

COMP3620 / 6320 – S1 2023

程序代写代做 CS 编程辅导



This lecture will be recorded

Turn off your camera if you do not want to be in the recording
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If you cannot see my whole slide, go to View Options -> Zoom Ratio and select
[Assignment](#) [Project](#) [Exam](#) [Help](#) Fit to Window

If you follow the class online and want to ask a question, either:

- Raise your hand and I will open your ~~QQ 749389476~~, or
- Type the question in the Q&A box <https://tutorcs.com>
- Since the lecture is live in person, I cannot constantly monitor the online part, so please be patient



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程序代写代做 CS编程辅导
COMP3620/6320



Email: tutorcs@163.com

QQ: 749389476

Course Organisation and Introduction

Prof. Jochen Renz (Convenor) <https://tutorcs.com>

Dr Peng Zhang (Co-convenor)

<https://cs.anu.edu.au/courses/comp3620/>

Course Organization

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- All the information about the course, assignments, labs, tutorials, policies etc are on the website:

<https://cs.anu.edu.au/courses/comp3620/>
WeChat: cstutorcs

- You must read the **policies** and **outline** sections at least once
 - Not knowing the policies in ~~Final tutor is not valid exam~~
- We will run the course via the corresponding WATTLE page. All non-public information such as slides, recordings, assignments etc can be found there.
- **Important: Please complete the Student On/Off Campus Declaration today!**

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Short Summary of the Course

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- **3 Topics (5-6 lectures each)**
– Search
– Knowledge Representation and Reasoning (KRR)
– Planning
- **3 Assignments (10% each)** WeChat: cstutorcs
– 100% penalty if late
– Plagiarism detection software, some automated testing and manually checking
- **6 Tutorials** Email: tutorcs@163.com
– 2 per topic
– 1 quiz per tutorial, 10% total marks (0 marks for tutorials you miss)
- **6 Labs** QQ: 749389476
- **Mid-semester exam (20%)** - **Hurdle:** mid-semester exam ≥ 40 (out of 100)
- **Final exam (40%)**



Tutorials, Labs, Assignments and Quizzes

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- **Tutorials (starting week 3,  selection will open on Friday 2pm!)**
 - The goal is to help understand material and prepare for the exams
 - We will discuss a list of questions. Please try answering them before the tutorial!
- **Quizzes:**
 - The goal is to provide you with a reality check 
 - Are you keeping up with the content or should you spend more time studying? 
- **Assignments:**
 - The goal is to put the course into practice by building substantial AI programs
 - This is essential to build a deep understanding of the course material 
- **Labs (no need to select a lab, you can just attend any, # will be cut):**
 - The goal is for you to get help from the tutors with the assignments
 - **Labs are unstructured and self-guided** (that is, you need to bring questions)
 - Get started well in advance to make the most of the opportunity

Contact & Information

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- The course page is the main source of information
 - It has priority in case of conflicting information
 - Use **Piazza** for all communications
 - See communication policy
- Assignment Project Exam Help**
- Email: tutorcs@163.com
<https://cs.anu.edu.au/courses/comp3620/policies/#communication> for more details of whom to contact in different situations
- <https://tutorcs.com>

CECC Class Representatives

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- Class Student Representation is an important component of the teaching and learning quality assurance and quality improvement processes within the ANU College of Engineering and Computer Science (CECC).
- The role of Student Representatives is to provide ongoing constructive feedback on behalf of the student cohort to Course Conveners and to Associate Directors (Education) for continuous improvements to the course.

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- **Roles and responsibilities:** Email: tutorcs@163.com
- Act as the official liaison between your peers and convener.
- Be available and proactive in gathering feedback from your classmates.
- Attend regular meetings, and provide reports on course feedback to your course convener
- Close the feedback loop by reporting back to the class the outcomes of your meetings.

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Why become a class representative?



- Ensure students have a voice to their course convener, lecturer, tutors, and College.
- Develop skills sought by employers, including interpersonal, dispute resolution, leadership and communication skills.
- Become empowered. Play an active role in determining the direction of your education.
- Become more aware of issues influencing you University and current issues in higher education.
- Course design and delivery. Help shape the delivery of your current courses, as well as future improvements for following years.

- Want to be a class representative? Nominate yourself today!
- Please nominate yourself to your course convener by end of Week 2, Sem 1, 2023.
- You are free to nominate yourself whether you are currently on campus or studying remotely.

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- Note: Class representatives will need to be comfortable with their contact details being made available via Wattle to all students in the class.
- For more information regarding roles and responsibilities, contact:
- ANUSA CECC representatives: sa.cecs@anu.edu.au



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Topics

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- What is AI?
- Foundational and Current Disciplines
- Brief History
- Ethics

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Artificial Intelligence

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John McCarthy
1927-2011



“The science and engineering of making intelligent machines”

- **Official birth:** Dartmouth College Meeting, 1956
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- **Ambitious goals:**
1. Understand “intelligence”
2. Build “intelligent” machines

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But ... what counts as an intelligent machine?

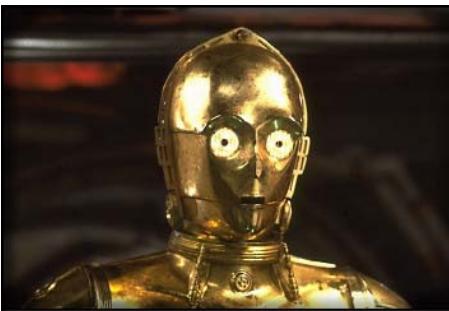
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What is an Intelligent Machine?

