Artificial Intelligence

CS 165A

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Prof. Yu-Xiang Wang

Computer Science
About myself

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Yu-Xiang is pronounced approximately as ['ju:'fi:əŋ], namely, y~eu~ee – sh~ih~ah~ng.


Short biography:

China => Singapore
⇒ PhD from Carnegie Mellon University
⇒ Scientist at Amazon AI
⇒ Professor at UCSB

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Call me: Yu-Xiang or Professor Wang. Don’t call me: Wang, Yu, Professor.
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Artificial Intelligence

• AI in the media
  – Popular movies
    ♦ 2001: A Space Odyssey
    ♦ Star Wars
    ♦ The Terminator
    ♦ The Matrix
    ♦ Artificial Intelligence: AI
    ♦ and many …
  – Popular press, novels

• Often portrayed as
  – A property of evil computers
  – Computers doing impossible things

• Public view
  – Books and movies have inspired many AI researchers
  – Books and movies have raised the public’s expectations
Artificial Intelligence
AI Is Transforming The Industries

☐ AI has transformed the IT industry
  ☐ Search Engine
  ☐ Speech Recognition
  ☐ Machine Translation
  ☐ Recommendation

☐ AI is transforming other industries
  ☐ Transportation
  ☐ Healthcare
  ☐ Finance
  ☐ Insurance, Law, HR, Travel, Media, …
  ☐ Semiconductor / Microprocessors
Artificial Intelligence

- Turing Test
  The "standard interpretation" of the Turing Test, in which player C, the interrogator, is given the task of trying to determine which player – A or B – is a computer and which is a human. The interrogator is limited to using the responses to written questions to make the determination. (wiki)

- Artificial Intelligence is an ultimate dream of computer science

Supplementary reading: Turing (1950) “Computing Machinery and Intelligence” [here].
Seminal event for AI as a field, in 1956:

The **Dartmouth Summer Research Conference on Artificial Intelligence**

“We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the **conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it**. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.”
Over-Confidence

Herbert Simon (1957)

It is not my aim to surprise or shock you - but the simplest way I can summarize is to say that there are now in the world machines that think, that learn and that create, ...

More precisely: within 10 years a computer would be **chess champion**, and an important new **mathematical theorem** would be proved by a computer.

Both of these milestones have now been achieved by computers, but each happened much later, more than 10 years:

1. Four color theorem proven in 1976 by Kenneth Appel and Wolfgang Haken
2. Deep Blue *chess* computer *defeated* Kasparov in 1997
History

- 1956: The **Dartmouth Summer Research Conference on Artificial Intelligence**, Seminal event for AI as a field

- 1976: **Four color theorem** was proven by Kenneth Appel and Wolfgang Haken

- 1997: Deep Blue **chess** computer defeated Kasparov \((10^{50})\)
  - “Saying Deep Blue doesn’t really think about chess is like saying an airplane doesn’t really fly because it doesn’t flap its wings.” --Drew McDermott

- Since 2012, we saw breakthroughs in **Speech Recognition, Image Recognition, Machine Translation, Autonomous Car**, etc.
- 2015, **CNN+ReLU** outperforms humans in image recognition.
- 2016, **AlphaGo** beat a 9-dan professional (Lee Sedol) \((10^{170})\)
- 2020, **GPT-3** is doing well simultaneously in many natural language tasks.
Question Answering

• IBM Watson / Jeopardy!

• Apple Siri
  – The application uses a natural language user interface to answer questions, make recommendations, and perform actions by delegating requests to a set of Web services.

• Amazon Echo / Google Home
  – Associate the natural language user interface with a speaker.

• Google demo of restaurant reservation
  – https://www.youtube.com/watch?v=eHvyKWS5QzE
Question Answering

Apple Siri

• “Hey Siri, what’s the best sushi place in town?”
• “Find videos I took at Iva’s birthday party”
• “What movies are playing today?”
• “Wake me up at 7 AM tomorrow”

Google Search

• “Who was U.S. President when the Angels won the World Series?”
• But, “Who was the UK prime minister when the Angels won the World Series?”
Can Computers Understand?

