

CS 561: Artificial Intelligence

Instructors: Prof. Laurent Itti (itti@usc.edu)

TAs:

- Jincheng He - jinchenh@usc.edu (50%)
- Kiran Lekkala - klekkala@usc.edu (50%)
- Kr Zentner - kzentner@usc.edu (50%)
- Maybe one more to be announced later by the department

Lectures: SGM-123, Monday & Wednesday 3:00pm-4:50pm

Office hours: Tues 2:00pm – 4:00pm, HNB-07A (Prof. Itti)

This class will use **courses.usciden.net** (Desire2Learn, **D2L**)

- Up to date information, lecture notes, lecture videos
- Homeworks posting and submission information
- Grades, relevant dates, links, etc.

Textbook: [AIMA] Artificial Intelligence: A Modern Approach, by Russell & Norvig. (4th ed)

Optional (ALFE): Autonomous Learning from the Environment by Shen

CS 561: Artificial Intelligence



Course overview: foundations of symbolic intelligent systems. Agents, search, problem solving, logic, representation, reasoning, symbolic programming, and robotics.

Prerequisites: CS 455x, i.e., programming principles, discrete mathematics for computing, software design and software engineering concepts. **Good knowledge of C++ and STL, or Java, or Python needed for programming assignments.**

Grading:

- 20% for midterm-1 +
- 20% for midterm-2 +
- 30% for final +
- 30% for 3 mandatory homeworks/assignments +
- bonus 5% for attendance (total points capped at 100%)

CS 561: Artificial Intelligence



Grading:

Grading is absolute and according to the following scale:

≥ 90 A+ (honorary – shows as A on transcript)

≥ 80 A

≥ 75 A-

≥ 70 B+

≥ 60 B

≥ 55 B-

≥ 50 C+

≥ 40 C

≥ 35 C-

< 35 F

Practical issues



- **Class mailing list:** will be setup on the D2L system and Piazza.
- **Homeworks:** See class web page on D2L. Homeworks are programming assignments.
 - Jan 17 – HW1 out Topic: search
 - Feb 5 – HW1 due
 - Feb 7 – HW2 out Topic: game playing
 - Mar 6 – HW2 due
 - Mar 18 – HW3 out Topic: neural networks
 - Apr 15 – HW3 due
- **Late homeworks:** Homework deadlines are on the due day at 11:59:59pm. **No late submissions will be accepted.**
- **Homework grading:** your homeworks will be graded by an A.I. agent (given to you in advance for testing) through the online system at **vocareum.com**.
- **Grade review / adjustment:** Requests will be considered up to 2 weeks after the grade is released. After that, it will be too late and requests for grading review will be denied.
- **Exams:**
 - Midterm 1: Mon Feb 12, 3:00pm – 4:50pm, in class (SGM-123)
 - Midterm 2: Mon Mar 25, 3:00pm – 4:50pm, in class (SGM-123)
 - Final exam: Friday May 3, 2:00pm – 4:00pm, room TBA

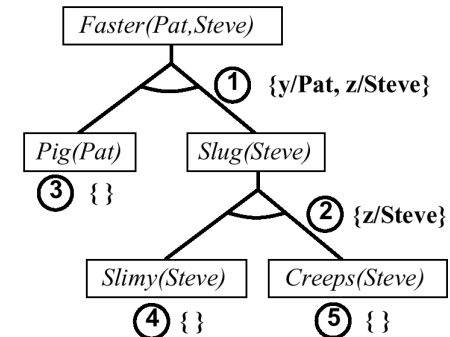
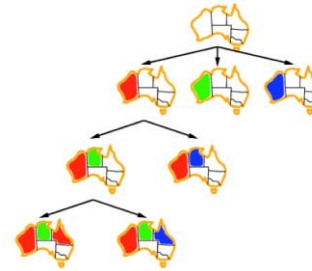
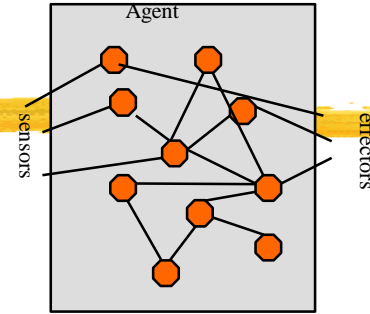
Practical issues



- **Attendance bonus:** For on-campus students only (students registered in the DEN section will receive it automatically).
- Can bring you up to 5% extra points for coming to class in person. Total points will be capped at 100%.
- Attendance will likely be checked using your USC ID, please bring it.
- Starts January 17 – no need to prove attendance until then.

