



# Introduction

CISC 7404 - Decision Making

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# Prerequisites

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- Python numerical programming

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- Statistics and probability

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Assignments in jax/equinox, similar to torch - final project in torch

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Assignments in jax/equinox, similar to torch - final project in torch

If you do not know numerical programming, **you must learn immediately**: <https://numpy.org/doc/stable/user/quickstart.html>

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Deep learning:



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**Deep learning:**

You should know:

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## Deep learning:

You should know:

- How to construct a neural network in torch

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- How to train a neural network
- Multilayer perceptrons
- Convolutional networks
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If you do not, review the deep learning slides: [https://github.com/smorad/um\\_cisc\\_7026](https://github.com/smorad/um_cisc_7026)

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**Question:** What does  $P(X = x)$  mean?



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**Question:** What does  $P(X = x)$  mean?

**Answer:** Probability of random variable  $X$  taking on a value of  $x$

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- The entropy of a distribution

**Question:** What does  $P(X = x)$  mean?

**Answer:** Probability of random variable  $X$  taking on a value of  $x$

If you did not know this, you should review!

# Grading

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# Grading

- Quizzes 30%

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- Assignments 30%

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- Assignments 30%
- Final Project 30%

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- Quizzes 30%
- Assignments 30%
- Final Project 30%
- Participation 10%

# Grading Quizzes:



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Final quiz score:  $(70 + 80) / 2 = 75\%$

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Final quiz score:  $(70 + 80) / 2 = 75\%$

**Example 2:** Quiz 1: 90%, Quiz 2: (sick) 0%, Quiz 3: 70%



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## Quizzes:

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Final quiz score:  $(90 + 70) / 2 = 80\%$

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**Example 1:** Quiz 1: 70%, Quiz 2: 80%, Quiz 3: 60%

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**Question:** What if you are sick for two quizzes?

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**Example 2:** Quiz 1: 90%, Quiz 2: (sick) 0%, Quiz 3: 70%

Final quiz score:  $(90 + 70) / 2 = 80\%$

**Question:** What if you are sick for two quizzes? Only one quiz dropped, other quiz is zero

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## Assignments:

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- Programming

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- Expect 2-3 assignments

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- Programming
- Expect 2-3 assignments
- We will use Google Colab: <https://colab.research.google.com>

# Grading

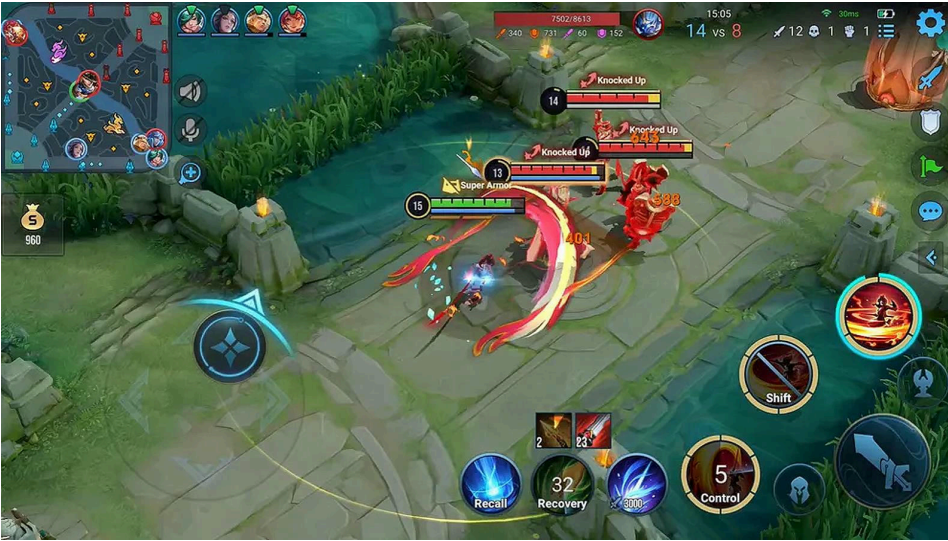
## Final Project:



# Grading

## Final Project:

## Honor of Kings

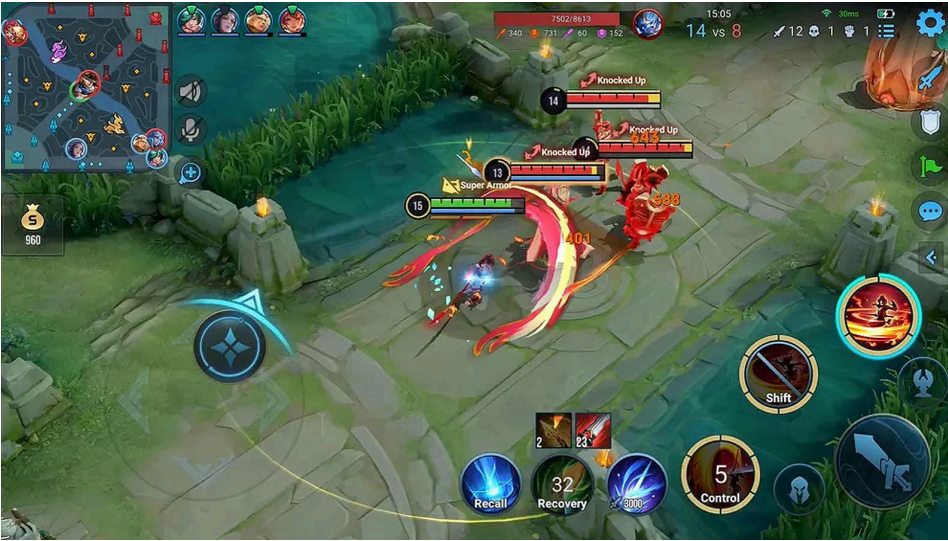


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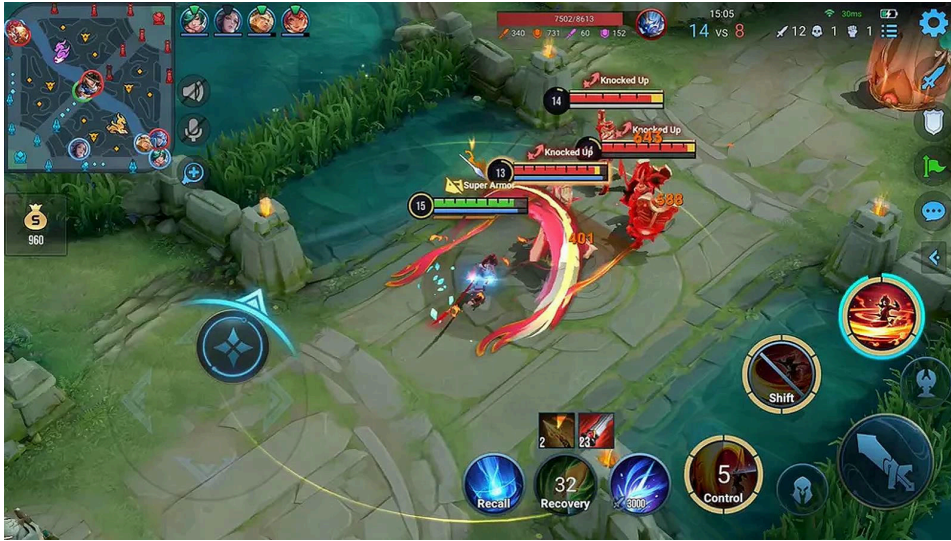
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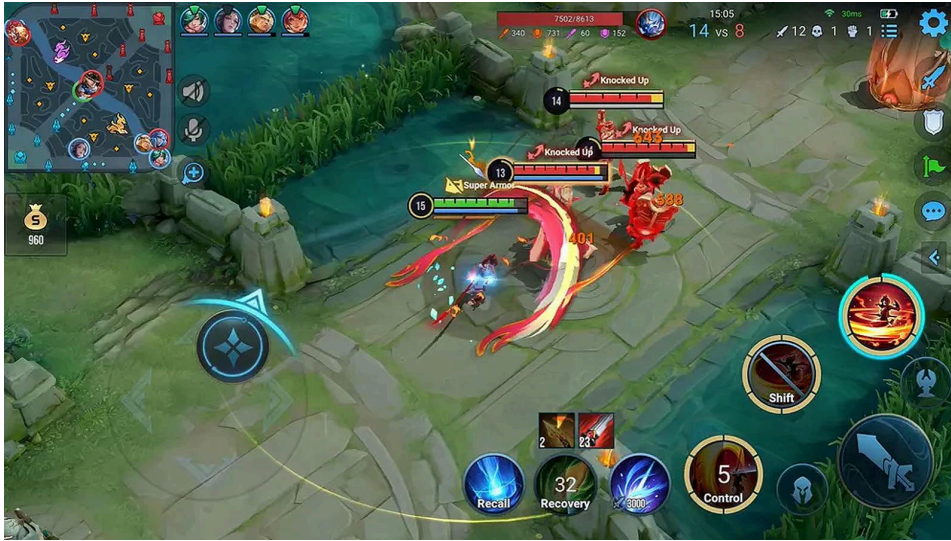


