Welcome to CSI 4106!

CSI 4106 - Fall 2025

Marcel Turcotte

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Preamble

Message of the day (MOTD)



- 2025-08 Chief Al Officer, Cohere
- 2023-03 2025-05 VP AI Research, Meta
- 2017-05 2023-02 Director, Facebook Artificial Intelligence Research (FAIR), Montréal
- 2004-08 Professor, McGill University

Cohere raises US\$500-million, hires former Meta AI expert Joelle Pineau, Joe Castaldo, The Globe and Mail, 2025-08-14.

Joëlle_Pineau, a distinguished Canadian computer scientist, was born in Ottawa and has had an exemplary career in the field of artificial intelligence research. She previously held the position of Vice President of Al Research at Meta and served as the Director of Facebook Artificial Intelligence Research (FAIR) in Montréal. Currently, she is the Chief Al Officer at Cohere.

Cohere, a Canadian AI company, is dedicated to the development of advanced natural language processing (NLP) technologies aimed at equipping businesses with state-of-the-art language models. Two of its cofounders, Aidan Gomez and Nick Frosst, previously conducted research at Google Brain. They are also co-authors of the landmark paper "Attention is All You Need," which introduced the transformer architecture, a key advancement in machine learning. The paper has 192,363 citations according to Google Scholar.

 Federal government taps Cohere to work on use of AI in public service, Anja Karadeglija, The Canadian Press, 2025-08-20.

https://youtu.be/Sq1QZB5baNw

The presentation includes four videos, but we will only watch one. These videos were chosen for their science fiction aspect and their use of generative AI.

Figure's approach is markedly different from earlier methods. The latter often relied on separate modules to solve different problems. For example, a robot would use a planning algorithm to find an optimal path, and the reasoning was heavily scripted ("on rails"), thus limiting tasks and learning capabilities.

Here, we see an end-to-end approach based on neural networks. Deep learning aims to produce flexible, general, and capable learning systems. Inspired by large language models (LLMs), we are now observing the development of large action models (LAMs).

The videos on the new models from Google DeepMind are equally impressive.

How do you feel about these developments?

https://youtu.be/Z3yQHYNXPws

https://youtu.be/UIZAiXYceBI

https://youtu.be/nXVvvRhiGjl

Learning objectives

- Clarify the proposition
- **Discuss** the syllabus
- Articulate the expectations
- Explore the various definitions of "artificial intelligence"

I want to clarify my proposal. I have chosen a specific approach to introduce the concepts and I would like to explain the reasons for this choice.

After presenting the course outline and expectations, we will discuss the different definitions of artificial intelligence.

Proposition

Course overview

Calendar description

The roots and scope of Artificial Intelligence. Knowledge and knowledge representation. Search, informed search, adversarial search. Deduction and reasoning. Uncertainty in Artificial Intelligence. Introduction to Natural Language Processing. Elements of planning. Basics of Machine Learning.

Here is the official course description. At the end of this presentation, you will find the Python code I used to produce this audio clip.

This course description dates back several years, placing machine learning at the end of the list.

Aims: Deep learning early

** (Legg and Hutter 2007)**

To the larger community of computer science and information technology, AI is usually identified by the techniques grown from it, which at different periods may include theorem proving, heuristic search, game playing, expert systems, neural networks, Bayesian networks, data mining, agents, and recently, deep learning.

• Deep learning is so dominant that I have chosen to structure everything around it

What does it means?

Good Old-Fashioned AI (GOFAI) relied on hand-crafted knowledge engineering, but it has been largely displaced by machine learning due to the increased availability of data, computing resources, and new algorithms.

. . .

Deep learning has significantly impacted various domains, including natural language processing, robotics, and computer vision.

. . .

However, deep learning has current **limitations**, particularly in **reasoning**, where symbolic AI excels and could potentially offer valuable insights.

But also

EVOLUTION, AI, AND THE FIVE BREAKTHROUGHS THAT MADE OUR BRAINS BRIEF HISTORY OF INTELLIGENCE MAX BENNETT

- In **A Brief History of Intelligence** (Bennett 2023), Max Bennett discusses **significant milestones in the evolution of human intelligence** and draws parallels to advancements in artificial intelligence (AI).
- Learning itself represents one of the earliest and most extensively understood milestones in the evolution of intelligence.

Curiously, the development of AI has been largely influenced by logical approaches (symbolic AI). The development of AI has been strongly marked by intellectual currents rooted in philosophy and mathematics, rather than in biology and its evolution. Reasoning in philosophy and mathematics relies on complex cognitive functions, perhaps less well understood and having evolved later.

Learning itself represents one of the first and most widely understood steps in the evolution of intelligence.

It would have been logical to approach the study of intelligence by progressing from simpler forms to more complex ones.