- They ate the pie with ice cream.
- They ate the pie with rhubarb.
- They ate the pie with paper plates.
- They ate the pie with cold milk.
- They ate the pie with friends.
- They ate the pie with dinner.
- They ate the pie with enthusiasm.
- They ate the pie with spoons.
- They ate the pie with napkins.
State-of-the-art AI for Question and Answers

- GPT-3 from OpenAI
- See example here: Giving GPT-3 a Turing Test

Q: What is your favorite animal?
A: My favorite animal is a dog.

Q: Why?
A: Because dogs are loyal and friendly.

Q: What are two reasons that a dog might be in a bad mood?
A: Two reasons that a dog might be in a bad mood are if it is hungry or if it is hot.

Q: How many eyes does a giraffe have?
A: A giraffe has two eyes.

Q: How many legs does a frog have?
A: A frog has four legs.

Q: Are there any animals with three legs?
A: No, there are no animals with three legs.

Q: Why don't animals have three legs?
A: Animals don't have three legs because they would fall over.
A lot more that GPT-3 is able to do:

• Generate well-written text

• Generate code for website layout, format charts / figures.

• Parse spreadsheets

• Translations: English ⇔ Chinese, Legal ⇔ Plain English

• Check out this video: https://youtu.be/_x9AwxfjxvE?t=219
Other cool demos of AI

- Learning to walk / run with Reinforcement Learning
  - https://youtu.be/gn4nRCC9TwQ

- Learning to generate a realistic face
  - https://www.thispersondoesnotexist.com/

- Learning to play “hide and seek” in creative ways:
  https://youtu.be/Lu56xV1Z40M?t=50

EBGAN (Zhao et al, 2016)  BEGAN (Berthelot et al, 2017)
“We are in the middle of a new industrial revolution.” --- Bernhard Schölkopf

- First two revolutions: our ability to harness energies
  - Coal / Fossil fuel
  - Electricity

- Third revolution: our ability to harness information
  - Digital revolution from 1950s.
  - Big Data revolution, most recently, AI revolution

- Fundamental societal changes
  - Job loss
  - Addiction, polarization
  - Privacy, fairness
  - Synthesize voice, face of any one
  - AI Weapons?

The exponential growth of AI as a field

“For those debating ML hype, getting a ticket to a ML conference is now more challenging than a Taylor Swift conference or a Hamilton showing.”

– Kaggle CTO Ben Hamner
Is it all just hype?

• AI research is supported by rigorous mathematical foundation.
  – Although… there’s caveat.
  – Theory is always a bit behind.

• AI Researchers know the limitations of their algorithms
  – (although…. sometimes it’s easy to go over the top)
Regardless, it is an exciting time!

- The field of AI is gathering talents from CS, Stats, Math, Physics, Engineering, Business like never before!
  - 70% PhD applicants to UCSB CS want to specialize in AI / ML!

- We are training the first generation of Da Vinci-like engineers / researchers in large scale
  - Who can swiftly leverage multiple branches of mathematics
  - Understand computing / computer systems / write efficient codes
  - Understand statistics / causality / handles big data
  - Inspired by ideas from neural science / biological world.
Goals of this course

- To teach you some ideas of AI
- To introduce you to a set of key techniques and algorithms from AI
- To get you thinking about how AI can be applied to a variety of real problems
- To help you understand what’s hard in AI
- To know where to find additional materials when needed in the future

- It is not about vision, natural language processing, machine learning, AlphaGo,…it is an entry level course
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<th>Topic</th>
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<td>2</td>
<td>Machine Learning</td>
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<td>Probabilistic Graphical Models</td>
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<td>Search: Problem solving with search</td>
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<td>Search: Search algorithms</td>
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<td>Search: Minimax search and game playing</td>
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<td>RL: Intro / Markov Decision Processes</td>
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<td>6</td>
<td>RL: Solving MDPs</td>
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<td>7</td>
<td>RL: Bandits and Exploration</td>
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<td>7</td>
<td>RL: Reinforcement Learning Algorithms</td>
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<td>8</td>
<td>RL: Reinforcement Learning Algorithms</td>
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<td>8</td>
<td>Logic: Propositional Logic</td>
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<td>9</td>
<td>Logic: First order Logic</td>
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<td>Responsible AI</td>
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<td>10</td>
<td>Responsible AI</td>
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<td>11</td>
<td>Final Review</td>
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<td>11</td>
<td>Final Exam (take-home)</td>
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It will be tough and time-consuming to many!

