity will aim to meet the power supply requirements of the electrolyzer under fluctuating input power conditions and to improve the overall system management, including the integration of energy storage systems.

Concas Sara

Research Topic:

Development of Methods and Models for the Recognition of Manipulated Digital Content and Anomalous Events in Crowded Environments.

Abstract:

The evolution of visual manipulation technologies and the increasing occurrence of anomalous behaviors in crowded environments have highlighted the need for intelligent tools capable of automatically analyzing images and videos. This research focuses on the development of a computer vision system designed to detect altered visual content, such as deepfakes and morphing, as well as to identify suspicious or violent behaviors within crowds, with particular attention to group dynamics and bullying phenomena.The scientific investigation aims to introduce a new architectural paradigm for the recognition of deviant behaviors through the use of advanced machine learning techniques and deep neural networks. The system is intended to automatically identify relevant signals in visual sequences and simulate their localization, in order to highlight potentially dangerous situations or subtly manipulated content.

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Fontes Pupo Ernesto

Research Topic:

Multicast Subgrouping for Mobility-as-a-Service over 5G and Beyond Networks.

Abstract:

5G and beyond technologies, particularly Multicast and Subgrouping techniques, have the potential to enhance mobility information services within the Smart Cities and Mobility-as-a-Service (MaaS) paradigm, making the entire process more sustainable. For example, these technologies enable users to share common routes or receive personalized information based on their planned itinerary. Specific radio resource allocation techniques can be improved through trust management in the information exchange among all actors involved in MaaS and mobility information services.

The research is structured around the following main points:

- Study of Multicast and Subgrouping techniques for 5G and beyond networks and their application within MaaS;
- Development of models for trust management in multicast subgrouping;
- Implementation of Multicast and Subgrouping techniques on Software Defined Radio (SDR) platforms and testing under real-world conditions.

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Fratta Matteo

Research Topic:

Investigation of Algorithms for the Prediction of Emotions and Quality Based on Facial Expressions, Vocal Characteristics, and Body Movements.

Abstract:

The research activity focuses on modeling and predicting the Quality of Experience (QoE) of multimedia content users through deep learning algorithms, based on their facial and vocal features as well as network quality metrics. The adopted approach is referred to as “multi-view,” as it integrates two or more studies (or views) containing partial and complementary data. This strategy enables improved predictive performance compared to individual models by providing a more comprehensive perspective of the scenario under analysis. Moreover, the multi-view approach is particularly valuable in contexts where privacy protection is a critical requirement, as it involves exchanging preprocessed data during an intermediate training phase, thereby avoiding the sharing of raw data. The objective of the research is to evaluate the predictive performance of the multi-view approach by comparing it with the more conventional “full-view” approach, in which a single study has access to the complete input dataset.

Jose Abey

Research Topic:

Enhancing Healthcare through Digital Twins: Predictive Approaches and Personalized Interventions for the Design of Holistic Well-Being Systems.

Abstract:

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The research activities focus on the use of Digital Twins (DTs) to support the ongoing transformation of healthcare. By integrating physiological, contextual, and lifestyle data, the Human Digital Twin is designed as a tool for predicting and preventing health issues through advanced sensor-based analytics, signal processing, and pattern recognition. These DTs act as real-time windows into the patient's condition, assisting medical diagnosis and delivering personalized health recommendations. For example, a DT could function as a personalized diabetes coach, continuously monitoring lifestyle habits and interacting with other DTs to suggest behavior modifications. This research aims to reshape healthcare by providing patients with actionable and forward-looking insights—moving beyond simple awareness and fostering lasting behavioral change.

La Cava Simone Maurizio

Research Topic:

Methods and Models for the Detection and Explainability of Facial Deepfakes.

