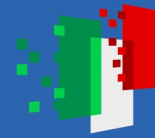




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Spoke 4 Adaptive AI

Nicola Gatti
Politecnico di Milano



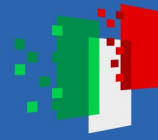
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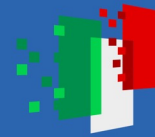




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People



POLITECNICO
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Scientific Sector	Critical mass	RTDA
Computer engineering	16	6
Control engineering	3	1
Bioengineering	2	1
Mathematical engineering	2	1
Philosophy	1	1
Electronic engineering	1	
Energy engineering	1	
Computer science	1	

Bocconi

Scientific Sector	Critical mass	RTDA
Theoretical physics	2	1
Statistics	1	1
Economic statistics	1	
Bioengineering	1	



Market research and trends



Entrepreneurship (TRL 5 — 9)

AIRIC



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Applied research (TRL 3 — 5)

Artificial Intelligence Research and Innovation Center



e l l i s European Laboratory for Learning and Intelligent Systems

MILAN

Foundational research (TRL 1 — 3)





AI Seminars: 2023

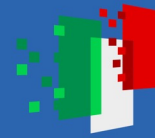
- 22 seminars in 2023 (one seminar every 2 weeks)
- speakers: every researcher working in/with AI
- guest speakers: MIT, Cambridge, Pompeu Fabra
- open to: students, PhDs, industries
- >100 physical attendees per seminar
- online streaming on YouTube channel



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Adaptive AI

Adaptivity

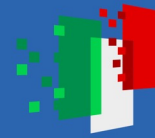
The algorithm changes its behavior



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The algorithm changes its behavior

Why?

Several reasons



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Adaptivity

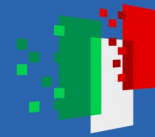
The algorithm changes its behavior

Why?

Several reasons

agent level

agent level: the agent's goals change or
new information is collected



Adaptive AI

Adaptivity

The algorithm changes its behavior

Why?

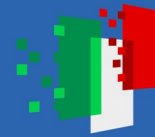
Several reasons

agent level

Online learning

- The learner collects information during its execution
- *Exploration* and *exploitation* are simultaneous
- The learner adapts its decision to the acquired information dealing with uncertainty
- Applications: *advertising, pricing*

agent level: the agent's goals change or new information is collected



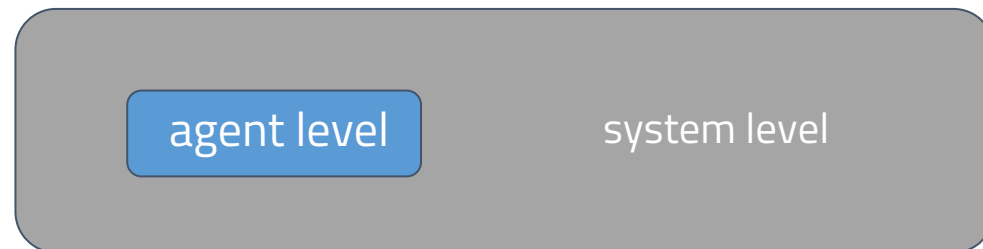
Adaptive AI

Adaptivity

The algorithm changes its behavior

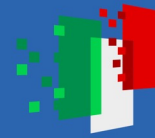
Why?

Several reasons



agent level: the agent's goals change or new information is collected

system level: the performance of the system is degrading



Adaptive AI

Adaptivity

The algorithm changes its behavior

Why?

Several reasons

agent level

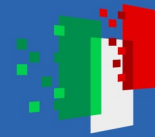
system level

Adaptive maintenance

- The system functioning may degrade at operation time
- *The algorithm aims at correcting the system change*
- In other case, the system can use a different hardware
- Applications: *manufacturing*

