

ISTI News

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Cover Story

The Era of Digital Agriculture

EDITORIAL

ISTI - Increasing our impact as
we come of age

GranoScan App | pag. 6

Contents

Editorial

ISTI – Increasing our impact as we come of age 3

Cover Story

The era of digital agriculture 6

New Projects

T-LADIES 12

MIGHT 13

REVOLUTION 14

Automatic monitoring of accessibility in public administration
web sites. 15

Selected Papers

A mobility-based deployment strategy for edge data
centers. 16

Federated feature selection for cyber-physical systems of
systems 17

Formal methods in railways: a systematic mapping study . . 18

Efficient static analysis and verification of featured transition
systems 19

Designing and testing systems of systems: from variability
models to test cases passing through desirability
assessment. 20

Self-adaptive testing in the field: are we there yet? 21

A representation protocol for traditional crafts 21

Multi-camera vehicle counting using edge-AI 22

Smartphone-based augmented reality for end-user creation of
home automations. 23

COVID-19 lockdowns reveal the resilience of Adriatic Sea
fisheries to forced fishing effort reduction 24

A high-resolution global-scale model for COVID-19 infection
rate 25

Automatic detection of potentially ineffective verbal
communication for training through simulation in
neonatology 26

Virtual research environments co-creation: the D4Science
experience. 27

Gross polluters and vehicle emissions reduction 28

Dynamic hard pruning of neural networks at the edge of the
internet 29

Using low-resolution SAR scattering features for ship
classification. 30

Machine and deep learning prediction of prostate cancer
aggressiveness using multiparametric MRI. 31

Anorexia nervosa, body image perception and virtual reality
therapeutic applications: state of the art and
operational proposal. 32

TagLab: AI-assisted annotation for the fast and accurate
semantic segmentation of coral reef orthoimages. 33

Automated generation of flat tileable patterns and 3D reduced
model simulation 34

Tracking the variation of complex mode shapes for damage
quantification and localization in structural systems 35

The kinetic casualty risk of uncontrolled re-entries before and
after the transition to small satellites and
mega-constellations 36

Innovation

Integrated Wi-Fi and LoRa network on UAVs to locate
distressed people during SAR operations 37

Awards and Achievements

Paolo Cignoni is a new member 2022 of the SIGGRAPH
Academy 38

Best Ph.D. Forum paper award at PerCom Conference
2022 38

EECIR 2022 Industry Impact Award 39

New President of the Italian Chapter of Eurographics 40

Honorable mention award at the 2022 ACM Conference on
Human Factors in Computing Systems (CHI) 40

Miscellaneous

Ph.D. dissertations 41

ISTI – Increasing our impact as we come of age

An important anniversary is on the horizon. ISTI was founded in 2001 but became fully operational in 2002; we are thus celebrating the first 20 years of our Institute. As part of

the celebrations, we feel that now is the time for a restyling: upgrading and extending the ways we communicate with the outside world – academia and industry. This restyl-

ing also includes our newsletter, ISTI News, now at issue number 11.

Improving our presence on social media and the web

Social media are now considered as essential tools for dissemination to the external world. Consequently, ISTI has recently invested considerable time and effort in redefining its website and in creating a more solid presence on various sites. In particular, we have decided to open an ISTI account on Twitter and to consolidate our presence on LinkedIn. As LinkedIn is primarily used for professional networking, it is somewhat mandatory for us to be active on this channel, whereas Twitter is popular with researchers.

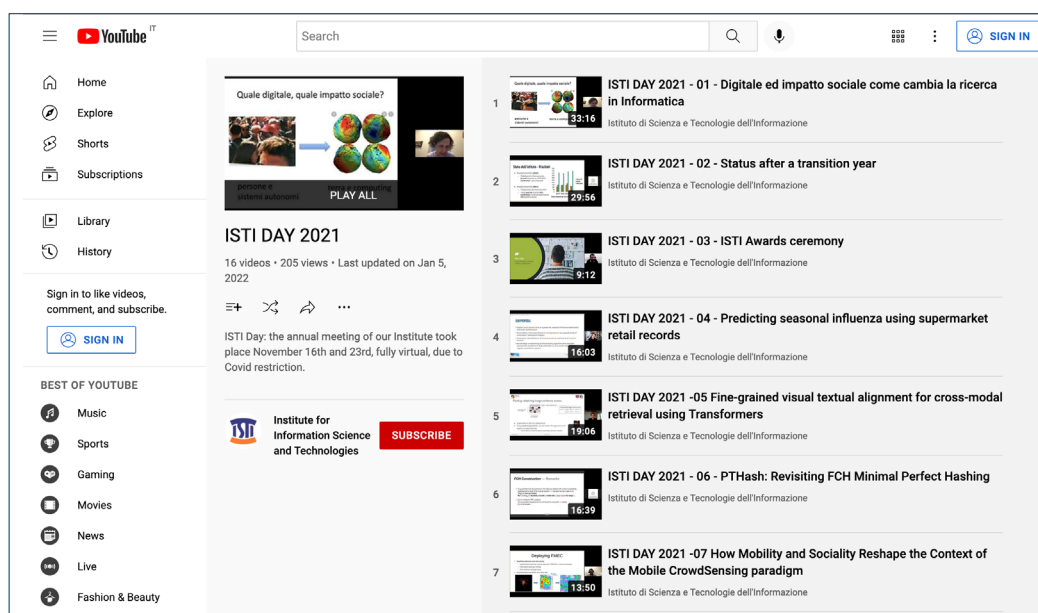
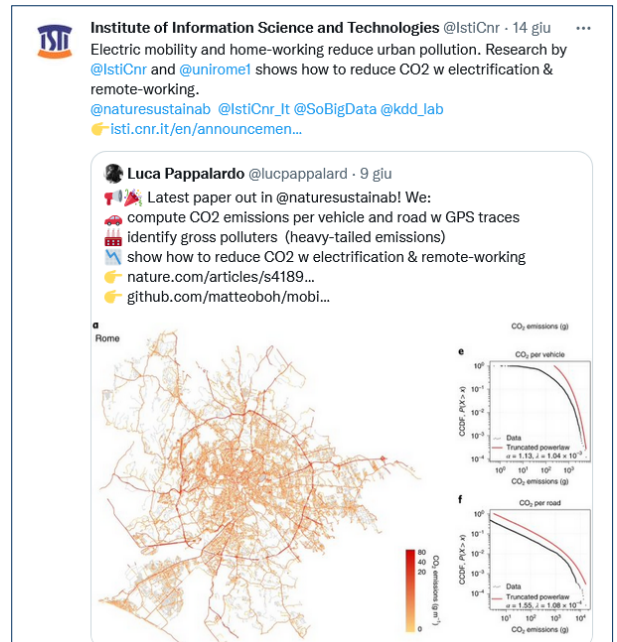
Scientists use Twitter to talk about their work, their successes and the challenges they are facing. They share their information on their latest work, and tweet about conferences they speak at or participate in. Furthermore, and importantly, Twitter also offers the opportunity to interact with other social actors and with the public. We thus decided to open two Twitter channels: @IstiCnr and @IstiCnr_It: the first dedicated

mostly to the scientific world (national and international), while the second is intended for the Italian general public. Now, after some months of testing, we are happy to officially and publicly launch these channels. The whole Institute is invited to send contributions.

It will be possible to employ the same communication channel to post news or information, both on the website and/or in the social channels.

In addition to LinkedIn and Twitter, we are also using YouTube to disseminate information on our results by means of recorded talks. For example, the annual ISTI Day (which took place last year in two half-day events on November 16th and 23th) presented a selection of recent

research results. These talks were recorded and posted on our YouTube channel (<https://www.isti.cnr.it/en/research/isti-day-2021>).



ISTI and the national press

It is also crucial to disseminate via the general press in order to reach a wider public, with the aim of demonstrating the importance of investing in research and the enormous

social benefits that can ensue. I'm happy to say that we have been successful in our push for a more impactful presence in the non-scientific press, with recently a steep increase

in the publication of the number of articles covering ISTI results: 5 articles in 2019, 32 in 2020 and 82 in 2021.

Revised and coordinated graphics for the basic communication channels of the Institute

In addition to our increased presence on social media, we have completely renewed ISTI's graphic image. The ISTI logo has been combined with the CNR logo, in order to comply with a request from CNR headquarters, and we have restyled our various means of communication: letter heads, business cards, brochures and flyers presenting the Institute and the Research Labs, our PowerPoint slide layout.

The underlying philosophy is immediacy in communication; all graphic material is organized in an attractive layout with a clear visual content hierarchy.



A new graphic design for our Newsletter

This Newsletter has also been restyled with a new layout. The cover page has undergone the most noticeable updates.

It is now dedicated to presenting the main highlight of the semester with an almost full-page image, plus a couple of additional

headlines evidencing other activities of importance.

Presenting ISTI to the Italian University

The shortage of young graduates willing to undertake a research training program is currently a problem. This is not an issue just for CNR, but for the entire Italian research community, especially for STEM disciplines (Science, Technology, Engineering and Mathematics). Recruiting young graduates is ever more difficult and affects all academic areas (research fellowships, PhD or temporary research positions). This phenomenon has become increasingly evident over the last few years leading, in recent months, to several ISTI Calls for Fellowships ending with no candidates. This is due to external factors: an

insufficient number of students and graduates in STEM disciplines, a strong gender gap (the small percentage of females attending and graduating in STEM degrees), industry looking desperately for engineers and computer scientists, often offering better wages and faster consolidation of contracts than the public research system. These factors make our recruiting process extremely difficult.

To help reverse this trend, we have planned a more active outreach policy. We already collaborate closely with local universities,

since the best way to attract students is to teach them and to be recognized as good professors. ISTI invests a considerable effort in teaching courses at Pisa University. In the current academic year, ISTI staff either presented or contributed to 29 university degree courses (many of them at the departments of Computer Science and Computer Engineering, but also in Digital Humanities and other departments); nine PhD courses were held by members of ISTI in 2021-22.

However, our presence in Pisa is not sufficient to secure the human resources we are

looking for. Thus, this spring, we began to collaborate actively with other universities. We organized presentations of ongoing research themes at ISTI in Italian locations where CNR does not already have a computer science institute. The first events took place at the University of Catania (April 21st), University of L'Aquila (May 18th) and University of Cagliari (May 24th). The leaflet of the Catania event is shown here.

The goal of these seminars is to present active research themes as well as the opportu-

nities offered by ISTI (PhD fellowships and young researcher training).

We have received some preliminary positive feedback. The success of this effort in attracting bright candidates will be measured by the interest in future calls for positions at ISTI. We are planning to repeat this initiative next fall.

It is our sincere hope that all these initiatives, aimed at increasing the dissemination of our activities and our impact on the outside

world, academia and non, will be rewarded by the creation of an inclusive environment in which the contribution of research is seen as an essential part of society as a whole.

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direttore@isti.cnr.it



Consiglio Nazionale delle Ricerche



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

LAVORARE CON LA SCIENZA

OPPORTUNITÀ DI
COLLABORAZIONE CON ISTI-CNR
PISA

21 APRILE
2022

ORE 11:00-13:00

AULA MAGNA



MATEMATICA
E INFORMATICA

PROGRAMMA

L'Istituto di Scienza e Tecnologie dell'Informazione (ISTI) del Consiglio Nazionale delle Ricerche (CNR) si presenta a studenti e docenti dell'Università di Catania.

L'incontro si articola su una serie di presentazioni, brevi trailer su temi di ricerca attualmente studiati in ISTI, che vogliono offrire ai docenti e agli studenti un quadro delle attività e delle opportunità di collaborazione e formazione offerte dall'Istituto.

- **Opening** | Roberto Scopigno, Direttore CNR-ISTI
- **Towards a Greener AI for Efficient Information Retrieval** | Franco Maria Nardini
- **Visual Processing from CH to fabrication and architecture** | Francesco Laccone
- **Engineering Resilient Software Systems** | Giulio Masetti
- **AI for Computer Vision and Multimedia Information Retrieval** | Fabio Carrara
- **Sensing Technologies for Ambient Intelligence** | Michele Girolami
- **Trustworthy AI: explaining classifiers for medical imaging** | Carlo Metta
- Domande e discussione

È possibile partecipare anche da remoto con il codice Microsoft TEAMS **5f0wqhv**. Per informazioni o problemi di connessione a TEAMS scrivere a informatica@dm1.unict.it

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https://www.isti.cnr.it/news.php

The era of digital agriculture

ICT solutions for a sustainable digital transformation

The impulse toward a more extensive introduction of Information and Communication Technology (ICT) in agriculture is currently experiencing momentum. A process of digital transformation has potential benefits for both producers and consumers, however, pushing technological solutions into a rural context raises several challenges (Bacco 2019).

Smart Farming and Digital Agriculture are the expressions most commonly used to refer to this transformation. The European Union (EU) has asserted that the most relevant technologies and techniques in this sector are satellite imagery, agricultural robots, and sensor nodes for data collection; Unmanned Aerial Vehicles (UAVs) are considered to have high potential for aerial imagery and actuation. These indications are contained in the declaration of cooperation on “A smart and sustainable digital future for European agriculture and rural areas”¹ signed by 26 EU countries.

At the core of this vision is the need for a sustainable future with an adequate food supply. According to the FAO (UN Food and Agriculture Organization), agricultural systems will evolve either in the direction of sustainable intensification or towards agroecology (Bellon-Maurel 2022). Contributions to the digital transformation of this sector must be made in a way that is sustainable for everyone: farms and farmers, nature, biodiversity, environment, climate, market, and consumers. Agroecology is a way of redesigning food systems to achieve true ecological, economic, and social sustainability, and the technologies employed must meet user needs while maintaining a robust

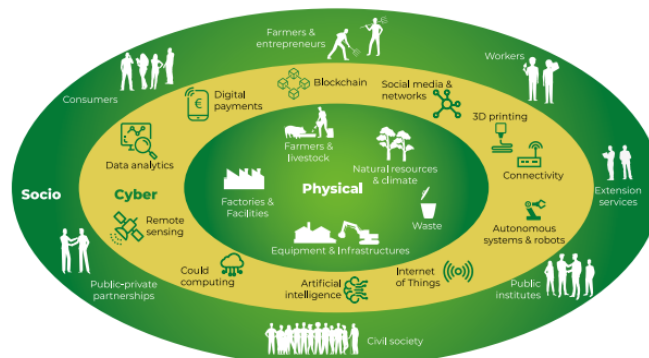


Fig. 1. Socio, Cyber and Physical (SCP) components of an agri-rural and forestry SCP system, highlighting its entities. (source https://desira2020.eu/wp-content/uploads/2021/12/DESIRA_NEI_briefing_v05.pdf)

stewardship of the environment. The social, cyber, and physical components of the system (see Fig. 1) must all be considered for the digital transformation to be sustainable. As shown in Figure 1, a number of technologies and paradigms are key to this transformation. At the Institute of Information Science and Technologies (ISTI), research is underway on most of them. In this article we present some of the most recent activities.

Artificial intelligence and computer vision for the safeguard of crops²

Many crops are subject to pests, weeds, plant diseases and abiotic stresses, which can result in suboptimal yields. A precise and punctual detection of these threats is often critical in protecting crops. Gaining insight into the health status of plants is vital for timely decision-making: treatments can then be planned and dosed cost-effectively and efficiently.

Artificial Intelligence and computer vision can help farmers to recognise threats and to take effective counter measures. Diseases, weeds, and damages in crops can be identified visually by processing aerial or proximity images. Research at ISTI aims at identifying

such threats using photos captured by conventional smartphones. This activity is the result of a collaboration of ISTI with Barilla G. e R. Fratelli S.p.A. (an international food company), Yoo-no Lab (an Italian IT group), and the Institute of Bioeconomy (IBE) of CNR.

The collaboration has produced the Granoscan app, which provides support for the viable cultivation of durum wheat. The app is free of charge and can be downloaded from the Google or Apple app stores or directly from the Web site at: <http://www.granoscan.it>

At the core of the app, there is a series of Artificial Intelligence algorithms that provide information on approximately a hundred different issues that can threaten the growth of wheat: ten different models have been developed, and each one is specialised in specific diseases, insects, weeds, or damages (abiotic stress), such as those caused by climatic events (e.g., frost).

Granoscan has been designed to be easy to use. By opening the app on a smartphone or tablet, a procedure helps the user to identify the type of disease they are facing, depending on the affected organs of the plants. In the case of disease or damage, the user is first prompted to choose the part of the wheat plant on which to focus (for example, the leaf

1 <https://digital-strategy.ec.europa.eu/en/news/eu-member-states-join-forces-digitalisation-european-agriculture-and-rural-areas#:~:text=26%20European%20countries%20signed%20a,and%20rural%20areas%20in%20Europe.>

2 PI: Massimo Martinelli, Davide Moroni

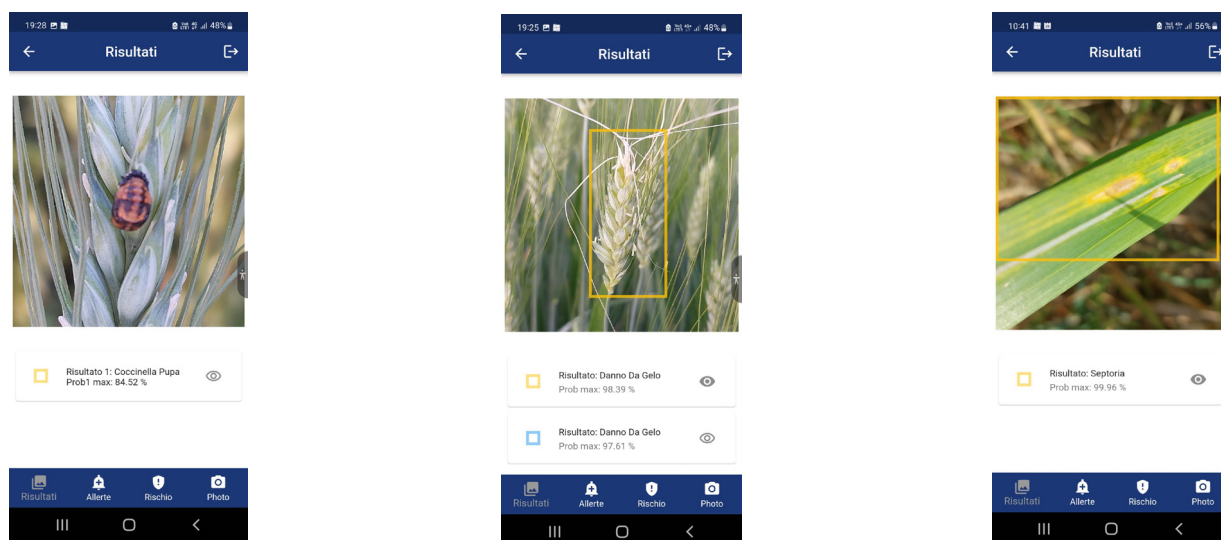


Fig. 2. Examples of detection achieved by GRANOSCAN

or the ear). A photo can then be taken (vertically or horizontally).

