Welcome to COMP3702/COMP7702 Artificial Intelligence!

A little about me

Name: Archie Chapman

Email: archie.chapman@uq.edu.au

Teaching: I have taught artificial intelligence, data analytics, machine learning, game theory and microeconomics to classes large and small, at university and for industry.

Research: Using AI, optimisation and machine learning methods to solve problems in power and energy systems, logistics and the circular economy.

Primary goals of this course

In COMP3702/COMP7702, we aim to introduce the foundational concepts and methods used in the field of artificial intelligence, namely:

1. searching for solutions to problems,
2. reasoning and planning with certainty,
3. reasoning and planning under uncertainty,
4. learning to act, and
5. reasoning about other agents,

and to develop the skills needed to apply these techniques to real–world problems.

Tentative weekly plan (see Learning Resources on BB, and watch for updates)

COMP3702 / COMP7702 Artificial Intelligence

		LECTURES		ASSESSMENT	
MODULES	*Week*		*Topics*	*RiPPLE*	*Assignments*
Module 0: Introduction	Week 1	Lecture 1.1	Course overview; Introduction to AI and rational agents		
Module 1: Search		Lecture 1.2	Introduction to search; Uninformed search		
		Lecture 1.3	Heuristic search		
	Week 2	*No lecture (public holiday)*			Assignment 0 (no marks)
	Week 3	Lecture 3.1 Lecture 3.2	Refinements to search strategies Bounded search		
	Week 4	Lecture 4	Search in continuous spaces		
Module 2: Reasoning and planning with certainty	Week 5	Lecture 5	Logic: Propositions and Inference	RiPPLE round 1 4 September	Assignment 1 4 September
	Week 6	Lecture 6.1 Lecture 6.2	Constraint satisfaction problems Constraint-based planning		
Module 3: Reasoning and planning under uncertainty	Week 7	Lecture 7.1 Lecture 7.2 Lecture 7.3	Probability review Decision theory Exploration vs exploitation trade-off and multi-armed bandits	RiPPLE round 2 18 September	
	Week 8	Lecture 8	MDPs 1: representation and exact algorithms		Assignment 2 25 September
	Mid semester break				
	Week 9	Lecture 9.1 Lecture 9.2	MDPs 2: approximations and refinements MDPs 3: Neuro-approximate DP for continuous spaces and actions		
Module 4: Learning to act	Week 10	Lecture 10	Reinforcement Learning 1	RiPPLE round 3 16 October	
	Week 11	Lecture 11	Reinforcement Learning 2		Assignment 3 23 October
Module 5: Reasoning about other agents	Week 12	Lecture 12.1 Lecture 12.2	Adversarial search (minimax) Game theory	RiPPLE round 4 30 October	Assignment 4 9 November (Monday)
	Study break				
	Exam week 1			Final exam	
	Exam week 2				

Some AI topics we do not cover in this course

- Natural language processing,
- Bayesian networks/graphical models, and most other machine learning topics (see COMP4702/COMP7703),
- Pattern Recognition and Analysis (see COMP3710),
- Image Processing and Computer Vision (see ELEC4630),
- Data Mining(see INFS4203)
- User experience and user interaction (UX/UI) design — see the the BInfTech User Experience Design Major, and/or the Master of Interaction Design for more.

You'll learn the most by doing

To help, we will provide:

Active lectures: Provide an introduction to various concepts and techniques in AI combined with a series of in-class activities.

Weekly tutorials: Provide opportunity to practice the techniques introduced in lectures.

Assignments: design and implement AI systems in four take-home assignments.

Learnersourcing and Adaptive learning: RiPPLE gives you an opportunity to create and evaluate high-quality learning resources, and uses explainable AI algorithms to provide personalised recommendation for learning resources to engage with.

Discussion forums: Piazza provides an opportunity for you to ask questions and engage with responding to questions posted by your peers, moderated by the teaching team.

Weekly tutorials

Tutorial exercises are provided to help you understand the materials discussed in lectures, and to improve your skills in solving AI problems, with support from tutors.

