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Istituto di Scienza e Tecnologie dell'Informazione "A. Faedo"

# ISTI News

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## Cover Story

## The New Challenge in the 5-6G Transition

EDITORIAL

CNR & DFKI uniting forces on AI

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# CNR & DFKI uniting forces on AI

The primary goal of research institutions is to advance science. Strong connections with foreign institutions are required to achieve this, as science is inherently multinational and extensive interactions and collaboration are needed to compete and succeed.

As part of CNR's active policy to establish robust international scientific collaborations, we have recently focused on strengthening the partnership between CNR and the Deutsche Forschungszentrum für Künstliche Intelligenz (DFKI). DFKI is a German research institution engaged in a wide range of topics related to Artificial Intelligence (AI). With over 30 centers of excellence, departments, and research laboratories spread across Germany, DFKI was established to foster the development and support of research on safe and reliable AI within Germany and Europe.

The two institutions signed a collaboration agreement in July 2023 at Villa Vigoni (Como, Italy).

Following this agreement, the first joint Workshop on AI and related technologies took place at the CNR Campus in Pisa on 18-19 April 2024. The workshop was organized by Cnr-Isti (Roberto Scopigno) and the CNR Unit for International Relations (Matteo Pardo).

The workshop assessed the current state of research within the two institutions, reviewed existing collaborations, and explored opportunities for further collaborations. A key objective was also to establish a strong mutual knowledge base to prepare proposals for the first call for bilateral projects scheduled for June 2024.

The workshop was well-attended, with over 50 researchers from both institutions participating. Regarding CNR's involvement, Cnr-Icar, Cnr-Iit, Cnr-Ilc, Cnr-Istc, Cnr-Isti, and Cnr-Stiima all contributed. Additionally, about twenty researchers represented the German research center.

The workshop format was designed to allow participants to present their current activities and vision through brief talks, while also initiating discussions on potential collaborations through moderated discussions. Each session (as outlined in the program below) combined presentations with moderated discussions to facilitate both knowledge sharing and collaboration exploration.

Participants presented and stimulated discussions on various themes related to AI, considering at the same time scientific challenges and societal opportunities. Discussions on AI and Natural Language Processing highlighted the opportunities offered by recent advances in Large Language Models as well as the challenges involved in mitigating the problem of large-scale misinformation.

AI offers new perspectives for supporting medical diagnoses and medical decisions. Several research areas were identified where a fruitful collaboration can be fostered. The workshop addressed themes related to the use of AI in Robotics, considering Human Robot Collaboration, Space Robotics, Decisional Control, and Adaptive Control, where AI can contribute significantly to enhancing the capabilities of current robotic systems. Additional interesting possibilities for interaction were the issues and opportunities of using AI in applicative areas including Human Computer Interaction, Underwater research, and Extended Reality, where AI offers the possibility of addressing

## EXTENDED PROGRAM

### Day 1 – April 18th

| | |
|---|---|
| 14:00 - 14:20 | **WS Opening \|** Matteo Pardo (CNR) |
| 14:20 - 15:00 | Session 1: **AI & Natural Language Processing**<br>Moderator: Andrea Esuli<br>Speakers:<br>Simonetta Montemagni (CNR-ILC)<br>Andrea Pedrotti (CNR-ISTI)<br>Simon Ostermann (DFKI-SLT / DFKI-MLT)<br>Carlos Franzreb (DFKI) |
| 15:00 - 15:45 | Session 2: **Embedded Intelligence & Effects of AI on Society**<br>Moderator: Chiara Boldrini<br>Speakers:<br>Andrea Passarella (CNR-IIT)<br>Mirco Nanni (CNR-ISTI)<br>Giuseppe Manco (CNR-ICAR)<br>Andrea Sipka (DFKI (DSA), RPTU Kaiserslautern) |
| 15:45 - 16:15 | **Coffee Break** |
| 16:15 - 17:00 | Session 3: **AI & Health - Intelligent support to medical decision processes**<br>Moderator: Sara Colantonio<br>Speakers:<br>Nadia Brancati (CNR-ICAR)<br>Alessandro Brusaferri (CNR-STIIMA)<br>Daniel Sonntag (DFKI Oldenburg) |
| 17:00 - 17:30 | Session 4: **Human Robot cooperation**<br>Moderator: Carmen Santoro<br>Speakers:<br>Nicola Pedrocchi (CNR-STIIMA)<br>Tim Schwartz (DFKI Saarbrücken) |

several still unsolved issues from a new perspective. There were also productive discussions on foundational themes related to the development of solutions for Neuro-symbolic Machine Learning, and the creation of an Embedded Intelligence, also considering their impact on society.

On the second day of the workshop, we were honored to have with us Prof. Maria Chiara Carrozza, the President of CNR, Prof. Antonio Krüger, the CEO of DFKI, and Dr. Emilio Fortunato Campana, the Director of the CNR Department on Engineering, Computing, and Technologies for Energy and Transportation (Cnr-Diitet).

President Carrozza stressed the importance of enhancing collaboration between Italy and Germany on issues of mutual interest and significant societal impact, such as AI. She expressed her hope that gatherings like this workshop would serve as an initial step towards establishing a common European research infrastructure for AI.

The presence of senior executives from both institutions provided an opportunity to brainstorm on potential future actions aimed at strengthening collaboration and for proposing ideas for funding institutions.

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## Day 2 – April 19th

| | |
|---|---|
| 09:00 - 9:40 | Session 5: **AI & Health - Smart, interactive and assistive techn**<br>Moderator: Chiara Boldrini<br>Speakers:<br>M. Antonietta Pascali (CNR-ISTI)<br>Franca Delmastro (CNR-IIT)<br>Roland Roller (DFKI - Speech and Language Technology)<br>Sebastian Vollmer (DFKI Kaiserslautern) |
| 09:40 - 10:10 | Session 6: **Neuro-symbolic Machine Learning**<br>Moderator: Andrea Esuli<br>Speakers:<br>Franco Alberto Cardillo (CNR-ILC)<br>Umberto Straccia (CNR-ISTI)<br>Philipp Slusallek (DFKI & Uni Saarbrucken) |
| 10:10 - 10:40 | **Coffee Break** |
| 10:40 - 11:00 | **Institutional Greetings** \| M. Chiara Carrozza (President of CNR)<br>Antonio Krüger (DFKI) |
| 11:00 - 11:40 | Session 7: **Explainable AI**<br>Moderator: Umberto Straccia<br>Speakers:<br>Fosca Giannotti (Scuola Normale Superiore)<br>Mirco Nanni (CNR-ISTI)<br>Philipp Slusallek (DFKI & Uni Saarbrucken)<br>Simon Ostermann (DFKI- SLT / DFKI-MLT) |
| 11:40 - 12:15 | Session 8: **AI & Human Computer Interaction**<br>Moderator: Paolo Cignoni<br>Speakers:<br>Fabio Paternò (CNR-ISTI)<br>Antonio Krüger (DFKI)<br>Fabrizio Nunnari (DFKI) |
| 12:30 - 14:00 | **Lunch** |
| 14:00 - 14:30 | Session 9: **AI & Robotics - Decisional Autonomy, Adaptive con**<br>Moderator: Giuseppe Amato<br>Speakers:<br>Andrea Orlandini (CNR-ISTC)<br>Sebastian Stock (DFKI-PBR) |
| 14:30 - 15:00 | Session 10: **Space Robotics**<br>Moderator: Luciano Anselmo<br>Speakers:<br>Angelo Oddi (CNR-ISTC)<br>Daniel Kühn (DFKI & Universität Bremen) |
| 15:00 - 15:30 | **Coffee Break** |
| 15:30 - 16:00 | Session 11: **AI & Underwater Research**<br>Moderator: Sara Colantonio<br>Speakers:<br>Massimiliano Corsini (CNR-ISTI)<br>Leif Christensen (DFKI & Universität Bremen) |
| 16:00 - 16:40 | Session 12: **AI & XR (eXtended Reality)**<br>Moderator: Fabrizio Falchi<br>Speakers:<br>Giuseppe Amato (CNR-ISTI)<br>Marco Sacco (CNR-STIIMA)<br>Nadia Robertini (DFKI & Uni Kaiserslautern)<br>Philipp Slusallek (DFKI & Uni Saarbrucken) |
| 16:40 – 17:00 | **Closing remarks** \| Antonio Krüger (DFKI) |

# The New Challenge in the 5-6G Transition

## A change of paradigm to design next-generation mobile networks

Mobile network services have significantly increased in quality and coverage during the last decade, especially in terms of data services. While 4G technology has enabled massive use of data services with ease and satisfaction for users, 5G technology promises to consolidate this trend by offering increasingly diverse connectivity that best covers urban and rural areas.


5G technology entails designing a more reliable and efficient network, due to the demand for more flexible services, higher capital (CAPEX) and operating (OPEX) efficiency, as well as growing data traffic. 5G technology thus involves renewing the radio standard and transforming the core and the transmission network into a Service Oriented Architecture (SOA) to optimize the available resources by meeting the needs of each service.

In this scenario, virtualization technologies are now essential tools for the future of telecommunications networks. These technologies are crucial in cutting expenses because they enable the use of general-purpose hardware for tasks that were previously exclusive to specialized equipment, such as switches and routers. This change is a more significant movement toward network function virtualization (NFV). It makes it easier to create and configure new containers or virtual machines (VMs) to handle growing services or relieve pressure. This means that operators can tailor their commercial offer, particularly for business users.

The introduction of AI in communication networks has led to further architectural evolution of the network, providing the tools for addressing any issues in network management by adopting, for example, optimized network slicing to guarantee the service level agreement (SLA). Emerging services can thus be delivered, such as augmented reality, telemedicine, and autonomous driving. This then avoids the need for people to expose themselves to risky jobs, and also provides more pervasive and effective health care.

To make network design more dynamic and efficient, 5G technology has introduced two crucial architectural aspects: the separation between the network functions (NFs) of the user plane (UP) and control plane (CP), and a decreased interdependence between the radio access network (RAN) and the core network (CN). This means that network deployments can evolve and be scaled up with the number of requested accesses to the infrastructure and the data traffic generated. This new approach increases the network's

flexibility and effectiveness in handling heterogeneous access technologies and service requests with different SLA, incentivizing the latest trends in terms of development for 5G infrastructure described below:

### Tailored 5G Core Implementation:

Mobile service providers are developing their packet core solutions (stand-alone) considering the evolution of radio access technologies for providing services such as ultra-low latency and network slicing at the best of their capabilities;

### Densification of the Access Coverage:

Carriers are deploying access radio infrastructures based on small cells to enhance the coverage capabilities of the cellular network even in very densely populated areas;

### Virtualization of the RAN:

Open RAN 5G is a network architecture that promotes interoperability and standardization of hardware and software from different vendors. Unlike traditional RAN systems, where a single vendor provides a closed solution, the Open RAN decouples hardware and software components, allowing operators to mix and match equipment from different vendors, even those operating in the satellite market. Open RAN can facilitate competitive and dynamic ecosystems, which can lead to more rapid advancements and improvements in network performance and services;

### AI Exploitation:

AI is revolutionizing 5G networks, triggering innovative solutions for automated network management. AI can automate complex network management tasks, such as network optimization regarding bandwidth, latency, and reliability; prediction of potential failures to reduce downtimes and operational costs; along with security enhancement detecting and responding to security threats in real-time.

These new technological trends have consequently opened up challenges:

- Operators face financial challenges installing 5G infrastructure, including hardware, software, spectrum acquisition, configuration, testing, and maintenance. Most of the costs are due to the high setup costs of microcells and small cells. These expenses significantly impact the overall budget and operational finances;
- 5G networks require many small cells to manage high traffic volumes via backhaul connections. Upgrading backhaul technology, such as using fiber optics or satellite connection for high-speed links, poses deployment challenges to meet 5G expectations;
- Developing a multi-provider 5G infrastructure over different countries involves challenges on spectrum licensing, data privacy, security, and environmental restrictions, which force operators to find agreements with regulators in the region where the network is deployed.

Nevertheless, the challenges for 5G to provide high bandwidth, as well as ultra-low latencies, have incentivized both residential and business users to demand services for applications such as cloud computing and AI-as-a-service. This has generated a higher demand than operators can currently satisfy. In fact, data traffic has reached an astonishing 2.6 billion Tera Byte (TB), with 76% expected from 5G technology, and by 2028, data traffic will reach 3.4 billion TB, illustrating the exponential growth driven by 5G connectivity. Consequently, research and development have become a priority in the industry, as proven by the over 20,800 patents submitted in the last few years.

Many research and technological development challenges are still open in this field. For this reason, ISTI and Huawei DataCom established a joint research laboratory in 2024 to investigate open issues in the field of AI for telecommunication and networking, leading them to collaborate at The European Telecommunication Standard Institute. Within the scope of agreed joint R&D projects, Huawei provides competencies and resources aimed at proof-of -concept applications and technology validations in test and real environments, as well as technical expertise. ISTI will exploit components of WNLAB for the development of agreed joint innovation initiatives using Huawei equipment and open-source software for research purposes. In addition to the mutual exchange of technical and scientific expertise, the collaboration aims to develop core competencies in the fields addressed. This can lead to joint participation in EU-funded projects, as well as involvement in standardization activities within the European Union.

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# ECHOES

## European Cloud for Heritage OpEn Science
## Funded by Horizon Europe

In June 2022, the European Commission announced its commitment to supporting the creation of a comprehensive collaborative cloud for cultural heritage. The aim is to strengthen connections between various heritage institutions and sector professionals, improving the understanding, documentation, preservation, and promotion of both tangible and intangible cultural heritage across Europe. A digital ecosystem will be set up to interconnect and harmonize practices related to cultural heritage digital objects.

The CNR, CNRS (Centre National de la Recherche Scientifique) and FSP (Fondation des Sciences du Patrimoine), therefore assembled a broad consortium of 51 European partners. These partners include research organizations, networks representing cultural heritage communities (museums, libraries, archives, restoration, and intangible cultural heritage professionals. CNRS, CNR and FSP will lead the project under the scientific coordination of Xavier Rodier (CNRS), with the participation of four institutes of CNR (ISTI, ISPC, ILC, and ICMATE). The project started on 1 June this year, and ISTI's Paolo Cignoni will lead the CNR participation.

The ECHOES project will foster the development of the Digital Commons through this digital environment, facilitating the collective enrichment and analysis of cultural heritage objects, facts, or phenomena. Actors—both human and artificial intelligence (AI)—will be able to develop their interpretations and thus contribute to the construction of knowledge. As a pilot project, ECHOES aspires to create the infrastructure and legal entity for the cloud in collaboration with and for the cultural heritage communities. ECHOES promotes a holistic approach to digital transformation, encouraging the co-construction of knowledge.

Thanks to a transparent governance approach and the application of open science principles, ECHOES will also integrate other European and national projects within the cloud.

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# ATRIUM

## Advancing FronTier Research In the Arts and hUManities
## Funded by Horizon Europe

Arts and Humanities is a very diverse field, covering a range of disciplines and communities of practice that have different epistemological and methodological foundations. However, research infrastructures in the Arts and Humanities domain have to cater to a very wide range of stakeholders and offer services that cut across discipline-specific boundaries.

The ATRIUM project (Advancing FronTier Research In the Arts and hUManities) will exploit and strengthen complementarities between leading European infrastructures - DARIAH, ARIADNE, CLARIN and OPERAS - in order to provide vastly improved access to a rich portfolio of state-of-the-art services available to researchers across countries, covering all phases of the research data life-cycle (creating, processing, analyzing, preserving, providing access to and reusing).

Cnr-Isti will contribute to this in two ways: firstly by supporting the access and manipulation of the metadata of heritage resources through advanced semantic-web tools, and secondly by working on the management and visualization of complex 3D datasets, through its open-source software solutions.

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# IRISCC

## Integrated Research Infrastructure Services for Climate Change risks Funded by Horizon Europe

Effective climate change adaptation requires a deep comprehension of climate change-induced risks, including their factors, such as hazards, exposure levels, inability to cope with the adverse effects of climate change and their impacts on human, production, and natural systems.

The Integrated Research Infrastructure Services for Climate Change Risks (IRISCC) is a collaborative network of leading research infrastructures spanning various disciplines, from the natural to the social sciences, and across multiple domains and sectors.

IRISCC is dedicated to advancing pioneering research and informed policy decisions to bolster Europe's capacity to withstand climate change. It serves as a comprehensive resource hub for diverse user groups, offering a meticulously curated catalogue of services. This catalogue facilitates transnational access (on-site and remote) and virtual engagement through three progressive stages to provide increasingly cohesive services.

The service Integration within IRISCC will include Service Design Labs that embrace collaborative design and interdisciplinary approaches alongside Service Demonstrators who will evaluate the efficacy of combined services across different research infrastructures. As well as serving the scientific community, IRISCC extends its expertise to policymakers and key stakeholders through knowledge services and risk management platforms.

The research facilitated by IRISCC is instrumental in shaping the future discourse on climate change, contributing to authoritative reports (such as those by the IPCC and IPBES) and supporting policy and decision-making aligned with climate adaptation goals.

IRISCC is pivotal in educating new scientists to become proficient in using research infrastructure services and managing data. The data generated by IRISCC will be open access, adhering to FAIR principles, and integrated with European initiatives such as the EOSC. IRISCC is also committed to forging strong connections with projects under Horizon Europe.

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# AGRITECH EU

## Digital agriculture for sustainable development
## Funded by Horizon Europe

The primary objective of the project is the design and delivery of higher education programme(s) – first level Master's (ISCED LEVEL 7 or equivalent) toglierei la parte in verde - the enrichment of existing bachelor's and master's degrees, and the development of self-standing modules/ courses (online or in-person) to train specialists in digital transition for farms and food companies, leading to recognized certifications.

These objectives will be achieved by a European consortium of seven higher education institutions, five businesses, and one centre of excellence.

Digitalization in agriculture can have four key benefits: increase in productivity, improve the efficiency and quality of work, reduce pressure on natural resources, and promote market integration. It can also enhance farmers' access to knowledge, foster peer-to-peer learning, support innovation networks, improve rural-urban and producer-consumer links, and reduce bureaucratic burdens. However, the opportunities for economic, social, and environmental prosperity enabled by digitalization also come with risks. Unregulated digitalization in agriculture, or incentivizing acceptance without offering sufficient (regulatory) protection, may have harmful economic, social, and environmental consequences for vulnerable individuals, communities, and regions across the EU. To maximize equitable opportunities and to mitigate the risks, companies need to increase their know-how and capabilities in order to use digital technologies effectively and responsibly.

The project aims to design and deliver international higher education programmers dedicated to training specialists in Digital Agriculture:

- to explore technological solutions for digital agriculture with a responsible innovation approach
- to interact with technology suppliers and developers for the design and selection of innovative applications
- to use digital agriculture tools
- to assess the socio-economic impacts of digital technologies

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# GreenDIGIT

## Greener Future Digital Research Infrastructures Funded by Horizon Europe

To maintain excellence in Research Infrastructures, it is essential to develop new technologies aimed at minimising environmental impacts, reflecting a wider societal goal to reduce ecological footprints. Digital infrastructures currently contribute 3 to 4% of global greenhouse gas emissions, and this figure is expected to triple by 2050. Therefore, prioritising the reduction of the environmental impact of these infrastructures is crucial.

GreenDIGIT brings together four major distributed Digital Infrastructures at different lifecycle stages: EGI, SLICES, SoBigData, and EBRAINS. These four infrastructures aim to reduce the environmental impact by developing solutions that are reusable across the whole spectrum of digital services on the ESFRI landscape, and also serving as a role model in doing so.

GreenDIGIT will capture best practices and existing solutions and will develop new technologies and solutions for all aspects of the digital continuum: from service provision to monitoring, job scheduling, resource allocation, architecture, workload and Open Science practices, task execution, storage, and use of green energy.

GreenDIGIT will deliver these solutions as building blocks, with a reference architecture and guidelines for RIs to lower their environmental footprint.

These new solutions will be validated through scientific use-cases from different disciplines. They will be promoted through an active dissemination and training programme for providers and users, in order to prepare the next generation of Digital RIs with a low environmental footprint.