The image is then sent to a server that uses a Machine Learning (ML) algorithm to detect and classify any diseases identified. The ML approaches used are based on deep learning paradigms for object detection and image classification. The answer is provided in a time varying between 100 and 200 milliseconds: the app displays the image with the findings highlighted and lists the classifications with the relevant accuracies (see Fig. 2).

When there is no network coverage in the field, the image is stored locally on the mobile phone and transmitted once the user reaches an area with coverage.

Granoscan aims at building a community and utilising a crowdsensing approach. The images and observations provided by the users, with their optional consent, are processed by ad hoc models to generate an information network among wheat producers. Community members can obtain updated information about the onset of plant diseases in the area in which they operate and can thus decide whether to act immediately or request the help of an expert.

A huge effort has been taken to train the deep learning paradigms: farmers working together with Barilla collected between 1000 and 4000 images for each computer vision task. Images of weeds at early stages of germina-

tion were also acquired by cultivating them deliberately. These images were reviewed and annotated manually by agronomists at IBE and computer scientists at ISTI. This effort has been rewarded by the development of high-performance AI algorithms, which in one case (weeds at a very early stage) has outperformed the human observer.

Granoscan is currently an operational service, and new data is collected regularly, thus increasing the image database. The growth of the knowledge base means that the AI algorithms can be trained to recognise new cases and focus on challenging examples.

Our research has shown that, at least from a technological perspective, there are no insurmountable barriers to realising Artificial Intelligence tools to support farmers working in the fields. We hope to extend the application of our artificial intelligence methods to other crops and, first and foremost, to all varieties of wheat, which represents a primary food source in most parts of the world.

Artificial intelligence³ and UAVs for real-time prescription maps

Unmanned Aerial Vehicles (UAVs) have found wide application in precision agriculture. This is because they can be used to monitor large areas of the countryside, thanks to imaging

techniques combined with computer vision solutions. Their potentiality is, however, even greater: they can play a key role in collaborative robotics in smart farming. For example, within the [5G Bari-Matera experimentation \(2019-2020\)](#), a UAV experimentation for Precision Agriculture⁴ was carried out: ISTI-CNR experimented obstacle detection techniques in agricultural land while the University of Basilicata experimented innovative techniques of variable rate fertilisation for cereal crops.

An autonomous tractor was connected in 5G with a ground-based server from which it received updated prescription maps in semi-real time, downstream of the image acquisition process from the UAV and the creation of the map itself. The UAV used was the Matrice 600-Pro (Fig. 3), already used for



Fig. 3. The Matrice 600-Pro UAV (Arturo Argentieri, ISASI-CNR, pilot)

⁴ Partners: TIM, CNR-ISTI, CNR-ISA-SI, Digimat, University of Basilicata.

other 5G experiments in Matera carried out by ISTI [D'Antonio 2021], equipped with a MicaSense Rededge-M v2.0 multispectral camera, an RGB sensor, a Raspberry PI single-board computer, and a 5G modem.

The UAV flies over the field and performs RGB and multispectral shots to assess in real-time the state of the ground to be treated and the presence of any obstacle. The images collected by the multispectral camera are sent to a partner server which generates the prescription map, while the images taken by the RGB sensor are sent to the ISTI server to be processed by AI algorithms for the recognition of any obstacles found. The coordinates of these obstacles are then used to modify the prescription map appropriately. Fig. 4 (a) shows an example of an image taken by the drone in which an empty stroller is detected and identified as a foreign object and, therefore, a potential obstacle for a tractor.



Fig. 4. (a) An example of an obstacle identified by ISTI AI algorithm



Fig. 4. (b) The flight plan for multispectral survey of the field

For each shot, the multispectral camera generates five images, respectively in the red, green, blue, near infrared, and red edge bands; each image per spectral band occupies about 2.5MByte. For a field of 6.7 hectares, with a 15-minute UAV flight at the height of 60 meters, the multispectral camera generates 9 GBytes of data, thus the need to have a 5G connection between the UAV and the servers. Flight speed and image acquisition frequency are set depending on the band available in the field under examination, considering an adequate image overlap. Fig. 4 (b) shows the flight plan used for the multispectral survey of the field

LPWAN LoRa-powered and blockchain for cattle monitoring (the AGRARIAN system)⁵

LoRa is a radio modulation technique with compelling features for IoT applications, including long-range, low power consumption and secure data transmission. In recent years, LoRa devices are becoming smaller and cheaper, facilitating their employment in new emerging agricultural scenarios, such

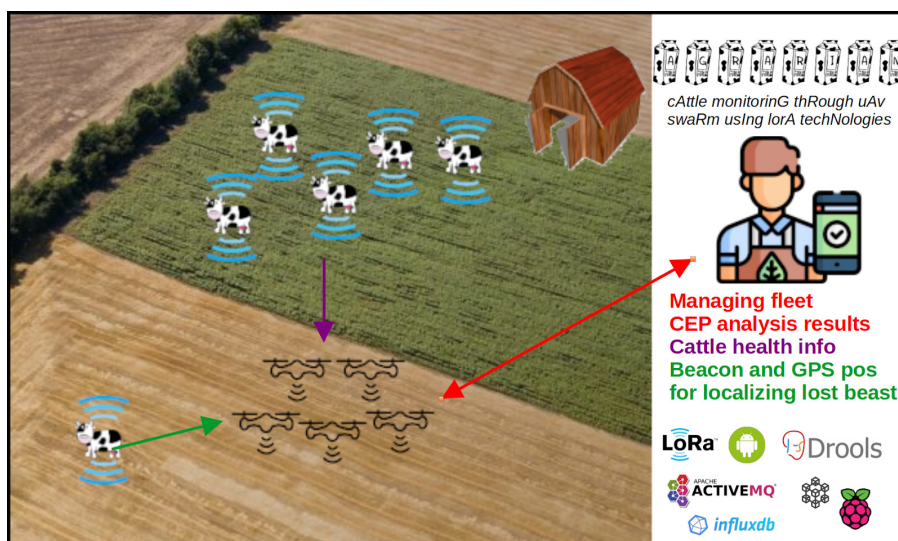


Fig. 5. Main concept of AGRARIAN (cAttle monitorinG thRough uAv swaRm using loRA techNologies).

as cattle monitoring.

Currently used infrastructure includes lightweight collars or tags containing a small LoRa device and a temperature sensor which is placed on the animal to provide information on well-being and data related to its position with respect to a LoRa-based gateway. However, at ISTI, new approaches are being designed that do not require an in-situ infrastructure. The proposed system (see Fig. 5) is composed of a UAV or a federated swarm of UAVs, equipped with hardware and software that monitor, analyse, track, and report cattle positions without the need for infrastructure on the ground.

The UAV (or UAV fleet) is equipped with a lightweight and low-power device capable of capturing the GPS position and analysing the LoRa beacons and the data sent by the LoRa devices on the cattle. With UAV fleets, information is shared through a distributed blockchain.

Monitoring activities analyse data gathered through the LoRa, tracking the behaviour of the herd. The analysis is performed onboard the UAV through a particular engine named “Event-Based Complex Event Processor” which is governed by a set of rules, easily generated and configured by the user.

Information captured and analysed by a single UAV or a fleet of UAVs can detect anomalies

and will either send alarms to the farmer’s mobile phone (if equipped with a LoRa device) or transmit the data to the cloud for offline examination and analysis.

The system can also be used, over a vast area, to locate a lost animal. UAVs capture beacons generated by the LoRa device on the animal and merge them with the GPS position and a database of other detected LoRa beacons. This information is sent to the farmer’s mobile phone; if this is idle other UAVs in the fleet will converge on the area to locate the lost animal.

The D4science infrastructure for agriculture⁶

Sustainability in agriculture must face the challenges of Climate Change (CC), the principal cause of droughts, exceptional precipitation, epidemics, and lowered production. By processing Big Data in agriculture, knowledge can be extracted that helps to manage these problems. However, this requires dedicated computer science systems that support data processing and guarantee transparency, i.e., repeatability and reproducibility.

These systems should use and offer data collection, storage, and processing tools from heterogeneous sources to understand com-

plex, multivariate, and unpredictable agricultural ecosystem dynamics.

The D4Science infrastructure (see Fig. 6), whose development and operation is led by ISTI-CNR, is an example of this type of innovative computer science system [Assante 2019]. It has been conceived to support the implementation of Virtual Research Environments (VREs) in an as-a-service providing mode and to enable co-creation [Assante 2022]. D4Science-based VREs are web-based, community-oriented, collaborative, user-friendly, open-science-enabler environments for scientists and practitioners willing to work together to perform specific (research) tasks.

From the end-user perspective, each VRE manifests in a unifying web application comprising components made available by “portlets” organised in custom pages and menu items and running in a simple web browser. Each component provides VRE users with facilities that rely on one or more services, offered by diverse providers. Each VRE acts as a gateway giving seamless access to the datasets and services of interest of a given community, while hiding any diversities originating from different resource providers. Basic components offered by the VREs enable users to work collaboratively, such as the workspace component which can be used to organise and share digital artefacts of interest and the social networking com-

6 PI: Leonardo Candela, Gianpaolo Corò

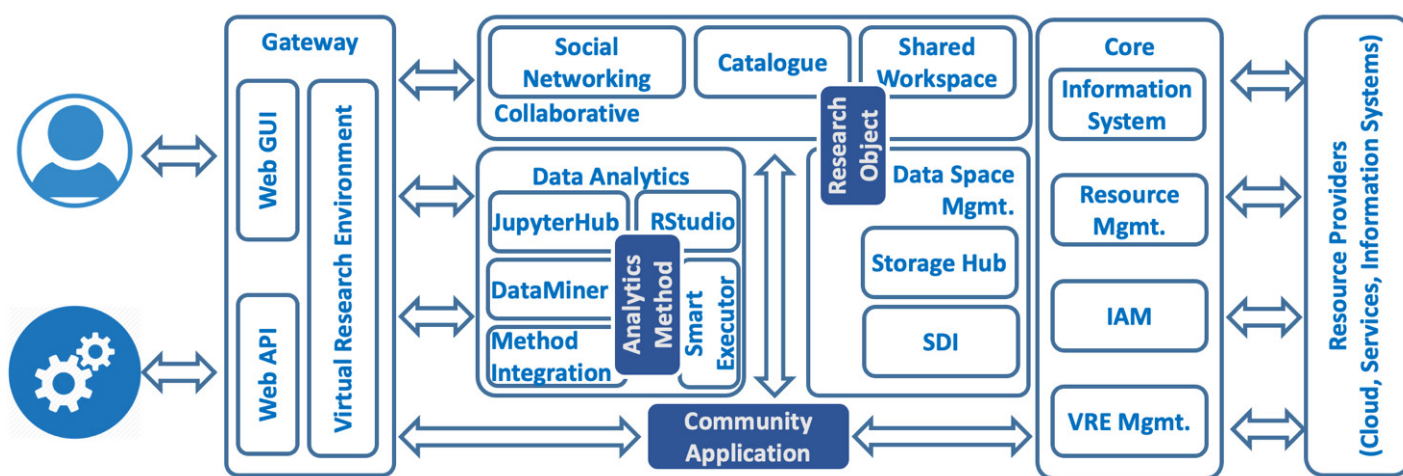


Fig. 6. D4Science VREs: Overall architecture

munication component. An additional platform for sharing and executing methods for data analytics makes the VRE a powerful tool for collaboratively gaining more insight into the available data.

The D4science distributed computing infrastructure is spread over four main, geographically distributed sites and managed across different administrative domains. This includes the ISTI site in Pisa, three sites operated on GARR premises (the Italian National Research and Education Network), and resources made available by the European Grid Infrastructure (EGI) federation (<https://www.egi.eu/egi-federation>), an initiative that offers 580 PetaBytes of online storage and over 38 Billion CPU hours. D4Science has proved to be a suitable solution for many diverse scientific communities including agri-food, earth sciences, marine sciences, social science and humanities [Assante 2022].

Within the context of the AGINFRA+ project, the D4Science infrastructure has been implemented for three use cases [Assante 2021]: (i) agro-climatic and economic modeling, focusing on tasks related to crop modeling and crop phenology estimation, (ii) food safety risk assessment, focusing on tasks to support scientists in the multidisciplinary field of risk assessment and emerging risk identification, and (iii) food security, focusing on tasks related to high-throughput phenotyping to support the selection of the most suitable plant species and varieties for given environments. A community-specific gateway has been created to provide the community with 16 specific VREs.

A recent ISTI-CNR study [Coro 2020] used the D4Science infrastructure to investigate the response of 10 world marine regions to CC; other studies have used the results to plan future water management in agriculture. ISTI-CNR research has evidenced that, in comparison with other marine areas, the Mediterranean Sea has an independent response and this could guarantee higher resilience to Mediterranean countries. On the other hand, northern seas face radical environmental changes. Cloud computing was

used to harmonise and analyse environmental Big Data through Map-Reduce strategies and to produce data and metadata applying standard annotations. Although the study was originally conceived for Marine Science, the transparency of the approach and the use of standards at all levels has fostered re-use of the data in other fields such as agriculture, energy management, and Earth Sciences.

Software and requirements engineering to co-design digital tools for forestry, agricultural, and rural areas⁷

When transforming an environment through the introduction of a digital system, traditional engineering approaches normally focus on the analysis of existing processes, stakeholders' needs, and social relations. While this can guide the engineering of solutions that take into account costs, benefits, budget and time constraints within a short-term perspective, it does not guarantee that sustainability concerns are addressed in the long run. This is particularly relevant for rural areas, including rural communities, agriculture, and forestry. This field is currently facing profound technological transformations, with digitalisation being regarded as a strategic enabler for sustainable growth at social, economic, and environmental levels. ICT solutions under the umbrella of preci-

sion agriculture, but also logistic systems that support the food value-chain, and even basic communication tools, are considered to be crucial when addressing the sustainability concerns of this domain. However, care must be taken as the transformation of an existing, highly traditional context by the introduction of a digital system can produce undesired consequences.

It is thus crucial that digital solutions must be designed in collaboration with the intended users, especially in rural areas, to overcome barriers that may hinder their employment, to leverage drivers that can support their diffusion, and to reflect on the potential impacts, both positive and negative, of digital tools after their deployment. The discussion in [Ferrari 2022] shows that typical barriers for the adoption of ICT solutions are not only the lack of connectivity in rural areas, but also inherent fear and distrust towards technology. In addition, the costs of technology and regulatory issues, often related to unclear data governance, are relevant barriers. The main drivers are economic, as technology can lead to cost reduction, but also institutional, since technology can improve monitoring as well as accountability. Regulators can play a crucial role through funding programmes and norms. Positive impacts are the elimination of repetitive labour and the possibility of exploiting economies of scale. On the other hand, negative impacts are the higher dependency on the technology as well as the social exclu-

7 PI: **Manlio Bacco, Alessio Ferrari**

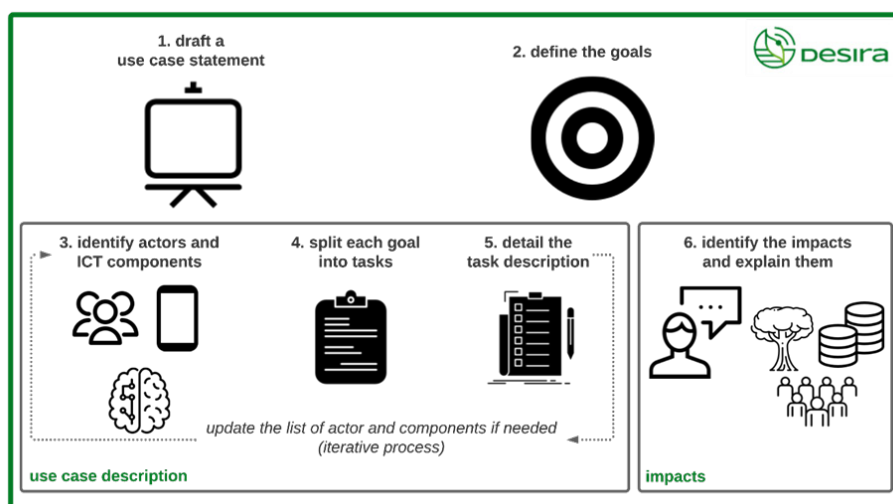


Fig. 7. DESIRA methodology to co-design use cases in Living Labs

sion of some players that cannot cope with the change, at least not quickly enough. The H2020 DESIRA project is actively investing such topics, and ISTI has proposed a methodology for Living Labs to co-design use cases⁸ with actors in rural areas. This should stimulate early reflections on potential drivers, barriers, and impacts that the digital solutions proposed could have when use (see Fig. 7).

8 In DESIRA, a use case is a description of goals to be achieved, tasks supporting the goals, involved actors, and physical and digital component of a socio-cyber-physical system.