- Tutorial worksheets will be available on BB each week.
- Tutorials follow the lecture schedule, one week behind.
- Tutorial exercises are not graded, but you are highly encouraged to do them.
- The skills you acquire in completing the tutorials will help you complete the assignments.
- You'll get the best learning outcome when you try to solve the tutorial exercises on your own before your tutorial session, and then use your tutorial session to ask about the difficulties you face when trying to solve the exercises.
- Videos of worked solutions to selected exercises will be made available on BB at the end of each week.

Piazza

- **Piazza** is a Q&A web service.
- It can be described as "mixture between a wiki and a forum.
- Piazza will be used by the teaching team to communicate with you
- You can use it to ask questions, and to respond to other students' questions.
- Register for the COMP3702/COMP7702 Piazza forum via the Blackboard, under *Learning Resources* $\rightarrow$ *Course Tools*

Assignments (50% of final mark)

Assignment 0 (0%): The purposes of Assignment 0 are to:

- refresh some of the core mathematical concepts and methods used in AI,
- introduce you to some of the programming tricks and tools needed for your assignments,
- give you a chance to learn how to the Gradescope code autograder.

Four graded assignments:

Assignment 1 (10%): on Module 1 due 4 Sept @11.59 pm

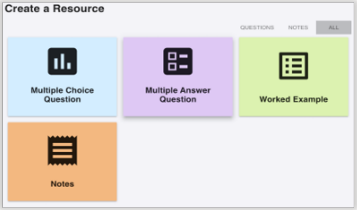
Assignment 2 (15%): on Module 2 due 25 Sept @11.59 pm

Assignment 3 (10%): on Module 3 due 23 Oct @11.59 pm

Assignment 4 (15%): on Module 4 due 9 Nov (first day of exams) @11.59 pm

Nb: Module 5 does not have an assignment; it will be assessed only in the final exam.

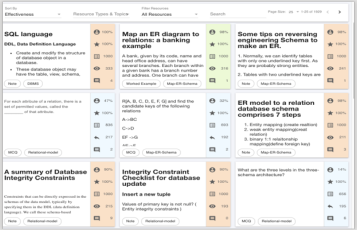
RiPPLE — Learnersourcing



Students author learning resources

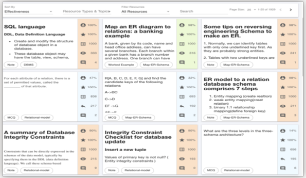
Resources are moderated by peers and tutors

Based on the moderations, a decision is made

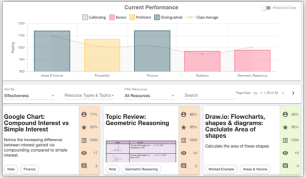


Effective resources are added to a repository

RiPPLE — Adaptive learning

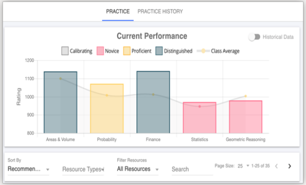


Students engage with a pool of resources



RiPPLE approximates student's mastery level across course topics

RiPPLE recommends learning resources to each student based on their learning needs



Mastery level of students is updated based on their creation moderation and responses

Final Exam

- Final exam during examination period
- Mock exams will be provided to help you effectively prepare.

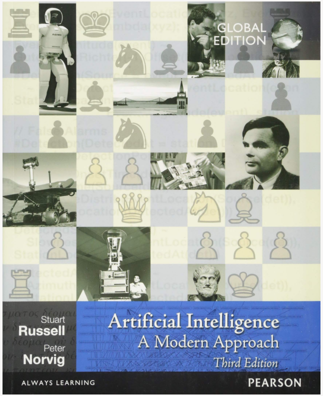
Assessment weightings and due dates

Task	*Weighting*	*Due date*
RiPPLE	10%	Weeks 5, 7, 10 and 12
Assignments	50%	Weeks 5, 8, 11 and first week of exams
Final Exam	40%	Exam period

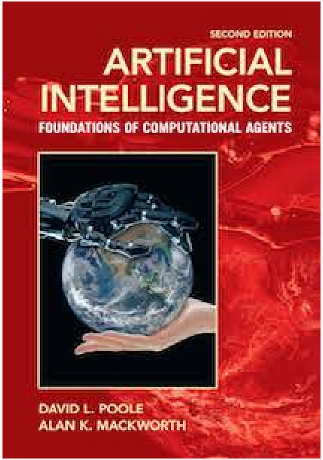
Get organised!

