UNIVERSITY OF NEBRASKA AT OMAHA
COURSE SYLLABUS/DESCRIPTION

Department and Course Number	CSCI 4480
Course Title	Introduction to Multi-agent and Multi-robot Systems
Course Coordinator	Raj Dasgupta
Total Credits	3
Date of Last Revision	May 14, 2015

1.0 Course Description

1.1 Overview of content and purpose of the course (Catalog description).
This course provides an introduction to topics at the intersection of robotics and software agents. The course covers topics that will allow students to learn algorithms and techniques used in designing multi-agent systems and use these techniques to control robots that make up a multi-robot system. This is a novel course which converges two parallel, closely related yet independently developed areas in artificial intelligence.

Planned Course Rotation. This course is planned to be offered in the Fall semester of odd years.

1.2 For whom course is intended.
The course is designed for undergraduate senior students majoring in computer science and for graduate students in computer science. It is likely to be attractive for undergraduate double majors in computer science and computer engineering. In general, the course is appropriate for students who wish to gain a broad understanding of the foundations of artificial intelligence and the way in which robots are used to solve problems in different domains.

1.3 Prerequisites of the course (Courses).
CSCI 3320/8325 – Data Structures
CSCI 4450/8456 – Introduction to Artificial Intelligence is a preferred pre-requisite, but is not essential for gaining a basic understanding of most of the topics in this course.

1.4 Prerequisites of the course (Topics).
- 1.4.1 Basic topics in programming;
- 1.4.2 Basic topics in data structures;
- 1.4.3 A reasonable degree of mathematical sophistication.
- 1.4.4 Introduction to artificial intelligence topics (preferred, but not required)

1.5 Unusual circumstances of the course.
None

2.0 Objectives

2.1 Understand the basic architectures used for designing the software controller for robots.
2.2 Understand the software techniques used for coordination in multi-agent systems.

2.3 Understand how multi-agent software techniques are used for distributed control of robots comprising a multi-robot system.

3.0 **Content and Organization** Contact Hours

1.0 **Introduction to Agents** (0.5 weeks)
- 1.1 Environments, agents, agents vs. objects
- 1.2 Abstract Architectures for Intelligent Agents

2.0 **Introduction to Robots** (0.5 weeks)
- 2.1 A brief history of robotics
- 2.2 Robot design paradigms: Hierarchical, Reactive and Hybrid
- 2.3 Sensors, Localization, Path planning

3.0 **Reactive Systems** (1 week)
- 3.1 Biological foundations of reactive behavior
- 3.2 Attributes of the Reactive Paradigm
- 3.3 Subsumption Architecture
- 3.4 Potential Fields Methodologies
- 3.5 The Limitations of Reactive Agents

4.0 Sensing Techniques for Robots (1 week)
- 4.1 Behavioral sensor fusion
- 4.2 Designing a sensor suite
- 4.3 Proprioceptive sensors
- 4.4 Proximity sensors
- 4.5 Computer vision, Range from vision

5.0 Hybrid Systems (1 week)
- 5.1 Attributes of the hybrid paradigm
- 5.2 Hybrid Robot Design
  - 5.2.1 Managerial architectures: AuRA, SFX
  - 5.2.2 State-hierarchy architectures
  - 5.2.3 Model-oriented architectures: Saphira, TCA
- 5.3 Hybrid Agent Systems: Touring Machines and InteRRaP
- 5.4 Evaluation of hybrid architectures

6.0 **Multiagent Interactions/Game Theory** (1 week)
- 6.1 Utilities and Preferences
- 6.2 Multiagent Encounters
- 6.3 Dominant Strategies and Nash Equilibria
- 6.4 The Prisoner's Dilemma

7.0 **Reaching Agreements with Multiple Agents** (1.5 week)
- 7.1 Auctions
- 7.2 Negotiation

8.0 Cooperative Distributed Problem Solving (1.5 week)
- 8.1 Task Sharing and Result Sharing
- 8.2 Coordination

9.0 Multi-robot systems (1 week)
- 9.1 Cooperative mobile robotics

9.2 A taxonomy for multi-agent robotics

10.0 Distributed terrain coverage with multiple robots (3 weeks)

10.1 Spanning Tree Coverage (STC) algorithm, Multi-robot Spanning Tree Coverage (MSTC) algorithm, Multi-robot Forest Coverage (MFC) algorithm

10.2 Ant-based coverage algorithms: ANT-WALK, ANT-WALK1, CLEAN and SWEEP protocols

10.3 Node-counting and LRTA* algorithm

10.4 Frontier-based dispersion algorithm

11.0 Multi-robot Task Allocation (MRTA) (2 weeks)

11.1 Formalization of the MRTA problem

11.2 Heuristics-based MRTA algorithms

11.3 Auction-based MRTA algorithms

12.0 Challenges and Future Directions in Multi-agent/Multi-robot Systems (1 week)

4.0 Teaching Methodology

4.1 Methods to be used.
The course will be presented primarily by lecture, with opportunities for discussion with and questions from the students.

4.2 Student role in the course.
Students will be expected to attend lectures, complete written and programmed assignments and periodic examinations.

4.3 Contact hours.
Three hours per week.

5.0 Evaluation

5.1 Type of student projects that will be the basis for evaluating student performance, specifying distinction between undergraduate and graduate, if applicable. For Laboratory projects, specify the number of weeks spent on each project).

Evaluation will be based principally on written and programmed assignments, and periodic examinations.