Education: specialisation in “digital agriculture for sustainable development”⁹

ISTI is now collaborating in the institution of a new course for specialisation: “Digital Agriculture for Sustainable Development”. Led by the Department of Agricultural, Food and Agro-Environmental Sciences of the University of Pisa jointly with the Department of Information Science, the Department of Information Engineering, ISTI, and the Quinn Consortium, the course will be held for the

first time in 2023. Students and professionals will be provided with the fundamentals to understand and use digital technologies in the agricultural field. The potential of ICT and its socio-economic implications will be discussed, equipping participants with the appropriate tools to choose digital technologies tailored to different contexts, as well as with the capacity to better interact with developers of innovative services and applications. More info at: <https://www.agr.unipi.it/corso-di-perfezionamento-agricoltura-digitale-per-lo-sviluppo-sostenibile>.

9 PI: Manlio Bacco, Paolo Barsocchi

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T-LADIES

Co-funded by the Italian Ministry of Education, University and Research (MIUR) under the Projects of National Interest (Progetti di Ricerca di Interesse Nazionale – PRIN) program



T-LADIES (Typeful Language Adaptation for Dynamic, Interacting and Evolving Systems) targets the development of advanced technologies, formal methods and tools for reliable and efficient distributed applications in cloud-to-edge-to-IoT systems. Conventional language and engineering techniques struggle to keep up with the pace at which such applications evolve and provide inadequate support for development/maintenance, automatic property verification/enforcement, and bug detection.

T-LADIES proposes to use dynamic language adaptation to improve the development/maintenance process in combination with advanced type systems to verify and enforce the properties of software (SW). The aim is to increase productivity and SW quality, while reducing development costs and time-to-market.

T-LADIES focuses on the Internet of Things (IoT), which is characterised by several in-

terconnected “things” that have heterogeneous capabilities and behaviour, and whose spatial distribution is a relevant parameter. These characteristics pose key challenges:

IoT applications are programmed in general-purpose, domain-agnostic languages, which hinders their maintenance, modification, and evolution. Since IoT is pervasive, it is desirable that domain experts—without advanced programming skills—can easily (re) program, maintain, and modify IoT applications.

“Things” are assumed to interact according to predefined schemes, whereas context and application changes call for supporting configurations that are unknown when “things” are conceived. Such flexibility requires richer ways to specify “things” capable of improving the approaches typically offered by general-purpose languages.

IoT applications are based on the interaction of “things” that dynamically vary in number and kind, which poses issues of correctness, dynamic evolution, and adaptation. The notion of interaction should thus be enriched to support variability, dynamic monitoring, property enforcing, and orchestration of the “things”.

IoT applications have to meet high-quality standards: absence of undesired situations (deadlocks, orphan messages,...), support for non-functional requirements (performance,

energy sustainability, ...), and resilience to varying execution contexts. The complexity of IoT applications makes it hard to meet and preserve such standards without automated tools.

T-LADIES addresses these challenges through an approach to SW development that mixes language adaptation, interaction mechanisms, and advanced type systems. In T-LADIES, language adaptation will make it possible to vary how the language behaves in different contexts and, consequently, to modify application behaviour accordingly, with no impact on the source code. Interaction mechanisms are intended to provide extra functionality to the mechanisms that are natively available in the context in which the application runs. Advanced type systems enable the behavioural specification of entities, the enforcing and verification of system properties, and the early detection of bugs.

The goal is to achieve results of both foundational and practical impact. The expected outcome is a novel formal approach to develop and maintain modern applications by focusing on dynamic adaptation, property enforcing, and component interaction. Its adoption will drastically improve the quality of SW on which our daily lives rely. Case studies from the IoT domain will drive the research and demonstrate the effectiveness of the approach.

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MIGHT

Funded by Progetti di Ricerca@Cnr (CNR Research Projects - National Research Council)

The understanding of the relationship among diet, metabolites, and host/microbiota is a key challenge when investigating personalized nutrition for the most fragile segments of the population, and the modulation of the gut microbiota through dietary interventions is one of the most promising approaches. The MIGHT project aims at disentangling key research questions behind food protein modifications and the effects on the host microbiota. The figure below summarizes how technological interventions can tune food quality with targeted functional improvements for health, defining the four strategic areas (SA) of this proposal. SA1 research question 1, includes tailored protein modifications in foods through Maillard reaction and their relationship with targeted nutrition. Glycation reactions

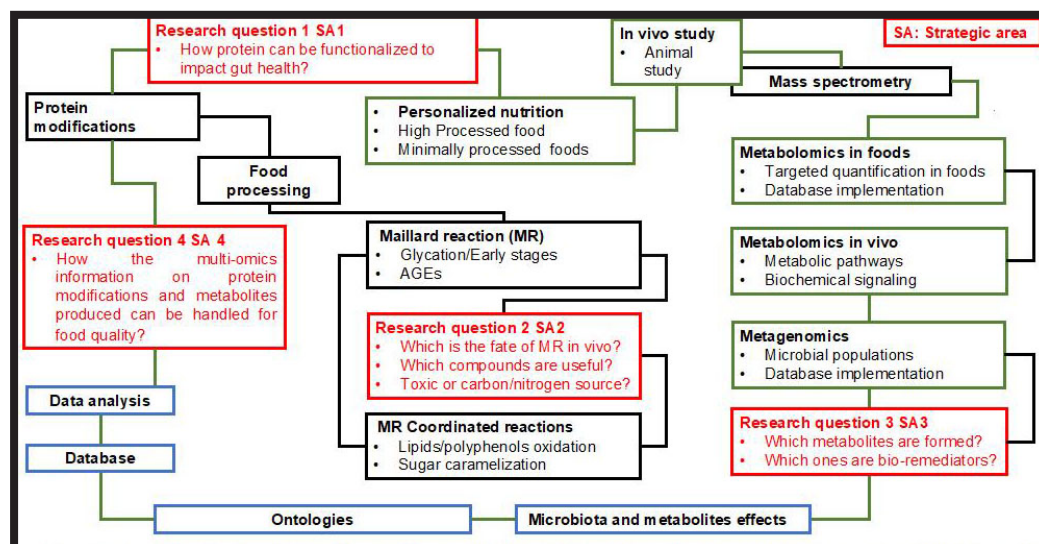
occupy a prominent place in Food Chemistry and Human Nutrition, but three crucial questions (part of SA2) remain unresolved: what are the molecular effects of dietary advanced glycation end-products (d-AGEs) in vivo? Are d-AGEs, carbon and nitrogen sources useful to shape gut microbiota? Does there exist a discrimination between 'good and bad' d-AGEs? Literature evidence suggests that glycation of lysine and arginine residues impairs overall protein digestibility and the quantity of glycated proteins that funnel the colon daily can reach up to 1 g, but the molecular fate of d-AGEs is still unknown. Metagenomics and metabolomics mass spectrometry approaches will answer the research questions 3 part of SA3: which metabolic products from glycated compounds possess bio-functional properties?

Do gut microbial populations work as bioremediators or boost formation of functional molecules (i.e. short chain fatty acids, SCFA)?

The data generated will flow into the construction of ontologies able to connect diet, metabolites, and microbiota in infants and potentially in the elderly, as two of the most fragile segments of the population.

The research will be conducted by 3 Research Units (RUs) of the project consortium consisting of IBBA-CNR, ISPAAM-CNR and ISTI-CNR.

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Schematic representation of the four strategic areas (SA) of the MIGHT proposal. Red boxes highlight key research questions, while black boxes outline Food Chemistry and technology aspects, green boxes nutrigenomics aspects, in blue boxes IT solutions.

REVOLUTION

Funded by Progetti di Ricerca@Cnr (CNR Research Projects - National Research Council)

The REVOLUTION project focuses on designing and implementing an integrated management system for architectural heritage and civil infrastructure. Based on long-term dynamic monitoring and numerical simulations, the approach uses a digital replica of the monitored building to assess its structural health and identify any damage.

Specifically, the project aims at developing a prototype of an open-source platform with a view to creating a Digital Twin (DT), which remotely supports diagnosis and conservation activities, allowing the planning of maintenance and management operations.

The platform will use cutting-edge technologies such as i) 2D/3D digitization tech-

niques; ii) reverse engineering procedures; iii) advanced monitoring networks; iv) numerical modelling.

The heart of the platform will be the NOSA-ITACA code, a software developed by MMS Lab to disseminate the use of mathematical models and numerical tools in the field of Cultural Heritage. NOSA-ITACA is the result of integrating the finite element code NOSA into the open-source graphic platform SALOME.

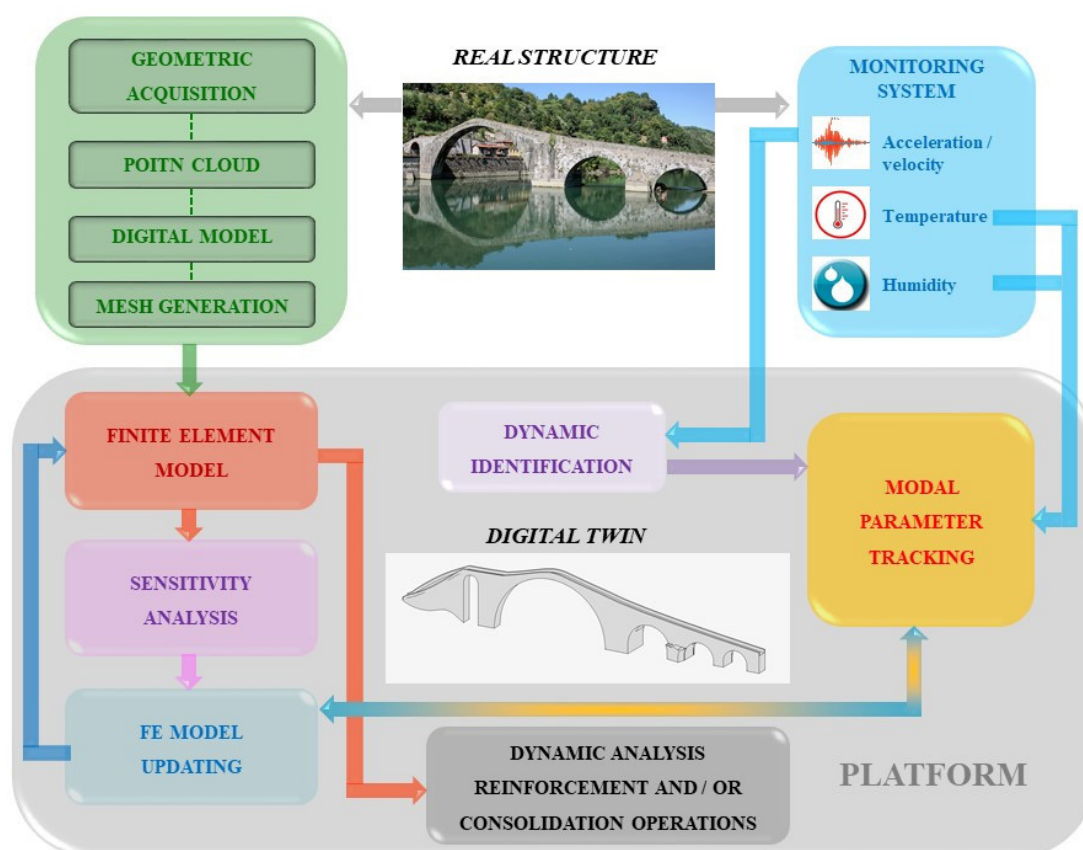
The NOSA-ITACA code will be improved and modified to become a platform capable of interfacing with other tools needed to create a Digital Twin of a structure. The platform will allow:

- to manage the geometric/digital acquisition of the structure obtained from a laser scanner survey and the corresponding finite element mesh;
- to process the data from the monitoring system;
- to calibrate the finite element model on the basis of recorded and processed data from the monitoring system, and perform structural analyses.

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www.nosaitaca.it/projects/revolution/



Automatic monitoring of accessibility in public administration web sites

Funded by the Italian National Recovery and Resilience Plan (PNRR) – Measure 1.4.2 Accessibility

ISTI has signed an agreement with the Agency for Digital Italy (Agenzia per l'Italia Digitale - Agid) for the development of an open system aimed at automatically monitoring the accessibility of websites of Italian national and local public bodies. This collaboration intends to contribute to the implementation of the official measures of the National Recovery and Resilience Plan focused on improving the accessibility of digital services provided to the public. It supports the evolution of the MAUVE ++ platform with the aim of providing public administrations with a cost-free system that automatically supports validation of websites accessibility.

The importance of providing Web applications accessible for all, including people with cognitive or physical disabilities, has become increasingly recognised. This is confirmed by measures included in national and international laws. A major initiative addressing these issues is the EU Directive on the "Accessibility of the Websites and Mobile Applications of Public Sector Bodies" that came into force on 26/10/2016, also known as the Web Accessibility Directive (WAD), which establishes accessibility requirements for the websites and mobile applications of public sector bodies. A crucial aspect of this directive regards website monitoring, which must be performed more systematically in terms of the number of Web pages involved, and with a certain level of frequency.

In parallel, the guidelines for the accessibility of Web Sites laid down by W3C in the Web Accessibility Initiative, are in continuous evolution with respect to the necessity to better address the various possible disabilities and the evolution of Web technologies.

The current version (2.1) is structured into principles, guidelines, success criteria, and techniques, which have increased with respect to the previous versions.

It is evident that thorough accessibility validation requires considerable effort due to the number of elements and aspects that have to be checked. Interest in the automatic support of this activity is thus growing. Further research and development in this area are being stimulated because of its potential to assist the collection and analysis of data on the effective application of the accessibility guidelines, detect non-compliance in a consistent manner, and provide relevant information on how to address potential problems. At the same time, it is important to be aware that not all accessibility issues can be detected automatically; some require manual checking by experts in the field, and subjective feedback must still be considered.

The Human Interfaces in Information Systems (HIIS) Laboratory of ISTI is participating in this activity. One of the principal areas of interest of the HIIS Lab is that of tools to support the evaluation of accessibility and usability. Over the years, the Lab has published numerous studies and proposed several systems in this sector. The most recent of these is MAUVE ++, which addresses three important emerging issues: accessibility monitoring, tool transparency, and support for dynamic Web sites. The first means the ability to indicate a set of Web pages and periodically check their level of accessibility in order to keep relevant stakeholders informed. The second aims to address an important problem that users of automatic validators often encounter also when us-

ing multiple tools: different results may be shown. The users are often disoriented by these variations, finding them confusing. Thus, it becomes important that such tools be transparent and indicate in detail what they are actually able to validate. The last issue aims to address the increasing use of development frameworks that implement dynamic Web sites, such as Angular or Vue.js, producing web pages that are substantially different when loaded in the Web browser from the static version.

Thanks to the upgrading of the MAUVE++ platform, by the end of June 2022, an initial monitoring of the accessibility of 10,000 websites of public administrations will be carried out, for a total of approximately 2 million web pages. These data will be made publicly available, and will contribute towards the annual national monitoring of websites (of which Agid is responsible for Italy) as established by European Directive 2102/2016. This general monitoring will be performed at least quarterly, and will be useful for analysing the actual state of accessibility of Italian Public Administration, identifying problematic areas, and stimulating more attention to the accessibility of digital technologies, which is an important issue for our society.

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A mobility-based deployment strategy for edge data centers

M. Girolami, P. Vitello, A. Capponi, C. Fiandrino, L. Foschini, P. Bellavista

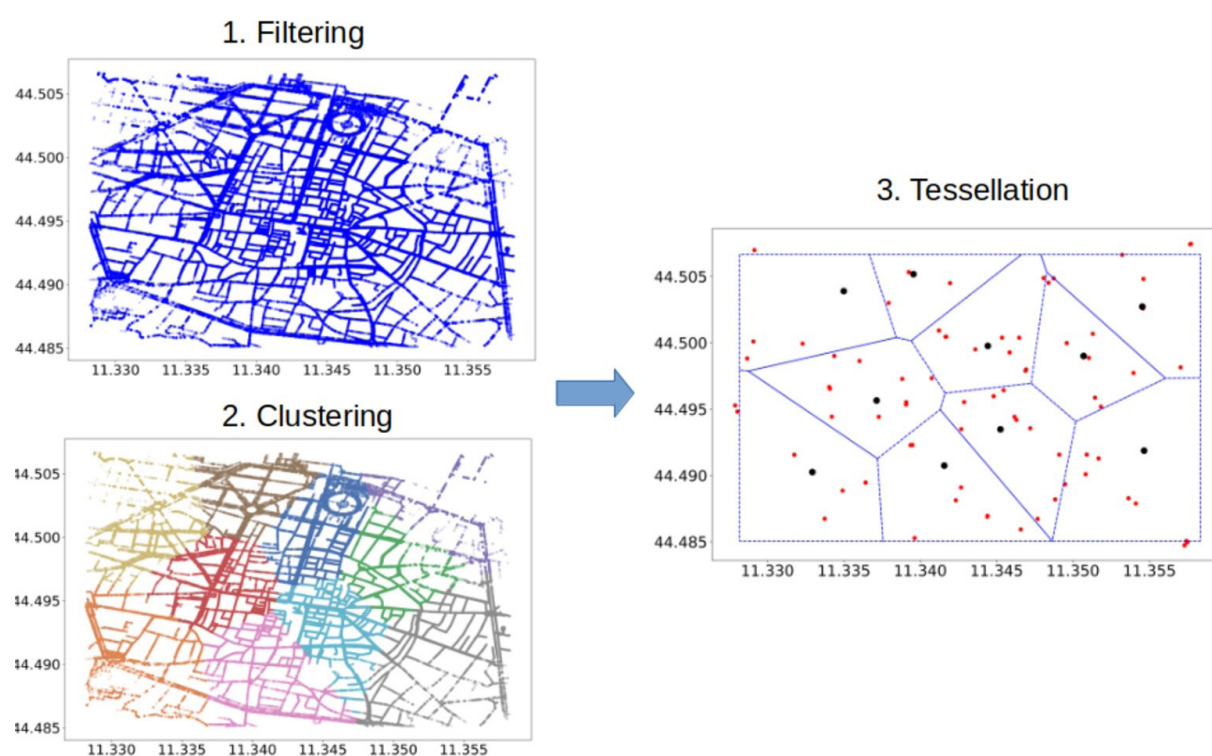
Journal of Parallel and Distributed Computing, vol. 164. Elsevier, 2022.