Aims: Applied

** Andrew Ng, The Batch, April 10, 2024**

Many software developers worry that large language models will make human coders obsolete. We doubt that AI will replace coders, but we believe that coders who use AI will replace those who don't.

• Whenever possible, concepts will be introduced with code.

Aims: Academic rigour

In pursuing clarity and accessibility, this course aims to strike a balance between **informal discourse** and the **precision** required for academic rigour. The objective is for learners to not only grasp but also **apply**, **evaluate**, and **critically analyze** the concepts discussed throughout the course.

Syllabus

Course information

Web sites

- turcotte.xyz/teaching/csi-4106
- uottawa.brightspace.ca

Schedule

• Lectures: Mon 13:00-14:20 and Wed 11:30-12:50 CRX C240

• Office hours: Mon 15:00-16:20 STE 5106

• Official schedule: www.uottawa.ca/course-timetable

Grading

Category	Percentage
Assignments	40% (4 x 10%)
Quiz	20%
Final examination	40%

Reading material

I will draw upon insights from the two comprehensive textbooks listed below, as well as relevant scientific publications. Additionally, all sources of information will be cited. For most people, I expect that my lecture notes will be sufficient.

- Russell, S., & Norvig, P. (2020). Artificial Intelligence: A Modern Approach (4th ed.).
 Pearson.
- Poole, D.L., & Mackworth, A.K. (2023) Artificial Intelligence: Foundations of Computational Agents (3rd ed.). Cambridge University Press. (Freely available online in HTML format)

The Campus Store has ordered a small number of copies of these books, for those interested.

We do not closely adhere to the framework proposed by (Russell and Norvig 2020) and (Poole and Mackworth 2023). Specifically, while these textbooks use the concept of an intelligent agent as a central theme, fields such as machine learning (ML), natural language processing (NLP), and vision operate as distinct communities. In these communities, problems are typically not framed in terms of agents.

There are two websites to use. On my personal site, you will find presentations and code examples. On Brightspace, you will submit your assignments and participate in discussion groups.

During class, visit my personal website. There, you can review the complete syllabus, the course schedule, information about the team, and the brief biography of the instructor.

Beta testers

This will be my second iteration of this content. Your help identifying what works and what doesn't will be most appreciated.

Warnings

CSI 4106 is an introductory course on artificial intelligence, offering a brief overview of various topics within this broad field. **Each topic covered could be explored in much greater depth through one or more graduate-level courses.** The primary objective of CSI 4106 is to provide students with a foundational understanding of the core areas that constitute artificial intelligence.

. . .

Overlaps with other courses are inevitable, but I will do my best to keep it at a minimum.

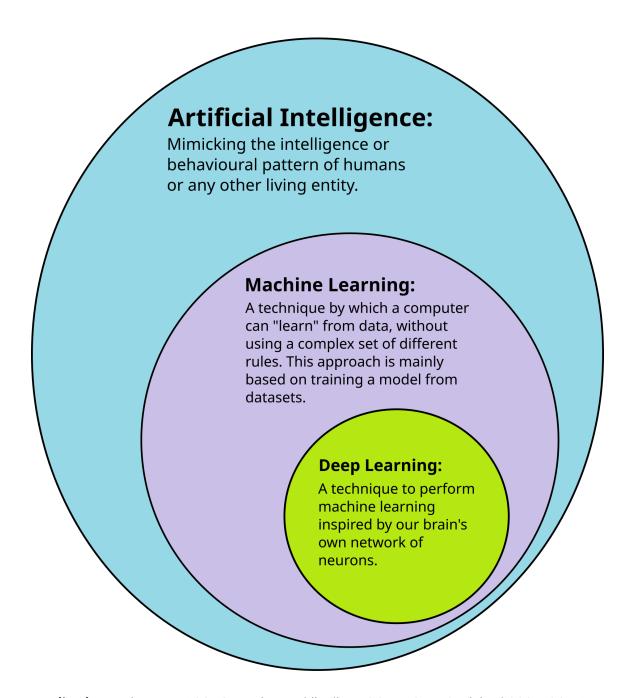
. . .

This is not a course on the impact of AI on society, including ethics, fairness, trust and safety.

This warning is actually for myself. These are topics I am passionate about, and I would love to share everything I know with you. However, that is obviously not possible. Generally, I will try to focus on a small number of approaches to thoroughly understand the subjects, rather than adopting an exhaustive approach.

Setting the Stage: Al, Deep Learning, and Diverging Views on Intelligence.

AI, ML, DL



Attribution: Avimanyu786SVG version: Tukijaaliwa, CC BY-SA 4.0, visited 2024-06-18.

Deep learning is so prevalent today that some people might confuse it with artificial intelligence. As the figure shows, deep learning is one of many techniques used in machine learning. Machine learning, in turn, is one of several disciplines within artificial intelligence. Other AI disciplines include knowledge representation, reasoning and planning, natural language processing, computer vision, and robotics.