• You need to use math:
  – Calculus, Linear Algebra, Probabilities.
  – Know how to do complexity analysis in Big O notation.

• You need to be able to code:
  – Mainly in Python (numpy, scipy)
  – Data structures: trees, graphs, hashtables, sparse matrices, etc…

• Homework assignments will complement the materials in the lectures.
  – That will help you gain deeper understanding of the topics.

• Formal prerequisite:
  – CS20, CS50, CS130A, PSTATS 120A.
It will be “worth it”.

• Like Jedi training.
  – The information can be presented to you, but you can only learn if you are actively looking and thinking.
  – I learn a lot more from doing homeworks on my own than just from the lectures.

• We (your instructor, TAs and peers) are ready to help you!
  – Discussion sessions on Friday, Office hours, Piazza
Expectation of you

• Academic Integrity
  – Homeworks are individual work
  – Discussion with your peers on the high level is fine.
  – Finding solutions to the exact questions on the internet is not OK.
  – Sharing equations, sharing code / pseudo-code are not OK.
  – If not sure if anything is a violation of the course policy, check with the TAs on Piazza.

• Creating a respectful learning environment for all
  – Be respectful to your peers and instructors
  – Harassment and discrimination of any form will not be tolerated.

* More details on these in the [syllabus].
Course information

• Web sites
    ♦ Announcements, syllabus, schedule, lecture notes, assignments, related links

• Discussion on Piazza:
  piazza.com/ucsb/fall2020/cs165a

• Homework submission on Gradescope
  – You will be added directly to it.

• Textbook
  – Other reference books will be referred to. (e.g., Sutton and Barto will be our main text for the RL part of the class)
Mode of Remote Instruction

• Synchronous Lectures (Recorded)
  – A TA will moderate the questions / address easy questions via chat
  – I will address questions not answered by TAs periodically during lectures.

• Asynchronous Discussion Sections (Recorded)
  – Videos will be released to you on Piazza
  – TAs will be at the Wednesday discussion class to answer questions and provide live interactions with students

• Office Hours from me and the TAs (not recorded)

• Asynchronous Q&A: Piazza
Workload and Grade

• 4 Homework Assignments, 2 Exams
• 60% Homework assignments
  15% Take-home midterm exam
  25% Take-home final exam
• x% bonus points:
  – For solving bonus questions in homeworks
  – For class participation

• Late Policy:
  – Each student has a total of 3 late days without penalties.
  – When your late days are used up, you may still submit. When submitted within a week of the due date you will receive 75% of the credits. Beyond that only 50%.
  – No late submission for the take-home exams are allowed.
Office Hours

- Instructor Office Hour: Thursday 2:00-3:00pm
- TA1: Xuandong Zhao, Office Hour:
- TA2: Kaiqi Zhang, Office Hour:
- TA3: Benu Changmai, Office Hour:

Single zoom link for all these OHs: announced on Piazza.

- **Ask your questions on Piazza!**
How to Maximize Your Learning

• Read textbook chapter (or other resources) before class
• Attend lectures and study the slides
• Read related chapters before the class

• Do your own “homework”, self-study
• Actively participate discussions on Piazza
• No last minute work
Useful resources

• Appendix A in the AIMA book for a mathematical review.