Within this project, ISTI will leverage its InfraScience and KDD labs to support the operation of a Virtual Research Environment (VRE) dedicated to Sustainable, Reproducible, and Open Science. This VRE will assist researchers in designing experiments that establish transparent Open Science practices, preventing the unnecessary repetition of experiments by ensuring that the results are reliable. Additionally, the VRE will include tools for assessing the environmental impact within the SoBigData RI, identifying sustainability best practices and opportunities. Features such as energy usage reporting and enhanced reproducibility capabilities will also be integrated to encourage the adoption of low-energy practices.

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# OSTrails

## Open Science Plan-Track-Assess Pathways Funded by Horizon Europe

Fragmentation and inefficiency in scientific data management pose significant threats to the progress of FAIR (Findable, Accessible, Interoperable, and Reusable) research practices. Existing infrastructure struggles to create a truly interconnected landscape. For instance, the lack of open, high-quality knowledge graphs hinders data traceability.

OSTrails brings together 38 partners and 24 pilots, fostering a collaborative spirit to address this challenge head-on. The project envisions a comprehensive solution that will revolutionize data management, establish interoperable knowledge graphs, and deliver modular FAIR tests. This holistic approach promises to propel FAIR principles to the forefront of the research lifecycle.

Recognizing the diverse tapestry of research disciplines and national contexts, OSTrails prioritizes flexibility. By fostering collaboration, it aims to enhance data traceability and enable evidence-based evaluation. Instead of simply refining existing tools, OSTrails pushes the boundaries by developing advanced processes and instruments for planning, tracking, and assessing scientific knowledge production.

Innovations that Empower:

- From Static to Dynamic: OSTrails breathes new life into Data Management Plans (DMPs). Given that they are no longer static documents, DMPs become dynamic, machine-actionable resources, empowering researchers to identify and implement FAIR practices with greater ease.
- Knowledge Graphs: The FAIR Landscape project establishes a network of open, interoperable Scientific Knowledge Graphs (SKGs). These enriched knowledge graphs will serve as a powerful testament of a community's commitment to FAIR principles, fostering transparency and trust.
- Modular Tests for Continuous Improvement: OSTrails delivers modular and extendable FAIR tests, paving the way for "machine-actionable" metrics. User-friendly guidance embedded within tools will further empower researchers throughout their research journey.

The OSTrails Commons: A Shared Resource for All.

The project's final outcome is the OSTrails Commons, a comprehensive repository of methods, tools, services, guidance, and training materials. These components act as building blocks for end-to-end solutions aimed at two key stakeholders:

- Researchers and research support personnel: By obtaining the necessary tools and knowledge, users can champion FAIR principles at every stage of the research lifecycle, regardless of the data format.
- Research funding organisations, research performing organisations, and publishers: These stakeholders will be equipped to drive significant improvements in research data management (RDM) across all shared, funded, and published research outputs.

OSTrails aims not only to reduce the barriers to adopting FAIR practices but also to shift the paradigm. It envisions a future where FAIR is not just assessed but actively practiced, leading to enhanced data traceability and a more robust, evidence-based approach to research evaluation. By embracing collaboration and acknowledging the diverse research landscape, OSTrails promises to weave a FAIRer fabric for scientific progress.

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# RAISE

## Robotics and AI for Socio-economic Empowerment
## Funded by MUR (Programma Ecosistema Innovativo PNRR- Spoke 5)

The purpose of Robotics and AI for Socio-economic Empowerment (RAISE) is to design human-based ecosystems backed by AI and Robotics aimed at a better future. RAISE stands for an inclusive urban and domestic environment, for personal and remote healthcare, environmental care and protection, and green and smart ports with the goal of improving services in these areas in Liguria. By valuing individuals' needs and bringing the research to the market, RAISE transfers technology, providing resources, knowledge, and support, while generating and supplying sustainable, inclusive, and resilient innovation.

The project is coordinated by IIT, UniGe, and CNR, with the contribution of 20+ affiliates, working on five different spokes: (i) Urban Technologies for Inclusive Engagement i.e. the design and development of technologies for the inclusive exploitation of the urban and domestic environment particularly issues related to cognitive and sensory disabilities, children, and the elderly; (ii) Smart Devices and Technologies for Personal and Remote Healthcare i.e. the creation of robotic systems, prostheses, exoskeletons, devices and intelligent environments for personal care, also remotely; (iii) Sustainable environmental caring and protection technologies i.e. the development of robotic systems, techniques for the accumulation and distribution of energy and systems for monitoring and preventing natural and anthropogenic risks for urban, terrestrial, marine and coastal ecosystems; (iv) Smart and sustainable ports i.e. the creation of monitoring and simulation systems, robotic and AI technologies for logistics and security in the port and marine sector; (v) Technology Transfer & Development i.e. the transfer of the knowledge generated by the ecosystem to the market with a consequent impact on economic, social and technological factors at local, national and international levels.

The InfraScience Lab contributes to these activities by supporting the development of an open data platform that leverages D4Science services and facilitates the publication of research data stemming from the research activities. This is done by promoting open science practices and making the published outcomes findable, accessible, interoperable and reusable.

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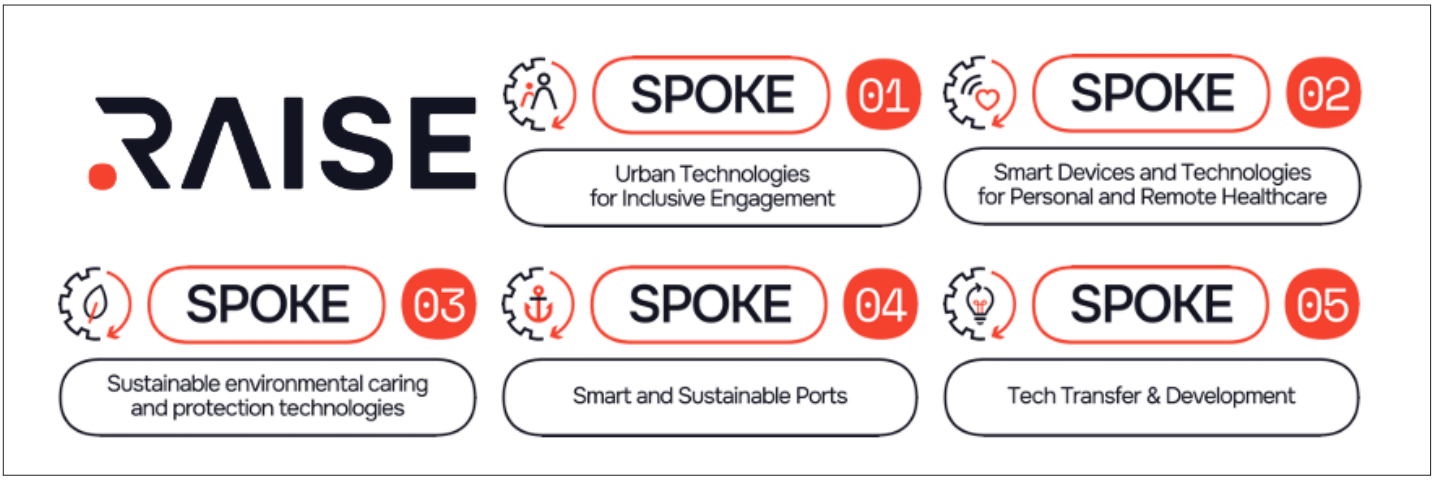
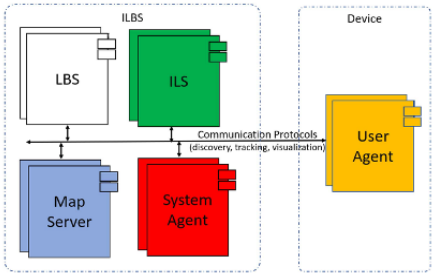


# Integrating Indoor Localization Systems through a Handoff Protocol

F. Furfari, M. Girolami, P. Barsocchi

IEEE Journal of Indoor and Seamless Positioning and Navigation, vol. 2. IEEE, 2024.




ILBS hardware and software subsystems.

The increasing adoption of location-based services drives the pervasive adoption of localization systems available anywhere. Environments equipped with multiple indoor localization systems (ILSs) require managing the transition from one ILS to another in order to continue localizing the user's device even when moving indoor or outdoor. In this article, we focus on the handoff procedure, whose goal is to enable a device to trigger the transition between ILSs when specific conditions are verified. We distinguish between the triggering and managing operations, each requiring specific actions. We describe the activation of the handoff procedure by considering three types of ILSs design, each with increasing complexity. Moreover, we define five handoff algorithms-based RSSI signal analysis and we test them in a realistic environment with two nearby ILSs. We establish a set of evaluation metrics to measure the performance of the handoff procedure.

**DOI:** 10.1109/JISPIN.2024.3377146

# FedCMD: a Federated Cross-modal Knowledge Distillation for Drivers' Emotion Recognition

S. Bano, N. Tonellotto, P. Cassarà, A. Gotta

ACM Transactions on Intelligent Systems and Technology, vol. 15. ACM, 2024.

Emotion recognition has attracted a lot of interest in recent years in various application areas such as healthcare and autonomous driving. Existing approaches to emotion recognition are based on visual, speech, or psychophysiological signals. However, recent studies are looking at multimodal techniques that combine different modalities for emotion recognition. In this work, we address the problem of recognizing the user's emotion as a driver from unlabeled videos using multimodal techniques. We propose a collaborative training method based on cross-modal distillation, i.e., "FedCMD" (Federated Cross-Modal Distillation). Federated Learning (FL) is an emerging collaborative decentralized learning technique that allows each participant to train their model locally to build a better generalized global model without sharing their data. The main advantage of FL is that only local data is used for training, thus maintaining privacy and providing a secure and efficient emotion recognition system. The local model in FL is trained for each vehicle device with unlabeled video data by using sensor data as a proxy. Specifically, for each local model, we show how driver emotional annotations can be transferred from the sensor domain to the visual domain by using cross-modal distillation. The key idea is based on the observation that a driver's emotional state indicated by a sensor correlates with facial expressions shown in videos. The proposed "FedCMD" approach is tested on the multimodal dataset "BioVid Emo DB" and achieves state-of-the-art performance. Experimental results show that our approach is robust to non-identically distributed data, achieving 96.67% and 90.83% accuracy in classifying five different emotions with IID (independently and identically distributed) and non-IID data, respectively. Moreover, our model is much more robust to overfitting, resulting in better generalization than the other existing methods.

**DOI:** 10.1145/3650040

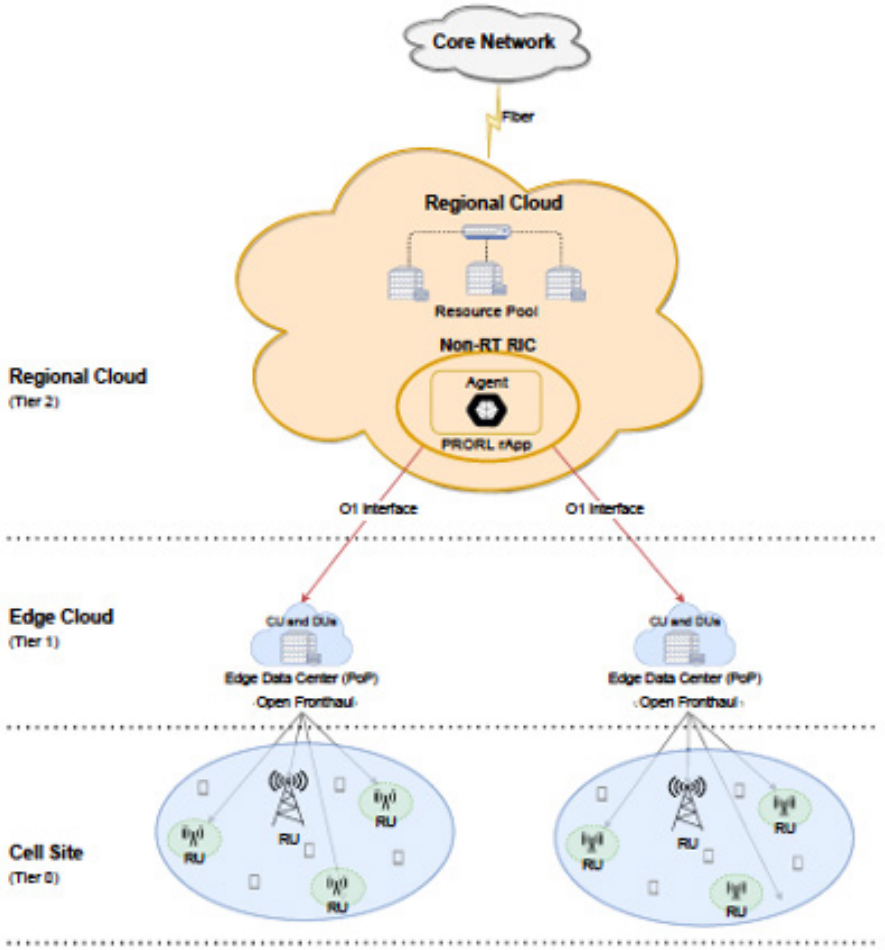
# PRORL: Proactive Resource Orchestrator for Open RANs using Deep Reinforcement Learning

A. Staffolani, V.-A. Darvariu, L. Foschini, M. Girolami, P. Bellavista, M. Musolesi

IEEE Transactions on Network and Service Management, Early Access, IEEE, 2024.

Open Radio Access Network (O-RAN) is an emerging paradigm proposed for enhancing the 5G network infrastructure. O-RAN promotes open vendor-neutral interfaces and virtualized network functions that enable the decoupling of network components and their optimization through intelligent controllers. The decomposition of base station functions enables better resource usage, but also opens new technical challenges concerning their efficient orchestration and allocation. In this paper, we propose Proactive Resource Orchestrator based on Reinforcement Learning (PRORL), a novel solution for the efficient and dynamic allocation of resources in O-RAN infrastructures. We frame the problem as a Markov Decision Process and solve it using Deep Reinforcement Learning; one relevant feature of PRORL is that it learns demand patterns from experience for proactive resource allocation. We extensively evaluate our proposal by using both synthetic and real-world data, showing that we can significantly outperform the existing algorithms, which are typically based on the analysis of static demands. More specifically, we achieve an improvement of 90% over greedy baselines and deal with complex trade-offs in terms of competing objectives such as demand satisfaction, resource utilization, and the inherent cost associated with allocating resources.

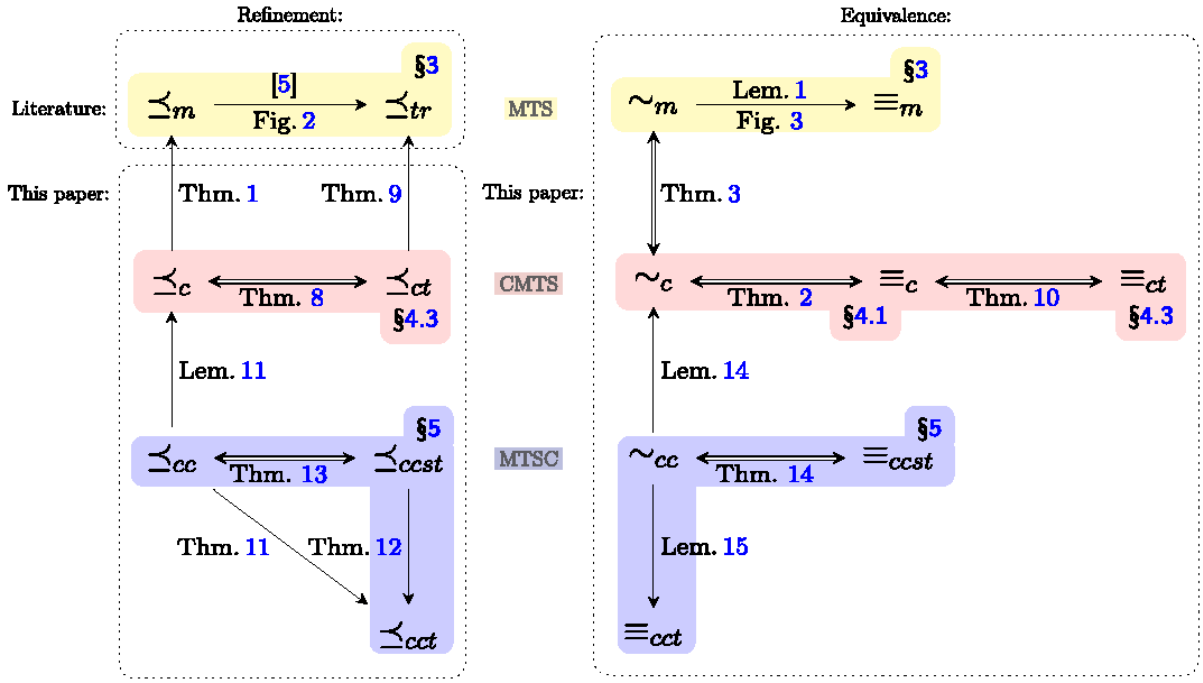
**DOI:** 10.1109/TNSM.2024.3373606




Graphical overview of our reference multi-tier O-RAN architecture.

# Coherent Modal Transition Systems Refinement

D. Basile, M. H. ter Beek, A. Fantechi, S. Gnesi
Journal of Logical and Algebraic Methods in Programming, vol. 138. Elsevier, 2024.




Overview of the main contributions of this paper: the yellow relations in the top row concern MTS, the red relations in the middle row concern CMTS, the blue relations in the bottom row concern MTSC; a single arrow represents implication, while a double arrow represents coincidence. It is also indicated which results are original and which are taken from the literature (viz., the results on MTS in the upper left box). Note that no specific theorem is central to all the others.

Modal Transition Systems (MTS) are a well-known formalism that extend Labelled Transition Systems (LTS) with the possibility of specifying necessary and permitted behaviour. Coherent MTS (CMTS) have been introduced to model Software Product Lines (SPL) based on a correspondence between the necessary and permitted modalities of MTS transitions and their associated actions, and the core and optional features of SPL.

In this paper, we address open problems of the coherent fragment of MTS and introduce the notions of refinement and thorough refinement of CMTS. Most notably, we prove that refinement and thorough refinement coincide for CMTS, while it is known that this is not the case for MTS. We also define (thorough) equivalence and strong bisimilarity of both MTS and CMTS. We show their relations and, in particular, we prove that also strong bisimilarity and equivalence coincide for CMTS, whereas they do not for MTS. Finally, we extend our investigation to CMTS equipped with Constraints (MTSC), originally introduced to express alternative behaviour, and we prove that novel notions of refinement and strong thorough refinement coincide for MTSC, and so do their extensions to strong (thorough) equivalence and strong bisimilarity. The figure illustrates our main contributions. Most notably, refinement of CMTS is proved to be sound and complete, while refinement is known to be sound but not complete for MTS (cf., e.g., [5]: K.G. Larsen, U. Nyman and A. Wąsowski, On Modal Refinement and Consistency. In Proceedings of the 18th International Conference on Concurrency Theory (CONCUR'07), Lecture Notes in Computer Science, vol. 4703. Springer, 2007, pp. 105–119, doi: 10.1007/978-3-540-74407-8_8).