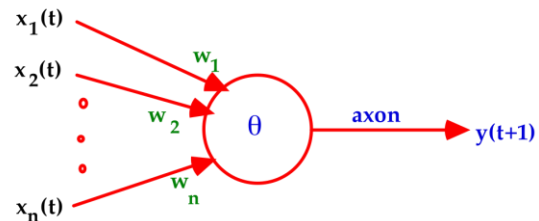
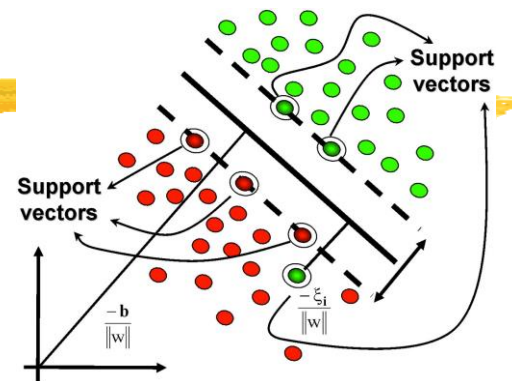
Course Overview

- Introduction, intelligent agents, rational behavior, optimal behavior.
- **Problem solving and search.** Complete and optimal search algorithms. Special cases: game playing, constraint satisfaction problems.
- **Symbolic reasoning and logical inference.** Design of a sound and complete inference procedure in first-order logic. Planning. Fuzzy logic.

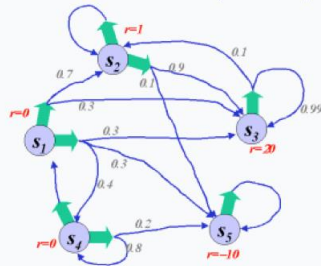


Course Overview

- **Learning from examples.** Decision tree learning, support vector machines.
- **Neural networks and deep learning.** Backpropagation algorithms and different types of deep networks.
- **Probabilistic reasoning.** Bayesian networks, Markov decision processes.

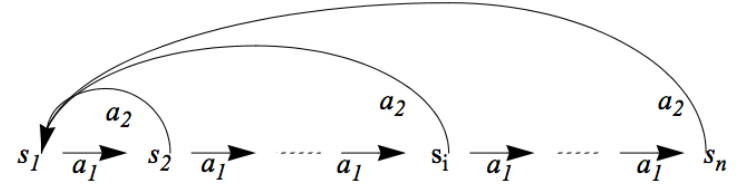


Markov Decision Process (discrete)

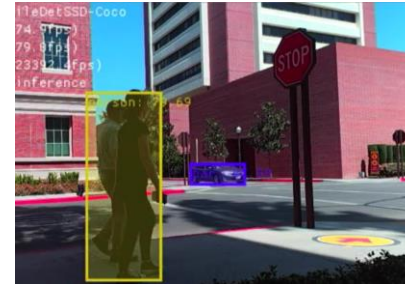


Course Overview

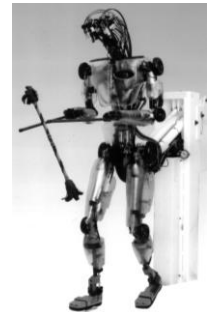
- **Reinforcement learning.** Explore the hardest problems in learning.



- **Overview of application domains.** Machine vision, natural language, robotics.



In: The student asked a question.
Out: L'étudiant a posé une question.