- Read the course profile
- Make sure that you can access the Blackboard site for the course
- Sign up for a tutorial session, and attend!
- Sign up for Piazza
- Review the RiPPLE material on Blackboard, and start using it as soon as it is made available.
- Watch out for announcements and updates through BB.

Additional learning resources: Textbooks



Russell& Norvig, 3e (R&N)
(Nb: 4e has recently been released)



Poole and Mackworth, 2e (P&M)
`https://artint.info/`

Anonymous feedback

- You can submit anonymous feedback to me and the tutors via Piazza, at any time.
- This provides you with the opportunity to express what you like or dislike about the course.
- Feedback of all kinds are welcome! We are always trying to improve COMP3702/7702.
- Please submit feedback as private posts.
- If appropriate, I might paraphrase your comment on the discussion boards and respond to it, or raise it in the lectures (anonymously, of course).

COMP3702/COMP7702
Artificial Intelligence

Module 0: Introduction

Dr Archie Chapman

Semester 2, 2020

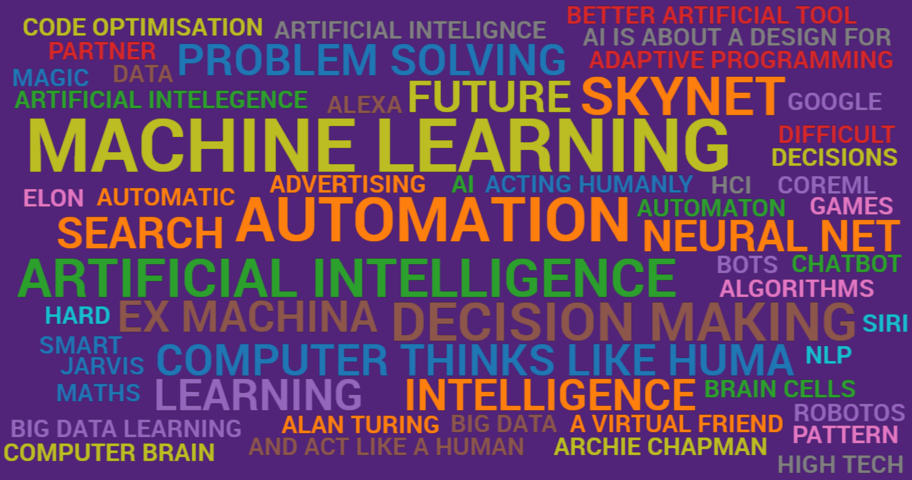
The University of Queensland
School of Information Technology and Electrical Engineering

Overview of Module 0

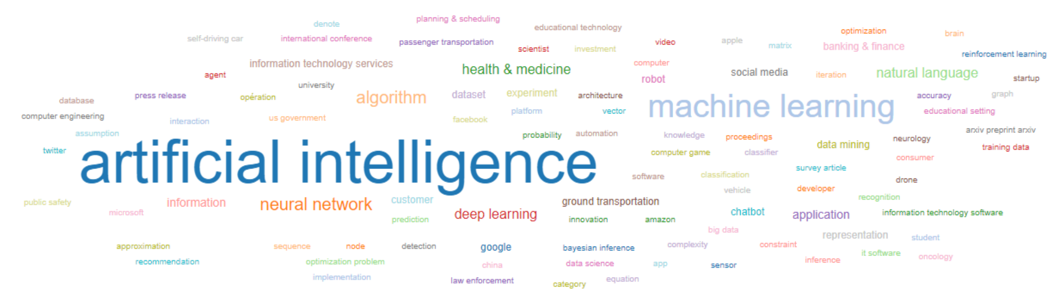
1. What is AI?
2. History of Artificial Intelligence
3. Intelligent agents
4. Goals of artificial intelligence
5. Intelligent agents acting in an environment
6. Dimensions of complexity

What is AI?

What do you think AI is? Live lecture wordcloud:



What is AI? Whatever AI researchers do! AAAI conference alert cloud



Source: `https://aitopics.org/search`

What is AI?