By the end of this course, this distinction should be very clear.

Schools of thought

- **Symbolic AI** (includes approaches based on logic)
- Connectionists (mostly neural networks)

Long seen as mutually exclusive

At the outset of this course, it is important to recognize that two main schools of thought exist in AI: **symbolic AI** and **connectionism**. Initially, the symbolic approach was dominant in the field of AI, but today, the connectionist approach prevails.

Towers of Hanoi

(for your information only)

https://youtu.be/PGuRmqpr6Oo

See also: Binary, Hanoi and Sierpinski, Part 1 and Part 2, by 3Blue1Brown.

Symbolic AI (Planning)

Problem

The **Towers of Hanoi** is a puzzle that consists of **three pegs** and **a number of disks of different sizes**. The puzzle **starts** with all the **disks stacked in decreasing size on one peg**, and the **goal is to move the entire stack to another peg**, following these rules:

- 1. Only one disk can be moved at a time.
- 2. A disk can only be placed **on top of a larger disk** or **on an empty peg**.

Rules

```
Action Move(X,Y,Z):

Preconditions = {Clear(X), On(X,Y), Clear(Z), Smaller(X,Z)};

Effects = {-On(X,Y), Clear(Y), On(X,Z), -Clear(Z)};
```

Start

```
D1, D2, D3, P1, P2, P3 are symbols, where D1, D2, and D3 are disks, and P1, P2, and P3 are pegs.

On(D1, D2), On(D2, D3), On(D3, P1),
```

```
On(D1, D2), On(D2, D3), On(D3, P1),
clear(D1), clear(P2), clear(P3),
Smaller(D1, D2), Smaller(D1, D3), Smaller(D2, D3),
Smaller(D1, P1), Smaller(D1, P2), Smaller(D1, P3),
Smaller(D2, P1), Smaller(D2, P2), Smaller(D2, P3),
Smaller(D3, P1), Smaller(D3, P2), Smaller(D3, P3).
```

Goal

```
On(D1, D2), On(D2, D3), On(D3, P3).
```

Solution

```
Move(D1, P1, P3)
Move(D2, P1, P2)
Move(D1, P3, P2)
Move(D3, P1, P3)
Move(D1, P2, P1)
Move(D2, P2, P3)
Move(D1, P1, P3)
```

STRIPS (Stanford Research Institute Problem Solver, 1971) is a classical AI planning system that represents problems in terms of:

- **States**: sets of logical predicates describing the world.
- Operators (Actions): defined by
 - Preconditions: predicates that must be true to apply the action,
 - Add list: predicates made true after execution,
 - Delete list: predicates made false after execution.
- **Goal**: a set of predicates to be achieved.

A plan is found by applying actions to transform the initial state into a goal state, updating the world via the add/delete lists.

These methods will be examined in depth starting from Lecture 16, focused on search methods, and Lecture 22, which will cover formal reasoning.

Symbolic AI (Kinship)

Problem

Given a few **facts** about who is parent of whom (**symbols**) and a handful of **Horn-clause rules**, infer new relations (e.g., **ancestor**, **siblings**, **grandparent**) by *logical deduction*.

Rules

```
father(F,C) := male(F), parent(F,C).
mother(M,C) := female(M), parent(M,C).

sibling(X,Y) := parent(P,X), parent(P,Y), X \= Y.

grandparent(G,C) := parent(G,P), parent(P,C).

ancestor(A,D) := parent(A,D).
ancestor(A,D) := parent(A,X), ancestor(X,D).
```

Facts

```
% facts/symbols
```

```
male(alan). female(brenda).
male(chris). female(dina).
male(eli). female(fiona).

parent(alan, chris).
parent(brenda, chris).
parent(chris, dina).
parent(dina, eli).
parent(dina, fiona).
```

Query

```
?- grandparent(G, dina).
% Expected: G = alan ; G = brenda.
?- ancestor(A, fiona).
% Expected: A = dina ; A = alan ; A = brenda ; A = chris ;
?- sibling(eli, fiona).
% Expected: true.
```

The preceding example demonstrates the application of logic programming, specifically Prolog, to articulate relationships between entities.

- Clear separation of knowledge (facts) and reasoning (rules).
- **Explanations**: Prolog's proof trees make deductions inspectable.
- **Recursion** illustrates expressive power (e.g., ancestor/2).

Symbolic AI (Prerequisites)

Problem

Given **course prerequisites** and a student's **completed** set, infer which courses they **can take next**. This shows *symbolic constraint reasoning*.

