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Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Future Artificial Intelligence Research

FAIR

Partenariato Esteso su Intelligenza Artificiale

Francesco Scarcello

Coordinatore SPOKE 9

Future Artificial Intelligence Research

Università della Calabria

Spoke Research Programs

Each FAIR spoke has its own research program organized in a set of work-packages to address its specific challenges:

- **Spoke 1 (Univ. Pisa) HUMAN-CENTERED AI**: interacting and collaborating with humans;
- **Spoke 2 (FBK, Trento) INTEGRATIVE AI**: integrating AI methods, technologies and disciplines;
- **Spoke 3 (Univ. Naples «Federico II») RESILIENT AI**: operating in challenging, noisy, uncertain real-world settings;
- **Spoke 4 (Politecnico di Milano) ADAPTIVE AI**: perceiving, learning and acting within dynamically evolving contexts;
- **Spoke 5 (Sapienza, Rome) HIGH-QUALITY AI**: meeting high-quality standards for high-risk, safety critical applications;
- **Spoke 6 (Univ. Bari) SYMBIOTIC AI**: promoting effective human-machine interactions and collaborations;
- **Spoke 7 (Politecnico di Torino) EDGE/EXASCALE AI**: operating on the edge and on the cloud;
- **Spoke 8 (Univ. Bologna) PERVASIVE AI**: operating ubiquitously in different social settings;
- **Spoke 9 (Univ. Calabria) GREEN-AWARE AI**: considering the environment dimension by design;
- **Spoke 10 (IIT, Genova) SUSTAINABLE AND BIO-COGNITIVE AI**: mimicking the biological systems at multiple scales.

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Transversal Projects

Coordination among the spokes is based on "Transversal Projects", i.e., inter-spoke activities

Transversal Projects aim to coordinate activities on relevant inter-spoke challenges which involve specific communities of researchers belonging to different spokes.

TP1: *Legal and Ethical Design of Trustworthy AI Systems*

TP2: *Vision, Language and Multimodal Challenges*

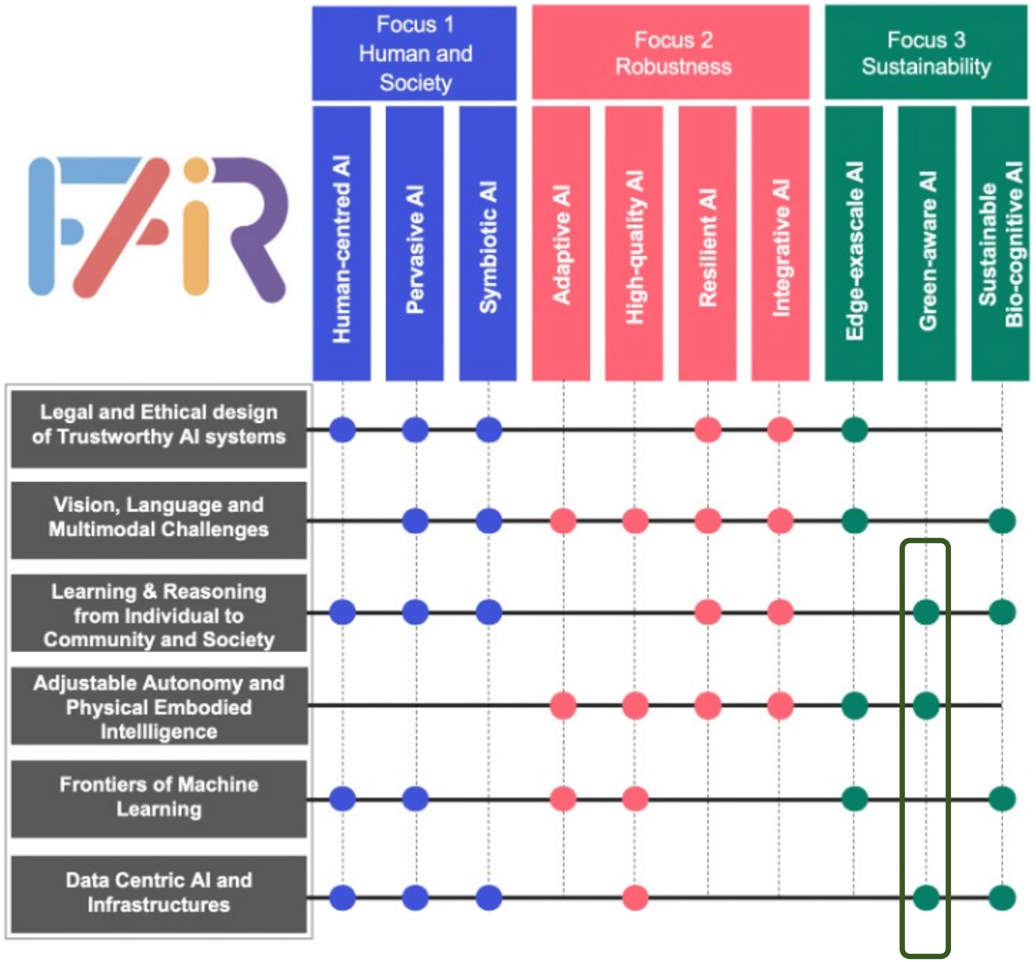
TP3: *Learning & Reasoning to assist decision making at multiple scales* (individual, community, and society)