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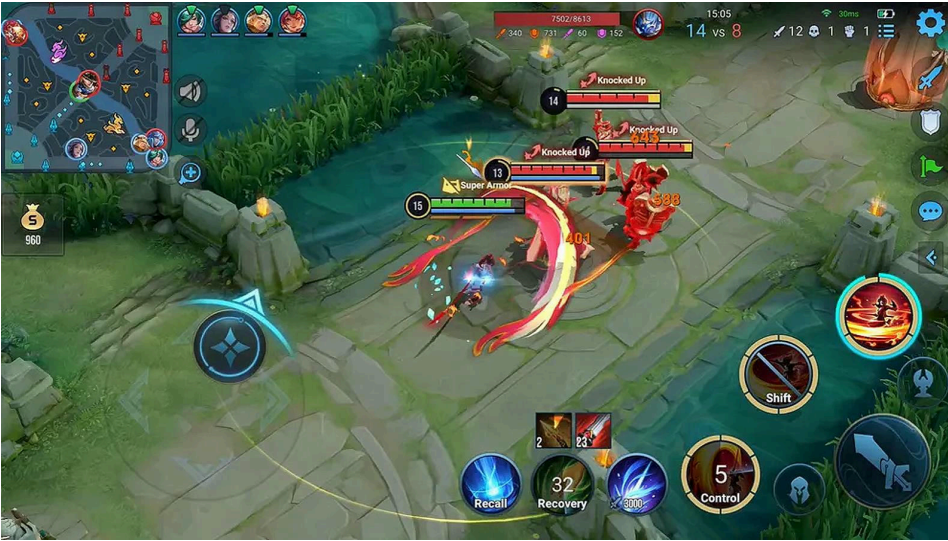
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# Grading

## Final Project:

### Honor of Kings



- Research project based on Tencent platform
- Train agents to play each other
- Implement RL algorithm, improve it, write up analysis
- More information later

# Grading

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### **Significance**

Despite active learning being recognized as a superior method of instruction in the classroom, a major recent survey found that most college STEM instructors still choose traditional teaching methods. This article addresses the long-standing question of why students and faculty remain resistant to active learning. Comparing passive lectures with active learning using a randomized experimental approach and identical course materials, we find that students in the active classroom learn more, but they feel like they learn less. We show that this negative correlation is caused in part by the increased cognitive effort required during active learning. Faculty who adopt active learning are encouraged to intervene and address this misperception, and we describe a successful example of such an intervention.

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Participation is **asking** or **answering** questions during lecture

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- Individual participation

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- Submitting LLM output for assignments

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It is not worth cheating, do your best and you will get partial credit

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I want you to **learn the material** so you succeed in life

## Machine Learning Engineer Interview

16 May 2024 ...



Anonymous interview candidate

✗ No offer — Neutral experience ✗ Difficult interview

### Application

I interviewed at Baidu in 16/5/2024

### Interview

it has 5 rounds of interviews, each of them is very long. I only managed to get to the second round with technical interview, and I failed. It's not a pleasant experience

### Interview questions [1]

Question 1

describe tree algorithm and write in python

[Answer question →](#)



Helpful



Share

# Cheating

## Machine Learning Engineer Interview

Aug 27, 2023 ...



Anonymous Interview Candidate



Beijing, Beijing

— Declined offer    Positive experience    Difficult interview

### Application

I applied online. I interviewed at ByteDance (Beijing, Beijing) in 8/27/2023

### Interview

machine learning knowledge, code. leetcode (medium, hard with python), AUC definition, method on dealing with long tailed data and causal inference, machine learning question and deep learning method such as attention mechanism.

### Interview questions [1]

Question 1

machine learning knowledge, code. leetcode, AUC definition, method on dealin...

[read more](#)

[Answer question](#) →

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**Ok:** LLM, why does my `Q` function return large values?

**Cheating:** LLM, implement the policy gradient algorithm in pytorch

# Lecture Topics

---



# Lecture Topics

- Basics

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- Basics
- Modern Methods

# Lecture Topics

- Basics
- Modern Methods
- Active Research

# Lecture Topics

## Basics:

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## Basics:

- Bandits

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## Basics:

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- Decision Processes

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- Bandits
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- Value Iteration
- Policy Gradient
- Actor Critic

# Lecture Topics

## Modern Methods:

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# Lecture Topics

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- Advantage Actor Critic
- Trust Region Policy Optimization
- Proximal Policy Optimization
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- Deep Deterministic Policy Gradient
- Soft Actor Critic
- Imitation learning

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- Memory

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- RL from Human Feedback

# What is Decision Making?

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The problem is **decision making**

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The problem is **decision making**

In this course, we will learn how to make good decisions

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- Cognitive science
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**Answer:** Given information, make a choice that impacts the world

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- What time should I leave for class?

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- Do I eat dumplings or noodles?
- What time should I leave for class?
- Should I go to school or find a job?
- Should I date this person?
- Where should I live?
- What should we use taxes for?

# What is Decision Making?

Humans are decision making machines – it is all we do!