Abstract:

In recent years, the widespread adoption and rapid evolution of deepfakes—videos and images synthetically manipulated using artificial intelligence to realistically replace a person's face with that of another—have raised significant ethical, social, and security concerns. Facial deepfakes, in particular, are becoming increasingly realistic and difficult to distinguish from authentic content. This trend poses serious threats across various domains, including disinformation, public opinion manipulation, online fraud, and reputational attacks targeting individuals and institutions. As a result, the development of robust and trustworthy tools for deepfake detection has become a critical necessity. This research project focuses on the development of novel methods and models for the automatic detection and explainable analysis of facial deepfakes. The objective is not only to accurately identify manipulated visual content but also to interpret and transparently communicate the reasoning behind the decisions made by AI systems. This aspect, known as model explainability, is essential for

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enhancing transparency, fostering ethical AI adoption, and building user trust. The research combines technical and scientific expertise with a strong emphasis on ethical and societal implications, aiming to protect citizens, public institutions, and critical infrastructure. The expected outcomes will contribute to the development of a more secure digital ecosystem and support key application areas such as news verification, cybersecurity, and forensic investigations, ultimately promoting a society more resilient to the misuse of digital technologies.

Mascia Antonello

Research Topic:

Development and Characterization of FET Devices Based on 2D Semiconductors.

Abstract:

The project aims to develop a novel fabrication technology for 2D materials based on Ion Jet Deposition (IJD), enabling their integration into thin-film electronic devices on flexible substrates. Additionally, the project seeks to enhance in-operando characterization of nanomaterials in order to better understand the fundamental mechanisms of the studied 2D materials. This knowledge will support the optimization of material design and functionality within two- and three-terminal electronic devices, such as field-effect transistors (FETs), with the goal of employing these materials as the active layer in such devices.

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Pasella Manuela

Research Topic:

Machine Learning Techniques for Pseudo-Measurement Prediction and Quality Estimation in Smart Grids.

Abstract:

The project focuses on the study and implementation of pseudo-measurement prediction algorithms in smart grids using machine learning techniques, with the aim of evaluating their quality. Specifically, algorithms for predicting active and reactive power will be developed based on artificial neural networks, in order to compare their performance with traditional measurement estimation methods, such as naïve or seasonal estimators. These algorithms are capable of providing estimates of electrical quantities that are not directly measured, by leveraging machine learning models trained on historical data. Moreover, the project aims to integrate the generated pseudo-measurements into a state estimator, in order to analyze the impact of such integration on the accuracy of system state estimation. The results obtained could promote the adoption of advanced machine learning techniques, offering a concrete opportunity to optimize the monitoring and management of smart grids.

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Piras Giorgio

Research Topic:

Robust and Efficient Machine Learning.

Abstract:

The research activity is focused on the study of the robustness of machine learning algorithms in resource-constrained scenarios, which consequently implies a reduction in model size. Typically, such size reduction is achieved through compression techniques, such as pruning methods. However, the use of these techniques results in a decrease in model performance, including robustness against adversarial attacks. It is therefore crucial to develop pruning techniques that remove redundant or less impactful model parameters while preserving and/or inducing robustness during the model reduction process—commonly referred to as adversarial pruning methods. In conclusion, the activity focuses on improving the robustness and efficiency of such adversarial pruning techniques through: (i) a systematization and taxonomy of existing methods; (ii) a benchmark for evaluating existing models, analyzing the issues of adversarial robustness evaluation; (iii) the improvement of methods through optimization techniques based on optimizing the flatness of the model's loss function.

Poursanidis Ioannis

Research Topic:

Electric propulsion system optimisation based on artificial intelligence algorithms and real-time simulations.

Abstract:

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The research activity concerns the development, modelling, management and control of hybrid energy storage systems for electric vessels, with particular reference to tugboats used within port areas. The goal of the activity is to develop highly integrated configurations, made up of different kinds of energy storage systems (electrochemical batteries, supercapacitors, fuel cells, etc.) in order to exploit their complementary features, regulating the energy flows among them and the electric propulsion motor without resorting to multiple power electronic converters. The proposed configurations, as well as the proposed management and control systems, will be validated through simulation and/or experimental studies, using appropriate software tools and hardware platforms available at the department laboratories.

