

1. Course Number and Course Title:

ML 508 – Cognitive Robotics

2. Credit Hours: 3 – 0 – 3

3. Prerequisites and/or Co-Requisites:

Prerequisite: Approval of the CSE Head of Department

Co-requisites: None

Competencies: Undergraduate-level knowledge of Artificial Intelligence and programming.

4. Name and Contact Information of Instructor:

Name: Dr. Michel Pasquier

Email: mpasquier@aus.edu

Office: ESB 2057

Phone: 06 515 2883

Office Hours: Posted on office door and iLearn; also by appointment

5. Course Description (Catalog Description):

Introduces the fundamental concepts and algorithms of cognitive robotics. Studies cognitive functions and architectures, from biological inspiration to computational models. Covers robot perception, learning, and action in the physical world, as applied to localization, mapping, manipulation, and motion planning. Examines selected advanced topics such as approximate reasoning, autonomous exploration, deep learning, and social cognition.

6. Textbook and other Supplemental Material:

Textbook:

- N. Correll, , B. Hayes, C. Heckman, A. Roncone, *Introduction to Autonomous Robots*, MIT Press, 2022. [free, online]

Supplemental material:

- D. Vernon, *Artificial Cognitive Systems: A Primer*, MIT Press, 2014.
- R. Sutton, A.G. Barto, *Reinforcement Learning*, 2nd edition, MIT Press, 2018.
- R. Siegwart and I.R. Nourbakhsh, *Introduction to Autonomous Mobile Robots*, 2nd edition, MIT Press, 2011.
- G. Bekey, *Autonomous Robots: From Biological Inspiration to Implementation and Control*, MIT Press, 2005.
- R. Pfeifer and J. Bongard, *How the Body Shapes the Way We Think: A New View of Intelligence*, MIT Press, 2007.
- F. Chollet, *Deep Learning with Python*, 2nd edition, Manning Press, 2021.
- R.F. Stengel, *Robotics and Intelligent Systems: A Virtual Reference Book*, Princeton University, 2017 [free, online].
- Selected articles and journal papers, simulation tools and data.

7. Course Learning Outcomes:

Upon completion of the course, students will be able to:

1. Appraise the growing importance of cognitive robots in human society.

2. Compare cognitive functions and architectures for cognitive robotics.
3. Select intelligent control and reinforcement learning techniques for motion control.
4. Coordinate perception using various sensors and data processing techniques.
5. Compute state estimation models and methods for localization and mapping.
6. Compose motion planning and collision avoidance algorithms to realize robot tasks.
7. Analyze selected issues in robot cognition such as learning and approximate reasoning.
8. Integrate state-of-the-art software tools to program autonomous robots.

8. Teaching and Learning Methodologies:

Methods include lectures, problem and project-based learning methods (assignments, exams, survey paper, research project, presentation), and class discussions.

9. Course Topics and Schedule:

Topic/Activity	Weeks
Introduction to cognitive autonomous robots	Week #1
Cognitive robot architectures, hierarchies, subsumption	Week #2
Behavioral control, reactive control, hybrid control	Week #3
Intelligent control, reinforcement learning	Week #4
Locomotion, forward and inverse kinematics	Week #5
Perception, sensors and sensor fusion	Week #6
Active perception, vision, object and place recognition	Week #7
Environment learning, deep learning, knowledge extraction	Week #8
Midterm exam	Week #9
State estimation, localization, and mapping	Week #10
Collision avoidance, obstacle prediction, exploration	Week #11
Maps, transformations, path planning, probabilistic routing	Week #12
Manipulation, dexterous grasping, deep reinforcement learning	Week #13
Selected topic: uncertainty, approximate reasoning, task learning	Week #14
Selected topic: student-teacher learning, social cognition	Week #15
Final Exam	Week #16

10. Schedule of Laboratory and other Non-Lecture Sessions:

In the three research projects, students will explore key tasks and apply fundamental techniques of real-world cognitive robotics. They will research and apply state-of-the-art models and algorithms for perception, motion planning, manipulation, exploration, etc. Deliverables include working programs and written reports justifying their approach and analyzing the results in depth. Course projects may be either individual or done in pairs, depending on their scope and complexity. Regardless, students will be evaluated individually based on their contributions.

Individual survey papers will aim to analyze and compare state-of-the-art approaches in a well-defined, narrow domain of cognitive robotics.

11. Out-of-Class Assignments with Due Dates:

Assignment	Due Date (tentative)
Homework 1 – Robot tasks and architectures	Week #4
Homework 2 – Robot programming and control	Week #7

Homework 3 – Robot perception and learning	Week #9
Homework 4 – Robot localization and motion planning	Week #11
Homework 5 – Case study in cognitive robotics	Week #13
Project 1 – Cognitive robot programming	Week #6
Project 2 – Perception, control, and learning	Week #10
Project 3 – Environment exploration and mapping	Week #14

12. Student Evaluation:

Assessment	Weight	Due Date (tentative)
Homework	10 %	cf. section 11
Survey Report	15 %	Week #14
Research Projects	30 %	cf. section 10
Midterm Exam	20 %	Week #9
Final Exam	25 %	Week #16

13. Assessment Instruments:

Assessment	Course Learning Outcomes
Homework	02-07
Survey Report	01-07
Research Projects	02-08
Midterm Exam	01-04
Final Exam	02-07

14. Contribution of Course to Program Outcomes:

MSML Program Outcomes	Emphasis in this course	Course Learning Outcomes
1. Perform research emphasizing creativity, independent learning, and scientific methods in the field of Machine Learning.	●	02-07
2. Apply advanced mathematics, computer science knowledge, and software tools in identifying, formulating, and solving real world problems.	●	03-07
3. Demonstrate an in-depth understanding of modern Machine Learning approaches, algorithms, and tools.	○	03, 07
4. Select and use techniques, skills, and modern tools necessary for research or professional practice.	●	02-08
5. Communicate effectively through technical presentations and reports.	○	01-07
6. Recognize the need for, and engage in, lifelong learning in professional areas.		
7. Attend to professional and ethical responsibilities within global and societal contexts.	○	01, 07

Emphasis: ● High; ● Medium; ○ Low; Blank – Nothing Specific Expected

15. Letter Grade Policy:

Total (T)	Letter Grade
$90 \leq T$	A
$85 \leq T < 90$	A-

$80 \leq T < 85$	B+
$75 \leq T < 80$	B
$70 \leq T < 75$	B-
$65 \leq T < 70$	C+
$60 \leq T < 65$	C
$T < 60$	F