• Standard mathematical notations used in ML / AI: http://www.deeplearningbook.org/contents/notation.html

• Chapter 2, Chapter 17-18 of the D2L book: http://d2l.ai/

• Probability / Linear Algebra review (shared with you on Piazza, will be covered next Wednesday)

• If you are having trouble understanding the probability part of above
  – Here is a more straightforward probability review
Remainder of the lecture: Intelligent agents

- Formally setting up the problem
  - Intelligent Agents
  - The Model-Inference-Learning Paradigm
  - Task environment
  - Model vs. reality
What's an Agent?

"An intelligent agent is an entity capable of combining cognition, perception and action in behaving autonomously, purposively and flexibly in some environment."

- **Possible properties of agents:**
  - Agents are **autonomous** – they act on behalf of the user
  - Agents can **adapt** to changes in the environment
  - Agents don't only act **reactively**, but sometimes also **proactively**
  - Agents have **social ability** – they communicate with the user, the system, and other agents as required
  - Agents also **cooperate** with other agents to carry out more complex tasks than they themselves can handle
  - Agents **migrate** from one system to another to access remote resources or even to meet other agents
Our view of AI

• AIMA view – AI is building intelligent (rational) agents
  – Principles of rational agents, and
  – Models/components for constructing them

• Rational = “Does the right thing” in a particular situation
  – Maximize expected performance (not actual performance)

• So a rational agent does the “right” thing (at least tries to)
  – Maximizes the likelihood of success, given its information
  – How is “the right thing” chosen?
    ♦ Possible actions (from which to choose)
    ♦ Percept sequence (current and past)
    ♦ Knowledge (static or modifiable)
    ♦ Performance measure (wrt goals – defines success)
Our model of an agent

- An agent **perceives** its environment, **reasons** about its goals, and **acts** upon the environment
  - Abstractly, a function from percept histories to actions
    \[ f : P^* \rightarrow A \]

- Main components of an agent
  - Perception (sensors)
  - Reasoning/cognition
  - Action (actuators)

- Supported by
  - knowledge representation, search, inference, planning, uncertainty, learning, communication….
Our view of AI (cont.)

- So this course is about designing rational agents
  - Constructing $f$
  - For a given class of environments and tasks, we seek the agent (or class of agents) with the “best” performance
  - Note: Computational limitations make complete rationality unachievable in most cases

- In practice, we will focus on problem-solving techniques (ways of constructing $f$), not agents per se
Ideal Rational Agent

• In other words…

“For each possible percept sequence, an ideal rational agent should do whatever action is expected to maximize its performance measure, on the basis of the evidence provided by the percept sequence and whatever built-in knowledge the agent has.”

Note that:

<table>
<thead>
<tr>
<th>Rational ≠ Omniscient</th>
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<tbody>
<tr>
<td>Rational ≠ Clairvoyant</td>
</tr>
<tr>
<td>Rational ≠ Successful</td>
</tr>
</tbody>
</table>
Describing the Task Environment

- **PEAS** – Performance measure, Environment, Actuators, Sensors
  - Goals may be explicit or implicit (built into performance measure)

- Not limited to physical agents (robots)
  - Any AI program
The Vacuum World: 3 min discussion

Performance measure, Environment, Actuators, Sensors
The Vacuum World

• Performance (P)
  – Keep world clean
  – Possible performance measures

• Environment (E)
  – Location
  – Cleanliness

• Three actions (A)
  – Move right
  – Move left
  – Remove dirt

• Sensed information (percepts) of environment (S)
  – Two locations
    ♦ Left
    ♦ Right
  – Two states
    ♦ Dirty
    ♦ Clean
## PEAS Descriptions

