Updated 16 AUG 2020 at 11:21pm

Georgia Institute of Technology / School of Interactive Computing
CS 4649/7649 Robot Intelligence: Planning

Instructor:	Prof. Matthew Gombolay	Matthew.Gombolay@cc.gatech.edu
Teaching Assistants:	Mr. Rohan Paleja	rpaleja3@gatech.edu
	Mr. Esmaeil "Esi" Seraj	eseraj3@gatech.edu
	Mr. Pradyumna "Prad" Tambwekar	ptambwekar3@gatech.edu
	Ms. Manisha Natarajan	mnatarajan30@gatech.edu

Credit: 3-0-3
Pre-requisites: Please see Oscar/Buzzport
Location: Coll of Computing 16
Remote URL: https://primetime.bluejeans.com/a2m/live-event/pccaxgcd
Time: MW 2:00 pm - 3:15 pm
Method: Partially at a Distance (BOR) Instructional Method

Textbooks: To supplement the course's lectures, students will be expected to complete the required readings from Russel & Norvig's textbook on AI. While this book is an excellent resource, it is expected that students may want to consult texts specifically on the topics of Reinforcement and Machine Learning by Sutton and Mitchell, respectively.

Required:

- Russell, S.J. and Norvig, P., 2016. *Artificial Intelligence: A Modern Approach*. Malaysia; Pearson Education Limited.

Optional:

- Sutton, R. S., & Barto, A. G. (1998). *Reinforcement learning: An introduction*. MIT press.
- Mitchell, T. M. (1997). *Machine learning*. *McGraw Hill*.

Description: surveys a wide array of techniques from the field of artificial intelligence (AI) which enable robots to make decisions and plan actions in our complex, uncertain world. This course will focus on giving students both the practical experience to imbue their own robots with AI as well as the theoretical foundation to soundly explore a rich set of cutting-edge, modern challenges in AI. This course will cover logic, search, activity and motion planning, Markov decision processes (MDPs), filtering and estimation, mathematical programming, and modern techniques such as Deep Reinforcement Learning.

Targeted Students: This course can benefit students in the College of Computing, ME, ECE, and Aerospace Engineering who seek to research, engineer, or operate autonomous, robotic systems. This course is designed to be accessible to undergraduate and graduate students of who have working knowledge of calculus, linear algebra, and applied probability. The course will include some proofs regarding the complexity of algorithms, *soundness*, *completeness*, and *necessary* and *sufficient* criteria; however, this material will be covered as a part of the course and will not be as intensive as a formal course on theory of computation. Further, this course assumes that students are proficient in Python.

Objectives and Expected Outcomes: This course aims to introduce the basic principles and techniques of AI for robotics. By the end of the course, the students should be able to:

1. Articulate the value of both deductive (old school) and inductive (new school) approaches to AI.
2. Analyze the attributes of students' own algorithms, such as complexity, soundness, etc.
3. Implement algorithms to enable robots to perform autonomous decision-making for both high-level (e.g., planning and scheduling) and low-level (e.g., motion/trajectory planning) tasks.
4. Formally model stochastic processes to enable robotic perception, decision-making, and action.

5. Design an integrative AI that harness both deductive and inductive techniques for state-of-the-art performance in gameplay competition.

CS 4649 (Undergraduate) Grading:

Homework	20%
Midterms	30% (15% each, with two midterms)
RBMC Competition	30%
Final Exam	20%

CS 7649 (Graduate) Grading:

Homework	15%
Midterms	30% (15% each, with two midterms)
RBMC Competition	20%
Graduate Student Projects	20% (10% each, with two projects)
Final Exam	15%

Attendance/Participation: Due to the COVID-19 pandemic as established by the World Health Organization, I will not be including attendance in a part of a formal grading assessment.

Homework: In addition to readings, the students will be given take-home assignments, which will be comprised of both coding assignments (e.g., implementing and evaluating algorithms) and analytical work (e.g., deriving the complexity of a specific algorithm). For the homework, you can work with other members of the class and utilize the internet; however, you must

1) Provide the names of other students you worked with and any sources you used.
2) You may not copy+paste code without proper attribution and confirmation that you are complying with the copyright terms/use of that source.

Failure to disclose your collaborators and sources will result in a referral to the Office of Student Integrity.

Late Policy: Late assignments (except for the final project) will be accepted with 1 letter grade off per 1 day, rounding up (e.g., 1 second and 23 hours 59 minutes 59 seconds each result in 1 letter grade off). The final project must be turned in on time. In the case of an excused absence, the student and teacher will work to arrange an extension under the guidelines of GaTech.

Office Hours: We will be using office hours as a mechanism to facilitate live interactions between instructors/TA's and enrolled students. The TA/instructor will provide students with a Bluejeans meeting invite prior to the start of office hours. Students will be able to join via Bluejeans. To ask questions, students will submit a written question to the instructor/TA into the Bluejeans chat box. To foster an equitable experience for all students, we ask that you only submit one question until everyone else in the Bluejeans meeting has had an opportunity to ask their own questions.

Mondays @11am	Ms. Manisha Natarajan	https://bluejeans.com/143727991
Tuesdays @ 11am	Mr. Esmaeil Seraj	https://bluejeans.com/685704932
Tuesdays @ 3pm	Dr. Matthew Gombolay	https://bluejeans.com/427390419
Thursday @ 6pm	Mr. Pradyumna Tambwekar	https://bluejeans.com/980488485
Fridays @ 4pm	Mr. Rohan Paleja	https://bluejeans.com/546609490

RCBM Competition: Students will conduct a group project (groups of 2-3). The project will be to develop an AI that plays Recon Blind Multi-Chess – take Chess, remove your ability to see the opponent, but give

yourself the ability to reveal a 3x3 grid on the board to "sense" before moving. The course will prepare you to bring together all the building blocks of an AI to challenge one to a competition! Grades will be based upon 1) how well you have incorporated multiple concepts of the course into your approach, 2) how well you document/present your approach in a final project report and presentations, and 3) bonus points for performing well in the competition. To receive full credit, your algorithm must incorporate: 1) search, 2) learning, and 3) reasoning about uncertainty. Further details will be provided.

