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SUSTAINABLE CITIES

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Cover picture: .

JOINT ERCIM ACTIONS

4 ERCIM "Alain Bensoussan" Fellowship Programme

SPECIAL THEME

Introduction to the Special Theme

5 Sustainable Cities
by the guest editors German Castignani (Luxembourg Institute of Science and Technology) and Georgios Mylonas (Industrial Systems Institute, Athena Research Center)

Sustainable Mobility

6 Green Mobility: Renewable Energy Hoarding for Electric Vehicle Charging
by Soteris Constantinou (University of Cyprus), Constantinos Costa (Rinnoco LTD), and Demetrios Zeinalipour-Yazti (University of Cyprus)

8 Sustainable Mobility: Increase of Capacity and Digitisation of Railway Transport
by Davide Basile, Maurice ter Beek and Alessio Ferrari (CNR–ISTI)

9 Human-centred Smart Mobility: Shaping the Future of Urban Transport
by Christian Cintrano, Gabriel Luque, and Jamal Toutouh (University of Málaga)

11 Developing Urban Services for Electromobility Planning through Local Digital Twins
by Noé Marius, Patrick Gratz, Laurence Johannsen, and German Castignani (Luxembourg Institute of Science and Technology)

Sustainable Energy

12 Predicting Energy Prices Using Cloud Forecasting Services
by Dominik Puecker, Thomas Weyse (University of Applied Sciences Burgenland), and Igor Ivkić (University of Applied Sciences Burgenland and Lancaster University)

14 Towards Exploring the Role of a Data Intermediary Within a Data Space
by Christoph Klikovits (Forschung Burgenland GmbH) and Silke Palkovits-Rauter (Fachhochschule Burgenland)

15 Enhancing Residential Energy Efficiency and Management Through IoT and Smart Grid Integration
by Donatos Stavropoulos (University of Thessaly), Panagiotis Tzimotoudis (University of Thessaly), and Thanasis Korakis (University of Thessaly)

17 Sustainable Energy Practices Empowered by Ethics and Regulatory Perspectives
by Luigi Briguglio, Tetiana Vasylieva, and Carmela Occhipinti (CyberEthics Lab.)

18 **Local Digital Twins for Positive Energy Districts**
by Pavel Kogut (Digital Resilience Institute), Eva Schmitz (Data Competence Center for Cities and Regions), and Arne Schilling (Virtual City Systems)

AI for Sustainability

20 **AI-based Anomaly Detection for Data-driven Decisions in Secure Smart Cities**
by Philipp Lämmel (Fraunhofer Institute for Open Communication Systems FOKUS), Stephan Borgert, Lisa Brunzel, ([ui!] Urban Software Institute GmbH), and Paul Darius (Fraunhofer Institute for Open Communication Systems FOKUS)

22 **Follow-The-Sun Computing – Merging Green Energy with Smart Computing**
by Janick Edinger (University of Hamburg)

23 **Transforming Public Transport Through Responsible AI: Insight from the FAITH Project**
by Giuseppe Riccardo Leone, Andrea Carboni, Davide Moroni, and Sara Colantonio (CNR-ISTI)

25 **Decentralised Material Recovery for a Sustainable Future**
by Eleni Troulaki and Michail Maniadakis (FORTH-ICS)

Inclusivity of Sustainable Cities

26 **Beyond the Tech: Why Social Acceptance Matters for Smart Cities' Cybersecurity**
by Lorena Volpini, Carmela Occhipinti (CyberEthics Lab.)

28 **Human Control in Green Smart Homes**
by Simone Gallo, Sara Maenza, Andrea Mattioli, and Fabio Paternò (CNR–ISTI)

29 **Sustainability and Human-Computer Interactions: Challenges for Future Research**
by Lou Schwartz, Valérie Maquil, and Mohamed Saifeddine Hadj Sassi (Luxembourg Institute of Science and Technology)

31 **Decision Support System for Inclusive Smart City Design: Baby Boomers as a Use Case**
by Rasha Abu Qasem (Fraunhofer Institute for Experimental Software Engineering IESE) and Nils Hausbrandt (Rhineland-Palatinate Technical University of Kaiserslautern-Landau)

32 **Technology in Communal Spaces for Social Sustainability**
by Gul Sher Ali and Sobah Abbas Petersen (Norwegian University of Science and Technology, Norway)

34 **ELABORATOR's Citizen-centric and Data-driven Approach Towards Sustainable, Safe and Inclusive Urban Design and Mobility**
by Jason Sioutis (ICCS), Anna Antonakopoulou, Vasileios Sourlas and Angelos Amditis (ICCS)

35 **Socio-technical Process Modelling to Foster Sustainable Digitalisation of Rural Areas**
by Chiara Mannari, Alessio Ferrari, and Manlio Bacco (CNR-ISTI)

Sustainable Cities Powered by Snap4City

37 **Multidomain Digital Twin Platform for Decision Makers**
by Paolo Nesi, Pierfrancesco Bellini and Marco Fanfani (UNIFI, DINFO, DISIT lab, Snap4City)

39 **Optimizing Mobility and Transport Infrastructures**
by Stefano Bilotta, Enrico Collini, Luciano Alessandro Ipsaro Palesi, Paolo Nesi (UNIFI, DINFO, DISIT lab)

40 **Enhancing City Sustainability: Smart Light Management with Snap4City in Merano**
by Nicola Mitolo (SNAP4 S.R.L.), Stefan Mutschlechner (ASM Merano), and Paolo Nesi (UNIFI, DINFO, DISIT lab)

RESRARCH AND INNOVATION

42 **D3 – An AI-based Solution to Road Defect Detection**
by László Tizedes, András Máté Szabó, and Anita Keszler (HUN-REN SZTAKI)

44 **Digital Physiotherapy with Edge Swarm Technology**
by Jean-Paul Calbimonte and Davide Calvaresi (HES-SO)

ANNOUNCEMENTS / IN BRIEF

45 **Dagstuhl Seminars and Perspectives Workshops**

45 **Horizon Europe Project Management**

45 **FMICS 2024 - 29th International Conference on Formal Methods for Industrial Critical Systems**

46 **SmartEdge & AIoTwin Summer School and Workshop**

46 **Edge AI Meets Swarm Intelligence**

47 **Forum Beyond Compliance 2024: Research Ethics in the Digital Age**

NEXT ISSUE

ERCIM News 139, October 2024
Special theme: Software Security

Call for contributions: https://ercim-news.ercim.eu/call

This issue of ERCIM News was supported by the EU project Snap4City.

ERCIM "Alain Bensoussan" Fellowship Programme

The ERCIM postdoctoral Fellowship Programme has been established as one of the premier activities of ERCIM. The programme is open to young researchers from all over the world. It focuses on a broad range of fields in Computer Science and Mathematics.

The fellowship scheme also helps young scientists to improve their knowledge of European research structures and networks and to gain more insight into the working conditions of leading European research institutions. The fellowships are of 12 months duration (with a possible extension), spent in one of the ERCIM member institutes.

Where are the fellows hosted?

Only ERCIM members can host fellows. When an ERCIM member is a consortium the hosting institute might be any of the consortium's members. When an ERCIM Member is a funding organisation, the hosting institute might be any of their affiliates. Fellowships are proposed according to the needs of the member institutes and the available funding.

The fellows are appointed either by a stipend (an agreement for a research training programme) or a working contract. The type of contract and the monthly allowance/salary depends on the hosting institute.

> "ERCIM fellowship helped me a lot in shaping my career. It provided me important insights into research opportunity. ERCIM community meetings became also very useful in finding new research horizons and collaborations. Thank you, ERCIM, for giving me a wonderful and productive experience!
>
> **Shipra SINGH**
> Former ERCIM Fellow

ERCIM encourages both researchers from academic institutions and scientists working in industry to apply.

Why to apply for an ERCIM Fellowship?

The Fellowship Programme enables bright young scientists from all over the world to work on a challenging problem as fellows of leading European research centers. In addition, an ERCIM fellowship helps widen and intensify the network of personal relations and understanding among scientists. The programme offers the opportunity to ERCIM fellows:

- to work with internationally recognized experts,
- to improve their knowledge about European research structures and networks,
- to become familiarized with working conditions in leading European research centres,
- to promote cross-fertilization and cooperation, through the fellowships, between research groups working in similar areas in different laboratories.

Equal Opportunities

ERCIM is committed to ensuring equal opportunities and promoting diversity. People seeking fellowship within the ERCIM consortium are not discriminated against because race, color, religion, gender, national origin, age, marital status or disability.

Conditions

Candidates must:

- have obtained a PhD degree during the last eight years (prior to the application year deadline) or be in the last year of the thesis work with an outstanding academic record. Before starting the grant, a proof of the PhD degree will be requested;
- be fluent in English.

Application deadlines

Deadlines for applications are currently 30 April and 30 September each year.

Since its inception in 1991, more than 790 fellows have participated in the program. In 2023, 19 young scientists began an ERCIM PhD fellowship, and throughout the year, 63 fellows were hosted. The Fellowship Program is named in honor of Alain Bensoussan, the former president of Inria, one of the three founding institutes of ERCIM.

http://fellowship.ercim.eu

> "The ERCIM fellowship is a rewarding programme for PhD holders who want a real experience that will enhance their career prospects. Such an experience is unforgettable for me. I became a better researcher and grew my research network during the programme. In addition to the academic aspect, I enjoyed the rich culture of my host country. I strongly recommend this programme for potential fellows.
>
> **Eniafe Festus AYETIRAN**
> Former ERCIM Fellow

Introduction to the Special Theme

Sustainable Cities

by the guest editors German Castignani (Luxembourg Institute of Science and Technology) and Georgios Mylonas (Industrial Systems Institute, Athena Research Center)

In recent years, urban environments worldwide have focused on sustainability to tackle rapid urbanisation, climate change, and resource constraints. This ERCIM News special theme "Sustainable Cities" highlights recent research and technological advancements in computer science, data science, AI/ML, and digital twins that drive this transformation through European research projects.

Diverse and interdisciplinary efforts are essential for fostering sustainable, resilient, and inclusive urban environments. However, the varying digital maturity levels of cities can pose significant barriers, such as inadequate infrastructure, insufficient funding, and unpreparedness to implement and sustain smart city technologies. Additionally, neglecting citizen engagement and co-creation can hinder the integration of advanced technologies, slowing the transition to a sustainable society. Addressing these challenges is crucial for all urban areas to progress towards becoming truly sustainable cities.

This ERCIM News special theme reports on academic and industry research addressing technologies, systems, applications, and services for sustainable smart cities, covering a range of crucial areas.

Sustainable Mobility

In the area of mobility, in recent years a plethora of approaches have been proposed and tried, with the electrification of transportation and the expansion of public means of transport, such as railways, gaining ground. In this setting, Constantinou et al. (p. 6) explore renewable energy hoarding for electric vehicle charging, while Basile et al. (p. 8) focus on the digitisation of railway transport. Cintrano et al. (p. 9) showcase a human-centred approach to rethink urban mobility solutions. Finally, Marius et al. (p. 11) showcase a Local Digital Twin (LDT) toolbox to allow cities to evaluate electromobility deployment strategies.

Sustainable Energy

Energy management is vital for urban sustainability, involving grid transformation, digital twins for system modeling, and new sustainable energy markets to support evolving energy production models. Puecker et al. (p. 12) propose an approach for predicting energy prices using cloud services while Klikovits et al. (p. 14) investigate the role of data intermediaries within data spaces to promote sustainable energy practices in cities. Stravropoulos et al. (p. 15) explore how integrating IoT and smart grid technologies in residential settings can significantly enhance energy efficiency and management. Briguglio et al. (p. 17) propose a framework to include AI ethics and regulatory governance in the development aspects related to the digitalisation of the EU energy sector. Also, Kogut et al. (p. 18) highlight the value of LDTs for their role in achieving positive energy districts.

AI for Sustainability

AI and novel approaches feature prominently in this special theme and are huge enablers of sustainability in cities and urban environments, also reflecting the rapid transformation of the field in computer science and the inclusion of such methods across the spectrum. Lämmel et al. (p. 20) propose an AI-based anomaly detection mechanism for secured IoT data exchanges in smart cities. Edinger (p. 22) introduces an innovative concept to assess the use of renewable energy to compensate increasing demand for computing in smart cities. Additionally, the use of responsible AI techniques for public transport transformation is explored by Leone et al. (p. 23). Finally, Troulaki et al. (p. 25) introduce an AI, data and robot-based portable material recovery facility, enabling the decentralised treatment of recyclable waste in cities.

Inclusivity of Sustainable Cities

Responding to the need to create sustainable, resilient and inclusive urban environments, in this cluster, several articles address aspects related to inclusivity and interaction between ICT systems for smart cities and citizens. Interfacing with inclusive smart cities encompasses various facets, such as the importance of social acceptance and human components in smart city cybersecurity, highlighted by Volpini et al. (p. 26). Gallo et al. (p. 28) introduce the use of human control mechanisms like conversational agents and mobile augmented reality in green smart homes. Schwartz et al. (p. 29) present different approaches for the design of IT tools that address environmental concerns. Abu Qasem et al. (p. 31) investigate the role of decision support systems for inclusive urban design. Technology's role in communal spaces for social sustainability is examined by Ali et al. (p. 32). Sioutis et al. (p. 34) explore citizen-centric and data-driven approaches to urban design and mobility management, and Mannari et al. (p. 35) investigate the challenges of the socio-technical process necessary for the digitalisation of rural areas.

Sustainable Cities Powered by Snap4City

Snap4City is an example of an open-source platform developed in Europe providing an integrated environment for managing smart city services, utilising big data, IoT, and AI to enhance urban sustainability and decision-making processes. In this thematic cluster, Nesi et al. (p. 37) highlight the value of multidomain digital twin platforms for city managers and decision-makers, and Bilotta et al. (p. 39) introduce the use of digital twins for CO_2 emission reductions through traffic flow optimisation. This cluster concludes with a Snap4City use case in the Italian city Merano, where Mitolo et al. (p. 40) demonstrate how to enhance city sustainability through smart light management.

We invite you to explore these insightful articles within thematic clusters, offering innovative solutions that shape the sustainable cities of tomorrow and showcase Europe's vibrant research ecosystem.

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Green Mobility: Renewable Energy Hoarding for Electric Vehicle Charging

by Soteris Constantinou (University of Cyprus), Constantinos Costa (Rinnoco LTD), and Demetrios Zeinalipour-Yazti (University of Cyprus)

The EcoCharge framework, developed at the University of Cyprus, allows eco-friendly electric vehicle charging by utilising an intelligent algorithm to connect drivers with the most environmentally sustainable chargers. This innovative approach enhances the use of renewable energy, minimises CO_2 emissions, and optimises charging through a user-friendly mobile GIS application.

Electric vehicles (EVs) and charging infrastructure are rapidly evolving to meet today's demands. Our main objective is to allow drivers to recharge their EVs from the most environmentally friendly chargers through an intelligent hoarding approach. These chargers maximise renewable (e.g., solar) self-consumption, thus reducing CO_2 production and also the need for expensive stationary batteries on the electricity grid to store renewable energy that cannot be used otherwise. We have employed a Continuous k-Nearest Neighbour query, where the distance function is computed using Estimated Components (ECs), i.e., a query we term CkNN-EC. An EC defines a function that can have a fuzzy value upon certain estimations. Specific ECs considered in this work include: (i) the (available clean) power at the charger, which depends on the estimated weather; (ii) the charger availability, which depends on the estimated busy timetables that show when the charger is crowded; and (iii) the derouting cost, which is the time to reach the charger depending on estimated traffic. We devised the EcoCharge framework that combines these multiple non-conflicting objectives into an optimisation task providing user-defined ranking means through an intuitive mobile GIS application. Particularly, our algorithm leverages lower and upper values derived from the ECs to recommend the top-ranked EV chargers, displaying them on an intuitive map interface to users.

Over the past few years, there has been a growing interest in the integration of Renewable Energy Sources (RES) with EV charging infrastructure (i.e., photovoltaic panels, wind turbines) [2]. It is common for people to charge their EVs during idle times, even when the battery is not substantially depleted, to ensure that the vehicle will be charged sufficiently for future travel: a behaviour we term "energy hoarding". EVs are seen as a way to improve the environment and mitigate greenhouse gas emissions; however, energy hoarding with non-renewable energy is negating environmental benefits. In the USA, the EV energy charging demand was attributed to 4.7 terawatt hours in 2020, and is expected to increase to ≈107 terawatt hours by 2035 [3]. Current applications (e.g., Plugshare, Ionity, Tesla's supercharger, EnBW, Shell recharge) focus on allowing users to know where to recharge, but do not list the environmental impact of the charging process (i.e., energy sourced from fossil fuel burning).

A renewable hoarding technique can be applicable in situations with idle time (i.e., while an EV user is parked or waiting). For example, consider the following real-life scenarios: (i) parents waiting in their idle EVs while their children attend after-school activities; (ii) electric taxis (e.g., Lyft, Uber, Bolt) during idle periods are waiting to be called or booked online; and (iii) an EV user going for groceries or clothing shopping. This can also be applied in similar situations, such as attending meetings, events, or conferences. Consequently, in all aforementioned cases, users could stop or deroute at some nearby charging station to efficiently charge their EVs using power generated from renewable sources, thus reducing the carbon footprint of their daily routine.

The decision of where to sustainably hoard depends on a variety of Estimated Components (ECs) on where and when to charge. Examples of these estimations are: (i) the available

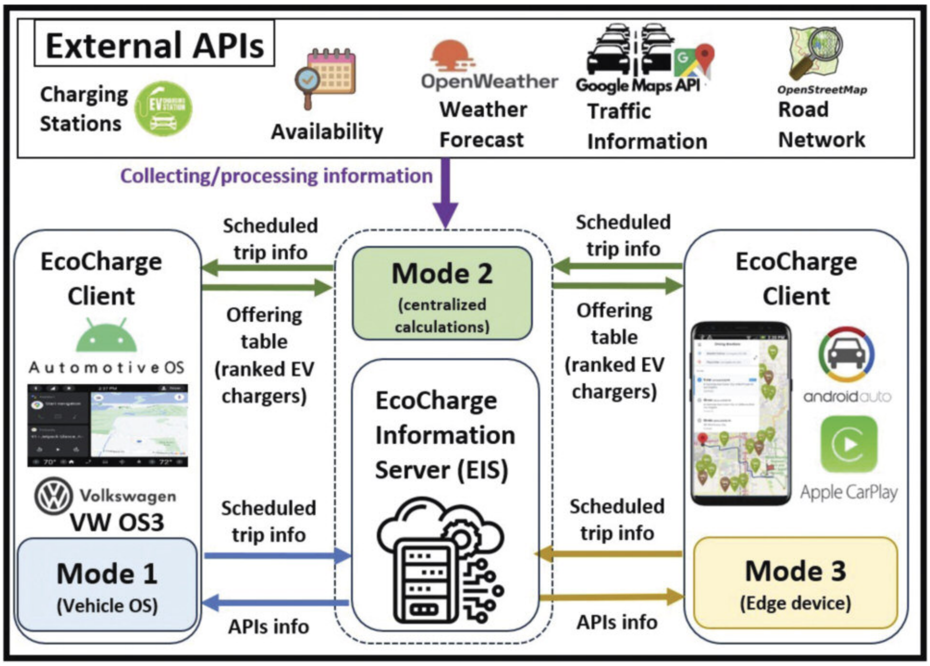
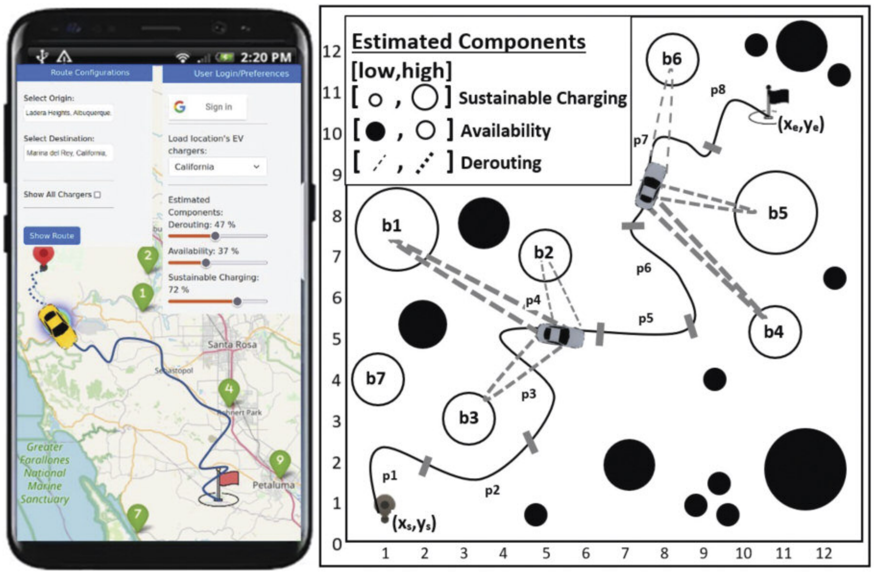


Figure 1: EcoCharge Architecture: The server takes as an input all EV chargers, availability information, weather forecast, road network data, and traffic conditions. The processed data can be provided to the client upon request through three discrete modes of operation.

Figure 2: EcoCharge application: An example of an Offering Table (O) for a moving vehicle on a scheduled trip. The ranking selection is determined by each EV charger's rate and solar production curve at a specific time, taking into account the estimated time of arrival (ETA).



clean power at the charger that depends on the estimated weather; (ii) the charger availability that depends on the estimated busy timetables showing when the charger is crowded; and (iii) the derouting cost to reach the charger that depends on estimated traffic. To tackle this challenge, a Continuous k-Nearest Neighbour (CkNN) query can be utilised to answer questions like which EV chargers are closer to a path. Our work falls under the concept of renewable hoarding techniques exploiting ECs. The objective is to optimise EV charging by utilising only RES and focusing solely on short-term travelling (i.e., urban setting). We model the problem as a CkNN-EC query [1] that retrieves the k-nearest neighbours of every point on a path segment (e.g., "find all my nearest EV chargers during my route from source to end point"), while considering ECs by employing a distance function that can express a fuzzy value.

Our innovative framework, called EcoCharge, utilises a CkNN-EC search and a dynamic caching technique to produce Offering Tables featuring sustainable chargers, ensuring timely responses. The ranking is derived from a cost function, employing an iterative deepening process to determine the kNN sets containing EV chargers from the query point within a predefined time window, while considering ECs, expressed through intervals (i.e., ranges of min-max values). EcoCharge can be used over three Modes: (i) Mode 1, operating in a vehicle's embedded operating system (e.g., Android Automotive OS, Volkswagen OS3); (ii) Mode 2, where calculations are conducted centrally on a server; and (iii) Mode 3, where functionalities are managed by an edge device (e.g., smart phone using Android Auto or Apple CarPlay).

As shown in Figure 1, the core of the system resides in an EcoCharge client supported by a centralised server, which interacts with external APIs to retrieve essential data. Leveraging external APIs, the EcoCharge Information Server (EIS) acquires real-time weather forecast data, detailed road network information, and a list of all available EV charging stations based on user's location. This centralised approach enables the server to efficiently consolidate the required data and distribute to individual clients upon request. Our application enhances user experience by integrating with the device's location services. Users can seamlessly set their desired trip destination and access route information via an intuitive GUI, leveraging the application's functionality for efficient navigation (see Figure 2).

The ability to accumulate renewable energy during production periods and take advantage of self-consumption is a key feature, making EcoCharge an environmentally friendly alternative to traditional charging methods. The system allows drivers to make informed decisions and choose the most sustainable charging stations along their scheduled route, while reducing the environmental impact of transportation.

Link:
[L1] https://ecocharge.cs.ucy.ac.cy/

References:

[1] S. Constantinou et al., "A framework for continuous kNN ranking of EV chargers with estimated components," in 40th IEEE International Conference on Data Engineering (ICDE'24), IEEE Computer Society, pp. 13, 2024.
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[3] S. Constantinou et al., "Green planning of IoT home automation workflows in smart buildings," in 2022 ACM Transactions on Internet of Things (TIOT '22), vol. 3, pp.30, 2022.

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Sustainable Mobility: Increase of Capacity and Digitisation of Railway Transport

by Davide Basile, Maurice ter Beek and Alessio Ferrari (CNR–ISTI)

Researchers from the Formal Methods and Tools (FMT) lab of CNR–ISTI work on the increase of capacity and digitisation of railway transport. The research is conducted in the context of the NextGenerationEU-funded project on "Railway Transportation" (Spoke 4), which is part of the National Centre for Sustainable Mobility (MOST).