TP4: *Adjustable Autonomy and Physical Embodied Intelligence*

TP5: *Hard-Sciences for Machine learning*

TP6: *Lifelong Learning*

TP7: *Data centric AI and Infrastructures*



By Roy Schwartz, Jesse Dodge, Noah A. Smith, Oren Etzioni
Communications of the ACM, 63(12), 2020

Creating efficiency in AI research will decrease its carbon footprint and increase its inclusivity as deep learning study should not require the deepest pockets.

Green AI and AI for green

- AI must be greener
- AI applications for SDGs

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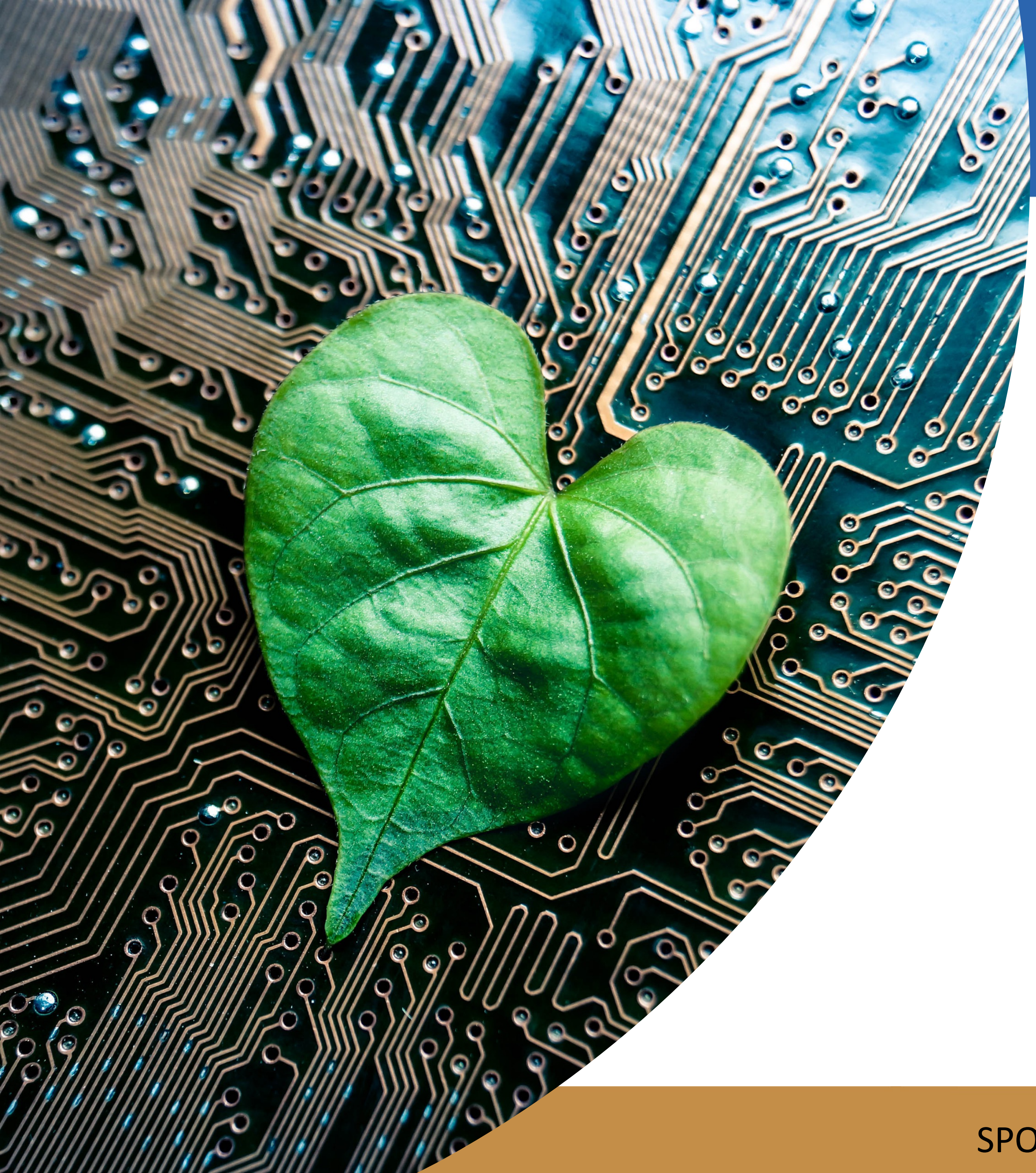