Rules

```
all_prereqs_met(Student, Course) :-
    \+ (prereq(Course, P), \+ completed(Student, P)).

can_take(Student, Course) :-
    all_prereqs_met(Student, Course),
    \+ completed(Student, Course).
```

Courses

```
% --- Course graph (facts, symbols) ---
```

```
prereq(csi2120, csi2110).
prereq(csi2110, iti1121).
prereq(csi2110, mat1338).
prereq(iti1121, iti1120).
```

Students

```
% --- Student record (facts, symbols) ---
completed(alex, iti1121).
completed(alex, iti1120).
completed(alex, mat1338).

Query
```

```
?- can_take(alex, csi2110).
% true
?- can_take(alex, csi2120).
% false
?- can_take(alex, iti1121).
% false
?- all_prereqs_met(alex, csi2110).
% true
```

Another example using logic programming (Prolog).

- Shows constraint satisfaction and closed-world negation.
- Easy to extend with electives, co-requisites, or anti-requisites.
- Produces auditable recommendations (why/why not).

Negation as failure, which is represented as \+ (backslash-plus), Prolog.

- \+ Goal succeeds if Goal cannot be proven.
- Semantics: **closed-world assumption** if it's not in the knowledge base, we assume it's false.

The rule

reads as:

```
"all_prereqs_met(Student, Course) holds if there does not exist a prerequisite P of Course such that Student has not completed P."
```

Or, more naturally:

"A student has met all the prerequisites for a course when every course that is listed as a prerequisite has already been completed by that student."

Symbolic Al

- "Their founding tenet held that knowledge can be represented by a set of rules, and computer programs can use logic to manipulate that knowledge." (Strickland 2021)
- "Researchers developing symbolic AI set out to explicitly teach computers about the world." (Strickland 2021)
- "(...) a physical symbol system has the necessary and sufficient means for general intelligent action."

(Newell and Simon 1976)

Note the importance of the word "explicitly" in this statement. It is not about providing examples to the computer, but rather about describing human knowledge using logic.

The researchers of the time were convinced that the symbolic approach was the key to success.

Symbolic Al

• What were the **primary challenges** associated with **symbolic AI**?

Connectionist

Inspired by biology, **artificial neural networks** (**ANNs**) are computational models designed to **mimic the human brain's network of neurons**. They consist of layers of **interconnected nodes (neurons)**, each **connection** having an associated **weight**.

. . .

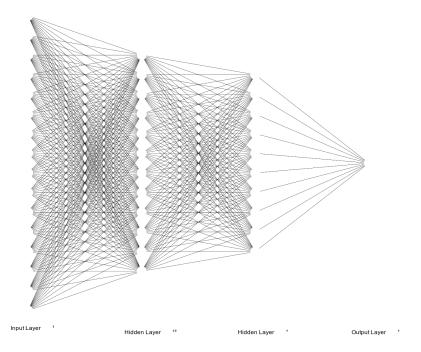
ANNs process input data through these weighted connections, and **learning** occurs by **adjusting the weights** based on **errors** in the **training data**.

See: playground.tensorflow.org

The term "connectionists" comes from the idea that nodes in these models are interconnected. Instead of being explicitly programmed, these models learn their behavior through training.

Deep learning is a connectionist approach.

Connectionist



Attribution: LeNail, (2019). NN-SVG: Publication-Ready Neural Network Architecture Schematics. Journal of Open Source Software, 4(33), 747, https://doi.org/10.21105/joss.00747 (GitHub)

Definnig Al

Survey

Perceptions and Attitudes Toward Artificial Intelligence.

- The majority of students exhibit a generally positive disposition towards AI. If your perspective differs, please elaborate.
- There is a wide range of opinions regarding the probability of catastrophic outcomes due to AI (P(doom)).
- A relatively small number of students express concern about AI replacing their jobs.
- Few students perceive current AI systems as genuinely intelligent.
- Views on Artificial General Intelligence (AGI) and Super-intelligence vary significantly.
- The primary concerns surrounding AI include potential job displacement and misuse, with privacy issues also noted.
- Many students regard the medical and healthcare sectors as areas where Al could exert significant influence.
- A substantial portion of students believes that AI is excessively hyped.

• Fewer than 20% of the students possess substantial experience in artificial intelligence.

Why definning AI?

- Enhancing Clarity and Communication: Establishing a mutual understanding of evaluation criteria, benchmarking tests, and milestones.
- Addressing Ethical, Social, and Legal Implications: Enabling policymakers to develop regulations that minimize Al-related risks.

An operational definition

** (Wang 2019)**

To the larger community of computer science and information technology, Al is usually identified by the techniques grown from it, which at different periods may include **theorem proving**, **heuristic search**, **game playing**, **expert systems**, **neural networks**, **Bayesian networks**, **data mining**, **agents**, and recently, **deep learning**.

Context

- Significant **hype**.
- Several leading companies, including DeepMind and OpenAI, are primarily focused on the development of **artificial general intelligence** (AGI).
- Should AGI become a reality, its implications could profoundly impact various aspects of our lives, including education, employment, economic structures, and scientific advancements.

All thus has great potential to influence the course of your lives. It is therefore relevant to take the time to define what Al is and to explore its different approaches.