Railway transportation by train, metro, or tram is among the most energy-efficient and environmentally friendly means of transportation. In the near future, the railway domain is expected to contribute significantly to the European Green Deal by improved digitalisation and big data analytics [L1]. The NextGenerationEU project on "Rail Transportation" (Spoke 4) of the National Centre for Sustainable Mobility (MOST) [L2] aims, among others, to increase railway capacity and digitisation in order to improve railway safety, efficiency of railway maintenance, and railway asset management. The FMT lab of CNR–ISTI is involved in two work packages: WP1 and WP3.

WP1 "Increase of capacity of railway transport" aims to increase the capacity through the innovation of railway signalling systems (ERTMS/ETCS Level 3) and the development of robust quantitative methods for the assessment of capacity of railway lines. In Task 1.3 "Resilient and sustainable railway infrastructure", we have so far investigated the combination of an academic formal verification tool with an industrial semi-formal model-based development tool to develop a railway interface, namely the RBC/RBC handover protocol (UNISIG Subset 039 and Subset 098 standard interface) of the ERTMS/ETCS signalling system [1]. The use of advanced formal verification techniques integrated with model-based development, reflects significant technological innovation and contributes to achieve the Sustainable Development Goals (SDG), specifically to safe, resilient and sustainable mobility (SDG 11).

WP3 "Digitisation of railway transport", coordinated by Maurice ter Beek, aims to promote digital products and processes to foster smart management, monitoring and predictive maintenance in order to reduce fatalities, reduce operating cost, and increase the overall mobility safety level. In Task 3.1 "Learning Formal Models for Predictive Maintenance", we have so far investigated possible efficient predictive maintenance solutions based on big data analytics for safe and sustainable infrastructure maintenance in the railway domain. Detecting and preventing failures in domains with high operational risks and costs, like the railway industry, is paramount to improve utilisation and reliability of equipment and to increase operational efficiency by minimising downtime and reducing costs. One essential approach to achieve this is the deployment of effective and efficient maintenance strategies. In particular, predictive maintenance aims to detect failures before they actually occur.

The development of effective and efficient predictive maintenance solutions for the railway domain is a challenging and emerging research field. In the literature [2], one distinguishes several classes of predictive maintenance on the basis of how the data is collected and exploited to implement the prognostics application, i.e. (physical) model-based, data-driven-based, knowledge-based, and digital twin-based. To produce the actual predictions, model-based approaches use the provided input data on a previously defined physical or mathematical model; data-driven approaches use a statistical model inferred from the data that was available at the time of the training of the prognostics application; knowledge-based approaches use domain knowledge (e.g. ontologies) or expertise of the system; and digital twin-based approaches use a real-time digital representation of the physical system to generate data imitating the real events.

While data-driven approaches require huge amounts of data to correctly infer a statistical model, model-based approaches are less dependent on data. Yet model-based solutions can become quite complex if the modelled system is complex, whereas the domain-agnostic nature of data-driven solutions guarantees instant applicability on the data – without the need of a model or detailed knowledge of the system. We are currently developing a data-driven approach to define cost-effective predictive maintenance strategies for on-board equipment. Efficient pre-

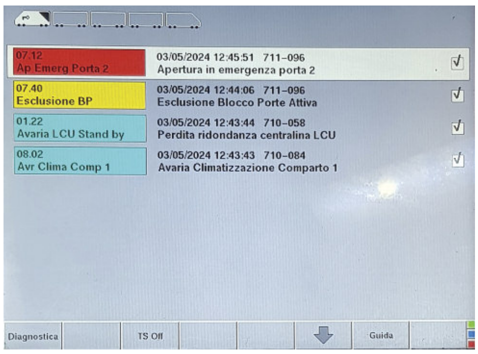

Figure 1: Trenord's Fiorenza maintenance facility, the largest railway maintenance facility in Italy with a maintenance and cleaning capacity of up to 140 full trains every week, and a train driver control screen displaying diagnostic information on rolling stock assets.

dictive maintenance allows the optimisation of energy consumption and reduction of emissions associated with railway operations, contributing to limiting and adapting to climate change (SDG 13).

For now, we focus on predictive maintenance solutions for the railway Traction Control Unit (TCU) and the Door Control Unit (DCU) of local commuter trains. The goal is to identify operational anomalies and potential defects in the data logs of these on-board units, enabling the scheduling of maintenance ahead of time [3]. The traction system is important since it enables adherence to acceleration and deceleration values mandated by the regulations, whereas the door system is related to the safety, security and efficiency of railway operations, implying that its failure can lead to operational disruptions or delays that may propagate through the railway network, thus causing economic loss and bad social reputation. Surprisingly, the door system is responsible for 30% to 60% of the total failures in railway vehicles [L3] (see Fig. 1). This high failure rate is due to the complexity of the system's mechatronic structure, as well as to the high stress during its lifecycle (e.g. frequent opening and closing due to high passenger flow, in particular on local commuter trains).

Spoke 4 received funding from the European Union – NextGenerationEU. The project will run until August 2025 and is coordinated by Marco Bocciolone from the Polytechnic University of Milan. Further partners in T1.3 and T3.1 include the universities of Florence, Naples, Parma, and Roma "Sapienza", as well as the industrial partners Accenture, Almaviva, Ferrovie Nord Milano (FNM), Hitachi, Intesa Sanpaolo, Lutech, Rete Ferroviaria Italiana (RFI), and Trenord.

Links:
[L1] https://kwz.me/hAQ
[L2] https://www.centronazionalemost.it/
[L3] http://www.railway-technical.com/trains/train-maintenance/

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Human-centred Smart Mobility: Shaping the Future of Urban Transport

by Christian Cintrano, Gabriel Luque, and Jamal Toutouh (University of Málaga)

Exploring the fusion of advanced technology and urban planning, the HUMOVE project is pioneering diverse smart mobility solutions, each designed with a human-centred approach. From enhancing pedestrian pathways to optimising e-scooter and electric vehicle infrastructures, discover how these case studies are actively redefining sustainable urban transport for a variety of city residents.

As the world urbanises at an unprecedented rate, the pressure on urban transportation infrastructure has never been more intense. The HUMOVE (Human-centred Smart Mobility) project [L1], led by experts from ITIS Software [L2] at the University of Málaga, focuses on rethinking urban mobility from a human-centred perspective, offering solutions that address both social and environmental needs.

HUMOVE is committed to creating intelligent mobility solutions that anticipate the needs of a growing and diverse urban population. The project takes a comprehensive approach, integrating advanced technologies and inclusive design to improve the mobility experience for pedestrians, cyclists, electric vehicle drivers, and public transport users. In this project, we have developed multiple intelligent systems to improve mobility from the citizen's point of view. In the this article, we will detail two use cases as representative examples of the project's results.

Our first example is a plan to smoothly integrate e-scooters into the city environment. This task aims to improve the current road infrastructure to make e-scooters a practical part of the city's multi-modal transport system [1]. The main objective is to enhance the connectivity and extend the coverage of bike lanes designed specifically for e-scooter use while keeping the implementation costs as low as possible.

We are taking a holistic approach to urban mobility by redesigning roadways to accommodate e-scooters and bicycles. Our goal is to create a more inclusive and efficient transport network. Introducing dedicated lanes will provide safer and faster travel for e-scooter users and help reduce congestion in urban centres.

Moreover, the strategic placement of these new infrastructures is guided by a comprehensive analysis that balances the benefits of improved travel times against the financial implications of road modifications. Through careful planning and the use of multi-criteria optimisation techniques, it has successfully identified key areas within Málaga city (Spain) where interventions would yield the most significant impacts. This methodical placement ensures that investments are made where they can provide maximum benefits in terms of accessibility and user satisfaction.

The outcomes from this service highlight a promising reduction in travel times for e-scooter users, which is instrumental in pro-

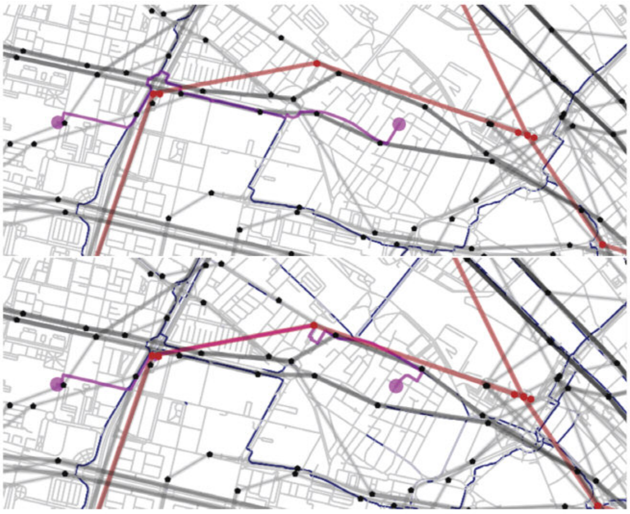

Figure 1: Example for the same route (fuchsia line) using the current infrastructure (top) and the proposed infrastructure (bottom). It shows how the proposed route allows combining e-scooter paths (blue lines) with public transport (red lines).

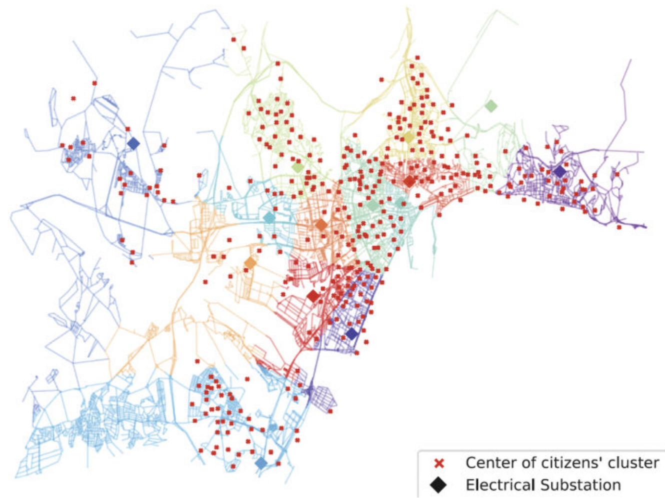

Figure 2: Citizen clusters, electrical substations, and road map of Malaga, Spain. Each edge represents a street segment associated with a substation.

moting wider adoption of this sustainable mode of transport. Additionally, the economic analysis accompanying the infrastructure developments confirms that the enhancements are not only feasible but also cost-effective, considering the long-term benefits of a more sustainable urban mobility system.

This case study from the HUMOVE project serves as a compelling example of how thoughtful integration of e-scooters into city planning can lead to significant improvements in urban mobility. It demonstrates a scalable model for other cities aiming to embrace sustainable transportation solutions and underscores the potential of e-scooters to contribute to a more dynamic and environmentally friendly urban environment (see Figure 1).

Another noteworthy application developed in the HUMOVE project focuses on optimising the placement of electric vehicle charging stations (EVCS) [2]. This initiative seeks to maximise the quality of service for electric vehicle users while simultaneously minimising deployment costs, embodying a quintessential smart city solution. This dual-objective approach is crucial as it ensures that EVCS are both accessible and economically viable.

The service uses advanced multi-objective metaheuristics to solve the location problem, considering various types of EVCS, each differing in service speed and cost. This strategy allows the city to cater to diverse user needs, from quick charges for commuters to deeper charges for longer-stay vehicles. The quality of service is assessed by how many users an EVCS can serve within its neighbourhood, reflecting its effectiveness in accommodating the city's electric mobility demand.

The economic impact is meticulously analysed through the costs associated with installing each station type and integrating them into the existing power grid (see Figure 2). By strategically placing these stations in optimal locations, the project aims to enhance the overall efficiency of the city's transportation network, reduce carbon emissions, and promote the adoption of electric vehicles.

The findings are promising, showcasing a potential improvement in terms of the number of vehicles loaded per hour, thus improving driver satisfaction without necessitating prohibitive costs. Such outcomes not only bolster the feasibility of electric vehicles as a sustainable transport option but also provide a scalable model that other cities could adopt, marking a significant step forward in urban mobility planning.

This application of this project vividly illustrates the potential of integrated, data-driven approaches to address complex urban challenges, paving the way for smarter, more sustainable cities.

In conclusion, the HUMOVE project represents not only a technical advancement but also a shift towards more inclusive and sustainable mobility. The applications detailed herein are just two examples of the myriad challenges addressed by the project, which continues to explore new frontiers in the design of intelligent transportation systems. By placing people and the planet at the heart of its priorities, HUMOVE is actively shaping the future of urban transport, demonstrating a commitment to comprehensive, human-centred solutions.

Links:
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[L2] https://itis.uma.es/

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Developing Urban Services for Electromobility Planning through Local Digital Twins

by Noé Marius, Patrick Gratz, Laurence Johannsen, and German Castignani (Luxembourg Institute of Science and Technology)

The deployment of electromobility in urban areas is crucial for sustainable development. Local Digital Twins (LDTs) are especially relevant to monitor, predict and simulate the potential of electromobility as well as process renewable energy scenarios to support the development of smart, sustainable and ultimately net-zero cities.

In the context of the European Testing and Experimentation Facilities (TEF), the CitCom.ai project [L1] focuses on smart cities and communities, emphasising mobility, connectivity and power-related topics. CitCom.ai provides topical TEFs where AI innovators create scalable AI-powered services for smart cities. The Luxembourg TEF specifically focuses on electromobility and its impact on urban mobility [1].

Cities and communities face challenges in deploying electromobility, particularly in the strategic placement of charging stations and ensuring energy capacity. Locating chargers requires considering multiple parameters: accessibility, demand, and grid infrastructure, balancing user convenience with minimal disruption. Poorly positioned chargers can lead to range anxiety (i.e. the driver's fear that their EV won't have sufficient charge to reach their destination) and underutilisation. Ensuring sufficient renewable energy capacity involves investing in renewable infrastructure or collaborating with energy operators to upgrade the grid as loads increase, manage peak demand, and integrate renewable sources.

As part of the Luxembourg TEF, we conduct a pilot experimentation of a LDT toolbox for electromobility planning, designed however to be replicable and scalable to different cities, topics and datasets. LDTs emerge indeed as powerful tools for city planners to make informed decisions, by creating dynamic, real-time virtual replicas of cities, allowing for precise planning and management of urban systems, such as electric vehicle (EV) infrastructure or renewable energy generation. LDTs integrate various data sources, including built environments and real-time telemetries (e.g. IoT, energy consumption), and can incorporate relevant demand and supply models for electromobility along with smart visualisation tools. In a first instantiation of our LDT toolbox, we collaborate with Differdange, a Luxemburgish city well-known for its industrial heritage and green spaces, committed to sustainability and actively pursuing net-zero carbon emissions through innovative urban planning, renewable energy initiatives, and eco-friendly transportation solutions.

Working with the city's energy and mobility experts, we developed an initial LDT architecture to model electromobility challenges, including charging points, buildings and solar patches. This architecture includes data collection and telemetry emulators, spatio-temporal and graph databases, DT cloud solutions, and smart maps and dashboards. We considered relevant city data, including current charging positions, load curves and energy consumption. Several models were derived from this data and integrated into the LDT; they are leveraged to produce synthetic telemetry and predictive telemetry depending on the parameters of a simulation.

As defined by Rasheed et al. [2], "a digital twin can be defined as a virtual representation of a physical asset enabled through data and simulators for real-time prediction, optimisation, monitoring, controlling, and improved decision making". Our digital twin toolbox comprises a set of off-the-shelf and custom-made technological building blocks that allows us to represent the physical assets as digital twins. Once instantiated the twins become live entities. We can interact with them either as a collection of twins or individually, monitor their statuses, predict, optimise, or even control the real physical asset if it is an IoT Device. The key features of the toolbox are:

- Orchestrator: Manages different pipelines to gather entities and triggers the generation of telemetry data from models if necessary.
- Handles Diverse Telemetry Sources: Enables interaction with real-time telemetry, collection of historical data, or generation of synthetic telemetry based on models for each entity.

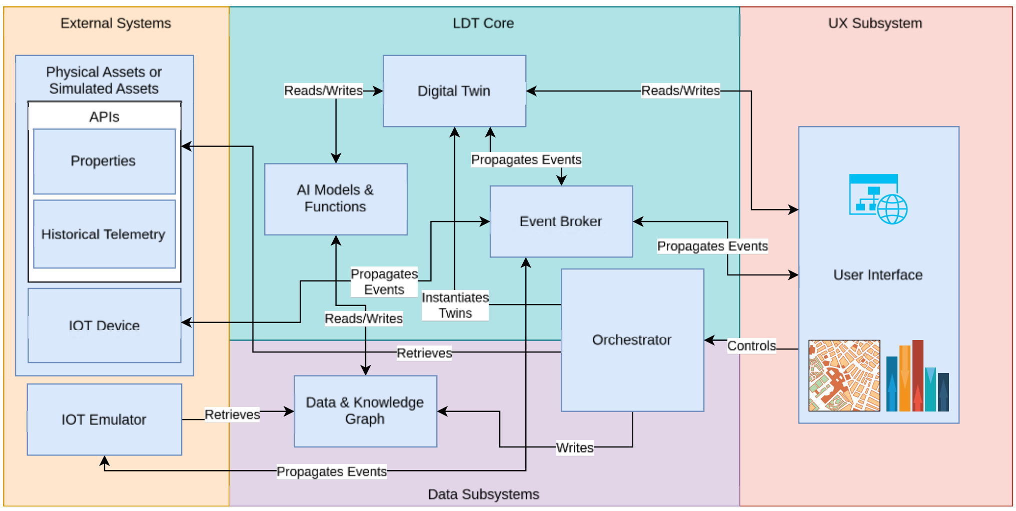

Figure 1: LDT high-level architecture diagram.

- IoT Emulator: Emulates IoT devices and plays historical or synthetic data.
- AI Models: We can plug in AI models to produce predictive telemetry, optimise performance, perform real-time monitoring, run simulations, and support decision making.

As shown on the high-level architecture diagram (Figure 1), we can populate on demand our digital twin with relevant entities based on a geocoordinate bounding box and date. The entities' models come from twin meta-models based on the NGSI-LD ontology developed for smart cities. During provisioning, the orchestrator triggers data pipelines to retrieve entities (physical assets or simulated ones) and store relevant telemetry data from models built by domain experts, AI models, or real datasets. Each entity is then instantiated in our Dynamic Digital Twin, where it can have its own interfaces and trigger events based on its properties and telemetry. We can interact with the digital twins through APIs or the user interface to run "what-if" scenarios or send commands to IoT devices. Moreover, our goal is now to further explore different technologies. For instance, we aim to replace components like Microsoft's Azure Digital Twin and the Digital Twins Definition Language (DTDL) based on the NGSI-LD ontology with other open-source solutions.

The pilot experimentation conducted through the project CitCom.ai shows the great potential of digital twins in terms of planning, simulation and prediction. It demonstrates that rapid experimentation in city-wide LDTs is possible, notably by allowing to:
- test and experiment with technologies to build a modular LDT architecture
- derive models to emulate telemetries in the digital twin
- collaborate with cities to understand their needs and leverage their data.

Beyond electromobility, we aim to expand the digital twin toolbox for various applications and for making them replicable. Future activities include refining the toolbox's capabilities, enhancing scalability, and integrating more advanced AI models for predictive analytics. We will continue exploring technologies incrementally, and building a multipurpose tool for cities to connect data, models and services, following advancements in LDTs, AI and data analytics.

The project CitCom.ai is co-funded through the EU Digital Europe Programme, call "Cloud data & TEF, 2022". The Luxembourg TEF is co-funded by the Luxembourg Ministry of Economy under an ERDF grant.

Link:
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Predicting Energy Prices Using Cloud Forecasting Services

by Dominik Puecker, Thomas Weyse (University of Applied Sciences Burgenland), and Igor Ivkić (University of Applied Sciences Burgenland and Lancaster University)

The energy sector is essential for economic development, and the liberalisation of the electricity market has made energy pricing dynamic, influenced by supply and demand. Accurate energy price forecasting is crucial for supply planning and investment decisions, offering security and risk minimization for producers and traders. We propose a cloud-based AI prototype that predicts energy prices using historical data. It details our method for assessing model accuracy by comparing actual to predicted prices, demonstrating how cloud technology can streamline data-intensive tasks in energy forecasting.

The energy market is a complex and volatile system that is influenced by many internal and external factors. Until now, the ability to accurately predict energy prices has been limited, in part due to limited technological forecasting capabilities. The use of cloud technology represents a new approach, which is described in this article. To illustrate this, Figure 1 shows the development of electricity prices in the German-Austrian energy market between 2003 and 2021.

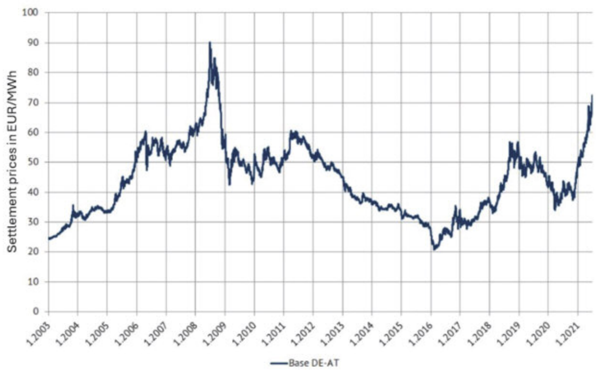

Figure 1: Electricity price development in the German-Austrian energy market from 2003 to 2021 [L1].

Over the years, the price of energy has been dynamic and highly volatile. This makes it essential that electricity traders and producers plan and calculate their purchases and production accurately. Ideally, they should be able to forecast the future so that they can adapt their strategy to changes as early as possible. The price of energy is subject to a certain degree of volatility due to the physical properties of electricity and non-stationary and seasonal demand [1]. As renewable energy, which is largely weather dependent, continues to expand, expected production is also becoming less predictable. The combination of these two factors adds an additional layer of complexity and makes energy price forecasting even more challenging [2].

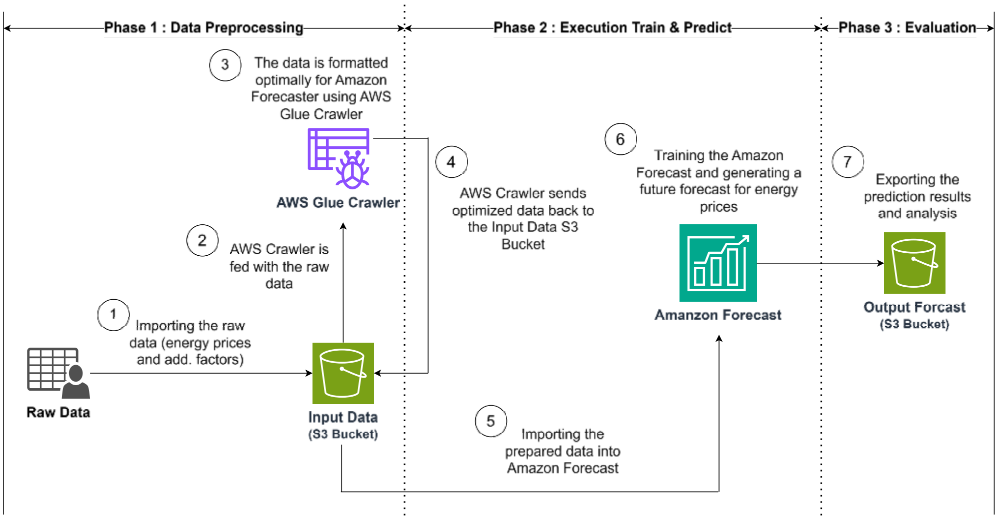

Figure 2: Design of the prototype to produce forecasting models using AWS.

