Spoke 10
Bio-socio-cognitive
AI
Massimiliano Pontil
Broad Objectives

- Draw inspiration from human and animal skills (from cognition to locomotion to social interactions) to design more efficient/resilient/interpretable/cooperative AI systems

- Understand how to leverage information from multiple data sources and across time, anticipating future, possibly long term, outcomes

- Combine machine learning (ML) with external manmade knowledge, with symbolic reasoning, and incorporating physical constraints in the form of mathematical equations

- Advance our understanding of core ML, especially when data arises from complex systems in science and engineering, with focus to Computational Chemistry and Robotics
Work-Packages

WP 10.1: **Neuro-inspired lifelong learning** (UNICT) PI: Concetto Spampinato

WP 10.2: **Multisensory learning and cross modal integration** (UNICT) PI: Sebastiano Battiato, co-PI: Maria Madonia

WP 10.3: **Egocentric Perception and 3D Vision** (UNICT-IIT) PIs: Giovanni M. Farinella, Alessio Del Bue

WP 10.4: **Physics informed machine learning** (IIT) PI: Michele Parrinello

WP 10.5: **Machine learning theory** (IIT) PI: Massimiliano Pontil

WP 10.6: **Embodied AI for Action and Perception** (IIT-UNICT) PIs: Lorenzo Natale, Paolo P. Arena

WP 10.7: **Grounded world models and hybrid reasoning** (CNR) PIs: Aldo Gangemi, Giovanni Pezzulo

WP 10.8: **Social, cooperative and collective intelligence** (CNR) PIs: Stefano Nolfi, Rino Falcone, co-PI: Daniela Giordano
Key Use Cases

1. Incremental and federated learning from medical image analysis and robot manipulation
2. Human-object interaction to provide augmented reality guidance for tool usage and safety reminders.
3. Accelerating simulations in computational chemistry through AI
4. Learning non-linear stochastic dynamical systems for time series (e.g., financial data, energy consumption, etc) analysis
5. Robot locomotion control and perception
**WP 10.1:** Neuro-inspired lifelong learning (UNICT)

**Task 10.1.4: Continual learning for robot manipulation**

- Code available

Contact persons: Concetto Spampinato (UNICT)
WP 10.1: Neuro-inspired lifelong learning (UNICT)

Task 10.1.4: Lifelong federated learning

- FedER: Federated Learning through Experience Replay for Medical Applications
- Code and data available

Contact persons: Concetto Spampinato (UNICT)
**WP 10.2: Multisensory cross-modal learning (UNICT)**

**Task 10.2.1: Multi-modal analysis of human**

- Longitudinal brain MRI study to segment multiple sclerosis lesions with deep learning techniques

- Code Available

- Dataset: ISBI 2015

Contact persons: Sebastiano Battiato (UNICT)
WP 10.3: Egocentric Perception and 3D Vision (UNICT-IIT)

Task 10.3.1: Self-training through exploration (IIT)

Object-detectors experience a drop in performance when deployed in new scenarios (e.g., new views gathered by a robotic agent exploring an environment).

Exploring actions with the aim of self-fine tuning its object detector (perception)

Contact persons: Alessio Del Bue (IIT)
**WP 10.3: Egocentric Perception and 3D Vision (UNICT-IIT)**

**Task 10.3.3: Modeling human-object interaction (UNICT)**

- Smart glasses with AI algorithms process images and videos to recognize human-object interactions, providing augmented reality guidance for tool usage and safety reminders.

- Code Available
- Datasets: Ego4D, Meccano

**Contact persons:** Giovanni Farinella (UNICT)
WP 10.4: Physics informed machine learning (IIT)

Task 10.4.1: Use AI to accelerate simulations in computational chemistry and beyond

- Use ML to predict the energy potential of complex chemical systems
- Graph neural networks and kernel methods
- Datasets: OC20 challenge

Contact persons: Massimilano Pontil, Michele Parrinello (IIT)
WP 10.5: Machine learning theory (IIT)

Task 10.5.1: Few-shot Learning, Pre-training and Meta-learning

- Meta-learning and transfer learning have several potential applications

- We proposed a theory which explain the empirical advantage of pretraining over standard meta-learning approaches to learn representations

Contact person: Massimilano Pontil (IIT)
WP 10.5: Machine learning theory (IIT)

Task 10.5.2: Machine learning methods for dynamical systems

- Novel cutting edge methods for learning non-linear stochastic dynamical systems
- Potential applications include financial data analysis, predicting energy prices, weather forecasting
- Code available

Contact person: Massimilano Pontil (IIT)
WP 10.6: Embodied AI for Action and Perception (IIT-UNICT)

Task 10.6.2: Use AI for robust locomotion control and perception (IIT)

To combine proprioceptive and exteroceptive sensor information and enhance the legged robots understanding of terrain traversability, ultimately to improve the footstep planning and robot stabilization.

- Use of **multimodal information** to map the environment, detect obstacles and classify terrain types
- Use of **realistic simulators**

Contact person: Lorenzo Natale (IIT)
WP 10.6: Embodied AI for Action and Perception (IIT-UNICT)

Task 10.6.2: Learning task-related object properties from multimodal integration and interaction (IIT)

Investigate learning methods for interacting with objects, using multi-modal information. Leverage foundation models devising methods to complement prior knowledge with robot’s experience and human interaction.

Application: robot grasping and object manipulation

Contact person: Lorenzo Natale (IIT)
WP 10.7: Grounded world models and hybrid reasoning (CNR)

Open-ended learning for robot pick-and-place in unstructured environments

Robot architecture using open-ended learning to pick-and-place small objects in shelves
Robot: Kuka arm-gripper; R-GBD camera with a deep network for segmentation, identification and grasping
Benchmark: KPIs in a simulated and real “warehouse” environment requiring picking objects from shelves

Contact person: Gianluca Baldassarre, Aldo Gangemi (CNR)