Artificial Intelligence

Guide to AI and Data Courses · Part I: Core

Intelligent agents | Search | Knowledge and logic | Uncertainty | Planning | Neighboring courses

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INTRODUCTION

What Question Does It Ask?

> **How does a machine act intelligently by searching, reasoning and planning?**

Artificial intelligence studies how to design **intelligent agents** that perceive their environment and choose the action that best serves their goal. The course brings search, logical inference, probabilistic reasoning, planning and learning into one framework. Machine learning is part of that framework, not all of it.

At a glance

APPROACH search, logic, probability and learning combined	**INPUT** problem definition: states, actions, goal	**OUTPUT** action sequence, plan or decision
SUCCESS MEASURE reaching the goal, cost, rationality	**MATH LOAD** medium: logic, probability, graphs	**DATA NEEDS** little; often a model and knowledge suffice

A Short History

1950
Turing proposes the imitation game (the Turing test) in "Computing Machinery and Intelligence".

1956
Dartmouth summer workshop: the name "artificial intelligence" is coined and the field is born.

1980s
Expert systems (MYCIN, XCON) go commercial; unmet expectations bring an "AI winter".

1997
Deep Blue beats Kasparov at chess: powerful search and a hand-written evaluation.

2016
AlphaGo beats Lee Sedol at Go: tree search, deep networks and reinforcement learning together.

2022
Large language models reach a mass audience through chat interfaces.

THE COURSE

Core Concepts

Intelligent agent
Perceives the environment through sensors, acts on it through actuators.

Rationality
Choosing the action expected to maximize the performance measure.

State-space search
BFS, DFS, A*; heuristic functions.

Adversarial search
Minimax and alpha-beta pruning in games.

Constraint satisfaction
Variables, domains, constraints: Sudoku, timetabling.

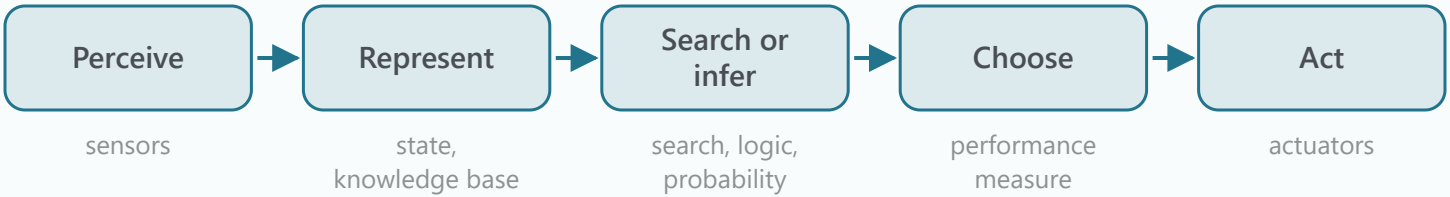
Logic and knowledge
Propositional and first-order logic, inference rules.

Uncertainty
Bayes' rule, Bayesian networks, decision theory.

Planning
Building a sequence of actions from start to goal.

THE COURSE

A Typical Workflow



Example: A navigation app senses its location, represents the road network as a graph, searches routes with A*, picks the fastest one and guides the driver by voice. Nothing in this loop is "learned"; the system is still AI.

THE COURSE

What Does the Course Cover?

1. Intelligent agents and types of environments
2. Uninformed search: BFS, DFS, uniform-cost search
3. Heuristic search: greedy best-first and A*
4. Local search: hill climbing, simulated annealing
5. Adversarial search: minimax and alpha-beta pruning
6. Constraint satisfaction problems and backtracking
7. Propositional logic and inference by resolution
8. First-order logic and knowledge representation
9. Classical planning: STRIPS and PDDL
10. Probability, Bayes' rule and Bayesian networks
11. Decision theory and Markov decision processes
12. Learning from examples and reinforcement learning

