Spoke 4: Adaptive AI
Nicola Gatti
(co-PI: Nicolò Cesa-Bianchi)
### People

<table>
<thead>
<tr>
<th>Scientific Sector</th>
<th>Critical mass</th>
<th>RTDA</th>
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<tbody>
<tr>
<td>Computer engineering</td>
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<td>6</td>
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<tr>
<td>Control engineering</td>
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<tr>
<td>Bioengineering</td>
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<tr>
<td>Mathematical engineering</td>
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<td>Philosophy</td>
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<td>Electronic engineering</td>
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<td>Statistics</td>
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<tr>
<td>Bioengineering</td>
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Market research and trends

Entrepreneurship (TRL 5 – 9)

Applied research (TRL 3 – 5)

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
Adaptive AI

Adaptivity  The algorithm changes its behavior
Adaptive AI

**Adaptivity**  The algorithm changes its behavior

**Why?**  Several reasons
Adaptive AI

Adaptivity  The algorithm changes its behavior

Why?  Several reasons

agent level: the agent’s goals change or new information is collected
Adaptive AI

Adaptivity  The algorithm changes its behavior

Why?  Several reasons

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
Adaptivity  The algorithm changes its behavior

Why?  Several reasons

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

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

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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
- Environment level: The environment changes

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

Applications:
- Time-series, trading
- Real-time bidding, games
Robust Adaptive AI

Adaptivity

\[ \downarrow \]

Dynamics

\[ \downarrow \]

Properties
Robust Adaptive AI

- 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

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- On average
- With high probability
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- Physics-based models
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- 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
Robust Adaptive AI

- Adaptivity
  - Dynamics
    - Properties
      - Convergence
      - Speed
      - Constraints
  - Assumptions
Robust Adaptive AI

Adaptivity

Dynamics

Properties

Convergence
Speed
Constraints

Assumptions

Real-world requirements
Foundational questions
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?

WP4.1 (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?
Foundational questions

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Adaptive algorithms in single-agent setting

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Adaptive algorithms in multi-agent setting

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

Question 4.2 How to develop a machine learning theory to deal with complex non-convex, overparameterized problems?

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

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

Question 4.3 How adaptivity theory can lead to the development of concrete applications?
Foundational questions

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**Question 4.3** How adaptivity theory can lead to the development of concrete applications?