The main objective of Multi-access Edge Computing (MEC) is to bring computational capabilities at the edge of the network to better support low-latency applications. Such capabilities are typically offered by Edge Data Centers (EDC). The MEC paradigm is not tied to a single radio technology, rather it embraces both cellular and other radio access technologies such as WiFi. Distributed intelligence at the edge for AI purposes requires careful spatial planning of computing and storage resources. The problem of EDC deployment in urban environments is challenging and, to the best of

our knowledge, it has been explored only for cellular connectivity so far. In this paper, we study the possibility of deploying EDC without analyzing the expected data traffic load of the cellular network, a kind of information rarely shared by network operators. To this purpose, we propose in this work CLUB, CLUstering-Based strategy tailored on the analysis of urban mobility. We analyze two experimental mobility data sets, and we analyze some mobility features in order to characterize their properties. Finally, we compare the performance of CLUB against state-of-the-art techniques in terms of the

outage probability, namely the probability an EDC is not able to serve a request. Our results show that the CLUB strategy is always comparable with respect to our benchmarks, but without using any information related to network traffic.

DOI: 10.1016/j.jpdc.2022.03.007

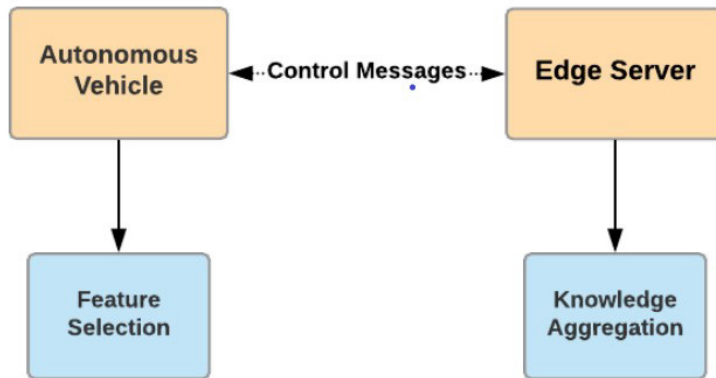


The processing pipeline used to deploy EDC with the CLUB strategy.

Federated feature selection for cyber-physical systems of systems

P. Cassarà, A. Gotta, L. Valerio

IEEE Transactions on Vehicular Technology, in press.IEEE, 2022.



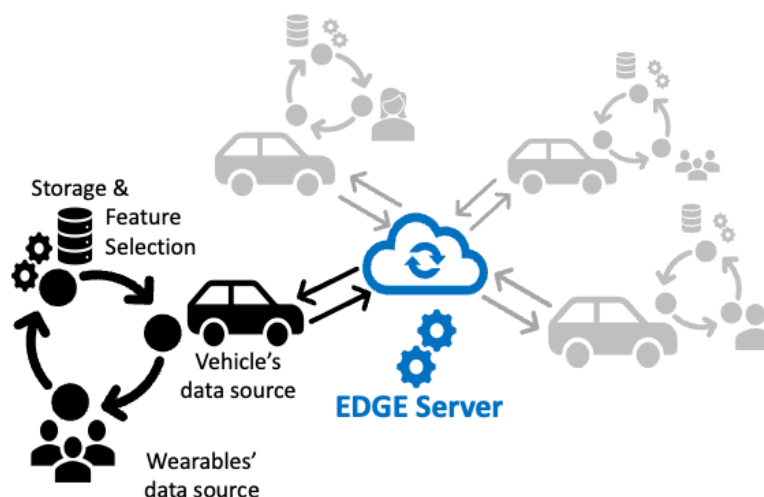
Feature selection and aggregation components of the proposed FFS system.

Autonomous vehicles (AVs) generate a massive amount of multi-modal data that once collected and processed through Machine Learning algorithms, enable AI-based services at the Edge. In fact, only a subset of the collected data present informative attributes to be exploited at the Edge. Therefore,

extracting such a subset is of utmost importance to limit computation and communication workloads. Doing that in a distributed manner imposes the AVs to cooperate in finding an agreement on which attributes should be sent to the Edge. In this work, we address such a problem by proposing a

federated feature selection (FFS) algorithm where the AVs collaborate to filter out, iteratively, the less relevant attributes in a distributed manner, without any exchange of raw data, through two different components: a Mutual-Information-based feature selection algorithm run by the AVs and a novel aggregation function based on the Bayes theorem executed on the Edge. The FFS algorithm has been tested on two reference datasets: MAV with images and inertial measurements of a monitored vehicle, WESAD with a collection of samples from biophysical sensors to monitor a relative passenger. The numerical results show that the AVs converge to a minimum achievable subset of features with both the datasets, i.e., 24 out of 2166 (99%) in MAV and 4 out of 8 (50%) in WESAD, respectively, preserving the informative content of data.

DOI: 10.1109/TVT.2022.3178612



System architecture. Data sources characterize two different Cyber Physical Systems (CPSs): the former that monitors the user through wearable sensors, the latter relative to the ADS.

Formal methods in railways: a systematic mapping study

A. Ferrari, M.H. ter Beek

ACM Computing Surveys, in press. ACM, 2022.

Formal methods are mathematically based techniques for the rigorous development of software-intensive systems. The railway signaling domain is a field in which formal methods have traditionally been applied, with several success stories. This article reports on a mapping study that surveys the landscape of research on applications of formal methods to the development of railway systems. Following the guidelines of systematic reviews, we identify 328 relevant primary studies, and extract information about their demographics, the characteristics of formal methods used and railway-specific aspects.

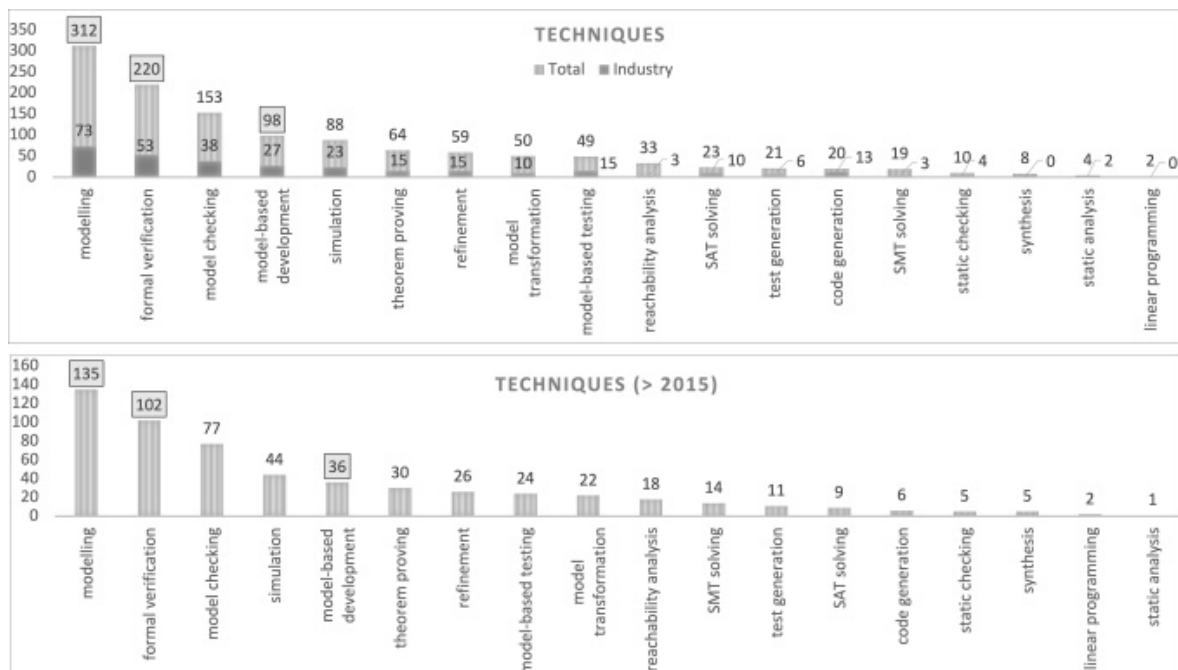
Our main results are as follows: (i) we identify a total of 328 primary studies relevant to our scope published between 1989 and 2020, of which 44% published during the last 5 years and 24% involving industry; (ii) the majority of studies are evaluated

through Examples (41%) and Experience Reports (38%), while full-fledged Case Studies are limited (1.5%); (iii) Model checking is the most commonly adopted technique (47%), followed by simulation (27 %) and theorem proving (19.5%); Less commonly used are techniques that are strictly related to code, as test or code generation; (iv) the dominant languages are UML (18%) and B (15%), while frequently used tools are ProB (9%), NuSMV (8%) and UPPAAL (7%); however, a diverse landscape of languages and tools is employed; (v) the majority of systems are interlocking products (40%), followed by models of high-level control logic (27%); (vi) most of the studies focus on the Architecture (66%) and Detailed Design (45%) development phases.

Based on these findings, we highlight current research gaps and expected actions. In

particular, the need to focus on more empirically sound research methods, such as Case Studies and Controlled Experiments, and to lower the degree of abstraction, by applying formal methods and tools to development phases that are closer to software development. Our study contributes with an empirically based perspective on the future of research and practice in formal methods applications for railways. It can be used by formal methods researchers to better focus their scientific inquiries, and by railway practitioners for an improved understanding of the interplay between formal methods and their specific application domain.

DOI: 10.1145/3520480



Efficient static analysis and verification of featured transition systems

M.H. ter Beek, F. Damiani, M. Lienhardt, F. Mazzanti, L. Paolini
Empirical Software Engineering , vol. 27. Springer, 2022.

A Featured Transition System (FTS) models the behaviour of all products of a Software Product Line (SPL) in a single compact structure, by associating action-labelled transitions with features that condition their presence in product behaviour. It may however be the case that the resulting featured transitions of an FTS cannot be executed in any product (so called dead transitions) or, on the contrary, can be executed in all products (so called false optional transitions). Moreover, an FTS may contain states from which a transition can be executed only in some products (so called hidden deadlock states). It is useful

to detect such ambiguities and signal them to the modeller, because dead transitions indicate an anomaly in the FTS that must be corrected, false optional transitions indicate a redundancy that may be removed, and hidden deadlocks should be made explicit in the FTS to improve the understanding of the model and to enable efficient verification—if the deadlocks in the products should not be remedied in the first place.

We provide an algorithm to analyse an FTS for ambiguities and a means to transform an ambiguous FTS into an unambiguous one.

The scope is twofold: an ambiguous model is typically undesired as it gives an unclear idea of the SPL and, moreover, an unambiguous FTS can efficiently be model checked. We empirically show the suitability of the algorithm by applying it to a number of benchmark SPL examples from the literature, and we show how this facilitates a kind of family-based model checking of a wide range of properties on FTSs.

DOI: [10.1007/s10664-020-09930-8](https://doi.org/10.1007/s10664-020-09930-8)

Table 2 Comparison of current implementation of static analysis algorithm with that in ter Beek et al. (2019a)

FTS	Characteristics			Computational effort				Results
Model	S	δ	Σ	Implementation in ter Beek et al. (2019a)		Current implementation		Runtime speedup
				Runtime (s)	Memory usage (Mb)	Runtime (s)	Memory usage (Mb)	
Vending machine (Classen 2011)	9	13	12	0.92	38.230	0.26	29.765	3.54x
Coffee machine (Asirelli et al. 2011)	14	23	15	2.822	40.140	0.29	30.305	9.72x
Soup component (Belder et al. 2015)	13	28	18	2.544	40.870	0.316	30.85	8.05x
Mine pump (system) (Classen 2011)	25	41	22	2.192	41.899	0.344	31.704	6.37x
Mine pump (controller) (Classen 2011)	77	104	22	8.12	49.091	0.548	36.295	14.82x
Coffee/Soup machine (Belder et al. 2015)	182	691	33	Timeout	–	37.766	119.427	>7200.00x
Mine pump (complete) (Classen 2011)	418	1,255	26	Timeout	–	98.994	119.127	>7200.00x
Claroline (Devroey et al. 2014a)	107	11,236	106	Timeout	–	2413.8	2010.229	>7200.00x

Designing and testing systems of systems: from variability models to test cases passing through desirability assessment

F. Lonetti, V. de Oliveira Neves, A. Bertolino

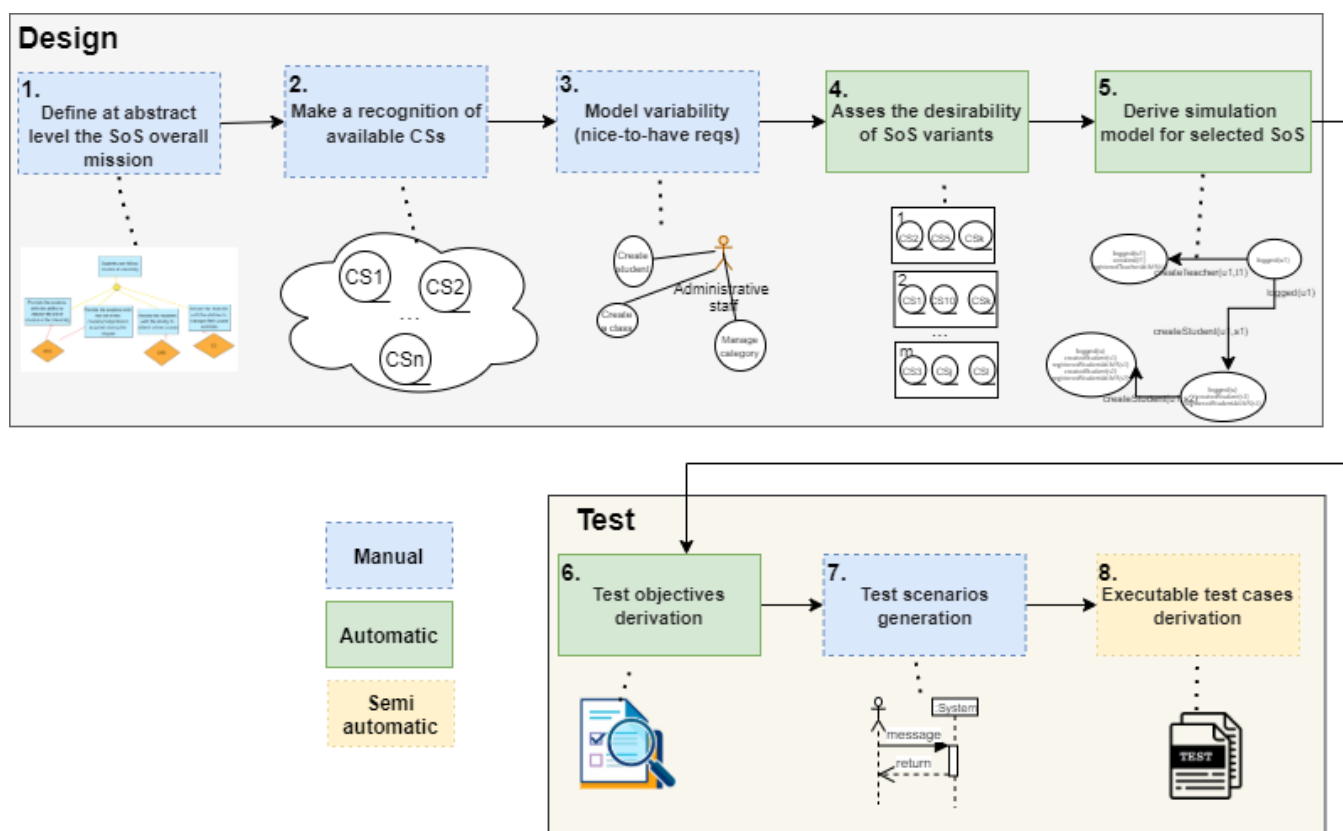
Journal of Software: Evolution and Process, in press. Wiley 2022.

A system of systems (SoS) is obtained by connecting a set of constituent systems (CSs) so that altogether they can achieve a global goal or mission that is beyond their individual capabilities. An important aspect in SoSs is variability, concerning both time and space. In the early stages of a SoS conception, several constituent systems could be available that provide similar functionalities. An SoS design methodology should provide adequate means to model variability in order to support the opportunistic selection of the most desirable SoS configuration. Thus, before a concrete SoS architecture has

been decided, the SoS engineer may want to choose, among several existing CSs, the ones that better contribute to achieve the planned mission with acceptable quality and costs. To address this problem, we propose to leverage the variability and asset reuse concepts defined in the Software Product Line domain to provide a design and testing approach called VANTESS (VARIability aware-designN and TESTing of SoS) for the opportunistic engineering of directed or acknowledged SoSs. VANTESS: (i) supports SoS modeling taking into account the variation points implied by the considered con-

stituent systems; (ii) includes an heuristics to weight benefits and costs of potential architectural choices (called as SoS variants) for the selection of the constituent systems; and finally (iii) also helps test planning for the selected SoS variant by deriving a simulation model on which test objectives and scenarios can be devised. We illustrate an application example of VANTESS to the “educational” SoS and discuss its pros and cons within a focus group.

DOI: 10.1002/smr.2427



Overview of the VANTESS approach.

Self-adaptive testing in the field: are we there yet?

S.Silva, A. Bertolino, P. Pelliccione

17th Symposium on Software Engineering for Adaptive and Self-Managing Systems. IEEE, 2022.

Testing in the field is gaining momentum, as a means to detect those failures that escape in-house testing by continuing the testing even while a system is operating in production. Among several approaches that are proposed, this paper focuses on the important notion of self-adaptivity of testing in the field, as such techniques need to adapt in many ways their strategy to the context and

the emerging behaviors of the system under test. In this work, we investigate the topic by conducting a scoping review of the literature on self-adaptive testing in the field. We rely on a taxonomy organized in some categories that include the object to adapt, the adaptation trigger, the temporal characteristics, the realization issues, the interaction concerns, the type of field-based approach, and the

impact/cost. Our study sheds light on self-adaptive testing in the field by identifying related key concepts and key characteristics and extracting some knowledge gaps to better guide future research.