This article explores the feasibility of using cloud services to create a model capable of predicting future energy prices. The objective is to leverage the advanced computational power, AI and Machine Learning (ML) capabilities provided by Amazon Web Services (AWS) to generate precise forecasts based on historical energy price data. To achieve this goal, we propose a prototype designed to operate in the AWS cloud platform, utilising managed services (Amazon Forecast) to predict energy prices. The cloud-based model is expected to be able to understand the behaviour of the electricity market based on the provided data, to recognise patterns and to predict future developments. Our approach extends the scope of the research beyond the evaluation of modelling techniques and (compared to related work) takes advantage of the state-of-the-art technologies provided by the cloud [3]. The overall idea is to let the AI-algorithm itself decide which model is best for modelling, rather than specifying a particular type of model. Figure 2 shows proposed AWS cloud-based prototype for predicting energy prices. The prototype is divided into three distinct phases. Each phase uses different cloud services at different times, and they contribute to each other. First, the raw historical data is imported and then pre-processed using the dedicated AWS Glue Crawler service (Phase 1: Data Preprocessing). This service prepares the data so that the AI can best interpret it and then identify patterns in it. This data is stored in the central Simple Storage Service (S3) bucket and is now ready for analysis. Next, Amazon Forecast Service uses the optimised data to train a predictor to create a model capable of predicting future energy prices (Phase 2: Execution Train & Predict). Amazon Forecast also supports model evaluation using a wide range of scientifically accepted methods and metrics for model validation. Finally, the predicted results are analysed to evaluate the performance of the generated model (Phase 3: Evaluate). To achieve a valid performance evaluation, the chosen approach compares actual energy prices (validation data) with the prices predicted by the model over a fixed period of time before the forecast is run. The purpose of this step is to show how much the Amazon Forecast Service prediction deviates from the actual values and it is used to determine a Proof of Concept (PoC) for the architecture created.

The main contribution of this article is a novel modelling approach to accurately predict future energy prices using cloud-based methods. In addition, we propose a cloud architecture that takes raw data from the energy market, learns from it, and (based on this) makes predictions (or forecasts) of future energy price developments. Our approach exploits the individual strengths of different cloud services, which in combination lead to the generation of predictive (or forecasting) models for energy prices. A key aspect of our approach is that the selection of the modelling algorithm is done completely autonomously by the AWS services, using ML to identify the most appropriate algorithm for the task. The cloud-based model simplifies the process of data handling and model training while enhancing the accuracy of predictions.

The research highlights the potential of cloud technologies in managing data-intensive tasks like energy price forecasting. Future research could explore the inclusion of additional factors, such as weather conditions and geopolitical events, to further improve the model's accuracy. Additionally, investigating other cloud services and ML techniques could provide deeper insights and more robust forecasting capabilities. By demonstrating the effectiveness of AWS cloud services in predicting energy prices, this study opens new avenues for applying cloud-based ML in the energy sector. The results indicate that cloud technology can significantly enhance forecasting accuracy, providing valuable insights for energy producers and traders. This approach not only improves the reliability of energy price forecasts but also offers a scalable and efficient solution for handling large datasets and complex variables, making it a promising tool for the energy industry.

Link: [L1] https://kwz.me/hDy

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Towards Exploring the Role of a Data Intermediary Within a Data Space

by Christoph Klikovits (Forschung Burgenland GmbH) and Silke Palkovits-Rauter (Fachhochschule Burgenland)

A data intermediary plays a crucial role by ensuring compliance with data exchange rules, facilitating a fair and secure flow of data between various partners. This mediation enhances transparency, resolves conflicts, and fosters trust, enabling compliant data sharing and collaboration within a data ecosystem. In the context of smart cities, this is particularly important as it ensures that the massive amounts of data generated by urban systems (including energy data such as smart meter data) are handled responsibly to support sustainable urban development and innovative public services.

The project USEFLEDS (Unleashing Sector-coupling Flexibility by means of an Energy Data Space) [L1], led by Forschung Burgenland GmbH and involving 13 other institutions, aims to unleash sector-coupling flexibility through the establishment of an energy data space. Situated in Austria and funded by the Austrian Research Promotion Agency (FFG), the project began in November 2023 and is slated to run for four years. The primary goal is to develop service-orientated solutions that close the gap between energy production and energy consumption to promote the energy transition. A key aspect of the project is the co-creation workspace, which acts as a communication channel between the various technical work packages and involved stakeholders. Future activities will concentrate on building a technical foundation to create a data ecosystem for the energy domain. The project has garnered significant interest from public authorities, underscoring its potential impact on the energy landscape. One key innovation that will drive this impact is the concept of data spaces.

Data spaces offer a platform designed for the secure, sovereign storage, management and exchange of data in accordance with the IDSA reference architecture model. They enable structured and secure handling of data and are used in various domains (energy transition, circular economy, mobility, etc.) Data spaces can enable a controlled multilateral exchange of data. The focus is on preserving the privacy and rights of data owners [1].

Several measures within the data space reference model can give data owners sovereignty over their information and allow them to determine who can access their data and under what conditions, which can strengthen both trust and compliance. Decentralised data storage can make access to sensitive data more difficult. Implemented security protocols and access controls and authentication procedures can optimise the level of security along the data value chain and restrict access to data to authorised users to minimise unauthorised access. Encryption algorithms during transmission and storage protect the integrity and confidentiality of information. Data spaces follow the principle of data protection through privacy by design by integrating data protection measures from the outset. In addition, transparency and traceability through comprehensive logging can increase user confidence and promote compliance with data protection regulations [2].

In addition to technical solutions, the introduction of federated services and standardised procedures strengthens governance aspects and enables a form of sovereign self-administration among equal partners (e.g. through smart contracts). However, this approach is viewed critically in the case of mandatory data exchange (e.g. sustainability goals).

Data intermediaries are crucial for secure and compliant data exchange, acting as neutral parties to mitigate risks and adhere to strict data protection standards. Regulatory frameworks like the Data Governance Act provide essential oversight, emphasising the importance of trust, transparency, and accountability in data transactions. The role of a data intermediary can be pivotal as a mediator by ensuring compliance with rules for data exchange. This facilitates a fair and secure flow of data between various partners, including mandatory tasks such as environmental protection [3].

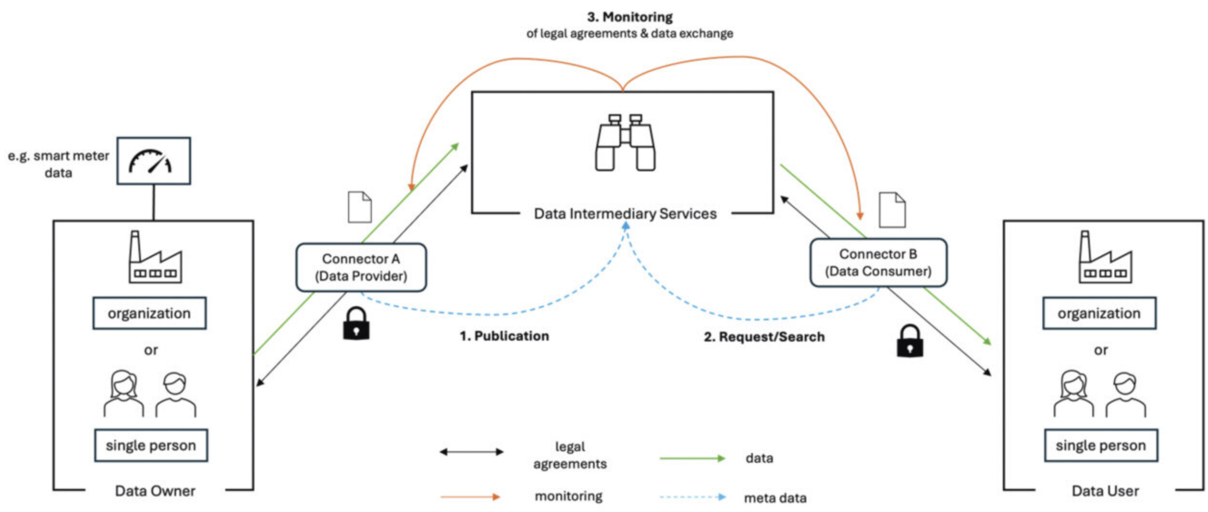

Figure 1: The role of a data intermediary within a data space scenario for exchanging energy data, specifically smart meter data.

Figure 1 illustrates the role of a data intermediary within a data space scenario for exchanging energy data, specifically smart meter data. The data provider publishes metadata through a data intermediary service, which is monitoring legal agreements and the data exchange itself. The data consumer, which may be an organisation or an individual, searches for or requests these data sets. Legal agreements between both parties facilitate data exchange via the data intermediary service.

In data ecosystems, governance services establish the legal basis for interactions through clear agreements, ensuring legal certainty and data integrity. Under the supervision of a data intermediary, the legal framework governing data sharing and usage can be monitored and managed in a controlled manner. This approach can mitigate potential tampering, enhance transparency, and resolve conflicts, thereby fostering trust and efficient data sharing and collaboration within the data ecosystem. By integrating governance guidelines within the reference architecture of data spaces, users gain clarity on data usage, which can increase trust and acceptance in digital energy services.

Link:
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Enhancing Residential Energy Efficiency and Management Through IoT and Smart Grid Integration

by Donatos Stavropoulos (University of Thessaly), Panagiotis Tzimotoudis (University of Thessaly), and Thanasis Korakis (University of Thessaly)

This article explores how integrating Internet of Things (IoT) and smart grid technologies in residential settings can significantly enhance energy efficiency and management, balancing energy demand and supply to create sustainable urban living environments.

The rapid urbanisation and increasing energy demand necessitate innovative solutions for sustainable city living. One promising approach lies in enhancing residential energy efficiency and management through the integration of IoT and smart grid technologies [1]. We have developed an experimental platform – a living lab comprising 50 households – to explore and validate these solutions in real-world settings.

IoT and Smart Grid Integration

The integration of IoT with smart grids forms a robust foundation for managing energy consumption in urban residential areas. This setup facilitates real-time data collection, communication, and control of various devices and systems connected to the grid. By deploying IoT-enabled smart meters, sensors and appliances, cities can monitor and optimise energy use effectively.

In the living lab in Volos, Greece, households are equipped with commercially available sensors and custom gateways based on single-board computers running open-source home automation frameworks. This infrastructure provides a scalable, reliable and practical platform for evaluating new energy management solutions before real-world deployment (see Figure 1).

Key Components of the Smart Home Testbed

1. IoT Gateways: Serving as the system’s backbone, IoT gateways like the Raspberry Pi 4B integrate with various sensors and devices within the home. These gateways collect data

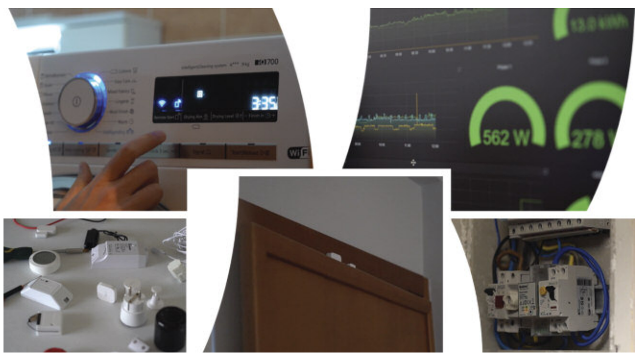

Figure 1: Integration of IoT and smart grid technologies in residential settings. Hardware components including smart appliances, IoT sensors and smart meters installed within the electrical panels.

on energy consumption, power usage and environmental conditions, transmitting this data to cloud-based services for analysis. A key characteristic of our custom gateway is its ability to integrate sensors and devices regardless of network access technology and vendor, achieved through the utilisation of open-source frameworks and hardware sniffers.

2. Smart Meters/Plugs and Relays: Installed within electrical panels, smart meters provide real-time energy consumption data. Smart plugs offer submetering capabilities and remote control of connected devices, essential for detailed monitoring and management of household energy usage. Additionally, smart relays are installed within specific circuits to control heavy load devices like electric water heaters.
3. Sensors and Actuators: Various sensors measure indoor and outdoor environmental conditions, while actuators enable control of home devices. Examples include commercial ZigBee temperature and humidity sensors, door contact sensors, motion sensors, and infrared hubs for controlling legacy devices like air conditioners without WiFi capabilities. These components allow for a comprehensive understanding of energy consumption patterns and the implementation of energy-saving measures.
4. Smart Appliances: IoT-enabled appliances, such as washing machines, dryers and dishwashers, can be remotely scheduled to operate during off-peak hours, optimising energy usage and contributing to demand response strategies. In the context of the European-funded project InterConnect [L1], manufacturers including BSH, Miele, and Whirlpool provided WiFi-enabled smart appliances capable of receiving remote control commands to initiate their operation earlier than their scheduled runtime.

Data Interoperability and Use Cases

A critical aspect of the smart home and grid experimental platform is data interoperability, achieved through the use of ontologies such as SAREF (Smart Appliances REFerence ontology) [2]. This framework ensures seamless data exchange and integration across various devices and platforms, supporting use cases that include machine learning, user engagement, and demand response. Within the InterConnect project, we utilised this semantic interoperability framework [L2] to integrate our experimental platform with services developed by other project partners, enabling the effective execution of the applications described below.

Machine Learning and Forecasting: By analysing collected data, machine learning algorithms can predict energy consumption patterns, identify opportunities for efficiency improvements, and optimise load management. Power consumption data is coupled with environmental data from sensors installed in the houses, enhancing the accuracy of the forecasting models. These predictive models help balance the grid and reduce peak demand, significantly contributing to overall energy efficiency. Implemented examples include personalised recommendations that encourage residents to shift their energy usage to times when renewable energy sources (RES) are abundant in the energy mix, thereby reducing their environmental footprint.

User Engagement and Feedback: Engaging residents through dashboards and mobile apps significantly enhances energy management. Users can monitor their energy usage, receive personalised recommendations, and provide feedback, fostering a dynamic interaction that promotes energy-saving behaviours. Tested methodologies included a mobile app that provided recommendations to residents and tracked whether these recommendations were followed. Additionally, the app allowed residents to specify their flexibility preferences, indicating times of the day they were willing to reduce their energy consumption by permitting remote control of their devices. This interactive approach not only encourages responsible energy use but also supports the grid's demand response strategies.

Demand Response: Demand response, or DR, is a critical component of modern energy management systems. It refers to the ability to adjust the demand for power instead of adjusting the supply. Implementing demand response strategies involves adjusting energy consumption based on real-time data and grid demands. Smart homes equipped with IoT devices can automatically reduce or shift energy usage in response to signals from utility companies, thereby enhancing grid stability and efficiency. During the pilot, two use cases were demonstrated: the first involved real-time device control for emergency situations, while the second offered scheduling capabilities for smart appliances over the next 24 hours to improve load balancing on the grid.

Conclusion and Future Directions

The development of IoT and smart grid technologies in residential settings presents significant potential for creating sustainable cities. By enhancing energy efficiency and management, these technologies can reduce the urban energy footprint and promote sustainable living practices.

Future initiatives aim to expand the experimental platform to include smart office buildings and retail establishments, further integrating IoT devices like air quality sensors and intelligent thermostats. The ultimate goal is to create an experimental platform that closely mirrors real-life scenarios, enabling thorough evaluation and optimisation of smart city solutions.

Links:
[L1] https://www.interconnectproject.eu/
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Sustainable Energy Practices Empowered by Ethics and Regulatory Perspectives

by Luigi Briguglio, Tetiana Vasylieva, and Carmela Occhipinti (CyberEthics Lab.)

The establishment of an ethics and regulatory governance framework during the whole development lifecycle ensures the embedding of values and rules, setting the stage for a transformative journey towards sustainable energy practices.

Daily news reports on global disasters and impacts caused by climate change, such as rivers that increasingly take on a torrential character and that suddenly flood inhabited lands or that dry up, extreme precipitations that in a single day cause entire season's worth of water to fall, melting of the ice of glaciers at high altitudes and at Arctic pole. These disasters are causing enormous losses of human life and putting at risk the availability of resources for future generations, raising questions of resilience and sustainability. Faced with these situations and the unanimous request of scientists and civil society, more than 100 nations have shared at COP 28 (the 28th annual United Nations climate meeting, held in December 2023 in Dubai) [1] their commitment with the fifth iteration of the Global Stocktake (GST), adopting eight steps to limit global temperature rise to 1.5 degrees C. The "Global Renewables and Energy Efficiency Pledge" is the first step and is characterised by ambitious targets, including (i) tripling global installed renewable energy capacity; (ii) doubling the annual rate of energy efficiency improvements; and (iii) elevating the principle of energy efficiency as the linchpin in policy, planning, and major investments.

Aligned with this commitment is the European initiative of the "Digitalising the Energy Sector – EU Action Plan" [2] that can significantly boost EU's energy efficiency, resilience and sustainability through the digital transformation. Indeed, this plan (launched in 2022) focuses on integrating digital technologies such as Artificial Intelligence (AI), Internet of Things (IoT), data space and blockchain to optimise energy production, distribution and consumption. Key objectives include improving grid resilience, enabling smart metering, and fostering innovation in renewable energy sources. Therefore, this plan can boost renewable energy use and unlock the full potential of the energy smart grid, taking care of relevant challenges, such as:

1. Grid Stability and Resilience: AI and IoT can optimise energy distribution and consumption, predicting and responding to fluctuations in demand. Blockchain can enhance grid security by ensuring transparent and tamper-proof energy transactions.
2. Energy Efficiency: IoT-enabled smart meters and AI-driven analytics can help reduce energy wastage by providing real-time data and insights, allowing consumers and companies to manage energy usage more effectively.
3. Integration of Renewable Energy Sources: AI and IoT can improve the integration and management of renewable energy sources by predicting production patterns and balancing supply and demand. Blockchain can facilitate decentralised energy trading, supporting the growth of renewable energy markets.
4. Cybersecurity: With the increasing digitalisation of the energy sector, ensuring robust cybersecurity measures is crucial. AI can detect and mitigate cyber threats in real-time, while blockchain and data space can provide secure data storage, data exchange and transaction validation, reducing vulnerabilities in the energy infrastructure.

In this context, the HEDGE-IOT [L1] project proposes an innovative digital framework to deploy IoT across the whole energy ecosystem (i.e. from "behind-the-meter" to the transmission level) and leverage AI/ML tools to enhance intelligence in both edge (i.e. in proximity of the IoT) and cloud layers. The HEDGE-IOT project aims to address challenges by considering, since the beginning and throughout all the lifecycle of the development process, the ethics and regulatory perspectives. Although this is the reasonable approach, at least to ensure compliance with the existing regulation, it is still surprisingly the most unusual and considered "out-of-box".

Therefore, the HEDGE-IOT project is establishing an ethics and regulatory governance (ERGO) framework considering provisionally relevant regulations, such as:

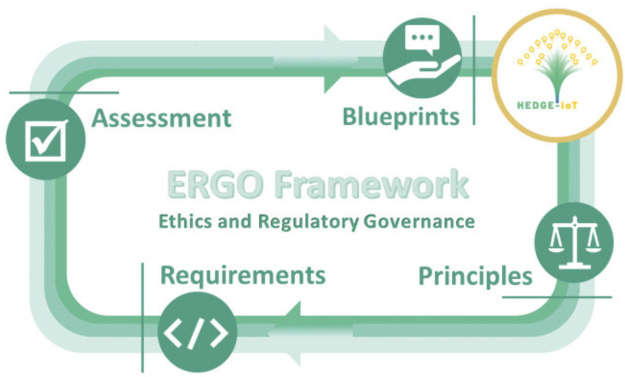

Figure 1: Overview of the Hedge IoT Ethics and Regulatory Governance (ERGO) framework.

1. Data Act (EU 2023/2854), ensuring fair use of, share and access to data (i.e. who can use what data and under which conditions) generated by IoT devices. The Data Act was published in December 2023, entered in force in January 2024, and it will become applicable from September 2025.
2. General Data Protection Regulation (EU 2016/679), which lays the foundation to ensure privacy and data protection rights of individuals when dealing with their personal data treatment.
3. AI Act (approved by the Council of the European Union on May 21st 2024), EU Ethics Guidelines for Trustworthy AI (2019) and the UN Interim Report "Governing AI for Humanity" [3] to ensure the trustworthiness, robustness and safety of AI systems and their adherence to EU values within the European market.

The HEDGE-IOT ERGO framework drives the research and innovation process by (i) setting key principles to be considered by the development team during the whole lifecycle, and based on these principles; and (ii) providing ethics and regulatory requirements to be embedded into the development of the system. To monitor and assess the compliance with the identified requirements, the ERGO framework is also defining assessment checklists, allowing the development team to be aware of potential ethics and regulatory concerns. The monitoring and assessment process, which is iterative and incremental, enabled by the ERGO framework will allow the project team to gather and collect experiences, concerns, countermeasures and lessons learned to be analysed and therefore to derive blueprints in terms of recommendations and policy options for improving future operational best practices and regulations.

This document is part of a project that has received funding from the European Union's Horizon Europe research and innovation programme under the Grant Agreement number 101136216.

Links:
[L1] https://hedgeiot.eu/
[L2] https://cyberethicslab.com

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Local Digital Twins for Positive Energy Districts

by Pavel Kogut (Digital Resilience Institute), Eva Schmitz (Data Competence Center for Cities and Regions), and Arne Schilling (Virtual City Systems)

Positive Energy Districts (PEDs) are a key building block in the future energy paradigm for carbon-neutral cities and communities. With digital twin technology, urban stakeholders can take advantage of smart planning and control measures to optimise PED development. A new PED-oriented digital twin that covers more domains than just energy is currently being created for Aarhus to fast-track its balanced transition to net zero.

PEDs produce more energy than they consume during a year, an outcome they achieve by implementing energy efficiency innovations and tapping into locally sourced renewables [1]. With the rise of modern technology, PED development is set to evolve towards a more agile arrangement in which decisions are first tested and fine-tuned in virtual environments prior to the on-the-ground deployment. An example would be a district heating system with a substantial renewables component that needs to handle peak loads during extreme weather conditions. Using a mix of consumption data and weather forecasts (temperature, wind, precipitation), the operator can model demand spikes and implement strategies to optimise a heating plant's load performance [2]. A key enabler of this virtual prototyping is Local Digital Twins (LDTs), a technology platform that combines static and dynamic data with simulation models to create a digital representation of a functional area.

However, current LDT implementations lack the sophistication necessary to characterise PEDs in all their complexity. Focusing on a limited number of urban systems in PED modelling will not do justice to the wider urban fabric without which no PED representation (and its development for that matter) can be considered complete. In order to overcome this shortcoming, a multi-dimensional LDT has been developed for the Brabrand district of Aarhus, Denmark. Called BIPED [L1], the solution integrates, in addition to energy and mobility, cross-sectoral "soft data" on Brabrand's social dimension and the environment to provide a more holistic PED twin that better represents physical reality.

Modelling scenarios

Relevant datasets and variables for PEDs are those used to construct its energy profile (district heating, energy consumption), mobility profile (road network, traffic flows), socio-environmental profile (demographics, perceptions of happiness and safety, green spaces, weather) as well as the 3D model of a district (based on remote sensing data) . To ensure accuracy and adoption by local stakeholders, models are calibrated by aligning them with real-world measurements. In the next step, models are brought to bear in getting actionable insights to end users, with measures being controlled in user-specific frontends (Figure 1). A key activity here revolves around what-if scenarios aimed at predicting system behaviour in response to specific interventions or unforeseen events.

Figure 1: BIPED user interface in VC Map.

Although PEDs focus on energy, ultimately they are about ensuring wellbeing and sustainability through an ambitious district transformation, and this requires taking the wider urban context into account. Besides strictly energy-related scenarios for district heating, for example, LDTs for PEDs should support simulations that cover additional domains affected by green policies.

LEZ impact

Low emission zones are intended to make urban environments healthier by reducing car traffic. An LDT can predict changes in traffic, estimate the resulting decrease in energy consumption, and calculate the potential reduction of air pollution in affected districts. Policy makers can use simulated results to examine trade-offs between expected benefits and drawbacks e.g. pollution displacement, increased travel times.

Road safety

As cities are being redeveloped to create more sustainable urban environments, one of the expected co-benefits is improved road safety. In this context, a multi-dimensional analysis of traffic accidents can guide the design and evaluation of urban policies to ensure that car-free city centres, cycling paths, micro-mobility and other green measures result in less accidents/injuries, not more.