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SPOKE 9 –GREEN-AWARE AI

Università della Calabria,
Consiglio Nazionale delle Ricerche

- consider the “green dimension” by design
- foundational aspects of green-aware AI agents and systems

Some needed methodological advances

- Knowledge representation and reasoning frameworks that are able to deal with the green dimension and to guide along this dimension planning, decision making, and also sub-symbolic tasks, in dynamic and uncertain contexts;
- Models of interaction for agents, both green-aware and non-green-aware, by considering different aspects, such as fair allocations and collective decision making;
- Techniques for green-aware learning that are able to work with limited resources and to meet green-aware requirements.

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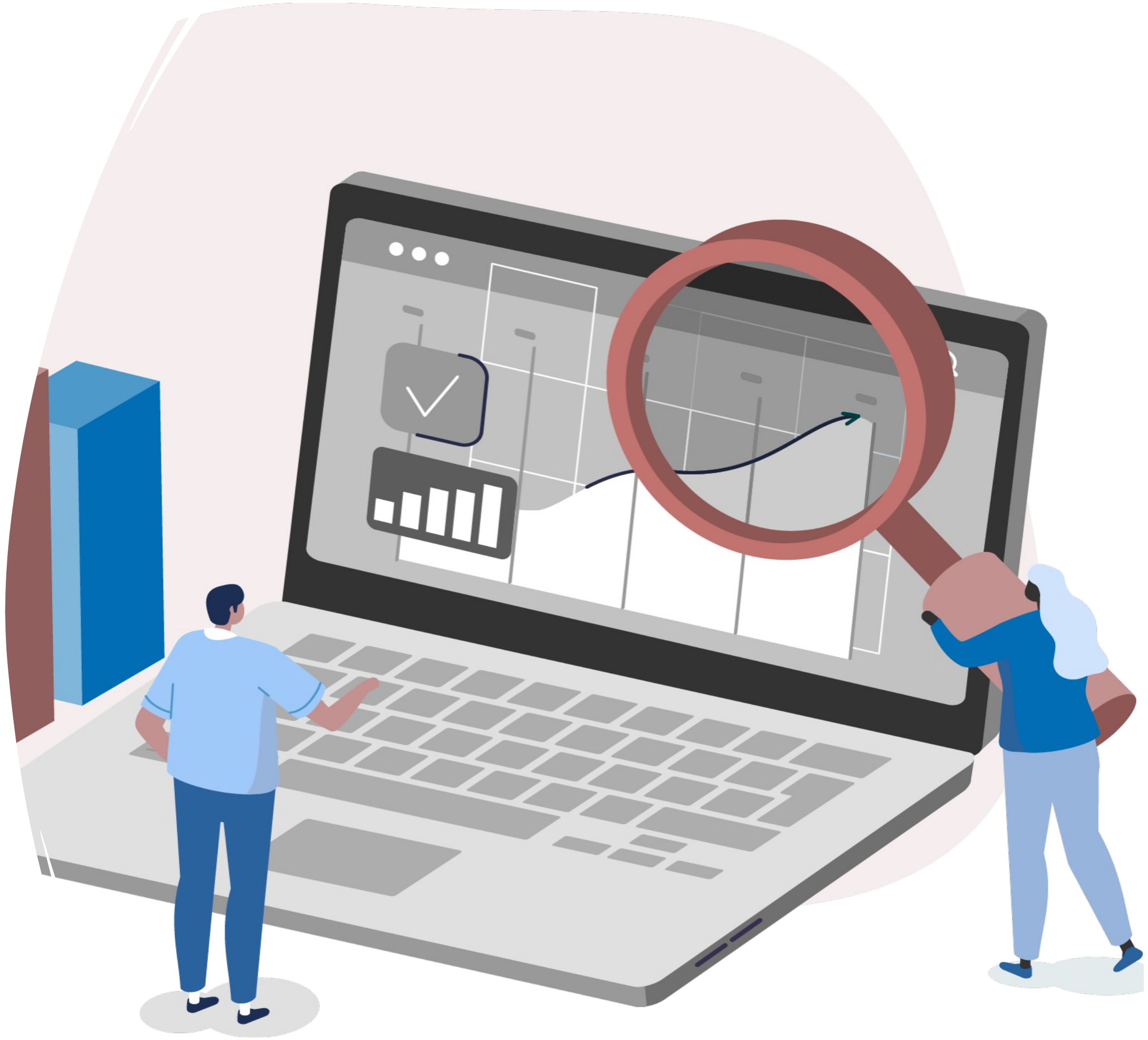
Spoke 9 - critical mass

- 33 persons
  - 29 UNICAL
  - 1 UNICAL/GSSI
  - 3 CNR
- 413 person months total

- + 15 RTDa



Workpackages

1. Knowledge representation and reasoning
2. Interactions among green-aware agents
3. Green AI
4. Green-aware explainable AI
5. Adjustable green-aware AI
6. AI for green (pilots)

Assets

Leading research groups in

- Knowledge representation and Hybrid systems
- Algorithmic game theory, Multiagent systems, Computational social choice, Cooperative Game Theory
- High-performance computing
- Edge computing and Internet of Things
- Explainable AI, Argumentation, Outlier Detection
- Machine Learning (deep learning, federated learning, graph-neural networks)
- Social network analysis, social media analytics, graph mining
- Optimization (with applications to energy, battery design, and more)
- Robotics and smart materials, manufacturing

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WP 9.1 – KR&R Frameworks for green aware AI

- Main goal: gap closing and advancement of KR&R
  - Gap closing tasks:

    Green-awareness via preference and probabilistic reasoning (KR ←→ ML)
    Regaining declarativity in resource demanding domains (KR ←→ Procedurality)
    Computational issues for cheap and efficient reas. with ASP (KR ←→ Efficiency)
  - Advancement tasks:

    Semantically explainable context-aware recommendations (KR → Semantic web)
    Stream reasoning for green-aware domains (KR → Stream reasoning)
  - KR&R on the field tasks:

    Knowledge Graphs for Sustainable Development Support (KR → Sus.Dev. Goals)
    ASP, ELP and Agents to manage the cities of the future (KR → Holistic cities)
    KR&R for environmental monitoring and decision support (KR → Environment)