Skills you will gain

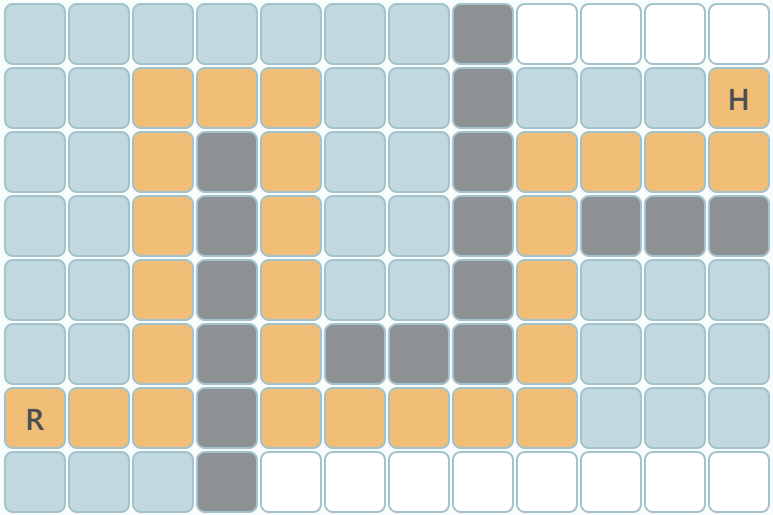
- formulating problems as state spaces
- implementing A* with heuristics
- logic programming in Prolog
- writing planning problems in PDDL
- building Bayesian networks with pgmpy
- comparing algorithms by complexity

A typical semester; the order and coverage vary between universities.

TRY IT

A Warehouse Robot Finds Its Way

A warehouse robot must travel from cell **R** between the shelves to the item in cell **H**. Click a cell to add or remove a shelf; compare how many cells the two search methods examine.



Breadth-first (BFS) **A* search**

Reset shelves

A*: 67 cells examined, path 26 steps. Comparison: BFS 77 cells, A* 67 cells. Both find the shortest path.

Blue cells are states the search examined, orange cells the path found. A* uses the remaining Manhattan distance to the goal as a **heuristic**, so it looks at fewer cells.

The problem is first set up as a **state space**: each cell is a state, each move an action, the target cell the goal. The search algorithm finds a path in this space; nothing is learned.

CONTEXT

Prerequisites

Courses worth knowing before this one, and why they are needed.

Course	Why it is needed
Probability and Statistics	reasoning under uncertainty, Bayes rule
Data Structures	stacks, queues, priority queues and graphs: the building blocks of search
Algorithms	graph search, shortest paths and complexity analysis
Discrete Mathematics	propositional logic, sets and proof techniques

CONTEXT

Are You Ready for This Course?