Traffic

A cross-domain LDT with a two-way synchronisation to the real world can assess the likelihood of traffic build-up caused by roadworks, bad weather or an accident and inform drivers

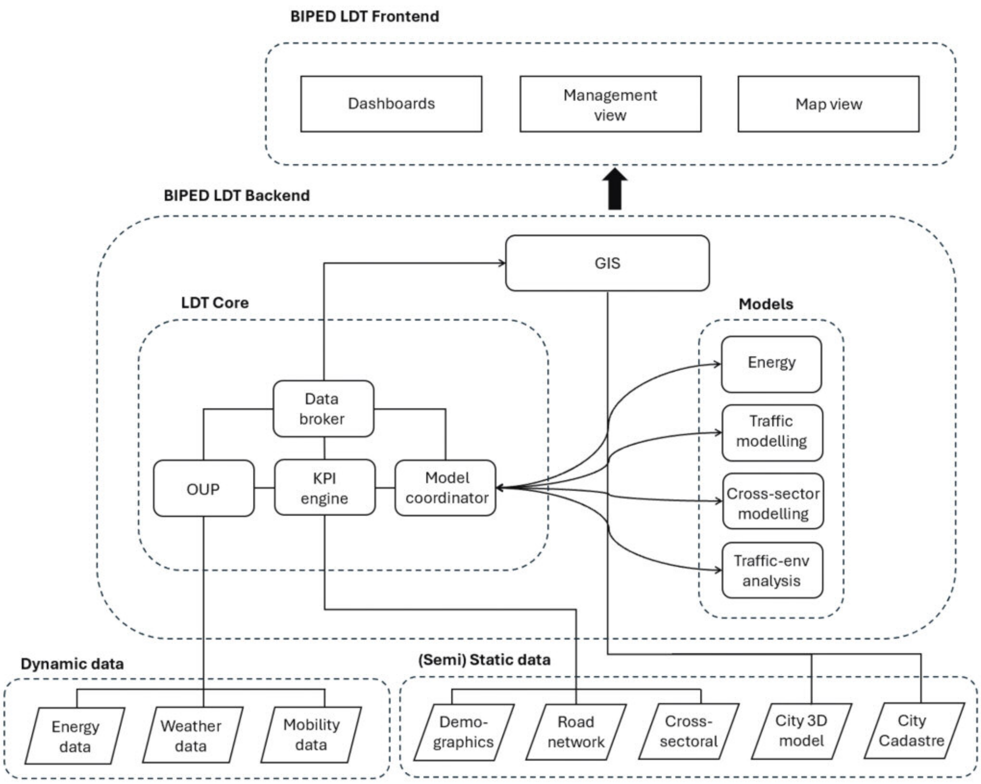

Figure 2: BIPED LDT architecture.

accordingly using messaging signs or app. In a scenario where a large influx of electric vehicles is expected, the road twin of an LDT can signal this prediction to its energy counterpart so that energy can be channelled from quieter places to meet increased demand.

Technical architecture

Given the need to integrate multiple components that can function independently, are easily manageable and scalable, a modular structure has been adopted for BIPED's architecture (Figure 2). In the LDT backend, the Core ingests and processes dynamic data (through the Open Urban Platform) and semi-static data (through the KPI Engine). The 3D model of a city comprising satellite imagery and building shapes is not funnelled through the Core to avoid unnecessary overload, and instead connects directly to the GIS publisher. The Core's Model Coordinator provides the necessary data to the models and stores simulation results for later use. The models leverage multi-source data to forecast energy demand, simulate traffic what-if scenarios, perform environmental analysis, emotional mapping, and more. The Data Broker provides data and metadata in a coherent bundle using standardised data structures and programmatic interfaces. Finally, all the necessary user interfaces (3D map, dashboards, management view) are provided through the frontend to enable data exploration and analysis, as well as system management.

By structuring LDT in modular units, developers can isolate and address specific functionalities without impacting the entire twin. Concurrent development can proceed without undermining the ability to troubleshoot, upgrade and optimise individual components as necessary. Furthermore, modularity facilitates the integration of new features and technologies, making it possible for BIPED to adapt to evolving user requirements.

This article is part of a project that has received funding from the European Union's Horizon Europe research and innovation programme under the Grant Agreement 101139060.

Link:
[L1] https://www.bi-ped.eu/

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AI-based Anomaly Detection for Data-driven Decisions in Secure Smart Cities

by Philipp Lämmel (Fraunhofer Institute for Open Communication Systems FOKUS), Stephan Borgert, Lisa Brunzel, ([ui!] Urban Software Institute GmbH), and Paul Darius (Fraunhofer Institute for Open Communication Systems FOKUS)

Digital transformation, innovations and increasing data collection in the field of administration and urban development are opening up more and more opportunities to incorporate urban data into key decision-making processes for our society. This dynamic decision-making basis influences the response of security and administrative authorities, which can lead to increased vulnerability to external attacks. The KIVEP project demonstrates how AI-based anomaly detection can be used in Internet of Things (IoT) networks to identify potential threats.

Information and Communication Technology (ICT) has led to the generation of vast amounts of data in all sectors, fostering interconnectedness. Smart cities use this data to improve areas such as transport, energy, water and waste management, climate monitoring and civil security. It is important to protect data used in decision-making and thus, IT security must be deeply integrated in secure smart cities. Advanced Deep Intrusion Detection Systems (Deep IDS) help distinguish normal traffic from potential attacks. As more smart cities and connected devices are created, the amount of sensitive data being sent increases. Research on smart city security, such as the KIVEP project [L1], looks at ways of preventing and detecting attacks on IoT devices.

Practical Example: AI-based Anomaly Detection

IoT is heavily used to collect data in smart cities. This is done by connecting small computers with sensors or actuators to the Internet. For example, in LoRaWAN, this is done through LoRaWAN network servers (LNS) and gateways. Gateway-level protocol anomaly detection requires insight into end-to-end encrypted packets. A simple solution would break end-to-end security. However, if a gateway is compromised, an attacker could access all data traffic from connected IoT devices. To address this, [ui!] and Fraunhofer FOKUS initiated the KIVEP project [L1] to enable privacy-preserving protocol anomaly detection on DIN SPEC 91357 compliant Open Urban Platforms [L2], hereby enhancing system robustness and improving overall security.

What is Anomaly Detection?

Anomaly detection is the problem of finding patterns in data that don't match what's expected [1]. These patterns that don't fit the norm are often called anomalies or outliers. Thus, anomaly detection can be used to find attacks in IT security. Here, an abnormal pattern in network traffic could for example mean that a computer is sending sensitive data to an unauthorised target [2].

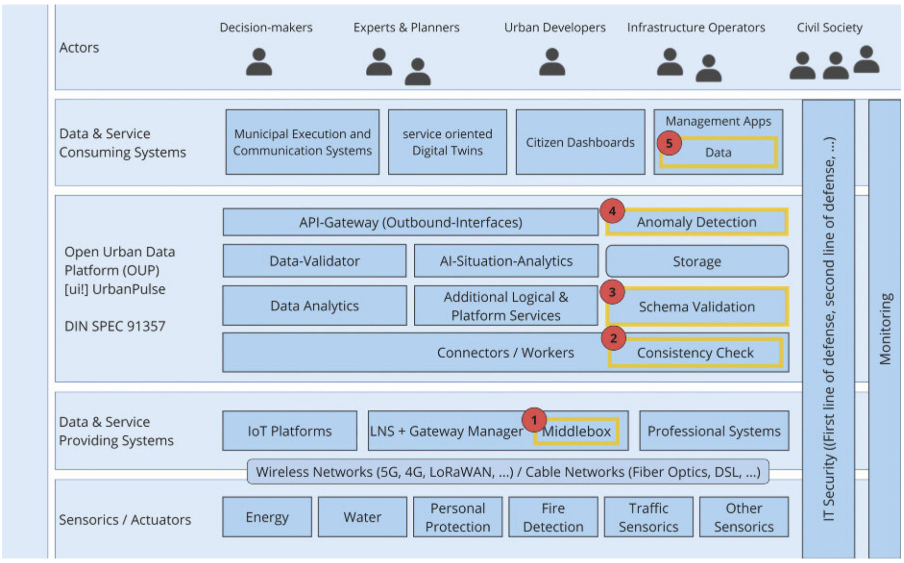

Figure 1: An Open Urban Platform (OUP) with KIVEP's AI-based anomaly detection.

A simple approach to anomaly detection is to define a normal range and declare any observation outside this range as an anomaly. However, this approach can be challenging for several reasons [1]:

- It is difficult to define a region as "normal" that encompasses every possible normal behaviour. In addition, the line between normal and abnormal behaviour is often difficult to draw precisely.
- When anomalies are the result of malicious actions, the malicious aggressors often adapt to make the anomalous observations appear normal, making the task of defining normal behaviour even more difficult.
- In many areas, normal behaviour is constantly evolving – including in a smart city – and a current definition of normal behaviour may no longer be representative in the future.

The developed solution can be seen in Figure 1. The middlebox (Figure 1.1 "Middlebox") is a virtual environment that detects anomalies in network traffic. It can be placed in different locations, depending on the needs of the network. When anomalies are detected, events are created and processed. These mechanisms could be placed directly in the middlebox or in the NOC or SOC.

Once the data has been extracted, it is verified to make sure it is correct (Figure 1.2 "Consensus verification"). This is important in allowing the data to be used in a use case. The used metrics can be updated and shown to users at the management app level. Before processing, a schema validation is done (Figure 1.3 "Schema validation"). This checks that the data matches the expected schema and requirements. Schema validation can check data types, barriers, and that all required data fields are present. The data is then processed and archived on the Open Urban Data Platform (OUP).

In the third step, the data is rigorously checked (Figure 1.4 "Anomaly detection"). This involves testing methods that can process large volumes of data. AI forecast results from data analytics are compared with actual data to identify anomalies in the data flows.

Lastly, all results are shown to the operators of the OUP (Figure 1.5 "Data"). If an anomaly is found, the results are shown. Then, standard security measures can be started after being checked.

Conclusion and Future Work

Digital transformations, new innovations and the increasing collection of data in the context of governance and urban development are creating more and more opportunities to incorporate urban data into sovereign and formative decisions for our society. This dynamic basis for decision-making means that attacks with the intention of damaging resources or people can have a major impact on the ability of security and administrative authorities to respond. OUPs are at the heart, enabling the transfer of verified, refined and validated data. The integration of security mechanisms is essential to guarantee this transfer at a high level of quality. Anomaly detection is an effective and efficient security mechanism. Using a variety of AI-based techniques, anomaly detection can identify patterns in the data that do not match the expected behaviour and react autonomously to these deviations. Due to the dynamic nature of the research field of IT security and cyber threats, the security of public administration decision-making systems will continue to be an important area of current and future research. Predominantly complex research topics such as homomorphic encryption, privacy-preserving mechanisms and the overall integration of security modules based on zero trust will become increasingly important as data-intensive systems help shape our society.

The KIVEP project is funded by the Federal Ministry of Education and Research (BMBF) under the code 16KIS1421.

Links:
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[L2] https://www.beuth.de/de/technische-regel/din-spec-91357/281077528

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Follow-The-Sun Computing – Merging Green Energy with Smart Computing

by Janick Edinger (University of Hamburg)

The Follow-The-Sun-Computing (FTSC) project aims to leverage surplus solar energy generated by households for distributed computing tasks, aligning sustainable energy with digital transformation. By shifting computationally intensive tasks to locations with excess solar power, the project creates a decentralised system that bypasses energy distribution challenges and reduces CO_2 emissions. This approach establishes a new market for computing power, utilising existing household infrastructure to achieve significant energy savings and environmental benefits.

Our current era witnesses two significant developments within the realm of the Twin Transformation – intertwining sustainability and digital transformation. These advances include: the groundbreaking accessibility of artificial intelligence (AI) models to the general public, and the ease with which individuals can generate solar power for household use. Although these developments appear independent at first glance, this project aims to identify and quantify the potential of a combined approach. The opportunities presented by intelligent digital assistants – especially voice agents – seem boundless. However, the high energy costs associated with new technologies pose a challenge. Currently, digital devices consume approximately 12% of global energy. Data centres in Germany alone consumed around 16 billion kWh in 2020, and this consumption is expected to rise. Efforts are underway to power data centres with green energy from renewable sources, but these efforts are hindered by limited energy distribution capacity.

On sunny days, substantial amounts of energy can be generated by photovoltaic (PV) or wind power plants, but often there are not enough means to transport this energy to consumers. In particular, large amounts of electricity from renewable energy sources in Germany cannot be transmitted to the energy-hungry industrial consumers in the south. Consequently, major energy producers are often disconnected from the grid and receive costly compensation in guaranteed feed-in tariffs. In 2022, over 800 million euros were paid in three German states alone for such compensations, while electricity needed elsewhere had to be purchased, potentially at high costs from conventional energy sources.

Private households face a similar challenge; advances in PV technology allow them to generate large amounts of electricity efficiently. Using this electricity within the household is not only the most efficient use of power but also offers cost advantages. However, when devices like electric cars and home batteries are fully charged, solar power systems may need to be shut down or the excess electricity sold to the grid. Legal hurdles and insufficient grid infrastructure exacerbate this issue. Solar and wind energy are highly regional phenomena, leading to simultaneous high energy production in neighbouring areas. This is where the Follow-The-Sun Computing project comes in. While transferring large amounts of electricity over long distances is technically complex and centrally controlled, data can be exchanged flexibly and locally with minimal latency. Computational tasks can be shifted to locations with surplus power. The necessary infrastructure, such as internet connectivity and capable computing devices, is already widely available in most households.

By consuming power where it is produced, this project eliminates the need for complex energy redistribution and bypasses administrative processes related to feed-in tariffs. Instead, a new market emerges where computational power is compensated through virtual or real currencies. Reciprocal models, not tied to actual currencies, are also conceivable. The granular nature of AI-agent requests, with computation times in the seconds-to-minutes range, allows for the real-time utilisation of unused computational capacities. Idle home computers, gaming consoles, and similar powerful devices can market their computing power – independently of grid feed-in regulations. This project seeks to identify and quantify the potential for using locally generated decentralised energy by distributing computational load. A system architecture based on the applicant's prior work will be developed, enabling load distribution based on current energy production. A pilot study will be con-

Figure 1: In FTSC, the aim is to evaluate the possibilities of sharing computing operations in a server farm cluster among a group of autonomous solar power plants. The initial solar panels for the FSTC project have been successfully commissioned.

ducted involving the installation and operation of PV systems and connected consumers. Consumers will be divided into end-user devices, subject to actual usage and varying demand, and dedicated devices exclusively for third-party computation tasks. The findings will form the foundation of a model demonstrating the approach's efficacy and potential for energy and CO_2 savings. Finally, various factors and parameters will be identified to optimise the approach for larger-scale implementation.

The project is structured into three major work packages. First, we assess the current state to estimate the potential of decentralised units for computationally intensive, request-based services. We capture and quantify the resource demands of traditional centralised computing, measuring attributes like system response time to ensure user experience remains consistent. Suitable measuring instruments are used to isolate and analyse resource usage, focusing primarily on energy consumption. A synthetic reference workload is generated to serve as a benchmark. Next, we design solar-powered, decentralised computing nodes, conceived as end-user devices in households. This involves configuring both hardware, consisting of PV modules and matched computing units, and software, including a lightweight operating system and middleware to enable workload distribution. Nodes use locally generated PV energy supplemented by grid connection for reliability. The middleware ensures tasks are routed to nodes with surplus solar power, tracked by intelligent meters, while a central scheduler optimises task delegation. Finally, we conduct a comprehensive evaluation and potential analysis of the decentralised solution, using the reference workload to redistribute tasks to solar-powered nodes when adequate energy is available. Nodes are installed in various German locations to capture regional effects and diverse measurements. The potential is assessed based on reduced energy demand in the central cluster minus the energy required for decentralised nodes during insufficient solar power. With this approach, we aim to establish a new market for computing power, utilising existing household infrastructure to achieve significant energy savings and environmental benefits.

Link:
https://www.inf.uni-hamburg.de/en/inst/ab/dos/newslist/2023-10-05-follow-the-sun-first-big-step.html

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Transforming Public Transport Through Responsible AI: Insight from the FAITH Project

by Giuseppe Riccardo Leone, Andrea Carboni, Davide Moroni, and Sara Colantonio (CNR-ISTI)

In the framework of the FAITH project, an AI-powered large-scale pilot is being organised to showcase the opportunities offered by advancements in edge computing and computer vision. The goal is to provide innovative ways to ensure safer and more sustainable public transport, encouraging modal shifts. Challenges in deploying responsible and trustworthy AI-based services will be addressed by assessing regulatory aspects and fostering co-design with end users and all the other stakeholders involved.

A connected, adaptive, sustainable and secure transport infrastructure constitutes a strategic asset in the development agenda of European countries [L1]. Adapting transport services to the actual loads and demands, planning and controlling fleets, optimising mobility and CO2 emissions, and ensuring the security and safety of citizens on board and in the stations are some of the key pursuits in the field. By exploiting the increasingly available sensor infrastructures and the massive amount of data they produce, AI-powered visual analytics may support several scopes to make transport safer, more reliable, more efficient and sustainable, thus positively impacting citizens' lives.

The integration of AI in multimodal transit systems is expected to spread, with a global market size valued at USD 2.3 billion in 2021 and expected around USD 14.79 billion by 2030 [L2]. However, several technological, regulatory and societal challenges need to be addressed to fully realise these expectations. Indeed, the real-world uptake of such AI-powered tools requires stakeholders to trust them. Operators should be reassured that the system is technically robust, accurate and reliable so they can rely on it safely.

Solutions should be resilient against malicious attacks or failures that could lead to disruption or, even worse, compromise public safety.

Moreover, privacy-by-design should be ensured, for instance, by implementing visual anonymisation in embedded edge computing and avoiding any form of biometrics, to guarantee unobtrusive monitoring of carriages and transport-related infrastructures.

The purpose of the large-scale pilot on public transit we are addressing in the context of the FAITH project [L3], is to develop and test experimental solutions to all these challenges, tailoring trustworthy AI visual analytics.

Pilot Description

The pilot will deliver a scalable privacy-preserving platform based on pervasive AI and video analytics that can help to im-

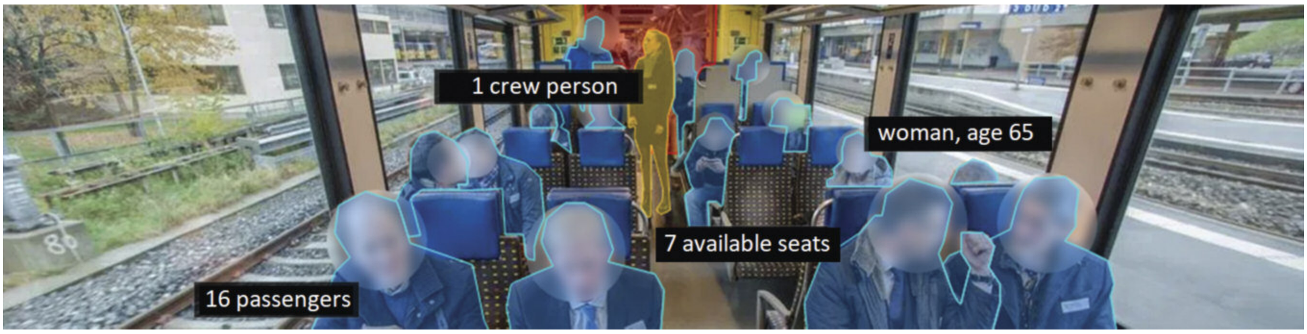

Figure 1: Privacy-by-design: the video streams are processed on edge and no image is stored permanently in all operations involving sensitive personal data such as seat counts or passenger analytics.

prove efficiency, safety and security onboard and in stations, by using privacy-preserving smart cameras that capture and analyse visual data in real time [1]. The video stream will be acquired onboard the coaches or in stations and other travel-related premises: mainly they will be obtained by equipping carriages, supplied by TRENITALIA, with dedicated systems to analyse closed-circuit video surveillance streams during traffic daily routine. The data will be anonymised and processed onboard for identifying several different types of objects: garbage, abandoned objects and their type, equipment, furniture and missing or damaged items. Moreover, it will be possible to identify safety issues and count available seats and the total number of passengers [2]. The aggregated information will be transmitted to an operation centre and made available for managers in an "augmented intelligence" mode.

To ensure its success, it is essential to engage relevant stakeholders in the pilot, including: a) Public transport operator managers, who will provide access to their facilities and vehicles and drive the technical and non-technical requirements and needs; b) Public transport planners, who as end users will be enabled to produce more accurate knowledge-based optimisation of lines, frequency and service and c) citizens, who as end users (travellers and/or commuters), will contribute to defining the requirements and will benefit from a superior level of safety and security as well as an improved planning of public transport.

System Architecture and AI Solutions
The core of the system is based on a set of integrated video analytics services based on deep learning models for: a) image analysis and object detection; b) scene analysis and activity recognition from video chunks; c) privacy-preserving visual anonymisation/obfuscation tools. Such services will be deployed onboard edge nodes without video transfer to remote locations, thus reducing security and privacy risks (see Figure 1). Only aggregated and/or obfuscated data will be transmitted outside the edge nodes and conveyed to higher layers for data integration and cross-correlation. Data will be collected massively and prescreened with the already available algorithms. This will allow a refinement of the existing algorithms and, if relevant, the addition of new ones for behaviour characterisation (e.g. loitering detection), for responding to other safety concerns (e.g. fall detection) or for security (e.g. unattended luggage). Finally, a model for performing multi-camera cross-correlation of the data extracted from single video streams and characterising mobility patterns will be deployed. The learning paradigm used by the AI-enabled system includes supervised approaches for object detection (YOLO-like models), person and face recognition, person characterisation, fall detection and/or identification of unattended luggage. Unsupervised/supervised approaches will be deployed for the analysis of streams of events (textual data) in real time.

The pilot will be implemented on a large scale, encompassing various factors such as geographical coverage, transportation facilities and computational aspects. In particular, we plan to demonstrate the scalability and portability of AI-based distributed video analytics by augmenting physical nodes with a fraction of virtualised nodes, leveraging the AI@Edge infrastructure available at CNR-ISTI. First results are expected by October 2025.

Links:
[L1] https://kwz.me/hDE
[L2] https://www.precedenceresearch.com/artificial-intelligence-in-transportation-market
[L3] https://si.isti.cnr.it/index.php/hid-notcategorized-category-list/274-faith-eu

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Decentralised Material Recovery for a Sustainable Future

by Eleni Troulaki and Michail Maniadakis (FORTH-ICS)

The RECLAIM project, funded by the EU's Horizon Europe programme, seeks to develop innovative solutions in the waste management industry, targeting regions where access to material recovery facilities is less sustainable. By integrating cutting-edge AI, data, and robotic technologies, the project introduces the first portable and robotic Material Recovery Facility (prMRF) enabling the decentralised treatment of recyclable waste.

The recovery of recyclable materials is a key element of the Circular Economy and the European Green Deal. The EU is continually increasing its targets for the recycling of municipal waste, in order to reintegrate valuable waste materials back into the economy, safeguard the environment, and protect human health. By 2025, 55% of municipal waste and 65% of packaging waste must be re-used or recycled [1]. Recent advances in technology and robotic sorting systems make the achievement of these goals more attainable. Robotic waste sorters have gained popularity and are now being adopted by several Material Recovery Facilities (MRFs) that are typically located near urban areas, to carry out municipal waste treatment. Despite the high productivity of industrial robotic waste sorters, transportation of waste to these large plants is costly and makes material recovery difficult due to the compression of waste during transport.

To minimise transportation and treatment costs, RECLAIM develops the first portable robotic Material Recovery Facility (prMRF) that enables local-scale material recovery with industrial-level efficiency. The prMRF developed in RECLAIM is hosted in an ordinary container (Figure 1) that is fully equipped with recycling machinery, deep learning-powered computer vision and hyperspectral imaging for advanced and accurate waste categorisation. Additionally, a team of highly efficient Robotic Recycling Workers (RoReWos) is being used, which is equipped with a range of grippers, specialised for different material types. The idea is to use multiple cost-effective robots, each one handling a different sorting task, rather than relying on a single, high-cost robot to perform all tasks. This approach enhances the effectiveness of the overall system by allowing each robot to specialise in handling and sorting of certain categories of recyclables.

The solution developed in RECLAIM is highly appropriate to address the need for effective material recovery in various scenarios, such as small islands, seasonally operated touristic areas with limited access to waste collection and recycling facilities, and large event venues (like exhibition centres, stadiums and festivals) where tons of waste are produced in a short timeframe. RECLAIM demonstrates how innovative technology can be used to bridge the gap between waste production and resource recovery, transforming potential waste into valuable resources. The prMRF is not just a technological advancement; it is crucial for developing a global, leakage-free circular economy model that will be highly beneficial to the environment, and the society. By enabling on-site recycling in areas previously lacking material recovery services, RECLAIM's prMRF addresses immediate waste management challenges and supports the broader goal of a sustainable, circular economy.

Figure 1: Exterior view of the RECLAIM's portable robotic Material Recovery Facility (prMRF).