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WP 9.2 - interactions among green-aware agents

It mainly considers game-theoretic models in settings where agents are selfish and their possible behaviour is subject to hard/soft constraints on the green impact of their actions

1) models and analysis of relevant green scenarios, resorting on tools and classical metrics in game theory
2) design of incentive/pricing mechanism for coordinating the agents so as to achieve desirable outcomes and green behaviour
3) incomplete information: strategyproof mechanism for eliciting preferences and learning preferences and solution concepts from data
4) graph mining and analysis of networks of green-aware agents, their interactions and social influence
5) logic-based frameworks for enabling the temporal reasoning for green-aware agents and the analysis of green-aware multi-agent systems evolving over time

WP 9.3 Green AI

- Investigates new **machine learning and AI algorithms** that are **able to deal with limited amounts of data and reduced computation resource**s for training
- **Exploites** available domain knowledge, **energy awareness techniques** and estimation of devices/computers energy consumption
- Explores **combinations of symbolic and sub-symbolic approaches in order to save hardware/software resources and energy**

WP 9.4 Green-aware XAI - tasks

- Argumentation-based analysis of low-level business process logs
- Argumentation-based persuasion for responsible energy consumption
- Explainable ontology-mediated query answering on environmental knowledge bases
- Interpretable graph neural network models for green-aware knowledge
- Social network and user behavior analysis for understanding the citizens' attitude to the green transition

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WP 9.5 – Adjustable Green aware AI

Design of **machine and deep learning** techniques able to analyze the activity of agents, humans, and sources of data in which the green dimension is relevant

- Rethinking planning strategies and algorithms for the green society
- Adjustable Green-aware Planning AI
- Adjustable Green-aware Machine Learning
- Green aware robot design and coordination strategies
- Tradeoff in practical reasoning of green-aware agents