I should warn you right away that there is no consensus on the definition of AI, nor on the definition of intelligence.

Daily **Mail**

21 June 2024

ChatGPT passes the famous 'Turing test' - suggesting the AI bot has intelligence equivalent to a human, scientists claim

Psychology Today

May 17, 2024

GPT-4 passes the Turing test, marking a potential inflection point in Al's mastery of human-like language.



FEBRUARY 22, 2024

The most recent version of ChatGPT passes a rigorous Turing test

Attribution: Melanie Mitchell, Substack post titled: The Turing Test and Our Shifting Conceptions of Intelligence, August 15, 2024.

Question

User: The man and the goat want to enjoy a picnic near a river, but there's a wolf. What to do with the zucchini?

. . .

ChatGPT 5: You've got the classic river-crossing (wolf-goat-cabbage ⇒ here, zucchini).

Boat carries you + one item. Unsafe pairings: wolf with goat; goat with zucchini.

Minimal plan:

- 1. Take goat over.
- 2. Return alone.
- 3. Take wolf over.
- 4. Bring goat back.
- 5. Take zucchini over.
- 6. Return alone.
- 7. Take goat over.

Conclusion: keep the zucchini never alone with the goat; ferry it on step 5.

. . .

Attribution: Andriy Burkov, published on LinkedIn 3 weeks ago.

Question

User: Surgeon but child, hopsital, it have a no, why it so?

. . .

ChatGPT 5: You're pointing to the classic riddle:

Car crash → injured child → surgeon says "I can't operate—this is my child."

Resolution: the surgeon is the child's mother (or another parent in a non-heteronormative family).

The "paradox" arises from implicit gender assumptions about surgeons.

. . .

Attribution: Andriy Burkov, published on LinkedIn 3 weeks ago.

The complex nature of intelligence

. . .

- "Artificial" pertains to the creation of entities or phenomena that mimic natural processes using technology or synthetic materials, a definition broadly recognized and accepted.
- Therefore, defining "artificial intelligence" fundamentally requires us to first clarify
 what we mean by "intelligence." Surprisingly, "[d]espite a long history of research
 and debate, there is still no standard definition of intelligence." (Legg and Hutter
 2007)

How do you define intelligence?

- What are the **characteristics** you associate with **intelligence**?
- "Intelligence is a very general mental capability that, among other things, involves
 the ability to reason, plan, solve problems, think abstractly, comprehend
 complex ideas, learn quickly and learn from experience."

 Originally published in the Wall Street Journal in 1994, the content was reprinted in 1997: (Gottfredson 1997)

Can AI make mistakes?

Essential abilities

** Douglas Hofstadter**

No one knows where the borderline between non-intelligent behavior and intelligent behavior lies, in fact, to suggest that a sharp border exists is probably silly. But essential abilities for intelligence are certainly:

- 1. to respond to situations very **flexibly**;
- 2. to take advantage of fortuitous circumstances;
- 3. to make sense out of ambiguous or contradictory messages;
- 4. to recognise the **relative importance of different elements** of a situation;
- 5. to find **similarities** between situations despite differences which may separate them;
- 6. to draw **distinctions** between situations despite similarities which may link them;
- 7. to **synthesize** new concepts by taking old concepts and putting them together in new ways;
- 8. to come up with ideas which are novel."

For certain complex concepts, drawing a clear boundary can prove challenging. Take the concept of life, for example. Humans, plants, and insects are considered living, as are microorganisms such as bacteria. However, viruses and viroids are not.

François Chollet, Creator of Keras

** François Chollet**

Real intelligence is not about mastering an individual skill, he argued, but about taking what has been learned and applying it to a new, different situation.

In his view, intelligence is the ability to **efficiently acquire new skills** that training did not prepare for, with the goal of accomplishing tasks that are sufficiently different from those a system has seen before.

The wider the scope of the new skills, the closer the computer comes to achieving artificial general intelligence.

"If you can make the learning process as information-efficient as a human mind, then you've got AGI," Chollet said.

So far, machines lag far behind, approximately 10,000 times less efficient than human brains. For instance, it took millions of images to teach computers to recognize pictures of cats, whereas humans learn to identify them based on only one or two examples.

Savage (2024)

Thinking, acting, humanly, rationally

Russell & Norvig considers two axes: thinking vs behaviour, human vs rationality.

	Thinking	Acting
Human-like	thinking humanly (simulation)	acting humanly (Turing test)
Rationality	thinking rationally (logic)	acting rationally (agent)

See also the appendix – Section 9 On Defining Artificial Intelligence

The question of intelligence has been the subject of much debate in the literature and the media, particularly when it comes to animals or computers. This abundance of information can bias our thinking.

A simple thought experiment might offer a new perspective: would you be able to recognize intelligence in an extraterrestrial entity?