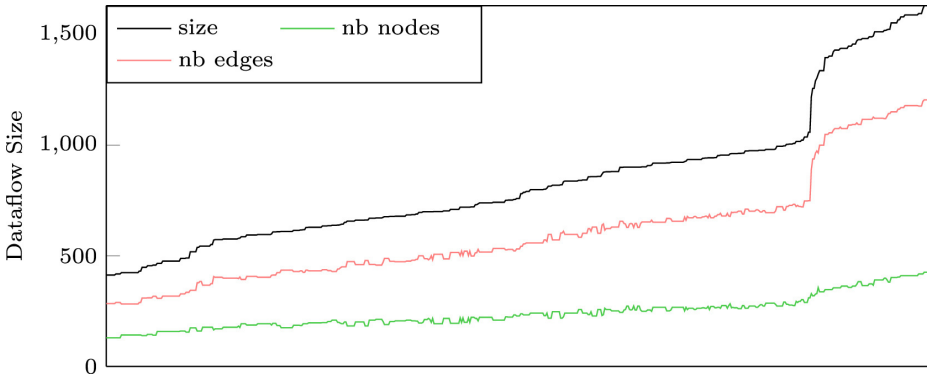
**DOI:** 10.1016/j.jlamp.2024.100954

# Product Lines of Dataflows

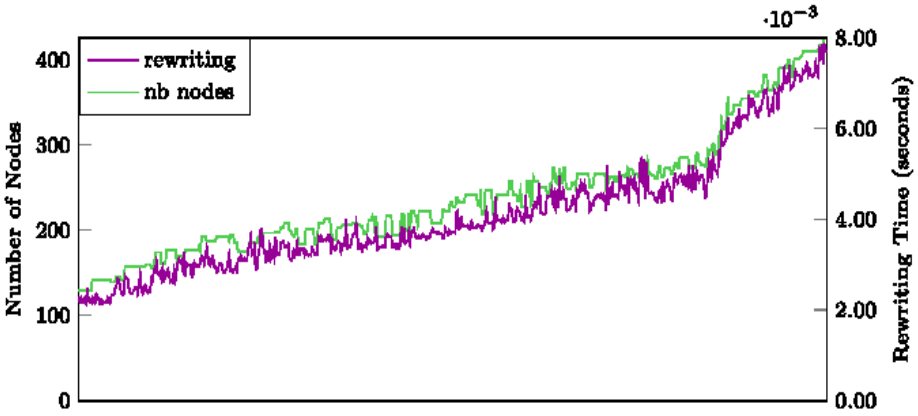
M. Lienhardt, M. H. ter Beek, F. Damiani

The Journal of Systems and Software, vol. 210. Elsevier, 2024.

Data-centric parallel programming models such as dataflows are well established to implement complex concurrent software. However, in the context of a configurable software, the dataflow used in its computation might vary with respect to the selected options: this happens in particular in fields such as Computational Fluid Dynamics, where the shape of the domain in which the fluid flows and the equations used to simulate the flow are all options configuring the dataflow to execute.




Size of generated Dataflows – the x-axis lists the 597 generated dataflows ordered by size (i.e., number of nodes + number of edges).




Computation time with respect to dataflow size; the x-axis lists the 597 generated dataflows ordered by size (i.e., the sum of the number of nodes and the number of edges).

In this paper, we present an approach to implement product lines of dataflows, based on Delta-Oriented Programming and term rewriting. This approach includes several analyses to check that all dataflows of a product line can be generated. Moreover, we discuss a prototype implementation of the approach and demonstrate its feasibility in practice. Since there are no standard benchmarks for dataflow generation, we constructed 597 dataflow generation problems to evaluate. The smallest generated dataflow has 129 nodes and 284 edges, while the largest has 426 nodes and 1205 edges. We first implemented a test product line, which contains a subpart of the available configuration space, with 97 features, 173 functions and 1493 deltas. We then computed the average time for the product line flattening and rewriting steps for our test. While the time taken by the former is bounded by the time needed to execute all its deltas, the rewriting step can take an arbitrary amount of time. The figure shows that in our test, the execution time for the rewriting step evolves linearly with respect to the number of nodes in the dataflow. Hence, we believe that our approach can scale to larger dataflows.

**DOI**: 10.1016/j.jss.2023.111928

# Flakiness Goes Live: Insights from an In Vivo Testing Simulation Study

M. Barboni, A. Bertolino, G. De Angelis

Information and Software Technology, vol. 167. Elsevier, 2024.

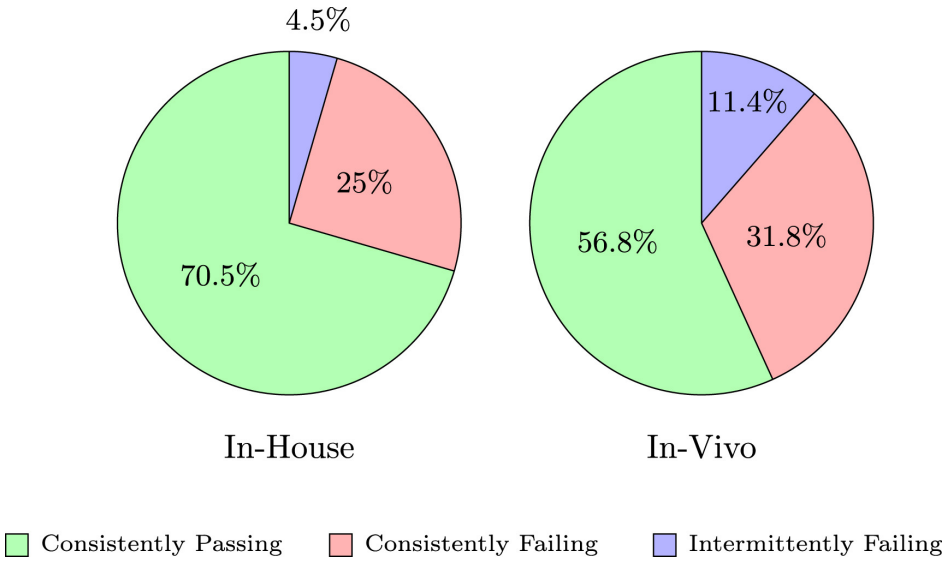
Context: Test flakiness is a topmost concern in software test automation. While conducting pre-deployment testing, those tests that are flagged as flaky are put aside for being either repaired or discarded.

Objective: We hypothesize that some flaky tests could provide useful insights if run in the field, i.e., they could help identify failures that manifest themselves sporadically during In House testing, but are later experienced in operation.

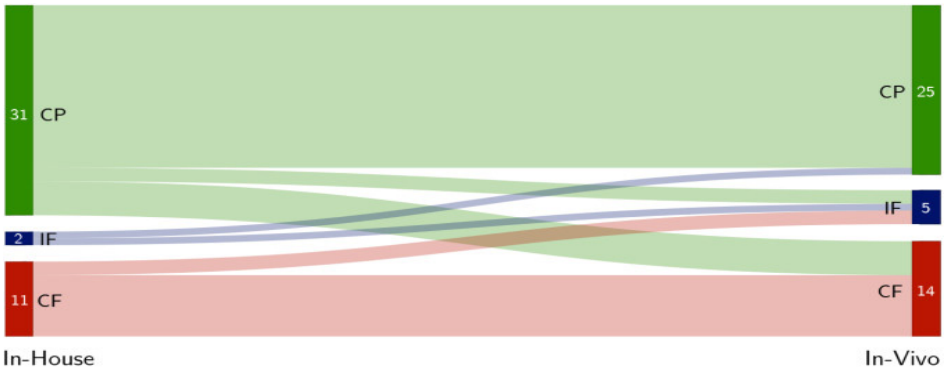
Method: We present the first simulation study to investigate the behaviour of flaky tests when moved to the field. The work compares the behaviour of known flaky tests from an open-source library when executed in the development environment vs. when executed in a simulation of the field.

Results: Our experimentation over 52 test methods labelled as flaky provides a first confirmation that moving from the development environment to the field, the behaviour of tests changes. In particular, the failure frequency of intermittently failing tests can increase, and we could also identify few cases of field failures that would have been hardly detected during In House testing due to the numerous combinations of inputs and states. In most cases, such flakiness was rooted in the design of the test method itself, however we could also identify an actual bug.

Conclusion: The results of our study suggest that the identification of an intermittently failing behaviour could be a valuable hint for a test engineer, and hence flaky tests should not be dismissed right away.




Percentage of CP, CF, and IF tests observed during each experimental phase (calculated considering the 44 adapted tests).

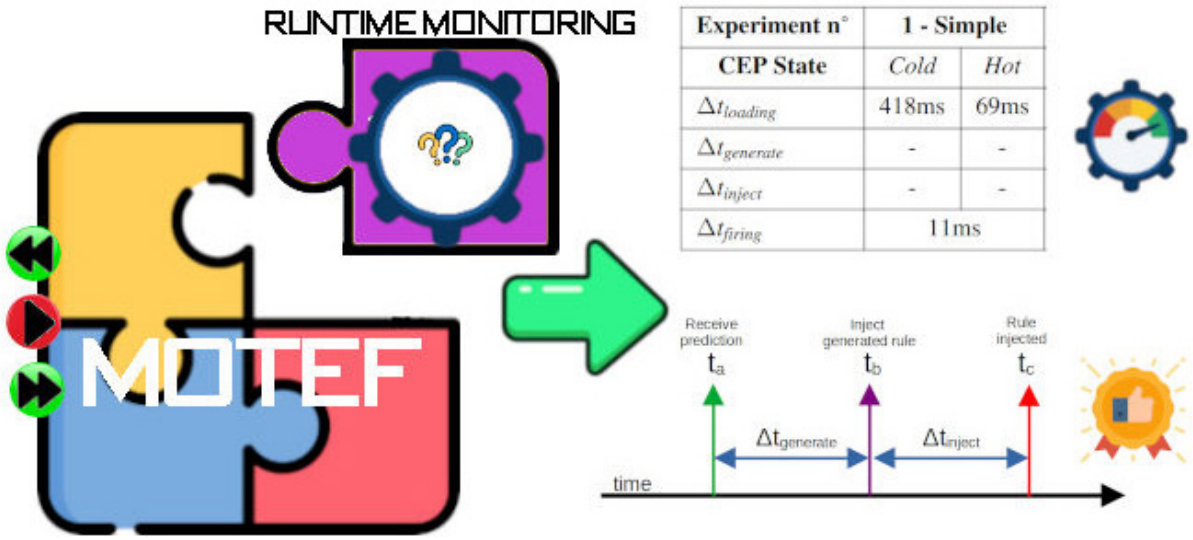



The Sankey diagram illustrates the behavioural evolution of the test cases when their execution is moved from In-House (left) to In Vivo (right). The test cases are denoted as: CP if they are Consistently Passing; IF if they are Intermittently Failing; CF is they are Consistently Failing. As shown, the test cases exhibit a different behaviour, and specifically 16% of the test cases that always passed In House (CP) exhibited a failing behaviour, either in consistent (CF) or intermittent (IF) way, when executed In Vivo.

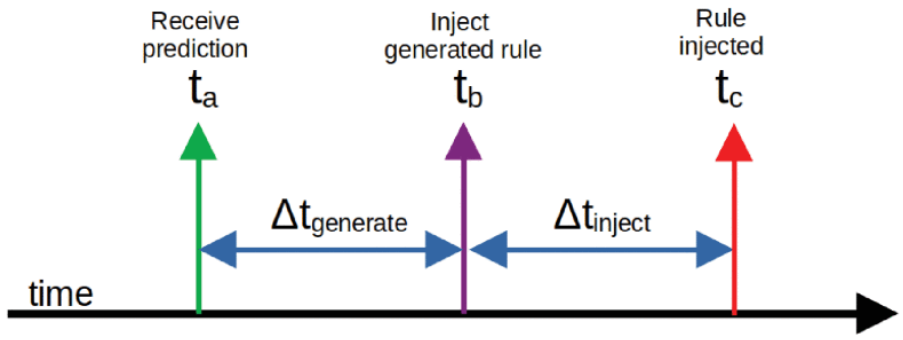
**DOI**: 10.1016/j.infsof.2023.107373

# MOTEF: a Testing Framework for Runtime Monitoring Infrastructures

A. Calabrò, E. Marchetti
IEEE Access, vol. 12. IEEE, 2024.




Abstract overview of MOTEF: a testing framework for runtime monitoring infrastructures.




Metrics for RQ2: Rule generation and injection from a prediction.

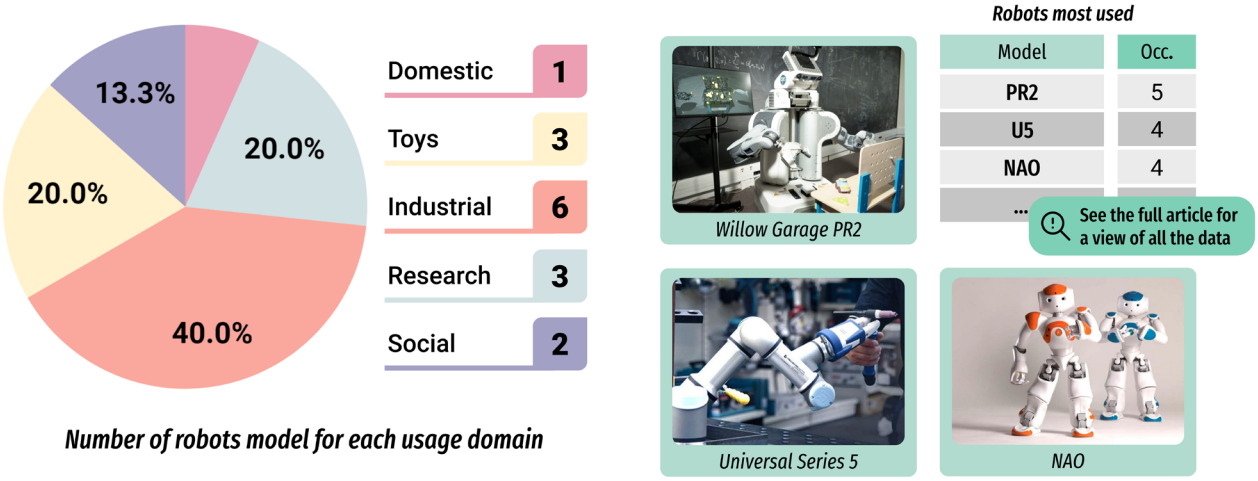
Intelligent monitoring systems can effectively predict or detect anomalies and issues in smart working systems and ecosystems and implement the proper countermeasures. However, for their effective and efficient use, attributes like responsiveness, performance, and quality should be properly tested and assessed before integrating the monitoring system into an ecosystem. The work aims to present a framework, called MOnitoring TEsting Framework (MOTEF), focused on the testing and evaluation of a generic monitoring system performance. In particular, the framework allows testing the monitoring system in isolation or when used in a smart environment to provide functional or non-functional property predictions. By simulating the runtime execution of a smart environment, MOTEF lets testing and assessment of a generic monitoring system establish its working boundaries. The results collected can be used to design a smart environment architecture to fulfil its global performance constraints better. This work presents the architecture of MOTEF and its preliminary implementation. It also validated and showcased the use of MOTEF in evaluating the performance of an existing monitoring system in isolation and when it is used in a smart environment. The results have been assessed by considering two research questions about the monitoring system's responsiveness and effectiveness in proving required functional or non-functional property predictions.

**DOI:** 10.1109/ACCESS.2024.3376239

# End-User Development for Human-Robot Interaction: Results and Trends in an Emerging Field

G. Vaiani, F Paternò

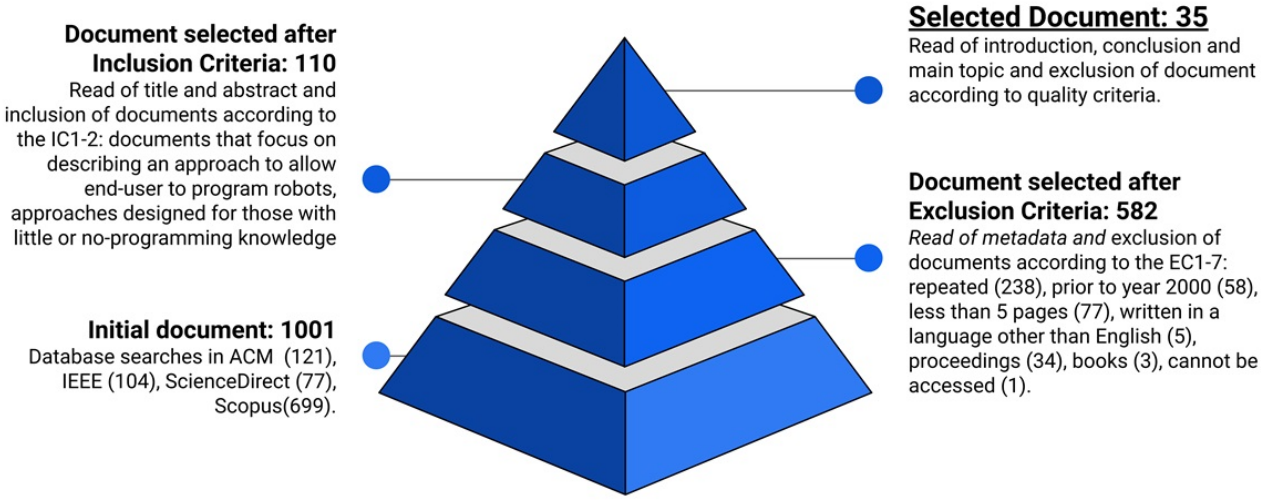
Proceedings of the ACM on Human-Computer Interaction, vol.8. ACM, 2024.




Robot tasks and domains.

This paper presents a comprehensive survey on End-User Development for Human-Robot Interaction, examining existing literature to validate findings and identify unexplored areas for future research. It explores the importance of End-User Development in allowing non-expert users to customise robots, covering methodologies, evaluation methods, robot types, and application contexts. The findings reveal various End-User Development approaches, evaluation practices, and robots application domains, leading to discussions on the untapped potential of End-User Development in enhancing Human-Robot Interaction across diverse fields. The document aims to provide groundwork for future studies, highlighting the necessity for new evaluation standards and greater customisation in robotic technologies.

DOI 10.1145/3661146

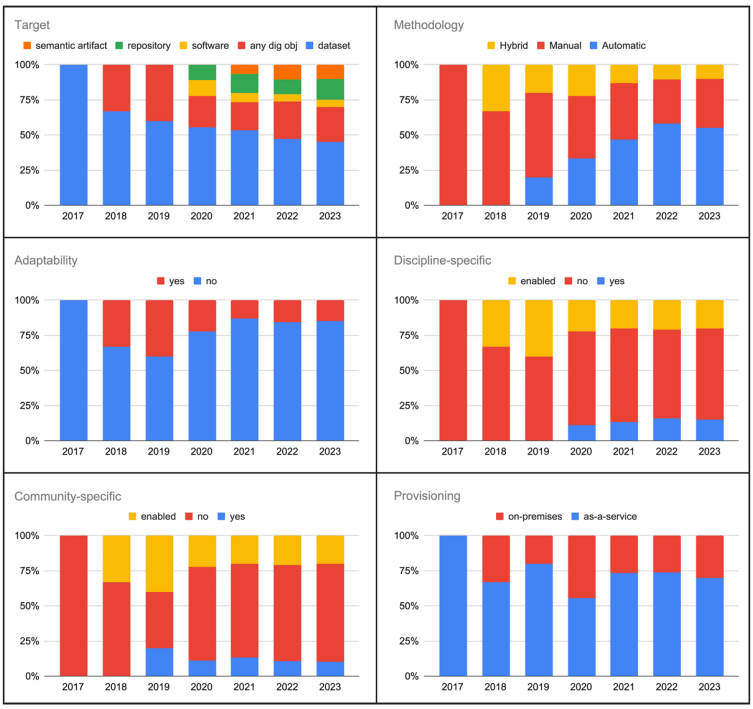



Search process flow

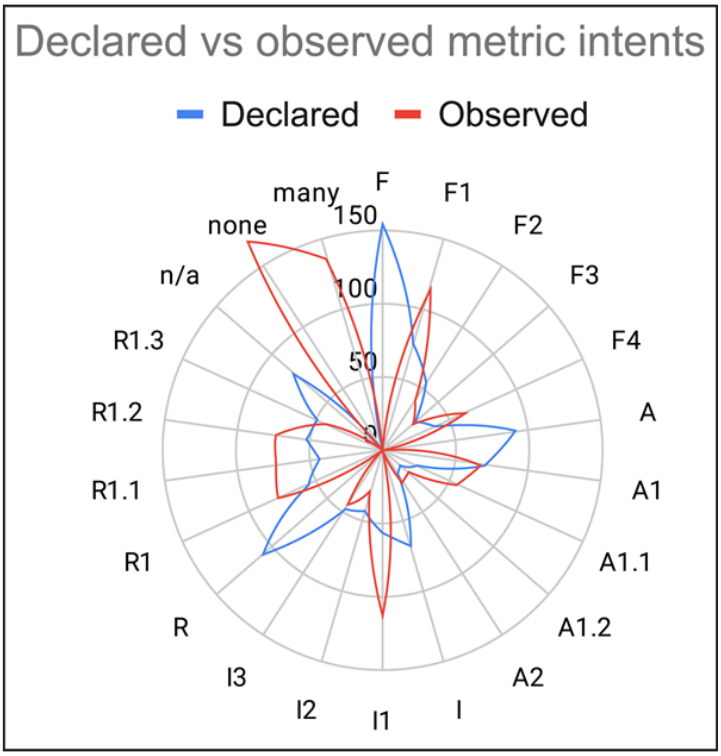
# The FAIR Assessment Conundrum: Reflections on Tools and Metrics

L. Candela, D. Mangione, G. Pavone

Data Science Journal, vol. 23. Ubiquity Press, 2024.