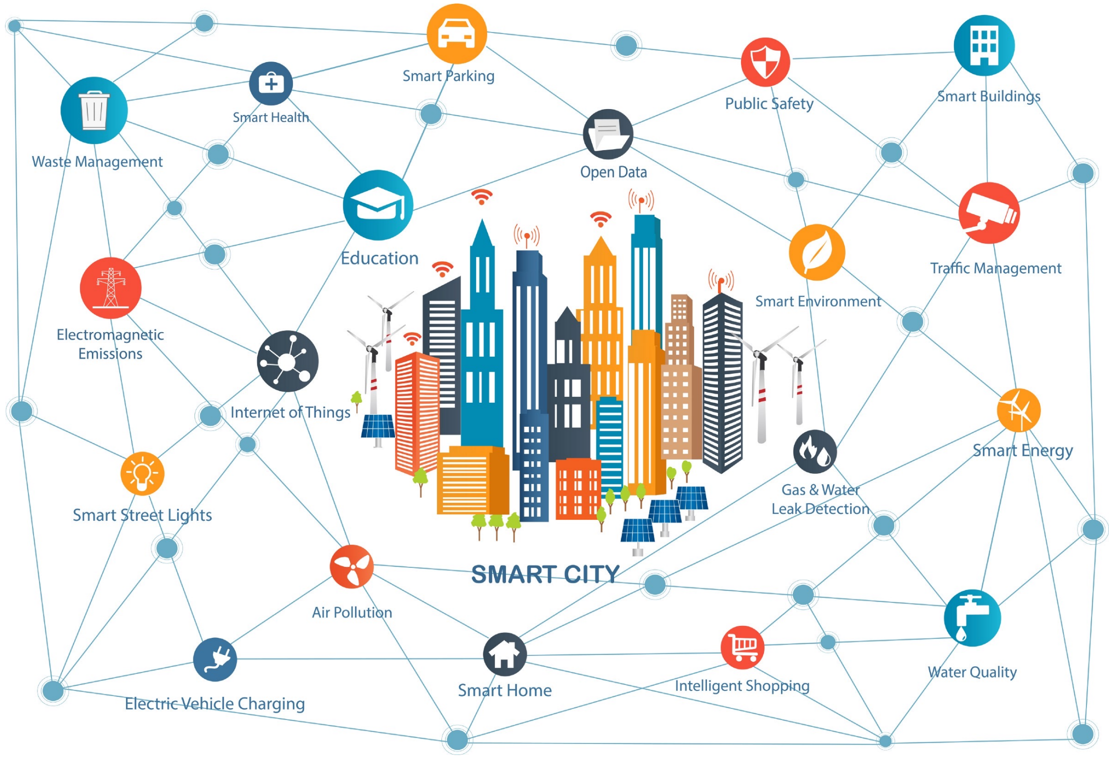
WP 9.6 – AI for Green

- Design and development of pilots/use cases, where AI techiniques can be used to enable a sustainable growth
- Application domains:
    - *Industry and Manufacturing*, focusing on green-aware and human-centric platforms in the context of Industry 5.0
    - *Environment, infrastructures and networks*, focusing on integrated renewable energy systems and smart energy management
    - *Smart cities, areas and communities*, focusing on green applications in the context of the Internet of Wearables or Internet of Medical Things

Some use cases

«AI for Green» applications:

- ***Holistic cities***
- ***Sustainable development support***
- ***Environmental and climate monitoring***
- Efficient and sustainable resource allocation, minimizing environmental impact



Some use cases

Deep learning on limited resource devices