Date	Topic	Reading
Mon Jan 8	1. Welcome – Introduction. Why study AI? What is AI? The Turing test. Rationality. Branches of AI. Brief history of AI. Challenges for the future. What is an intelligent agent? Doing the right thing (rational action). Performance measure. Autonomy. Environment and agent design. Structure of agents. Agent types.	AIMA 1, 2 (ALFE 1)
Wed Jan 10	2. Problem Solving & Search – Types of problems. Example problems. Basic idea behind search algorithms. Complexity. Combinatorial explosion and NP completeness. Polynomial hierarchy.	AIMA 3 (ALFE 2, 6)
Mon Jan 15	Martin Luther King's Birthday – NO CLASS	
Wed Jan 17	3. Uninformed Search – Depth-first. Breadth-first. Uniform-cost. Depth-limited. Iterative deepening. Examples. Properties.	AIMA 3 HW1 out
Mon Jan 22	4. Informed search – Best-first. A* search. Heuristics. Hill climbing. Problem of local extrema. Simulated annealing. Genetic Algorithms.	AIMA 3, 4 (ALFE 6)
Wed Jan 24	5. Game Playing – The minimax algorithm. Resource limitations. Alpha-beta pruning. Chance and non-deterministic games.	AIMA 5

Mon Jan 29	6. Continue game Playing – The minimax algorithm. Resource limitations. Alpha-beta pruning. Chance and non-deterministic games.	AIMA 5
Wed Jan 31	7. Constraint satisfaction – Node, arc, path, and k-consistency. Backtracking search. Local search using min-conflicts.	AIMA 6 (ALFE 6)
Mon Feb 5	8. Agents that reason logically – Knowledge-based agents. Logic and representation. Propositional (boolean) logic. Inference in propositional logic. Syntax. Semantics. Examples.	AIMA 7 (ALFE 3) HW1 due
Wed Feb 7	9. First-order logic – Syntax. Semantics. Atomic sentences. Complex sentences. Quantifiers. Examples. FOL knowledge base. Situation calculus. Describing actions. Planning. Action sequences.	AIMA 8, AIMA 10 HW2 out
Mon Feb 12	Midterm exam 1 – in classroom – 3:00pm - 4:50pm SGM-123	
Wed Feb 14	10. Inference in first-order logic – Proofs. Unification. Generalized modus ponens. Forward and backward chaining. Resolution. Proof by contradiction.	AIMA 9

Mon Feb 19	President's day – NO CLASS	
Wed Feb 21	11. Logical reasoning systems – Indexing, retrieval and unification. The Prolog language. Theorem provers. Frame systems and semantic networks.	AIMA 9
Mon Feb 26	12. Planning – Definition and goals. Basic representations for planning. Situation space and plan space. Examples.	AIMA 11 (ALFE 6)
Wed Feb 28	13. Fuzzy logic – concepts, fuzzy inference, aggregation, defuzzification. Examples.	Handout
Mon Mar 4	14. Learning from examples – supervised learning, training / validation / test sets, cross-validation, learning decision trees, support vector machines.	AIMA 19 + handout (ALFE 4)
Wed Mar 6	15. Learning with neural networks – bio-inspired models, integrate and fire models, perceptrons, backpropagation algorithm, Hopfield networks. How to size a network? What can neural networks achieve?	Handout + AIMA 21 HW2 due
Mon Mar 11	Spring Recess – NO CLASS	
Wed Mar 13	Spring Recess – NO CLASS	



Mon Mar 18	16. Advanced concepts in neural networks – convnets, deep learning, autoencoders, applications and state of the art.	Handout HW3 out
Wed Mar 20	17. Continue advanced concepts in neural networks – generative models, generative adversarial networks, recurrent networks, transformers, foundation models.	Handout
Mon Mar 25	Midterm exam 2 – in classroom – 3:00pm - 4:50pm SGM-123	
Wed Mar 27	18. Neural networks applications, issues of fairness and bias.	AIMA 27
Mon Apr 1	19. Reasoning under uncertainty – probabilities, conditional independence, Markov blanket, Bayes nets.	AIMA 12, 13
Wed Apr 3	20. Continue Reasoning under uncertainty – Probabilistic inference, enumeration, variable elimination, approximate inference by stochastic simulation, Markov chain Monte Carlo, Gibbs sampling.	AIMA 13, 14 (ALFE 5)