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What is an Intelligent Machine?

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- 4 different perspectives corresponding to two dimensions
 1. thinking vs acting (thinking vs reasoning vs actions/behavior)
 2. human vs rational (acting like a human vs close to optimal)



| | |
|--|---------------------------------|
| Systems that think like humans WeChat: cstutorcs | Systems that think rationally |
| Systems that act like humans Assignment System Exam Help rationally | Help rationally |

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- **Rationale:**
 1. The ability to think is what distinguishes humans from animals. But a machine could behave inteligentcs.com without thinking.
 2. Humans exhibit intelligence. But why not aim at super-human, optimal behavior, especially for specific tasks?

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What is an Intelligent Machine?

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| | | |
|--------------------------------|---|-------------------------------|
| Systems that think like humans |  | Systems that think rationally |
| Systems that act like humans |  | Systems that act rationally |

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- Making machines with minds in the full and literal sense [Haugeland 85]
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- Making computers do things at which, for now, people are better [Kurzweil 90]
- Studying the computations that enable perception, reasoning, and actions [Winston 92]
- Concerned with the automation of intelligent behavior [Luger & Subblefield 93]
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Whether machines can think is as relevant as whether submarines can swim [Dijkstra 84]

Acting Humanly: The Turing Test

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- “Computing Machinery and Intelligence” [Turing 50]
- Operational test for intelligent behavior
- Imitation game: computer passes the test if interrogator cannot tell which is the machine (no physical presence)
- Focused on major AI components:
 - Natural language processing
 - Knowledge representation & reasoning
 - Learning
- Prediction: by 2000, 30% chance to fool a human in a 5-minutes conversation

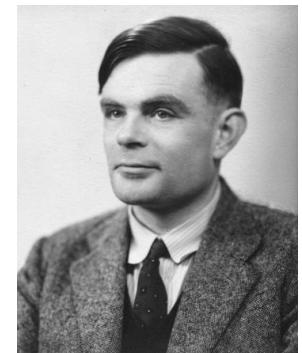
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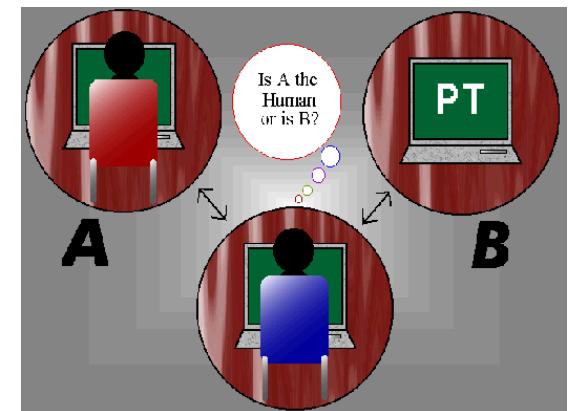
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Alan Turing
1912-1954



Acting Humanly: The Turing Test

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- Eliza (Weizenbaum 66) rule-based program replicating a psychotherapist.
Primitive natural language processing.
- Loebner Prize (\$100,000) since 1991
 - A.L.I.C.E 3 bronze medals
 - Mitsuku 3 bronze medal in 2013, 2016-2019



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www.mitsuku.com

Patient: I feel sad.

Eliza: Do you often feel sad?

Patient: Not very often.

Eliza: Please, go on.

Human: Does god exist?

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Mitsuku: The bible is the most significant piece of evidence that God exists, but it is not a scientific proof.

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Human: Okay, but do you believe in god?

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Mitsuku: Yeah, okay, I believe there is probably something out there but I doubt it is a man with a long beard sat on a throne.

- Now in 2023 we have ChatGPT

Thinking Humanly: Modelling Cognition

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- Objective: develop scientific understanding of the activities of the brain
- Two approaches:



1. Cognitive Science (top down):

uses computer models and experimental psychology techniques to predict and test behavior of human subjects

2. Cognitive Neuroscience (bottom up):

uses computer imaging & other neurological data to observe the brain in action

– Project to simulate the brain www.humanbrainproject.eu

– Related to the AI field of neural networks (see deep learning)

- These days, both disciplines are distinct from AI

Thinking Rationally: Laws of Thought

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- Objective: formalise and mechanise valid reasoning
- Direct line through maths and philosophy to modern AI
- **Logic:** notation and rules to derive valid conclusions
 - Aristotle's syllogism
 - Mathematical development of classical logic
 - Propositional & first-order logic (Boole, Frege, 1850s)
 - Most of mathematics can be derived from axioms of set theory
 - Non-classical logic to formalise common-sense reasoning
 - Default logic (by default, birds fly)



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Tweety is a bird
Birds fly

Tweety flies

P(a)

$\forall x P(x) \rightarrow Q(x)$

Q(a)



Thinking Rationally: Laws of Thought

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- **Limit 1: Undecidability**

- Gödel's Theorem: every computable consistent theory extending arithmetic has formulas true but not provable within the theory.



- **Limit 2: Complexity**

- Non-trivial to formalise a real-world problem in logic
 - Most problems are NP-complete or harder

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- **Limit 3: Scope**

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- Not all intelligent behavior requires reasoning (much doesn't)

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- **Limit 4: Purpose**

- Reasoning to prove what? Notion of “goal” is missing

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Acting Rationally: Rational Agents

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- An **agent** is an entity that perceives and acts in its environment (driverless car, electronic trading system, energy management system)
- **Rationality** is about doing the right thing:
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- Decision which achieves the best (expected) outcome, given the information available and time available (limited rationality)
- **This course (and much of today's AI) is about designing rational agents:** for any given class of environment and task, we seek the agent with the best performance.
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Rational Decisions?