A representation protocol for traditional crafts

X. Zabulis, N. Partarakis, C. Meghini, A. Dubois, S. Manitsaris, H. Hauser, N.M. Thalmann, C. Ringas, L. Panesse, N. Cadi, E. Baka, C. Beisswenger, D. Makrygiannis, A. Glushkova, B.E.O. Padilla, D. Kaplanidi, E. Tasiopoulou, C. Cuenca, A. Carre, V. Nitti, I. Adami, E. Zidianakis, P. Doulgeraki, E. Karouzaki, V. Bartalesi, D. Metilli

The Journal of the Association for Information Science and Technology, in press. ASIS&T, 2022.

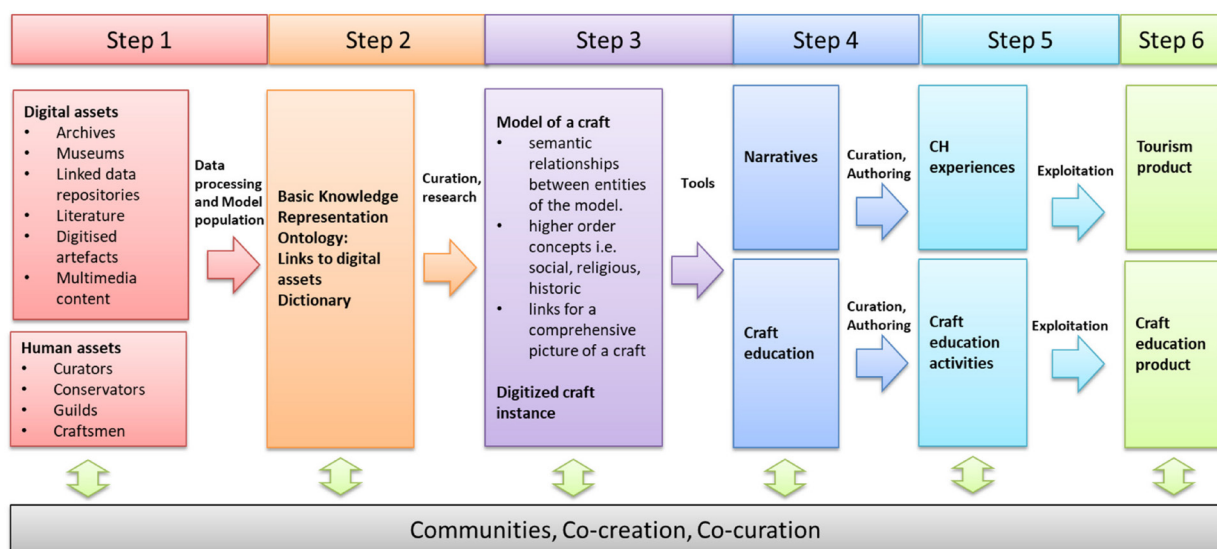
A protocol for the representation of traditional crafts and the tools to implement this are proposed. The proposed protocol is a method for the systematic collection and organization of digital assets and knowledge, their representation into a formal model,

and their utilization for research, education, and preservation. A set of digital tools accompanies this protocol that enables the online curation of craft representations. The proposed approach was elaborated and evaluated with craft practitioners in three

case studies. Lessons learned are shared and an outlook for future work is provided.

DOI: 10.3390/heritage5020040

Illustration of protocol steps.



Multi-camera vehicle counting using edge-AI

L. Ciampi, C. Gennaro, F. Carrara, F. Falchi, C. Vairo, G. Amato
Expert Systems with Applications, vol. 207. Elsevier, 2022.

This paper presents a novel solution to automatically count vehicles in a parking lot using images captured by smart cameras. Unlike most of the literature on this task, which focuses on the analysis of single images, this paper proposes the use of multiple visual sources to monitor a wider parking area from different perspectives. The proposed multi-camera system is capable of automatically estimating the number of cars present in the entire parking lot directly on board

the edge devices. It comprises an on-device deep learning-based detector that locates and counts the vehicles from the captured images and a decentralized geometric-based approach that can analyze the inter-camera shared areas and merge the data acquired by all the devices. We conducted the experimental evaluation on an extended version of the CNRPark-EXT dataset, a collection of images taken from the parking lot on the campus of the National Research

Council (CNR) in Pisa, Italy. We show that our system is robust and takes advantage of the redundant information deriving from the different cameras, improving the overall performance without requiring any extra geometrical information of the monitored scene.

DOI: [10.1016/j.eswa.2022.117929](https://doi.org/10.1016/j.eswa.2022.117929)

An example of two cameras monitoring the same parking area with partially overlapping fields of view. This redundancy provides robustness and fault-tolerance but also raises the problem of aggregating knowledge extracted from the individual cameras.



Smartphone-based augmented reality for end-user creation of home automations

R. Ariano, M. Manca, F. Paternò, C. Santoro

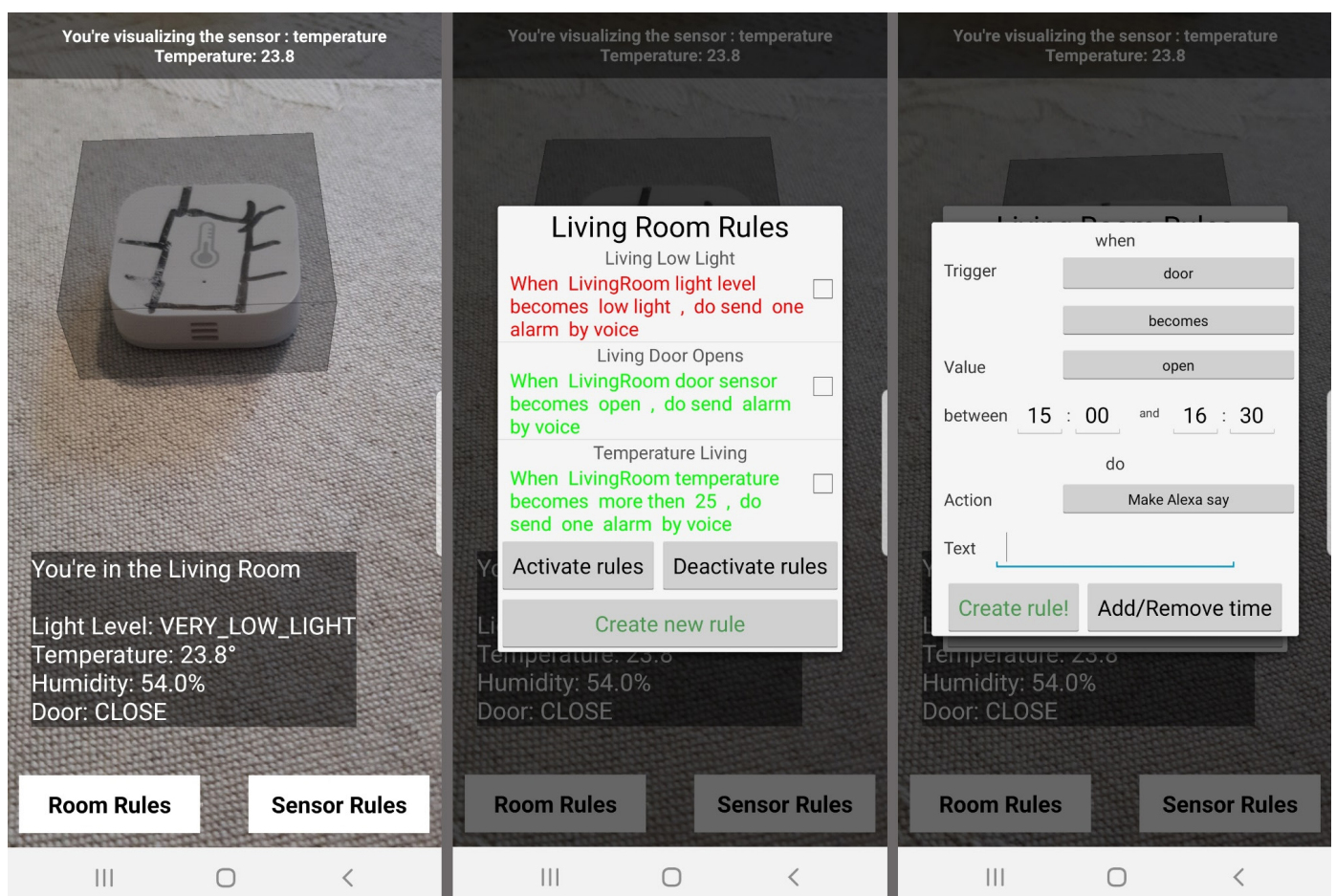
Behaviour & Information Technology, in press. Taylor&Francis, 2022.

In the last few years, several end-user tools have been designed to help people who are not professional developers in programming their smart environments. However, such tools are often based on structured visual editors providing abstract representations of the available connected sensors and objects, which can be problematic for end users, and do not particularly encourage their participation. This work aims to make the end-user experience of creating everyday

automations involving various types of connected sensors and objects more engaging by replacing extensive, static, structured and comprehensive abstract visual tools with more narrowed, relevant, context-sensitive, dynamic, augmented reality-based representations. We present a solution for this purpose that mobile users can exploit through their smartphone. End users can use the smartphone camera to frame the relevant sensor or object through the devel-

oped prototype, then get the current automations associated with it, edit their definition, create new ones as well as monitor the automations involving the whole current environment. We also report a first user test of the developed prototype deployed in a home equipped with connected sensors and objects, which yielded positive feedback.

DOI: 10.1080/0144929X.2021.2017482



(left) The app shows info on the current room (Living Room) and the detected sensor; (centre) The app shows the rules created for the current room; (right) The support for creating new rules.

COVID-19 lockdowns reveal the resilience of Adriatic Sea fisheries to forced fishing effort reduction

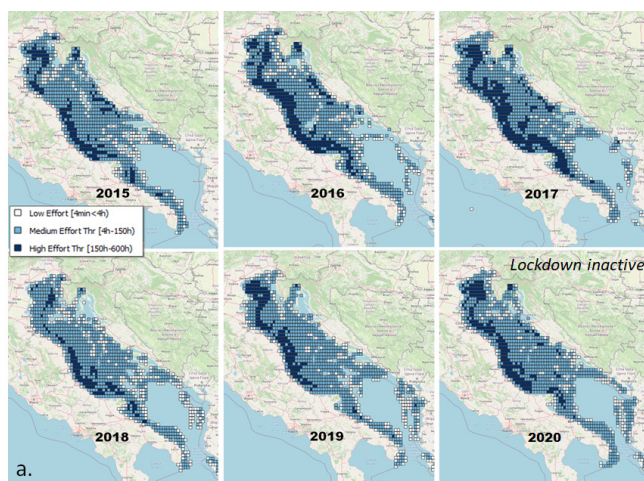
G. Coro, A.N. Tassetti, E.N. Armelloni, J. Pulcinella, C. Ferrà, M. Sprovieri, F. Trincardi, G. Scarcella
Scientific Reports, vol. 12. Springer Nature, 2022.

The COVID-19 pandemic provides a major opportunity to study fishing effort dynamics and to assess the response of the industry to standard and remedial actions. Knowing a fishing fleet's capacity to compensate for effort reduction (i.e., its resilience) allows differentiating governmental regulations by fleet, i.e., imposing stronger restrictions on the more resilient and weaker restrictions on the less resilient. In the present research, the response of the main fishing fleets of the Adriatic Sea to fishing hour reduction from

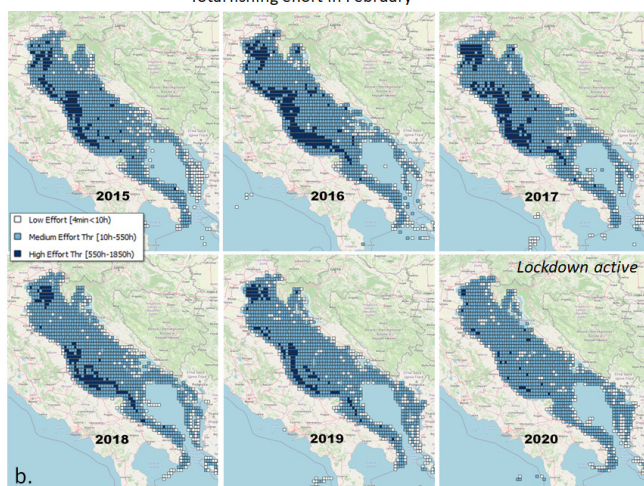
2015 to 2020 was measured. Fleet activity per gear type was inferred from monthly Automatic Identification System data. Pattern recognition techniques were applied to study the fishing effort trends and barycentres by gear. The beneficial effects of the lockdowns on Adriatic endangered, threatened and protected (ETP) species were also estimated. Finally, fleet effort series were examined through a stock assessment model to demonstrate that every Adriatic fishing fleet generally behaves like a stock

subject to significant stress, which was particularly highlighted by the pandemic. Our findings lend support to the notion that the Adriatic fleets can be compared to predators with medium-high resilience and a generally strong impact on ETP species.

DOI: 10.1038/s41598-022-05142-w



Total fishing effort in February



Total fishing effort in March-to-May

Comparison of the distributions of total fishing hours in the Adriatic Sea (0.1° resolution) in 2015–2020 in (a) February and (b) March-to-May (aggregated). The classification of the 2015 distribution is used for all years for consistency. Maps were created with QGIS v.3.20.2 (www.qgis.org) using the OSM-Standard map of the QuickMapService plugin as the background map.

A high-resolution global-scale model for COVID-19 infection rate

G. Coro, P. Bove

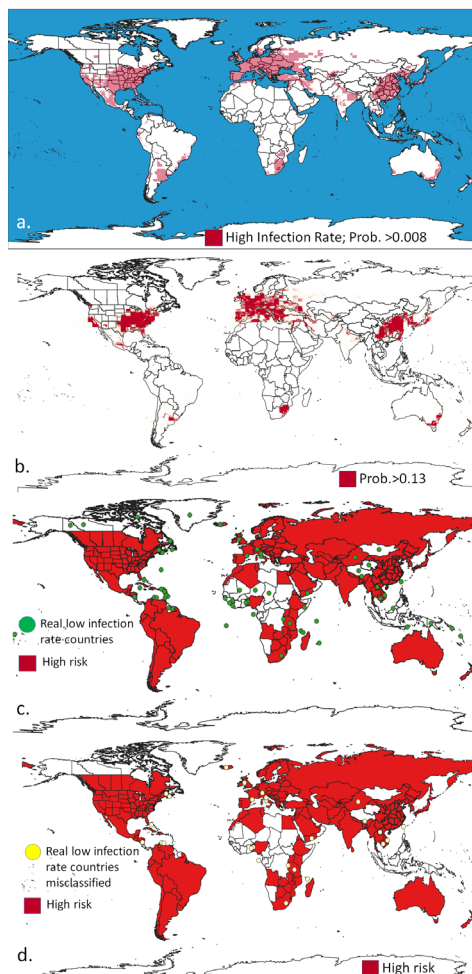
ACM Transactions on Spatial Algorithms and Systems, vol. 8. ACM, 2022.

Several models have correlated COVID-19 spread with specific climatic, geophysical, and air pollution conditions, and early models had predicted the lowering of infection cases in Summer 2020. These approaches have been criticized for their coarse assumptions and because they could produce biases if used without considering dynamic factors such as human mobility and interaction. However, human mobility and interaction models alone have not been able to suggest more innovative recommendations than simple social distancing and lockdown, and would definitely need to include information about the base environmental suitability of

a World area to COVID-19 spread. This scenario would benefit from a global-scale high-resolution environmental model that could be coupled with dynamic models for large-scale and regional analyses. This article presents a 0.1° high-resolution global-scale probability map of low and high-infection-rates of COVID-19 that uses annual-average surface air temperature, precipitation, and CO₂ as environmental parameters, and Italian provinces as training locations. A risk index calculated on this map correctly identifies 87% of the World countries that reported high infection rates in 2020 and 80% of the low and high infection-rate countries over-

all. Our model is meant to be used as an additional factor in other models for monthly weather and human mobility. It estimates the base environmental inertia that a geographical place opposes to COVID-19 when mobility restrictions are not in place and can support how much the monthly weather favors or penalizes infection increase. Its high resolution and extent make it consistently usable in global and regional-scale analyses, also thanks to the availability of our results as FAIR data and software as an Open Science-oriented Web service.

DOI: 10.1145/3494531

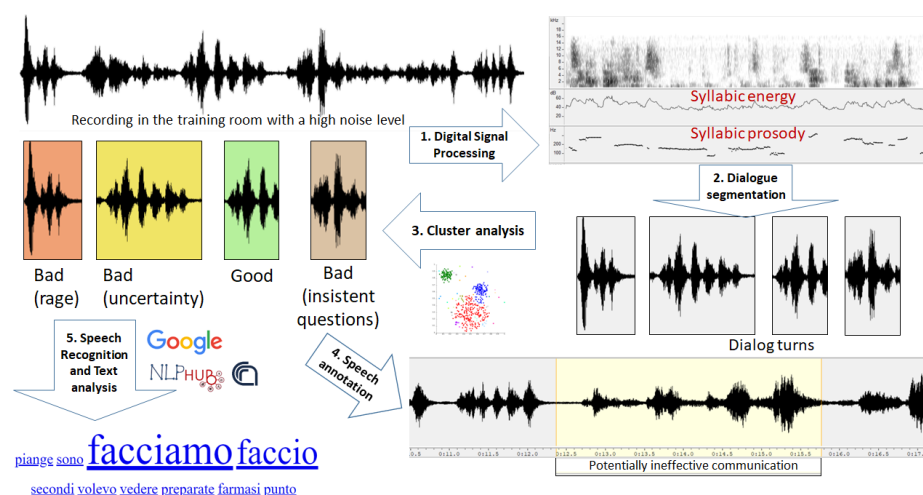


Visualization of the output produced by our model: (a) distribution of high-infection-rate areas using the MaxEnt balanced threshold (0.008), (b) probability peak areas in the MaxEnt distribution (0.13 threshold), (c) overlap between low infection rate countries extracted from real data and our risk map, and (d) highlight of low infection rate countries not predicted by our model.

