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NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Future Artificial Intelligence Research

Spoke 10
Bio-socio-cognitive AI

Massimiliano Pontil

Future Artificial Intelligence Research

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

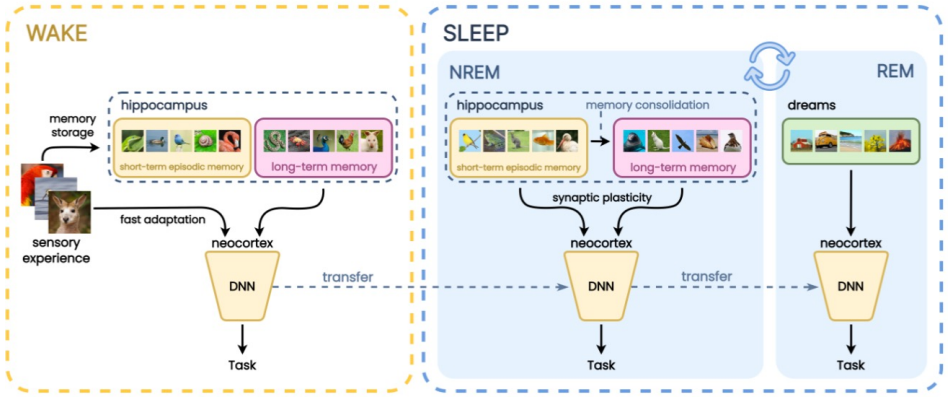
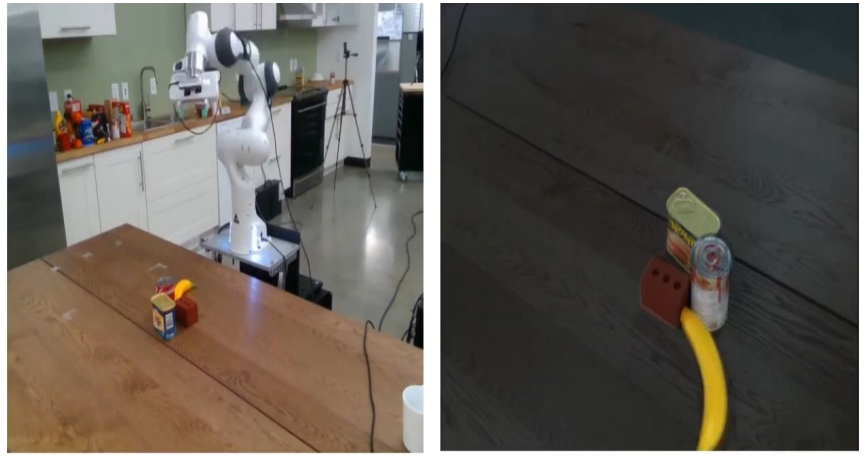


Fig. 1: **Wake-Sleep Consolidated Learning**: in the wake stage, the model (which emulates the neocortex) fast adapts to the

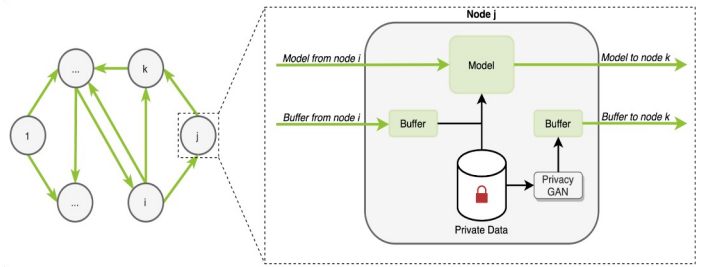


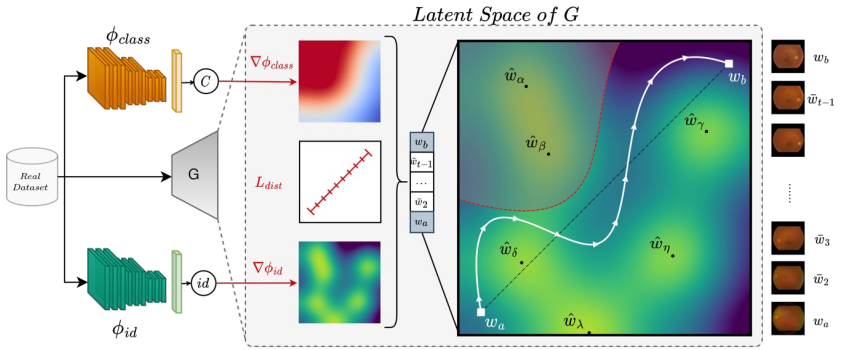
Contact persons: Concetto Spampinato (UNICT)

