COURSE TITLE: Search Methods in Artificial Intelligence
Plaksha University, Semester No. 5 (Year 2023)
Class (Monday, Wednesday, Friday), Class time (10 a.m.)
Room No. 2202

Instructor:
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Course Description

For an autonomous agent to behave in an intelligent manner it must be able to solve problems. This means it should be able to arrive at decisions that transform a given situation into a desired or goal situation. The agent should be able to imagine the consequences of its decisions to be able to identify the ones that work. In this first course on AI, we study a wide variety of search methods that agents can employ for problem solving.

Course Overview

We begin the history of AI and look at philosophical perspectives.

Then we look how to formalize search problems in the state space and in the solution space. We look at the idea of heuristic functions. We then move on to stochastic local search methods to address the fact that search and optimization can be hard problems.

Following that we look at finding optimal solutions and look at algorithm A* and its variations.

Then we look at goal trees which are a different approach to defining search spaces. We also look at algorithms for playing board games like chess and observe their relation with goal trees.

The next module looks at how the activity of planning is posed as search, and study different algorithms for planning.

We study how forward chaining rule-based systems have been deployed for capturing expert knowledge and business rule management systems.

Towards the end we see how deduction in logic is posed as a search problem, and finally how constraint satisfaction is a unified approach to solve problems with a combination of search and reasoning.

Learning Objectives

Understand the central role of search in problem solving, which is a core component of AI, along with knowledge and memory.

Apply the knowledge acquired in the course to formulate problem solving as a search problem.

Analyze a given problem to decide what formalism is appropriate and what algorithm to use.

Synthesize a solution package to solve a given problem.

Learning Outcomes (Statements starting with measurable verbs suitable for evaluation) | To be used when faculty want to give grades and marks.

By the end of this course, each student will have had the opportunity to:

1. Define the domain functions to pose a problem as a search problem
2. Evaluate the benefit of a heuristic function for guiding a search algorithm.
3. Study the travelling salesperson problem and choose an appropriate algorithm to solve it within given time constraints.
4. Implement a program to play board games like chess (in our case Othello).
5. Understand how a rule-based system works (evaluated in the written exam)
6. Become familiar with automated planning approaches (evaluated in the written exam)
7. Get a glimpse of a unifying problem solving approach in the form of constraints processing. (evaluated in the written exam)

Required Texts

Deepak Khemani, Search methods in Artificial Intelligence, Cambridge University Press, 2023 (forthcoming).

Additional Readings

1. Deepak Khemani. A First Course in Artificial Intelligence, McGraw Hill Education (India), 2013. (Chapters 1 – 8, some parts from Chapters 9 and 10).
2. Stefan Edelkamp and Stefan Schroedl. Heuristic Search: Theory and Applications, Morgan Kaufmann, 2011.
3. John Haugeland, Artificial Intelligence: The Very Idea, A Bradford Book, The MIT Press, 1985.
4. Pamela McCorduck, Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence, A K Peters/CRC Press; 2nd edition, 2004.
5. Eugene Charniak and Drew McDermott, Introduction to Artificial Intelligence, Addison-Wesley Publ., 1985.
6. Zbigniew Michalewicz and David B. Fogel. How to Solve It: Modern Heuristics. Springer; 2nd edition, 2004.
7. Judea Pearl. Heuristics: Intelligent Search Strategies for Computer Problem Solving, Addison-Wesley, 1984.
8. Elaine Rich and Kevin Knight. Artificial Intelligence, Tata McGraw Hill, 1991.
9. Stuart Russell and Peter Norvig. Artificial Intelligence: A Modern Approach, 3rd Edition, Prentice Hall, 2009.
10. Patrick Henry Winston. Artificial Intelligence, Addison-Wesley, 1992.

Class Schedule

Date	Title	Topics	Assignments Due date
Week 1+2	Introduction	Overview and Historical Perspective, Turing Test, Physical Symbol Systems and the scope of Symbolic AI, Agents.	
Week 2	State Space Search	State Space Search Domain Independent Algorithms Deterministic Search DFS and BFS Comparing DFS and BFS Depth First Iterative Deepening	Assignment 1 Due: Start of Week 3
Week 3	Heuristic Search	Heuristic Functions and the Search Landscape. Best First Search, global search, local search, Hill Climbing, local maxima. Solution Space Search, the SAT problem, perturbative neighbourhood functions, Beam Search, dense and sparse neighbourhoods, Variable Neighbourhood Descent The Traveling Salesman Problem, Greedy Constructive Methods, path representation, n-city exchange, n-edge exchange Escaping Local Optima, Tabu Search, tabu tenure, SAT example	Assignment 2 Due: Start of Week 4
Week 4	Stochastic Local Search	Iterated Hill Climbing, exploitation, exploration, Random Walk, Stochastic Hill Climbing, temperature, Simulated Annealing.	
Week 4+5	Population Based Methods	What is life?, nature, design, evolution, Creatures. Genetic Algorithms: Survival of the Fittest, natural selection, genetic algorithms, crossover. Genetic Algorithms and SAT Genetic Algorithms for the TSP. Path Adjacency, and Ordinal. Fitness function, Cycle Crossover, PMX, Order Crossover, Alternating Edges Crossover, Heuristic Crossover Emergent Systems. Conway's Game of Life, Ant Colony Optimization. Biosemiotics, ant colonies, pheromone trails, shortest paths, Swarm Optimization, TSP	Assignment 3 Due: Start of Week 7
Week 6	Finding optimal paths	Quality of solution, Refinement Search, estimated cost, TSP, Branch & Bound. Dijkstra's algorithm, Algorithm A*, Admissibility of A*, Monotone Condition, IDA*, RBFS, DNA Sequence Alignment, Pruning OPEN and CLOSED lists in A*.	