Mon Apr 8	21. Probabilistic decision making – utility theory, decision networks, value iteration, policy iteration, Markov decision processes (MDP), partially observable MDP (POMDP).	AIMA 17, 18 (ALFE 5)
Wed Apr 10	22. Reinforcement learning – RL task formulation, Q learning, deep Q-networks, policy gradients, imitation learning.	AIMA 22
Mon Apr 15	23. AI for machine vision – physics of image formation, image processing, classes of computer vision algorithms, deep learning approaches.	AIMA 25 HW3 due
Wed Apr 17	24. AI for natural language processing – parsing and syntax, similarity measures, clustering, topic analysis, machine translation, dialogue systems, language generation, vision/language models.	AIMA 23, 24
Mon Apr 22	25. AI for robotics – Basic robotics concepts, locomotion, manipulation, Monte-Carlo localization, simultaneous localization and mapping (SLAM), deep learning for robotic control.	AIMA 26
Wed Apr 24	26. General outlook and conclusions.	AIMA 27, 28

More on homeworks and grading



- In each homework you will implement some algorithms from scratch.
- But our goal is to focus on A.I. algorithms, not on low-level programming. Hence I recommend C++/STL so that you can use the STL containers (queue, map, etc) instead of pointers and memory management. But the language you use is up to you (C++11, Java, or Python).
- Code editing, compiling, testing: we will use www.vocareum.com which will be linked to desire2learn (this is in progress at this time).
- Your program should take no command-line arguments. It should read a text file called "input.txt" that contains a problem definition. It should write a file "output.txt" with your solution. For each homework, format for files input.txt and output.txt will be specified and examples will be given to you.
 - The grading will, 50 times:
 - Create an input.txt file
 - Run your code
 - Compare output.txt created by your program with the correct one.
 - If your outputs for all 50 test cases are correct, you get **100** points.
 - Otherwise, you get **100 - 2xN** points where N is the number of failed test cases.

As of last semester,
Newer versions
May be installed now

We will support C++11,
Python3, and Java.

gcc - 5.5
valgrind - 3.11
ar - 2.26.1
php - 7.0.32
python2 - 2.7.12
python3 - 3.5.2, 3.6.4
Java 1.8 - 1.8.0_191
perl - 5.22.1
make - 4.1

TA office hours



To be announced soon by the department

Piazza



- We will use piazza.com for questions and answers related to class material.
- Please register here:

<http://piazza.com/usc/spring2024/csci561>

- Guidelines:
 - You may ask any question related to material covered in lectures, discussions, or exams.
 - You may ask **clarification questions only** related to the homework definitions.
 - You may not ask for advice on how to solve some aspect of a homework problem.
 - You may not post code snippets related to homework problems.
 - You may not post test cases or input/output examples related to homework problems.
 - As a general rule, remember that homeworks are to be solved strictly individually.

Academic Integrity

- Familiarize yourself with the USC Academic Integrity guidelines.
- Violations of the Student Conduct Code will be filed with the Office of Student Judicial Affairs, and appropriate sanctions will be given.
- Homework assignments are to be solved **individually**.
- You are welcome to discuss class material in review groups, but do not discuss how to solve the homeworks.
- **Exams are closed-book with no questions allowed.**
- **Please read and understand:**

<http://policy.usc.edu/student/scampus/>

<https://sjacs.usc.edu/students/>

Academic Integrity

- **All students are responsible for reading and following the Student Conduct Code.**
Note that the USC Student Conduct Code prohibits plagiarism.
- Some examples of what is not allowed by the conduct code: copying all or part of someone else's work (by hand or by looking at others' files, either secretly or if shown), and submitting it as your own; giving another student in the class a copy of your assignment solution; and consulting with another student during an exam. If you have questions about what is allowed, please discuss it with the instructor.
- Students who violate university standards of academic integrity are subject to disciplinary sanctions, including failure in the course and suspension from the university. Since dishonesty in any form harms the individual, other students, and the university, policies on academic integrity will be strictly enforced. Violations of the Student Conduct Code will be filed with the Office of Student Judicial Affairs.