FAIR Assessment tools trends.




Comparison of the metrics distributions with regard to their declared and observed intent.

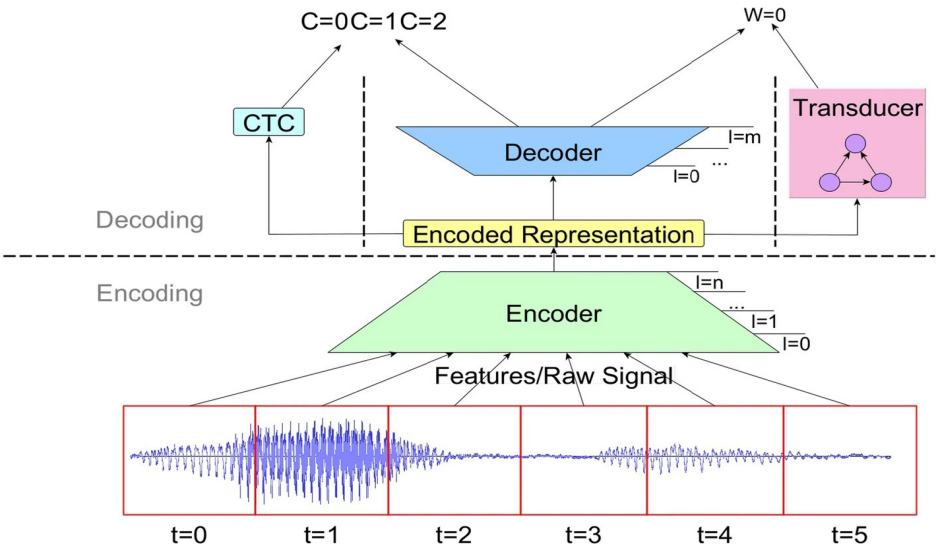
Several tools for assessing FAIRness have been developed. Although their purpose is common, they use different assessment techniques, they are designed to work with diverse research products, and they are applied in specific scientific disciplines. It is thus inevitable that they perform the assessment using different metrics. This paper provides an overview of the actual FAIR assessment tools and metrics landscape to highlight the challenges characterising this task. In particular, 20 relevant FAIR assessment tools and 1180 relevant metrics were identified and analysed concerning (i) the tool's distinguishing aspects and their trends, (ii) the gaps between the metric intents and the FAIR principles, (iii) the discrepancies between the declared intent of the metrics and the actual aspects assessed, including the most recurring issues, (iv) the technologies used or mentioned the most in the assessment metrics. The findings highlight (a) the distinguishing characteristics of the tools and the emergence of trends over time concerning those characteristics, (b) the identification of gaps at both metric and tool levels, (c) discrepancies observed in 345 metrics between their declared intent and the actual aspects assessed, pointing at several recurring issues, and (d) the variety in the technology used for the assessments, the majority of which can be ascribed to linked data solutions. This work also highlights some open issues that FAIR assessment still needs to address.

**DOI:** 10.5334/dsj-2024-033:

# Exploring Emergent Syllables in End-to-end Automatic Speech Recognizers through Model Explainability Technique

V.N. Vitale, F. Cutugno, A. Origlia, G. Coro

Neural Computing and Applications, vol. 36. Springer, 2024.

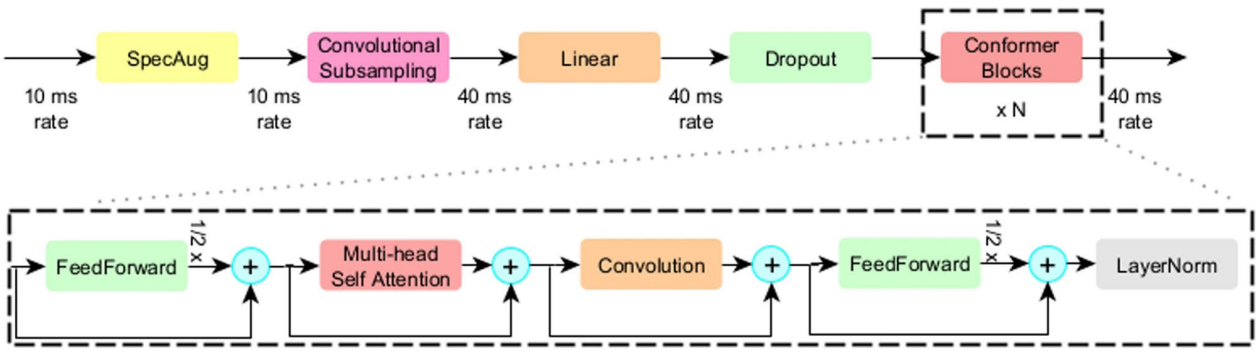



Example architectural schema of an end-to-end automatic speech recognition model.

Automatic speech recognition systems based on end-to-end models (E2E-ASRs) can achieve comparable performance to conventional ASR systems while reproducing all their essential parts automatically, from speech units to the language model. However, they hide the underlying perceptual processes modelled, if any, and they have lower adaptability to multiple application contexts, and, furthermore, they require powerful hardware and an extensive amount of training data. Model-explainability techniques can explore the internal dynamics of these ASR systems and possibly understand and explain the processes conducting to their decisions and outputs. Understanding these processes can help enhance ASR performance and reduce the required training data and hardware significantly. In this paper, we probe the internal dynamics of three E2E-ASRs pre-trained for English by building an acoustic-syllable boundary detector for Italian and Spanish based on the E2E-ASRs' internal encoding layer outputs.

We demonstrate that the shallower E2E-ASR layers spontaneously form a rhythmic component correlated with prominent syllables, central in human speech processing. This finding highlights a parallel between the analysed E2E-ASRs and human speech recognition. Our results contribute to the body of knowledge by providing a human-explainable insight into behaviours encoded in popular E2E-ASR systems.

**DOI**: 10.1007/s00521-024-09435-1

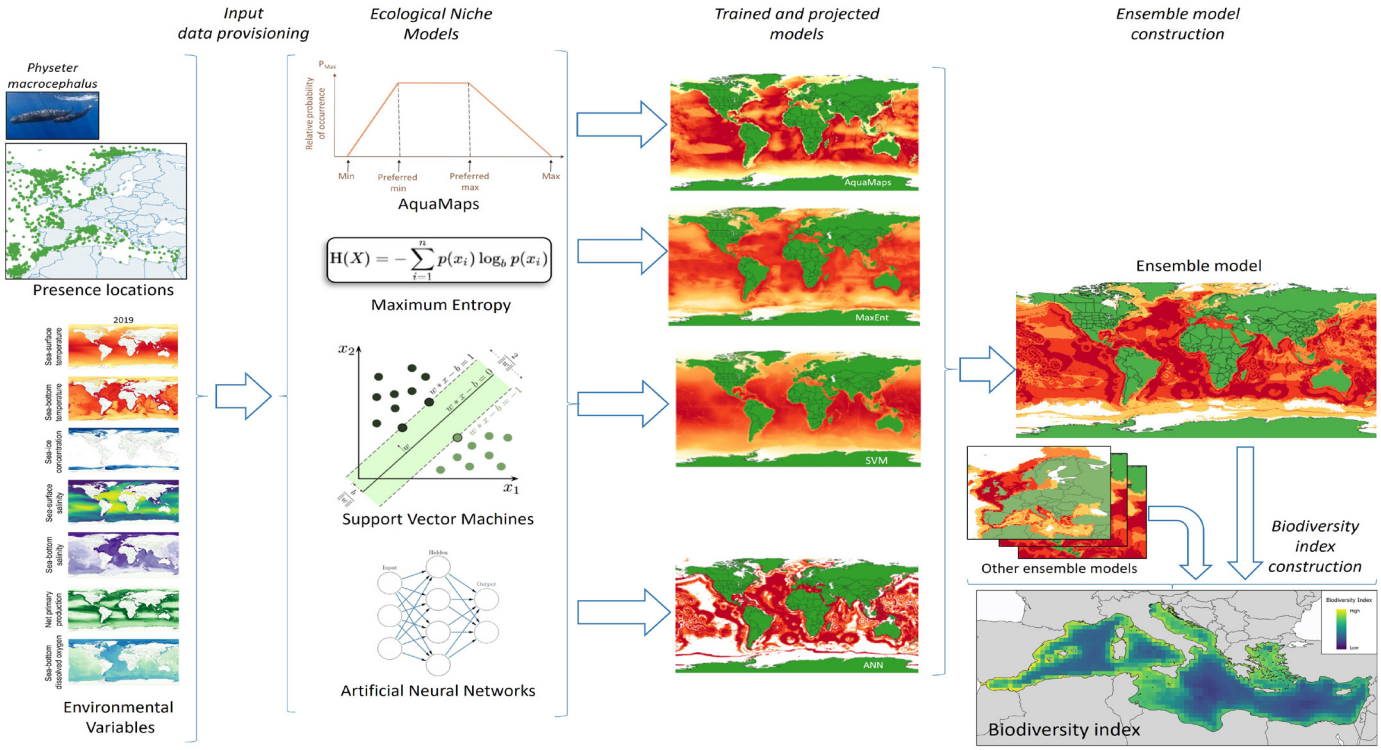



Typical architectural schema of a Conformer block within a generic deep-learning model's encoder.

# An Open Science Automatic Workflow for Multi-model Species Distribution Estimation

G. Coro, L. Sana, P. Bove

International Journal of Data Science and Analytics. Springer, 2024.




General schema of our workflow.

Integrated Environmental Assessment systems and ecosystem models study the links between anthropogenic and climatic pressures on marine ecosystems and help understand how to manage the effects of the unsustainable exploitation of ocean resources. However, these models have long implementation times, data and model interoperability issues and require heterogeneous competencies. Therefore, they would benefit from simplification, automatisation, and enhanced integrability of the underlying models. Artificial Intelligence can help overcome several limitations by speeding up the modelling of crucial functional parts, e.g. estimating the environmental conditions fostering a species' persistence and proliferation in an area (the species' ecological niche) and, consequently, its geographical distribution. This paper presents a full-automatic workflow to estimate species' distributions through statistical and machine learning models. It embeds four ecological niche models with complementary approaches, i.e. Artificial Neural Networks, Maximum Entropy, Support Vector Machines, and AquaMaps. It automatically estimates the optimal model parametrisations and decision thresholds to distinguish between suitable- and unsuitable-habitat locations and combines the models within one ensemble model. Finally, it combines several ensemble models to produce a species richness map (biodiversity index). The software is open-source, Open Science compliant, and available as a Web Processing Service-standardised cloud computing service that enhances efficiency, integrability, cross-domain reusability, and experimental reproduction and repetition.

We first assess workflow stability and sensitivity and then demonstrate effectiveness by producing a biodiversity index for the Mediterranean based on 1500 species data. Moreover, we predict the spread of the invasive Siganus rivulatus in the Mediterranean and its current and future overlap with the native Sarpa salpa under different climate change scenarios.

**DOI:** 10.1007/s41060-024-00517-w

# DESIRE-ME: Domain-Enhanced Supervised Information Retrieval Using Mixture-of-Experts

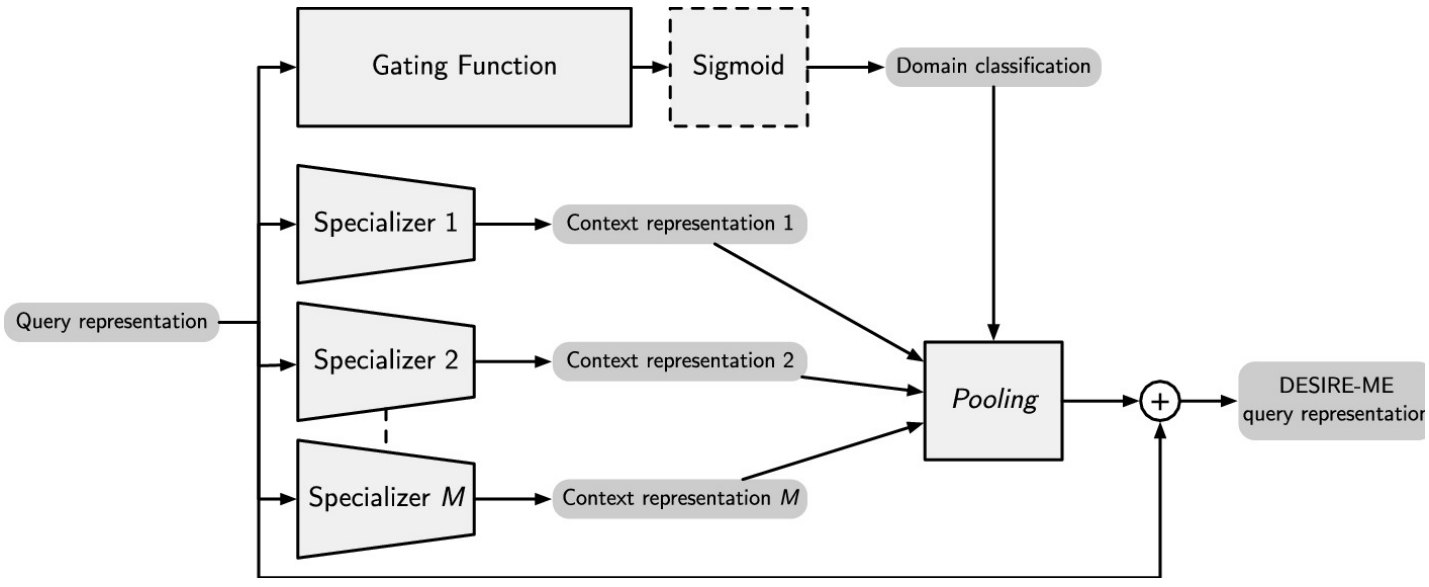
P. Kasela , G. Pasi , R. Perego, N. Tonellotto

46th European Conference on Information Retrieval, ECIR 2024. Lecture Notes in Computer Science, vol 14609. Springer, 2024.

The Information Retrieval research landscape has been fundamentally reshaped by the rapid adoption and emergence of neural models, generating a new paradigm known as Neural Information Retrieval. Within this transformation, one prominent application of neural models within IR systems is achieved through dense retrieval techniques that have shown promising results in situations where understanding the semantic context of queries and documents is crucial for accurate retrieval. However, their training requires large labeled datasets, and the resulting models are typically highly specialized to the task they are trained on and do not generalize well to a new task or domain without additional fine-tuning. Numerous efforts have been directed toward creating a single neural model that can generalize across many domains, but achieving this goal has proven challenging.

In particular, open-domain question answering requires retrieval systems able to cope with the diverse and varied nature of questions, providing accurate answers across a broad spectrum of query types and topics. To deal with such topic heterogeneity through a unique model, we propose DESIRE-ME. This neural information retrieval model leverages the Mixture-of-Experts framework to combine multiple specialized neural models. We rely on Wikipedia data to train an effective neural gating mechanism that classifies the incoming query and that correspondingly weighs the predictions of the different domain-specific experts. This allows DESIRE-ME to specialize adaptively in multiple domains. Through extensive experiments on publicly available datasets, we show that our proposal can effectively generalize domain-enhanced neural models. DESIRE-ME excels in handling open-domain questions adaptively, boosting by up to 12% in NDCG@10 and 22% in P@1, the underlying state-of-the-art dense retrieval model

**DOI:** 10.1007/978-3-031-56060-6_8

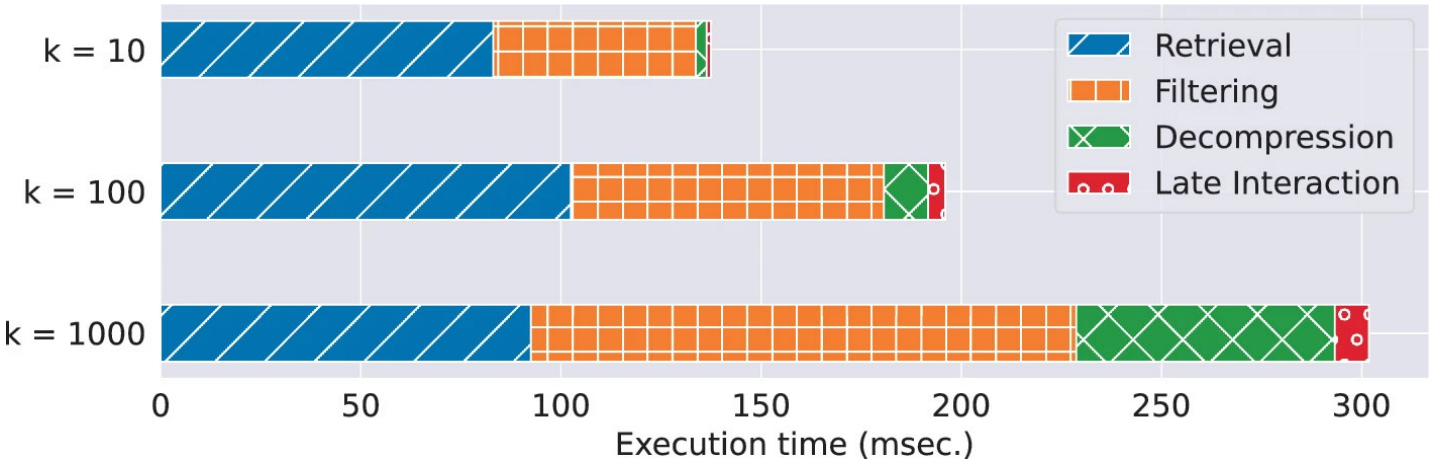



The MoE module of the proposed model.

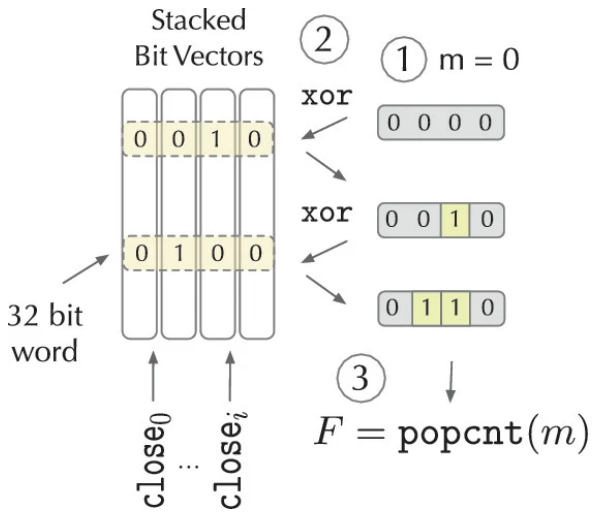
# Efficient Multi-Vector Dense Retrieval with Bit Vectors

F.M. Nardini, C. Rulli, R. Venturini

46th European Conference on Information Retrieval, ECIR 2024. Lecture Notes in Computer Science, vol 14609. Springer, 2024.




Breakdown of the PLAID average query latency (in milliseconds) on CPU across its four phases.




Vectorized Fast Set Membership algorithm based on bit vectors.

Dense retrieval techniques employ pre-trained large language models to build a high-dimensional representation of queries and passages. These representations compute the relevance of a passage with respect to a query using efficient similarity measures. In this line, multi-vector representations show improved effectiveness at the expense of a one-order-of-magnitude increase in memory footprint and query latency by encoding queries and documents on a per-token level.

Recently, PLAID has tackled these problems by introducing a centroid-based term representation to reduce the memory impact of multi-vector systems. By exploiting a centroid interaction mechanism, PLAID filters out non-relevant documents, thus reducing the cost of the successive ranking stages.