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“All we have to decide is what to do with the time that is given to us”

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If we learn to make better decisions, we can lead better lives

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Make the best possible decision, given the information we have

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With an optimal decision making machine, you can create:

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We will find methods that **guarantee** optimal decision making

With these methods, we can create optimal decision making machines

With an optimal decision making machine, you can create:

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# What is Decision Making?

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- Best possible scientist (what to research?)

If the machine understands **why** it makes decisions, it is conscious

# What is Decision Making?

Let us discuss the history of decision making to better understand it

# History of Decision Making

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# History of Decision Making

**Question:** Who was the first to apply decision making algorithms?

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Decides to move away from danger and move towards food

# History of Decision Making

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**3.5 GYA:** Single cell organism

Decides to move away from danger and move towards food

Decision making is necessary for life



# History of Decision Making



# History of Decision Making



**200 kYA:** Humanoid hunter-gatherers develop more complex decision making capabilities

# History of Decision Making



**200 kYA:** Humanoid hunter-gatherers develop more complex decision making capabilities

Sequence of decisions to make fire



# History of Decision Making



**200 kYA:** Humanoid hunter-gatherers develop more complex decision making capabilities

Sequence of decisions to make fire

Sequence of decisions to plant crops

# History of Decision Making



**500 BCE:** Humans begin to study decision making

# History of Decision Making



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Sun Tzu studies and writes about various forms of decision making

# History of Decision Making



**500 BCE:** Humans begin to study decision making

Sun Tzu studies and writes about various forms of decision making

E.g., zero sum games: “Attack where he is unprepared; appear where you are not expected.”

# History of Decision Making



**400 BCE:** Aristotle creates the earliest recorded framework for decision making



# History of Decision Making



**400 BCE:** Aristotle creates the earliest recorded framework for decision making

Syllogistic logic and deductive reasoning from axioms

# History of Decision Making



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# History of Decision Making



**400 BCE:** Aristotle creates the earliest recorded framework for decision making

Syllogistic logic and deductive reasoning from axioms

**Axiom 1:** All philosophers prioritize knowledge over leisure

**Axiom 2:** I am a philosopher

**Decision:** I must attend lecture instead of the party



# History of Decision Making



**1654:** Pascal formalizes decision making under uncertainty with “Pascal’s Wager”

# History of Decision Making



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**Premise:** You are in bed, about to die. Should you believe in God?