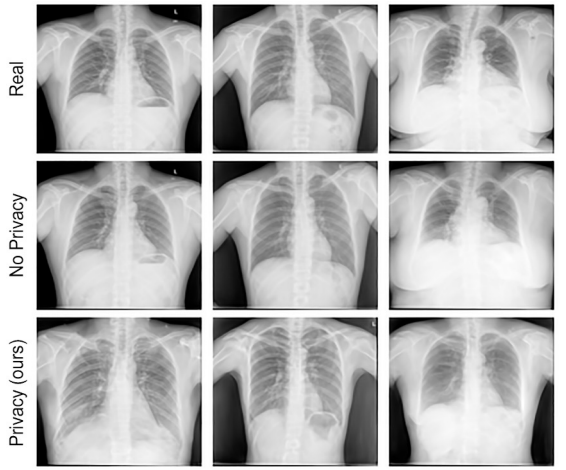
WP 10.1: Neuro-inspired lifelong learning (UNICT)

Task 10.1.4: Lifelong federated learning

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

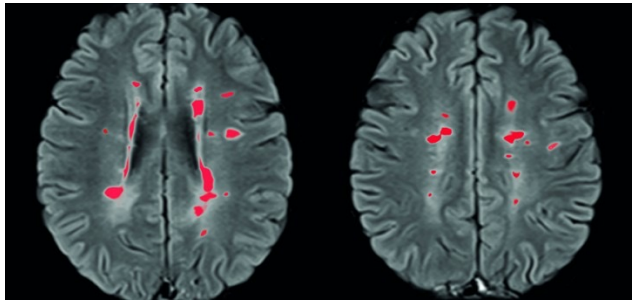






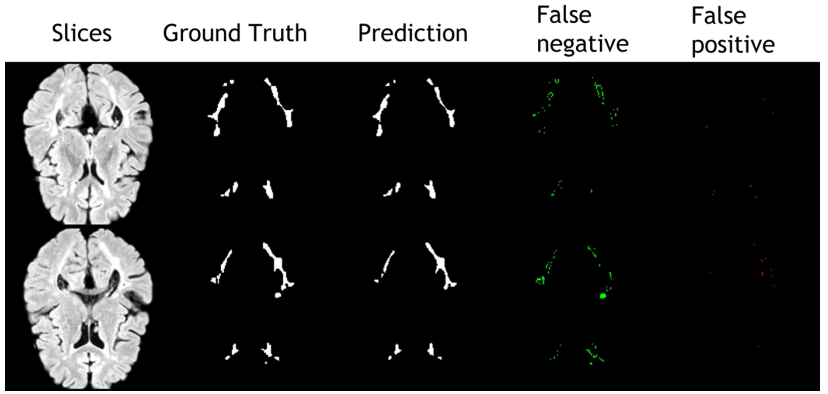
Contact persons: Concetto Spampinato (UNICT)

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)

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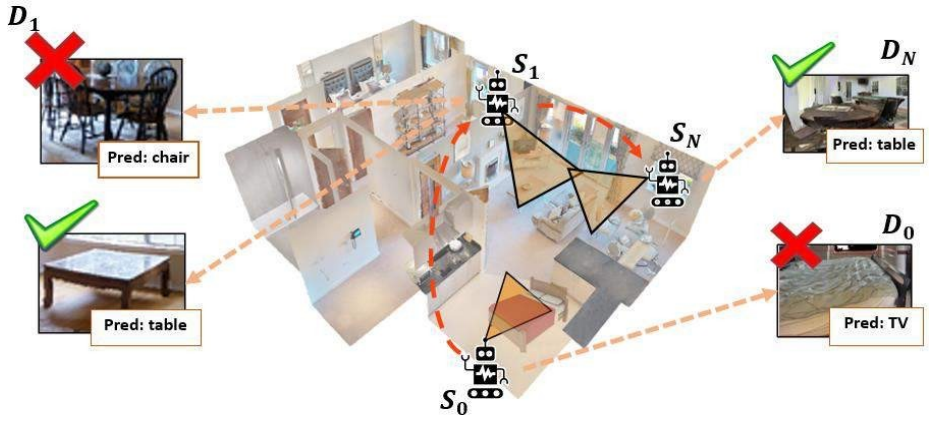
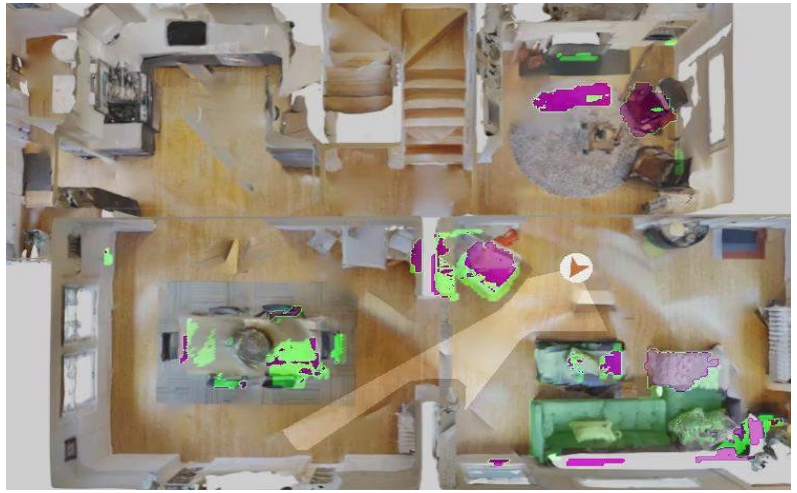
WP 10.3: Egocentric Perception and 3D Vision (UNICT-IIT)