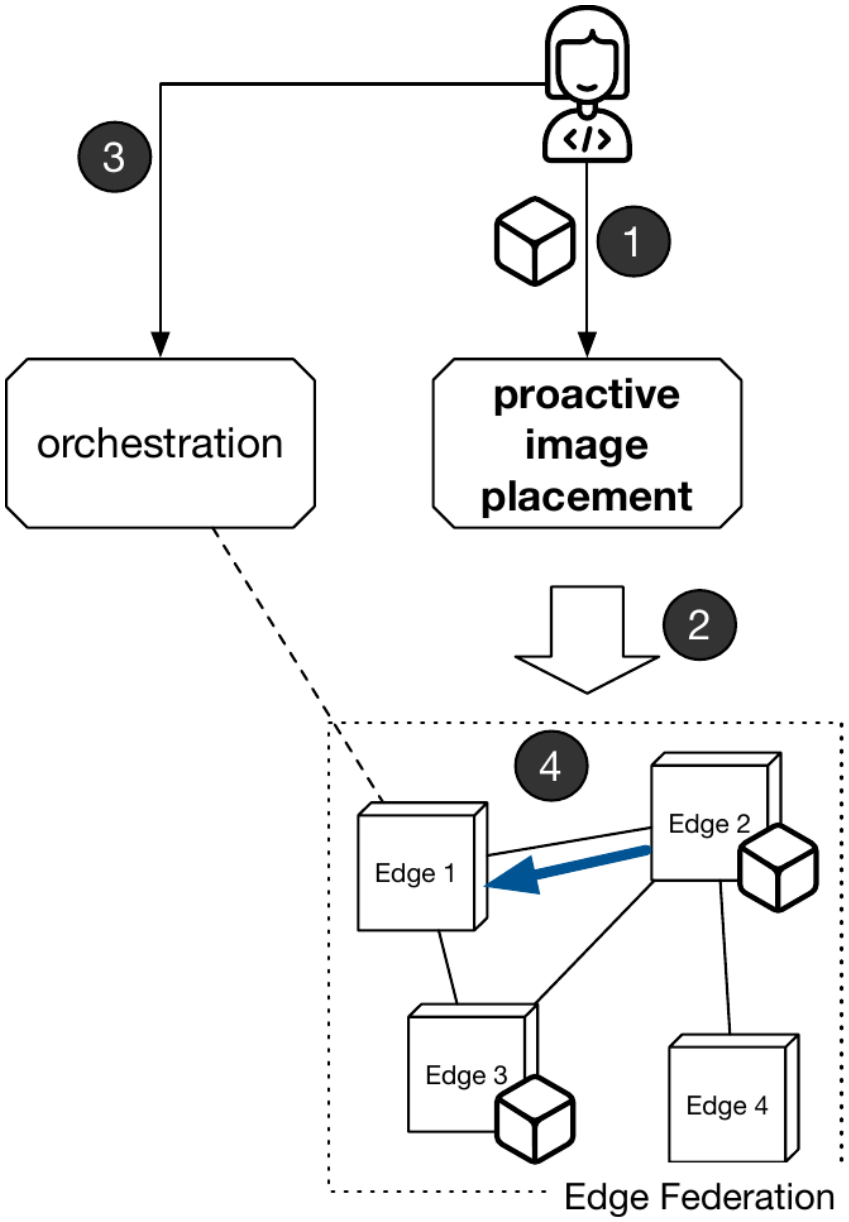
This paper proposes "Efficient Multi-Vector dense retrieval with Bit vectors" (EMVB), a novel framework for efficient query processing in multi-vector dense retrieval. First, EMVB employs a highly efficient pre-filtering step of passages using optimized bit vectors. Second, the computation of the centroid interaction happens column-wise, exploiting SIMD instructions, thus reducing its latency. Third, EMVB leverages Product Quantization (PQ) to reduce the memory footprint of storing vector representations while jointly allowing for fast late interaction. Fourth, we introduce a per-document term filtering method that further improves the efficiency of the last step.

Experiments on MS MARCO and LoTTE show that EMVB is up to 2.8x faster while reducing the memory footprint by 1.8x with no loss in retrieval accuracy compared to PLAID.

**DOI:** 10.1007/978-3-031-56060-6_1

# Pro-active Component Image Placement in Edge Computing Environments

A. Makris, E. Psomakelis, E. Carlini, M. Mordacchini, T. Theodoropoulos, P. Dazzi, K. Tserpes
Future Generation Computer Systems, vol. 157. Springer, 2024.




Envisioned system model. In step (1), a developer prepares an application to be run on the edge. In step (2), a proactive image placement service stores the image in a subset of the available edge resources. In step (3), an orchestration service decides Edge 1 as the best resource to run the application. In step (4), Edge 1 downloads the application from Edge 2.

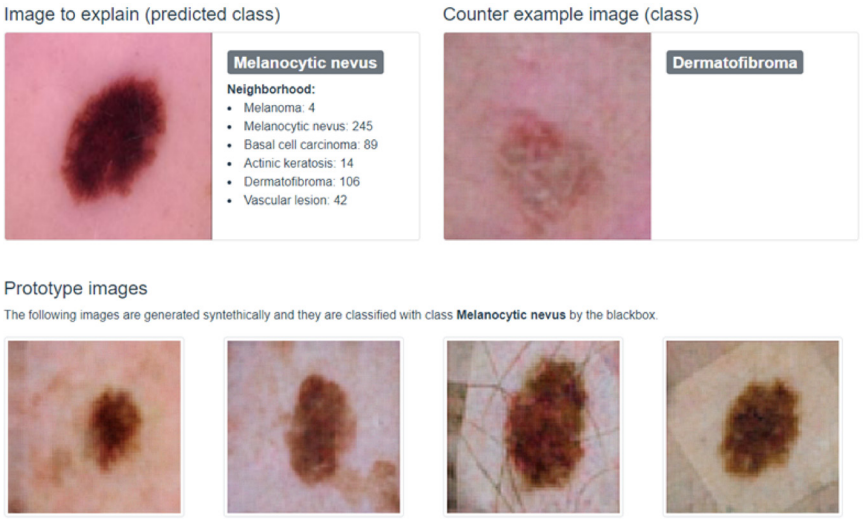
Edge computing has attracted a lot of attention both from industry and academia in recent years and is considered a key enabler for addressing the increasingly strict requirements of the next generation of interactive, on-demand applications. Unlike Cloud computing, in Edge computing, the computation is placed closer to the end-users, the so-called Edge, to facilitate low-latency and high-bandwidth applications and services that would not be feasible using cloud and far remote processing alone. However, the distributed, dynamic, and heterogeneous environment in Edge computing and the diverse applications' requirements make service placement in such infrastructure challenging. A critical aspect of Edge computing is the management of the placement of the applications in the network system to minimize each application's runtime, given the resources of the system's devices and the capabilities of the system's network. To this end, we propose an empirical, experimental analysis by comparing the results of different placement strategies and edge communication networks. In particular, we model the problem of proactive placement of application images as a Minimum Vertex Cover problem. We have considered several approximated implementations of the problem, and compared them with the optimal solution (when possible), aiming to determine which approach exhibits superior performance. Our results demonstrate that the Greedy implementation offers the best trade-off regarding performance, cost function, and execution time.

**DOI:** 10.1016/j.future.2024.04.007

# Towards Transparent Healthcare: Advancing Local Explanation Methods in Explainable Artificial Intelligence

C. Metta, A. Beretta, R. Pellungrini, S. Rinzivillo, F. Giannotti

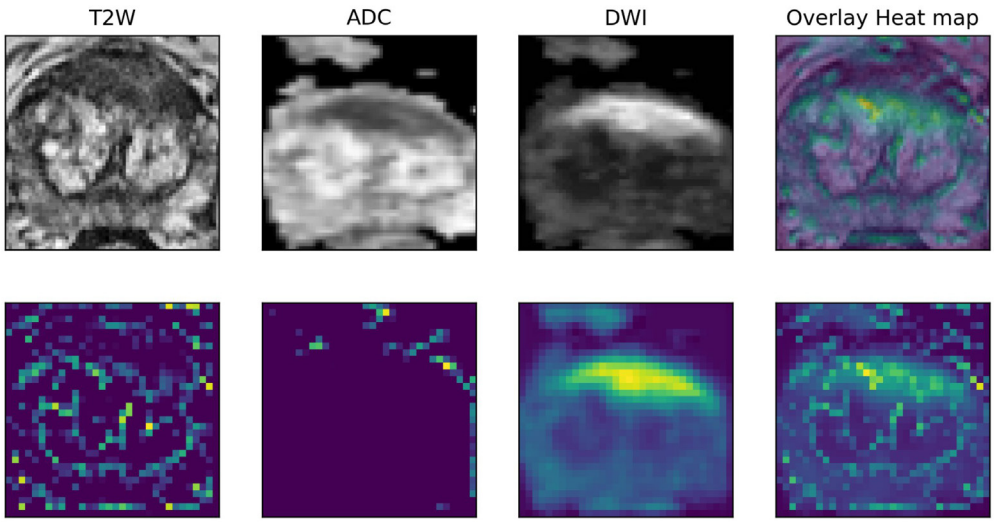
Bioengineering, vol 11. MDPI, 2024.




Some benign and malignant samples from the utilized BreakHis dataset.

This paper focuses on the use of local Explainable Artificial Intelligence (XAI) methods, particularly the Local Rule-Based Explanations (LORE) technique, within healthcare and medical settings. It emphasizes the critical role of interpretability and transparency in AI systems for diagnosing diseases, predicting patient outcomes, and creating personalized treatment plans. While acknowledging the complexities and inherent trade-offs between interpretability and model performance, our work underscores the significance of local XAI methods in enhancing decision-making processes in healthcare. By providing granular, case-specific insights, local XAI methods like LORE enhance physicians' and patients' understanding of machine learning models and their outcome. Our paper reviews significant contributions to local XAI in healthcare, highlighting its potential to improve clinical decision making, ensure fairness, and comply with regulatory standards.

**DOI:** 10.3390/bioengineering11040369

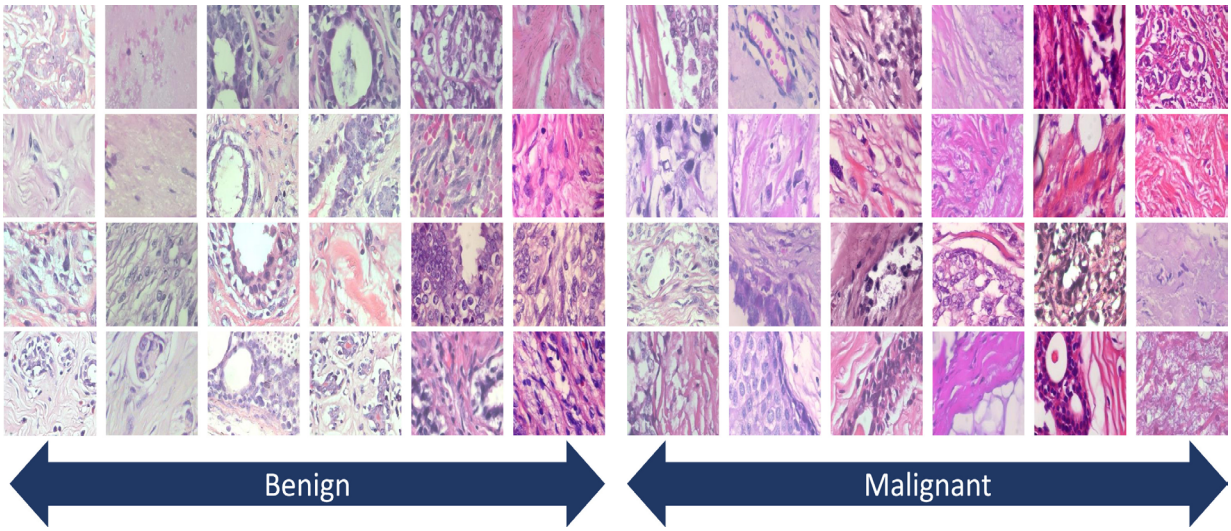



A saliency map extracted from a 3-channel multimodal classifier comprising T2W, ADC, and DWI images of a prostatic gland with a high-grade prostate lesion. Each activation map sizes the contribution of each modality.

# Exploiting Causality Signals in Medical Images: a pilot study with empirical results

G. Carloni, S. Colantonio

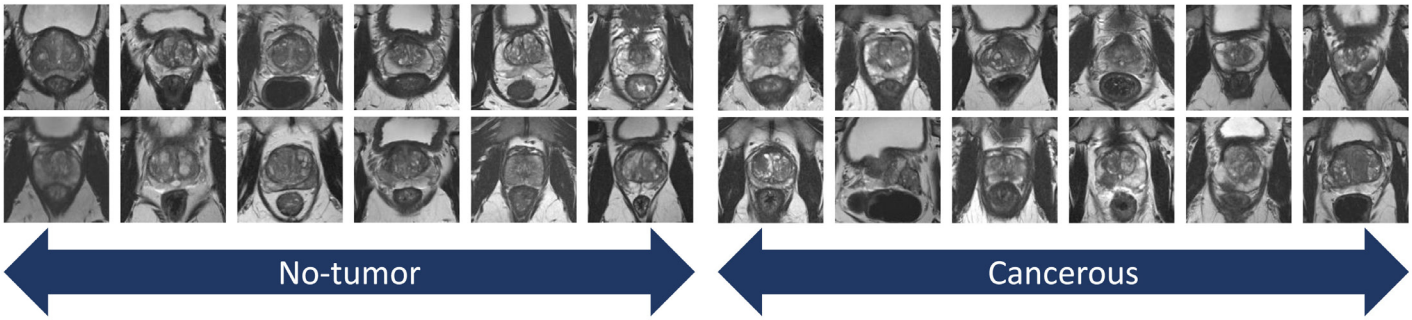
Expert Systems with Applications, vol. 249. Elsevier, 2024.




Some benign and malignant samples from the utilized BreakHis dataset.

We present a novel technique to discover and exploit weak causal signals directly from images via neural networks for classification purposes. This way, we model how the presence of a feature in one part of the image affects the appearance of another feature in a different part of the image. Our method consists of a convolutional neural network backbone and a causality-factors extractor module, which computes weights to enhance each feature map according to its causal influence in the scene. We develop different architecture variants and empirically evaluate all the models on two public datasets of prostate MRI images and breast histopathology slides for cancer diagnosis. We study the effectiveness of our module both in fully-supervised and few-shot learning, we assess its addition to existing attention-based solutions, we conduct ablation studies, and investigate the explainability of our models via class activation maps. Our findings show that our lightweight block extracts meaningful information and improves the overall classification, together with producing more robust predictions that focus on relevant parts of the image. That is crucial in medical imaging, where accurate and reliable classifications are essential for effective diagnosis and treatment planning.

**DOI:** 10.1016/j.eswa.2024.123433

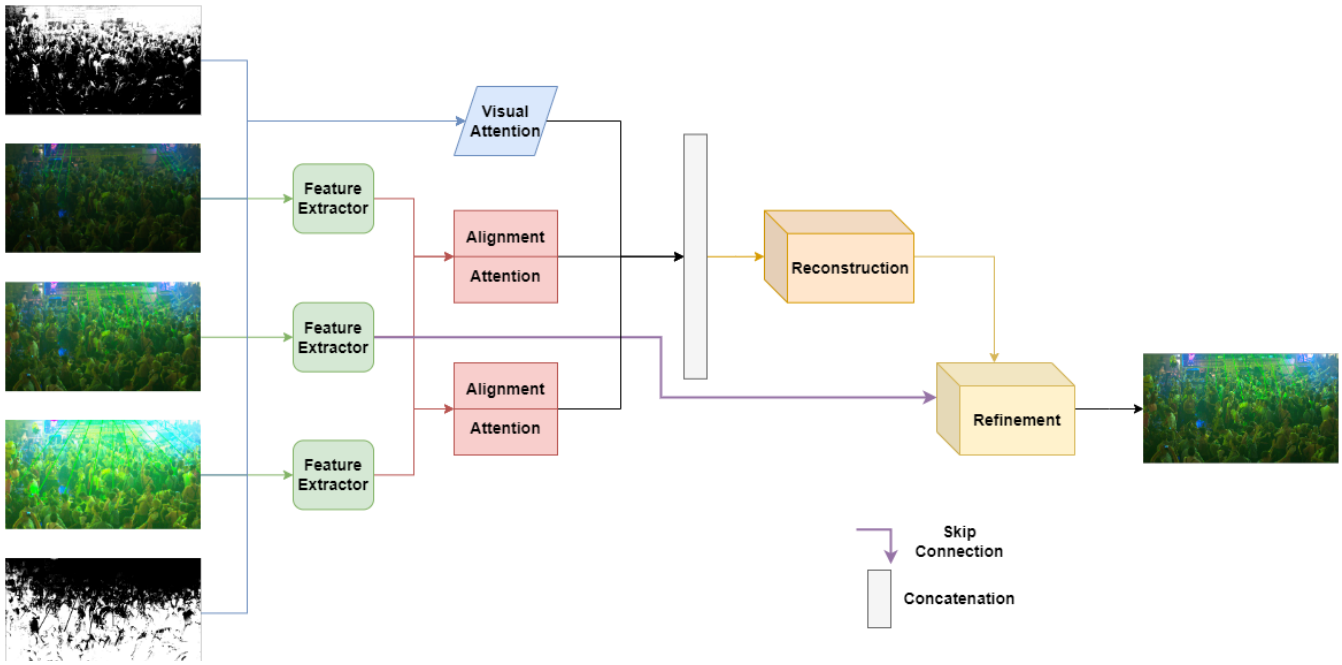



Some no-tumor and cancerous samples from the utilized PI-CAI dataset.

# GranoScan: an AI-powered Mobile App for In-field Identification of Biotic Threats of Wheat

R. Dainelli, A. Bruno, M. Martinelli, D. Moroni, L. Rocchi, S. Morelli, E. Ferrari, M. Silvestri, S. Agostinelli, P. La Cava, P. Toscano

Frontiers in Plant Science, vol. 15. Frontiers Media, 2024.




Examples of images manually annotated for object detection tasks: leaf disease – (A) septoria; (B) powdery mildew; (C) yellow rust; leaf damage –(D) damage from cereal leaf beetle; spike disease - (E) Fusarium head blight; and stem disease – (F) black rust.