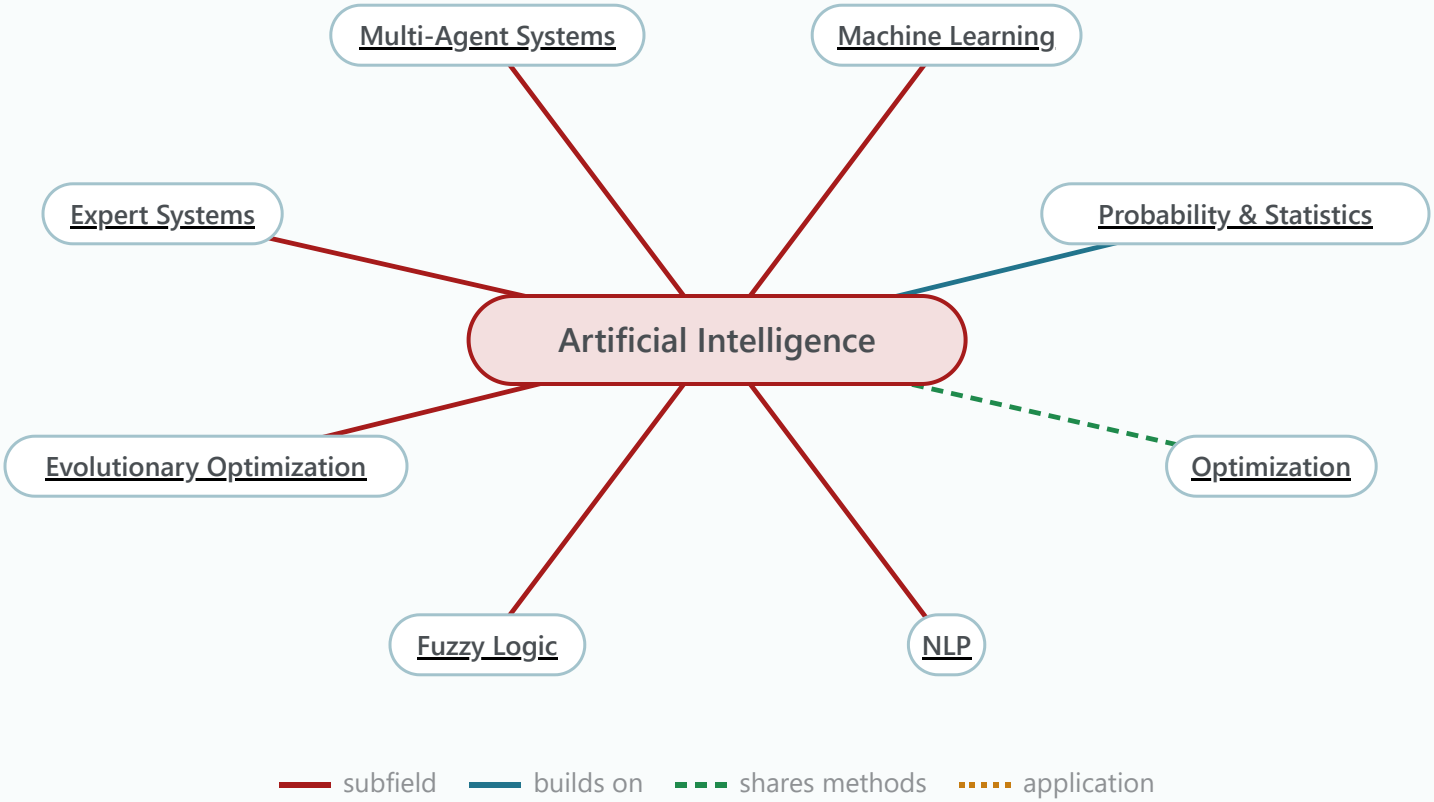
Ask yourself; for every "no", the right-hand column shows where to start.

Ask yourself	If not, start with
Can you trace BFS and DFS on a graph step by step on paper?	Graphs and queues from a data structures course
Can you explain a priority queue and big-O notation?	Complexity analysis from an algorithms course
Can you build a truth table with "and", "or" and "implies"?	Propositional logic from discrete mathematics
Can you explain conditional probability and Bayes' rule?	Probability and Statistics

If you can say "yes" to most of these, you are ready; one or two gaps can be closed during the semester.

CONTEXT

Neighbouring Courses



OVERLAP

Overlapping Courses

Relation	Course	Shared ground
subfield	Machine Learning is a subfield of this course	an agent that learns from data; statistical generalization instead of search
subfield	Natural Language Processing and Text Mining is a subfield of this course	language understanding and generation
subfield	Fuzzy Logic and Fuzzy Systems is a subfield of this course	approximate reasoning
subfield	Evolutionary and Metaheuristic Optimization is a subfield of this course	heuristic search
subfield	Expert Systems and Knowledge Representation is a subfield of this course	symbolic AI, logic and rules
subfield	Multi-Agent Systems is a subfield of this course	the agent concept, collective decisions
builds on	This course builds on Probability and Statistics	reasoning under uncertainty, Bayes rule
shares methods	Shares methods with Optimization	state-space search, constraint satisfaction

DIFFERENCES

Where It Differs (1/2)

Criterion	Artificial Intelligence	Machine Learning	Expert Systems
Core question	How does a machine act intelligently by searching, reasoning and planning?	How does a program generalize from examples?	How is an expert's knowledge written down and used for inference?
Approach	search, logic, probability and learning combined	statistical learning	symbolic logic and rules
Input	problem definition: states, actions, goal	labeled or unlabeled examples	facts and expert rules
Output	action sequence, plan or decision	a model that makes predictions	conclusion with justification
Success measure	reaching the goal, cost, rationality	error on unseen data	expert agreement, explainability
Math load	medium: logic, probability, graphs	high: linear algebra, probability, optimization	low: propositional and predicate logic
Data needs	little; often a model and knowledge suffice	moderate to large	little; a knowledge base

- **Machine Learning:** AI can find how to reach a goal by search or inference; ML learns the same behavior by generalizing from data.
- **Expert Systems:** Expert systems are one approach within AI (rules and logic); AI also covers search, probability and learning.