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)

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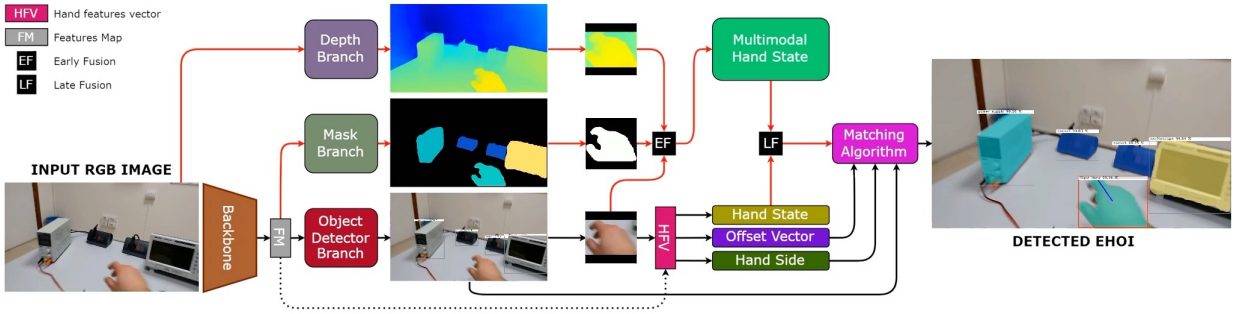
WP 10.3: Egocentric Perception and 3D Vision (UNICT-IIT)

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)

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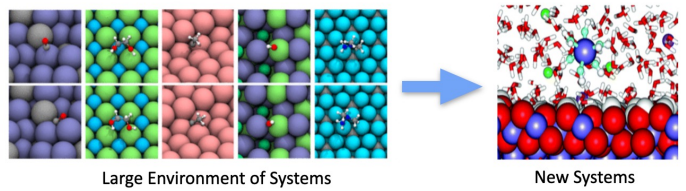
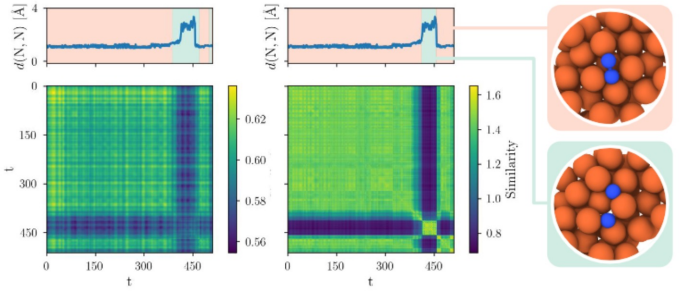
WP 10.4: Physics informed machine learning (IIT)