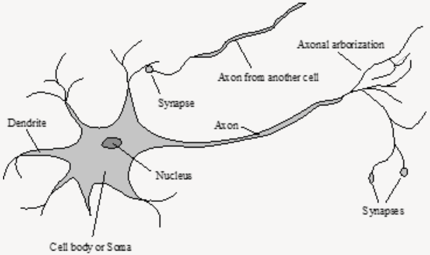
The study and designs of mechanisms that...

- think like humans?
- think rationally?
- act like humans?
- act rationally?

What is AI?

The study and designs of mechanisms that...

- **think like humans?** Build something like a brain! But how does a human brain work?
- think rationally?
- act like humans?
- act rationally?



Maybe machines can reach intelligence a different way to the human brain?

What is AI?

The study and designs of mechanisms that...

- think like humans?
- **think rationally?** Automated reasoning and logic are foundational topics in AI.
- act like humans?
- act rationally?

It is unclear if logic really captures the type of knowledge that people have or need help with.

Plus, it's really hard to search through logical statements...

What is AI? The Turing Test

The study and designs of mechanisms that...

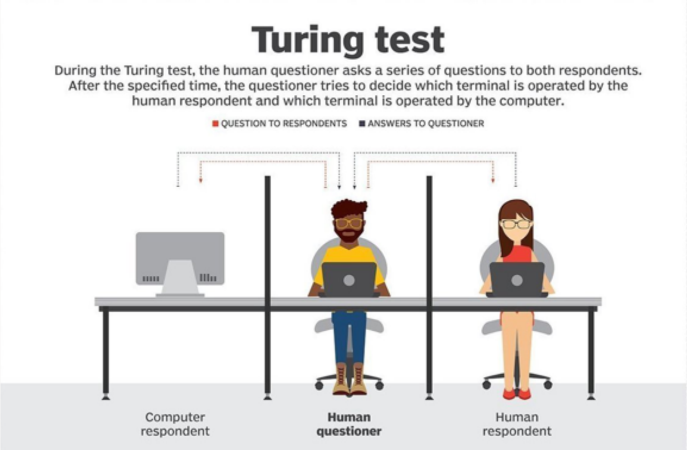
- think like humans?
- think rationally?
- **act like humans?** The Turing test: can a human tell if a computer is a computer?
- act rationally?

The Turing Test — Alan Turing (1950)

In the Turing test, the computer is asked questions by a human interrogator.

Computer passes the test if the interrogator cannot tell whether the responses come from a human or a computer.

The Turing test simplifies the question "is the machine intelligent" into "can the machine imitate a human?"



Source: https://medium.com/@fatihbildiriciii/yapay-zeka-e%C4%9Fitim-serisi-b%C3%B61%C3%BCm-3-69884059e2c1

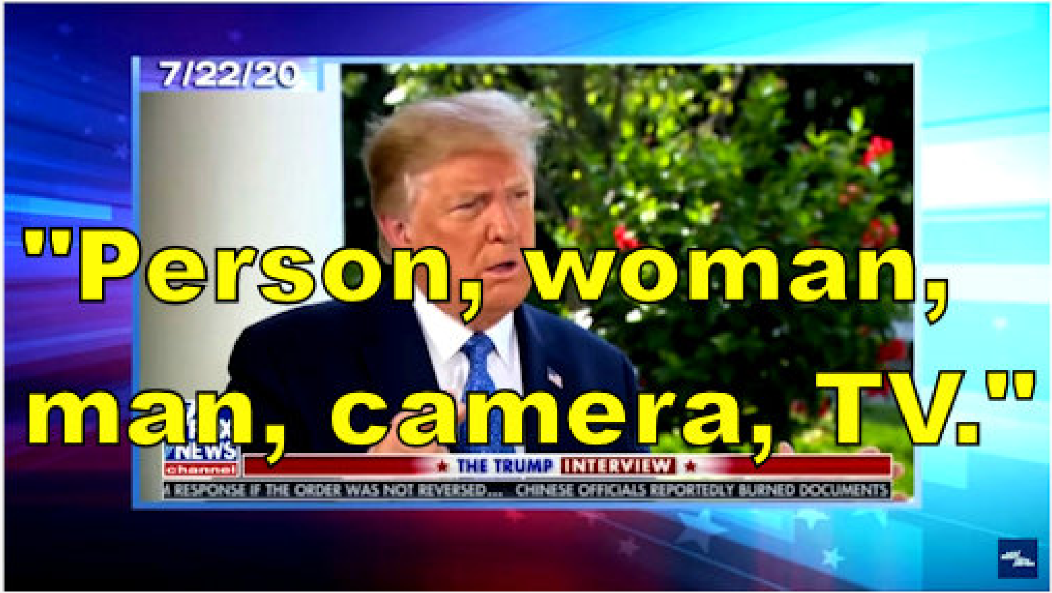
What is AI?