- Implementation of an energy saving training strategy for a deep learning library on IOT devices (on going on TensorFlow Lite Micro).
- The goal is to solve practical challenges in terms of data, memory, and computing constraints for extreme edge devices.
- Optimization methods for facing the limitations in storage use and processing time (in the training phase) have been designed implemented.

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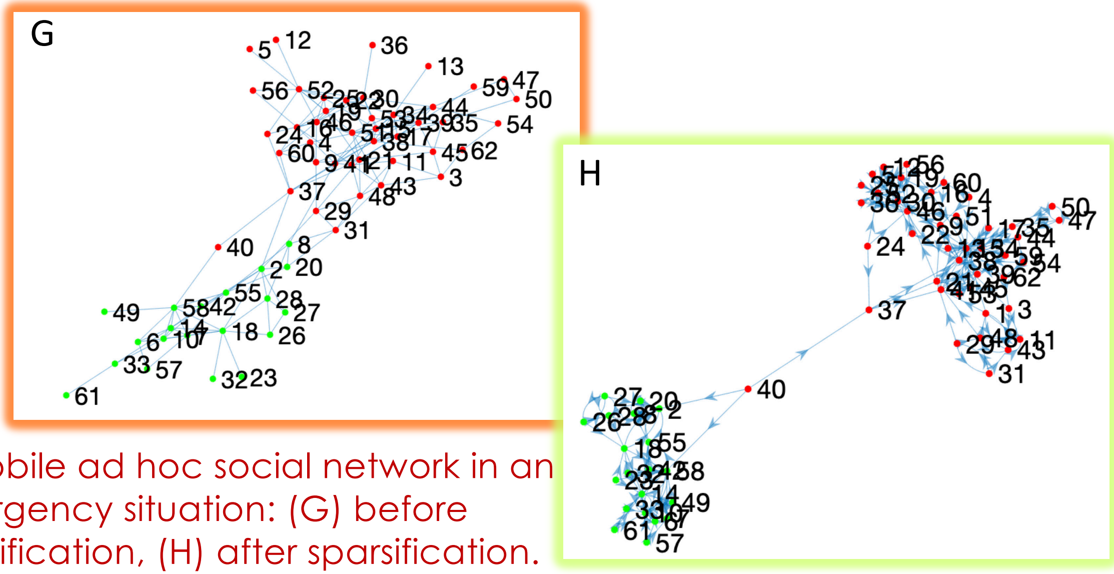
Disaster management situations – graph sparsification

- Disaster network science: novel discipline exploiting Complex Network theory to manage emergencies or disasters. Disaster network management common issues:
  - Fast detection of phenomena occurring in the network → timely response and intervention from public organization/rescue teams is a requirement
  - Energy lack→ in blackout situations, devices should process less information to save energy and prolong battery lifetime