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- We currently have 215 students in this course
- We have 12 tutorials. How many online tutorials do we need?
- I asked you to complete the online/offline form on wattle:
 - 127 students completed: 112 in person, 15 online.

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- So what is the rational decision???

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Tutorials

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| Mondays | | Tuesdays | | Wednesdays | |
|---------------------|-----------|---------------------|-------------|---------------------|-----------|
| 09:00 AM - 10:30 AM | In Person | 12:00 PM - 01:30 PM | In Person | 11:00 AM - 12:30 PM | In Person |
| 10:30 AM - 12:00 PM | In Person | 01:30 PM - 03:00 PM | Online Only | 12:30 PM - 02:00 PM | In Person |

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| Thursdays | | Fridays | |
|---------------------|-------------|---------------------|-----------|
| 10:00 AM - 11:30 AM | In Person | 01:00 PM - 02:30 PM | In Person |
| 11:30 AM - 1:00 PM | In Person | 02:30 PM - 04:00 PM | In Person |
| 03:00 PM - 04:30 PM | In Person | | |
| 04:30 PM - 06:00 PM | Online Only | | |

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Labs

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| Tuesdays | Wednesdays |
|--|--|
| 03:00 PM - 05:00 PM Every Week Online Only | 02:00 PM - 04:00 PM Every Week In Person |

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| Thursdays | Email: tutorcs@163.com QQ: 749389476 | Fridays |
|---------------------|--|---|
| 02:00 PM - 04:00 PM | One week before each assignment due Online Only | 09:00 AM - 11:00 AM One week before each assignment due In Person |

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Artificial Intelligence

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“The science and engineering of building intelligent machines”



- Ambitious goals:

1. Understand “intelligence”
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- Accurate models
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of cognitive science, neuroscience and psychology
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2. Build “intelligent” machines
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- Focus on developing
https://tutores.com methods that match or exceed human performance in certain domains, possibly by different means.



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Foundational and Current Disciplines

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Foundational Disciplines

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- **Philosophy:** logic, reasoning, methods, foundations of learning, language, and rationality
- **Mathematics:** proofs, decision theory, complexity, probability
- **Economics:** theory of rational decisions, game theory
- **Computer Sc. & Engineering:** algorithms, efficient computer design, control theory concepts (e.g. stability)
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- **Cognitive Science:** behaviorism, adaptation, perception, experimental methods
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- **Neuroscience:** information processing by the brain
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- **Linguistics:** language representation, language & thought



Current Disciplines

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- **Knowledge representation & reasoning:** how to efficiently represent information and use this to answer questions and draw conclusions
- **Problem solving, planning & search:** how to constructively solve problems and make decisions.
- **Machine learning:** inference from data to extrapolate patterns and adapt to new situations. Assignment Project Exam Help
- **Natural language processing:** Email: tutorcs@163.com
communication with humans QQ: 749389476
- **Computer vision:** processing and making sense of visual information about the environment.
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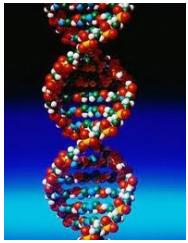
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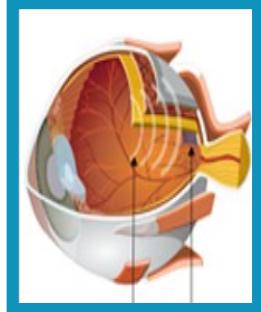
Applications

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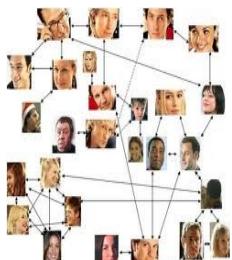
Perseverance landing (3 mins)
<https://youtu.be/4czjS9h4Fpg>



Health



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Financial markets



| Movies You Might Have Missed | | | |
|------------------------------|-----------------------------|------|-------|
| Add Q | Nick and Norah's Infinite P | PG13 | ★★★★★ |
| Add Q | Lakeview Terrace | PG13 | ★★★★★ |
| Add Q | Nights in Rodanthe | PG13 | ★★★★★ |
| Add Q | Changeling | R | ★★★★★ |
| Add Q | Pride and Glory | R | ★★★★★ |
| Add Q | Zack and Miri Make a Porno | R | ★★★★★ |
| Add Q | Quarantine | R | ★★★★★ |
| Add Q | Madagascar: Escape 2 Afr | PG | ★★★★★ |

Web mining
and applications



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Defence
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Energy



Transport



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Brief History

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Brief History

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| | | |
|----------|---|-----------------|
| 1950: | Turing test | NNs |
| 1950s: | Early programs including  von Neumann's, theorist, neural nets | Birth |
| 1956: | Dartmouth meeting, "Artificial Intelligence" adopted | Optimism |
| 1965: | Robinson's complete algorithm for logical reasoning | Realism |
| 1966-74: | AI discovers complexity, neural nets research disappears | Expert Systems |
| 1969-79: | Early knowledge-based systems  | Winter |
| 1980-88: | Expert systems industry booms  | Foundations |
| 1988-93: | Expert systems industry "busts", AI Winter | NN returns |
| 1988-00: | Greater technical depth, resurgence of probabilities  | Data, multicore |
| 1985-95: | Neural nets return, lead to, and replaced by modern SML  | NN again |
| 2003-: | Human-level AI back on the agenda | Maturity? |
| 2010-: | Deep learning: neural nets Research is in favour again  | |
| 2013-: | Ethical issues make the headlines | |
| 2022-: | Everyone is talking about ChatGPT | |