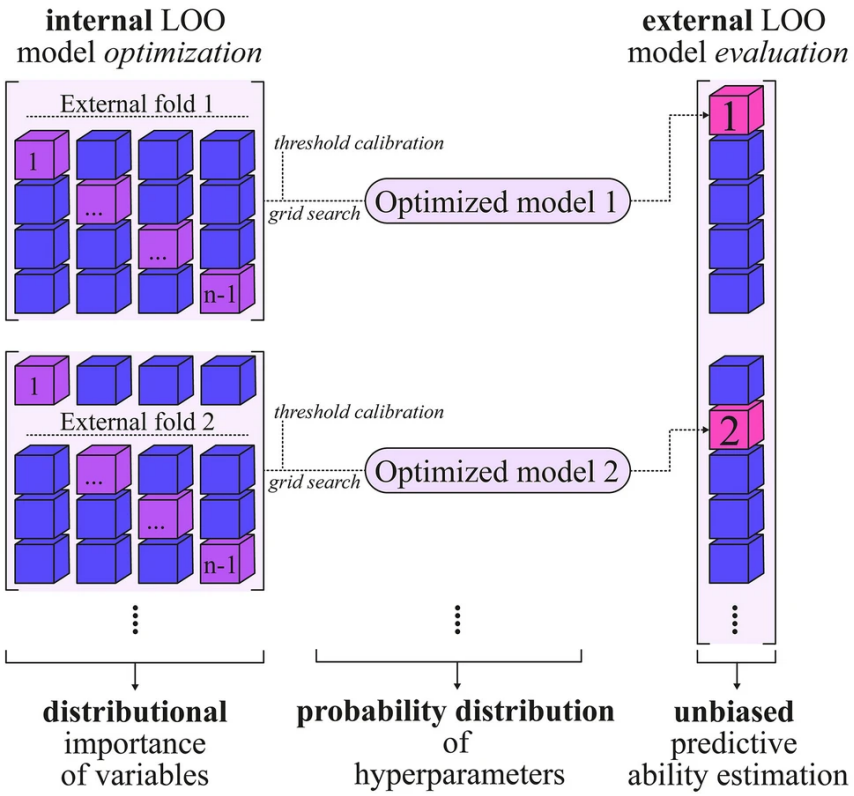
Capitalizing on the widespread adoption of smartphones among farmers and the application of artificial intelligence in computer vision, a variety of mobile applications have recently emerged in the agricultural domain. This paper introduces GranoScan, a freely available mobile app accessible on major online platforms, specifically designed for the real-time detection and identification of over 80 threats affecting wheat in the Mediterranean region. Developed through a co-design methodology involving direct collaboration with Italian farmers, this participatory approach resulted in an app featuring: (i) a graphical interface optimized for diverse in-field lighting conditions, (ii) a user-friendly interface allowing swift selection from a predefined menu, (iii) operability even in low or no connectivity, (iv) a straightforward operational guide, and (v) the ability to specify an area of interest in the photo for targeted threat identification. Underpinning GranoScan is a deep learning architecture named efficient minimal adaptive ensembling that was used to obtain accurate and robust artificial intelligence models. The method is based on an ensembling strategy that uses as core models two instances of the EfficientNet-b0 architecture, selected through the weighted F1-score. In this phase a very good precision is reached with peaks of 100% for pests, as well as in leaf damage and root disease tasks, and in some classes of spike and stem disease tasks. For weeds in the post-germination phase, the precision values range between 80% and 100%, while 100% is reached in all the classes for pre-flowering weeds, except one. Regarding recognition accuracy towards end-users in-field photos, GranoScan achieved good performances, with a mean accuracy of 77% and 95% for leaf diseases and for spike, stem and root diseases, respectively. Pests gained an accuracy of up to 94%, while for weeds the app shows a great ability (100% accuracy) in recognizing whether the target weed is a dicot or monocot and 60% accuracy for distinguishing species in both the post-germination and pre-flowering stage. Our precision and accuracy results conform to or outperform those of other studies deploying artificial intelligence models on mobile devices, confirming that GranoScan is a valuable tool also in challenging outdoor conditions.

**DOI:** 10.3389/fpls.2024.1298791

# Adaptive Machine Learning Approach for Importance Evaluation of Multimodal Breast Cancer Radiomic Features

G. Del Corso, D. Germanese, C. Caudai, G. Anastasi, P. Belli, A. Formica, A. Nicolucci, S. Palma, M.A. Pascali, S. Pieroni, C. Trombadori, S. Colantonio, M. Franchini, S. Molinaro

Journal of Imaging Informatics in Medicine, vol. 37. Springer, 2024.




Optimization and validation scheme adapted to the dimension (n = 69) of the dataset. The external LOO model evaluation uses a leave-one-out approach to provide an estimate of performance for each patient, at the cost of increased computational complexity. Each model evaluation is performed after an optimization (i.e., internal LOO) using an additional LOO strategy combined with a grid search for the optimal hyperparameter. To reduce positively biased estimates, every optimized model calibrates its internal threshold.

Breast cancer holds the highest diagnosis rate among female tumors and is the leading cause of death among women. Quantitative analysis of radiological images shows the potential to address several medical challenges, including the early detection and classification of breast tumors. In the P.I.N.K study, 66 women were enrolled. Their paired Automated Breast Volume Scanner (ABVS) and Digital Breast Tomosynthesis (DBT) images, annotated with cancerous lesions, populated the first ABVS+DBT dataset. This enabled not only a radiomic analysis for the malignant vs. benign breast cancer classification, but also the comparison of the two modalities. For this purpose, the models were trained using a leave-one-out nested cross-validation strategy combined with a proper threshold selection approach. This approach provides statistically significant results even with medium-sized data sets. Additionally it provides distributional variables of importance, thus identifying the most informative radiomic features. The analysis proved the predictive capacity of radiomic models even using a reduced number of features. Indeed, from tomography we achieved AUC-ROC 89.9% using 19 features and 92.1% using 7 of them; while from ABVS we attained an AUC-ROC of 72.3% using 22 features and 85.8% using only 3 features. Although the predictive power of DBT outperforms ABVS, when comparing the predictions at the patient level, only 8.7% of lesions are misclassified by both methods, suggesting a partial complementarity. Notably, promising results (AUC-ROC ABVS-DBT 71.8% - 74.1% ) were achieved using non-geometric features, thus opening the way to the integration of virtual biopsy in medical routine.

**DOI:** 10.1007/s10278-024-01064-3

# Bending-Reinforced Grid Shells for Free-form Architectural Surfaces

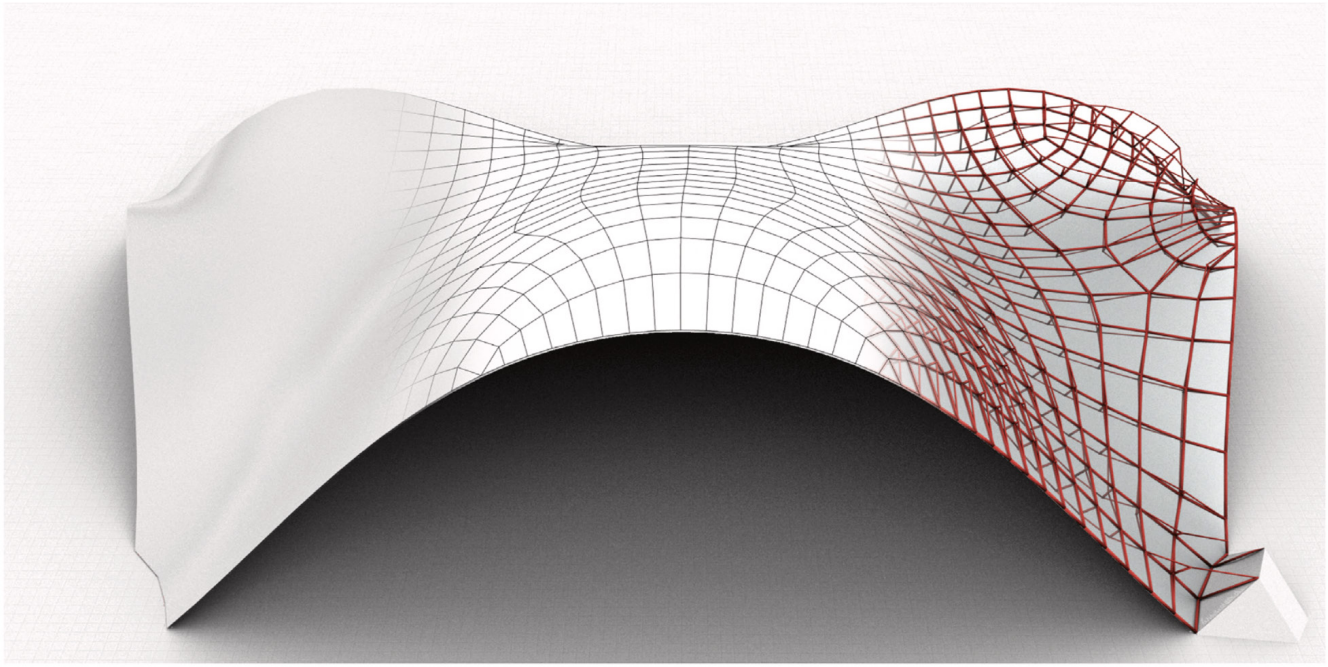
F. Laccone, N. Pietroni, P. Cignoni, L. Malomo
Computer-Aided Design, vol. 168. Elsevier, 2024.

Grid shells are elegant and lightweight structures used in architecture to cover large spaces. Their lightness is due to the structural efficiency resulting from membrane actions through axial forces along a grid of beams.

Usually, the shape of a grid shell is a product of the joint efforts of architects and engineers who closely collaborate in the early conceptual design phase. Thus, it fulfills aesthetic and functional requirements while guaranteeing structural efficiency. However, this joint effort only sometimes happens, and the shape is sometimes sculpted with artistic intents only, resulting in free-form shapes that are inefficient for given load and boundary conditions.

We introduce a new method for designing reinforcement for grid shells and improving their resistance to out-of-plane forces inducing bending. The central concept is to support the base network of elements with an additional layer of beams placed at a certain distance from the base surface. We exploit two main techniques to design these structures: first, we derive the orientation of the beam network on a given initial surface forming the grid shell to be reinforced; then, we compute the height of the additional layer that maximizes its overall structural performance. Our method includes a new formulation to derive a smooth direction field that orients the quad remeshing and a novel algorithm that iteratively optimizes the height of the additional layer to minimize the structure's compliance. We couple our optimization strategy with a set of constraints to improve buildability of the network and, simultaneously, preserve the initial surface. We showcase our method on a significant dataset of shapes to demonstrate its applicability to cases where free-form grid shells do not exhibit adequate structural performance due to their geometry.

**DOI:** 10.1016/j.cad.2023.103670



Our bending-reinforced grid shell: starting from a generic continuous free-form surface, we define a tessellation to align the structural elements in a discrete setting based on the FE analysis for the continuous surface; then, we compute a network of beams with variable height from the starting tessellation, which lies on the input surface.

# Self-supervised High Dynamic Range Imaging: What Can Be Learned from a Single 8-bit Video

F. Banterle, D. Marnerides, T. Bashford-Rogers, K. Debattista
ACM Transactions on Graphics, vol. 43. ACM, 2024.

To capture the full range of color and shades of brightness in the real world, high dynamic range (HDR) imaging is employed. Even though modern sensors, cameras, and smartphones can capture HDR imagery, a large amount of content was and still is captured in standard dynamic range (SDR) or is converted to SDR after capture.

When presenting this content on HDR displays, or using this imagery for applications where HDR values are required, SDR values need to be boosted to HDR; a process known as Inverse Tone Mapping Recently, Deep Learning-based methods for inverse tone mapping standard dynamic range (SDR) images to obtain high dynamic range (HDR) images have become very popular. These methods manage to fill over-exposed areas convincingly both in terms of details and dynamic range. To be effective, deep learning-based methods need to learn from large datasets and transfer this knowledge to the network weights. In this work, we tackle this problem from a completely different perspective. What can we learn from a single SDR 8-bit video?

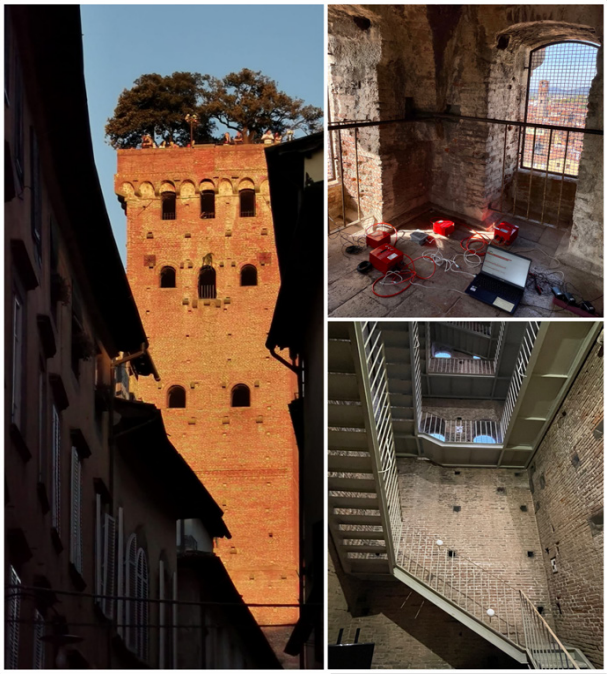
We propose a fundamentally different approach based on this observation: much of the information required for inverse tone mapping may be present in an SDR video sequence. This can be a result of a variety of effects that are present in videos but not in still images. For example, motion in the scene or from the camera can uncover detail that was badly exposed in earlier frames. In addition, changes in the lighting of the scene, or luminance variations due to automatic exposures from the camera can also create a similar effect, where information otherwise lost in some frames exists in some others. Our approach attempts to gather and distill this information present in a single SDR video in order to recover information in over-exposed and under-exposed areas of the same video.

**DOI:** 10.1145/3648570


An example of our inverse tone mapping operator applied to an SDR version frame from the Carousel fireworks 02 sequence [13]. Our method can recover missing texture, colors, and dynamic range details in a convincing way.

# Deep Learning and Structural Health Monitoring: Temporal Fusion Transformers for Anomaly Detection in Masonry Towers

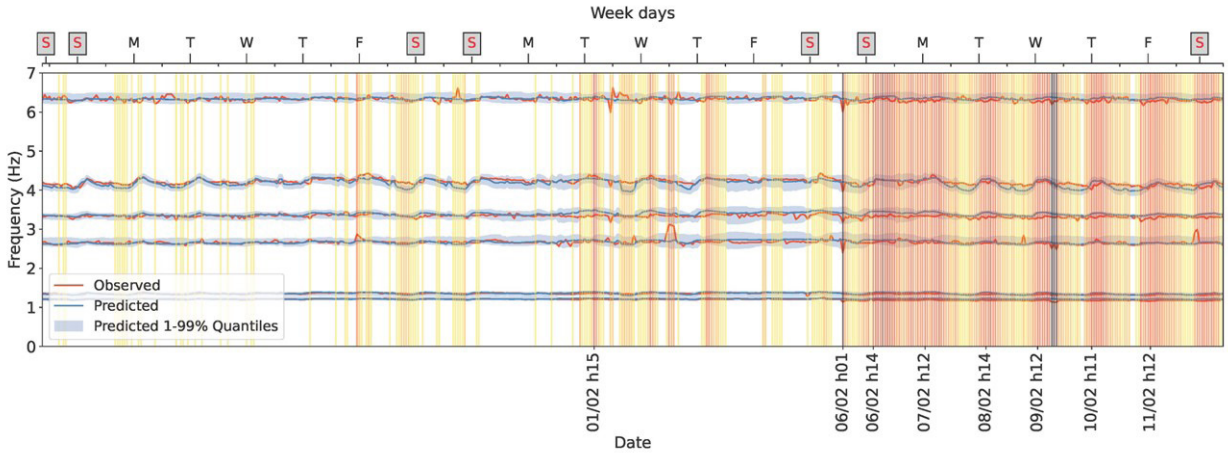
F. Falchi, M. Girardi, G. Gurioli, N. Messina, C. Padovani, D. Pellegrini
Mechanical Systems and Signal Processing, vol. 215. Elsevier, 2024.



The Guinigi tower in Lucca and the sensor equipment.

Detecting anomalies in the vibrational features of age-old buildings is crucial within the Structural Health Monitoring (SHM) framework. The SHM techniques can leverage information from onsite measurements and environmental sources to identify the dynamic properties (such as the frequencies) of the monitored structure, searching for possible deviations or unusual behavior over time. The Temporal Fusion Transformer (TFT) network is a deep learning algorithm designed for multi-horizon time series forecasting and initially tested on electricity, traffic, retail, and volatility problems. In this paper, it is applied to SHM. More precisely, the TFT approach is adopted to investigate the behavior of the Guinigi Tower located in Lucca (Italy) and subjected to a long-term dynamic monitoring campaign. The TFT network is trained on the tower's experimental frequencies enriched with other environmental parameters. The transformer is then employed to predict the vibrational features (natural frequencies, root mean squares values of the velocity time series) and detect possible anomalies or unexpected events by inspecting how much the actual frequencies deviate from the predicted ones. The TFT technique is used to detect the effects of the Viareggio earthquake that occurred on 6 February 2022, and the structural damage induced by three simulated damage scenarios.

**DOI:** 10.1016/j.ymssp.2024.111382:

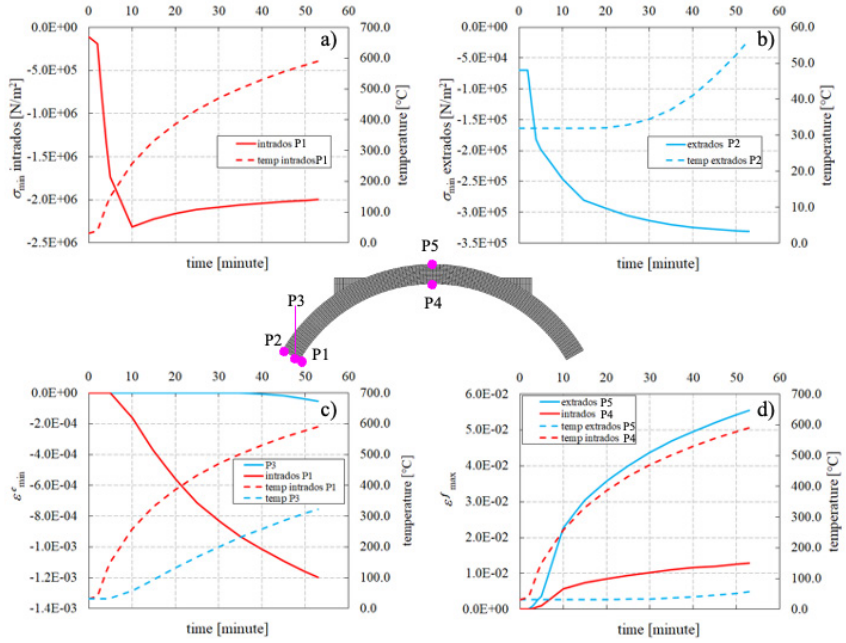



Anomaly plots for a simulated damage scenario.

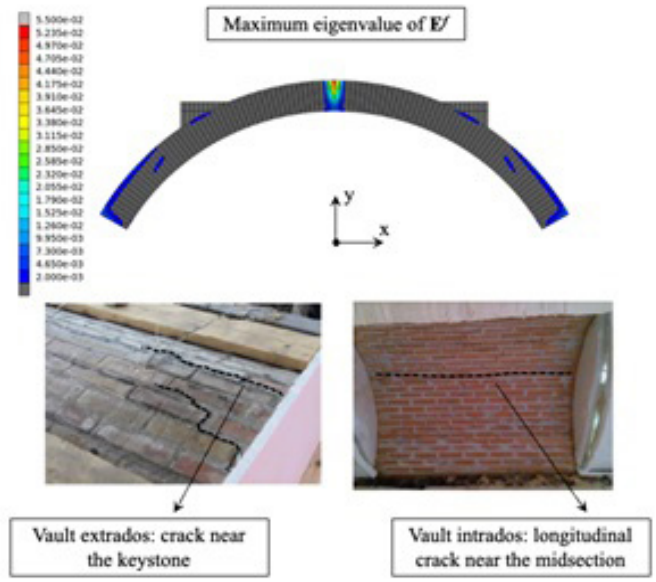
# Thermo-Mechanical Analyses of Masonry Structures in Fire Conditions

D. Pellegrini

Finite Elements in Analysis and Design, vol. 234. Elsevier 2024.




Time history of: the minimum eigenvalues of the stress tensor at the interlock section intrados (a) and extrados (b); the minimum eigenvalues of the crushing strain tensor at the interlock section (c); the maximum eigenvalues of the fracture strain tensor at the kevstone (d).




Maximum eigenvalue of the fracture strain tensor in the numerical model (top); experimental crack detected in the vauly at the end of fire test (bottom).

Historic masonry buildings are highly vulnerable to anthropic actions and environmental factors due to their low tensile strength and bounded compressive strength. Over the years, numerous studies and experimental campaigns have been conducted to characterise the buildings' response to external actions and identify solutions for their conservation against multiple factors, such as climatic changes, material ageing and earthquakes. However, the historic masonry structures' response in case of fire and their safety assessment in post-fire conditions, still needs to be thoroughly investigated both from an experimental and numerical point of view. In addition, in Europe, no specific code lays down rules on the fire protection of cultural heritage. To this aim, the present paper generalises the constitutive equation of masonry-like (or no-tension) materials under non- isothermal conditions to the case in which the masonry has weak tensile strength and bounded compressive strength, even temperature dependent. The generalised constitutive equation is implemented in NOSA-ITACA code and the explicit solution to the equilibrium problem of a masonry circular ring in plane strain condition is calculated and compared with the numerical solution. Subsequently, the code is used to perform an uncoupled thermo-mechanical analysis of a real case study: a masonry barrel vault tested in fire conditions. The agreement between the experimental and numerical results paves the way for further study and research.

