



## **Reinforcement Learning Based Systems**

<b>Course Code:</b>	28656
<b>Course Type:</b>	Theoretical
<b>Credits:</b>	3
<b>Course Status:</b>	Elective Specialized Graduate Course
<b>Prerequisite:</b>	Supervisor Approval

**Aim/Scope/Objectives:** This course intends to give graduate students the required knowledge for designing intelligent systems based on reinforcement learning, in which the system learns through the interaction between its agents and the environment. This course covers all the required bases, and the students are trained to implement a research project in Python. This course has extensive applications in robotics, biomechanics, control, and decision-making in complex systems.

### ***Course Outline:***

#### **1- An overview on Learning Based Systems**

- 1-1- Introducing different learning based systems
- 1-2- Basic elements of a reinforcement learning system
- 1-3- Examples for reinforcement learning systems

#### **2- The Official form of Reinforcement Learning Problem**

- 2-1- Different structures of intelligent agents
- 2-2- Environment characteristics
- 2-3- Markov decision feature in reinforcement learning problems
- 2-4- Value functions
- 2-5- Optimal policy and Bellman optimality equations

#### **3- Methods of Action Selection**

- 3-1- Approximation of action-value
- 3-2- Direct and search methods
- 3-3- Improvement of Softmax search method
- 3-4- Upper confidence bound (UCB) action selection

#### **4- Dynamic Programing**

- 4-1- Policy evaluation
- 4-2- Policy improvement
- 4-3- Policy iteration
- 4-4- Value iteration
- 4-5- Performance of dynamic programing

#### **5- Monte Carlo Methods**

- 5-1- Monte Carlo value function prediction
- 5-2- Monte Carlo action-value function prediction
- 5-3- Monte Carlo control
- 5-4- On-policy Monte Carlo control
- 5-5- Generalized Policy Iteration (GPI)
- 5-6- Off-policy Monte Carlo control

#### **6- Temporal-Difference Learning**

- 6-1- TD prediction
- 6-2- Batch updating in TD



- 6-3- Control based on TD
  - 6-3-1 Sarsa learning algorithm
  - 6-3-2 Q-learning learning algorithm
  - 6-3-3 Expected Sarsa learning algorithm
- 6-4- Evaluation methods of reinforcement learning algorithms
- 7- n- Step Temporal-Difference Learning and Eligibility Trace**
  - 7-1- n- Step bootstrapping methods
    - 7-1-1 n-Step TD prediction
    - 7-1-2 n-Step Sarsa learning algorithm
  - 7-2- Eligibility trace
    - 7-2-1 TD( $\lambda$ ) prediction
    - 7-2-2 Sarsa ( $\lambda$ ) learning algorithm
- 8- Important Topics in Reinforcement Learning**
  - 8-1- Generalization in Reinforcement Learning
  - 8-2- Deep Reinforcement Learning and DQN
  - 8-3- Policy Gradient Methods
  - 8-4- Actor-Critic Methods
  - 8-5- Imitation Learning
  - 8-6- Maximum Entropy Reinforcement Learning
- 9- Advance Deep Reinforcement Learning Structures**
  - 9-1- Deep Deterministic Policy Gradient (DDPG)
  - 9-2- Twin Delayed Deep Deterministic Policy Gradient (TD3)
  - 9-3- Soft Actor Critic (SAC)
  - 9-4- Trust Region Policy Optimization (TRPO)
  - 9-5- Proximal Policy Optimization (PPO)
  - 9-6- Asynchronous Advantage Actor-Critic (A3C)
  - 9-7- Synchronous Advantage Actor Critic (A2C)
  - 9-8- Safe Reinforcement Learning
  - 9-9- Multi-Agent Reinforcement Learning

**Grading:** 50% Final exam, 20% Homework, 30% Term paper

**References:**

- 1- Richard S. Sutton, Andrew G. Barto, "Reinforcement Learning: An Introduction", second edition, MIT press, 2018.
- 2- Hao Dong, Zihan Ding, Shanghang Zhang, "Deep Reinforcement Learning, Fundamentals, Research and Applications, Springer, 2020.
- 3- Miugel Morales, "Grokking Deep Reinforcement Learning", Manning Co., 2022.
- 4- Stefano V. Albrecht, "Multi-Agent Reinforcement Learning Foundations and Modern Approaches", MIT Press, 2024.
- 5- Thanh T. Nguyen, et al. , "A multi-objective deep reinforcement learning framework", Engineering Applications of Artificial Intelligence, Vol. 96, 2020.
- 6- Aske Plaat, "Deep Reinforcement Learning", Springer, 2022.
- 7- Ivan Gridin, "Practical Deep Reinforcement Learning with Python", BPB online, 2022.
- 8- Maxim Lapan,"Deep Reinforcement Learning Hands-On", Second edition, Packt, 2020.
- 9- Sudharsan Ravichandiran, "Hands on Reinforcement Learning with Python", Packt, 2018.
- 10- Andrea Lonza, "Reinforcement Learning Algorithms with Python", Packt, 2019.