# History of Decision Making

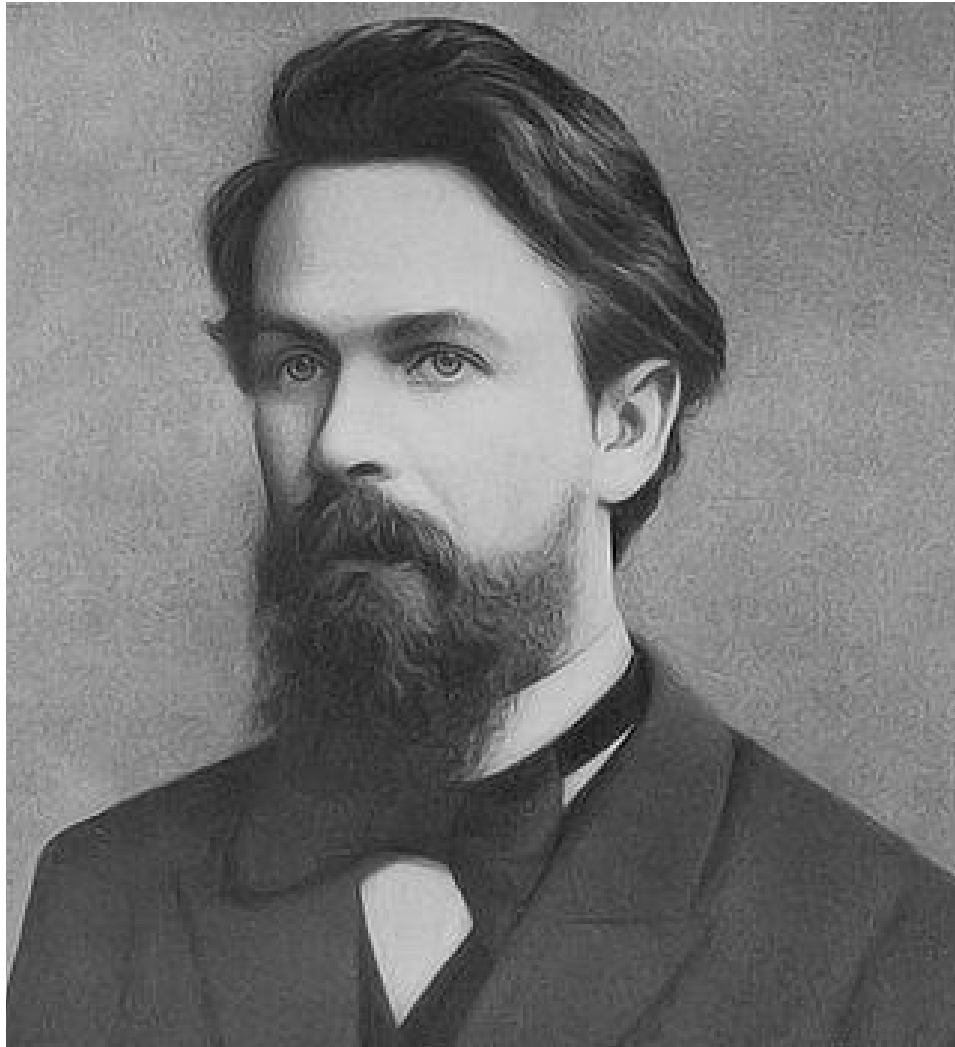


**1654:** Pascal formalizes decision making under uncertainty with “Pascal’s Wager”

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	Believe	Do not believe
God exists	Good	Bad
God does not exist	Neutral	Neutral