Moreover, the RECLAIM adopts a "Citizen Science" approach, encouraging participation from citizens of all ages, genders, and educational backgrounds in generating data for the advancement of waste management technologies. In particular, the Institute of Digital Games at the University of Malta (UoM), has designed and developed a novel Recycling Data Game (RDG), which enables citizens to participate in project activities by providing annotations to be used in deep learning for the re-training of the computer vision module. As a result, the RDG serves two main purposes: a) increasing awareness and social sensitivity about recycling and b) supporting the training and optimisation of AI algorithms to accomplish better results in identification, segmentation and categorisation of materials, which is crucial for the operation of the prMRF.

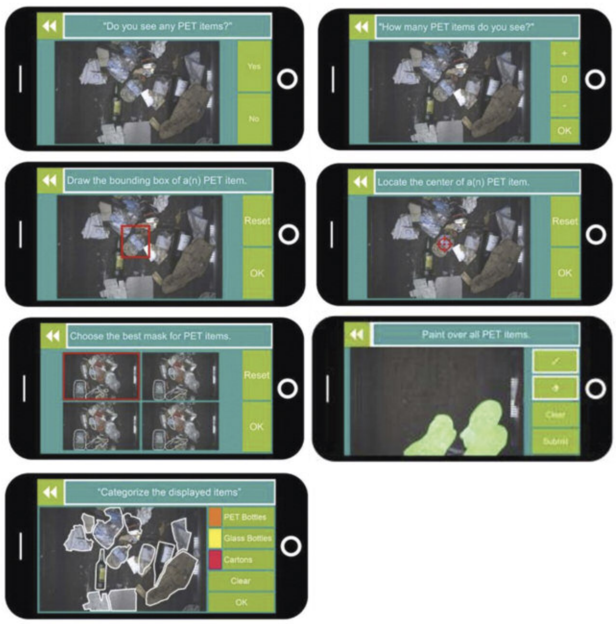

Figure 2: The seven mini-games that were developed by the University of Malta for the RECLAIM's Recycling Data Game (RDG).

The environmental game mentioned above includes seven different challenges (mini-games): "Paint", "Detect", "Count", "Outline", "Locate", "Choose" and "Categorise". Through these seven challenges the players of the game are being involved in data-annotation and reviewing activities on real-world images captured by cameras installed in the project's prMRF (Figure 2). The data collected by players/users are then used to train deep neural networks (DNNs) that identify and categorise recyclable materials, significantly enhancing the operation of the portable robotic material recovery unit.

RECLAIM is a three-year project (September 1st, 2022 – August 31st, 2025) coordinated by the Foundation for Research & Technology – Hellas (FORTH). The rest of the consortium consists of nine more partners: KU Leuven, ROBENSO – Robotic Environmental Solutions, HRRC – Hellenic Recovery Recycling Corporation, IRIS, AIMPLAS – Plastics Technology Centre, AXIA Innovation, UoM – L-Universita ta' Malta, ISWA – International Solid Waste Association and ION Ionian Islands Local Authorities.

Links:
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Beyond the Tech: Why Social Acceptance Matters for Smart Cities' Cybersecurity

by Lorena Volpini, Carmela Occhipinti (CyberEthics Lab.)

Imagine a busy city powered by cutting-edge technology driven by sustainability. But what if the focus on technology overlooks the human element? Technological advancements offer exciting possibilities for creating sustainable and efficient smart cities. However, focusing solely on technical solutions can overlook a crucial element: the human factor. Cybersecurity projects, essential for protecting these advancements, often prioritise technical-first approaches. This can create a blind spot, neglecting how society might perceive and react to these innovations. The Horizon 2020 project "IRIS – artificial Intelligence threat Reporting and Incident response System" [L1] recognises this challenge. It emphasises that robust cybersecurity goes beyond information security. It's also about building trust and fostering social acceptance for these technologies within smart cities.

As the smart city landscape expands to include more Internet of Things (IoT) and Artificial Intelligence (AI)-enabled platforms, the challenges associated with threat intelligence increase in both complexity and novelty. These include identifying attack vectors, responding effectively and facilitating the secure sharing of relevant data – all specific to these emerging technologies. To address these growing threats, the IRIS project envisions a centralised platform designed specifically for Computer Emergency Response Teams (CERTs) and Computer Security Incident Response Teams (CSIRTs). The IRIS platform is designed and developed to enable them to assess, detect and respond to threats and vulnerabilities targeting IoT and AI-driven ICT systems, while also facilitating information sharing. With the aim of strengthening European CERTs/CSIRTs capabilities, IRIS enables them to minimise the impact of cybersecurity and privacy risks in smart cities. To ensure the effectiveness of the IRIS platform, extensive demonstrations and validations have been conducted in highly realistic environments involving three European smart cities, Helsinki, Tallinn and Barcelona, their CERTs/CSIRTs and associated cybersecurity authorities. The IRIS project started in September 2021 and it is expected to be completed in August 2024.

By recognising the social implications of cybersecurity in smart cities, the IRIS project looks at two crucial dimensions. Firstly, it recognises that robust cybersecurity can actually unlock the potential of smart city services. By fostering trust and security, it becomes a hidden enabler of social acceptance of smart cities. Secondly, IRIS acknowledges that cybersecurity in smart cities is a double-edged sword. While it protects vital infrastructure, it also interacts with a public consciousness that is still incipient. Think of it this way: without a clear understanding of how these systems work and why, society might naturally mistrust the unfamiliar.

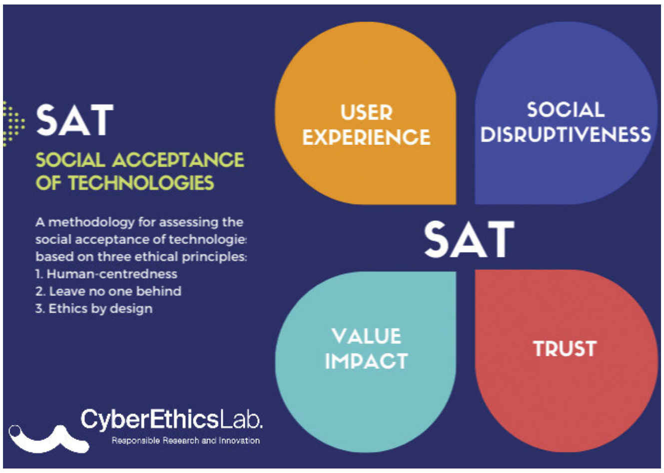

Figure 1:- Social Acceptance of Technology (SAT) assessment model.

Without careful planning, a lack of stakeholder engagement in the process may lead to dissatisfaction and resistance to innovation designed to improve city life. IRIS goes beyond simply securing smart city services and infrastructure; it seeks to reconcile security with the broader vision of a resilient, user-centred, cross-border cybersecurity system fully integrated to the urban future.

IRIS focuses on two key aspects of social acceptance of technology innovation in smart cities. Firstly, it considers how society might react to these innovations, and secondly, how organisations responsible for cybersecurity (like CERTs and CSIRTs) might adopt or reject them. While these aspects are connected, understanding the society's response can be tricky. Public reactions are complex and can't always be easily measured. This can be frustrating in research, where scientists often prefer clear-cut results. Social science research, which explores these nuanced reactions, can sometimes seem less useful because it doesn't provide simple answers.

To address these challenges, IRIS uses a special evaluation method called Social Acceptance of Technology (SAT) [1] developed by the R&D department of CyberEthics Lab. [L2]. SAT helps researchers assess acceptance in a way that works better with the research and development process. It does this by focusing on two things:

1. Four key factors that influence acceptance: These factors, displayed as four coloured "bubbles" in Figure 1, include user experience, social disruptiveness, value impact, and perceived trustworthiness. SAT recognises that these factors don't have simple cause-and-effect relationships, but they are significant since they all focus on the co-constitutive bond of the "society and technology" relation [2].
2. The specific context: SAT also considers the specific reasons why users and organisations might accept or reject a technology. This helps researchers understand the "why" behind the "yes" or "no".

While the main purpose of SAT in IRIS is to evaluate project demonstrations, it also helps improve the design of these innovations. On the one hand it urges designers and developers to think of the human factor in a novel way. IRIS Technology innovation was conceived and designed to be used by CERT and CSIRTs but, as a matter of fact, it is applied to smart transport and smart grid. SAT helps innovators to focus not just on intended end users, but also all those social actors involved in smart transport and energy distribution, who have interest in the innovation at hand or may be affected by it. By incorporating SAT testing early in the development process, innovations can be adapted to better align with people's values and expectations. This proactive approach can lead to more socially responsible and cost-effective solutions.

Ultimately, SAT aims to analyse the perceptions of various stakeholders. This allows researchers to infer how acceptable an IRIS solution might be overall. However, this "collective judgement" can change over time and across different regions. The good news is that by working together and discussing these findings, IRIS partners can use this feedback to guide further development. In the IRIS project, SAT proved to be a valuable tool for gathering feedback and building innovations that are both responsible and sustainable. It also helped to promote engagement and awareness among stakeholders.

"This document is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 101021727."

Links:
[L1] https://www.iris-h2020.eu/
[L2] https://cyberethicslab.com/en/

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Human Control in Green Smart Homes

by Simone Gallo, Sara Maenza, Andrea Mattioli, and Fabio Paternò (CNR–ISTI)

We present an approach to supporting human control in green smart homes. The approach is based on a set of tools for allowing end users to create automations through innovative interaction modalities, execute them, and receive relevant explanations about the resulting behaviours and their relevance for the user goals, in particular those that are connected to sustainability principles.

The increasing availability of sensors, connected objects and intelligent services has made it possible to obtain smart homes able to support automations involving the dynamic composition of objects, services and devices. Since each household has specific needs and preferences that can also vary over time, it is crucial to empower its users to directly control such automations, even when people have no programming experience.

Automations can support goals aligned with circular economy principles, like energy saving and waste recycling. We have designed and prototyped various tools that can be deployed in real-home environments. These tools include meta-design tools for creating and controlling home automations, innovative control methods using conversational agents and augmented reality, and tools for simulations and "what if" analyses to evaluate potential impacts on aspects relevant to the circular economy.

We have also developed AI-based techniques that can be used to suggest recommendations to users by indicating elements judged appropriate in specific situations to complete the automations being created.

Specific techniques have also been developed to highlight potential errors detected while users specify rules or issues existing in their current rule sets (e.g. conflicts between rules): in particular, clear and understandable explanations are provided to users, describing the problem and why a specific modification would be needed to resolve it.

The Approach

Smart homes feature connected objects and sensors coordinated through automations. Users typically configure these automations using trigger-action programming (TAP), which follows an "if/when...then" structure. Despite this, users often find it challenging to understand and manage the behaviour of these environments, particularly when multiple automations are active simultaneously.

We propose a novel solution, ExplainTAP, whose objective is to support users in detecting and understanding possible problems between TAP rules, such as conflicts and unexpected direct and indirect rule activations. ExplainTAP provides users with a tool to simulate and analyse the context in which rules could activate, and with explanations to make the behaviour of the smart space more transparent [2]. It also considers the possible long-term user goals, identifies inconsistencies between automations and these goals, and proposes improvements for the automations. This tool is also integrated into a larger platform, including a digital twin for allowing users to view and monitor the home's energy consumption in real-time [1].

ExplainTAP is connected with Home Assistant (see Figure 1), which is the most widely used open-source tool for managing automations, involving a rich and active community of amateurs [3]. In this way, ExplainTAP can receive real-time information on the state of the environment and of the automations currently active in it.

The ExplainTAP Rule Analysis backend exposes features to make the automated environment more transparent to the user:
- Rule Context Simulator: It builds a logical organisation of the contextual aspects of the spaces where the platform is deployed (i.e. which objects in which room, the services they expose, and the values of environmental variables such as temperature, humidity or air quality). Then, it checks which triggers are satisfied by the specified context data (detected or inserted by the user).
- Direct/indirect Rule Chain Detection: Starting from the trigger's activation, it checks whether these changes lead to new activations. Another function monitors whether the activation of a rule may indirectly cause another one to activate, exploiting the semantic definitions module. For instance, a rule to automate the air circulation in the house may unexpectedly activate another rule that starts the heating when the temperature is under a value, leading to energy waste.
- Why/Why Not Analysis: It stores the triggers that verify or do not verify in the context, and the specific pieces of con-

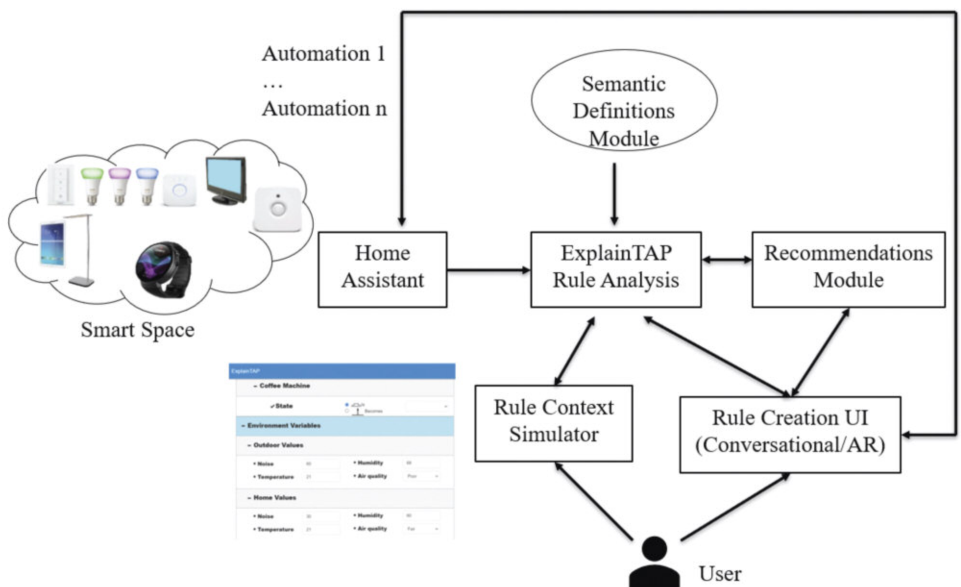

Figure 1: The proposed platform.

text that lead to the activations/not activations, also generating a corresponding textual explanation.
- Conflict Analysis: It detects rules whose actions operate on the same object or whether there is a containment relation between the objects in the rules, detects whether the action's values are incompatible, and detects periods when both can be activated at the same time, in this case notifying the user.
- Goal-Based Rule Analysis: It inspects the automations and detects whether they can conflict with the user-selected goal. It also provides suggestions for modifying the automations according to these goals. For instance, if the energy-saving goal is selected, ExplainTAP can suggest an alternative action for an automation with the same effect but with less impact on energy consumption.

The Goal-Based Rule Analysis relies on the semantic definitions module, the current indoor and outdoor environmental values retrieved from Home Assistant (which can be modified by the user to simulate specific situations), and user preferences.

The semantic definitions module contains information about the objects that can act on the environment commonly found in smart home installations. For each object, this information includes: which triggers it can activate, with a description of the reason; a list of goals on which a specific state of the object can have a positive or negative effect, including the reasons; the list of the variables that it can increase/decrease when a specific state of the object is active, with associated the level of confidence for such prediction.

The recommendations module aims to make the creation of automations easier through suggestions that take into account the users' preferences, the automations they have already made, and the partial rule they are currently entering. This module is also connected with the Rule Analysis backend. In this way, recommendations that conflict with user goals are discarded, and the user is warned if these may cause conflicts with the already created automations.

Links:
[L1]: https://hiis.isti.cnr.it/lab/home
[L2]: https://hiis.isti.cnr.it/eud4gsh/index.html

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Sustainability and Human-Computer Interactions: Challenges for Future Research

by Lou Schwartz, Valérie Maquil, and Mohamed Saifeddine Hadj Sassi (Luxembourg Institute of Science and Technology)

The climate crisis demands the design of IT tools that address environmental concerns. But how to achieve this? We deployed three different approaches to find answers, identifying key challenges for future research in human-computer interaction.

In a situation of climate emergency with increasing pollution and waste, computer science researchers must question the impact of their research on sustainability and focus on how to design for the future. As highlighted by Norman [1], Humanity-Centred Design (HyCD) is a method for shaping sustainable futures, placing humanity at the forefront rather than focusing on individual needs. HyCD operates at the intersection of the environmental impact, the responsibility and ethics of the technology and the social impact and equity. This balance aims for fairness, supports those in need, and firmly opposes unethical practices like child labour. The five principles of HyCD are:
1. Solve the core root issues (i.e. the cause, not the symptoms).
2. Focus on the entire ecosystem of people (including all living things and the physical environment).
3. Take a long-term systems point of view.
4. Continually test and refine.
5. Design with the community and by the community.

However, it is not yet clear how a HyCD approach can be implemented in research for computer science and interactions.

A first good practice in HyCD is to look for workarounds already used by people and transform them into a sustainable product or a service with the objective of reducing users' time, effort, research, and cost (e.g. How do people manage without packaging? How do people get to a place without a car?) [2].

An example of such a workaround is the use of video conferencing tools to avoid the need of travelling and the related impact on the environment. Experts that make essential decisions today, often rely on large interactive displays to present data in different scales and views and discuss them jointly in meetings. When meeting remotely and using video conferencing tools, they lose the overview of the data as well as the advantage to work in a collocated workspace where they can rely on non-verbal communication (i.e. gaze, gestures, body position, etc.) to make their intentions clear. Based on this workaround and their current practices, we developed an advanced video conferencing system that, in addition to a normal video connection, tracks and displays natural hand gestures (mid-air pointing, agree and disagree, and hand-raise gestures), touching and attention direction to allow a smoother and enhanced collaboration over distance on large interactive displays [L1],

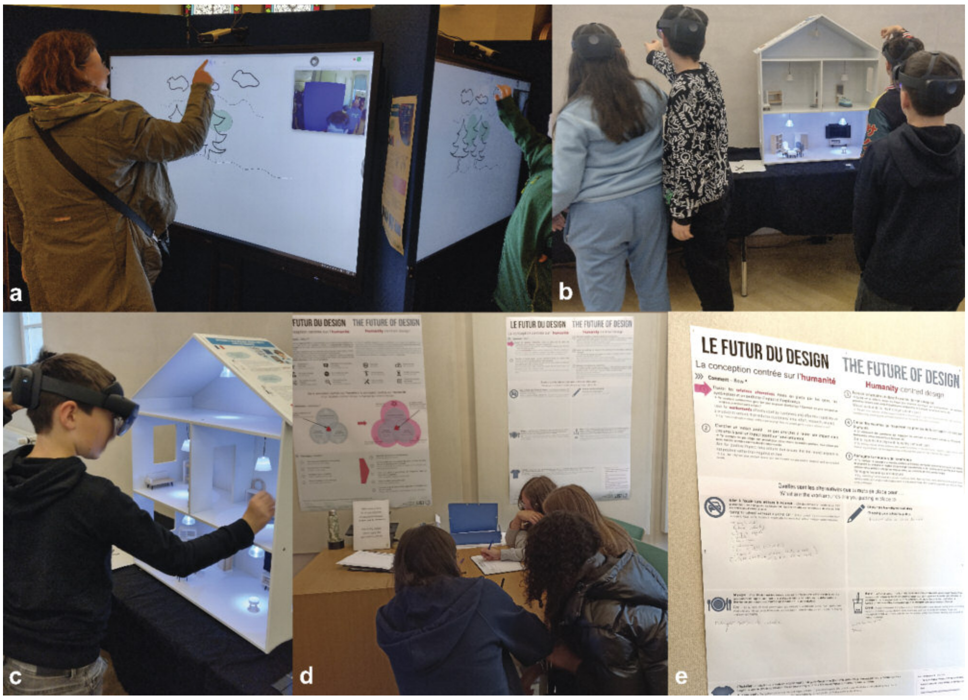

Figure 1: Humanity-centred-design approach implemented: a) advanced video conferencing system on large interactive displays; b) and c) eco-feedback technology using augmented reality; d) and e) activities to find workarounds with children.

as shown in Figure 1(a). This system also enables indication of the authorship of each recognised action.

But how to identify interesting workarounds? The main advice given by HyCD experts is to design with and/or by the communities of end users. In this way, we engaged children (8–15 years old) in activities to find workarounds for the need to receive education at school and to travel there by car, as seen in Figure 1(d) and Figure 1(e). Each workaround was then discussed to identify improvements that will facilitate easier adoption. The objective is twofold in this kind of activity. On the one hand, it enables collection of workarounds and maybe finding new ideas for a future more sustainable service or product. On the other hand, pupils were pushed to think about their own impact on the environment. The mentioned workarounds include home schooling and alternative transportation methods to get to school (e.g. on foot, by bike, by scooter, by e-scooter or by e-car). We observed that the notion of workaround is not obvious.

Enabling all citizens to think about their own impact, possible solutions and how they could apply them in their daily lives is a major lever of change. To enable citizens to think about their impact, an Eco-Feedback Technology (EFT) can be used. An EFT "provides feedback on individual or group behaviours with a goal of reducing environmental impact" [3]. We developed an EFT that gives feedback to participants about the impact of their daily decisions about food shopping at the supermarket (e.g. it is preferrable to avoid industrial food products and meat), or the equipment of a house (e.g. a shower is better than a bathtub, it is preferable to add solar panels), as seen in Figure 1(b) and Figure 1(c). We used augmented reality (AR) as it allows testing different behaviours and solutions without impacting the real world. This application was showcased at a public science fair, demonstrating practical applications of AR in environmental education.

Through our research we identified the following challenges for the design of sustainable human-computer interactions:

1. How can workarounds be identified and used as a basis for future research and solutions?
2. When a new technological solution is designed, what methods and measurement scales can be employed to evaluate its impact and ensure that it improved on or was at least in alignment with the principles of HyCD? [2]
3. How to enable citizens to better understand the situation and their impacts on each decision? [1]

Link:
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Decision Support System for Inclusive Smart City Design: Baby Boomers as a Use Case

by Rasha Abu Qasem (Fraunhofer Institute for Experimental Software Engineering IESE) and Nils Hausbrandt (Rhineland-Palatinate Technical University of Kaiserslautern-Landau)

Decision Support Systems (DSS) have been used for several city planning activities. In this article, we show how DSS can also be used to emphasise inclusiveness in smart city design by assuring the accessibility of services to all citizens, especially vulnerable ones.

Urban and regional planning is a complex procedure. It incorporates multiple regulations alongside many social, environmental and economic factors. This can lead to undesired neglect of some groups of people like people with disabilities or elderly generations, and withdrawal of their needs while planning spaces. Today with the advancement in Information Technology and the shift towards smart cities, this procedure can be made easier by adapting solutions such as DSS. A DSS helps city planners understand the implications of their plans from multiple perspectives and can support them in designing inclusive cities for diverse groups of people.

In our research project "Ageing Smart – Smart structured areas", funded by the Carl Zeiss Foundation, we investigate the best ways to design and implement a DSS that supports inclusive city design. Our consortium contains a collection of interdisciplinary chairs at the Rhineland-Palatinate Technical University of Kaiserslautern-Landau (RPTU) and two German research institutes: Fraunhofer Institute for Experimental Software Engineering (IESE) and the German Institute for Artificial Intelligence (DFKI).

Inclusive city design is commonly defined in terms of the UNDP Human Development Index [1], which is derived from three factors: economic status, access to and status of education, and access to and status of health. We focus our work on the improvement of inclusiveness in city planning by enhancing accessibility for the city's services and facilities while considering the spatial mobility of groups that previously did not have access to certain services. As a use case, we study the baby boomer sector in Germany, and we show how to incorporate their current and future mobility needs into the city plans with the help of DSS.

The German baby boomer cohort of the birth years 1955 to 1969 forms 25% of the current population and many of them are in the process of settling into retirement. This will create a high need for many services, especially medical ones. In Germany, there is already a problem in the distribution of General Practitioners (GPs), which are the first point of contact for patients, with an evident lack of them in rural and subrural areas. Another problem is that many of the doctors today belong to the baby boomer generation themselves. That will lead to a wave of medical care demands that we need to address in the current city plans.