So let's talk about ChatGPT

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- Query: Who is Prof. Jochen Renz?
- ChatGPT: Professor Jochen Renz is an academic in the field of artificial intelligence and computer science. He is currently a professor of computer science at the University of Liverpool in the United Kingdom. His research interests include knowledge representation and reasoning, natural language processing, and the intersection of these areas with artificial intelligence. Before joining the University of Liverpool, Professor Renz held academic positions at the University of Freiburg in Germany and the Australian National University in Canberra, Australia. He has also been a visiting scholar at several institutions around the world, including Stanford University and the University of Edinburgh. Professor Renz has published numerous research papers and articles in top-tier computer science and artificial intelligence journals and conferences. He has also served on the program committees of many international conferences and workshops in his field.

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- Should you use ChatGPT? Yes, by all means. It is important to use new technology, particularly in this course. But remember to always reference it properly when you use it.
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- Should you trust ChatGPT? See above and decide for yourself. Use it as a time saver, and a learning tool, but always check the answers! Remember NP-hardness? Coming up with a solution is exponential, checking a solution is polynomial
- How about plagiarism? It's risky. What if a classmate receives and uses the same answer as you? All plagiarism flags will go off and you are in trouble. But I used ChatGPT. Nice answer in your plagiarism interview!
- Note: If you are taking this course to learn something about ChatGPT, I have to disappoint you. We are not covering the relevant areas in this course. Possibly in one of the guest lectures.

AI Achievements – Predictions

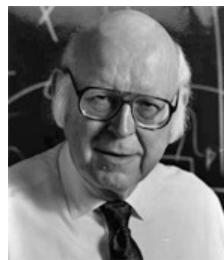
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- **1958:** “within ten years a digital computer will be the world's chess champion”
[Allen Newell]
- **1965:** “machines will be capable in twenty years, of doing any work a man can do.” **[Herb Simon]**
- **1970:** “In from three to eight years we will have a machine with the general intelligence of an average human being”
[Marvin Minsky]



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Assignment [Marvin Minsky]



Allen Newell
1927-1992

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Marvin Minsky
1927-2016

AI Achievements – The Reality

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- **1991:** Proverb solves crossword faster than human
- **1991:** AI solves Gulf-war logistics planning problems
- **1997:** IBM Deep Blue beats chess champion Kasparov
- **1999:** AI agent controls NASA deep space 1 probe
- **2001:** autonomous military drones unveiled
- **2005:** Driverless vehicles complete the 212km DARPA Grand Challenge through the Mojave desert
- **2007:** Checkers game completely solved
- **2009:** Google autonomous car drives in traffic
- **2011:** IBM Watson wins Jeopardy!
- **2016:** Google alphago beats go champion Lee Sedol
- **Today:** AI is everywhere, injects billions into economy



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AI Achievements – New Predictions



- 2030: “an AI system with an understanding of existence at the level of a mouse” [Rodney Brooks]



Rod Brooks
1954-

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- Not in his lifetime: “a robot that has any real idea about his own existence, or the existence of humans in a way a 6 years old child would” [Rodney Brooks]

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Toby Walsh
1964-

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- 2050: “Germany will loose to a robot soccer team.” [Toby Walsh]

Humanoid Robot Soccer - 1998

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Humanoid Robot Soccer - 2018

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AI Ethics

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AI Ethics and Risks

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- People might lose their jobs
 - AI creates wealth and takes dangerous and boring jobs for us
- Accountability loss: **who is responsible**, AI, owner, creator?
 - Similar issues elsewhere (medicine, software, plane crash)
- AI reproducing our **negative biases** and attitudes (e.g. racism)
 - AI should share our **positive values**
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- Use of AI as **weapon** (e.g. drones)
 - Can also save lives? Every beneficial invention can be misused



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AI Ethics and Risks

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- AI Success might end of the human era
 - Kurzweil, Musk, Hawking!
 - Once machine surpasses human intelligence it can design smarter machines.
 - Intelligence explosion and singularity which human era ends



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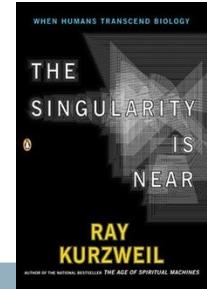
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- Many counter arguments
 - limits to intelligence
 - nothing special about human intelligence
 - computational complexity
 - “intelligence to do a task” ≠ “ability to improve intelligence to do a task”

Stunning AI Breakthrough Takes Us One Step Closer To The Singularity

George Dvorsky
Oct 19, 2017, 8:30am· Filed to: [ai](#)

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Robotics Laws

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The Three Laws of Robotics [Azimov 1942]

1. A robot may **not injure a human being**, or, through inaction, allow a human being to come to harm.
 2. A robot must **obey the orders given it by human beings** except where such orders would conflict with the First Law.
 3. A robot **must protect its own existence** as long as such protection does not conflict with the First or Second Law
- A robot may **not injure humanity**, or, through inaction, allow humanity to come to harm



UK Principles of Robotics [EPSRC 2011]

Robots are multi-use tools. Robots should **not be designed solely or primarily to kill or harm humans**, except in the interests of national security.