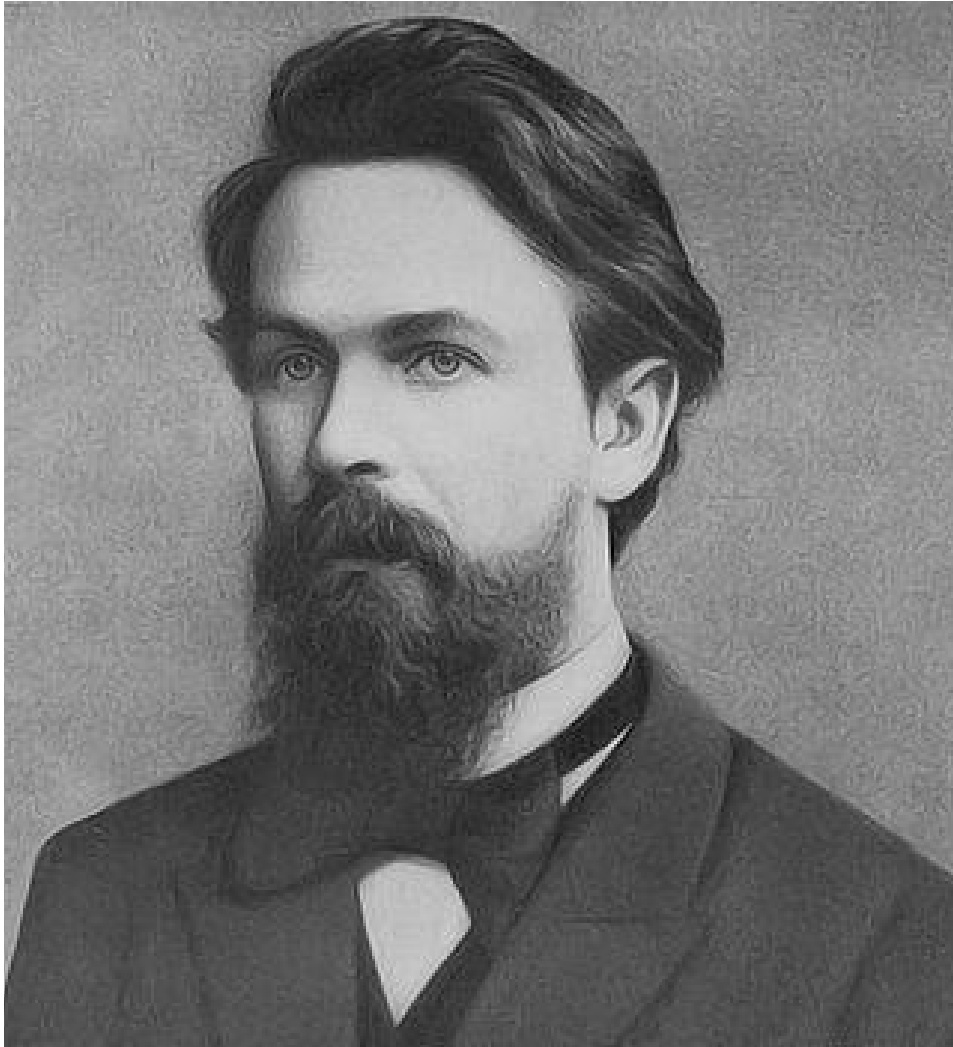
# History of Decision Making



**1906:** Markov discovers Markov processes



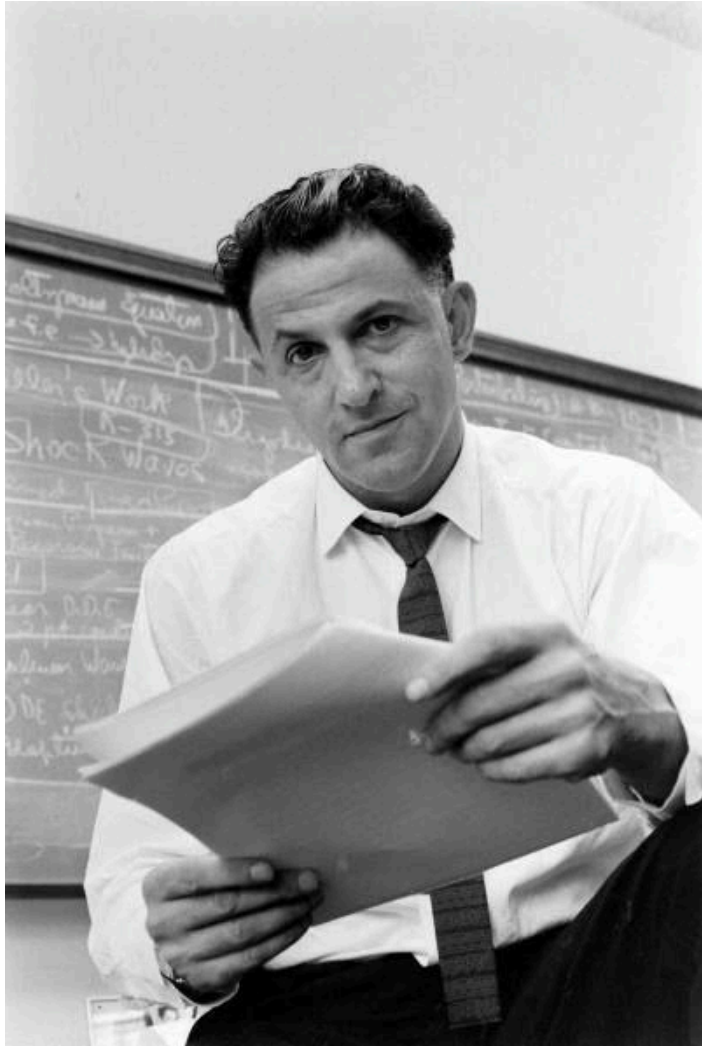
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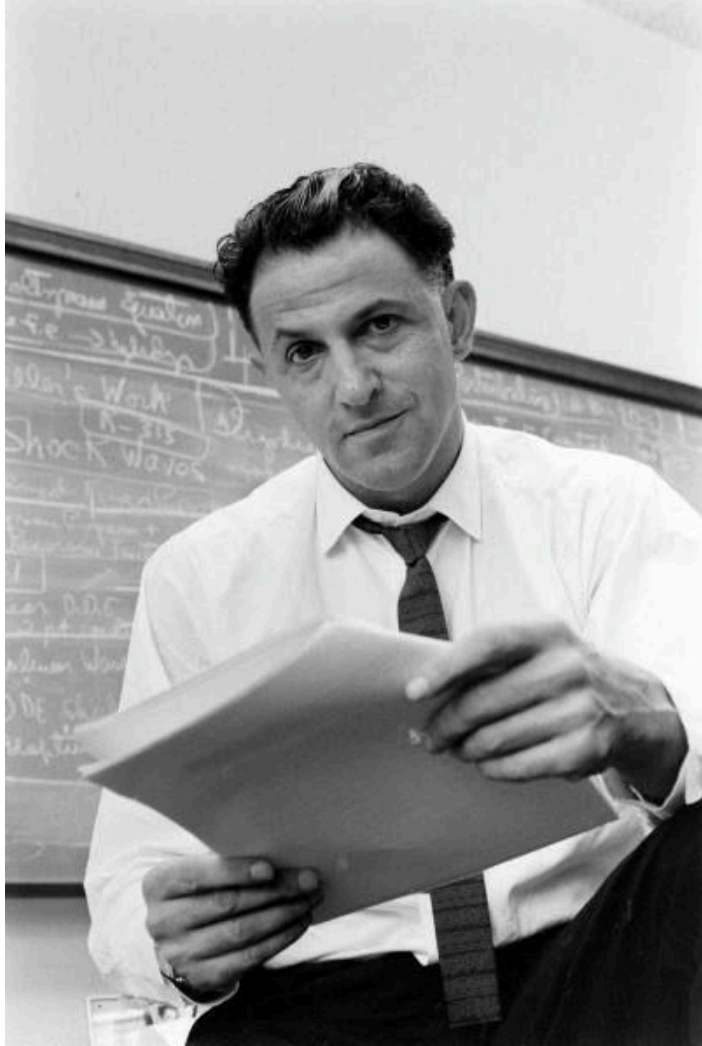
Modern decision making relies on Markov processes

# History of Decision Making



**1953:** Bellman discovers dynamic programming

# History of Decision Making



**1953:** Bellman discovers dynamic programming

Gives us the **Bellman equation**, the basis for optimal decision making

# History of Decision Making



**1983:** Sutton solves the Bellman equation using neural networks

# History of Decision Making



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Combines reinforcement learning and neural networks