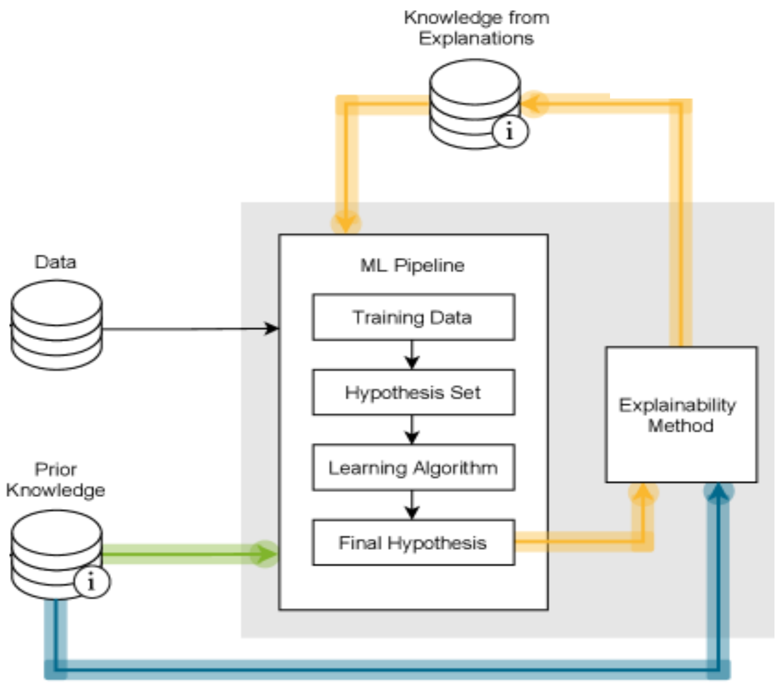


A mobile ad hoc social network in an emergency situation: (G) before sparsification, (H) after sparsification.

- Real-world networks, however, are characterized by
  - very-high edge density
  - weighted edges
- Analyzing such networks with computational methods is very hard → in disaster scenarios we need fast responses.
- *Solution: Graph sparsification,* build a sparse graph H from the original G by including a subset of edges of G
  - the most important edges are kept → less storage space, lower computational time to process it.

"Informed ML for Green Healthcare AI"

- **Goals**:
  - Make the training and application of ML-based models greener and more socially sustainable in AI-powered healthcare scenarios.
  - Exploit the knowledge and human expertise available in these scenarios for the sake of data- and compute- efficiency.
- **Approach:** Devise machine learning models & methods that
  - complement existing domain/task knowledge (e.g., diagnosis models/rules) with ML-based models induced from example data,
  - use conditional computation and model compression, and
  - integrate preference/constraints in both training and application.
- **Possible tasks** (if data, knowledge and experts are available)
  - Green-ML solutions for diagnosis; Green-ML solutions for care-flow process analysis and improvement; Green-ML solutions for healthcare Virtual Assistants.



Credit: Beckh, Müller, Jakobs, Toborek, Tan, Fischer, Welke, Houben, von Rueden, (2021), *ArXiv, abs/2105.10172*.