October 5, 2007

M [REDACTED]
Case # [REDACTED]
[REDACTED]
Los Angeles, CA [REDACTED]

Dear M [REDACTED]

**Division of
Student Affairs**

Student Judicial
Affairs and
Community Standards

I have received a report from Professor Itti Engineering, concerning an alleged act of academic dishonesty which occurred in CSCI-561 (#30219) during the Fall Semester (20073).

Specifically, the complaint alleges that you violated Student Conduct Code §§:

11.12A Acquisition of term papers or other assignments from any source and the subsequent presentation of those materials as the student's own work, or providing term papers or assignments that another student submits as his/her own.

11.14B Unauthorized collaboration on a project, homework or other assignment. Collaboration between students will be considered unauthorized unless expressly part of the assignment in question or expressly permitted by the instructor.

11.15A Attempting to benefit from the work of another or attempting to hinder the work of another student.

11.15B Any act which may jeopardize another student's academic standing

11.15B Any act which may jeopardize another student's academic standing

11.21 Any act which gains or is intended to gain an unfair academic advantage may be considered an act of academic dishonesty.

The complaint concerns your assignment completed on or about September 26, 2007.

As a consequence of the complaint a review of the allegations is necessary. The guidelines for the review process (summary enclosed) can be found in the Student Conduct Code in the current *SCampus*. Please familiarize yourself with the standards and expectations concerning academic honesty prior to our meeting and the review. According to University policy, you will not be permitted to drop the course with a mark of 'W' (see enclosure).

Please contact the Office of Student Judicial Affairs and Community Standards at (213) 821-7373 to schedule a meeting with me and for a review of the matter. If you do not respond by **October 19, 2007**, an administrative hold may be placed on your record prohibiting further registration and enrollment transactions. A review also may be conducted in your absence should you choose not to respond.

Sincerely,



Raquel Torres-Retana

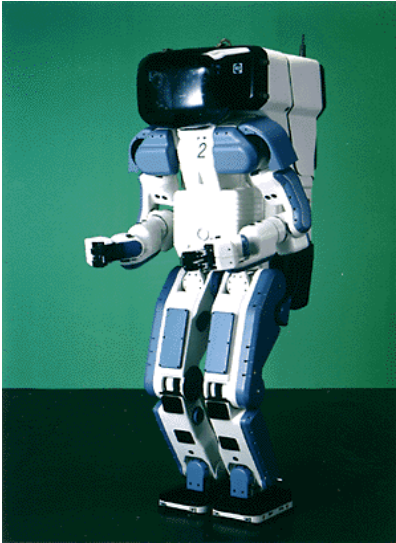
Director, Office of Student Judicial Affairs and Community Standards

University of
Southern California
Figueroa Building
Room 107
Los Angeles,
California 90089-1265
Tel: 213 821 7373
Fax: 213 740 7162

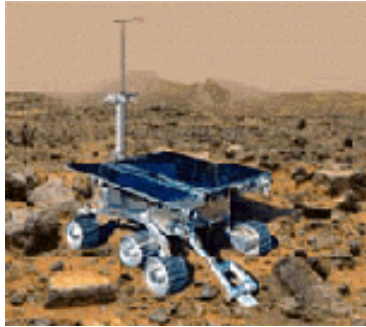
cc: Professor Laurent Itti
Kelly Goulis, Viterbi School of Engineering

Enclosures

Why study AI?



Labor



Science

Google™

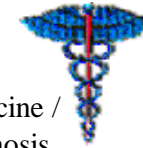


YAHOO!