The study and designs of mechanisms that...

- think like humans?
- think rationally?
- **act like humans?** The Turing test: can a human tell if a computer is a computer?
- act rationally?

Stop and think: Do we really want computers to act like humans?

Do we really want computers to think and act like humans?



What is AI?

The study and designs of mechanisms that...

- think like humans?
- think rationally?
- act like humans?
- **act rationally?** Aka intelligent agents (approach taken in R&N and P&M texts)

Not sure that this *truly* captures the variety of AI research going on right now, but it is a good place to start. . .

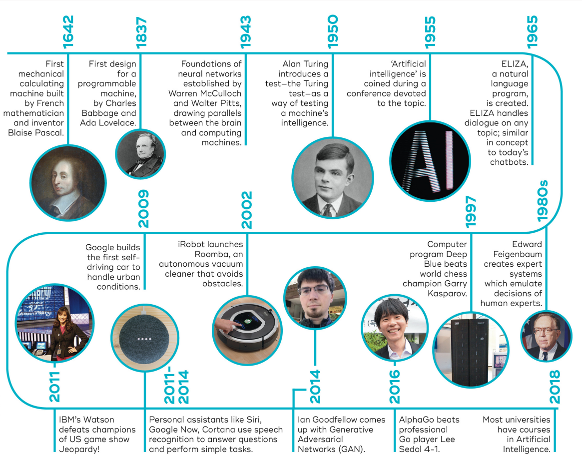
What is AI?

- Association for the Advancement of Artificial Intelligence (AAAI) offers this on its home page: **AI is “the scientific understanding of the mechanisms underlying thought and intelligent behavior and their embodiment in machines.”**
- Poole and Mackworth say Artificial intelligence is "**the synthesis and analysis of computational agents that act intelligently**."
- I say: "AI is the study and development of algorithms for solving problems that we typically associate with intelligence."
- AI is a disperse collection of topics. We address core method and models in this course, which have found had wide-spread use application and as building-blocks in more sophisticated AI systems.

We won’t do all of AI in this course!

History of Artificial Intelligence

A brief history of Artificial Intelligence



Source: `https://qbi.uq.edu.au/brain/intelligent-machines/history-artificial-intelligence`

For more of the history and development of AI, read Chapter 1 of R&N or P&M.

Intelligent agents

What is an intelligent computational agent?

- An **agent** is something that **acts** in an environment.
- An agent acts **intelligently** if. . .

What do you think it means for an agent to act intelligently?

Enter your suggestions here:

`https://apps.elearning.uq.edu.au/wordstream/69994`

What is an intelligent computational agent?

- An **agent** is something that **acts** in an environment.
- An agent acts **intelligently** if:
  - its actions are appropriate for its goals and circumstances
  - it is flexible to changing environments and goals
  - it learns from experience
  - it makes appropriate choices given perceptual and computational limitations

Examples of agents

- **Organisations:** Microsoft, Facebook, Government of Australia, UQ, ITEE,...
- **People:** teacher, doctor, stock trader, engineer, researcher, travel agent, farmer, waiter,...
- **Computers/devices:** air-conditioner thermostat, airplane controller, network controller, movie recommendation system, tutoring system, diagnostic assistant, robot, GPS navigation app, Mars rover...
- **Animals:** dog, mouse, bird, insect, worm, bacterium, bacteria,...
- book(?), sentence(?), word(?), letter(?)
  Can a book or article *do* things?
  Convince? Argue? Inspire? Cause people to act differently? *Learn* from experience?