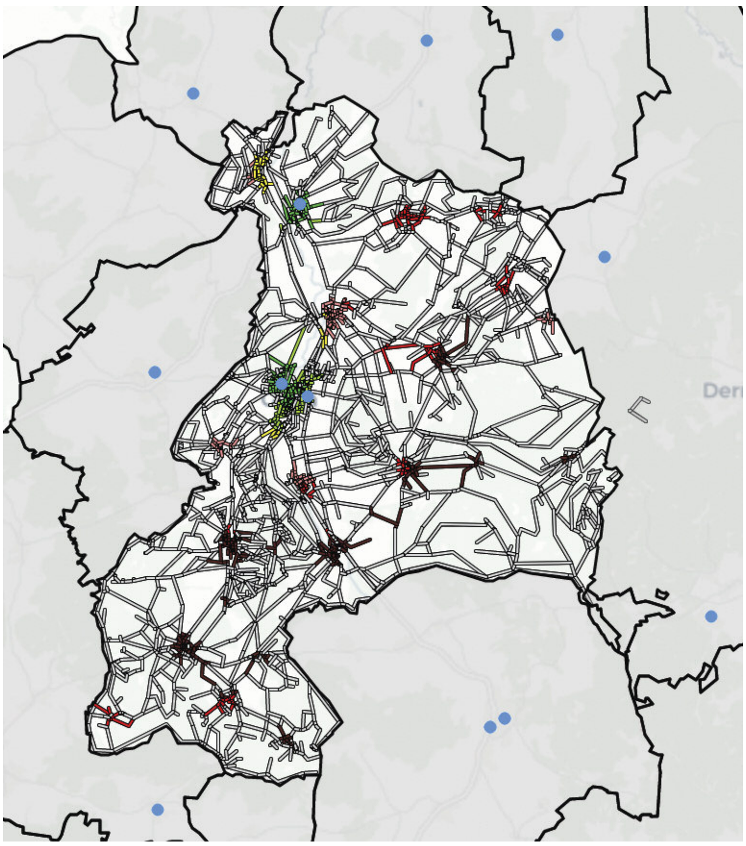

Figure 1: Reachability heat map, which colours each populated area of the city in terms of its distance (on foot and by public transport) to the nearest GP (blue markers). For a distance of less than 15 (15–30, 30–45, 45–60, 60–90, ≥90) minutes to the nearest GP, the areas are coloured green (light green, yellow, pink, red, brown).

To better understand the current and foreseen requirements of the different citizen sectors, especially the baby boomers, we have conducted multiple workshops with city officials and planners. The workshops were designed to grasp the status quo of the baby boomers' behaviours with a particular focus on their mobility requirements. Based on that, we designed the baby boomers' mobility profiles, which provide a quantification of their actions according to the mobility means, i.e. by foot, by car, or via public transportation. The profiles are the input for the analysis model, which is the basic component of the DSS.

The analysis model consists of a reachability analysis model and a location optimisation model. The reachability model offers an intuitive analysis tool that shows the accessibility of services for baby boomers within the city. In our example, we focus on the accessibility of GPs, dental, and general specialist practices as well as hospitals and pharmacies in and from the individual local communities. The reachability modelling enables the decision-makers to assess how resilient the current situation for baby boomers is and to identify the future under-supplied areas. The DSS can thus show the impact of the opening or closing of a GP practice on the accessibility factor or even the impact of relocation or establishment of a new bus route on medical care coverage. The location optimisation model allows the determination of the optimal location for the construction of new neighbourhoods, new clinics, or even new bus stops.

The computations of the analysis model are based on the mathematical theory of intermodal route planning [2] and thus allow reasonable combinations of different means of transport along a route. The user of the DSS can set many parameters such as walking times, public transport transfer times, or the time at which the analyses are carried out. Figure 1 shows a reachability heat map of the GPs in the city of Kusel – a rural German city – at 10.00am, considering the official bus timetable, where travelling is only allowed on foot or by bus, but not by car. The red zones show the places where the baby boomers have problems reaching the needed medical services.

We have seen how the basic analysis core of the DSS enables the comparative analysis of different settings and gives the decision-makers a clear understanding of different scenarios at current times and in the future. It also allows them to recognise the impact of their decisions on the baby boomers' medical care needs and coverage. In other words, the DSS facilitates the inclusiveness of baby boomers in future city plans because of the comprehensive user profile that reflects their behaviours. Building more user profiles for diverse sectors of citizens and highlighting their needs will reinforce the creation of an inclusive smart city that accommodates everyone.

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Technology in Communal Spaces for Social Sustainability

by Gul Sher Ali and Sobah Abbas Petersen (Norwegian University of Science and Technology, Norway)

Early-stage doctoral students are often vulnerable to feelings of isolation. This research explored the integration of Information and Communication Technologies (ICT) for enhancing social sustainability. The findings of a case study demonstrated how technology-based social infrastructures within academic communal spaces could mitigate isolation among students by fostering community engagement. The research is done as part of the SWELL project (at NTNU, Norway) which aims for sustainable health and wellbeing in the built environments through innovative solutions.

The rising mental health issues among students pose a significant challenge for the higher education sector [1]. The wellbeing of doctoral students is particularly affected by various stressors, but the lack of social connectedness due to the solitary nature of their work is a substantial factor. Social connectedness encompasses the feeling of forming close bonds with individuals or groups. It is a multi-dimensional concept that includes the sense of community belonging, social appraisal (how one interprets others' behaviours), and relationship salience (the experience of connectedness despite physical absence) [2]. These are also common issues that research on sustainable communities and urban spaces addresses. Therefore, this research offers valuable insights into how technology could be integrated into communal spaces to supplement existing social practices such as socialising and sharing. The research expands the social connectedness framework (see Figure 1) by incorporating communal technologies into academic settings. This integration not only improves social connectedness, but also aligns with educational sustainability by facilitating continuous learning and interaction among students, which is crucial for fostering informed, engaged, and resilient urban communities. Additionally, the study highlights the importance of addressing privacy concerns and finding a balance between digital and physical interactions.

This case study is conducted as a part of the SWELL project [L1]. The project aims at studying health and wellbeing in the built environment, with a specific focus on the transformative role of ICT in fostering community and enhancing social sustainability. The objective is to understand how ICT can foster behavioural changes conducive to social sustainability in the built environment and to design ICT artefacts that support such behaviour change. The findings of this study provide insights for urban policymakers and technology developers interested in creating sustainable, inclusive, and supportive urban environments.

In this case study, we conducted semi-structured interviews with seven early-stage international doctoral students (at NTNU, Norway). These individuals were selected as they were in a transitional phase that impacts their social connectedness. The interviews were complemented using brochures of

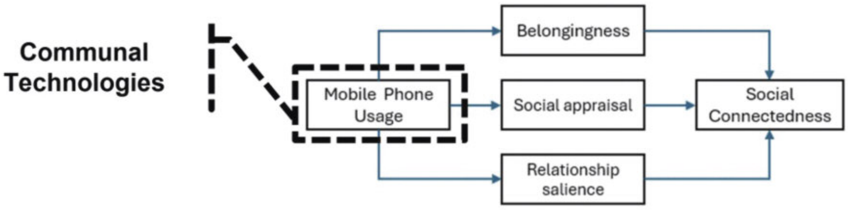

Figure 1: Enriched social connectedness framework, adopted from [2].

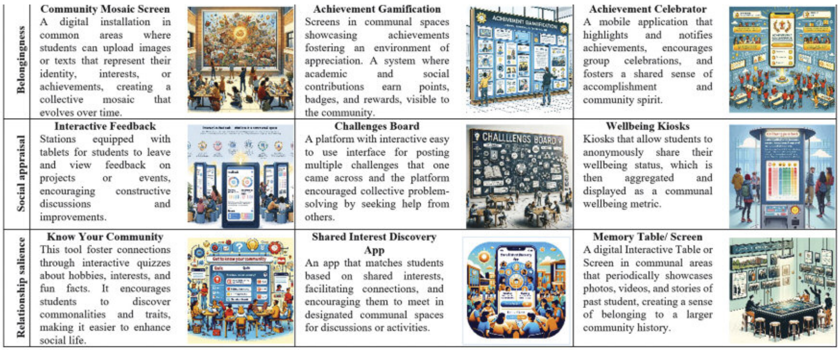

Figure 2: Brochures of questionable concepts (the images created by Dall-E based on given description).

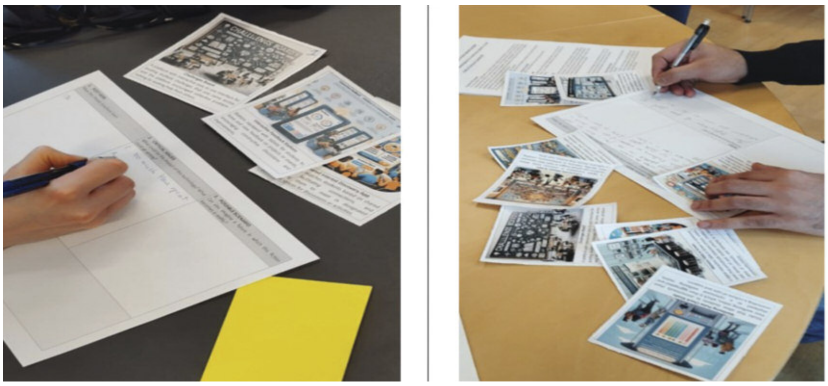

Figure 3: Interview session and worksheet instrument used to gather data.

questionable concepts [3] depicting fictional technologies. The questionable concepts were designed to provoke thought and discussion about possible ICT implementations in communal spaces. These speculative technological concepts (see Figures 2 and 3) aimed at fostering each dimension of social connectedness – belongingness, social appraisal, and relationship salience. For instance: communal digital noticeboards for sharing academic achievements and personal milestones, interactive mosaic screens that display ongoing community activities, and mobile apps designed to celebrate personal and communal achievements. Such technologies are envisioned to create a lively and interactive communal space that encourages students to engage more deeply with their academic community.

The analysis revealed significant insights on the integration of ICT that could transform communal spaces into hubs of social activity. The students expressed a strong preference for technologies that facilitate real-time social interactions over those that offer only digital communication. For instance, one student highlighted the potential of a communal mosaic screen to not only display information but also to invite others to meet in person based on shared interests. Technologies that provide a balance between digital interaction and personal privacy were particularly favoured by the students. The achievement celebration app, which allows students to opt in or out depending on their comfort with public accolades, was noted for its ability to foster a sense of community while respecting individual privacy preferences. The visibility of shared interests and the recognition of individual and group achievements through communal technologies plays a crucial role in turning solitary routines into collaborative and interactive experiences. These interactions are not only vital for social wellbeing but also for academic success, as they provide platforms for feedback, collaboration, and professional growth. Additionally, employing ICT in this manner showcases a practical application of urban data analytics and enhanced our understanding of digital infrastructure that can support sustainable cities.

A recurring theme throughout the interviews was the concern over privacy. The design of communal technologies, therefore, must prioritise privacy to prevent potential overexposure that could deter their use. Moreover, while digital technologies are beneficial, our findings emphasise the importance of their role in facilitating rather than replacing face-to-face interactions. The technology should be seen as a bridge to physical community building rather than diminishing the richness of direct social interactions. This research provides valuable inputs to develop a roadmap for educational and urban policymakers and technology developers looking to enhance communal spaces with ICT, ultimately contributing to the social sustainability within smart urban environments.

Link:
[L1] https://www.ntnu.edu/sustainability/swell

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ELABORATOR’s Citizen-centric and Data-driven Approach Towards Sustainable, Safe and Inclusive Urban Design and Mobility

by Jason Sioutis (ICCS), Anna Antonakopoulou, Vasileios Sourlas and Angelos Amditis (ICCS)

Discover how the ELABORATOR project [L1] is transforming urban mobility across Europe with sustainable, inclusive, and innovative solutions. Supported by Horizon Europe, this initiative unites cities, researchers, and industry leaders to develop efficient transportation networks and climate-neutral urban environments. Learn more about their groundbreaking work and future plans to revolutionise urban living.

Urban mobility is undergoing a profound transformation, thanks to the ELABORATOR project. Funded by Horizon Europe, this initiative is dedicated to creating sustainable, climate-neutral cities by fostering innovative, inclusive and efficient transportation solutions. ELABORATOR’s multifaceted approach brings together diverse stakeholders from various sectors, setting the stage for a revolution in urban mobility across Europe.

Vision and Objectives

ELABORATOR is a cornerstone of the European Green Deal, aiming to drastically reduce urban carbon emissions and promote sustainable living. The project’s vision encompasses developing comprehensive mobility solutions that address the unique challenges of urban environments. These solutions aim to integrate advanced technologies and sustainable practices to create efficient, green transportation networks.

Key objectives of ELABORATOR include:

1. Enhancing Mobility Solutions: The project focuses on developing innovative, user-friendly transportation options that reduce dependence on private vehicles, thereby cutting emissions and alleviating traffic congestion.
2. Promoting Inclusivity: Ensuring mobility solutions are accessible to all demographics, including the elderly, people with disabilities, and economically disadvantaged groups, is a priority. Inclusive design ensures that everyone can benefit from improved urban mobility.
3. Fostering Collaboration: By encouraging partnerships across sectors, ELABORATOR leverages diverse expertise and resources to accelerate the development and deployment of sustainable mobility technologies.
4. Supporting Policy Development: The project provides data-driven insights to inform urban mobility policies, aligning them with sustainability goals and ensuring effective implementation.

Living Labs and Pilot Projects

A core feature of ELABORATOR is the establishment of Living Labs in six Lighthouse cities and six Follower cities across Europe. These cities, including Milan, Lund, and Velenje, serve as experimental grounds where innovative mobility solutions are demonstrated, evaluated and refined. The Living Labs facilitate the transfer of knowledge and successful practices, making it easier to scale solutions across different urban contexts.

Figure 1: Helsinki, Finland is among the six Lighthouse cities that will pilot key interventions.

Among the pilot projects are initiatives focused on:

- Electric Vehicle Integration: Cities are testing the integration of electric vehicles (EVs) into their transportation networks, including the development of EV charging infrastructure and incentives for EV adoption.
- Bike-Sharing Schemes: Developing and promoting bike-sharing programmes that provide affordable and eco-friendly transportation alternatives for urban residents.
- Pedestrian-Friendly Urban Areas: Redesigning city spaces to be more pedestrian-friendly, which includes expanding sidewalks, creating pedestrian zones, and improving public transit connectivity.

Community Engagement

Engaging local communities is vital for the success of ELABORATOR. The project actively involves citizens in the planning and implementation processes to ensure that the mobility solutions developed meet the actual needs and preferences of the urban population. This engagement not only enhances the relevance and effectiveness of the solutions but also fosters a sense of ownership and commitment among residents.

Knowledge Hub

To support the dissemination and replication of successful mobility solutions, ELABORATOR has established a comprehensive Knowledge Hub. This hub consolidates research findings, best practices, and policy recommendations, making them accessible to stakeholders across Europe. The Knowledge Hub serves as a valuable resource for cities looking to adopt and adapt innovative mobility solutions, facilitating widespread adoption and scalability.

Impact and Future Prospects

ELABORATOR’s impact is already visible in the participating cities, where significant advancements in sustainable urban mobility are taking shape. For instance, Milan has imple-

Figure 2: Lund, Sweden is one of the six Followers cities that will learn and exchange with the Lighthouse cities to plan and implement their own sustainable solutions.

mented inclusive mobility pilots that enhance accessibility for all citizens, while Lund focuses on integrating smart transportation systems to streamline urban mobility.

The future prospects for ELABORATOR are promising. The project aims to expand its network of cities and stakeholders, fostering a Europe-wide movement towards sustainable urban mobility. By maintaining its emphasis on collaboration, innovation, and inclusivity, ELABORATOR is well-positioned to continue driving the transition to climate-neutral urban environments.

The ELABORATOR project stands as a testament to the European Union's commitment to sustainable development and innovation. By bringing together a diverse array of stakeholders and focusing on practical, scalable solutions, ELABORATOR is paving the way for a future where urban mobility is efficient, inclusive and environmentally friendly. As the project continues to evolve, its contributions will be instrumental in shaping sustainable cities across Europe, making a significant impact on both the environment and the quality of urban life.

Link:
[L1] https://www.elaborator-project.eu/

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Socio-technical Process Modelling to Foster Sustainable Digitalisation of Rural Areas

by Chiara Mannari, Alessio Ferrari, and Manlio Bacco (CNR-ISTI)

The adoption of digital technologies in rural areas holds promising potential in terms of economic, productive and environmental benefits, in line with the United Nations (UN) Sustainable Development Goals (SDGs). However, digitalisation is a socio-technical process presenting challenges at multiple levels. Socio-technical process modelling supports interdisciplinary teams in the early evaluation of the impacts of digitalisation in real contexts by performing representations of business processes transformed after the introduction of digital solutions.

The adoption of digital technologies in rural areas has raised significant attention in recent years. Historically, technological innovations in agriculture and rural areas in general have led to substantial economic, social and environmental transformations. Nowadays, Internet of Things (IoT) components allow the development of sophisticated applications, Artificial Intelligence (AI) can contribute to automating manual tasks, and 5G networking, handheld devices and edge computing can make the technology more user-friendly, accessible and affordable to users, in line with the UN SDGs.

However, the transition towards smart rural areas is a socio-technical process of digitalisation presenting challenges with double-edged effects and generating potential winners and losers. To minimise the risk of undesired consequences, it is becoming increasingly important to support early evaluation of the impacts of digitalisation by performing analysis from multiple perspectives, including social and economic [1].

In such a context, Socio-technical Process Modelling (STPM) can support multiple stakeholders and interdisciplinary research teams in the analysis of digitalisation by providing easy-to-read graphical representations of the transformation of business processes after the introduction of digital technologies.

The STPM method is being developed by a research team at the Institute of Information Science and Technologies "A. Faedo" (ISTI) of CNR in the context of the Horizon Europe project "CODECS: Maximizing the co-benefits of agricultural digitalisation through conducive digital ecosystems" (2022-2026) coordinated by the University of Pisa [L1].

The method is based on the application of Model-driven Requirements Engineering techniques (MoDRE) leveraging different diagrammatic notations to model the process-as-is and the process-to-be in the context of the transformation of business agricultural processes after the introduction of digital technology.

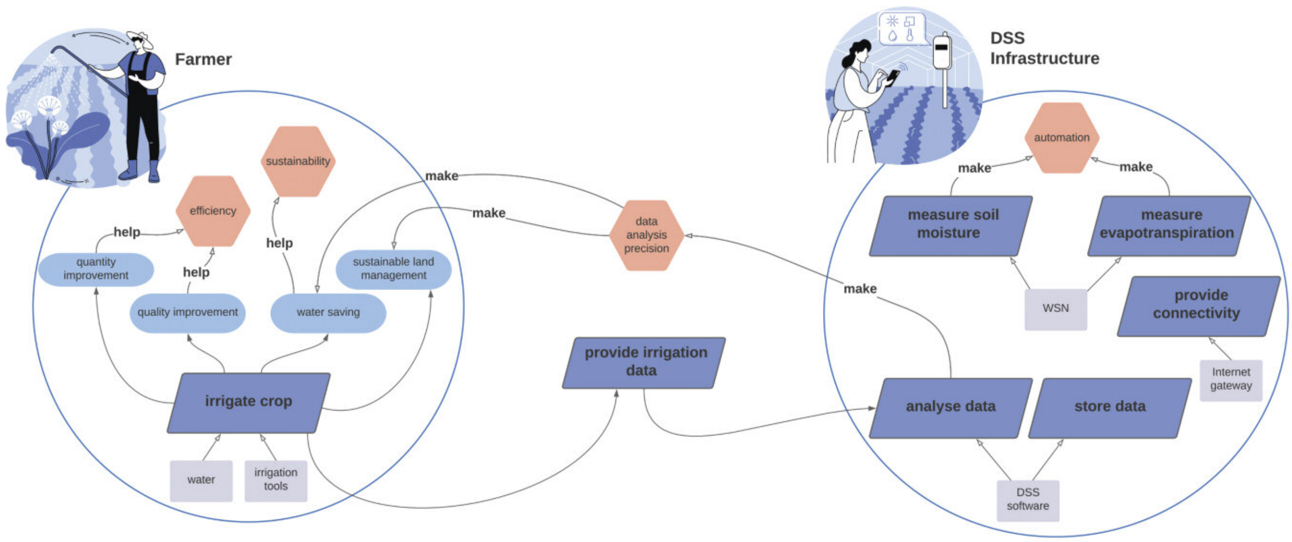

Figure 1: iStar goal diagram representing the actors' goals towards the process.

To ensure completeness, the representation of a process transformation focuses on complementary dimensions corresponding to three types of models, i.e. structure, goal and process. These models are developed using different formal notations:
1. Structure: the UML class diagram provides an overview of the process structure extending to the system in which the process is being applied. This model includes actors, resources, tools, and infrastructure involved in the process-to-be and their relationships.
2. Goal: the iStar diagram models the actors, goals and activities of the process-to-be focusing on the intentional, social and strategic dimensions (Figure 1).
3. Process: the BPMN diagram represents the detailed flow of the process, including actors' tasks, procedures and communications. For this type of model, multiple diagrams are developed to represent both the process-as-is and the process-to-be. Furthermore, an overlapping visualisation

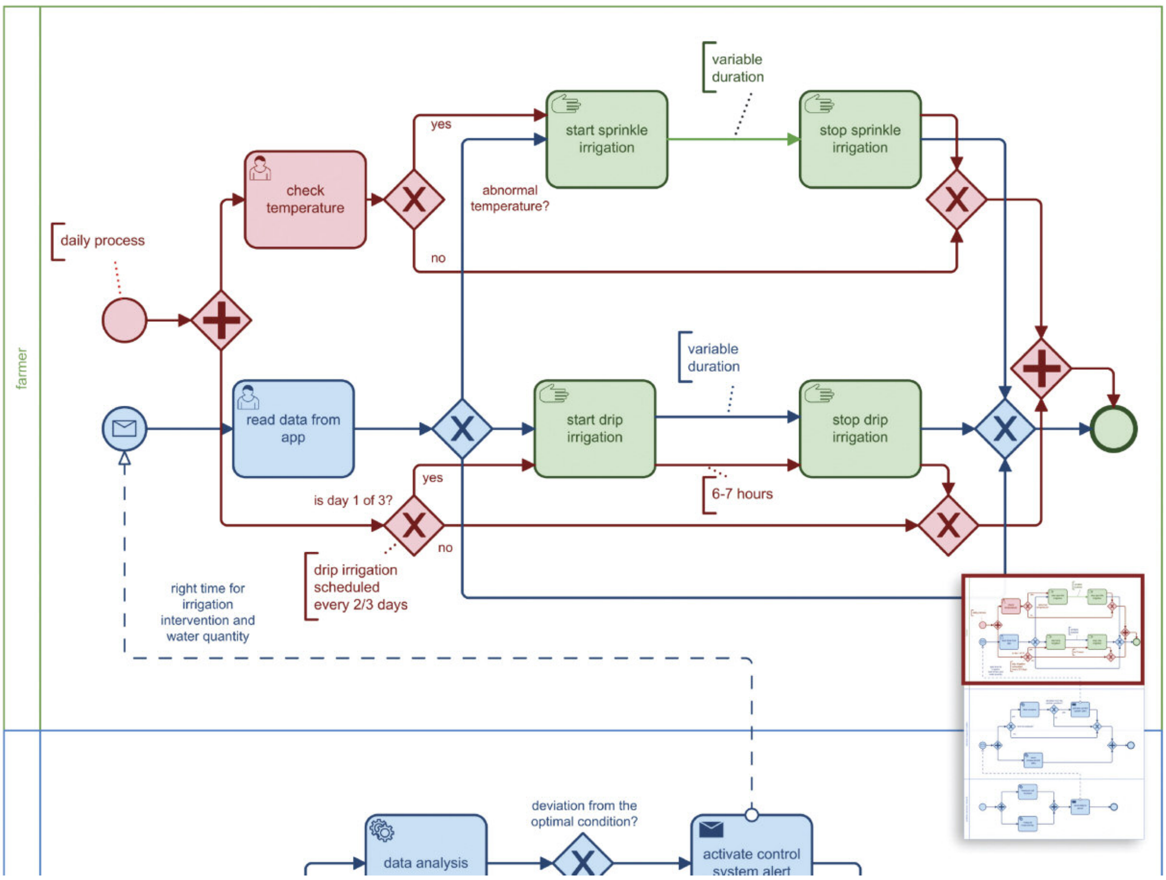

Figure 2: Magnified version of the smaller preview (bottom right) of an overlap of two BPMN diagrams representing the process transformation. The new participants, activities and gateways introduced by technology are in blue; in green the activities and gateways that do not change; in red the activities and gateways that are not present anymore.

allows comparisons between the process-as-is and the process-to-be (Figure 2).

The formal representations resulting from the STPM method constitute an insight into understanding the process transformation and design material for further development.