Graduate Student Projects: Graduate students will be assigned two projects. These projects will consist of coding assignments to explore the topics of 1) probabilistic search and 2) motion planning. Details of these projects will be announced later.

Accommodations: If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404) 894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to discuss your needs and to obtain an accommodations letter. Please e-mail me as soon as possible to set up a time to discuss your learning needs.

Academic Integrity: Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit this link. Any student suspected of cheating or plagiarizing will be reported to the Office of Student Integrity.

Student-Faculty Expectations Agreement: At GaTech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See this agreement for an articulation of expectations you can have of me and I have of you. Respect for knowledge, hard work, and cordial interactions will help build the environment we seek.

Piazza: We will host a Piazza page for this class. Behavior on piazza should be courteous, professional, and relevant to facilitate learning. Piazza is not a reddit or 4chan forum. Piazza is not a mechanism to express personal frustrations or to vent. Venting or attacks against any other student, TA, or instructor may result in consequences, including referral to the Office of Student Integrity. We are all stressed out. Please do your part to help make this course a safe learning environment for everyone. We do encourage students to try to answer each other's questions. We will review such "peer" responses and make sure they are accurate. To help answer students' questions in a timely manner, the instructor and TA will be reviewing new posts on Piazza five times per day, Monday-Friday. We will do our best to review posts on weekdays at 9am, 11am, 1pm, 3pm and 5pm. However, we may not review posts on holidays, e.g. Labor Day.

Email Policy: If you have a question and want to ask an instructor/TA, please use Piazza first! Please do not email or use Canvas for communications about the normal function of the course (e.g., homework questions, project questions, syllabus questions, etc.). Please go to Piazza. We all get notifications when you post there. Canvas is a relatively clumsy system for responding to your questions, and we do not want to lose track of anything you ask. Further, email-based communication for a course this large also leaves much to be desired. As such, please post everything to Piazza! Outside of normal course questions, if you have an illness, mental health concern, emergency, ethics violation concerns, please email the instructor directly. If it is a life-threatening emergency, you should always call 9-1-1.

Statement of Intent for Inclusivity: As members of the Georgia Tech community, we are committed to creating a learning environment in which all students feel safe and included. Because we are individuals with varying needs, we are reliant on your feedback to achieve this goal. To that end, we invite you to

enter into dialogue with us about the things we can stop, start, and continue doing to make our classroom an environment in which every student feels valued and can engage actively in our learning community.

Tentative Topical Outline:
Note: All due dates are for 1:59pm Eastern (e.g., PSet1 is due at 1:59pm ET on August 24th, 2020).

	Date	Topic	Due
Week 01	08/17	Welcome to CS 4649 / 7649	
	08/19	Foundations I: State Space Search	Reading: Ch. 3
Week 02	08/24	Foundations II: Complexity of State Space Search	Reading: Ch. 4
	08/26	Foundations III: Probabilistic Search	**Due: PSet1** Reading: Ch. 6
Week 03	08/31	Constraints I: Constraint Programs; Arc Consist.	Reading: Ch. 10
	09/02	Constraints II: CSP Methods & Complexity	**Due: PSet2**
Week 04	09/07	**Labor Day Holiday**	
	09/09	Constraints III: Activity Planning	**Due: PSet3**
Week 05	09/14	Constraints IV: Motion Planning	
	09/16	***Midterm 1 Preparation (In-class & remote options)***	**Due: PSet4**
Week 06	09/21	**Midterm 1**	
	09/23	ML I: Markov Decision Processes	Reading: Ch. 17
Week 07	09/28	ML II: Reinforcement Learning (RL)	
	09/30	ML III: Neural Networks	**Due: PSet5**; Reading: Ch. 19
Week 08	10/05	ML IV: Deep Reinforcement Learning (Part 1)	Reading: Ch. 20
	10/07	ML V: Deep Reinforcement Learning (Part 2)	**Due: PSet6**
Week 09	10/12	Uncertain World I: Reasoning	**Grad student project #1 due** Ch. 13-14
	10/14	Uncertain World II: Inferring State (Part 1)	**Due: PSet7**; Ch. 15
Week 10	10/19	Uncertain World III: Inferring State (Part 2)	Rabiner ’89;
	10/21	***Midterm 2 Preparation (In-class & remote options)***	**Due: PSet8**
Week 11	10/26	**Midterm 2**	
	10/28	Math. Prog. I: Modelling	
Week 12	11/02	Math. Prog. II: Linear Programing (LP)	**Due: PSet9**
	11/04	Math. Prog III: Lagrange Method & KKT Conditions	
Week 13	11/09	Math. Prog. IV: Mixed-Integer LP	**Due: PSet10**
	11/11	Math. Prog. V: Robust Optimization	**Grad student project #2 due**
Week 14	11/16	**RBMC – Round Robin**	
	11/18	**RBMC – Tournament**	
Week 15	11/23	*“The Future of Robot Intelligence: Planning”*	
	11/25	***Final Exam Preparation (In-class & remote options)***	
Final	12/07	**Final Exam | Monday, December 7th, 2:40PM - 5:30PM**	