agent level: the agent's goals change or new information is collected

system level: the performance of the system is degrading



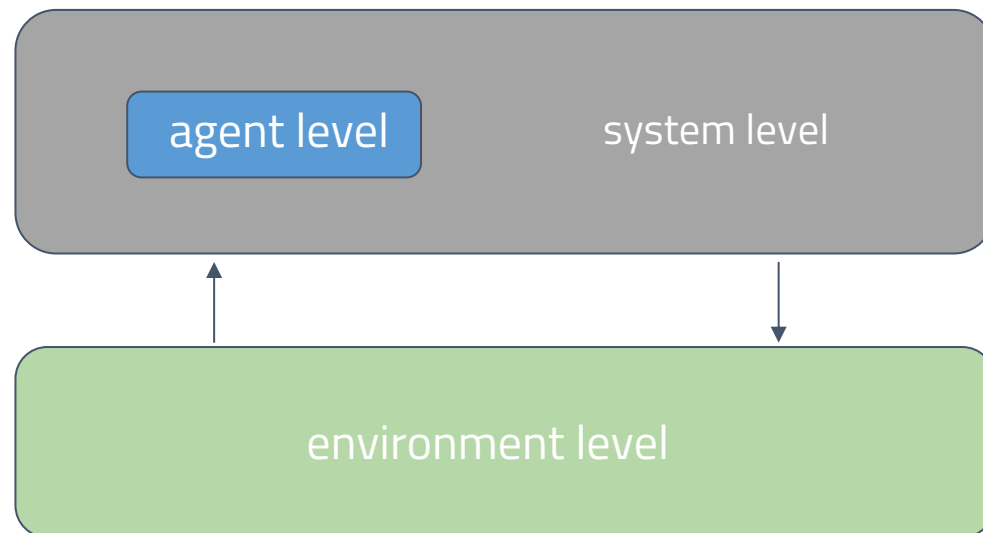
Adaptive AI

Adaptivity

The algorithm changes its behavior

Why?

Several reasons



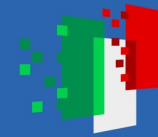
Adaptive maintenance

- The system functioning may degrade at operation time
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agent level: the agent's goals change or new information is collected

system level: the performance of the system is degrading

environment level: the environment changes



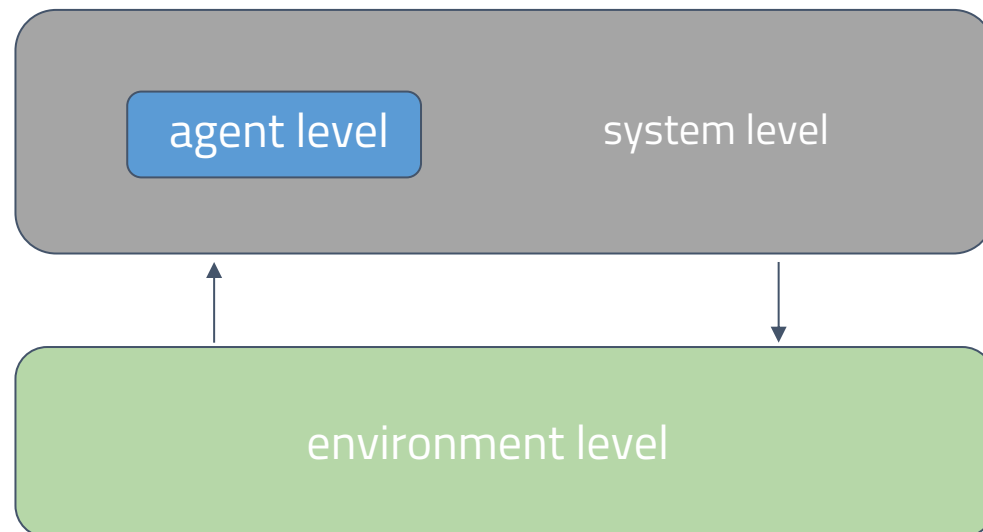
Adaptive AI

Adaptivity

The algorithm changes its behavior

Why?

Several reasons



Stochastic environment

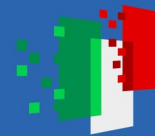
Forecasting

- The environment can change
- *New state prediction*
- Applications: *time-series, trading*

agent level: the agent's goals change or new information is collected

system level: the performance of the system is degrading

environment level: the environment changes



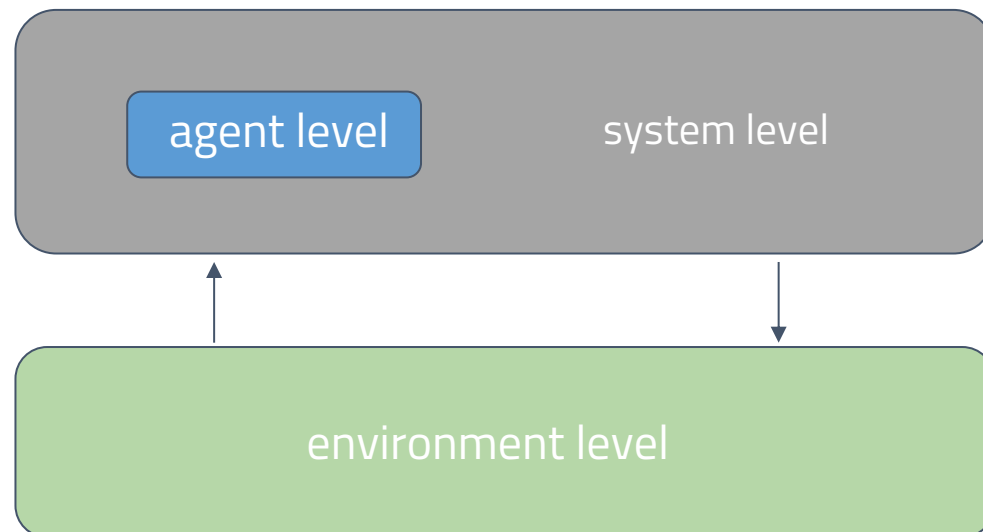
Adaptive AI

Adaptivity

The algorithm changes its behavior

Why?