Automatic detection of potentially ineffective verbal communication for training through simulation in neonatology

G. Coro, S. Bardelli, A. Cuttano, N. Fossati

Education and Information Technologies, in press. Springer, 2022.



Overall scheme of the proposed workflow: Step 1 (digital signal processing) calculates energy and pitch at a syllabic scale; step 2 (dialogue segmentation) divides the audio into portions with coherent intonation contours (tone units); step 3 (cluster analysis) detects the tone units containing potentially ineffective verbal communication; step 4 (speech annotation) produces an annotation file specifying the intervals of potentially ineffective communication; step 5 (speech recognition and text analysis) transcribes the audio of the tone units through an automatic speech recogniser and extracts a word cloud of ineffective communication keywords. The cloud indicates major communication issues, e.g., “facciamo” (let us do) has a higher weight than “faccio” (I do), suggesting that the team leader is uncertain about which actions to take and would require support to improve leadership and organisation skills.

Training through simulation in neonatology relies on sophisticated simulation devices that give realistic feedback to trainees during simulated scenarios. It aims at training highly specialised medical teams in established operational skills, timely clinical manoeuvres, and successful synergy with other professionals. For effective teaching, it is essential to tailor simulation to trainees’ emotional status and communication abilities (human factors), which in turn affect their

interaction with the equipment, the environment, and the rest of the team. These factors are crucial to achieving optimal timing and cooperation during a clinical intervention, to the point that they can determine the success of a complex operation such as neonatal resuscitation. Ineffective teams perform in a slow and/or poorly coordinated way and therefore jeopardise positive outcomes. Expert trainers consider human factors as crucial as technical skills. In this context, new

technology can help measure learning improvement by quantitatively analysing verbal communication within a medical team. For example, Artificial Intelligence models can work on audio recordings, and draw from extensive historical archives, to extract useful human-factor related information for the trainers.

In this study, we present an automatic workflow that supports training through simulation in neonatology by automatically detecting dialogue segments of a simulation session with potentially ineffective communication between team members due to anger, stress, fear, or misunderstandings. Rather than working on audio transcriptions, the workflow analyses syllabic-scale (100-200 ms) spoken dialogue energy and intonation. It uses cluster analysis to identify potentially ineffective communication and extracts the most important related words after audio transcription. Performance is measured against a gold standard containing annotations of 79 minutes of audio recordings from neonatal simulations, in Italian, under different noise conditions (from 4.63 to 14.17 SNR). The workflow also identifies viable words for trainers to conduct the debriefing session, and can be easily extended to other languages and applications in health-care. We consider it a promising first step towards introducing new technology to support training through simulation centred on human factors.

DOI: 10.1007/s10639-022-11000-z

Virtual research environments co-creation: the D4Science experience

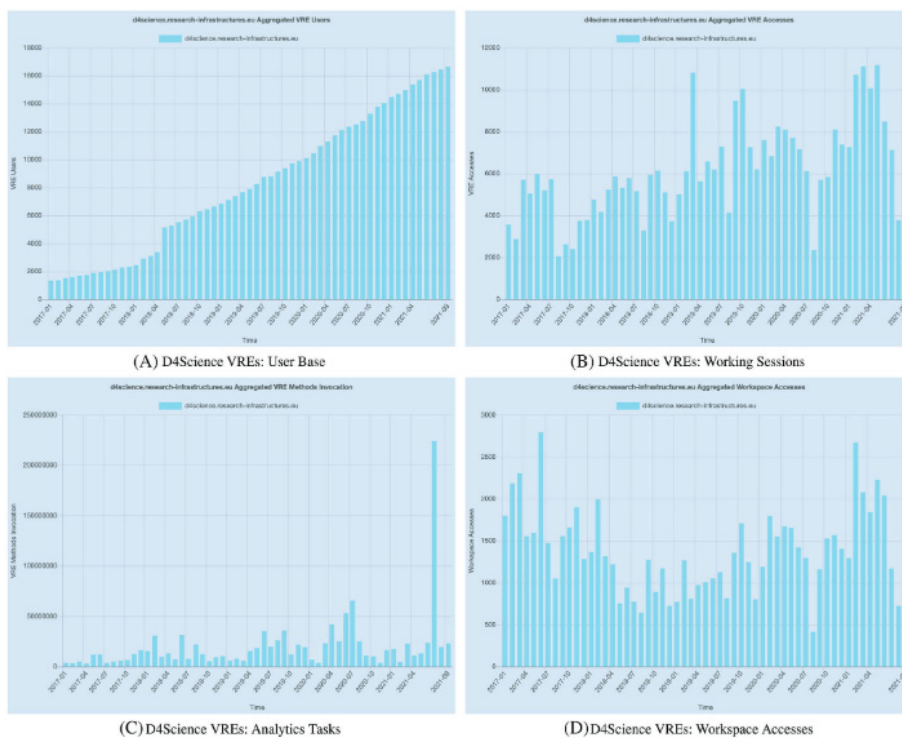
M. Assante, L. Candela, D. Castelli, R. Cirillo, G. Coro, A. Dell'Amico, L. Frosini, L. Lelii, M. Lettere, F. Mangiacrapa, P. Pagano, G. Panichi, T. Piccioli, F. Sinibaldi
 Concurrency and Computation, in press. Wiley, 2022.

Virtual research environments are systems called to serve the needs of their designated communities of practice. Every community of practice is a group of people dynamically aggregated by the willingness to collaborate to address a given research question. The virtual research environment provides its users with seamless access to the resources

of interest (namely, data and services) no matter what and where they are. Developing a virtual research environment thus to guarantee its uptake from the community of practice is a challenging task. In this article, we advocate how the co-creation driven approach promoted by D4Science has proven to be effective. In particular, we present the

co-creation options supported, discuss how diverse communities of practice have exploited these options, and give some usage indicators on the created VREs.

DOI: 10.1002/cpe.6925



D4Science VREs usage indicators from Jan. 2017 to September 2021.

Gross polluters and vehicle emissions reduction

M. Böhm, M. Nanni, L. Pappalardo
Nature Sustainability, 2022.

Vehicles' emissions produce a significant share of cities' air pollution, with a substantial impact on the environment and human health.

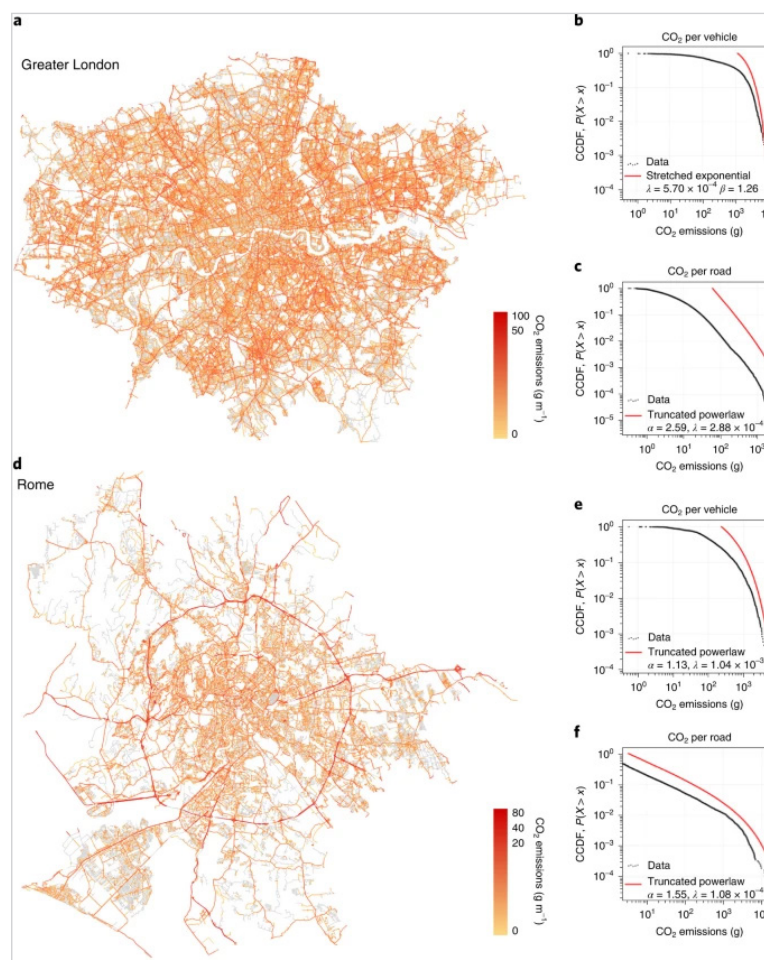
Traditional emission estimation methods use remote sensing stations, missing vehicles' full driving cycle, or focus on a few vehicles.

We use GPS traces and a microscopic model

to analyse the emissions of four air pollutants from thousands of private vehicles in three European cities. We find that the emissions across the vehicles and roads are well approximated by heavy-tailed distributions and thus discover the existence of gross polluters, vehicles responsible for the greatest quantity of emissions, and grossly polluted roads, which suffer the greatest amount of emissions.

Our simulations show that emissions reduction policies targeting gross polluters are way more effective than those limiting circulation based on a non-informed choice of vehicles. Our study contributes to shaping the discussion on how to measure emissions with digital data.

DOI: 10.1038/s41893-022-00903-x



Distributions of emissions.

Dynamic hard pruning of neural networks at the edge of the internet

L. Valerio, F.M. Nardini, A. Passarella, R. Perego

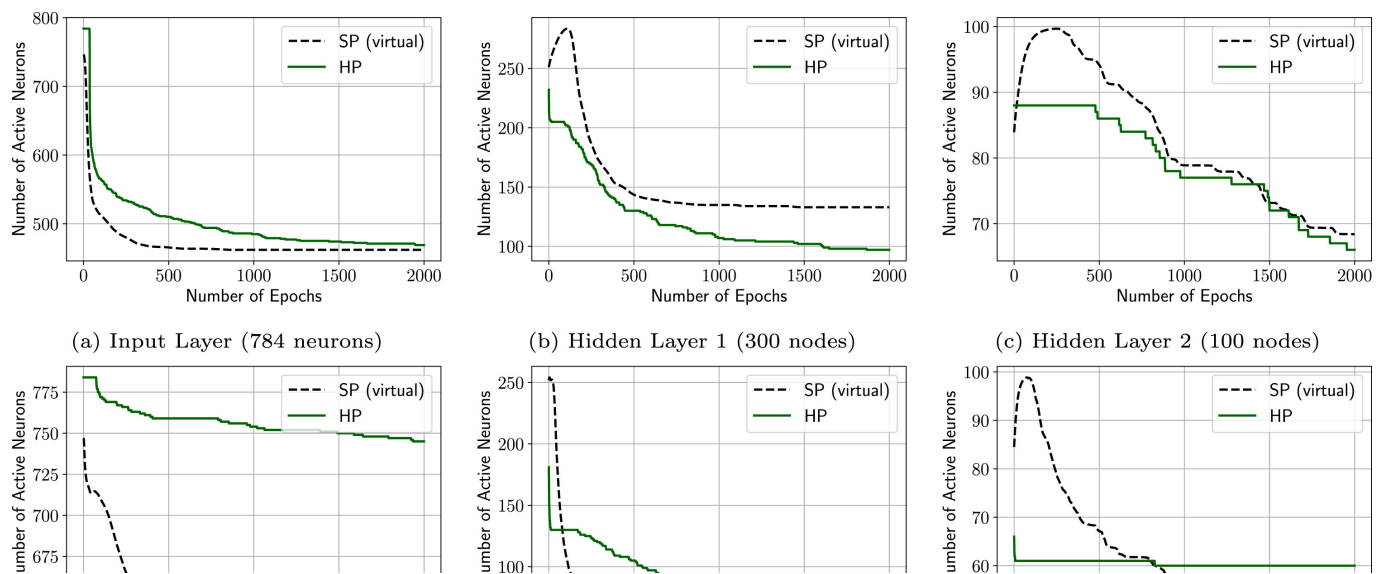
Journal of Network and Computer Applications, vol. 200. Elsevier 2022.

In the last years, AI solutions have been successfully adopted in a variety of different tasks. Neural networks (NN) are among the most successful technologies that achieve state-of-the-art performance in several application fields, including image recognition, computer vision, natural language processing, and speech recognition. Nevertheless, it has been proven that NNs may suffer over parametrization. In edge/fog computing, this might make their training prohibitive on resource-constrained devices, contrasting with the current trend of decentralizing intelligence from remote data centers to

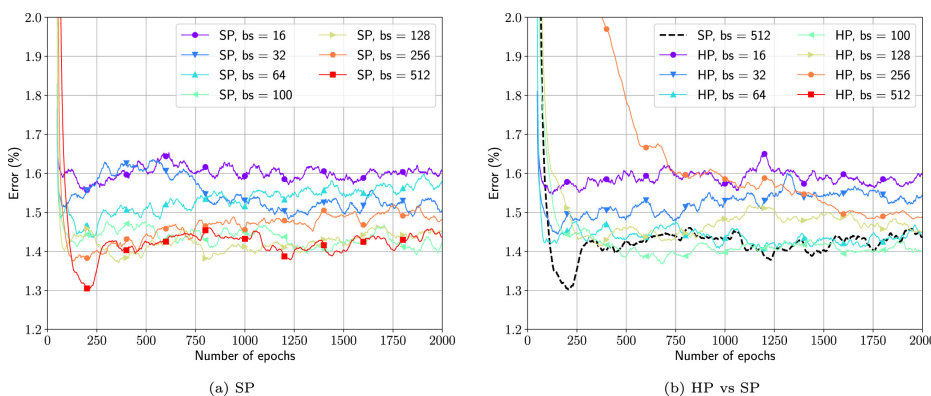
local constrained devices. In this paper, we investigate the problem of training effective NN models on constrained devices having a fixed, potentially small, memory budget. We target techniques that are both resource-efficient and performance effective while enabling significant network compression. Our Dynamic Hard Pruning (DynHP) technique incrementally prunes the network during training, identifying neurons that marginally contribute to the model accuracy. DynHP enables a tunable size reduction of the final neural network and reduces the NN memory occupancy during training. Freed memory

is reused by a dynamic batch sizing approach to counterbalance the accuracy degradation caused by the hard pruning strategy, improving its convergence and effectiveness. We assess the performance of DynHP through reproducible experiments on three public datasets, comparing them against reference competitors. Results show that DynHP compresses a NN up to 10 times without significant performance drops (up to 3.5% additional error w.r.t. the competitors), reducing up to 80% the training memory occupancy.

DOI: 10.1016/j.jnca.2021.103330



First row refers to MNIST, second row refers to Fashion-MNIST. The curves show the number of active neurons for SP and HP for each layer of the network, i.e., input and two hidden layers, by increasing the number of epochs of the training.



MNIST dataset. Misclassification error (%) of SP and HP for different sizes of mini-batches as a function of the number of epochs of the training.

Using low-resolution SAR scattering features for ship classification

E. Salerno

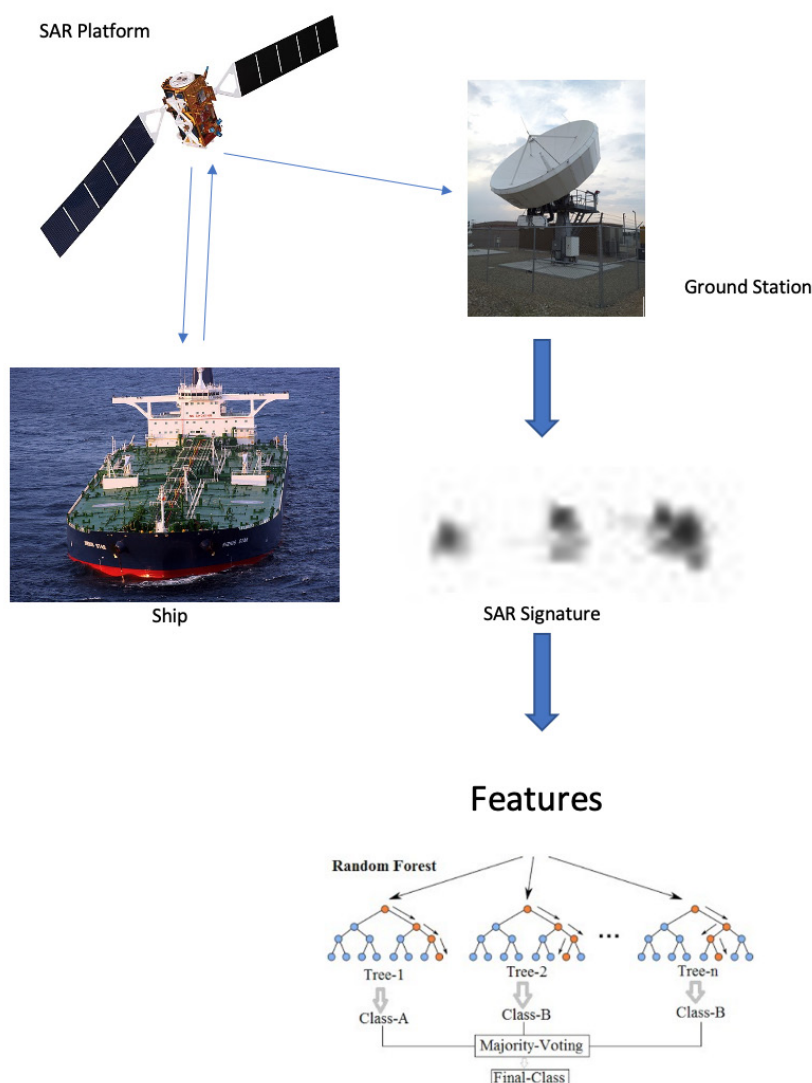
IEEE Geoscience and Remote Sensing Letters, vol. 19. IEEE, 2022.

This letter reports an experimental study aimed at establishing the questionable usefulness of scattering attributes for ship classification from moderate-resolution SAR images. About 2700 example images representing four ship types have been extracted from the OpenSARShip annotated data set

and used to form the training and test sets for random forest models. After importance ranking and cross-validation, different subsets of both geometric and scattering attributes were selected from a fixed training set and used to train the classifier. The results from the validation using the test sets show

that the scattering attributes give a significant contribution in terms of overall classification accuracy.