This research has been conducted within the framework of the project "Revolution" (Progetti di Ricerca @CNR, 2022-2025) funded by the Italian National Research Council

**DOI:** 10.1016/j.finel.2024.104128

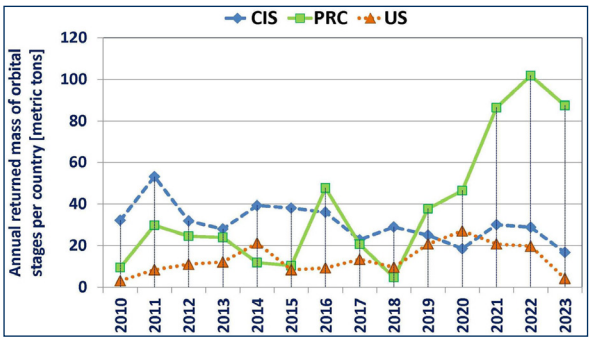
# On the Need to Assess and Mitigate the Risk from Uncontrolled Re-entries of Artificial Space Objects in View of the Current and Future Developments in Space Activities

C. Pardini, L. Anselmo

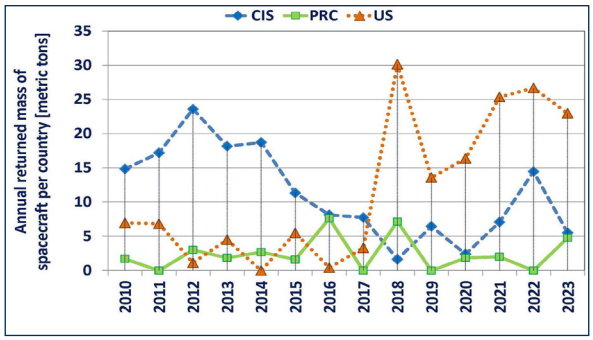
Acta Astronautica, vol. 219. Elsevier 2024.

From 1 January 2010 to 24 August 2023, 566 orbital stages and 511 spacecraft with a radar cross section > 1 $m^2$ have re-entered without control the Earth's atmosphere. The total returned mass was 1650 metric tons, corresponding to a mean of 115 metric tons per year. 77% of the mass belonged to orbital stages, 23% to spacecraft. The uncontrolled re-entries of orbital stages are currently dominated by China, accounting for more than half of the decaying mass, while for spacecraft 2/3 of the mass belongs to American satellites. 60% of the re-entries occurred within 2 years of the launch. The ground casualty expectancy due to orbital stages was always predominant over that from spacecraft, by an average factor of nearly three. From 2010 to 2018, the total casualty probability remained substantially stable, with a mean annual value just over 1%. Since 2019, instead, the annual casualty probability of both spacecraft and orbital stages progressively increased, reaching a total value of around 3% in 2022 and 2023 (extrapolated). Even assuming a stable launch activity, in the coming years, when many of the recently launched spacecraft will start to re-enter, the casualty expectancy of orbital stages will remain basically the same, while that of spacecraft might progressively increase by a factor of 20. This would lead to an annual casualty probability of about 20%, even more in case of a further growth in launch activity, very likely based on current forecasts. The quick implementation of widespread and effective mitigation measures, like controlled de-orbiting and design for demise, is therefore necessary, to prevent the situation from deteriorating too much.

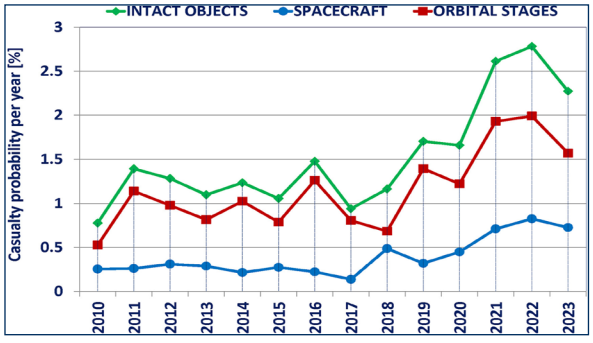
**DOI:** 10.1016/j.actaastro.2024.03.057




Mass (kg) of large orbital stages re-entered uncontrolled from 1 January 2010 to 24 August 2023, due to the three main players, that is Russia (CIS), China (PRC) and the United States (US).




Large spacecraft mass (kg) re-entered uncontrolled from 1 January 2010 to 24 August 2023, due to the three main players, that is Russia (CIS), China (PRC) and the United States (US).




Annual global casualty probability associated with the uncontrolled re-entry of large spacecraft, orbital stages or both (intact objects), from 1 January 2010 to 24 August 2023.

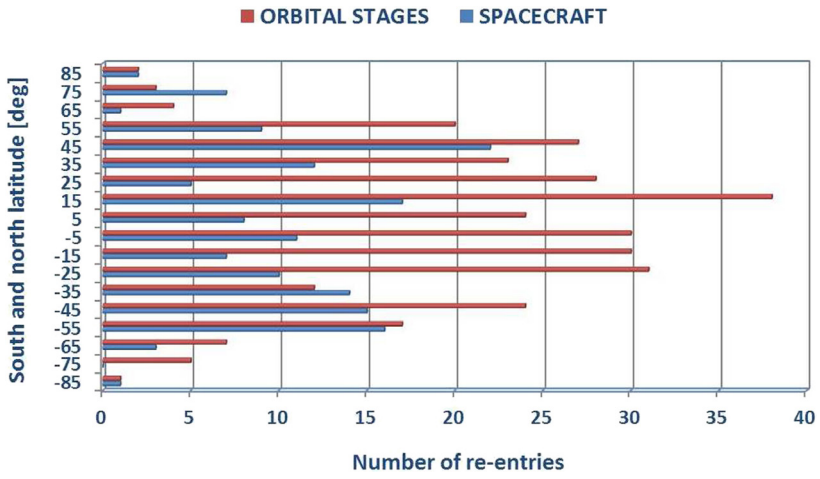
# The Risk of Casualties from the Uncontrolled Re-entry of Spacecraft and Orbital Stages

C. Pardini, L. Anselmo

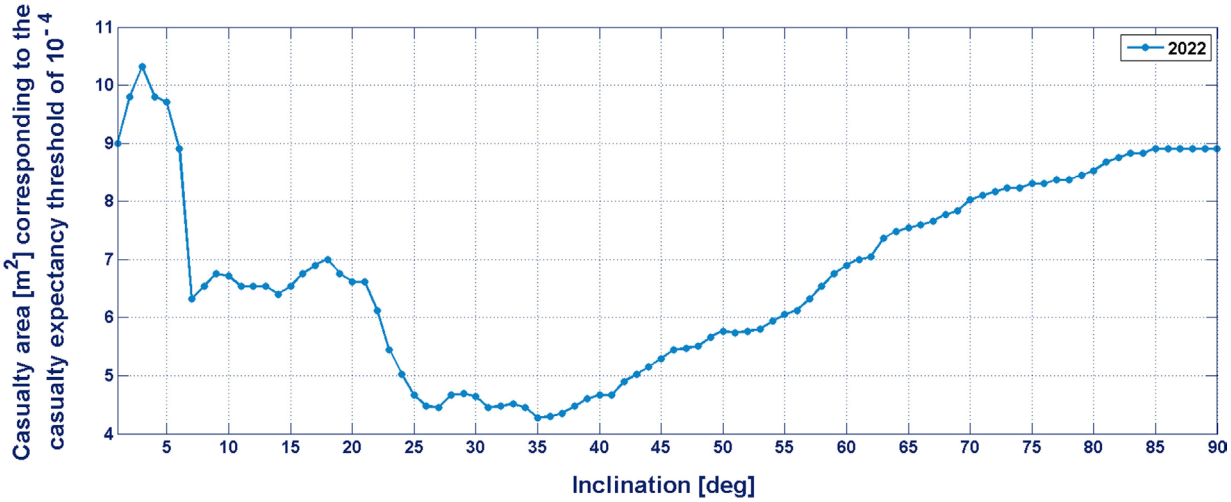
Journal of Space Safety Engineering, vol. 11. Elsevier 2024.

From the beginning of 2010 to the end of 2022, 951 intact objects (spacecraft and orbital stages) with a radar cross-section greater than one square meter re-entered the Earth's atmosphere uncontrolled. The total returned mass was about 1500 t, with a mean of 116 t per year, mostly concentrated (80%) in orbital stages. On average, objects with a mass greater than 500 kg re-entered every 8 days, those exceeding 2000 kg every 2 weeks, and those above 5000 kg around 3 times per year. Only 4% of the re-entries came from orbits with an eccentricity greater than 0.1, while 41% were from nearly circular orbits with eccentricity lower than 0.001. 52% of the re-entries occurred in the northern hemisphere and 48% in the southern one. The areas of the planet most affected were those between 30° and 60° north. However, excluding the polar regions, the re-entry flux per unit area was relatively uniform, from 60° south to 60° north, implying a ground casualty risk mainly driven by the population density. 84% of orbital stages and 19% of spacecraft exceeded a casualty expectancy of $10^{-4}$, the ceiling recommended by several guidelines and standards worldwide. The total ground casualty expectancy over the 13 years analyzed was estimated to be 0.194, corresponding to a probability of injuring or killing at least one person of about 18%. After remaining relatively stable from 2010 to 2018, the casualty expectancy and probability have grown systematically from then on, leading in 2022 to a chance of casualty of 2.9%, with orbital stages and spacecraft contributing, respectively, 72% and 28%.

**DOI:** 10.1016/j.jsse.2024.02.002




Distribution per latitude bands of the number of uncontrolled re-entries of orbital stages and spacecraft occurred between 2010 and 2022, and characterized by an uncertainty window of ±1 minute.




Casualty area corresponding to the casualty expectancy threshold of $10^{-4}$, estimated in 2022 as a function of the orbit inclination of re-entering objects.

# The IMAGO Web Application

## A web application to explore the IMAGO archive

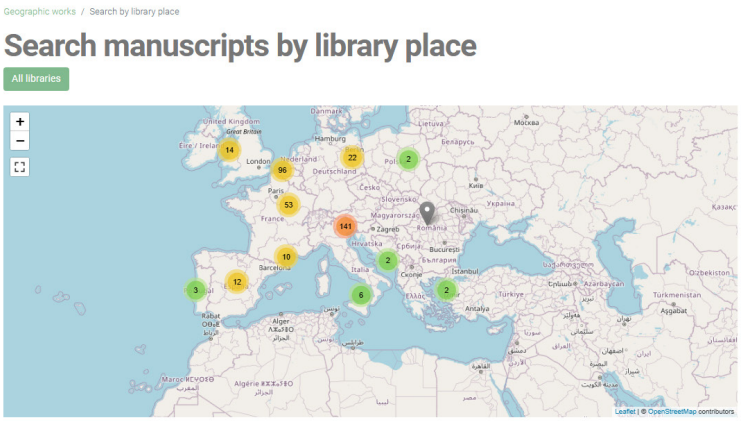
Studying how during the Middle Ages and Renaissance the world was represented through maps and literature is a rich and complex field of research aimed at understanding the history of knowledge, the identity of peoples and nations, and the development of modern geographical thought. This period produced diverse literary works that described countries, lands, and cities, spanning various genres such as universal descriptions, travel diaries, itineraries, and topographical treatises.

The Index Medii Aevi Geographiae Operum (IMAGO) research combines expertise in medieval literature, philology, and the Digital Humanities. The project aims to new tools for the scientific community, particularly scholars interested in Medieval and Renaissance geographical literature. The web application enables users to access and display data in a user-friendly and intuitive way, exploiting Semantic Web technologies. The web application is available at the following link: https://imagoarchive.it/archive/. The code, developed using the three main languages for web development (HTML, CSS, and JavaScript), is publicly available on GitHub: https://github.com/AIMH-DHgroup/archive.

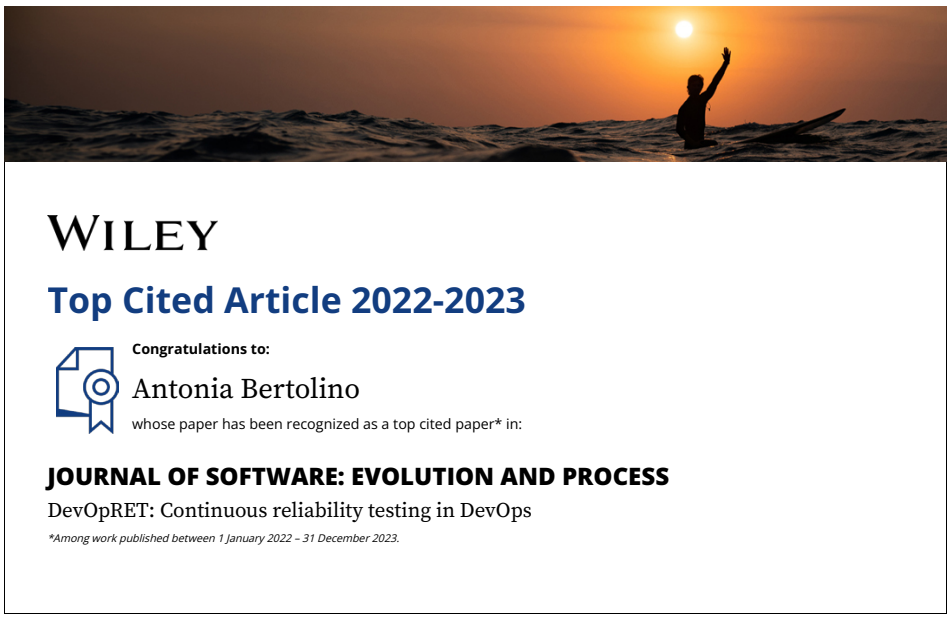
The software supports two types of searches within the Knowledge Graph: research through maps and textual search. A text search enables users to search by century for lemmas, authors, works, literary genres, and manuscripts. It is also possible to search using maps for places cited in works, libraries where manuscripts are collected, and places where print editions are edited. All the data gathered within the project are published as Linked Open Data (LOD).

The project has concrete applications not only in the fields of medieval and digital philology but also in the geographical and historical sciences. In fact, the Web portal and the Knowledge Graph are fundamental tools for advancing medieval and humanistic geography studies.

**Contact: Valentina Bartalesi, AIMH Lab**
valentina.bartalesi@isti.cnr.it
https://imagoarchive.it

# Top Cited Article 2022-2023




Wiley congratulates Antonia Bertolino for her article "DevOpRET: Continuous reliability testing in DevOps" published at Journal of Software: Evolution and Process, recognized as a top cited article among papers published between January 2022 and December 2023.

**Contact: Antonia Bertolino, SEDC Lab**
antonia.bertolino@isti.cnr.it

# Francesco Spinnato is one of the winners of the SOCINT-G-Research Award 2024

## Senate of the Republic, Rome, January 25, 2024

Francesco Spinnato, recently awarded a PhD in Data Science from the Scuola Normale Superiore, was one of the three winners of the SOCINT-G-Research Award. This is an award for the best doctoral theses in Italy in the fields of Mathematics, Physics, Computer Science/Computer Engineering, Artificial Intelligence, and Data Science. The doctoral program attended by Spinnato is a collaboration between the University of Pisa, the Scuola Normale Superiore, the Scuola Superiore Sant'Anna, the IMT School for Advanced Studies Lucca, and the Italian National Research Council (CNR).

The award ceremony was held earlier this year at the Senate of the Republic in Rome, and was opened by Senator Enrico Borghi and Antonio Felice Uricchio, president of the National Agency for the Evaluation of the University and Research System. The award was made possible thanks to the efforts of Luigi Rucco, Secretary General of SOCINT, and the coordination of Liuva Capezzani for SOCINT and Charles Martinez for G-Research.

Francesco Spinnato was honored for his thesis entitled "Explanation Methods for Sequential Data Models," a doctoral thesis in Artificial Intelligence, supervised by Anna Monreale and Riccardo Guidotti of the Department of Computer Science at the University of Pisa, and Mirco Nanni of ISTI-CNR. The other two winners were Yuri Cacchiò from the University of Rome "La Sapienza", and Marco Reale from the University of Palermo. The prizes are worth 10,000 euros each, the highest amount ever awarded in Italy in this field. The winners also received a sculpture by French artist Rémy Tassou.

"I am truly happy about this recognition and especially to see that there is increasing interest in Italy in valuing research in quantitative fields, particularly in artificial intelligence," commented Francesco Spinnato. "It's a very current topic, and awards like this can give an extra push to PhD students across Italy to do their best. I sincerely thank SOCINT and G-Research for giving me this opportunity."

Spinnato also reflected on his doctoral journey, describing it as "an important formative period, sometimes difficult, but one that has helped me grow both as a person and as a researcher." He highlighted the collaboration between different institutions, such as the University of Pisa, Cnr-Isti, and the Scuola Normale Superiore, as one of the strengths of the Data Science doctoral program. On February 1, Spinnato began his new role as a researcher at the University of Pisa but still associated with Cnr-Isti. "In these three years, I have seen that research is not easy; but I am enthusiastic and I always try to do my best," he concluded.

**Contact: Francesco Spinnato, KDD Lab**
francesco.spinnato@isti.cnr.it

# The VISIONE system won the Video Browser Showdown 2024

## Amsterdam, The Netherlands, January 29, 2024

The VISIONE system, developed by Giuseppe Amato, Paolo Bolettieri, Fabio Carrara, Fabrizio Falchi, Claudio Gennaro, Nicola Messina, Lucia Vadicamo, and Claudio Vairo from the AIMH laboratory of Cnr-Isti, was ranked first at the 13th Video Browser Showdown (VBS2024) — an international competition in interactive video retrieval. VISIONE was ranked as the best interactive video search system in four out of the seven tasks carried out in the competition by both expert and novice users, and was the overall winner of the competition (https://videobrowsershowdown.org/hall-of-fame/).

The competition, held on January 29, 2024, in Amsterdam, The Netherlands, as part of the International Conference on Multimedia Modeling (MMM 2024), saw the participation of 12 international teams from Austria, China, Czech Republic, Germany, Greece, Iceland, Ireland, Italy, Singapore, Switzerland, The Netherlands, and Vietnam. These teams competed in a 6-hour challenge, which consisted of different video search tasks using three datasets with approximately 2500 hours of video content. VISIONE integrates multiple search functionalities that enable users to search for video segments using textual and visual queries, and by date. VISIONE exploits state-of-the-art deep learning approaches for the visual content analysis and highly efficient indexing techniques to ensure a fast response and scalability.

An interactive online demo of VISIONE is available at https://visione.isti.cnr.it/, and a demonstration video can be viewed at https://www.youtube.com/watch?v=aXGfBaNTQVQ

**Contact: Lucia Vadicamo, AIMH Lab**
lucia.vadicamo@isti.cnr.it

# Carmen Pardini ends her term as Chair of IADC Working Group 2

## Her two-year assignment concluded at the end of the 42nd IADC Plenary Meeting in Bengaluru

After serving as Deputy Chair of the Working Group 2 of the Inter-Agency Space Debris Coordination Committee (IADC) from 2020 to 2022, and as Chair since 2022, Carmen Pardini concluded her two-year term at the end of the 42nd IADC Plenary Meeting, hosted this year, from 16 to 19 April 2024, by the Indian Space Research Organisation (ISRO) in Bengaluru, the capital and largest city of the southern Indian state of Karnataka.

The IADC is the main international governmental forum for the worldwide coordination of activities related to the study, characterization and mitigation of the space debris problem. Currently consisting of 13 space agencies, representing Canada, China, Europe, France, Germany, India, Italy, Japan, Russia, South Korea, Ukraine, United Kingdom, and the United States, its primary purposes are to exchange technical information on space debris research activities, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities, and to identify debris mitigation options. It also plays a prominent role in advising the international community, for instance the Committee on the Peaceful Uses of Outer Space (COPUOS) of the United Nations. Carmen, a staff researcher of the Space Flight Dynamics Laboratory, coordinated the activities of the Working Group 2, in charge of «Environment and DataBase», during a period characterized by great changes in space activities, new challenges in debris mitigation and remediation, and increased awareness of the relevance of the problem at all levels.