Rationality



** (Mohammed, Sookram, and Saridakis 2019)**

Rationality involves the **evaluation of choices to achieve a goal or to find the optimal solution to a problem**. Simon (1972, p. 161) defined rationality as "a style of behavior that is appropriate to the **achievement of given goals**, within the **limits imposed by given conditions and constraints**."

Attribution: NBC Television, Public domain, via Wikimedia Commons

Narrow vs General Al

Artificial General Intelligence (AGI)

Artificial general intelligence (AGI) refers to a form of artificial intelligence (AI) that either equals or exceeds human proficiency across a diverse array of cognitive functions.

AKA **human-level intelligence**. As opposed to **narrow intelligence**, the current status of AI, which is designed to perform a specific task or a limited range of tasks, operating under predefined constraints and without general cognitive abilities.

AlphaFold (1, 2, & 3)

I repeat, there is nothing wrong with narrow AI.

- «Two papers in this week's issue dramatically expand our structural understanding of proteins. Researchers at **DeepMind**, Google's London-based sister company, present the latest version of their **AlphaFold** neural network.»
 - Jumper et al. (2021)

Al effect/paradox

```
** (Wang 2019)**
```

(...) as soon as a computer system is built to solve a problem successfully, the problem is no longer "only solvable by the human mind," so does not need intelligence anymore. Consequently, "Al is whatever hasn't been done yet" (Hofstadter, 1979; Schank, 1991), which is known as "the Al Effect" (McCorduck 2004).

The paradox of AI is quite fascinating. In the early days of AI, researchers focused on problems like differential equations or chess.

Each time a computer solves one of these major problems, we come to think that perhaps that problem didn't really require intelligence to be solved after all.

The defeat of Garry Kasparov at the hands of IBM's Watson is a perfect example.

Impact

Economical

** Beyond the hype: Capturing the potential of AI and gen AI in tech, media, and telecom 2024-02-22**

McKinsey research estimates that $\operatorname{gen} \operatorname{Al}$ could add to the economy between 2.6trillion and 4.4 trillion annually while increasing the impact

of all artificial intelligence by 15 to 40 percent.

In fact, it seems possible that within the next three years, anything not connected to AI will be considered obsolete or ineffective.

Subfields of Al

- 1. Machine Learning: Credit card fraud detection
- 2. Deep Learning: Image and facial recognition
- 3. Natural Language Processing: Virtual assistants like Siri or Alexa
- 4. Computer Vision: Autonomous vehicles
- 5. Robotics: Industrial automation in manufacturing
- 6. Expert Systems: Medical diagnosis support
- 7. **Speech Recognition:** Voice-to-text transcription services
- 8. Planning and Decision Making: Supply chain optimization
- 9. **Reinforcement Learning:** Game AI in complex strategy games
- 10. Knowledge Representation: Semantic web technologies for information retrieval

Our Final Invention

** (Russell and Norvig 2020)**

All expert Kai-Fu Lee predicts that its **impact** will be **"more than anything in the history of mankind."**

https://youtu.be/ixgunKpy61s

What Does the Al Boom Really Mean for Humanity? | The Future With Hannah Fry. Bloomberg Originals, posted on YouTube on 2024-09-12.

https://youtu.be/sK5_pQV_QEA

Questions

- Can the concept of intelligence be considered **independently** of the entities that express it? This is the problem of **embodiment**.
- Can a **machine** exhibit human-level intelligence?
- Is it possible to dissociate the following concepts from that of intelligence?
 - Agency.
 - Sentience.

- Consciousness.
- Emotions.
- Language.
- Mind.
- Can an Al suffer?

For me, an interesting definition of intelligence would be similar in nature to that of computation.

Using **computation** as an analogous concept can help clarify this question. Theoretically, computation is often considered in an abstract manner, independent of any physical implementation. The **Church-Turing theorem**, a fundamental principle in computer science, states that any computation that can be performed by a machine (specifically, a Turing machine) is universally applicable. This implies that the concept of computation can exist independently of its hardware or specific physical form.

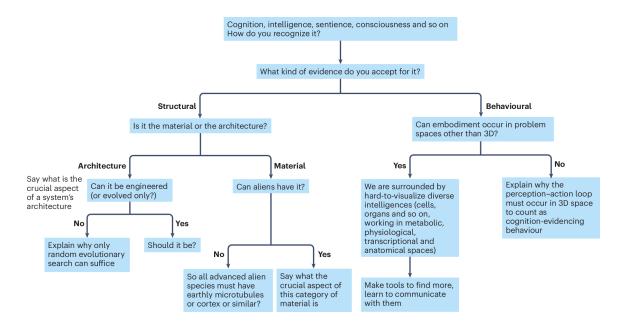
I must confess: until 2022, I was rather skeptical. I often drew a parallel between artificial intelligence and alchemy. Alchemists never succeeded in transmuting lead into gold because it is a physical process, but their approach led to the development of chemistry. Similarly, we may never be able to replicate human intelligence, but the impacts of Al are immense and often unexpected, like the garbage collector introduced by Lisp.