DOI: 10.1109/LGRS.2022.3183622



Simplified full-chain process for ship classification. Top left, downward arrow: the target vessel is probed by synthetic aperture radar pulses. Top left, upward arrow: the backscattered signal is received by the SAR sensor. Right: the signal is received by a ground station and processed to reconstruct the SAR image, then all the targets are detected and located, the relevant features are extracted from the target SAR signatures and fed into a trained random-forest classifier for ship type prediction.

Machine and deep learning prediction of prostate cancer aggressiveness using multiparametric MRI

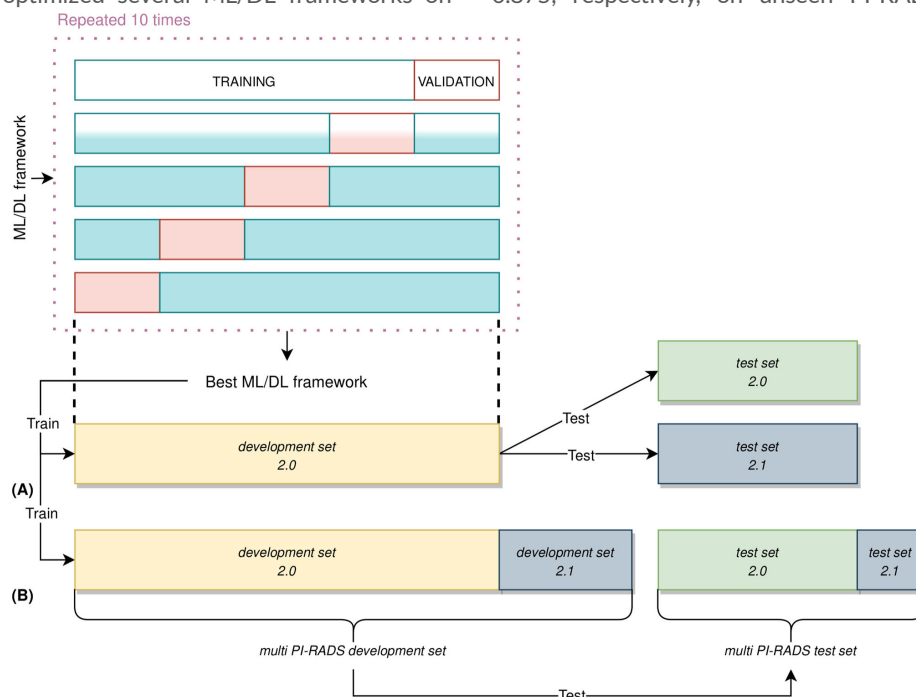
E. Bertelli, L. Mercatelli, C. Marzi, E. Pachetti, M. Baccini, A. Barucci, S. Colantonio, L. Gherardini, L. Lattavo, M. A. Pascali, S. Agostini, V. Miele
Frontiers in Oncology, vol. 11. Frontiers, 2022.

Prostate cancer (PCa) is the most frequent male malignancy and the assessment of PCa aggressiveness, for which a biopsy is required, is fundamental for patient management. Currently, multiparametric (mp) MRI is strongly recommended before biopsy. Quantitative assessment of mpMRI might provide the radiologist with an objective and noninvasive tool for supporting the decision-making in clinical practice and decreasing intra- and inter-reader variability. In this view, high dimensional radiomics features and Machine Learning (ML) techniques, along with Deep Learning (DL) methods working on raw images directly, could assist the radiologist in the clinical workflow. The aim of this study was to develop and validate ML/DL frameworks on mpMRI data to characterize PCas according to their aggressiveness. We optimized several ML/DL frameworks on

T2w, ADC and T2w+ADC data, using a patient-based nested validation scheme. The dataset was composed of 112 patients (132 peripheral lesions with Prostate Imaging Reporting and Data System (PI-RADS) score ≥ 3) acquired following both PI-RADS 2.0 and 2.1 guidelines. Firstly, ML/DL frameworks trained and validated on PI-RADS 2.0 data were tested on both PI-RADS 2.0 and 2.1 data. Then, we trained, validated and tested ML/DL frameworks on a multi PI-RADS dataset. We reported the performances in terms of Area Under the Receiver Operating curve (AUROC), specificity and sensitivity. The ML/DL frameworks trained on T2w data achieved the overall best performance. Notably, ML and DL frameworks trained and validated on PI-RADS 2.0 data obtained median AUROC values equal to 0.750 and 0.875, respectively, on unseen PI-RADS

2.0 test set. Similarly, ML/DL frameworks trained and validated on multi PI-RADS T2w data showed median AUROC values equal to 0.795 and 0.750, respectively, on unseen multi PI-RADS test set. Conversely, all the ML/DL frameworks trained and validated on PI-RADS 2.0 data, achieved AUROC values no better than the chance level when tested on PI-RADS 2.1 data. Both ML/DL techniques applied on mpMRI seem to be a valid aid in predicting PCa aggressiveness. In particular, ML/DL frameworks fed with T2w images data (objective, fast and non-invasive) show good performances and might support decision-making in patient diagnostic and therapeutic management, reducing intra- and inter-reader variability.

DOI: 10.3389/fonc.2021.802964



Nested validation scheme in our ML/DL analysis. **(A)** On development set 2.0 only, 5-fold CV was used to identify the best performing framework, along with performing hyperparameters optimization. The best performing ML/DL framework was then used to train the final framework on the entire development set 2.0. This framework was then evaluated on an unseen test set 2.0 and test set 2.1, independently. **(B)** The best performing framework was still trained on multi PI-RADS development set (i.e., the union of development set 2.0 and development set 2.1 and evaluated on unseen multi PI-RADS test set (i.e., the union of test set 2.0 and test set 2.1).

Anorexia nervosa, body image perception and virtual reality therapeutic applications: state of the art and operational proposal

M. Magrini, O. Curzio, M. Tampucci, G. Donzelli, L. Cori, M.C. Imiotti, S. Maestro, D. Moroni
International Journal of Environmental Research and Public Health, vol. 19. MDPI, 2022.

Anorexia Nervosa (AN) patients exhibit distorted body representation. The purpose of this study was to explore studies that analyze virtual reality (VR) applications, related to body image issues, to propose a new tool in this field. We conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, EMBASE, Scopus, and Web of Science databases were explored; the review included 25 studies. Research has increased over the last five years. The selected stud-

ies, clinical observational studies ($n = 16$), mostly concerning patients' population with AN ($n = 14$) or eating disorders (EDs) diagnosis, presented multiple designs, populations involved, and procedures. Some of these studies included healthy control groups ($n = 7$). Studies on community sample populations were also selected if oriented toward clinical applications ($n = 9$). The VR technologies in the examined period (about 20 years) have evolved significantly, going from very complex and bulky systems, requiring very powerful computers, to agile systems. The

advent of low-cost VR devices has given a big boost to research works. Moreover, the operational proposal that emerges from this work supports the use of biofeedback techniques aimed at evaluating the results of therapeutic interventions in the treatment of adolescent patients diagnosed with AN.

DOI: [10.3390/ijerph19052533](https://doi.org/10.3390/ijerph19052533)



Example of avatar of progressively increasing BMI in the proposed VR application.

TagLab: AI-assisted annotation for the fast and accurate semantic segmentation of coral reef orthoimages

G. Pavoni, M. Corsini, F. Ponchio, A. Muntoni, C. Edwards, N. Pedersen, S. Sandin, P. Cignoni
Journal of Field Robotics, vol. 39. Wiley, 2022.

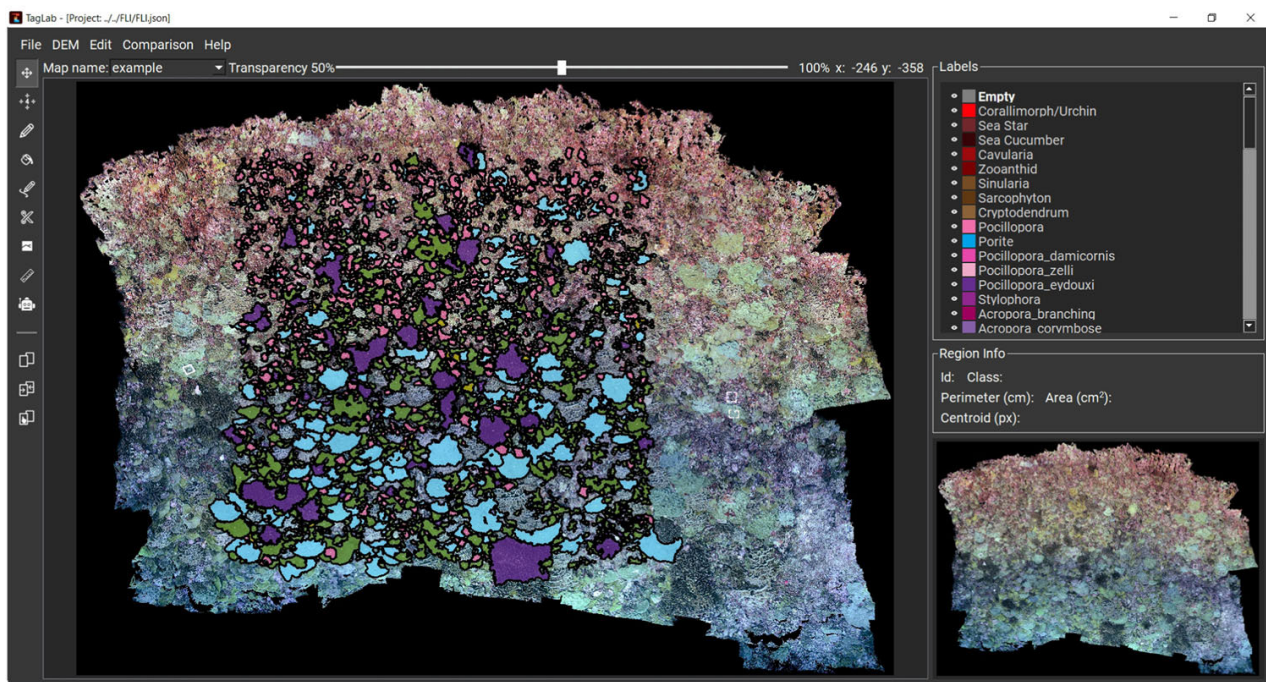
Semantic segmentation is a widespread image analysis task; in some scientific applications (medical, biological, archaeological, etc.), it requires such high accuracy that it still has to be done manually, taking a long time. Deep learning-based approaches can significantly reduce such times, but current automated solutions may produce results below expert standards. In these scenarios, the ability of experts to perform complicated choices remains irreplaceable. Intelligent human-centered solutions represent a good compromise between automatic image anal-

ysis speed and high per-pixel accuracy.

This paper presents TagLab, an AI-based interactive tool for labeling and analyzing geo-referenced ortho-images. This software guides scientists through the recognition pipeline, from preparing the dataset for training a neural network, to the model optimization, to the editing of automatic prediction. We evaluated TagLab's efficiency in annotation time and accuracy on a user study based on one of the most challenging annotation tasks: the semantic segmentation of

coral communities for ecological modeling purposes. According to the results, TagLab increases the annotation speed up to 90% for non-expert users. More generally, TagLab speeds up human labeling while preserving an expert-level accuracy. This open-source software bridges the technology gaps between the state-of-the-art automatic recognition pipelines and the existing manual annotation tools for scientific applications.

DOI: 10.1002/rob.22049



TagLab's main user interface splits into three main components: the central Working View, the Toolbar on the left, and a right area containing three panels: the Labels, the Region info, and the Map Viewer. The Working View covers the central part of the interface and visualizes the orthoimage with overlaid semantic annotations (colored polygons).

Automated generation of flat tileable patterns and 3D reduced model simulation

I. Manolas, F. Laccone, G. Cherchi, L. Malomo, P. Cignoni
Computers & Graphics, vol. 106. Elsevier, 2022.

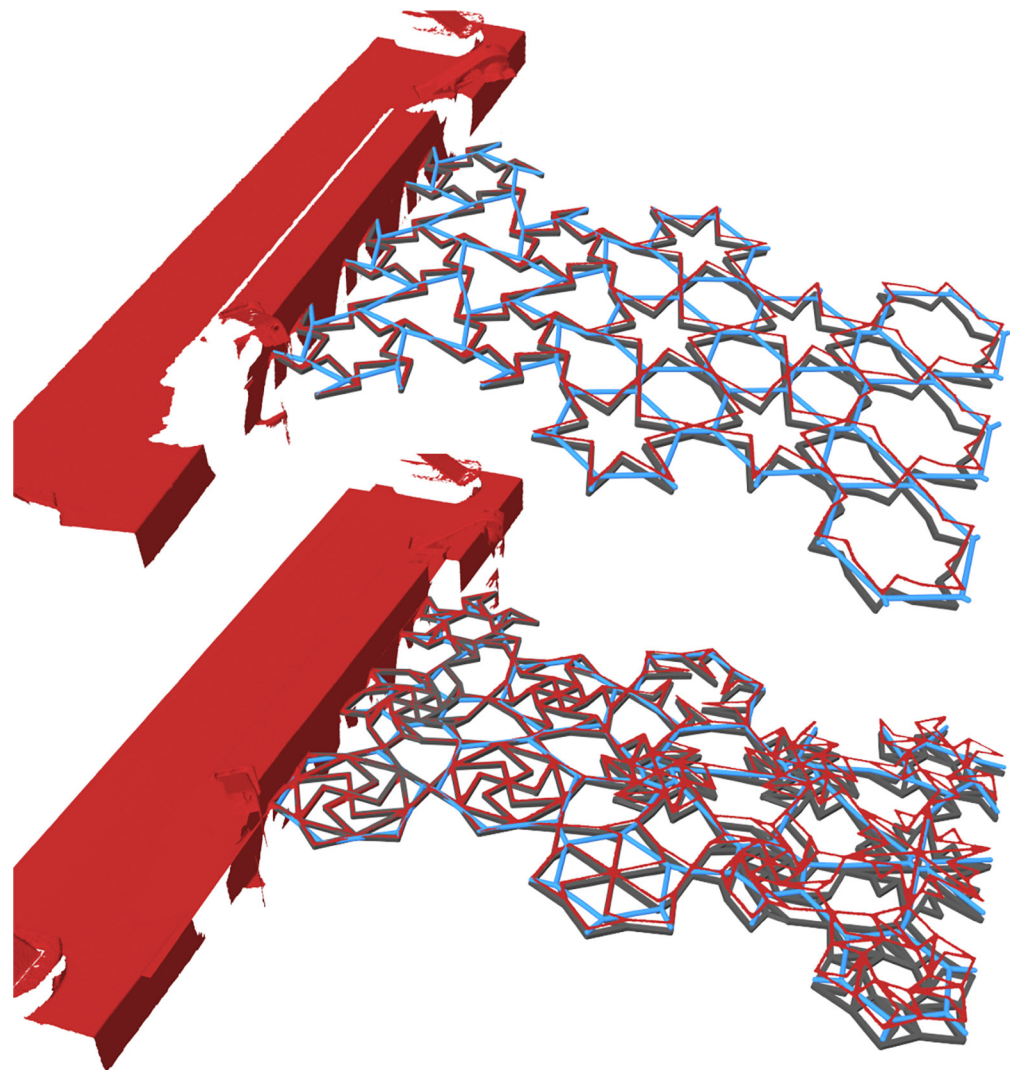
The computational fabrication community is developing an increasing interest in the use of patterned surfaces, which can be designed to show ornamental and unconventional aesthetics or perform as a proper structural material with a wide range of features. Geometrically designing and controlling the deformation capabilities of these patterns in response to external stimuli is a complex task due to the large number of variables involved.

This paper introduces a method for generating a set of flat, tileable, 2D pattern geometries, which can be arranged heterogeneously over a surface, and a fast tool to simulate the deformation behavior of such patterned surfaces. Our strategy opens a broader design space of flat patterns that can be deformed in 3D. Our approach relies on a model-reduction strategy that enables the mechanical simulation of tiled patterns at interactive rates.

This method is included in a design pipeline that transforms a generic flat surface into a pattern tessellation, which can deform under a given loading scenario. To validate our approach, we apply our method to different contexts, including real-scale 3D printed specimens, for which we compare our results with the ones provided by a ground-truth solver.

DOI: 10.1016/j.cag.2022.05.020

Physical tests (red) in comparison with deformations of the pattern (dark gray) and the reduced model (blue).



Tracking the variation of complex mode shapes for damage quantification and localization in structural systems

M.G. Masciotta, D. Pellegrini

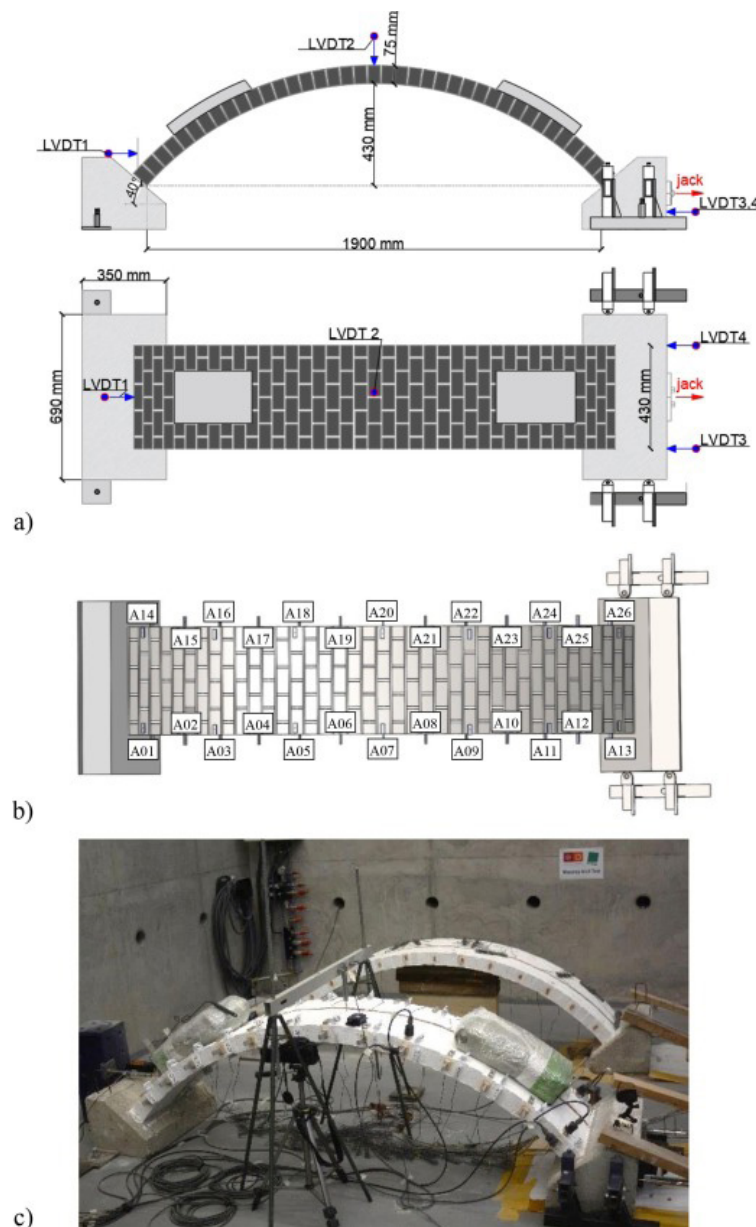
Mechanical Systems and Signal Processing, vol. 169. Elsevier, 2022.