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2. Humans, not robots, are responsible agents. Robots should be designed & operated as far as is practicable to **comply with existing laws & fundamental rights freedoms**,
3. Robots are products. They should be designed using processes which **assure their safety and security**.
4. Robots are manufactured artefacts. They **should not be designed in a deceptive way** to exploit vulnerable users; instead their machine nature should be transparent.
5. **The person with legal responsibility for a robot should be attributed.**

Summary

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- How to think or how to behave like humans or being rational?
 - This course about acting naturally
- AI related to many fields including philosophy, mathematics, economics, neuroscience, psychology, computer sci. and control theory
 - WeChat: cstutors
- 50+ years of progress along many different paradigms: logic, expert systems, neural nets, learning, probabilities
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- Increasingly scientific: focus on experimental comparisons and theoretical foundations
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- AI is a high-risk high-gain area with major ethical implications

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Intelligent Agents



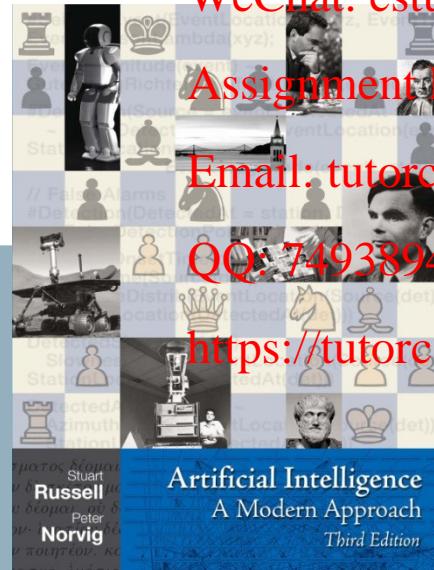
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Chapter 2

Outline

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- Agents and environments
- Rationality
- PEAS (Performance measure, Environment, Actuators, Sensors)
- Environment types
- Agent types

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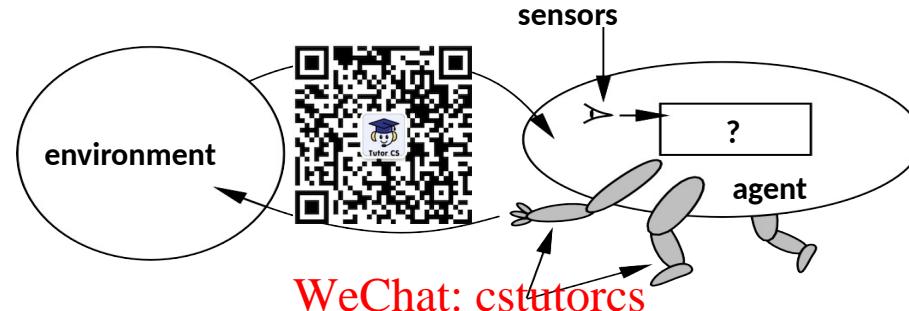
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Agents and Environments

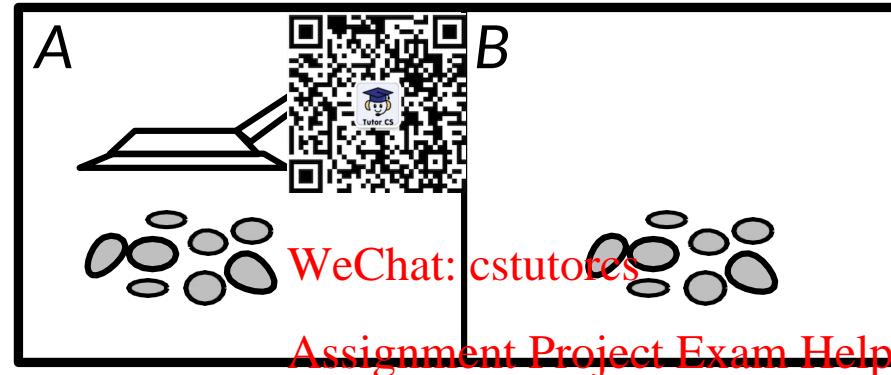
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- **Agents** include humans, robots, software, thermostats, etc.
- **Percept** refers to the agent perceptual input at any given instant
- The **agent function** maps from percept histories to actions:
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 - $f: P^* \rightarrow A$
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- The **agent program** implements f on the physical **architecture**.

Vacuum-cleaner World

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- **Percepts:** current location and its content, e.g., (A, Dirty)
- **Actions:** *Left, Right, Suck, NoOp*

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A Vacuum-cleaner Agent

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| Percent sequence | Action |
|------------------------|--------|
| (A) | Right |
| (A) | Suck |
| (E) | Left |
| (B, Dirty) | Suck |
| (A, Clean), (A, Clean) | Right |
| (A, Clean), (A, Dirty) | Suck |
| ... | |

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function REFLEX-VACUUM-AGENT(*(location, status)*) returns an action

if *status* = Dirty then return Suck

else if *location* = A then return Right

else if *location* = B then return Left

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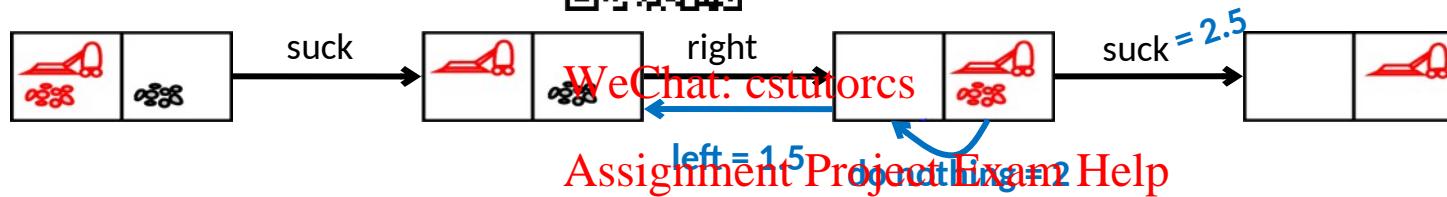
- What is the **right** function?
- Can it be implemented in a small agent program?