Then, it struck me: I am a scientist, and I wondered what it would mean if we were not able to produce intelligence comparable to that of humans.

Richard Feynman, who received the Nobel Prize in Physics in 1965, famously said, "What I cannot build. I do not understand."

Why seek to dissociate intelligence from other concepts such as agency, consciousness, and emotions? A computer system devoid of these attributes seems, indeed, far less daunting.

Deepen the Reflection



Rouleau, N. & Levin, M. (2024). Discussions of machine versus living intelligence need more clarity. *Nature Machine Intelligence*, 6(12), 1424–1426.

Prologue

Summary

- Discussed the syllabus
- Distinguish the concept of artificial intelligence from the concept of machine learning
- Distinguish symbolic AI from connectionnist AI
- Explored the various definitions of "artificial intelligence"

Next lecture

· Introduction to machine learning

References

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Appendix: On Defining Artificial Intelligence

Wang (2019)

An **agent** and its **interaction with the environment** are specified as a tuple:

where

- ullet P represents a sequence of **input signals**, $P=\langle p_0,\dots,p_t
 angle$
- ullet S represents a sequence of **internal states**, $S=\langle s_0,\dots,s_t
 angle$
- ullet A represents a sequence of **actions**, $A=\langle a_0,\dots,a_t
 angle$

For a sequence of moments, $0, \ldots, t$.

Human (H) vs Computer (C)

** (Wang 2019)**

All is conceived as computer systems that are similar to the human mind in a certain sense, though a computer and a human mind cannot be identical in all aspects.

$$\langle P^H, S^H, A^H \rangle \approx \langle P^C, S^C, A^C \rangle$$

. . .

Wang (2019) proposes 5 perspectives: **Structure-AI**, **Behavior-AI**, **Capability-AI**, **Function-AI**, and **Principle-AI**.

1. Structure-Al

(brain modelling, cognitive science)

** (Wang 2019)**

I call this type of definition "Structure-AI," since it requires an AI system to go through isomorphic states or structure changes as the brain does when they are given similar input, which will produce similar output, so the three components of the two are pairwise similar to each other:

$$P^H \approx P^C, S^H \approx S^C, A^H \approx A^C$$

2. Behaviour-Al

(Turing Test)

** (Wang 2019)**

One way to acknowledge a human-like mind without demanding a human-like brain is to associate intelligence to the external behaviors of the agent.

After all, **if an agent behaves like a human, it should be considered as intelligent**, no matter whether it looks like a human, either inside or outside.

$$P^H \approx P^C, A^H \approx A^C$$

3. Capability-AI (Employment Test)

** (Wang 2019)**

In the agent framework, it means that C is similar to H in the sense that there are moments i and j that:

$$p_i^C pprox p_j^H, a_i^C pprox a_j^H$$

** (Wang 2019)**

the action (solution) the computer produces for a percept (problem) is similar to the action produced by a human to a similar percept (...) In this way, the intelligence of a system is identified by a set of problems it can solve, while whether they are solved in the "human way" does not matter.

Capability-Al (contd)

** (Nilsson 2005)**

"I suggest we replace the Turing test by something I will call the 'employment test.' To pass the employment test, **AI programs must be able to perform the jobs ordinarily performed by humans**. Progress toward human-level AI could then be measured by the fraction of these jobs that can be acceptably performed by machines"

4. Function-Al

** (Wang 2019)**

In the agent framework, this "Function-Al" perspective takes C to be similar to H in the sense that there are moments i and j that:

$$a_i^C pprox f^C(p_i^C), a_i^H pprox f^H(p_i^H), f^C pprox f^H$$

** (Wang 2019)**

Here the function can correspond to searching, **reasoning**, **learning**, etc., and since **the focus is on the functions** (i.e., input-output mappings), the concrete input and output values of the two agents do not have to be similar to each other.

6. Principle-AI (rationality, logicist)

```
** (Wang 2019)**
```

As in any field, there are researchers in AI trying to find **fundamental principles** that can uniformly explain the relevant phenomena. Here the idea comes from the usage of intelligence as a form of *rationality* (. . .) that can make the **best-possible decision** in various situations, according to the experience or history of the system.

$$A^{C} = F^{C}(P^{C}), A^{H} = F^{H}(P^{H}), F^{C} \approx F^{H}$$

** (Wang 2019)**

The above F is often not formally specified, but described informally as a certain "principle," which is not merely about a single type of problem and its solution, but about the agent's life-long history in various situations, when dealing with various types of problems.