As part of the project activities, the method is being applied to 20 European Living Labs that are part of the CODECS Consortium. Living Labs are communities of local practices, including farmers, knowledge intermediaries, stakeholders, and policymakers carrying out co-design activities to address emerging challenges. In these collaborative environments, the discussion of environmental sustainability coupled with the challenge of digital transformation has promising potential in the design and evaluation of services that meet users' and societal needs. An inventory of the most widespread technologies for agriculture can be extracted from the use cases from the CODECS Living Labs. A consistent part of the digital solutions under evaluation is related to precision agriculture systems. These can include IoT components and machine learning models at different levels of technological maturity and integration in context. Figures 1 and 2 illustrate a case study of an irrigation process transformed after the introduction of a precision irrigation system. To support the analysis of the process re-engineering impacts, the STPM method is applied in different situations and for multiple purposes through a collaborative procedure for data collection and graphical modelling.

In the context of CODECS, the modelling activity is performed pursuing the following objectives: support information exchange between stakeholders; understand how current processes are re-engineered; drive further analysis, e.g. cost-benefits analysis; elicit requirements for human-centric digital solutions.

The overall objective of the method is to include domain experts and practitioners both in the evaluation of available solutions and in the design and development of new digital technologies for agriculture following a human-centric approach.

This work has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101060179.

Links:
[L1] https://www.horizoncodecs.eu

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Multidomain Digital Twin Platform for Decision Makers

by Paolo Nesi, Pierfrancesco Bellini and Marco Fanfani (UNIFI, DINFO, DISIT lab, Snap4City)

Snap4City is a digital twin platform for decision makers to operate and plan city activities, using contextual and historical data to support planning and generate problem-solving suggestions. The platform integrates ML/AI analytics, providing seamless suggestions and XAI annotations for decision makers. Recently, interactive 3D digital twin models have been provided for real-time simulation of changes and their effects on KPIs like decongestion and emissions.

Snap4City [L1] is a digital twin platform [L2] designed for decision makers to perform activities of operation and planning in the cities and control rooms. Operation means at least to monitor, control, predict and react in real time to current operational conditions and related events. For this purpose, data are collected and processed and early warning is computed by using a range of data analytics and AI processes. Planning means to assess the city's condition in terms of contextual and historical data, the desiderata/objectives and goals / key performance indicators to provide support in planning, generating suggestions, solutions to the problems, etc. The operation is always to be performed in real time or quasi real time, while the plan may take time. Recently, what-if analysis and optimisation tools, typically applied in plan are also used in operation for fast reaction to critical conditions, and the time to plan has been considerably shortened. Snap4City provides an integrated solution for data gathering, indexing, computing, and information distribution, thus realising a continuously updated digital twin of the urban environment at global and local scales for monitoring operation and planning. It addresses 3D building models, road networks, Internet of Things entities, points of interest, paths, as well as results from analytical processes for traffic density reconstruction, pollutant dispersion, predictions, and what-if analysis for assessing impact of changes, all integrated into a freely accessible interactive 3D web interface, enabling stakeholder and citizen participation in city decision processes.

The architecture of Snap4City is shown in Figure 1. The multidomain platform allows collecting and automatically processing and representing complex data of several different kinds. For example, traffic flows which are graphs changing over time, origin destination matrices which are maps/graphs changing over time, time series, heatmaps, trajectories and routings, scenarios to be assessed, events and intervention of restoring in the city, etc. The more relevant domains that are presently strongly interconnected are: mobility and transport, environmental, and energy.

Snap4City is an open-source IoT platform coordinated by the DISIT Lab of the University of Florence [L4]. Snap4City is an official FIWARE (an open-source initiative that provides a universal set of APIs that allow the development of smart applications in multiple sectors) and EOSC (European Open

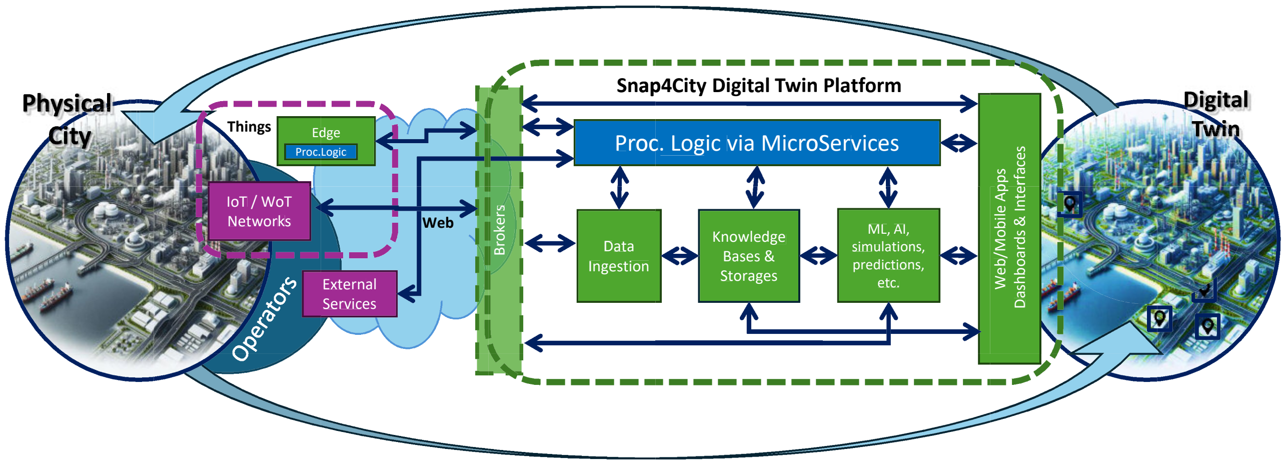

Figure 1: Snap4City digital twin conceptual architecture.

Science Cloud) platform and it includes a set of Node-RED libraries. It is at present in operational use on several federated installations. The Snap4City platform is able to manage multiple tenants and billions of data per day with the key focus on interoperability, decision making, in operation and plan. The Snap4City framework is implemented in several smart cities and areas in Italy (Merano, Cuneo, Florence, Lonato del Garda, etc.) and across Europe (Malta, Rhodes, Varna, Limassol, Valencia, Pont Du Gard, Dubrovnik, Mostar, and West Greece, etc.), as well as on almost all continents. The largest installation of the platform manages multi-tenant, advanced smart city IoT/IoE applications and involves 20 organisations, 40 cities and thousands of operators and developers.

The main drivers for sustainability are decongestion of traffic and services, decarbonisation, improvement of services' accessibility and of security/safety, and possibly the improvement of quality of life. For example, (i) traffic decongestion can be obtained by reducing the number of cars in stop-and-go conditions – this would also imply reducing emissions, depending on the kind of vehicles that are typically in the city, thus stimulating the decarbonisation with e-vehicle diffusion (the actual solutions could be several, from changing the transportation infrastructure, optimising the semaphore cycles, etc.); (ii) making mobility services more accessible would imply having more rides or different paths of public transportations and in some cases increasing emissions; (iii) reducing the critical conditions could improve safety, maybe at the expense of monitoring more carefully all the city areas and thus spending more energy and computational power. A list of artificial intelligence Snap4City tools (AI, explainable AI, XAI tools) for decision makers in improving sustainability of their city is available at [L3].

The first step of those activities is the data ingestion and modelling, field interoperability and data processing area capabilities for collecting data from any source and exchanging data in push toward any brokers, gateways, and services. This area is interoperable with a large number of protocols and formats and enables federation of smart cities. Real-time data, as well as event-driven streams, are ingested using IoT brokers and indexed and shadow stored into a graph database (based on Km4City ontology, and data model for digital twins) and time series storage cluster, thus making them accessible to other consumer processes and brokers. Internal brokers are based on Orion Broker NGSI (also compatible with smart data models, and data spaces). Data can be retrieved in pull or in an event-driven/push way. Node-RED flows are used to enable data interoperability with third party services such as: GIS (Geographic Information Systems), ITS (Intelligence Transport Systems), TV cam services, CKAN open data networks, BIM servers, social media, data gateways, etc. Specific libraries of microservices for data transformation has been developed and made freely available to develop custom-made processing logic.

The ML/AI analytics are in most cases seamless for the decision makers, who are receiving suggestions from AI and also via some XAI annotations. Recently, the provision of interactive 3D digital twin models is actually requested by decision makers for its immediate representation to perceive an awareness of the situations, and to perform real-time simulation of changes, estimating their effects in terms of KPIs on decongestion, travel time, emissions, etc. The specific action is founded as CAI4DSA cascade project of FAIR PE on Future Artificial Intelligence, PNRR.

Links:
[L1] https://www.snap4city.org
[L2] https://digitaltwin.snap4city.org
[L3] https://www.snap4city.org/997
[L4] https://www.disit.org

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Optimizing Mobility and Transport Infrastructures

by Stefano Bilotta, Enrico Collini, Luciano Alessandro Ipsaro Palesi, Paolo Nesi (UNIFI, DINFO, DISIT lab)

Snap4City is a platform enabling decision-makers to efficiently plan and manage city operations. This article is emphasizing CO2 emission reductions through traffic flow optimization.

Improving transportation infrastructure primarily targets the effective reduction of traffic congestion, CO_2 emissions, travel time and fuel consumption. These challenges are tackled through optimization strategies that consider the current traffic flow and traffic graphs knowledge. Research in this field focuses on multiple aspects and can be categorised into two main types: a) those enhancing the existing road infrastructure, such as navigation algorithms and public transport planning, and (b) those that propose changes to the existing transportation infrastructure itself, like modifying the road graph structure and traffic signals.

For the existing infrastructure (a) enhancements may impact specific user groups, such as public transport user and drivers using navigation apps, indirectly improving overall mobility. Infrastructure modifications (b), would require city investments and impact all road users. The effectiveness of such strategies is evident in New York City's 2009 reduction of traffic congestion through the use of taxi GPS data to identify the critical congestion zones.

Simulation tools for assessing the impact of road modifications on traffic distribution are of key relevance for city decision-makers to improve urban mobility and reduce emissions. Many solutions utilise agent-based models which are loaded with virtual or actual data. In those simulators, agents of vehicles navigate in the simulated road network environment according to their described statistical behavior. Examples of simulator tools are SUMO (Simulation of Urban MObility) and PTV Vissim. The simulated traffic flows, and tiny details of the statical behavior of the vehicles, serve as a benchmark for assessing the actual flows. Better results can be obtained by using data coming from real sensors data.

Thanks to the development in the Internet of Things (IoT), it is possible to monitor real-time traffic data such as vehicle flow and density at strategic locations. Traffic Flow Reconstruction (TFR) algorithms leverage this data to compute the traffic in the whole network using neuro-symbolic approaches [1], thus avoiding reliance on virtual simulations alone. This real-time reconstruction offers a precise view of road network conditions in each segment of the road network (also in the road segments in which the sensors are missing), aiding in decision-support systems that monitor and manage city mobility.

The computing of TFR is at the basis of numerous traffic infrastructure calculations and optimization, such as traffic-conditioned routing and crossroad cycling, computation of the match from transportation offer and mobility demand, resulting in what if analysis and optimization (see Figure 1). Recently, these activities, traditionally performed by agent-based simulators, have also become the domain of smarter AI-driven solutions that support decision-makers.The main motivations optimization and what-if analysis targets are the decongestions of traffic and services, improvement of quality of public transportation services, and the quality of life. For example, traffic decongestion can be obtained by reducing the number of vehicles in crowded conditions, which also implies the reducing of emissions, changing/forcing the routing, optimizing the semaphore cycles, etc.; making mobility services more accessible would be obtained by providing more rides or different paths of public transportations and in some cases increasing emissions and expenses. Thus, tradeoff among conflicting targets have to be identified. For this reason, a scenario editor is provided [2], and a large range of interactive visualization tools have to be used for showing the effects and results to work with the decision makers and collect from them final decision and eventually suggestions in short time [3].

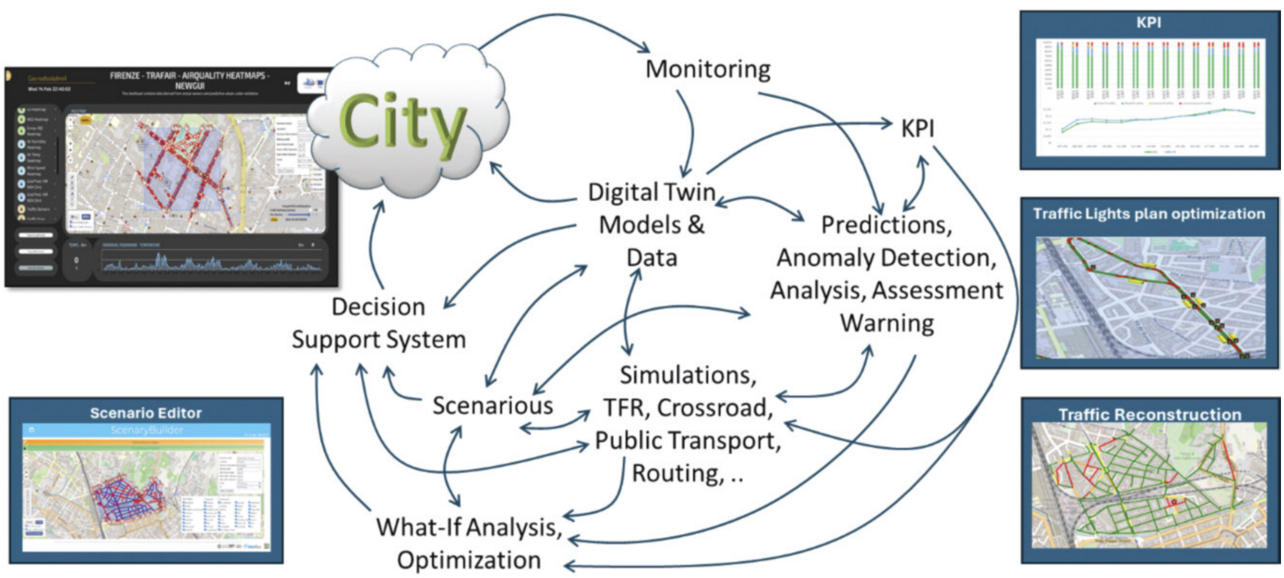

Figure 1: SASUAM Platform architecture for transportation infrastructure optimisation.

A list of artificial intelligence Snap4City tools which can be combined to create solutions for decision makers in improving sustainability of their city is available at [L1]. Snap4City is a platform designed for decision maker to perform activities of operation and plan in the cities and at the support of control rooms. Snap4City is an open-source IoT platform coordinated by the DISIT Lab of the University of Florence. Snap4City is an official FIWARE (an open-source initiative that provides a universal set of APIs to manage Orion broker that allow the development of data flow applications in multiple sectors) and EOSC (European Open Science Cloud) platform and it includes a set of Node-RED libraries for data interoperability and transformation. It is at present in operational use on several federated installations. The Snap4City platform is able to manage multiple tenants and billions of data per day with the key focus on interoperability, decision making, in operation and plan. The Snap4City framework is implemented in several smart cities and areas in Italy (Merano, Cuneo, Florence, Lonato del Garda, etc.) and across Europe (Malta, Rhodes, Varna, Limassol, Valencia, Pont Du Gard, Dubrovnik, Mostar, and West Greece, etc.), by the European Commission on ISPRA JRC, as well as in almost all continents. The largest installation of the platform manages multi-tenant, advanced smart city IoT/IoE applications and involves 20 organizations, 40 cities and thousands of operators and developers.

The project is funded by the CN MOST, PNRR, and by its Scalability subproject SASUAM. SASUAM is a CN MOST scalability project that aims to implement scalable methods and algorithms for urban traffic management.

Links:
[L1] https://www.snap4city.org
[L2] https://www.snap4city.org/997

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Enhancing City Sustainability: Smart Light Management with Snap4City in Merano

by Nicola Mitolo (SNAP4 S.R.L.), Stefan Mutschlechner (ASM Merano), and Paolo Nesi (UNIFI, DINFO, DISIT lab)

This article explores how the Merano Municipal Services Company (ASM Merano), with the support of SNAP4, is leveraging the Snap4City platform to revolutionise public lighting management. By implementing smart, adaptive lighting systems based on real-time traffic conditions, they aim to enhance energy efficiency, improve road safety, and accelerate the city's transition to a sustainable future. Discover how this innovative approach is setting new standards for smart city operations and sustainability.

The main challenges cities are facing today relate to the management of services and infrastructure in areas such as mobility and transportation, energy, governance, welfare, tourism, culture, environment, weather, and education. These areas influence each other, and under critical conditions, a domino effect becomes inevitable, causing additional problems and loss of control. Transforming a city into a smart city is a complex process that requires expertise, technological innovation, willingness to change, and collaboration among various stakeholders.

Municipalities must create sustainable solutions to optimise energy consumption, with public lighting being a critical factor in achieving these objectives and enhancing sustainability in line with the Sustainable Development Goals (SDGs). Efficient public lighting management includes designing algorithms and systems that adjust the intensity and timing of the lights based on actual needs, thereby reducing energy consumption. Additionally, adopting renewable energy sources to power these systems contributes to the promotion of green energy in urban areas. These interventions not only optimise energy usage but also support a sustainable energy transition, reducing environmental impact and improving the overall energy efficiency of cities.

The Snap4City open-source solution for smart light management is innovative, economically sustainable and technologically reliable. Public administrations can easily access and use the solution, adopting open technology to avoid vendor lock-in and proprietary technologies.

To this end, the Merano Municipal Services Company (ASM Merano), with the support of SNAP4 [L1], utilised the Snap4City platform [1], [L2] to implement a smart light management system for monitoring and controlling public lighting, encompassing thousands of luminaires [L3]. The solution is deployed on a public cloud, leveraging Merano's existing LoRaWAN network and connecting DALI 2 nodes, FlashNet, among others, which communicate through LoRaWAN gateways linked to an open-source network server based on the ChirpStack open-source solution. Snap4City is used for pro-

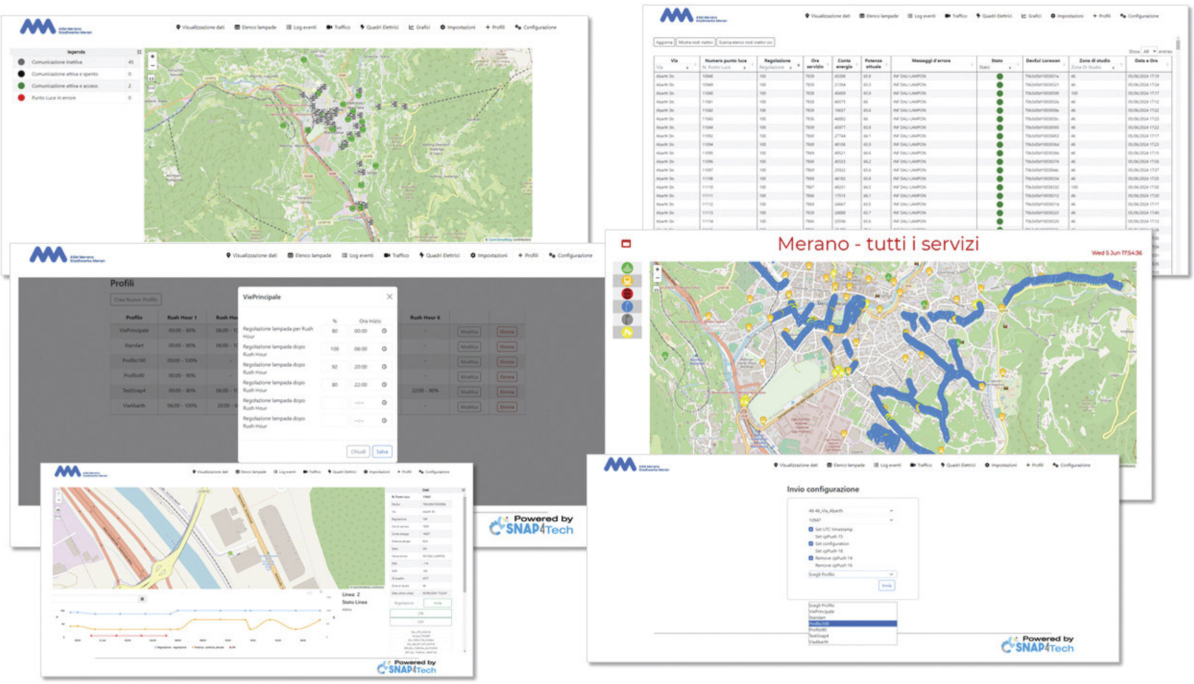

Figure 1: The Snap4City dashboards.

gramming and managing dimming profiles (unicast and multicast), monitoring status and managing errors, and includes the monitoring of cabinets powering the luminaires and data from traffic sensors in different critical cross roads. The smart light management system incorporates adaptive lighting based on traffic conditions, known as Traffic Adaptive Installation (TAI). This system uses sensors and data analytics to monitor the flow of vehicles in the monitored areas. When traffic volume is high, the lighting intensity increases to ensure safety and visibility. Conversely, during periods of low traffic, the lighting intensity is reduced to save energy.

TAI represents one of the latest innovations in sustainable public smart light management. It enables automatic adjustment of street lighting based on traffic conditions. Utilising traffic monitoring data from various measurement points, Snap4City facilitates remote management of TAI in a simple and flexible manner, adhering to the standards defined in UNI11248:2016 [L3]. This is achieved by sending the necessary lighting regulation commands to the affected luminaires in multicast mode. This integrated technology offers numerous benefits for both administrations and citizens, including energy savings and improved road safety.

Using the Snap4City solution, several dashboards have been created, enabling operators to monitor and manage all the luminaires, network areas, and service quality. Snap4City dashboards simplify the service management modalities including dimming profiles and TAI modalities for the different zones in the areas.

In particular, the dashboards (see Figure 1) are providing:
- The map of the whole city area involved with custom dynamic pins geographically positioned in the map and representing the luminaries, cabinets, gateways and traffic sensors, changing their status in real time according to the data received. This allows providing stakeholders an immediate overview of the status of the implemented infrastructure, and identifying anomalies and dysfunctions.
- Real-time trend of the ingested data allows monitoring of the streetlights and cabinets data over time.
- The user interface to add new nodes in the multicast group, manage and set the different configuration and dimming profiles of all nodes connected in the network, by managing in the backend all the process logic to decode/code the proprietary protocol messages and commands.
- Program and manage the TAI enabling an integrated and sustainable smart adaptive lighting solution. The dashboard provides an interface for programming the time-controlled variations of luminance level in relation to hourly traffic flow, weather conditions or other parameters.

The solution implemented with Snap4City demonstrated the potential of an integrated approach for managing smart city operations more flexibly. This helps the municipality and stakeholders make better decisions. Merano and SNAP4 provided a practical solution for optimising energy consumption and usage, accelerating the city's smart city development and better addressing future sustainable energy transitions.

Links:
[L1] https://www.snap4.eu
[L2] https://www.snap4city.org
[L2] https://www.snap4.eu/products/smart-lights.html
[L3] https://store.uni.com/uni-11248-2016

Reference:
[1] C. Garau, et al, "A big data platform for smart and sustainable cities: environmental monitoring case studies in Europe," in Proc. of Int. Conf. on Computational Science and its Applications, ICCSA2020. Cagliari, Italy, 1–4 July 2020. https://kwz.me/hDc

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European Research and Innovation

D3 – An AI-based Solution to Road Defect Detection

by László Tizedes, András Máté Szabó, and Anita Keszler (HUN-REN SZTAKI)

Automated road defect detection is a key component in the development and maintenance of smart cities, leading to safer, more efficient and sustainable urban environments. An artificial intelligence-based system capable of detecting potholes, speed bumps and manhole covers, among other road hazards, was developed as a result of the cooperation between D3 Seeron startup company and HUN-REN SZTAKI, and was supported by ESA Spark Funding. The proposed system combines the low computational demands of vision-based object detection with the precise distance measurement of LiDAR technology.

As smart transportation technology evolves, the need for greater integration of digital devices in vehicles has increased, particularly in automated environmental sensing and vehicle control. In a smart city, integrating automated road defect detection systems is essential to enhance the quality of transportation by providing real-time feedback on road conditions. This feedback allows vehicles to adjust their routes and driving behaviours dynamically, ensuring safer and more reliable travel.

Moreover, automated road anomaly detection contributes significantly to the overall infrastructure management of a smart city. By continuously monitoring and reporting the state of the roads, these systems provide valuable data to traffic control centres that can be used to reduce traffic congestion and to plan cost-efficient road maintenance. In this way, automated road defect detection not only supports safer driving but also enhances the efficiency and sustainability of urban transportation networks.