Where It Differs (2/2)

Criterion	Artificial Intelligence	Optimization	Multi-Agent Systems
Core question	How does a machine act intelligently by searching, reasoning and planning?	How do we find the values that make an objective function best?	How do several autonomous agents decide together or against each other?
Approach	search, logic, probability and learning combined	mathematical model of objective and constraints	interacting autonomous agents
Input	problem definition: states, actions, goal	objective function and constraints	agents, goals, protocols
Output	action sequence, plan or decision	optimal or near-optimal solution	joint behavior, equilibrium
Success measure	reaching the goal, cost, rationality	objective value, convergence rate	social welfare, stability
Math load	medium: logic, probability, graphs	the theory itself	medium: game theory
Data needs	little; often a model and knowledge suffice	none	little; simulation

- **Optimization:** Optimization solves a problem already stated mathematically; AI starts by modeling it as agent, environment and goal.
- **Multi-Agent Systems:** AI focuses on the decisions of a single agent; multi-agent systems study agents that affect one another.

PRACTICE

Applications

Games
Chess and Go engines, computer opponents in games.

Route planning
Navigation, logistics, paths of warehouse robots.

Scheduling
Class timetables, flight crews and shift plans.

Virtual assistants
Systems that understand speech and turn it into tasks.

Autonomous vehicles
Where perception, prediction and planning meet.

Decision support
Diagnosis suggestions in medicine, fault diagnosis in engineering.

PRACTICE

Risks and Ethics

The wrong performance measure

An agent maximizes its measure literally: a route planner that only minimizes travel time can push traffic onto side streets past schools.

Search that does not scale

State spaces grow exponentially; a search that takes seconds on a toy problem runs out of memory and time at real size.

An incomplete knowledge base

A system that treats whatever is missing from its rules as false draws confident but wrong conclusions from one forgotten rule.

Responsibility for autonomy

When an autonomous car or weapon system decides on its own, it becomes unclear who answers for its mistakes.

In depth: Explainable AI and AI Ethics.

PRACTICE

Tools and Datasets

Tools and libraries

Python | Prolog | PDDL planners | Google OR-Tools | Gymnasium | pgmpy (Bayesian networks)

Classic example problems

8-puzzle | n-queens | Sudoku | Wumpus world | Traveling salesman | Chess and Go

An AI course usually gives a **problem definition** instead of a dataset: once states, actions and the goal are known, the solution is found by search.

PRACTICE

Common Misconceptions

Common belief	In fact
AI and machine learning are the same thing.	ML is a subfield of AI. Search, planning and logic are AI even without learning.
AI aims to think like humans.	The course mostly aims at **acting rationally**; imitating humans is only one approach.
Chess engines learn by playing.	Classic engines like Deep Blue use search and a hand-written evaluation; learning is not required.
Chatbots are all of AI.	Large language models come from NLP and generative models; AI is a much broader field.

NEXT STEPS

After This Course

Courses that build on or extend this one

Machine Learning | Natural Language Processing and Text Mining | Fuzzy Logic and Fuzzy Systems | Evolutionary and Metaheuristic Optimization | Expert Systems and Knowledge Representation | Multi-Agent Systems

Related careers

AI engineer | Researcher | Game AI developer | Robotics software engineer | Decision support specialist

AI is the roof of this guide: machine learning, natural language processing, fuzzy logic, evolutionary optimization, expert systems and multi-agent systems are its branches. To decide which branch interests you, a good start is to see this course's search, logic and uncertainty topics first.

NEXT STEPS

Further Reading

- Russell and Norvig, *Artificial Intelligence: A Modern Approach*, 4th ed., Pearson, 2020.
- Poole and Mackworth, *Artificial Intelligence: Foundations of Computational Agents*, 3rd ed., Cambridge University Press, 2023.
- Nilsson, *The Quest for Artificial Intelligence*, Cambridge University Press, 2010 (history of the field).
- Turing, "Computing Machinery and Intelligence", *Mind* 59(236), 1950.

The End

Chapter 2: Artificial Intelligence

← Previous chapter · Map of the field · Next chapter →