5.2 Basis for determining the final grade (Course requirements and grading standards) specifying distinction between undergraduate and graduate, if applicable.

5.2.1 Undergraduate section

Components	Grading
Programming Assignments	35%
Intermediate Exams	30%
Final Exam	35%

Projects related to the topics in the course can also be assigned to students based on interest and time.

5.2.2 Graduate section

Components	Grading
Programming Assignments	30%
Intermediate Exams	20%
Final Exam	30%
Project	20%

5.3 Grading scale and criteria.
The following is the possible grading scale and criteria = accumulated grade points from 5.2:

Points	Grade
97-100%	A+
93-96%	A
90-92%	A-
87-89%	B+
83-86%	B
80-82%	B-
77-79%	C+
73-76%	C
70-72%	C-
67-69%	D+
63-66%	D
60-62%	D-

6.0 Resource Material

6.1 Textbooks and/or other required readings used in course.(6.1.1 and 6.1.2 are the two required textbooks for this course)

6.1.1 H. Choset, K. Lynch, S. Hutchinson, G. Gantor, L. Kavraki and S. Thrun, "Principles of Robot Motion: Theory, Algorithms, and Implementations", Bradford Book, 2005.

6.1.2 M. Wooldridge, "An introduction to multiagent systems," 2nd edition, Wiley, 2009.

6.1.3 R. Murphy, "An introduction to AI robotics," MIT Press, 2000.

6.1.4 N. Correll, "Introduction to Autonomous Robots," Creative Commons License, 2014.

6.1.5

6.2 Other suggested reading materials, if any.

6.2.1 Books

6.2.1.1 R. Siegwart and I. Nourbaksh, "Introduction to Autonomous Mobile Robots," MIT Press, 2004.

6.2.1.2 S. Russell and P. Norvig, "Introduction to Artificial Intelligence," Prentice Hall, 2005.

6.2.1.3 G. Weiss (ed), "Multi-Agent Systems," 2nd Edition, MIT Press, 2013.

6.2.2 G. Dudek, M. Jenkins, E. Milios, D. Wilkens : A taxonomy for Multi-agent Robotics. Autonomous Robots, 3(4): 5-29 (1996)

6.2.3 Y. Uny Cao, Alex S. Fukunaga, Andrew B. Kahng: Cooperative Mobile Robotics: Antecedents and Directions. Autonomous Robots, 4(1): 7-27 (1997)

6.2.4 Yoav Gabriely, Elon Rimon: Competitive on-line coverage of grid environments by a mobile robot. Computational Geometry, 24(3): 197-224 (2003).

6.2.5 Noam Hazon, Fabrizio Mieli, and Gal A. Kaminka. Towards Robust On-Line Multi-Robot Coverage. In *Proceedings of IEEE International Conference on Robotics and Automation (ICRA-06)*, 2006.

6.2.6 X. Zheng, S. Jain, S. Koenig and D. Kempe. Multi-Robot Forest Coverage. In *Proceedings of the IEEE International Conference on Intelligent Robots and Systems (IROS),* pages 2318-2323, 2005.

6.2.7 Israel A. Wagner, Michael Lindenbaum, Alfred M. Bruckstein: MAC Versus PC: Determinism and Randomness as Complementary Approaches to Robotic Exploration of Continuous Unknown Domains. International Journal of Robotic Research, 19(1): 12-31 (2000)

6.2.8 W. Agassounon and A. Martinoli. Efficiency and robustness of threshold-based distributed allocation algorithms in multi-agent systems. Proc. *AAMAS 2002*, pages 1090–1097.

6.2.8.1 Robert Zlot, An Auction-Based Approach to Complex Task Allocation for Multirobot Teams, PhD dissertation (tech report CMU-RI-TR-06-52), December 2006.

6.2.9 Journals

6.2.9.1 Autonomous Robots

6.2.9.2 International Journal of Robotics Research

6.2.9.3 Journal of Autonomous Agents and Multi-Agent Systems

6.2.9.4 Journal of AI Research

6.2.9.5 Artificial Intelligence

6.2.9.6 IEEE Transactions on Robotics

6.3 Other sources of information.
None

6.4 Current bibliography of resource for student's information.
None

7.0 Computer Science Accreditation Board (CSAB) Category Content (class time in hours)

CSAB Category	*Core*	*Advanced*
Data structures	0	0
Computer organization and architecture	0	0

Algorithms and software design	3	12
Concepts of programming languages	0	0

8.0 Oral and Written Communications

Every student is required to submit at least __0___ written reports (not including exams, tests, quizzes, or commented programs) to typically _____ pages and to make ___0__ oral presentations of typically _____ minutes duration. Include only material that is graded for grammar, spelling, style, and so forth, as well as for technical content, completeness, and accuracy.

9.0 Social and Ethical Issues

No coverage

10.0 Theoretical Content

		Contact hours
10.1	Design of controllers for robotic systems	3.5
10.2	Coordination techniques using multi-agent systems	3.5
10.3	Terrain coverage using multi-robot systems	2.5
10.4	Multi-robot task allocation	2.5

11.0 Problem analysis

Students will analyze problems related to robot controller design, multi-agent coordination, multi-robot terrain coverage and multi-robot task allocation.

12.0 Solution design

Students will develop solutions for problems in the areas of robot controller design, multi-agent coordination, multi-robot terrain coverage and multi-robot task allocation.

CHANGE HISTORY

Date	***Change***	***By whom***	***Comments***
02/23/2009	Initial version	Dasgupta	New course submitted based on previous special topics course on this topic