Week 7	Game Playing	Game Theory Popular Recreational Games Board Games and Game Trees The Evaluation Function in Board Games Algorithm Minimax and Alpha-Beta Pruning A Cluster of Strategies SSS*: A Best First Algorithm SSS*: A Detailed Example Other games	Assignment 4 Due: Start of Week 11
Week 8	Automated Domain Independent Planning	The Blocks World Domain State Space Planning: Forward and Backward Goal Stack Planning (GSP) GSP: A Detailed Example Plan Space Planning (PSP) PSP: A Tiny Example Multi-Armed Robots	
Week 9	Problem Decomposition	Sub-problems, AND-OR trees, symbolic integration, SAINT, SIN, MACSYMA, Expert Systems, Dendral, expert chemist Goal trees, solved nodes, AND nodes, OR nodes, Algorithm AO*, AO*: An Illustration	
Week 10	Rule Based Expert Systems	Pattern Directed Inference Systems The Inference Engine The OPS5 Language Conflict Resolution Business Rule Management Systems The Rete Net Rete Algorithm: Optimizing the Match Rete Algorithm: Conflict Resolution	
Week 11	Reasoning in First Order Logic	Rules of Inference Forward Reasoning First Order Logic Implicit Quantifier Notation Backward Reasoning Depth First Search on Goal Trees Incompleteness...	
Week 12	Constraint Satisfaction Problems	Binary Constraint Networks Interpreting Line Drawings Model Based Diagnosis Solving CSPs Arc Consistency, AC-1, AC-3 Propagation = Reasoning Lookahead Search	

Grading and Assignments

There are four assignments (60 points in all), a mid-semester (20 points), and the end semester (20 points)

Assignment 1: 10 points
The task in this assignment is to choose a domain and define the domain functions for search.

Assignment 2: 20 points

Implement DFS and BFS for the above domain. Define a heuristic function and implement Best First Search for the same domain. Compare the performance of the three algorithms on some sample problems.

Assignment 3: 15 points
Implement a solver for the Traveling Salesperson Problem. The specifications will be given at the end of Week 4. You may choose any algorithm. Evaluation will be based on quality of solution found for some test cases. There will be a test submission followed by a final submission.

Assignment 4: 15 points
Implement a program to play the game of Othello.

Assignments may be done in groups of two.

Participation

Participation is not mere attendance in the class! In order to effectively participate in the course, it is critical that each member of the team read the course assignments and participate in class discussions and simulations and in group work. The participation grade will be based on your participation both in class as a whole and in small groups. This grade is a "value added" assessment; in other words, sheer frequency or volume of verbal activity is not necessarily the goal of class participation. The grade is derived from meaningful dialogue based on reading and thinking reflectively.

To participate in class more fully, you might consider, for example, commenting on specific issues raised in the class readings; illustrating specific issues from the readings with examples from your personal experience; raising questions not covered in the readings; comparing or contrasting ideas of various theorists from the readings; or supporting or debating the insight or conclusions of a classmate (or the instructor!) by referencing concepts, experiences or logical reasoning.

Part of participation also includes setting the tone of collegiality, whether that is through contributing to a snack table, engaging in conversation with classmates during breaks, or making fellow students feel welcome. Participation is not merely an intellectual exercise; it is also a community building experience.

Attendance

Attendance is expected in this course in order to achieve maximum learning for all participants. Unforeseen circumstances do sometimes arise, so periodic absences may occur. If you find that you must miss or be late to a class meeting, please contact the instructor prior to the start of class. **While there are no 'positive' points for mere attendance, absences or tardiness from class may result in points deducted from your class participation.**

Incompletes

An "Incomplete" grade will be awarded in case a student does not complete any assessment or evaluation exercise as a result of which they do not meet the passing criterion. [This is only for medical/social emergencies beyond control of students or cases of pending disciplinary investigation and must be approved by the Dean, Academic Affairs].

Scholastic Dishonesty | Academic Integrity
Situations involving academic integrity are governed by the UG academic policy. Here are the specifics:

The instructor shall report case to the Academic Integrity Committee, which, after taking into due consideration the nature of the evaluation component and the intensity of the offence, as well as the number of times the student has committed prior offenses, will prescribe the appropriate corrective action.

Advising

My goal is to be as available as possible to meet your needs during the semester. To reach me:

- I will be available after each class for half an hour
- E-mail: This is a good way to contact me.
- In Person: Although I will try to make myself available to you if you 'drop by', please do not expect a substantive conversation; I may have other commitments. I am available for appointments, however, and will be happy to meet with you in person.

To make a phone or in-person appointment, please contact my teaching Fellow, Kanishk Bansal at kanishk.bansal@plaksha.edu.in