The Project

We aimed to develop a system that uses the vehicle's environmental sensor data (camera and LiDAR) to provide the driver or the self-driving vehicle's control system with information about the presence of obstacles on the road surface (see Figure 1). The automation of vehicle control heavily depends on the vehicle's ability to sense its surroundings, which relies on processing data from various sensors, each with its own unique characteristics. By leveraging these diverse sensor inputs, the developed system aims to deliver comprehensive and reliable environmental awareness, enhancing both the safety and efficiency of autonomous vehicle operations.

Unlike the majority of previous solutions that focus on road quality assessment, this method doesn't rely on post-processing of the recorded data. Therefore, the output of our system is not only useful for reporting issues to traffic centres, but it can also provide vital information for the control system of a self-driving vehicle immediately.

The six-month-long project [L1] ended in 2024 and was a joint effort of D3 Seeron and the Institute for Computer Science and Control (HUN-REN SZTAKI) [L2]. In the past decades D3 Seeron has developed applications that have provided a solution to challenges from large-scale data processing to image processing to the application of artificial intelligence. The mission of HUN-REN SZTAKI includes pursuing focused, basic and applied research on areas defined by the mainstream of world trends and the domestic requirements and challenges.

The developed D3 platform contains a Sensor Fusion Engine and a Framework providing a robust and flexible solution. HUN-REN SZTAKI contributed to the project with the image processing and space-technology-based LiDAR point cloud processing algorithms. These algorithms were the result of combining a previous ESA-funded research project (DUSIREF [L3]) and technology developed with the support of the Hungarian National Lab for Autonomous Systems. The detection system with the D3 platform is illustrated in Figure 2. It uses camera imagery captured by a RGB camera to detect road surface anomalies. In order to modify the speed or the trajectory of the vehicle, the control system requires accurate location estimation regarding the detected objects on the road. The distance is measured using LiDAR technology. The fusion of RGB camera and LiDAR is used to determine the object's position. The proposed setup leverages the low computational demands of vision-based object detection methods and integrates them with the precise distance measurement capabilities of LiDAR technology. Given the critical need for rapid data processing in controlling an autonomous vehicle, our system

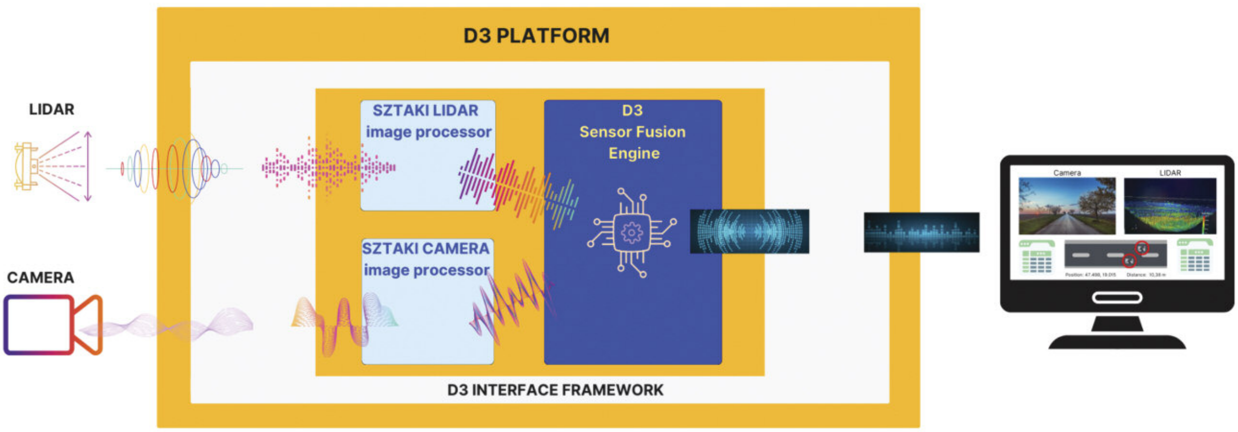

Figure 1: Our platform contains a Sensor Fusion Engine and a Framework. It processes information from the sensors and provides feedback to the driver/control system of the vehicle. If necessary, the information can also be forwarded to the traffic control centre.

utilises the Robot Operating System and the algorithms run locally on an embedded NVIDIA Jetson AGX Xavier device. However, the data provided by the method can not only be used on-board but can be stored in a cloud for further smart maintenance planning.

Figure 2: The aim of the project was to develop a system that uses the vehicle's environmental sensor data (camera and LiDAR) to provide the self-driving vehicle's control system with information about the presence of obstacles on the road surface.

The road hazards are identified by a deep learning algorithm utilising a convolutional neural network, processing images from the camera. The neural network was trained by using a combination of publicly available datasets and our own recordings. The dataset included the following road hazard classes: pothole, road drainage, manhole cover, bicycle mark, and speed bump. Potholes and speed bumps are of particular interest because they require the vehicle to slow down to prevent accidents. However, the other classes also play a crucial role in the detection system. Including these additional road hazard classes in the training data enhances the overall recognition accuracy for the more critical classes. To make the identification process more robust, a tracking algorithm was also developed that follows the detected hazard through multiple frames. A detected speed bump is shown in Figure 3.

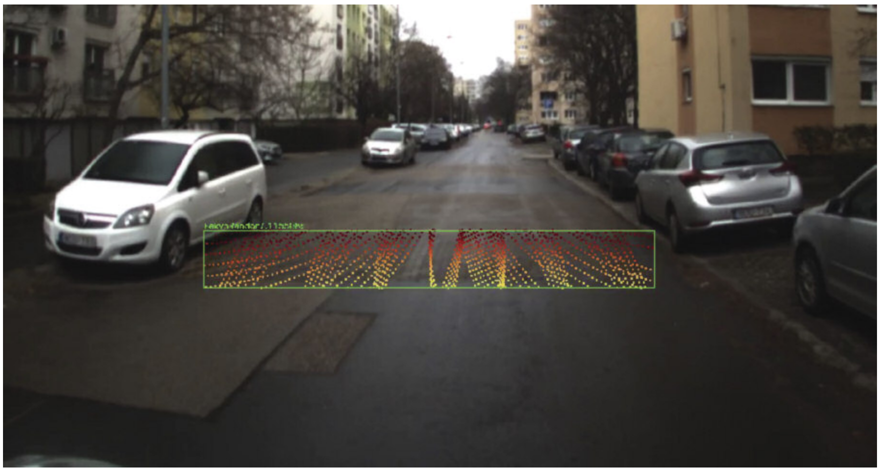

Figure 3: Sample output (detected speed bump) of the system: the merging of the camera's image and the LiDAR's point cloud. The camera provides the input for the deep learning-based object detection algorithm, while the LiDAR provides the location information of the detected objects.

Two LiDARs with distinct scanning patterns were tested. The Ouster LiDAR has a more mainstream circular pattern, while the Livox AVIA LiDAR has a non-repetitive rosette scanning pattern. The objective was to determine if the scanning pattern significantly impacts the results or if the method is sufficiently general to function with both. Our findings indicated that the system can effectively integrate both scanning technologies.

Conclusion

With the development of driver support systems and self-driving vehicles, the amount of information integrated into them is bound to expand. Users will expect not only the autonomous navigation of predefined routes but also a higher level of comfort. The road anomaly data we collect can contribute to a more comfortable travelling experience and can also aid road maintenance teams in planning future repairs. Due to the low resource and hardware requirements of the developed tool, it can be integrated into existing driver support / self-driving systems.

Links:

[L1] https://sztaki.hun-ren.hu/en/innovation/projects/road-defect-detection
[L2] https://sztaki.hun-ren.hu/en/science/departments/mplab
[L3] https://sztaki.hun-ren.hu/tudomany/projektek/dusiref

References:

[1] J. Kocić, N. Jovićić, and V. Drndarević, "Sensors and sensor fusion in autonomous vehicles," 26th Telecommunications Forum (TELFOR), 2018, pp. 420–425.
[2] A. Börcs, B. Nagy, and C. Benedek, "Instant Object Detection in Lidar Point Clouds," in IEEE Geoscience and Remote Sensing Letters, vol. 14, no. 7, pp. 992-996, July 2017. https://www.doi.org/10.1109/LGRS.2017.2674799
[3] L. K. Suong and K. Jangwoo, "Detection of potholes using a deep convolutional neural network," Journal of Universal Computer Science, vol. 24, no. 9, pp. 1244–1257, 2018.

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Digital Physiotherapy with Edge Swarm Technology

by Jean-Paul Calbimonte and Davide Calvaresi (HES-SO)

In the frame of the EU funded SmartEdge project, we introduce a novel physiotherapy solution, moving beyond traditional methods and subjective assessments. Our innovative approach ensures precise evaluation and timely feedback, transforming the way pain, muscular resistance, and treatment progress are monitored.

Commercial solutions in the market and current physiotherapy practices have several significant limitations, including closed technological ecosystems, subjective assessment, inaccurate precision, and a lack of reliable and timely feedback that can lead to an inadequate evaluation of pain, muscular resistance, and the evolution of the treatment.

SmartEdge Solution for Physiotherapy

In the context of SmartEdge, we target a physiotherapy scenario, aiming at showcasing the usage of the SmartEdge solution to (i) enable multi-joint tele-rehabilitation guided by an anthropomorphic avatar-based UI, leveraging wearable and environment nodes that join the swarm; and (ii) to allow the dynamic formation and edge participation in the swarm.

In particular, head and neck rehabilitation and physiotherapy can be necessary for chronic conditions and for recovery from injuries or surgical interventions. The proposed solution is antipodal to traditional treatments, which are often observation-based and through episodic verification of the therapist. Patients can perform prescribed exercises at home supported by personalized assistive technologies and in the hospital during the visit, observing the same protocol and measurements.

The envisioned solution may entail the interoperation of heterogeneous sensor nodes, such as wearable/environmental dynamically, as well as the involvement of user interfaces to engage the patient and monitor the ongoing sessions and long-term evolution.

Integration of Wearable Technology and Environmental Sensors

In doing so, the use case shows how heterogeneous sensors and edge devices can interoperate and work towards a common goal, following self-organizing patterns and combining diverse complementary functionalities. In this use case setting, a patient will be wearing a set of wearable sensors (e.g., Nordic Thingy52 equipped with accelerometer, gyroscope, mini speakers, etc.) and capturing the movements of neck, head, and shoulders. Meantime, each patient will have access to a tablet providing on-time feedback (visual/auditive indicators guiding and providing feedback on the running exercise) and access to personalized exercise and progress monitoring.

Additionally, environment sensors deployed in the room will contribute with data related to external conditions (e.g., temperature, CO_2, luminosity, etc.) which may have an incidence on the exercises and therapeutic recommendations. Providing additional cues, motivation, and persuasion support, an anthropomorphic avatar in the tablet UI will be provided to the patient, reacting, and interacting according to the therapy goals and achievements of the participant.

Multi-patient Challenges and Semantic Models

Moreover, the patient may need in-time feedback about the exercise. Extending this scenario to a multi-patient setting entails additional challenges (e.g., cross-swarm sensor heterogeneity, activities to be detected, and scaling to real-time multi-patient monitoring). Indeed, different patients might follow their own specific therapy, having different therapies/prescriptions and body parts to rehabilitate.

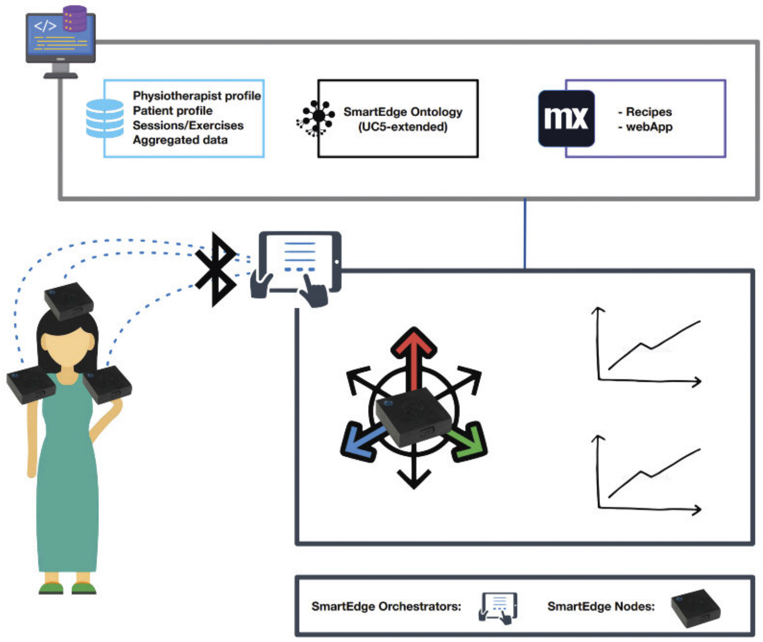

Figure 1: Personalized assistive technologies in neck and head rehabilitation include exercises, wearable sensor nodes, kinematic analysis of motion, real-time exercises' guidance, monitoring and feedback, and aggregated historical data.

Therefore, it is essential that beyond the real-time interactions within the sensing ecosystem, a digital rehabilitation system must also rely on semantic models for representing information within the swarm devices across patients and healthcare providers, using technology standards such as RDF for the description of the device's capabilities, and enabling the formation and orchestration of the swarm.

Link:
https://www.smart-edge.eu/

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SCHLOSS DAGSTUHL
Leibniz-Zentrum für Informatik

Call for Proposals

Dagstuhl Seminars and Perspectives Workshops

Schloss Dagstuhl – Leibniz-Zentrum für Informatik is accepting proposals for scientific seminars/workshops in all areas of computer science, in particular also in connection with other fields.

If accepted, the event will be hosted in the seclusion of Dagstuhl's well known, own, dedicated facilities in Wadern on the western fringe of Germany. Moreover, the Dagstuhl office will assume most of the organisational/ administrative work, and the Dagstuhl scientific staff will support the organizers in preparing, running, and documenting the event. Thanks to subsidies the costs are very low for participants.

Dagstuhl events are typically proposed by a group of three to four outstanding researchers of different affiliations. This organizer team should represent a range of research communities and reflect Dagstuhl's international orientation. More information, in particular details about event form and setup, as well as the proposal form and the proposing process, can be found on

https://www.dagstuhl.de/dsproposal

Schloss Dagstuhl – Leibniz-Zentrum für Informatik is funded by the German federal and state government. It pursues a mission of furthering world class research in computer science by facilitating communication and interaction between researchers.

Important Dates

- *Next submission period:* October 15 to November 1, 2024
- *Seminar dates:* Between October 2025 and August 2026 (tentative).

ERCIM
European Research Consortium
for Informatics and Mathematics

Horizon Europe Project Management

A European project can be a richly rewarding tool for pushing your research or innovation activities to the state-of-the-art and beyond. Through ERCIM, our member institutes have participated in more than 100 projects funded by the European Commission in the ICT domain, by carrying out joint research activities while the ERCIM Office successfully manages the complexity of the project administration, finances and outreach.

Horizon Europe:How can you get involved?

The ERCIM Office has recognized expertise in a full range of services, including:

- Identification of funding opportunities
- Recruitment of project partners (within ERCIM and through ournetworks)
- Proposal writing and project negotiation
- Contractual and consortium management
- Communications and systems support
- Organization of attractive events, from team meetings to large-scale workshops and conferences
- Support for the dissemination of results.

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Call for Participation

FMICS 2024 - 29th International Conference on Formal Methods for Industrial Critical Systems

Co-located with Formal Methods (FM) 2024 in Milan, 9-11 September 2024

The Formal Methods for Industrial Critical Systems (FMICS) conference series offers a platform for researchers and practitioners focused on the development and application of formal methods in industry. FMICS brngs together scientists and engineers to share their experiences in industrial applications of formal methods. Additionally, the conference promotes research and development to enhance formal methods and tools for industrial use.

The invited speakers are Byron Cook from University College London and Amazon Web Services, who will present "The Business of Proof" and Thierry Lecomte from CLEARSY, who will discuss "B+ or How to Model System Properties in a Formal Software Model".

The conference features 14 selected papers, related to the following topics:

- Case studies and experience reports on industrial applications of formal methods;
- Methods, techniques, and tools to support automated analysis, certification, debugging, learning, optimization, and transformation of complex, distributed, real-time, embedded, mobile, and autonomous systems;
- Verification and validation methods that address shortcomings of existing methods with respect to their industrial applicability;
- Transfer to industry and impact of adoption of formal methods on the development process and associated costs in industry.
- Application of formal methods in standardisation and industrial forums.

More information:
https://fmics.inria.fr/2024/
https://www.fm24.polimi.it

SmartEdge & AIoTwin Summer School and Workshop

16-20 September 2024, Dubrovnik, Croatia

The SmartEdge project is happy to announce a Summer School in collaboration with the EU funded AIoTwin project, scheduled from 16-20 September 2024.

In addition to a technical workshop titled 'Edge AI meets Swarm Intelligence' (refer to the separate announcement on the right), participants of the SmartEdge Summer School will engage in sessions with AIoTwin. These sessions will feature poster presentations of the latest PhD research, tutorials, and hands-on sessions with SmartEdge's advanced hardware and systems during open-door demonstrations.

Experts from top institutions will share their insights in keynote sessions. Don't miss this opportunity to join a transformative learning journey shaping the future of AIoT and Edge AI.

Schedule for the week

- 16-18 September – AIoTwin Summer School: Keynote talks, Tutorials, Hands-on workshops
- 18 September – Joint Sessions SmartEdge & AIoTwin:
  - Technical Workshop on "Edge AI meets Swarm Intelligence"
  - Poster session, SmartEdge open-door demonstration
- 19-20 September – SmartEdge Summer School: Keynote talks, Tutorials, Hands-on sessions.

Programme of the SmartEdge Summer School

Thursday 19 September – SmartEdge Summer School (1/2):
- 08:45-09:00: Morning coffee
- 09:00-10:30: "Accelerating Data Processing through Hardware/Software Co-Design in SmartEdge", Keynote by Philippe Cudre-Mauroux (University of Fribourg)
- 10:30-11:00: Coffee break
- 11:00-11:45: "Virtual environment and Traffic Scene Graph", Tutorial by Louay Bassbouss (Fraunhofer FOKUS) and Duong Tran (Bosch)
- 11:45-12:30: "Smart City and SmartEdge", Tutorial by Kari Koskinen (Conveqs)
- 12:30-13:30: Lunch break
- 13:30-14:15: "Smart Factory Mobile Robotic", Tutorial by Alan Cueva Mora (Dell)
- 14:15-15:00: "Low-Code Edge Intelligence in Smart Factories", Tutorial by Kirill Dorofeev (Siemens)
- 15:00-15:30: Coffee break
- 15:30-16:15: "Swarm Intelligence for Group Sickness Monitoring", Tutorial
- 16:15-17:00: "Edge Intelligence in Digital Rehabilitation", Tutorial by Davide Calvaresi and Berk Buzcu (Hes-so)
- 17:00-18:00: Hands-on session.

Friday 20 September – SmartEdge Summer School (2/2)
- 08:45-09:00: Morning coffee
- 09:00-10:30: "Neuro-Symbolic AI: Combining Semantic Technologies and Neural Networks", Keynote by Trung Kien Tran (Bosch)
- 10:30-11:00: Coffee break
- 11:00-11:45: "In-Network Machine Learning", Tutorial by Changgang Zheng, Peng Qian and Hongyi Chen (University of Oxford)
- 11:45-12:30: "Tools for Continuous Semantic Integration", Tutorial by Kirill Dorofeev (Siemens)
- 12:30-13:30: Lunch break
- 13:30-14:15: Tutorial by Anh Le Tuan (Technical University of Berlin)
- 14:15-15:15: Hands-on session
- 15:15-15:45: Coffee break
- 16:15-17:00: Closing of the SmartEdge summer school.

The event is located at the University of Zagreb Centre for Advanced Academic Studies (CAAS), Don Frana Bulica 4, in 20000 Dubrovnik, Croatia.

ERCIM is a partner of the SmartEdge project.

More information:
For registration and accommodation, please visit the Summer School web page at:
https://www.smart-edge.eu/summer-school-2024/

Call for participation

Edge AI Meets Swarm Intelligence

18 September 2024, Dubrovnik, Croatia

As part of the SmartEdge & AIoTwin Summer School, the "Edge AI meets Swarm Intelligence" technical workshop is held on 18 September 2024.

Edge AI represents a novel computing paradigm designed to facilitate local data storage and processing, with AI algorithms enabling data treatment directly at the edge of the network. This approach aims to bring intelligence to the end-devices, facilitating real-time decision-making and empowering devices to operate autonomously, reducing reliance on external cloud services.

One of the key topics of interest is to develop low-code programming tool chains or platforms for edge intelligence to enable swarm computing paradigms. The tools will reduce the efforts of building smart systems requiring a collective of heterogeneous devices, sensors, vehicles and robots to collaborate towards a common goal. Such a solution aims at enabling Swarm Intelligence concepts, which are a form of AI that mimics the collective behavior of decentralized, self-organized systems, like those observed in nature.

Researchers working on the two projects share similar research interests in terms of enabling AI at the edge and dealing with the heterogeneity of such environments. Heterogeneity can refer here to differences in network capabilities, processing power, software stacks, APIs, and security protocols across the Cloud-Edge Continuum infrastructure, e.g. continuum reference architecture proposed by EUCloudEdgeIoT.

The primary goal of this workshop is to foster collaboration and the exchange of ideas among researchers and stakeholders. The workshop can provide a platform for participants to share their experiences, best practices, case studies, and to identify emerging research areas and potential solutions to existing challenges.

Topics

Topics are related to the design, development, and evaluation of architectures, technologies, and applications for "Edge AI" and "Swarm Intelligence", including but not limited to:
- Network optimization and interoperable protocols for Edge AI and Swarm Intelligence
- Novel system architectures and hardware designs in Edge AI and Swarm Intelligence
- Network security, data privacy, confidence, and trust in Edge AI and Swarm Intelligence
- AI-enabled resource allocation, federated learning, and swarm intelligence
- Next generation smart use-cases enabled by Edge AI and Swarm Intelligence
- Intelligence in distributed computing continuum systems
- Novel results in embedded AI, in-network computing or heterogeneous computing
- Methods, resources, and experimental findings in autonomous systems.

Agenda

- 08:15-08:45: Morning coffee
- 08:45-09:00: Opening ceremony
- 09:00-10:15: "Techniques for safe and highly available cloud applications", keynote by Carla Ferreira (TarDIS)
- 10:15-10:30: Coffee break + posters session
- 10:30-12:00: Papers track
- 12:00-13:00: Lunch break + posters session
- 13:00-14:30: Free slot/activity
- 14:30-14:45: Coffee break + poster sessions
- 14:45-16:00: Papers track
- 16:00-16:15: Coffee break + poster sessions
- 16:15-17:30: Papers track
- 17:30-17:45: Closing the workshop.

Workshop chairs

- Ivana Podnar Zarko (University of Zagreb, Croatia)
- Philippe Cudre-Mauroux (University of Fribourg, Switzerland)
- Trung-Kien Tran (Bosch, Germany)
- Danh Le-Phuoc (TU Berlin, Germany).

More information:
https://www.smart-edge.eu/eamsi24/
https://www.smart-edge.eu/summer-school-2024/
https://easychair.org/my/conference?conf=eamsi24

DIGITAL ETHICS IN RESEARCH

Call for Participation

Forum Beyond Compliance 2024: Research Ethics in the Digital Age

Budapest, 14-15 October 2024

ERCIM, SZTAKI, and the French CCNE-numérique are organising the third edition of the Forum Beyond Compiance on 14-15 October 2024 in Budapest. The program will consist of invited presentations, invited contributions to round tables, a tutorial session, and selected contributions. The programme will be structured into six topical sessions focusing on ethical issues in digital research about:
- Cultural Influences,
- Democracy,
- Regulation Making,
- Cooperative Agents,
- Digital Health,
- Emerging Topics;

as well as two sessions for a Tutorial and Selected Contributions. Presentations will include case study reports, novel developments from research projects, policy recommendations, or proposals and hypotheses put forward for discussion.

The organizing committee of the Beyond Compliance Forum is the Digital Ethics Task Group of ERCIM, currently composed of:
- Christos Alexakos (ISI/ATHENA RC, Greece)
- Emma Beauxis-Aussalet (VU, Netherlands)
- Gabriel David (INESC TEC, Portugal)
- Claude Kirchner (CCNE and Inria, France)
- Guenter Koch (AARIT, Austria, and Humboldt Cosmos Multiversity, Spain)
- Sylvain Petitjean (Inria, France)
- Andreas Rauber (TU Wien, Austria)
- Vera Sarkol (CWI, Netherlands)

More information:
https://www.ercim.eu/beyond-compliance

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