Francesco De Lellis

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

Tutor: Mario di Bernardo co-Tutor: Giovanni Russo

(University of Salerno)

Cycle: XXXV Year:2020

My background

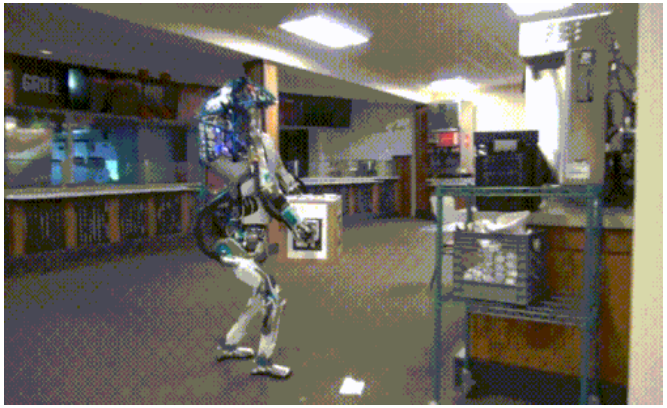
- MSc degree in Control Engineering
- Member of research group on “Sincronizzazione e Controllo di Reti e Processi” (SINCRO)
- PhD start date: 01/11/2019
- Scholarship: University of Naples Federico II ITEE grant

Summary of study activities

- My research has been focused on finding ways to combine model-based nonlinear control approaches with Reinforcement Learning (RL) algorithms
- Ad hoc PhD courses / schools
  - Machine Learning
  - Model Predictive Control
- Courses attended borrowed from MSc curricula
  - Statistical Learning
- Conferences / events attended
  - IEEE CSS Modeling and Control the COVID-19 outbreak
  - Learning for Dynamics and Control (L4DC)
  - Second Symposium on Machine Learning and Dynamical Systems

Research field of interest

- Reinforcement Learning can be used to control unknown and uncertain systems but requires much data and long learning times
- My goal is to combine nonlinear control methods with Reinforcement Learning
- **key research question:** Can we use control based approaches to enhance Reinforcement Learning algorithms and improve data efficiency while reducing learning times?

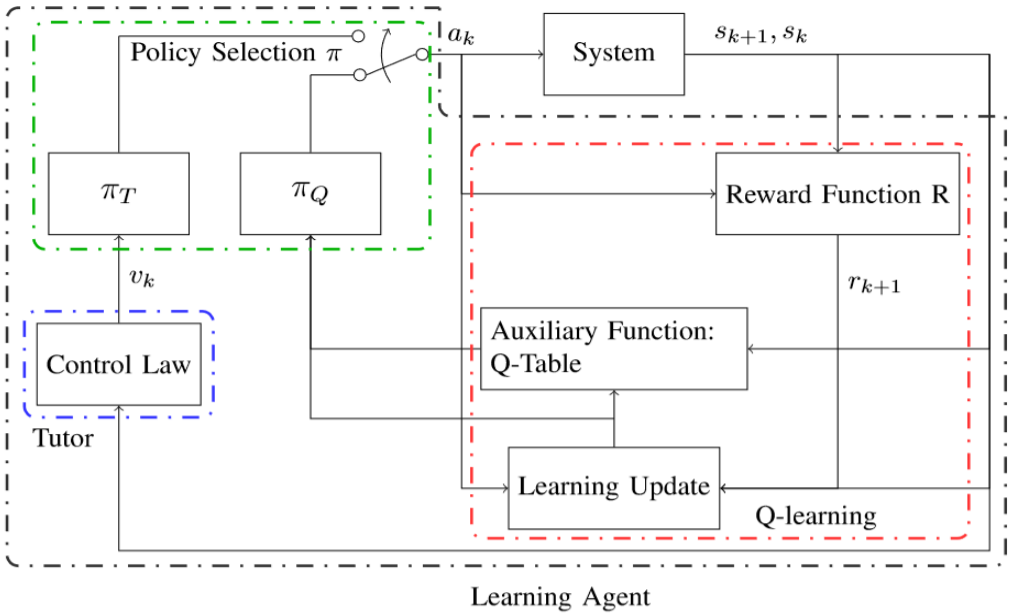


Research activity(1)