Code of the day

```
In [1]: |#!/usr/bin/env python3
        # -*- Mode: Python -*-
        # ai_lecture-01.py
        # Author : Marcel Turcotte & ChatGPT 5
        # Created On : Tue Feb 13 16:29:41 2024
        # Last Modified By: Marcel Turcotte
        # Last Modified On: Thu Aug 28 15:03:14 EDT 2025
        # In 2024, I developed the initial version of this script.
        # This year, I used ChatGPT to revise the code to align with the most recent
        # enhance its educational value by incorporating detailed comments,
        # and improve its suitability as an instructive example.
        Didactic example: translate EN->Canadian French, then synthesize audio in EN
        CLI options:
            -- format : audio output format (mp3, wav, etc.)
            --voice : TTS voice (e.g., nova, alloy, verse, etc.)
           --model : TTS model (tts-1-hd for high quality, gpt-4o-mini-tts for low
        Examples:
            python ai lecture-01.py --format mp3 --voice nova --model tts-1-hd
```

```
python ai_lecture-01.py --format wav --voice alloy --model gpt-4o-mini-t
.....
from __future__ import annotations
import os
import argparse
from pathlib import Path
from openai import OpenAI, APIError, APIConnectionError, APITimeoutError
# Configuration
client = OpenAI() # Reads OPENAI API KEY from environment
# Text Utilities
# -----
def translate_to_canadian_french(input_text: str) -> str:
    """Translate English text to Canadian French (CSI4106→CSI4506)."""
    instructions = (
        "You are a careful translator. Translate the user's English text int
        "Preserve technical terms and course names. "
        'If the course code "CSI4106" appears, translate it as "CSI4506".'
    )
    try:
        resp = client.responses.create(
           model="qpt-40",
            instructions=instructions,
            input=input text,
            temperature=0.2,
           max_output_tokens=1200,
        return resp.output text or ""
    except (APIConnectionError, APITimeoutError) as net_err:
        print(f"[Network issue] {net_err}")
    except APIError as api err:
        print(f"[OpenAI API error] {api_err}")
    except Exception as e:
        print(f"[Unexpected error] {e}")
    return ""
# Audio Utilities
def synthesize_speech(
   text: str,
   output_path: Path,
    model: str = "tts-1-hd",
    voice: str = "nova",
```

```
response_format: str = "mp3",
) -> bool:
   Stream synthesized speech to a file on disk.
   Returns True on success, False otherwise.
   output path.parent.mkdir(parents=True, exist ok=True)
       with client.audio.speech.with streaming response.create(
           model=model,
            voice=voice,
            input=text,
            response_format=response_format,
        ) as response:
            response.stream_to_file(str(output_path))
        return True
   except (APIConnectionError, APITimeoutError) as net_err:
        print(f"[Network issue] {net err}")
   except APIError as api err:
        print(f"[OpenAI API error] {api_err}")
   except Exception as e:
        print(f"[Unexpected error] {e}")
    return False
# Example script logic
def main(audio_format: str, voice: str, model: str) -> None:
   """Translate the course intro and synthesize EN & FR audio files."""
    input_text_en = (
        'Welcome to CSI4106, "introduction to artificial intelligence"! '
        "In this course, you will learn about the roots and scope of Artific
        "Knowledge and knowledge representation. Search, informed search, ad
        "Deduction and reasoning. Uncertainty in Artificial Intelligence. "
        "Introduction to Natural Language Processing, Elements of planning,
   )
    input_text_fr = translate_to_canadian_french(input_text_en)
   if not input text fr:
        print("[Warning] Translation failed; defaulting to English text only
   speech_file_path_fr = Path(f"01_tts_course_description-fr-{voice}.{audid
   speech_file_path_en = Path(f"01_tts_course_description-en-{voice}.{audic
   if input_text_fr:
        ok_fr = synthesize_speech(
            input text fr, speech file path fr, model=model, voice=voice, re
        print(f"[{'OK' if ok_fr else 'Error'}] FR audio → {speech_file_path_
    ok en = synthesize speech(
        input_text_en, speech_file_path_en, model=model, voice=voice, respor
    )
```

```
print(f"[{'OK' if ok_en else 'Error'}] EN audio → {speech_file_path_en}"
if __name__ == "__main__":
    if not os.getenv("OPENAI_API_KEY"):
        raise RuntimeError("OPENAI API KEY is not set in environment or .env
    parser = argparse.ArgumentParser(description="Translate course intro and
    parser.add argument(
        "--format",
        default="mp3",
        choices=["mp3", "wav", "aac", "flac", "opus", "pcm"],
        help="Audio output format (default: mp3).",
    parser.add argument(
        "--voice",
        default="nova",
        help="TTS voice (default: nova). Try 'alloy', 'verse', etc.",
    parser.add_argument(
        "--model",
        default="tts-1-hd",
        choices=["tts-1-hd", "gpt-4o-mini-tts"],
        help="TTS model: 'tts-1-hd' for high quality, 'gpt-4o-mini-tts' for
    )
    args = parser.parse_args()
    main(args.format, args.voice, args.model)
```

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