Rationality

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The **performance measure** evaluates the **environment sequence**

- one point per room cleaned in T time steps?
- one point per clean room per step, minus half a point per action?
- penalize for $> k$ dirty rooms



A **rational agent** chooses whichever action maximizes the **expected value** of the performance measure **given the percept sequence to date**

- Rational \neq omniscient
 - percepts may not supply all relevant information
- Rational \neq clairvoyant
 - action outcomes may not be as expected
- Hence, rational \neq successful

PFAS

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To design a rational agent, you must specify the **task environment**



Consider, e.g., the task of ~~driving~~ getting a **driverless taxi**:

- **Performance measure:** WeChat: cstutorcs
 - safety, destination, profits, legality, comfort, ...
- **Environment:** Assignment Project Exam Help
 - streets/freeways, traffic, pedestrians, weather, ...
- **Actuators:** QQ: 749389476
 - steering, accelerator, brake, horn, blinkers, ...
- **Sensors:** <http://tutors.com>
 - GPS, video, accelerometers, gauges, engine sensors, ...

Internet shopping agent

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Consider, e.g., the task of ~~designing~~ ~~building~~ an **internet shopping bot**:

- **Performance measure:**
– price, quality, appropriateness, efficiency
- **Environment:** WeChat: cstutorcs
– user, WWW sites, vendors, shippers
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- **Actuators:** Email: tutorcs@163.com
– display to user, follow URL, fill in form
- **Sensors:** QQ: 749389476
– HTML pages (text, graphics, scripts), user input
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Properties of Task Environments

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• Fully vs partially observable

- do the agent sensors give access to all information about the environment state?



• Deterministic vs stochastic

- is the next state completely determined by the current state and executed action?

• Known vs unknown

- does the agent know the environment's laws of physics?

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• Episodic vs sequential

- is the next decision independent of the previous ones?

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• Static vs dynamic

- can the environment change whilst the agent is deliberating?
- **Semi-dynamic:** only the performance score changes.

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• Discrete vs continuous

- can time, states, actions, percepts be represented in a discrete way?

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• Single vs multi-agent

- is a single agent making decisions, or do multiple agents need to compete or cooperate to maximise interdependent performance measures?

Environment types

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| | Crossword | Poker | Part picking robot | Taxi |
|---------------|-----------|------------------------------|--------------------|------|
| Observable | Yes | No | | |
| Deterministic | Yes | No | | |
| Known | Yes | Yes | | |
| Episodic | No | No | | |
| Static | Yes | WeChat: cstutorcs | | No |
| Discrete | Yes | Assignment Project Exam Help | | No |
| Single-agent | Yes | Email: tutorcs@163.com | Yes | |

The environment type largely determines the agent design

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The real world is (of course) partially observable, stochastic, sequential, dynamic, continuous, multi-agent.

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Agent types

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- Four basic types of agents in increasing generality:
 - simple reflex agents
 - reflex agents with state
 - goal-based agents
 - utility-based agents
- All these can be turned into learning agents

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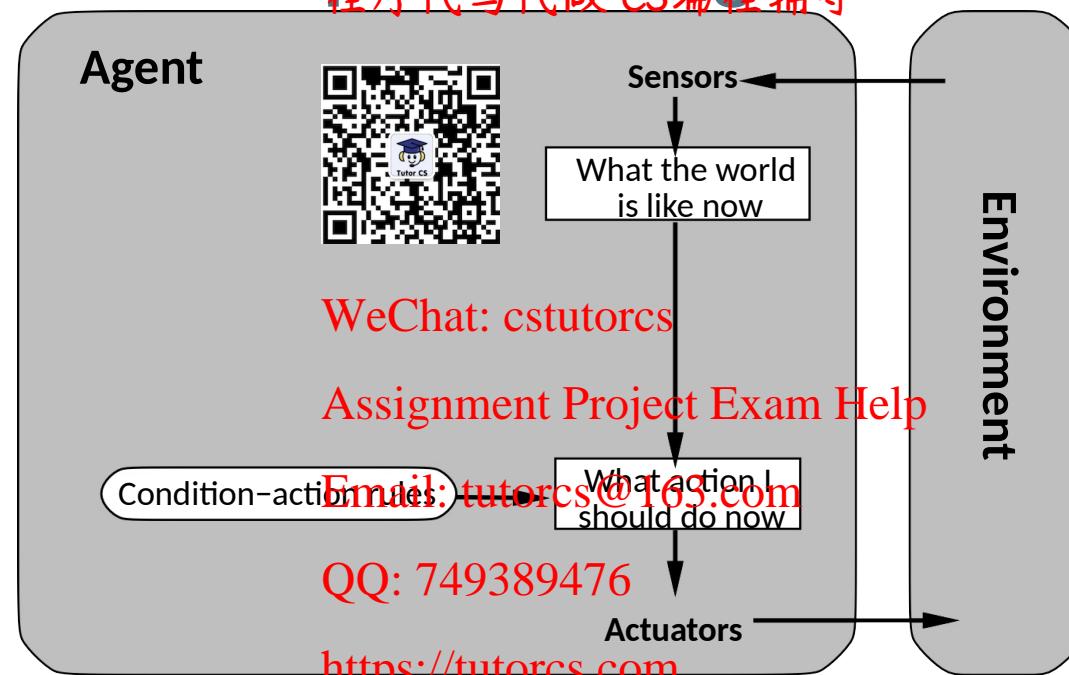
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Simple reflex agents



Decisions are made based on the **current percept** only. Raises issues for partially observable environments.

