Francesco De Lellis

Nonlinear and distributed control strategies based on reinforcement learning for complex and multi-agent systems

Tutor: prof. Mario di Bernardo
co-Tutor: prof. Giovanni Russo

Cycle: XXXV

Year: 2021

My background

- MSc degree in Control Engineering
- Member of the research group on “Sincronizzazione e Controllo di Reti e Processi” (SINCRO)
- PhD start date: 01/11/2019
- Scholarship: University of Naples Federico II ITEE grant
- Ongoing collaborations:
  - Prof. Giovanni Russo from University of Salerno
  - Prof. Mirco Musolesi from University College London

Research field of interest

- Reinforcement learning (RL) offers powerful algorithms to search for optimal controllers of systems with nonlinear, possibly stochastic dynamics that are unknown or highly uncertain
- State of the art RL encounters different limitations when applied to develop Control Strategies for dynamical systems:
  - Data efficiency
  - High-dimensional continuous state and action spaces
  - Training off-line: Safety
- For these reasons I am putting effort into adapting existing Reinforcement Learning strategies specifically for control application by:
  - Leveraging partial/incorrect modeling
  - Driving the learning process with partially faulty control laws

Summary of study activities

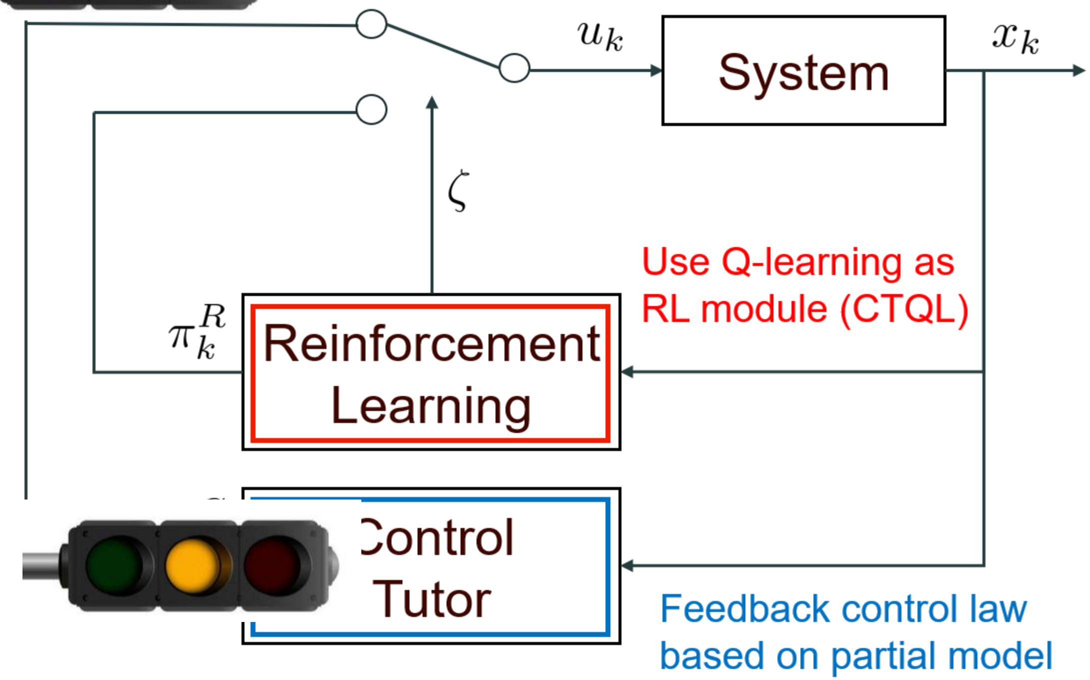
- The study activities have been focused on testing the Control Tutored Reinforcement Learning strategy developed during the studies
- Ad hoc PhD courses / schools:
  – Reinforcement Learning Virtual School
  – FMG Data-Driven Control Summer School
  – IELTS Course organized by CLA
  – Strategic Orientation for STEM research and writing
- Conferences / events attended:
  – European Control Conference 2021 (ECC21)
  – SIAM Conference on Applications of Dynamical Systems (DS21)
  – IEEE International Workshop on Cellular Nanoscale Networks and their Applications (CNNA21)

Research activity(1)

- The **research idea**: 
  - Determine under which condition it is useful to bring control laws into RL algorithms
  - Determine what kind of advantages these strategies can have in the control of dynamical system
- The **methodologies:** 
  - Defining the key features of the RL part and the Control part
  - Apply the strategy on a unified framework (e.g.OpenAI gym)
  - Compare the results with the existing solution in literature

Research activity(2)

