ECE 457A Cooperative and Adaptive Algorithms

ONLINE ASYNCHRONOUS LEARNING OFFERING

Spring 2021

INSTRUCTOR INFORMATION

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TA INFORMATION

TA	Contact Information	Contact	Interactive Help Sessions
TBA		Online	TBA
TBA		Online	TBA

COURSE DESCRIPTION

There are many computational problems in our real life that are computable within a reasonable amount of time using a reasonable computing device. For this type of problems we seek algorithms that can deterministically search for optimal solutions in reasonable time. On the other hand, there are problems that are hard, if not impossible, to compute, or complex enough to the extent that deterministic methods take too long to find solutions- even approximate solutions. Some of these problems are ill-conditioned, in the sense that a small change in the independent variables (inputs) causes a large change in the dependent variables, making it difficult for classical techniques to find the solution, even though we are certain that a solution exists. Examples of these problems are: circuit layout design, task allocation, task scheduling, transportation path planning, constraint satisfaction, game playing, to name a few. For most of these problems, the speed at which we get a solution is critical, and hence it is often acceptable to trade the solution exactness (accuracy, completeness, or

precision) for speed. Furthermore, there are problems in our real life for which we lack proper models. Thus, devising algorithms for this type of problems using classical algorithmic strategies does not even apply.

In all such cases, good enough solutions is better than none at all. Therefore, we seek algorithms that can explore and exploit the problem solution space to find solutions that are practically acceptable. This pragmatic thinking of problem-solving has manifested itself into various untraditional problem-solving strategies or techniques, such as heuristic based, meta-heuristics based techniques, and evolutionary or biologically inspired techniques.

The course starts by addressing ill-structured, ill-posed and well posed problems, and establish the need for computational intelligence methods for dealing with them. Several combinatorial and nonlinear problems will be highlighted and employed as uses cases. The course discusses the importance of proper problem formulation and algorithm adaptation. It introduces classical search algorithms, and the concepts of heuristics and metaheuristics and their use in conjunction with classical search methods. The course discusses how complex problems are approached using heuristics and metaheuristics based techniques. The course also introduces the concepts of algorithmic cooperation and adaptation, and how they are influencing the emergence of methods for solving complex problems. The course illustrates how the concepts of cooperation and adaptation are manifested in nature and how such cooperative problem solving models are inspiring new types of solution methods. Topics to be covered include: search algorithms, deterministic as well heuristic/meta-heuristic based techniques, cooperation and adaptation and the concepts of supervised and unsupervised algorithm learning. It covers techniques such as neuro-computing, evolutionary computing, swarm intelligence, genetic algorithms, genetic programming, evolutionary strategies, ant-colony algorithms, particle swarm methods, and reinforcement learning methods. It discusses the use of these techniques in solving continuous and discrete complex problems that arise in various engineering applications. In particular the course will discuss the importance of optimization in large scale engineering problems and discuss how the studied meta-heuristic techniques can be used in solving deep-learning optimization problems.

Prereq: Level at least 4A Computer Engineering or Electrical Engineering or Software Engineering.
Antireq: CS 486, SYDE 422/522

LEARNING OBJECTIVES

- Motivate the need for algorithms that exhibit a degree of intelligence: logical, computational, and biologically inspired.
- Introduce the concepts of cooperation and adaptations and how they are influencing new methods for solving complex problems.
- Study meta-heuristics, evolutionary computing methods, swarm intelligence, ant-colony algorithms, particle swarm methods. reinforcement learning,

- Illustrate the use of these algorithms in solving continuous and discrete, and machine learning problems that arise in engineering applications.

DETAILED COURSE TOPICS:

Week	Topic	Publication Date: Lecture Slides And Videotaped Lectures
May 11,2020	⊙ Introduction: About this course, AI, Adaptation, Cooperation, goals and definitions of artificial intelligence; ⊙ intelligent agents and their environment. ⊙ ill-structured problems and need for approximate algorithms, cooperation and adaptation in nature.	Part 1: May 11,2020 Part 2: May 13,2020
May 18, 2020	⊙ Search: state space problem formulation and representation; ⊙ uninformed search; ⊙ heuristic search; iterative improvement search; constraint satisfaction; game-playing.	Part 1: May 18, 2020 Part 2: May 20, 2020
May 18, 2020	⊙ Review of blind search, ⊙ use of heuristic search methods and meta-heuristic algorithms ⊙ Trajectory Methods: Tabu search ⊙ Engineering use cases	Part 1: May 25 Part 2: May 27
June 1, 2020	⊙ Tabu Search (CONT) ⊙ Simulated Annealing ⊙ Engineering use cases	Part 1: June 1, 2020 Part 2: June 3, 2020