Some use cases

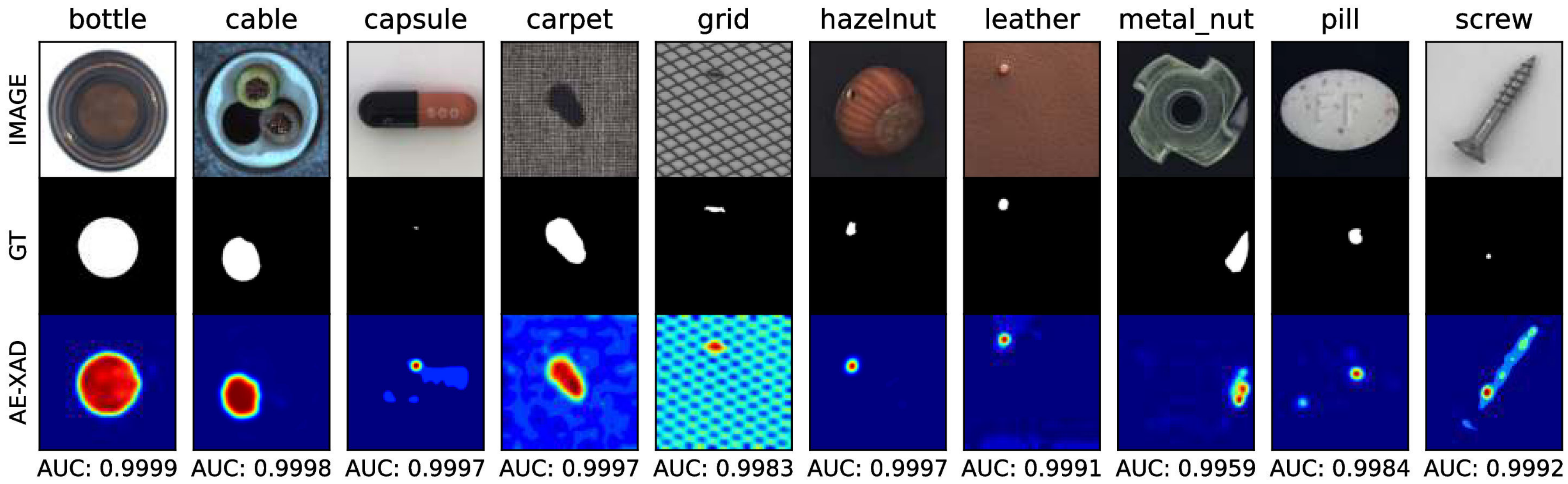
Social network analysis

- Opinion dynamics
- Information diffusion
- Reaction to decision

Some use cases

Outliers and anomaly detection

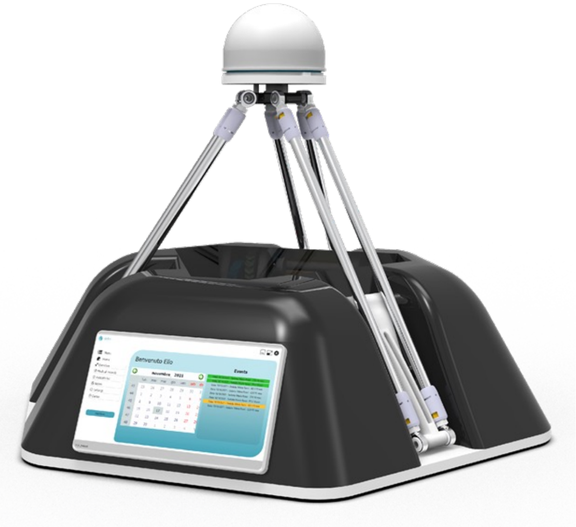
- Manufacturing defects
- Fraud detection
- Medical Data
- Cyber intrusion



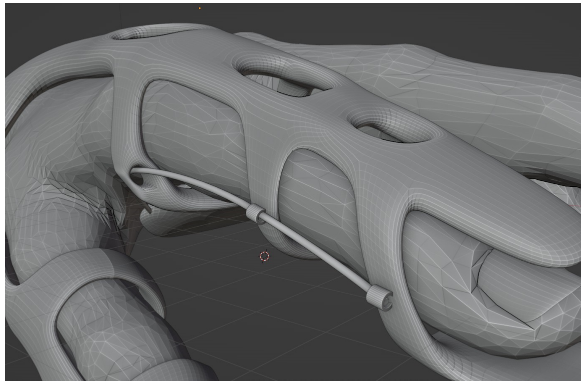
Some use cases

Engineering pilots

- Robotics
- Smart Materials
- Smart energy management
- Additive manufacturing and machining
- Human Activity and Emotion Recognition
- Battery Energy Storage System



Rehabilitation devices



Soft robotics