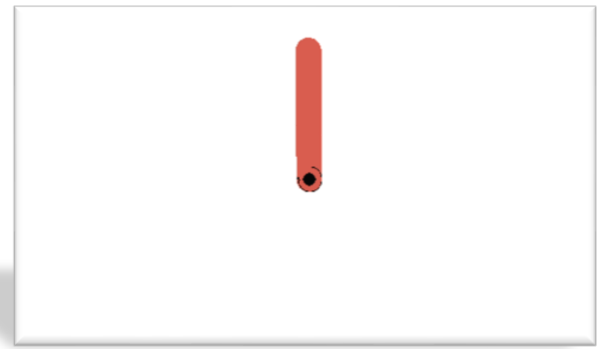
- The **developments**:
  - Formalization of the Control Tutor Reinforcement Learning
  - The CTQL strategy
  - Deep CTQL

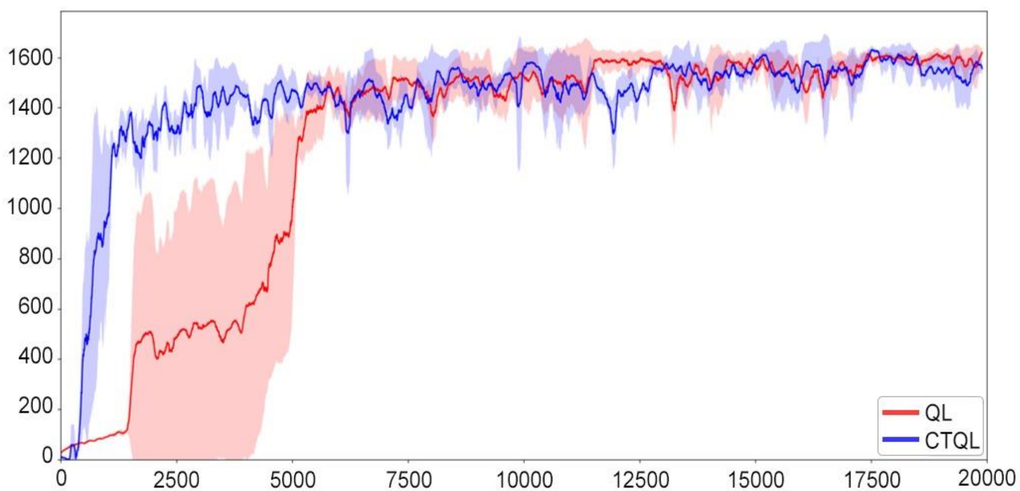


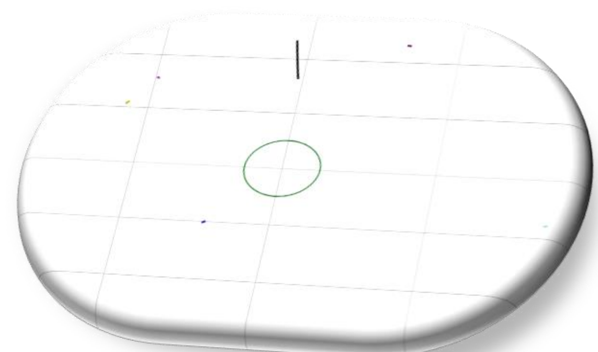
- The **expected results:**
  - Shorter learning times
  - Increased robustness of the final control solution
  - Less dependency on the hyperparameter tuning

activity and future research

- The **validation**: 
  - Validation of novel strategies have to be done on a unified framework like the OpenAI gym
  - The benchmarking has to be done with the use of specific metrics







Products

[P1]	Francesco De Lellis, Giovanni Russo, and Mario di Bernardo. *"Tutoring Reinforcement Learning via Feedback Control", European Control Conference (ECC), 2021*
[P2]	Francesco De Lellis, Fabrizia Auletta, Giovanni Russo, Pietro De Lellis and Mario di Bernardo. *"An Application of Control-Tutored Reinforcement Learning to the Herding Problem",* IEEE International Workshop on Cellular Nanoscale Networks and their Applications (CNNA), 2021
[P3]	Marco Coraggio, Shihao Xie, Francesco De Lellis, Giovanni Russo, Mario di Bernardo. *"Intermittent non-pharmaceutical strategies to mitigate the COVID-19 epidemic in a network model of Italy via constrained optimization "*, Accepted by Conference of Decision and Control (CDC), 2021

Next years

- First year credits:

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	3.2	8	0.24	11.44
Bimonth 2	3.6	2.8	8	0.24	14.64
Bimonth 3	0	5.4	5	0.16	10.56
Bimonth 4	5	3.8	6	0.32	15.12
Bimonth 5	0	1.6	6	0.28	7.88
Bimonth 6	4	2.4	8	0.1	14.5
Total	12.6	19.2	41	1.34	74.14
Expected	10 - 20	5 - 10	30 - 45	0 – 1.6	45 – 96.6

Didactic support for the course
Dinamica e Controllo Non Lineare

- Expected credits:

	Courses	Seminars	Research	Tutorship	Total
Year 1	10.6	6.8	41.6	1.6	61
Year 2	12.6	19.2	41	1.34	74.14
Year 3	6.8	0	60	1.6	68.6