June 8, 2020	⊙ Genetic algorithms, cooperation in GA. ⊙ Engineering use cases	Part 1: June 8, 2020 Part 2: June 10, 2020
June 15, 2020	⊙ Introduction to Swarm Intelligence: cooperation and adaptation methods inspired by nature. ⊙ Ant Colony algorithms: ACO- cooperative and multi-ant-colonies. ⊙ Engineering use cases	Part 1: June 15, 2020 Part 12, June 17, 2020
June 22, 2020	⊙ Particle swarm algorithms: particle swarm optimization, ⊙ cooperation within the swarms, cooperation among swarms, swarm ensembles. ⊙ Engineering use cases	Part 1: June 22, 2020 Part 2: June 24, 2020
June 29, 2020	⊙ Evolutionary Strategies and Genetic Programming	Part 1: June 29, 2020 Part 2: July 1, 2020
July 6, 2020	⊙ Supervised vs Unsupervised Learning Algorithms	Part 3: July 6, 2020 Part 4: July 8, 2020
July 13, 2020	⊙ Machine Learning and Optimization	Part 1: July 13, 2020 Part 2: July 15, 2020
July 20, 2020	⊙ Reinforcement Learning Engineering use case	Part 1: July 20, 2020 Part 2: July 22, 2020
July 27, 2020	⊙ Reinforcement Learning Engineering use case	Part 1: July 27, 2020 Part 2: July 29, 2020
August 3, 2020	⊙ Pre-Final Exam Review Lecture	August 3, 2020

LEARNING RESOURCES

This course will be offered as an asynchronous teaching module.

LECTURE NOTES AND VIDEOTAPED LECTURES:

1. Course notes: The lecture slides in PPT format will published on the course web site on LEARN. The course syllabus provides publication dates for these slides.
2. Video recorded lectures in synchrony with the lecture slides will be published on the course website on LEARN. The course syllabus provides publication dates for these slides.

TEXTBOOKS (OPTIONAL):

1. Fundamentals of Computational Swarm Intelligence, Andries P. Engelbrecht, Wiely and Sons, 2006.
2. Introduction to evolutionary computing, by Eiben and A, Smith, J.E, Springer, Berlin, 2003.
3. Search and Optimization by Metaheuristics Techniques and Algorithms Inspired by Nature
   Ke-Lin Du, M. N. S. Swamy
4. Search Algorithms Types: Breadth and Depth First Search Algorithm
   Merium Hazem Anwar Labib Bishara, Merihan Hazem Anwar Labib Bishara

***Lectures will be based mainly, but not exclusively, on material in these textbooks and other resources. Lectures will not follow the same sequence as the material presented in the texts.*

Booth the lecture notes and the videotaped lectures are copy-right protected material. Please do not attempt to publish or distribute them.

RESEARCH ARTICLES:

Research articles that report recent developments related to the course topics will be published on the course website regularly.

ASSESSMENTS

- Assignments: There will be 4 assignment that will be used to reinforce course material. They will carry a total weight of 25% of the course's 100% final grade.
- Midterm: 25% of the course's 100% final grade.
- A final exam will be administered to test the student 's comprehensive understanding of the course material. This part will carry 50% of the course's 100% final grade.

The final course grade will be calculated using the following categories:

Assessment	**Percentage of Final Grade**
Assignments (4)	25%

Midterm	25%
Final Examination	50%

COURSE POLICIES

- **Late-work policy**: If you **submit** work after the deadline your mark will be reduced by 10% for each working day that the work is **late**. For example, an assignment worth 20 points would lose 2 point per day (max 2 days of lateness).
- **Integrity:** (Please refer to the University of Waterloo Policy 71) "*Academic integrity is a commitment to five basic values: honesty, trust, fairness, respect and responsibility. It applies to all academic endeavours – teaching, learning and scholarship, and applies to a range of academic activities, from conduct in research to the writing of co-op work term reports*.

  Students are expected to know what constitutes academic integrity, to avoid committing offences, and to take responsibility for their actions.

  Students are responsible for demonstrating behaviour that is honest and ethical in their academic work. Such behaviour includes:

  - *Abiding by University policies and provincial and federal legislation.*
  - *Following the expectations articulated by instructors for referencing sources of information and for group work.*
  - *Submitting original work, citing sources fully, and respecting the authorship of others.*
  - *Preventing their work from being used by others, e.g. not lending assignments to others, protecting access to computer files.*
  - *Asking for clarification of expectations as necessary. Students who are in any doubt as to whether an action on their part may be viewed as a violation of the standards of academic integrity should ask their instructors, lab assistants and/or advisors.*
  - *Adhering to the principles of academic integrity when conducting and reporting research."*

  Accommodations for students with disabilities: "If you have a disability and require accommodations, please refer to https://uwaterloo.ca/english-teaching-portal/managing-your-section-or-tutorial/accommodating-students-disabilities

  If you have an accommodations letter from the Disability Services Office, I encourage you to discuss your accommodations and needs with me as early in the semester as possible. I will work with you to ensure that accommodations are provided as appropriate.