Ruggeri Simona

Research Topic:

Strategies for Innovative and Sustainable Energy Development in Sardinia.

Abstract:

The research activity aims to identify strategies for sustainable energy development in Sardinia, with the aim of promoting technology transfer to the productive sector and increasing the involvement of local communities in sustainable innovation processes. After a detailed analysis of the regional energy context, different development alternatives will be examined, taking into account economic, technological, social and environmental factors. Particular attention will be paid to the potential of each alternative, the necessary network infrastructure and the related investments. Local and national impacts will also be assessed. The options identified will be compared using multi-criteria algorithms.

Salimbeni Andrea

Research Topic:

Highly Integrated Hybrid Energy Storage Systems for Electric Vessels.

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Abstract:

The research activity focuses on the development, modeling, management, and control of hybrid energy storage systems for electric vessels, with particular attention to tugboats operating within port areas. The objective is to design highly integrated configurations composed of different types of energy storage systems (electrochemical batteries, supercapacitors, fuel cells, etc.), in order to exploit their complementary characteristics. This includes managing energy flows between the various storage units and the electric propulsion motor without relying on multiple power electronic converters. The proposed configurations, along with the associated management and control systems, will be validated through simulation and/or experimental studies, using dedicated software tools and hardware platforms available in the department's laboratories.

Sanna Alessandro

Research Topic:

Advanced Techniques for Firmware Reverse Engineering in IoT Devices.

Abstract:

The project focuses on the analysis of firmware extracted from IoT devices using reverse engineering techniques. These devices, often deployed in sectors like healthcare, smart cities, and transportation, operate on highly diverse and frequently non-standard architectures. This heterogeneity complicates security analysis, as existing tools often lack compatibility and standardisation. As a result, researchers must develop ad-hoc tools, including static analysis systems like binary disassemblers and dynamic analysis frameworks such as emulators, to understand firmware behavior and uncover undocumented functionalities. Security concerns in the IoT space are exacerbated by inadequate coding practices, minimal testing, and opaque vendor implementations. These issues lead to exploitable vulnerabilities and privacy risks. Some manufacturers further complicate analysis by incorporating obfuscation or anti-reverse engineering techniques, ostensibly to protect

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intellectual property. While these measures may deter malicious actors, they also impede legitimate security evaluations. We plan to addresses these challenges by proposing a collaborative framework for IoT security evaluation. We also identify the need for clearer expectations from manufacturers, whose emphasis on rapid commercialisation often leads to devices being released with latent vulnerabilities. By examining the roles and motivations of various stakeholders, we define a workflow that accounts for architectural diversity and anti-analysis mechanisms. Ultimately, our goal is to bridge the gap between manufacturers and security analysts. By fostering cooperation and refining methodologies, we aim to support the creation of more secure and transparent IoT systems.

Taki Mohamad

Research Topic:

Fabrication of a wearable platform for the detection of biochemical species on skin.

Abstract:

Dr. Taki's work is part of the GLUCOMFORT project, which aims to develop a wearable electronic platform for detecting biochemical parameters on the skin. Specifically, the research focuses on developing an electronic interface module for reading the sensors integrated into the flexible platform and transmitting the data via Bluetooth protocol to a smartphone app developed by a project partner. Additionally, Dr. Taki contributes to the development of the flexible platform itself, a temporary tattoo created on a substrate no thicker than 2 micrometers and equipped with electrochemical sensors for detecting glucose extracted through reverse iontophoresis.

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-Start of activities in 2023:

Sivasubramaniyam Vigneselvan

Research Topic:

Research and Development of Low-Power, Cost-Effective Intelligent Sensors for Outdoor Environmental Parameter Monitoring.

Abstract:

The activity of this project focuses on the design and development of an intelligent environmental monitoring system intended for use in various means of transportation, including buses, cars, and trains. The system consists of a network of compact, low-power wireless sensors (ultra low power technology) for monitoring both environmental parameters such as temperature, humidity, atmospheric pressure, and air quality, as well as mechanical parameters like vibrations. These sensors are integrated into a platform based on an ultra low power microcontroller, enabling efficient data collection and processing. The design includes IoT and Wi-Fi connectivity to enhance system flexibility, allowing remote monitoring and seamless communication between sensor nodes and control units. Recognizing the importance of sustainability and energy independence, the project also explores the integration of energy harvesting methods from renewable sources such as solar, thermal, and vibrational energy.