Several reasons



Stochastic environment

Forecasting

- The environment can change
- *New state prediction*
- Applications: *time-series, trading*

Adversarial environment

Strategic interaction

- Multiple agents play simultaneously
- *Optimal strategy*
- Applications: *real-time bidding, games*

agent level: the agent's goals change or new information is collected

system level: the performance of the system is degrading

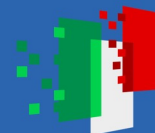
environment level: the environment changes



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Robust Adaptive AI

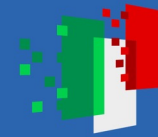
Adaptivity



Dynamics



Properties



Robust Adaptive AI

Adaptivity



Dynamics



Properties



Convergence

Speed

Constraints

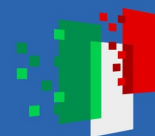
- **Last-iterate**
- **On average**
- **With high probability**

- **Regret bounds**

- **Decentralized dynamics**
- **Distributed dynamics**
- **Centralized dynamics**

- **Communication**

- **Physics-based models**
- **Approximating dynamics**
- **Surrogate models**
- **Overparameterized**



Robust Adaptive AI

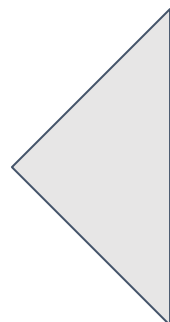
Adaptivity



Dynamics



Properties



Convergence

Speed

Constraints

- Last-iterate
- On average
- With high probability

- Regret bounds

- Decentralized dynamics
- Distributed dynamics
- Centralized dynamics

- Communication

- Physics-based models
- Approximating dynamics
- Surrogate models
- Overparameterized

- Reinforcement learning
- Online learning
- Bandit algorithms
- Online convex optimization
- Game theory
- Multi-agent learning
- Deep learning
- Physics-based learning
- Change detection tests

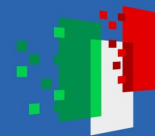
- Computer vision
- Natural language processing



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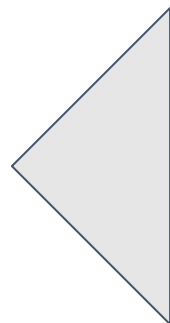
Adaptivity



Dynamics



Properties



Convergence

Speed

Constraints



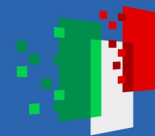
Assumption



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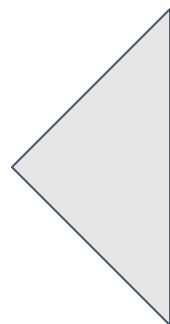
Adaptivity



Dynamics



Properties



Convergence

Speed

Constraints



Assumption



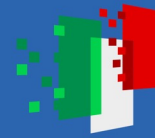
**Real-world
requirements**



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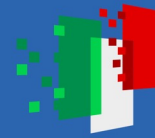
Foundational questions



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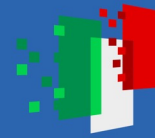
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Foundational questions

Question 4.1 How to develop a unifying theory of single- and multi-agent adaptivity, where adaptivity at different levels (environment, system, agent) are harmonized?

WP4.3 (Zecchina, Cesa-Bianchi, Restelli)

Overparameterized problems



Foundational questions

- Question 4.1** How to develop a unifying theory of single- and multi-agent adaptivity, where adaptivity at different levels (environment, system, agent) are harmonized?
- Question 4.2** How to develop a machine learning theory to deal with complex non-convex, overparameterized problems?

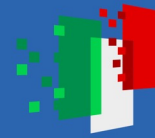
WP4.3 (Zecchina, Cesa-Bianchi, Restelli)

Overparameterized problems

**WP4.1 (Roveri, Dedè,
Mezard)**

**Adaptive algorithms in
single-agent setting**

**WP4.2 (Amigoni,
Schiaffonati, Prandini)**
**Adaptive algorithms in multi-
agent setting**



Foundational questions

- Question 4.1** How to develop a unifying theory of single- and multi-agent adaptivity, where adaptivity at different levels (environment, system, agent) are harmonized?
- Question 4.2** How to develop a machine learning theory to deal with complex non-convex, overparameterized problems?
- Question 4.3** How adaptivity theory can lead to the development of concrete applications?

WP4.3 (Zecchina, Cesa-Bianchi, Restelli)

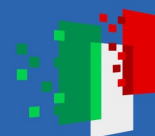
Overparameterized problems

WP4.1 (Roveri, Dedè,
Mezard)
Adaptive algorithms in
single-agent setting

WP4.2 (Amigoni,
Schiaffonati, Prandini)
Adaptive algorithms in multi-
agent setting

WP4.4 (Ceri, Paganoni,
Buffa)
Personalized medicine

WP4.5 (Matera, Boracchi,
Matteucci)
Multimodal interaction



Foundational questions

- Question 4.1** How to develop a unifying theory of single- and multi-agent adaptivity, where adaptivity at different levels (environment, system, agent) are harmonized?
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