<table>
<thead>
<tr>
<th>Agent Type</th>
<th>P</th>
<th>E</th>
<th>A</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical diagnosis system</td>
<td>Healthy patient, minimize costs</td>
<td>Patient, hospital</td>
<td>Questions, tests, treatments</td>
<td>Symptoms, findings, patient’s answers</td>
</tr>
<tr>
<td>Satellite image analysis system</td>
<td>Correct categorization</td>
<td>Images from orbiting satellite</td>
<td>Print a categorization of scene</td>
<td>Pixels of varying intensity, color</td>
</tr>
<tr>
<td>Part-picking robot</td>
<td>Place parts in correct bins</td>
<td>Conveyor belt with parts</td>
<td>Pick up parts and sort into bins</td>
<td>Pixels of varying intensity</td>
</tr>
<tr>
<td>Refinery controller</td>
<td>Maximize purity, yield, safety</td>
<td>Refinery</td>
<td>Open, close valves; adjust temperature</td>
<td>Temperature, pressure readings</td>
</tr>
<tr>
<td>Interactive English tutor</td>
<td>Maximize student’s score on test</td>
<td>Set of students</td>
<td>Print exercises, suggestions, corrections</td>
<td>Typed words</td>
</tr>
</tbody>
</table>
Environments

• Properties of environments
  – Fully vs. partially observable
  – Deterministic vs. stochastic
  – Episodic vs. sequential
  – Static vs. dynamic
  – Discrete vs. continuous
  – Single agent vs. multiagent

• The environment types largely determine the agent design

• The real world is partially observable, stochastic, sequential, hostile, dynamic, and continuous
  – Bummer…
New paradigm: Modeling-Inference-Learning

(Idea and example taken from Percy Liang’s teachings)
Paradigm: Modelling

Real world

Modeling

Model
Paradigm: Inference
Paradigm: Learning

Model without parameters

+data

Learning

Model with parameters
Structure of the course

Probabilistic Graphical Models / Deep Neural Networks

- Classification / Regression
- Bandits
- Search
- Game playing
- Markov Decision Processes
- Reinforcement Learning
- Logic, knowledge base
- Probabilistic inference

Reflex Agents  Planning Agents  Reasoning agents

Low-level intelligence  High-level intelligence

Machine Learning

(Again this idea is adapted from Percy Liang's teachings)
Generic Agent Program

- Implementing $f : P^* \rightarrow A$ ...or... $f(P^*) = A$
  - Lookup table?
  - Learning?

```
function SKELETON-AGENT(percept) returns action
  static: memory, the agent’s memory of the world

  memory ← UPDATE-MEMORY(memory, percept)
  action ← CHOOSE-BEST-ACTION(memory)
  memory ← UPDATE-MEMORY(memory, action)
  return action
```

e.g.,
Table-Driven-Agent
Add percept to percepts
LUT [percepts, table]
NOP
AIMA’s categorization of agent programs

- Simple reflex agent
- Model-based reflex agent
- Goal-based agent
- Utility-based agent
- Learning agent

(Read more in Section 2.4 of the AIMA book.)

Potential mid-term questions:
1. Where do these agent fall under our new categorization?
2. What are these agent’s “Modelling-Inference-Learning” components?
Quiz: What kind of agent it is in the Vacuum world?

- Reflex, planning, reasoning?
- What is the model? Are there any learning components?
When to use which type of agent?

• Depends on the problem (task environment)
  – Stochastic/deterministic/stateful/adversarial …

• Depends the amount of data available
  – Often we need to learn how the world behaves

• Depends on the dimensionality of your observations

Solving the right problem approximately vs Solving an approximation of the problem exactly
“All models are wrong, but some are useful.”

George Box  
(1919 - 2013)
Next three lectures: machine learning

- Chapter 18 in AIMA (3rd Edition) (more extensive coverage in the 4th Edition)
- Chapter 1 in D2L: Intro to ML [link](http://d2l.ai/chapter_introduction/index.html)
- Chapter 1 in ESL: A more extensive introduction to ML
- Chapter 3,4,11 in D2L:
  - Chapter 3,4: From linear classification to neural networks
  - Chapter 11: Optimization in ML.
Final notes

• Submit (anonymous) feedbacks here: https://forms.gle/CkfYBNnjR7durZ7g6
  – What do you like / dislike about the course so far?
  – Are you following the lectures?
  – Am I going too fast or too slow?
  – Which AI topic from the course-schedule that you are most excited about?

• Homework 1 will be released tonight! Start early!

• If you haven’t yet, please answer the new student poll: https://forms.gle/iFoR7R27V5AQGrKX6