Goals of artificial intelligence

Goals of artificial intelligence

- **Scientific goal:** to understand the principles that make intelligent behavior possible in natural or artificial systems.
  - analyze natural and artificial agents
  - formulate and test hypotheses about what it takes to construct intelligent agents
  - design, build, and experiment with computational systems that perform tasks that require intelligence
- **Engineering goal:** design useful, intelligent agents.
  - Always make the "best" decision given the available resources (knowledge, time, computational power and memory)
  - Best: Maximize certain performance measure(s), usually represented as a *utility* function
    More on this throughout the semester

In this class...

- We are interested in building software systems (called agents) that behave rationally
- i.e. Systems that accomplish what they are supposed to do, well, given the available resources
- Don't worry about how close the systems resemble humans and about philosophical questions on what "intelligence" is (not that we are not interested in this!)
- But we may use inspirations from humans or other "intelligent" beings and systems

Intelligent agents acting in an environment

Recall our goal: To build a useful, intelligent agent

To start with:

- Computers perceive the world using sensors.
- Agents maintain models/representations of the world and use them for reasoning.
- Computers can learn from data.

So, to achieve our goal, we need to define our "agent" in a way that we can program it:

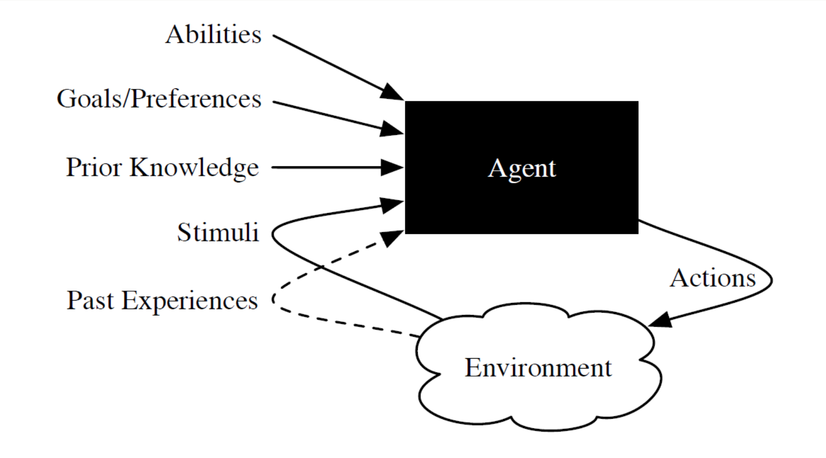
- The problem of constructing an agent is usually called the agent design problem
- Simply, it's about defining the components of the agent, so that when the agent acts rationally, it will accomplish the task it is supposed to perform, and do it well.

Some important things we don't address in this course

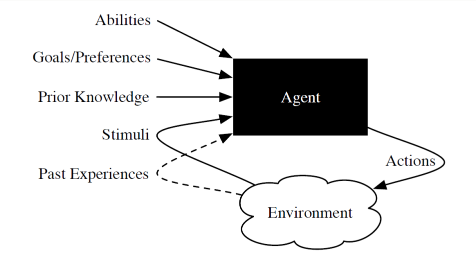
- **User interaction**: Making agents interact comfortably with humans is a substantial challenge for AI developers.
- **Ethics of AI**: AI applications can impact society in both positive and negative ways.

Agents acting in an environment: inputs and output

An agent performs an action in the environment; the environment generates a percept or stimuli. The percept generated by the environment may depend on the sequence of actions the agent has done.



Inputs to an agent



- **Abilities** — the set of possible actions it can perform
- **Goals/Preferences** — what it wants, its desires, its values...
- **Prior Knowledge** — what it knows and believes initially, what it doesn't get from experience...
- **History of stimuli**
  - (current) **stimuli** — what it receives from environment now (observations, percepts)
  - **past experiences** — what it has received in the past

Autonomous car

- **abilities:** steer, accelerate, brake
- **goals:** safety, get to destination, timeliness ...
- **prior knowledge:** street maps, what signs mean, what to stop for ...
- **stimuli:** vision, laser, GPS, voice commands ...
- **past experiences:** how braking and steering affects direction and speed...