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He is still alive and might answer your emails



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We use his textbook: *An Introduction to Reinforcement Learning*

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**1997:** DeepBlue beats world champion Kasparov at chess





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<https://www.youtube.com/watch?v=KF6sLCeBj0s>

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**2016:** AlphaGo beats world champion Sedol at Go



# History of Decision Making



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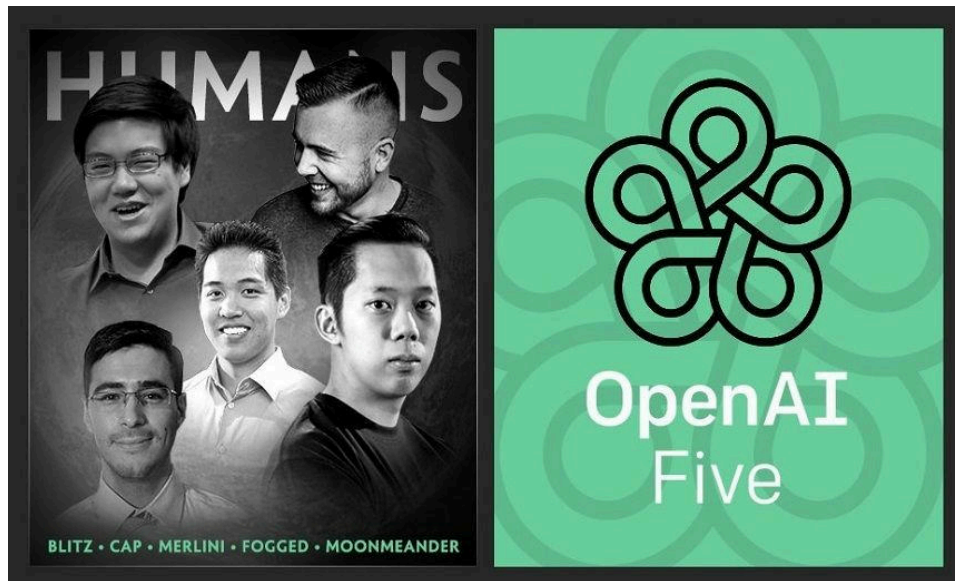
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# History of Decision Making