Example

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```
function REFLEX-VACUUM-CONTROLLER(location, status) returns an action
  if status = Dirty then return Suck
  else if location = A then return Right
  else if location = B then return Left
```



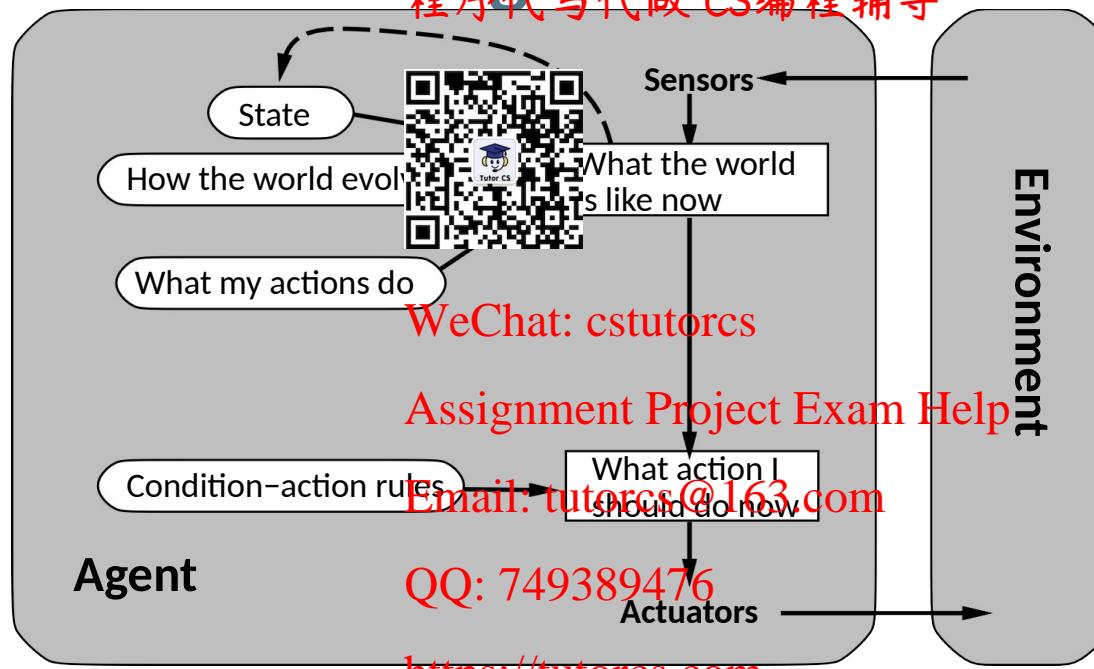
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Reflex agents with state



The **internal state** keeps track of relevant unobservable aspects of the environment. The **environment model** describes how the environment works (how the environment state is affected by actions)

Example

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```
function VACUUM-AGENT-WITH-STATE( (location, status) ) returns an action
static: last_A, last_B, n = 0
        n is initially infinity
        increment last_A and
        if location = A then
        else last_B = 0
        case
            status = Dirty: WeChat: cstutorcs
            return Suck
            location = A: Assignment Project Exam Help
            if last_B > 3 then return Right
            else return NoOp
            location = B:
            if last_A > 3 then return Left
            else return NoOp
```

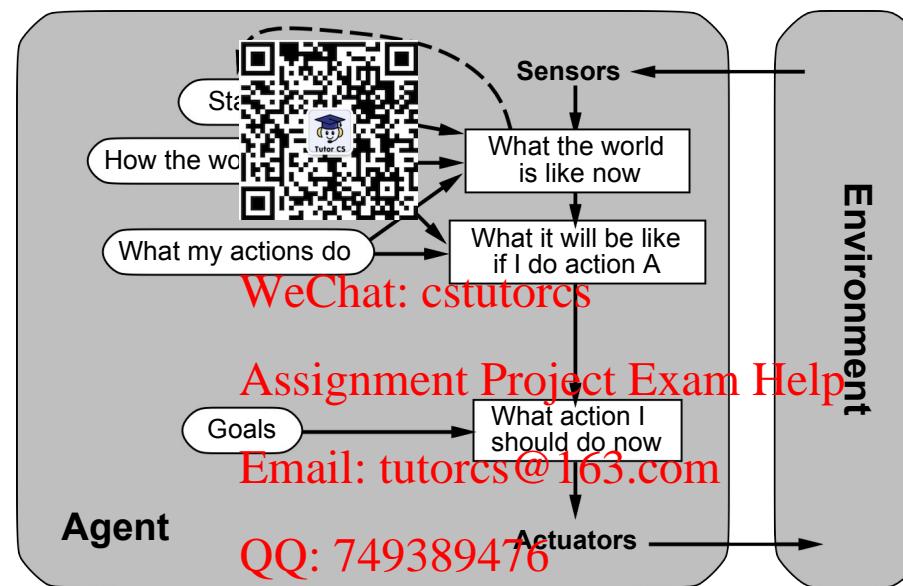


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The time passed since a location was visited is a proxy for the likelihood of this location's status changing from clean to dirty.