Air-conditioner thermostat and controller agent

- **abilities:** turn air-conditioner on or off
- **goals:** conformable temperature, save energy, save money
- **prior knowledge:** 24 hour cycle, weekends
- **stimuli:** temperature, set temperature, who is home, outside temperature, rooftop PV generation...
- **past experiences:** when people come and go, who likes what temperature, building thermal dynamics...

Example agent

- **abilities:**
- **goals:**
- **prior knowledge:**
- **stimuli:**
- **past experiences:**

Dimensions of complexity

Dimensions of complexity in agent design (P&M Ch 1.5)

- Research proceeds by making simplifying assumptions, and gradually reducing them.
- Each simplifying assumption gives a dimension of complexity
  - multiple values in a dimension: from simple to complex
  - simplifying assumptions can be relaxed in various combinations
- Much of the history of AI can be seen as starting from the simple and adding in complexity in some of these dimensions.

Dimensions of complexity in agent design

From P&M Ch 1.5:

Dimension	Values
Modularity:	flat, modular, hierarchical
Planning horizon:	non-planning, finite stage, indefinite stage, infinite stage
Representation:	states, features, relations
Computational limits:	perfect rationality, bounded rationality
Learning:	knowledge is given, knowledge is learned
Sensing uncertainty:	fully observable, partially observable
Effect uncertainty:	deterministic, stochastic
Preference:	goals, complex preferences
Number of agents:	single agent, multiple agents
Interaction:	offline, online

Modularity

- Model at one level of abstraction: **flat**
- Model with interacting modules that can be understood separately: **modular**
- Model with modules that are (recursively) decomposed into modules: **hierarchical**
- Flat representations are adequate for simple systems.
- Complex biological systems, computer systems, organizations are all hierarchical.

Is the environment continuous or discrete?

- A flat description is typically either **continuous** (exclusive-)or **discrete**
- hierarchical reasoning is often a hybrid of continuous and discrete.

Planning horizon

...how far the agent looks into the future when deciding what to do.

- **Static:** world does not change
- **Finite stage:** agent reasons about a fixed finite number of time steps
- **Indefinite stage:** agent reasons about a finite, but not predetermined, number of time steps
- **Infinite stage:** the agent plans for going on forever (i.e. process oriented)

Representation

Much of modern AI is about finding compact representations and exploiting the compactness for computational gains.

An agent can reason in terms of:

- **Explicit states — ** a state is one way the world could be
- **Features** or **propositions.**
    - States can be described using features.
    - 30 binary features can represent $2^{30} = 1,073,741,824$ states.
- **Individuals** and **relations**
    - There is a feature for each relationship on each tuple of individuals.
    - Often an agent can reason without knowing the individuals or when there are infinitely many individuals.

Computational limits

- **Perfect rationality:** the agent can determine the best course of action, without taking into account its limited computational resources.
- **Bounded rationality:** the agent must make good decisions based on its perceptual, computational and memory limitations.

Learning from experience

Whether the model is fully specified a priori:

- **Knowledge is given.**
- **Knowledge is learned from data or past experience.**

…always some mix of prior (innate, programmed) knowledge and learning (nature vs nurture).

Uncertainty

There are two dimensions for uncertainty:

- **Sensing uncertainty** or noisy perception
- **Effect uncertainty**

In this course, we restrict our focus to **probabilistic** models of uncertainty. Why?

- Agents need to act even if they are uncertain.
- Predictions are needed to decide what to do:
  - definitive predictions: you will be run over tomorrow
  - point probabilities: probability you will be run over tomorrow is 0.002 if you are careful and 0.05 if you are not careful
  - probability ranges: you will be run over with probability in range [0.001,0.34]
- Acting is gambling: agents who don't use probabilities will lose to those who do.
- Probabilities can be learned from data and prior knowledge.

Sensing uncertainty

Whether an agent can determine the state from its stimuli:

- **Fully-observable**: the agent can observe the state of the world.
- **Partially-observable**: there can be a number states that are possible given the agent's stimuli.

Effect uncertainty

If an agent knew the initial state and its action, could it predict the resulting state?