**2018:** OpenAI Five beats world champions at Dota2

# History of Decision Making

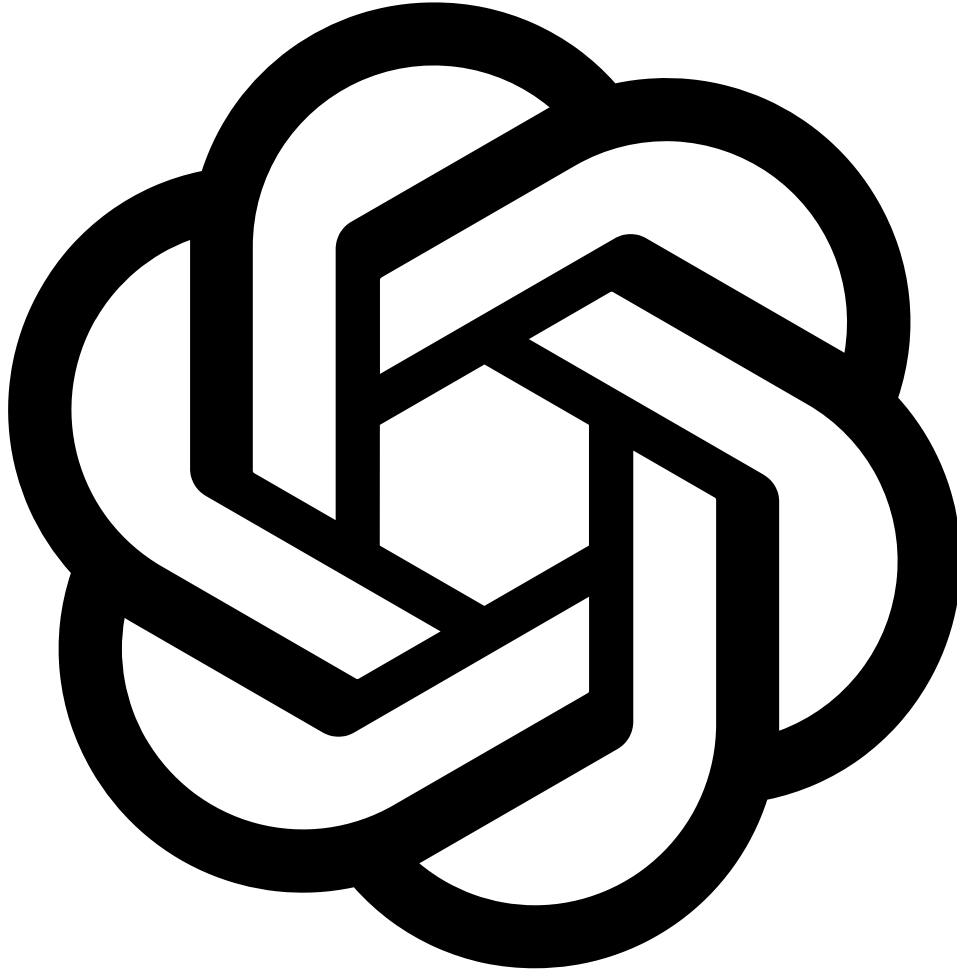


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[https://www.youtube.com/watch?v=eHipy\\_j29Xw](https://www.youtube.com/watch?v=eHipy_j29Xw)

# History of Decision Making

**2020-2024:** GPT-3, GPT-4 trained using reinforcement learning





# History of Decision Making

2025?

# Decision Making and Deep Learning

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We will formally define decision making and reinforcement learning later in the course

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For now, I want to clarify decision making in the context of machine learning

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How does decision making differ from regular deep learning?

# Decision Making and Deep Learning

In deep learning, we usually know the answer

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$$f(x, \theta) = y$$

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In decision making, we often do not know the answer!

$$f(\boldsymbol{x}, \boldsymbol{\theta}) = ?$$

What does this mean?

# Decision Making and Deep Learning

**Example:** You train a model  $f$  to play chess

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$$f : X \times \Theta \mapsto Y$$

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# Decision Making and Deep Learning



What is the correct answer?

# Decision Making and Deep Learning



What is the correct answer?

We do not know the answer

# Decision Making and Deep Learning



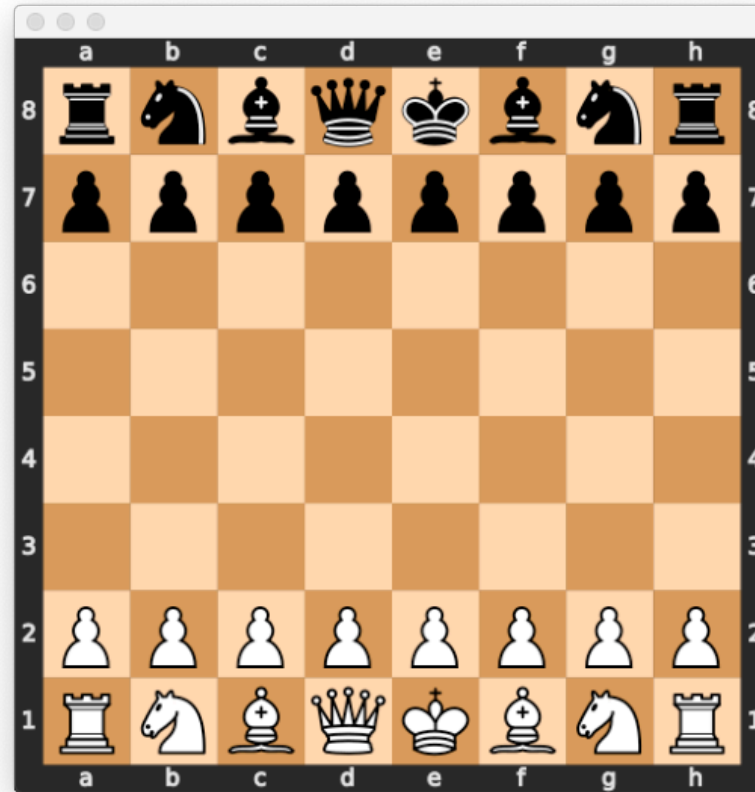
How can we learn a model without an answer?

# Decision Making and Deep Learning



An answer gives us just one move

# Decision Making and Deep Learning



An answer gives us just one move      We need many moves to win

# Decision Making and Deep Learning

Decision making can give us the best **sequence** of moves to:

# Decision Making and Deep Learning

Decision making can give us the best **sequence** of moves to:

- Win a game of chess

# Decision Making and Deep Learning

Decision making can give us the best **sequence** of moves to:

- Win a game of chess
- Drive a customer to the store



# Decision Making and Deep Learning

Decision making can give us the best **sequence** of moves to:

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# Decision Making and Deep Learning

Decision making can give us the best **sequence** of moves to:

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- Treat a sick patient

# Decision Making and Deep Learning

Decision making can give us the best **sequence** of moves to:

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- Drive a customer to the store
- Cook a tasty meal
- Treat a sick patient
- Prevent climate change

# Decision Making and Deep Learning

Decision making can give us the best **sequence** of moves to:

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- Prevent climate change
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We do not know the correct moves

But with decision making, we can find them!

# Questions?

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# Homework

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- Review prerequisites

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