Goal-Based agents

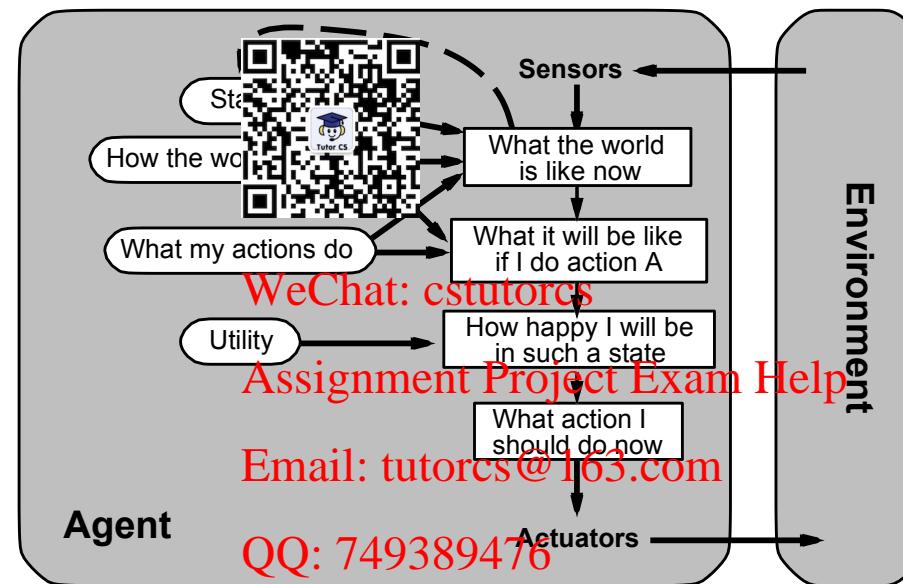
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- The **goal** describes desirable situations. <https://tutorcs.com>
- The agent combines goal and environment model to choose actions.
- **Planning** and **search** are AI subfields devoted to building goal-based agents.

Utility-based agents

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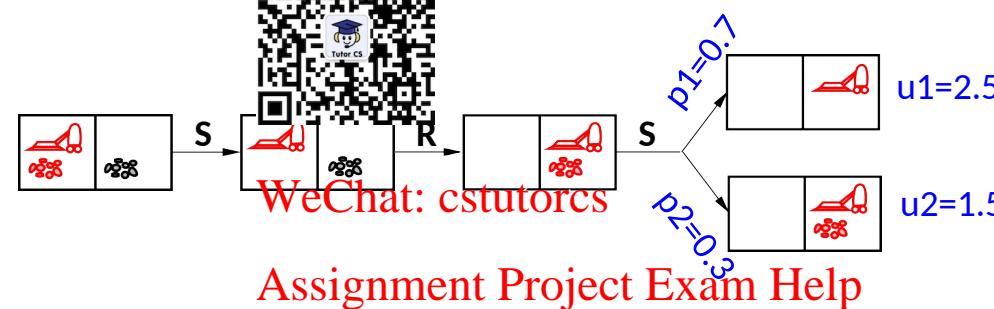


- The **utility function** internalises the performance measure.
- Under uncertainty, the agent chooses actions that maximise the expected utility.

Utility-based agents

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Rational agent: chooses the action that maximises expected utility:



Expected utility of :

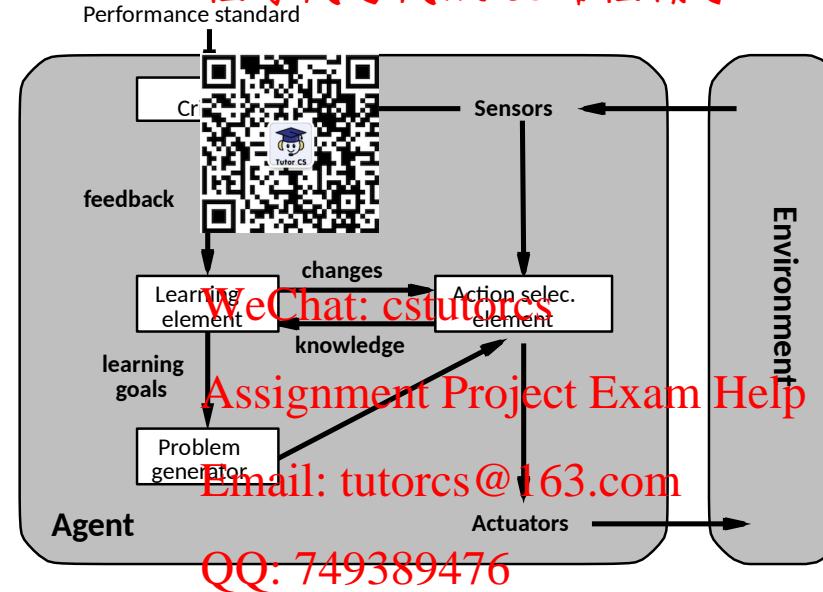
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- has an expected utility of 2.2 <https://tutorcs.com>
- has an expected utility of 2
- has an expected utility of 1.5

Learning agents

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- The **action selection** element is what we described earlier.
- The **learning** element uses feedback from the **critic** to modify the action selection.
- The **problem generator** suggests actions that lead to new informative experience.

Exploration vs Exploitation

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A fundamental dilemma for learning agents:



- **Exploitation**: greedily uses what it knows. An agent has learnt to select the action that will, in the light of the current knowledge, have the best outcome
- **Exploration**: taking some other (possibly random) action to learn more, hoping to find something even better

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Typically, a smart agent explores <https://tutor.cs.com> more in early stages than later on