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



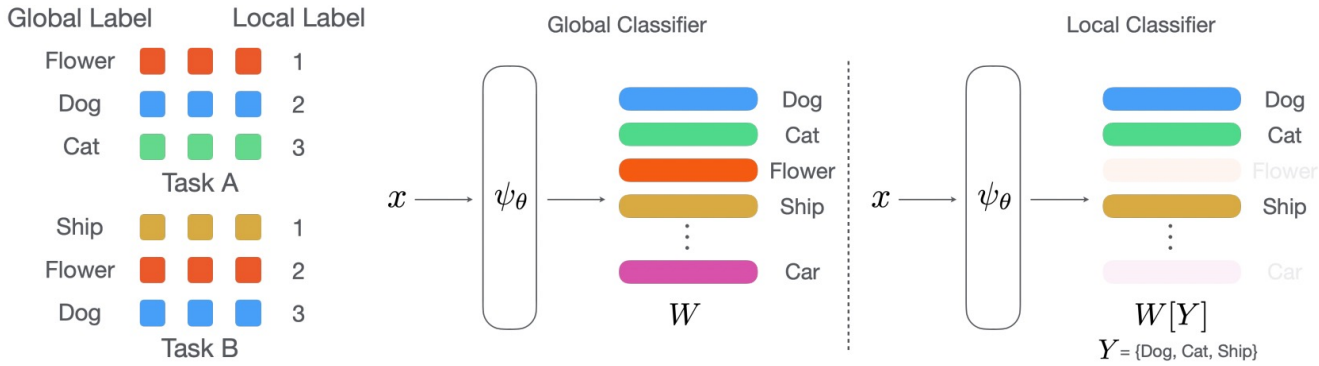


Contact persons: Massimilano Pontil, Michele Parrinello (IIT)

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

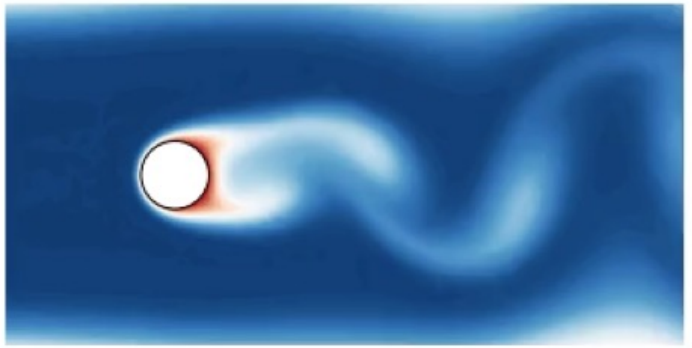


Contact person: Massimilano Pontil (IIT)

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)

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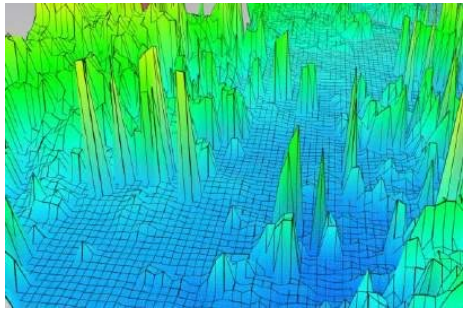
WP 10.6: Embodied AI for Action and Perception (IIT-UNICT)

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)

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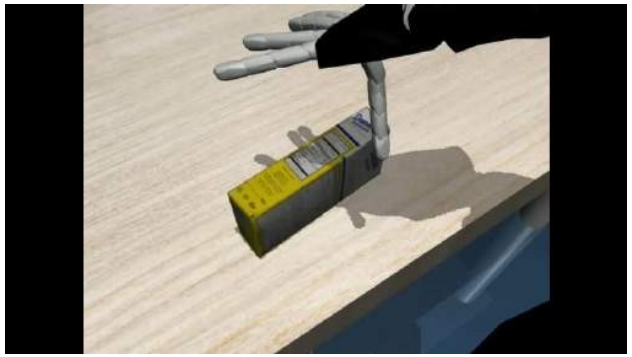
WP 10.6: Embodied AI for Action and Perception (IIT-UNICT)

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

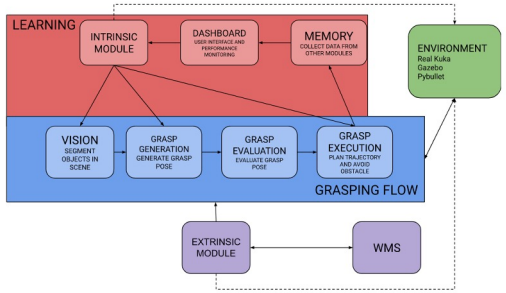


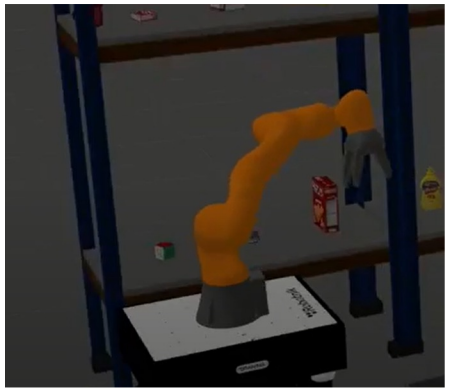
Contact person: Lorenzo Natale (IIT)

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)