- **research idea** :
  - Develop feedback control schemes combining nonlinear control laws with RL algorithms
  - Characterize stability and performance of such hybrid strategies both numerically and analytically
- **methodology**
  - Formulate the control problem as a constrained optimization problem (MDP)
  - Analyze the convergence and stability of the control and the data efficiency of the new algorithm
  - Validate numerically on a set of benchmark problems

Research activity(2)

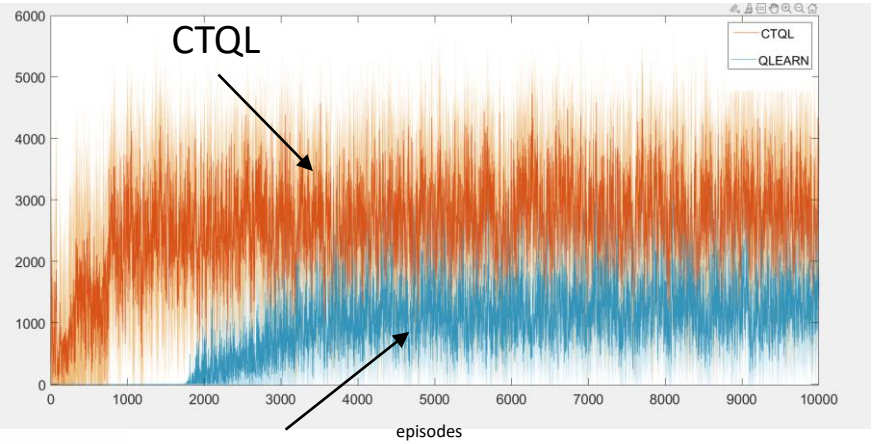
- **Developments**:
  - Formalization of a new Control-Tutored Q-Learning strategy



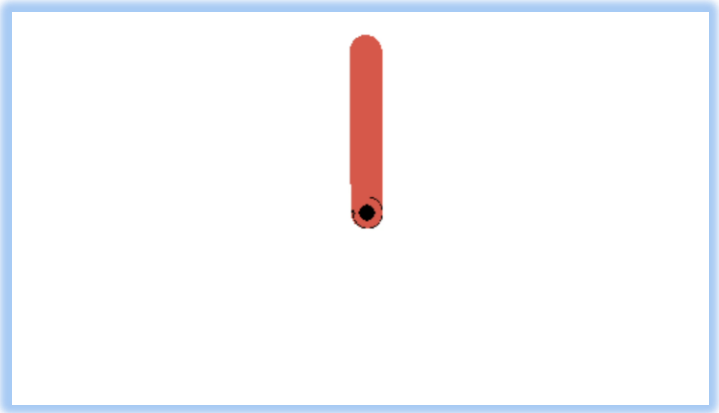
- **Expected results**
  - Shorter learning times and better data efficiency
  - Increased robustness of the final control solution
  - Less dependency on the hyperparameter tuning

Research activity(3)

- **Validation**:
  - Validation of novel strategies is carried out on a unified framework like the OpenAI gym to compare the solutions with those already existing in literature
  - Benchmarking is done via a set of metrics to assess control performance and RL process



QL



Inverted Pendulum Stabilization using CTQL

Products

[P1]	F. Della Rossa*, D. Salzano*, A. Di Meglio*, F. De Lellis*, M. Coraggio, C. Calabrese, A. Guarino, R. Cardona-Rivera, P. De Lellis, D. Liuzza, F. Lo Iudice, G. Russo, M. di Bernardo, "A network model of Italy shows that intermittent regional strategies can alleviate the COVID-19 epidemic", *Nature Communications*, 11, 5106, 2020.
[P2]	F. De Lellis, F. Auletta, G. Russo, P. De Lellis, M. di Bernardo,"Control-Tutored Reinforcemen Learning", arXiv:1912.06085, 2019,

Next years

- First year credits:

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	0.4	9.6	0	10
Bimonth 2	0	0.2	9.8	0	10
Bimonth 3	0	1.6	8.2	0.5	10.3
Bimonth 4	7	2.4	5	0.5	14.9
Bimonth 5	3.6	1	5	0	9.6
Bimonth 6	0	1.6	4	0.6	6.2
Total	10.6	6.8	41.6	0	61
Expected	20 - 40	5 - 10	10 - 35	0 – 1.6	35 – 86.6

- Expected credits:

	Courses	Seminars	Research	Tutorship	Total
Year 2	20	5	40	1.6	66.6
Year 3	0	0	60	1.6	61.6