Real structures mode shapes estimated by modal analysis techniques have a common feature: in most cases they are complex, and their level of complexity can be soundly influenced by the presence and extent of physical damage, which also affects the distribution of energy dissipation mechanisms within the structures. Starting from the

contributions available in the literature, the present paper investigates, from a numerical and experimental point of view, the correlation existing between localized damage and variation of global modal complexity indices conventionally employed to quantify the nonproportionality of damping in structural systems. Finally, driven by the inferences

made through numerical and experimental test cases by tracking the variation of complex modes over multiple and progressive damage scenarios, a new index for damage localization and quantification is formulated and validated against real data.

DOI: 10.1016/j.ymssp.2021.108731



Geometry of the experimental arch along with the (a) static and (b)-(c) dynamic test layouts.

The kinetic casualty risk of uncontrolled re-entries before and after the transition to small satellites and mega-constellations

C. Pardini, L. Anselmo

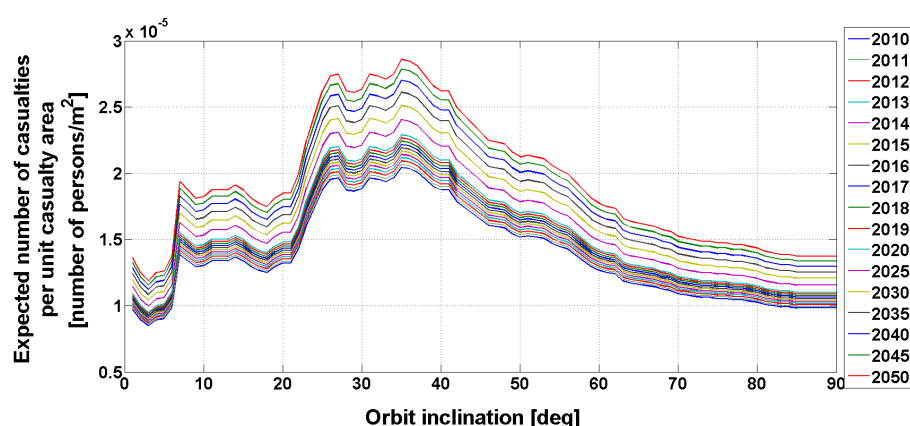
Journal of Space Safety Engineering, in press. Elsevier, 2022.

Over the last 11 years (2010-2020), more than 600 intact objects larger than 1 m² have re-entered without control into the Earth's atmosphere. The total returned mass was approximately 1100 metric tons, roughly corresponding to the re-entry of nearly 100 metric tons per year, mostly concentrated (79%) in rocket bodies. Objects with a mass greater than 500 kg re-entered every about 8 days, those exceeding 2000 kg every about 2 weeks and those heavier than 5000 kg one or twice per year. The to-

tal casualty expectancy associated with uncontrolled re-entries over the past 11 years was of the order of 1.4×10^{-1} , that in 2020 was almost 1.7×10^{-2} , corresponding to a probability of having had at least one victim of approximately 13% and 2%, respectively. Unlike the alert threshold of 10^{-4} , linked to single re-entry events, no cumulative risk limit exists for satellite re-entries over one year or more. However, the casualty probability, although still relatively small, cannot be considered negligible, even in view of the

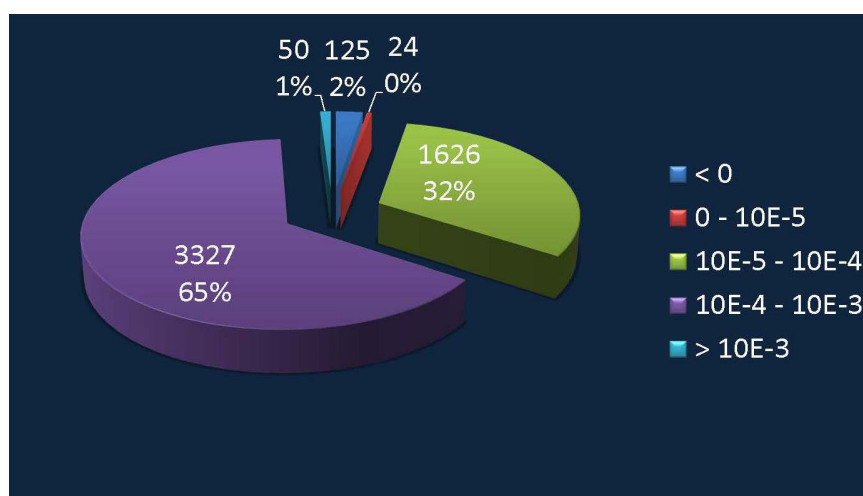
launches of mega-constellations planned in the coming years. For instance, if no design for demise was implemented, the addition of 4000 spacecraft re-entering annually would increase the probability of having at least one victim to nearly 30% per year, while 20,000 more satellites would boost it to almost 80%.

DOI: 10.1016/j.jsse.2022.04.003



Expected number of casualties per unit casualty area versus inclination from 2010 to 2050.

Distribution, per casualty expectancy interval, of the re-entries of large intact objects occurred from 1 January 2010 to 31 December 2020.



Integrated Wi-Fi and LoRa Network on UAVs to Locate Distressed People during SAR Operations

Capturing unexploited information to improve SAR operations

Nowadays, we often witness Search and Rescue (SAR) operations performed using Unmanned Aerial Vehicles (UAVs) with cameras, and in some cases thermocameras. However, in certain scenarios with adverse weather conditions, such as low visibility or dense vegetation, cameras cannot provide useful results. The main problematic issues in SAR are: i) people lost in vast areas not covered by GSM or mobile signals, and difficult to locate; ii) the need to address critical time constraints: people with injuries, people lost in dangerous situations, adverse weather conditions; iii) limited resources: only a small number of UAVs is available im-

mediately. In order to solve such issues, we propose an open-source, lightweight and low-cost solution that can be installed on top of a UAV, conceived for the analysis of Wi-Fi beacons or probe requests in areas without network or other relevant infrastructure. Our proposed solution relies on LoRa communications and uses a Complex Event Processor (CEP) to enhance and enrich data analysis and provide first-aid information in scenarios where the person in difficulty has installed a specific mobile application. Alternatively, it can analyze data gathered from the BAN (Body Area Network) of the person in distress. The proposed system has been

validated in a simulated scenario in which the drone took off and began hovering from a distance of ~150 meters from the point of abandonment, reaching an altitude of 35 meters and moving at 5.4 km per hour. The device made its first detection at a height of 86.5 mt above sea level.

Contact: Antonello Calabrò, SEDC Lab
antonello.calabro@isti.cnr.it



Paolo Cignoni is a new member 2022 of the SIGGRAPH Academy



Paolo Cignoni has been chosen to be one of the four new members for 2022 of the ACM SIGGRAPH Academy.

The ACM SIGGRAPH Academy is an honorary group of individuals who have made substantial contributions to the field of computer graphics.

These are principal leaders of the field, whose efforts have shaped the disciplines and/or industry, and led the research and/or innovation in computer graphics and interactive techniques.

ACM SIGGRAPH Academy members are selected by an ACM SIGGRAPH Academy Committee consisting of five voting members from across the SIGGRAPH community.

Paolo Cignoni, first Italian to be selected for being a member of ACM SIGGRAPH Academy has been chosen: "For contributions in geometry processing and computational fabrication, and for releasing important open-source tools".

<https://www.siggraph.org/awards/acm-siggraph-academy/>

Best Ph.D. Forum paper award at PerCom Conference 2022

Pisa, Italy, March 21-25, 2022



The paper "Driver Stress Identification in Real-World Driving Tasks" by Saira Bano, supervised by Alberto Gotta and Nicola Tonelotto has been conferred with the "Best PhD

forum Paper Award" at the 20th International Conference on Pervasive Computing and Communications 2022: <https://percom.org/PerCom2022/>.

Contact: Saira Bano, WN Lab
saira.bano@isti.cnr.it

ECIR 2022 Industry Impact Award

The winner of the ECIR 2022 Industry Impact Award is the paper “Ensemble model compression for fast and energy-efficient ranking on FPGAs” by V. Gil-Costa, F. Loor, R. Molina, F.M. Nardini, R. Perego, S. Trani.

It's a paper investigating the use of cost-effective SoC-FPGA (System on Chip - Field Programmable Gate Arrays) devices for speeding-up inference tasks based on complex machine-learned models.

Latency and throughput at inference time are critical aspects in many machine learning applications where there is a high rate of incoming requests, and tight constraints on prediction quality impose the adoption of computationally-expensive models. In such cases, quality-of-service requirements entail optimization of model accuracy, subject to performing inference in near real-time or within a limited time budget. In our study, as

a use case where finding the best trade-off between model accuracy and inference time is important and challenging, we consider the task of ranking documents according to their relevance for queries submitted to large-scale Web search engines, e-commerce platforms, and online social networks.

Since the memory footprint of ranking models limits the effective exploitation of programmable logic for large-scale inference tasks, we investigate binning and quantization techniques to reduce the memory occupation of state-of-the-art models based on forests of decision trees, and we optimize the forest traversal algorithm for deployment on low-cost, energy-efficient FPGA devices. The results of reproducible experiments, conducted using publicly available Learning-to-Rank datasets, show that our model compression techniques do not significantly impact the accuracy. Moreover,

the reduced space requirements allow the models and the logic to be replicated on the FPGA device so that several inference tasks can be executed in parallel.

The paper discusses in detail the experimental settings and the feasibility of the deployment of the proposed solution in a real setting. The results of the experiments conducted show that our FPGA solution achieves state-of-the-art performances and consumes from 9× up to 19.8× less energy than an equivalent multi-threaded CPU implementation. The research has been conducted within the framework of the CNR bilateral project HAMLET: Hardware Acceleration of Machine Learning Tasks, funded by CONICET (Argentina) and CNR.

DOI: 10.1007/978-3-030-99736-6_18



New President of the Italian Chapter of Eurographics

Daniela Giorgi will lead the Italian Chapter of the European professional association for Computer Graphics

Daniela Giorgi, Senior Researcher at the Visual Computing Lab, was elected President of the Italian Chapter of Eurographics, the main European professional association for Computer Graphics, from 30 March 2022. The Chapter was established in 2001 to raise interest in Computer Graphics in Italy, and to facilitate communication between research groups inside and outside Italy. The Chapter also runs the annual international conference STAG (Smart Tools and Applications in Graphics). Since 2014, STAG has brought together researchers from both the national and the international scientific

communities in order to share their latest developments in Visual Computing; the best papers are published in Computers & Graphics (Elsevier). The conference also grants awards for the best PhD and Master theses in Computer Graphics by Italian students. Daniela will serve as President of the Eurographics Italian Chapter for a three-year term, ending in 2025.

Contact: Daniela Giorgi, VC Lab
daniela.giorgi@isti.cnr.it



Honorable mention award at the 2022 ACM Conference on Human Factors in Computing Systems (CHI)

Cecilia Panigutti and Fosca Giannotti from the Scuola Normale Superiore (SNS), Dino Pedreschi from the University of Pisa and Andrea Beretta from CNR-ISTI have won the Honorable Mention Award for their paper:

“Understanding the impact of explanations on advice-taking: a user study for AI-based clinical Decision Support Systems”.

Trust in AI applications exists on a spectrum that goes from distrust to over-reliance. In the context of the use of AI systems in high-

stakes applications such as clinical Decision Support Systems (DSS), having an appropriate level of trust in AI suggestions is of pivotal importance to ensure human oversight over the system. Ideally, AI explanations should help with the trust calibration process, allowing doctors to adjust their level of trust according to the actual reliability of the AI system.

This paper investigates the impact of AI explanations on trust and technology adoption in healthcare. The researchers conducted an online user study recruiting 28 health-

care professionals and designed an estimation task that allowed them to evaluate the implicit trust of the clinicians in an AI-based clinical DSS that explained its suggestions. Comparing this explainable clinical DSS to its black-box version, the research showed that healthcare professionals trusted more the AI system when an explanation for the DSS decision is provided.

<https://programs.sigchi.org/chi/2022/index/content/69037>

Ph.D. dissertations

Computational methods for improving manufacturing processes

Author: Thomas Alderighi, University of Pisa

Supervisors: Paolo Cignoni and Luigi Malomo, ISTI CNR

The last two decades have seen a rapid and wide growth of digital fabrication machinery and technologies. This has led to a massive diffusion of these technologies both in the industrial setting and within the hobby and makers' communities. While the applications to rapid prototyping and simple download-and-print use cases can be trivial, the design space offered by these numerically controlled technologies (e.g. 3D printing, CNC milling, laser cutting, etc.) is hard to exploit without the support of appropriate computational tools and algorithms.

In this thesis, we investigate how the potential of common rapid prototyping tools, com-

bined with sound computational methods, can be exploited to provide novel and alternative fabrication methods and to enhance existing ones, making them available to non-expert users.

The thesis makes four contributions. The first is a novel technique for the automatic design of flexible moulds for casting highly complex shapes. The second is a method for the automatic volumetric decomposition of objects in parts that can be cast using two-piece reusable rigid moulds. Automating the design of this type of mould can directly impact industrial applications, where the use of two-piece, reusable, rigid moulds is a de-fac-

to standard, for example, in plastic injection moulding machinery. The third contribution is a pipeline for the fabrication of tangible media for the study of complex biological entities and their interactions. Finally, the fourth contribution tackles another important problem related to the fabrication of parts using FDM 3D printing technologies. With this method, we present an automatic optimization algorithm for the decomposition of objects in parts that can be individually 3D printed and then assembled, with the goal of minimizing the visual impact of support artifacts.

Deep learning techniques for visual counting

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This thesis investigates and enhances the visual counting task, and automatically estimates the number of objects in still images or video frames. Recently, due to a growing interest in this area, several Convolutional Neural Network (CNN)-based solutions have been suggested by the scientific community. These artificial neural networks provide a way to automatically learn effective representations from raw visual data and can be successfully employed to address typical challenges characterizing this task, such as different illumination and object scale variations. Aside from these difficulties, the thesis identifies some other crucial limitations in the adoption of CNNs and proposes some general solutions. These solutions have been experimentally evaluated

in the context of the counting task, which is shown to be particularly affected by these shortcomings.

In particular, the problem related to the lack of data needed to train current CNN-based solutions has been tackled. Given that the budget for labeling is normally limited, data scarcity still represents an open problem, particularly evident in tasks such as counting, where the objects to be labeled are hundreds, or even thousands, per image. Specifically, synthetic datasets gathered from virtual environments, where the training labels are automatically collected, have been introduced. Domain Adaptation strategies, aiming at mitigating the domain gap existing between training and test data distribu-

tions, are proposed. A counting strategy that takes advantage of the redundant information characterizing datasets labeled by multiple annotators is also presented. Moreover, the engineering challenges implied by the adoption of CNN-based techniques in environments with limited power resources have been addressed. Solutions for counting vehicles directly onboard embedded vision systems are introduced. Finally, an embedded modular Computer Vision-based system that can carry out several tasks to help monitor individual and collective human safety rules, such as estimating the number of people present in a region of interest, has been designed.

Relational learning in computer vision

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The increasing interest in social networks, smart cities, and Industry 4.0 is encouraging the development of techniques for processing, understanding, and organizing vast amounts of data. Recent advances in Artificial Intelligence brought to life a subfield of Machine Learning called Deep Learning, which can automatically learn common patterns from raw data directly, without relying on manual feature selection. This framework overturned many computer science fields, such as Computer Vision and Natural Language Processing, producing astonishing results.

Nevertheless, many challenges are still open. Although deep neural networks have obtained impressive results on many tasks, they cannot perform non-local processing

by explicitly relating potentially interconnected visual or textual entities. This relational aspect is fundamental for capturing high-level semantic interconnections in multimedia data or understanding the relationships between spatially distant objects in an image.

This thesis tackles the relational understanding problem in Deep Neural Networks, considering three different yet related tasks: (1) Relational Content-based Image Retrieval (R-CBIR), which consists of retrieving images with given relationships among objects, (2) Visual-Textual Retrieval, which aims at finding images given natural textual descriptions (or vice-versa), and (3) the Same-Different tasks, which are simple visual reasoning problems that require com-

paring distant shapes in the image to understand whether they are the same shape or not. We use state-of-the-art deep learning methods for relational learning, such as Relation Networks and Transformer Networks, to compare the different entities in an image or text. The results show that deep learning architectures able to relate different high-level entities can perform very well on these tasks with respect to recurrent or fully-convolutional networks. Furthermore, we find that relational architectures able to match images and textual descriptions create high-level visual features that capture very high semantics from the images and achieve the best results in the important context of semantic image retrieval.

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