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Uras Marco

Research Topic:

Design and Experimental Validation of a Distributed Device-to-Cloud Architecture for WiFi Device Counting through Sniffing on a Distributed Platform.

Abstract:

Within the scope of analyzing presence and mobility flows in public and private environments, passive counting of mobile devices via WiFi sniffing represents a promising methodology that combines effectiveness, cost-efficiency, and privacy preservation. This work presents the design and experimental evaluation of a distributed device-cloud solution for the detection and counting of WiFi devices, based on a network of low-power sensing nodes and a cloud platform for centralized data processing.

The edge nodes, developed on open-source embedded hardware, perform passive sniffing of management frames transmitted by WiFi devices (e.g., probe requests, beacons), apply anonymization techniques (e.g., hashing, entropy reduction), and transmit the collected data in real-time to a scalable cloud backend, where deduplication, temporal clustering, and aggregated analysis are performed. The proposed architecture follows an edge-to-cloud paradigm, wherein distributed intelligence alleviates computational load and reduces latency in the transmission and processing of information. The experimental campaign, conducted in controlled and semi-open environments, has a twofold objective: firstly, to validate the counting accuracy against known ground truth; secondly, to analyze challenges related to MAC address randomization, signal persistence over time, and optimal spatial coverage of the sensing node network. The results demonstrate the technical and scientific feasibility of the approach, as well as its potential applicability in scenarios such as smart cities, non-intrusive behavioural analysis, security management at public events, and optimization of commercial spaces. This contribution lies within the field of technologies for non-intrusive observation of collective behaviours and aims to provide a methodological and technological framework supporting future interdisciplinary research in urban data science, Internet of Things, and privacy engineering.

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-Start of activities in 2022:

Scrugli Matteo Antonio

Research Topic:

Implementation of Neural Networks on Low-Power Microcontrollers.

Abstract:

The research focuses on the implementation of neural networks on low-power microcontrollers, with the aim of enabling AI-based processing directly at edge nodes. The activity involved adapting deep learning models to the limited computational and energy resources typical of such devices, through optimization techniques, quantization strategies, and adaptive workload management. Configurable runtimes and scalable software architectures were developed for ARM Cortex-M microcontrollers, providing an effective trade-off between accuracy, responsiveness, and energy consumption. The proposed solutions were validated on real-world use cases, particularly in ECG monitoring, demonstrating the effectiveness of the approach in wearable and long-term medical applications.

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CONTRATTI DI RICERCA

-Start Reserch in 2025:

Lucia Pintor

Research Topic:

Key Value Indicators for Sustainable Telecommunication Networks.

Abstract:

The project aims to strengthen the role of networks as sustainable and resilient infrastructures for the benefit of society, in alignment with the goals of the 2030 Agenda. Expected outcomes include the development of a set of Key Value Indicators (KVIs) for modern telecommunication networks, methodologies for their management in multi-operator environments, and recommendations for the development of technical standards. Special attention will be given to interoperability among stakeholders, transparency in measurement processes, and the resolution of conflicts between operators pursuing differing sustainability objectives.

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BORSISTI POST DOC

-Inizio Attività :2024

Soma Gian Giuseppe

Research Topic:

Planning Models for Distribution Systems with Simulated Flexibility Markets for Local Service Provision.

Abstract:

The research grant focuses on the development of distribution systems, taking into account the role of flexibility enabled by energy storage systems, and involving both energy producers and consumers, including scenarios with differentiated networks and energy carriers. The research aims to develop models and planning techniques for distribution systems in highly complex contexts, requiring long-term analysis through models with high temporal and spatial resolution, while also considering the regulatory framework and emerging flexibility markets.

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