The dynamics can be:

- **Deterministic**: the resulting state is determined from the action and the state
- **Stochastic**: there is uncertainty about the resulting state.

Preferences

What does the agent try to achieve?

- **achievement goal** is a goal to achieve. This can be a complex logical formula.
- **complex preferences** may involve tradeoffs between various desiderata, perhaps at different times.
  - **ordinal** only the order matters
  - **cardinal** absolute values also matter

Examples: coffee delivery robot, medical doctor

Number of agents

Are there multiple reasoning agents that need to be taken into account?

- **Single agent** reasoning: any other agents are part of the environment.
- **Multiple agent** reasoning: an agent reasons strategically about the reasoning of other agents.

Agents can have their own goals: cooperative, competitive, or goals can be independent of each other

Interaction

When does the agent reason to determine what to do?

- **reason offline**: before acting
- **reason online**: while interacting with environment

Dimensions of complexity in agent design

From P&M Ch 1.5:

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Example problem class: State-space search (Module 1)

Dimension	Values
Modularity	flat, modular, hierarchical
Planning horizon	non-planning, finite stage, indefinite stage, infinite stage
Representation	states, features, relations
Computational limits	perfect rationality, bounded rationality
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Number of agents	single agent, multiple agents
Interaction	offline, online

Example problem class: Deterministic planning using CSP (Module 2)

Dimension	Values
Modularity	flat, modular, hierarchical
Planning horizon	non-planning, finite stage, indefinite stage, infinite stage
Representation	states, features, relations
Computational limits	perfect rationality, bounded rationality
Learning	knowledge is given, knowledge is learned
Sensing uncertainty	fully observable, partially observable
Effect uncertainty	deterministic, stochastic
Preference	goals, complex preferences
Number of agents	single agent, multiple agents
Interaction	offline, online

Example problem class: Markov decision processes (MDPs, Module 3)

Dimension	Values
Modularity	flat, modular, hierarchical
Planning horizon	non-planning, finite stage, indefinite stage, infinite stage
Representation	states, features, relations
Computational limits	perfect rationality, bounded rationality
Learning	knowledge is given, knowledge is learned
Sensing uncertainty	fully observable, partially observable
Effect uncertainty	deterministic, stochastic
Preference	goals, complex preferences
Number of agents	single agent, multiple agents
Interaction	offline, online

Example problem class: Reinforcement learning (Module 4)

Dimension	Values
Modularity	flat, modular, hierarchical
Planning horizon	non-planning, finite stage, indefinite stage, infinite stage
Representation	states, features, relations
Computational limits	perfect rationality, bounded rationality
Learning	knowledge is given, knowledge is learned
Sensing uncertainty	fully observable, partially observable
Effect uncertainty	deterministic, stochastic
Preference	goals, complex preferences
Number of agents	single agent, multiple agents
Interaction	offline, online

Example problem class: Classical game theory (Module 5)

Dimension	Values
Modularity	flat, modular, hierarchical
Planning horizon	non-planning, finite stage, indefinite stage, infinite stage
Representation	states, features, relations
Computational limits	perfect rationality, bounded rationality
Learning	knowledge is given, knowledge is learned
Sensing uncertainty	fully observable, partially observable
Effect uncertainty	deterministic, stochastic
Preference	goals, complex preferences
Number of agents	single agent, multiple agents
Interaction	offline, online

The real world: Humans

Dimension	Values
Modularity	flat, modular, hierarchical
Planning horizon	non-planning, finite stage, indefinite stage, infinite stage
Representation	states, features, relations
Computational limits	perfect rationality, bounded rationality
Learning	knowledge is given, knowledge is learned
Sensing uncertainty	fully observable, partially observable
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Attributions and References

Thanks to Dr Alina Bialkowski and Dr Hanna Kurniawati for their materials.

Many of the slides in Module 0 are adapted from David Poole and Alan Mackworth, *Artificial Intelligence: foundations of computational agents*, 2E, CUP, 2017 `http://https://artint.info/`.

Other materials derived from Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3E, Prentice Hall, 2009.

All remaining errors are Archie's — please email if you find any: archie.chapman@uq.edu.au