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# Best Paper Award at FORTE 2024

## At the 44th IFIP WG 6.1 International Conference on Formal Techniques for Distributed Objects, Components, and Systems, Groningen, The Netherlands, June 17-21, 2024


Diego Latella (right) receives the Best Paper Award from Ivan Lanese (left), Chair of IFIP WG 6.1 on Architectures and Protocols for Distributed Systems

This year the Best Paper Award went to Nick Bezhanishvili, Vincenzo Ciancia, David Gabelaia, Mamuka Jibladze, Diego Latella, Mieke Massink, and Erik P. de Vink. Vincenzo, Diego and Mieke are members of the FMT lab at CNR-ISTI. Their paper, entitled "Weak Simplicial Bisimilarity for Polyhedral Models and SLCSη" was presented by Diego Latella at the 44th International Conference on Formal Techniques for Distributed Objects, Components, and Systems (FORTE 2024), which was held as part of the 19th International Federated Conference on Distributed Computing Techniques (DisCoTec 2024).

In the context of spatial logics and spatial model checking for polyhedral models — which is the mathematical basis for visualisations in continuous space — this paper proposes a weakening of simplicial bisimilarity. It also proposes a corresponding weak notion of ±-bisimilarity on cell-poset models, i.e. the discrete representation of polyhedral models. Two points are shown to be weakly simplicial bisimilar if and only if their representations are weakly ±-bisimilar.

The advantage of this weaker notion is that it leads to a greater reduction in models than its counterpart which was introduced by the authors in a previous work. This is important, since real-world polyhedral models, such as those found in domains exploiting mesh processing, typically consist of large numbers of cells.

The paper also proposes SLCSη, a weaker version of the Spatial Logic for Closure Spaces (SLCS) on polyhedral models, and the proposed bisimilarities are shown to enjoy the Hennessy-Milner property: two points are weakly simplicial bisimilar if and only if they are logically equivalent for SLCSη. Similarly, two cells are weakly ±-bisimilar if and only if they are logically equivalent in the poset-model interpretation of SLCSη. This work was performed in the context of the geometric spatial model checker PolyLogicA and the polyhedral semantics of SLCS.

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# Huawei CNR-ISTI Joint Research Activities on Network Intelligence

We are pleased to announce that Huawei and Cnr-Isti have signed a Memorandum of Understanding (MoU) and a Non-Disclosure Agreement (NDA) to collaborate on several key research topics:

- Intelligent Network Management
- Distributed Network Programming
- Intelligent SLA Management on 5G integrated by NTN

In addition, during the MPLS 2024 International Congress in Paris, Pietro Cassarà was honored for his outstanding research work conducted in collaboration with Huawei over the past few years. This achievement has strengthened Huawei's research partnership with Cnr-Isti. In fact, Huawei has now donated a state-of-the-art networking infrastructure to our institute. This infrastructure will be instrumental in supporting the research activities.

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# Whispers in the Snow

## Investigating LoRa Technology in Avalanche Search and Rescue Operations

Long-range (LoRa) technology has become a popular choice for low-power wide-area networks (LPWANs) due to the impressive distances that can be reached, the ability to penetrate obstacles, and low-cost devices.

This project focuses on a novel application of LoRa: Search and Rescue (SaR) in avalanche scenarios, where the challenge is to located buried victims, whose transmitter has been buried under snow. This study presents an experimental setup and methodology for characterizing, for the first time, LoRa signal propagation in this challenging environment. Two key factors differentiate this scenario from other typical applications: the lack of a line of sight (LOS) between the transmitters and receivers, and the significant signal attenuation caused by environmental factors such as temperature, humidity, and most importantly, the properties of the snow itself.

We organized a test site on an open plateau at Col de Mez located at 1850 meters in the Dolomites (Italy). The test site was equipped with one transmitter and four receivers covering a square region of 100 m and replicating a real-world avalanche field.

Data collection focused on two key variables: 1) the depth of the target and 2) the type of snow. Concerning the depth, we executed tests at 0. 50cm and 1 below ground, while in terms of the snow type, we collected data in winter with dry, cold snow, and in the spring with wet snow, which degrades signal propagation. Under these conditions, we measured and analyzed the Received Signal Strength (RSS) and Signal-to-Noise Ratio (SNR) to understand how LoRa propagates in such a challenging environment.

We also investigated the maximum range of LoRa's signal in these conditions. The aim was to quantify the effective communication distance achievable despite the presence of a snowpack. The results of these tests were highly encouraging, demonstrating the potential for effective operation even in the harshest environments, with a range surpassing 400 meters from the buried transmitter.

Lastly, our data collection also involved a professional drone equipped with an omnidirectional antenna, which captured measurements across a 100-meter square grid with 121 data points.

This rich dataset offers two promising avenues for further investigation. First, we aim to create a detailed picture of LoRa propagation under various snow conditions. Second, we are interested in evaluating the possibility of using LoRa to locate a buried target using localization and proximity detection algorithms.

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# Ph.D. dissertations

## Distributed Artificial Intelligence for the Internet of Things

Author: Saira Bano, University of Pisa
Supervisors: Nicola Tonellotto (University of Pisa), Alberto Gotta, Cnr-Isti

The work addressed in this thesis is built around three main objectives. The first goal was to develop a scalable framework for distributed and federated learning that utilizes an in-network caching mechanism with Apache Kafka to improve communication efficiency between clients and servers. This work also includes the novel client selection process that reduces bottlenecks, manages communication costs, and optimizes the overall use of computing resources. This system was developed using Pytorch, Python, Kafka Python, and Zookeeper. The second goal focuses on developing distributed algorithms for applications such as emotion or stress recognition of drivers by incorporating cross-modal knowledge distillation into the federated learning paradigm. This process involves transferring knowledge from a sensor domain to a visual domain on a resource-constrained device, optimizing bandwidth utilization, and accelerating the federated learning process. Tensorflow, Keras, Python, and its libraries, such as Numpy, SciKit, and Pandas, are used to develop these emotion recognition systems. This work also includes the development of the Artificial Intelligence as a Service (AIaaS) toolkit, which consists of a driving session simulated by the CARLA software, an MQTT broker that is used to publish the driver's facial features and sensor data. A programming tool called Node-Red connects hardware devices, retrieves the data from the MQTT broker, and stores it in the Influx DB database. A visual tool called Grafana is configured to retrieve the data from Influx DB for graphical visualization and record the driver's synchronized facial features and sensor readings for real-time monitoring. The dissertation also addresses the challenges of scarcity and missing data in federated models by using generative models to create synthetic samples and fill gaps in datasets. These generative models effectively capture the underlying data structures and generate missing values, thereby increasing the resilience of the federated model.

## Individual Human Mobility Models for Sustainable cities applications

Author: Agnese Bonavita, Scuola Normale Superiore of Pisa
Supervisor: Mirco Nanni, Cnr-Isti

Humans are inherently mobile creatures. The way we move around our environment has consequences for a wide range of problems, including the design of efficient transportation systems and the planning of urban areas. Having good prediction models able to abstract and infer human mobility behaviours within a city is of extreme importance to improve the urban life. This thesis proposes to study human behavior and dynamics through a combination of techniques from network science and data mining. In the context of human mobility, we use GPS data from vehicles to define trajectories in order to understand the mobility patterns. We based our mobility models on the Individual Mobility Networks, a graph representation of users trips that will be presented and used in this thesis. Our work also aims to represent a step towards a reliable Mobility Analysis framework, capable to exploit the richness of the spatio-temporal data nowadays available. The work done is an exploration of meaningful open challenges, from an efficient Trajectory Segmentation of low sampling GPS data to the definition of a stable car crash prediction model. From simulation of electric vehicles to the ethics aspects of mobility data usage we have today many ways to make our cities more sustainable and smart. Another promising perspective is the use of such extracted knowledge to investigate more extensive topics such as Geographical Transfer Learning and Explainability. Further experimentation has been performed in order to improve the characterization of the individual human movements having a more complete and richer picture of that.

# Optimizing Medical Image Segmentation using a Priori Knowledge in Attention Mechanism-Enriched Convolutional Neural Networks

Author: Rossana Buongiorno, University of Pisa
Supervisors: Sara Colantonio, Danila Germanese, Cnr-Isti, Pietro Ducange (University of Pisa)

Recent advancements in medical image segmentation have been significantly influenced by the integration of Deep Learning (DL) and medical imaging technologies. This progress, particularly through Convolutional Neural Networks (CNNs), has transformed medical image analysis by enabling automatic feature extraction with high accuracy. Despite these advances, several challenges still hinder widespread clinical adoption. CNNs, while effective, often struggle with complex image regions that even experts find challenging. To overcome these issues, attention and recurrence mechanisms have been introduced. Attention mechanisms improve the network's focus on relevant image areas, while recurrence mechanisms help capture long-range dependencies for better contextual understanding. The doctoral thesis investigates the efficacy of these mechanisms in binary medical image segmentation, aiming to find a balance between resource use, data availability, and segmentation accuracy. Findings indicate that attention mechanisms enhance accuracy by dynamically adjusting weights to different image regions, although directing CNN's attention precisely remains difficult for subtle variations critical for diagnosis. Building on these insights, the thesis proposes integrating spatial priors into CNN architectures within an Attention-UNet, resulting in the development of SPI-net. SPI-net combines an Attention-UNet backbone with an upstream block for extracting spatial priors and a novel branch with long skip connections for injecting context-aware information. SPI-net's application to COVID-19 infection segmentation, guided by spatial prior knowledge, demonstrated superior performance over traditional methods, underscoring the importance of spatial priors in improving segmentation accuracy.

# Model checking properties with identity binding in space-time

Author: Laura Bussi, University of Pisa, Italy
Supervisors: Fabio Gadducci (University of Pisa), Vincenzo Ciancia, Cnr-Isti

Spatial logics are formalisms for expressing topological properties of structures based on geometrical entities and relations. Their models range from topological spaces to general graphs, and the properties of interest often concern reachability over infinite paths with a wide range of applications. In this thesis, we consider an extension of the logic SLCS, the Spatial Logic for Closure Spaces, providing it with an existential quantifier. We then equip the logic with temporal operators and provide a linear-time semantics over finite traces. The considered models are graphs. In particular, images are interpreted as graphs, thus model checking of spatial logics can be used for image analysis. Such ideas are the theoretical grounds of the model checker VoxLogicA, and of its applications to image analysis. Considered applications are medical image analysis and model checking of video streams, which is made feasible by exploiting GPU acceleration.

# Enhancing Author Name Disambiguation Workflows in Big Data Scholarly Knowledge Graphs

Author: Michele De Bonis, University of Pisa
Supervisors: Paolo Manghi, Fabrizio Falchi, Cnr-Isti, Marco Avvenuti (University of Pisa)

In the context of Open Science, Scholarly Knowledge Graphs (SKGs) are "big data" metadata collections that aggregate bibliographic metadata records and semantic relationships describing research products and their associations between them.

Motivated by the challenges posed by SKG construction, this Ph.D. thesis makes pioneering contributions to the field of Author Name Disambiguation (AND). This perennial issue addresses the challenge of identifying and removing duplicate author nodes representing the same author in the SKG. The thesis discerns two main interwoven imperatives in the duplicate resolution processes: mitigating the efficiency challenge derived by the inherent quadratic complexity in comparing hundreds of millions of author nodes; and the effectiveness challenge introduced by the efficiency optimization strategies, which renounce parts of the matches in favour of a lower computation time.

To address the efficiency challenge, the thesis introduces FDup, a groundbreaking framework meticulously designed to reimagine and enhance the traditional disambiguation workflow. This optimization is achieved through the incorporation of a decision tree-based comparison technique. To address the effectiveness challenge, the thesis leverages Graph Neural Networks (GNNs) and proposes two dedicated GNN architectures to enhance the effectiveness of Author Name Disambiguation via an evaluation of the outputs of a disambiguation algorithm: the first technique evaluates similarity relationships with an attentive neural network integrating GraphSAGE models; the second technique evaluates groups of duplicates with a combination of Graph Attention Network (GAT) and Long Short-Term Memory (LSTM) components.

In summary, this thesis is a responsive and forward-thinking contribution within the landscape of Open Science and SKGs.

# Artificial Intelligence for Multi-Connectivity in Beyond-5G Networks

Author: Achilles Kiwanuka Machumilane, University of Pisa
Supervisors: Giuseppe Amato, Claudio Gennaro, Alberto Gotta, Cnr-Isti

This work investigates learning-based scheduling systems using Actor-Critic Reinforcement Learning (AC-RL) and Generative Artificial Intelligence (GenAI) to support Multi-Connectivity (MC) in fifth- generation (5G) and beyond mobile networks. MC improves reliability, throughput, data rates, load balancing, and bandwidth aggregation by utilizing the different channel characteristics of each path. The study focuses on MC in terrestrial networks (TN) and non-terrestrial networks (NTN) such as satellites, High Altitude Platforms (HAPs), and Unmanned Aerial Systems (UAS). The scheduling system can support Access Traffic Steering, Splitting, and Switching (ATSSS), a 3GPP standard for MC. The system developed in this work uses AC-RL to predict the line- of-sight (LOS) of multiple satellites connected to a UE and distributes traffic to appropriate satellite links to avoid traffic loss due to LOS variations. However, since the process of LOS estimation with RL is modeled as a partially observable Markov decision process (POMDP) for scalability reasons, the agent takes a very long time to converge in a system with many links compared to the satellite visibility time, which is usually very short, in the order of a few minutes. To address this problem, we use GenAI, specifically Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs), to generate synthetic LOS states and transform the partially observable Markov decision process into a fully observable process to speed up the learning process and allow the agent to converge within the satellite visibility time. This work addresses single-user communication, but can also be extended to multi-user communication by using a multi-agent AC-RL algorithm with multi-objective functions where the agents can compete or cooperate to optimize shared resources.

# Biased Echoes: Unraveling Mechanisms of Opinion Dynamics and their Impacts in Online Social Networks

Author: Valentina Pansanella, Scuola Normale Superiore, Pisa
Supervisors: Giulio Rossetti, ISTI-CNR, Tiziano Squartini (IMT-Lucca)

The societal role played by public and individual opinions is crucial, not only because they shape our culture but also because they drive individual and - indirectly - collective actions, by influencing political decisions. Therefore, it is important to address and solve the problem of understanding how opinions form and evolve (in the context of online social networks), as this has significant implications for opinion dynamics, polarization, and social AI. Despite skepticism and contrasting empirical insights, the digital era led to additional complexities into this process and posed a threat for a healthy process of opinion evolution, contributing to the creation and maintenance of polluted information environments. In this thesis, therefore, our aim was to investigate the interplay of biases and network effects in driving opinion formation and diffusion in online social networks. We first review the state-of-the-art in computational social sciences, focusing on the structures used to model societies, such as graphs, temporal graphs, and higher-order structures. We then delve into the milestones of opinion dynamics, discussing models that account for the impact of different underlying structures and characteristic elements of the digital space, such as algorithmic bias. The literature on opinion dynamics is wide, ranging from binary opinions and pair-wise interactions models to continuous opinions on time-evolving higher-order systems, in a never-ending effort to reduce the gap between reality and the models' predictions. However, despite such a rich set of mathematical studies, the works concerning the validation of models on real data are scarce. Our approach was therefore two-fold. First, we developed models of opinion dynamics that incorporate specific characteristics of the opinion formation process and simulate their long-term consequences, i.e., until the studied population reaches an equilibrium, if possible. This thesis places a strong emphasis on capturing the realistic dynamics of online environments by examining the interplay between algorithmic and cognitive biases, which are inherent in all the models under study. These biases are then scrutinized in conjunction with other factors, such as network effects, dynamic influences, and the presence of external agents, including mass media. The resulting models are designed to ease the analysis of various scenarios akin to those observed in social media. Additionally, we developed a hybrid approach that uses existing opinion dynamics models for a time-aware user-level estimate of "open-mindedness" from real online discussions data, using both Reddit and Twitter as a case study. Lastly, we employed such method to "validate" one of the proposed models on an online discussion from Twitter around the Black Lives Matter controversy during Euro2020, introducing a pipeline for employing models to explain the unfolding of polluting phenomena on social media. Throughout the work our focus is to use the simplicity and interpretability of opinion dynamics model to better understand such a complex real phenomenon.

# Explanation Methods for Sequential Data Models

Author: Francesco Spinnato, Scuola Normale Superiore of Pisa
Supervisors: Riccardo Guidotti and Anna Monreale (University of Pisa), Mirco Nanni, ISTI-CNR

Sequential data is integral to many fields and plays a fundamental role in high-stakes decision-making, such as in healthcare, finance, transportation, and many other domains. However, the state-of-the-art approaches for sequential data predictions are usually black-box models, hardly interpretable from a human standpoint. In critical domains, the ability to explain a model's decisions is vital to establish a trustworthy relationship between human experts and AI systems. Thus, effective eXplainable AI (XAI) methods for sequential data can provide deeper insights across various domains, enhancing trust in machine learning decisions and reinforcing expert accountability in decision-making processes. This work tackles the challenge of explaining sequential data models from three distinct angles: the input, the output, and the explanation. Specifically, the input focuses on the diverse kinds of sequential data, proposing a comprehensive definition that encompasses forms like time series, trajectories, and text. The output pertains to the target variable in supervised learning, which can be either categorical or continuous, as seen in classification and regression tasks. Lastly, this work focuses on the explanation, which is the core of XAI, presenting various visualization techniques to aid users in understanding predictions from sequential data models. We analyze different combinations of input, output, and explanation types, proposing solutions tailored to the unique requirements of each task and challenge.

# Welcome aboard!

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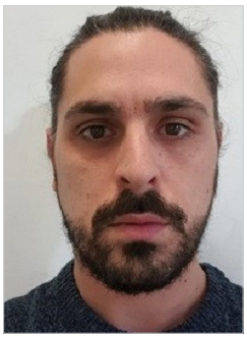

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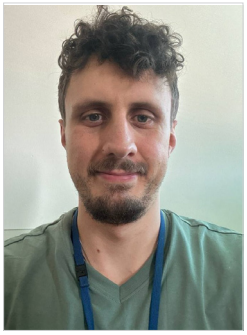

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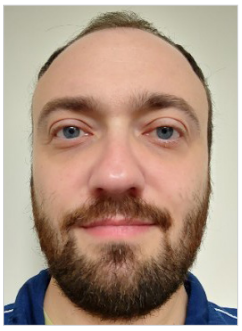

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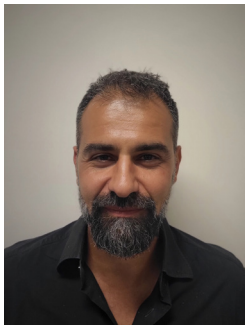

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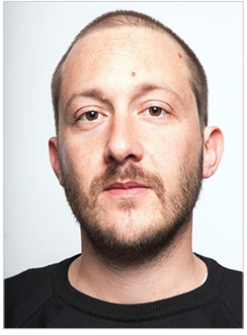

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# Conferences - Co-organized by ISTI

Workshop on AIML Integrated Terrestrial and Non-terrestrial networks
co-located with the MeditCom 2024
July 8–11, 2024, Madrid, Spain
https://meditcom2024.ieee-meditcom.org/

Learning to Quantify: Methods and Applications (LQ 2024)
co-located with the ECML/PKDD conference
September 9-13, 2024, Vilnius, Lithuania
https://lq-2024.github.io/

17th International Conference on the Quality of Information and Communications Technology (QUATIC 2024)
September 11-13, 2024, Pisa, Italy
https://2024.quatic.org/

MmIXR: Special Session on Multimedia Indexing for XR
co-located with CBMI 2024
September 18-20, 2024, Reykjavik, Iceland
https://cbmi2024.org/

Workshop IMTA IX - Image Mining. Theory and Applications
in conjunction with ICPR
December 1-5, 2024, Kolkata, India
https://imta.isti.cnr.it/

13th International Workshop on Computational Intelligence for Multimedia Understanding (IWCIM)
in conjunction with IEEE ISCAS 2025
May 25 - 28, 2025, London (UK)
https://iwcim.itu.edu.tr/


17th Advanced Infrared Technology and Applications (AITA) Conference
September 15 - 19, 2025, Kobe, Japan
https://english.jsndi.jp/aita2025/index.html


https://iui.acm.org/2025/

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