Search engines, co-pilots



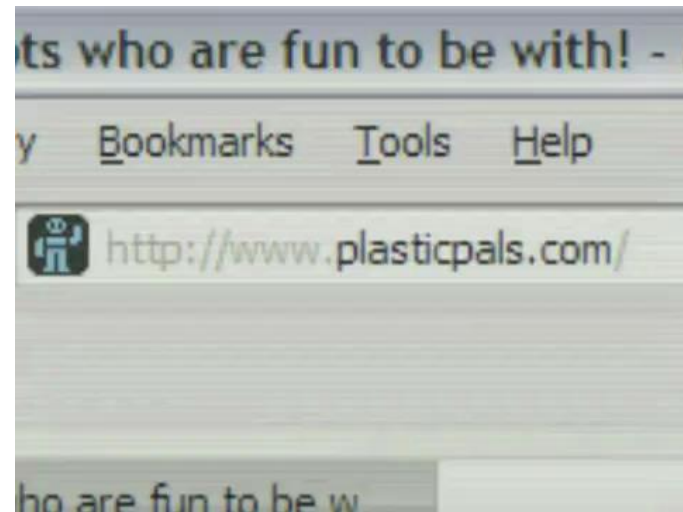
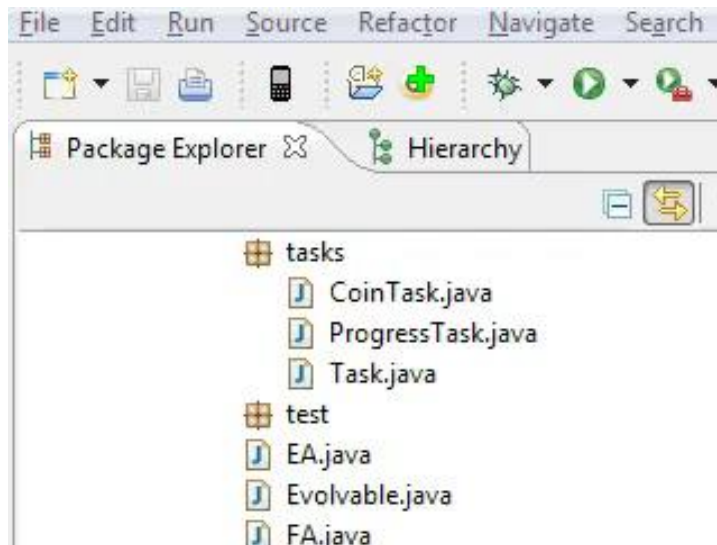
Appliances /
Internet of Things (IoT)



Medicine /
Diagnosis

What else?

Why study AI?



Why study AI?

TEXT DESCRIPTION

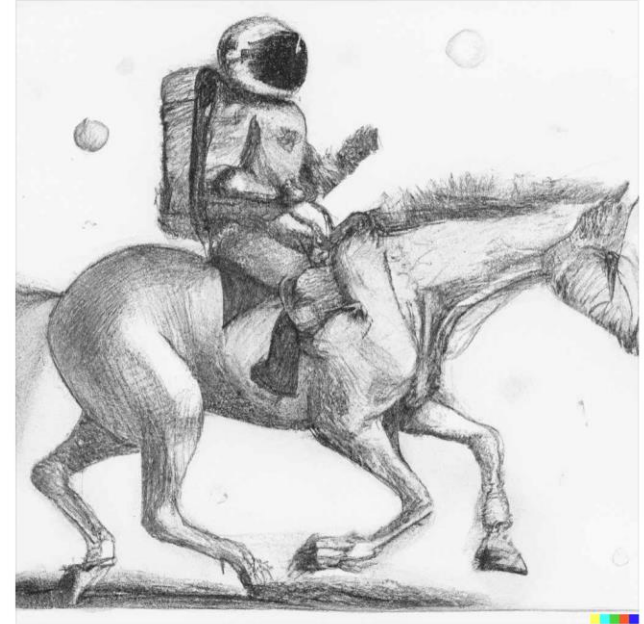
An astronaut riding a horse

lounge in a tropical resort in space

in a photorealistic style in the style of Andy Warhol as a pencil drawing



DALL-E 2



Why study AI?

<https://chat.openai.com>

ChatGPT:

SP

can you solve my AI homework?



I'd be happy to help you with your AI homework! Please provide more information about the assignment, such as the specific topic or problem you're working on, and any details or constraints that are relevant. This will allow me to better understand your needs and give you the most helpful guidance.



SP

but that would not be ethical!

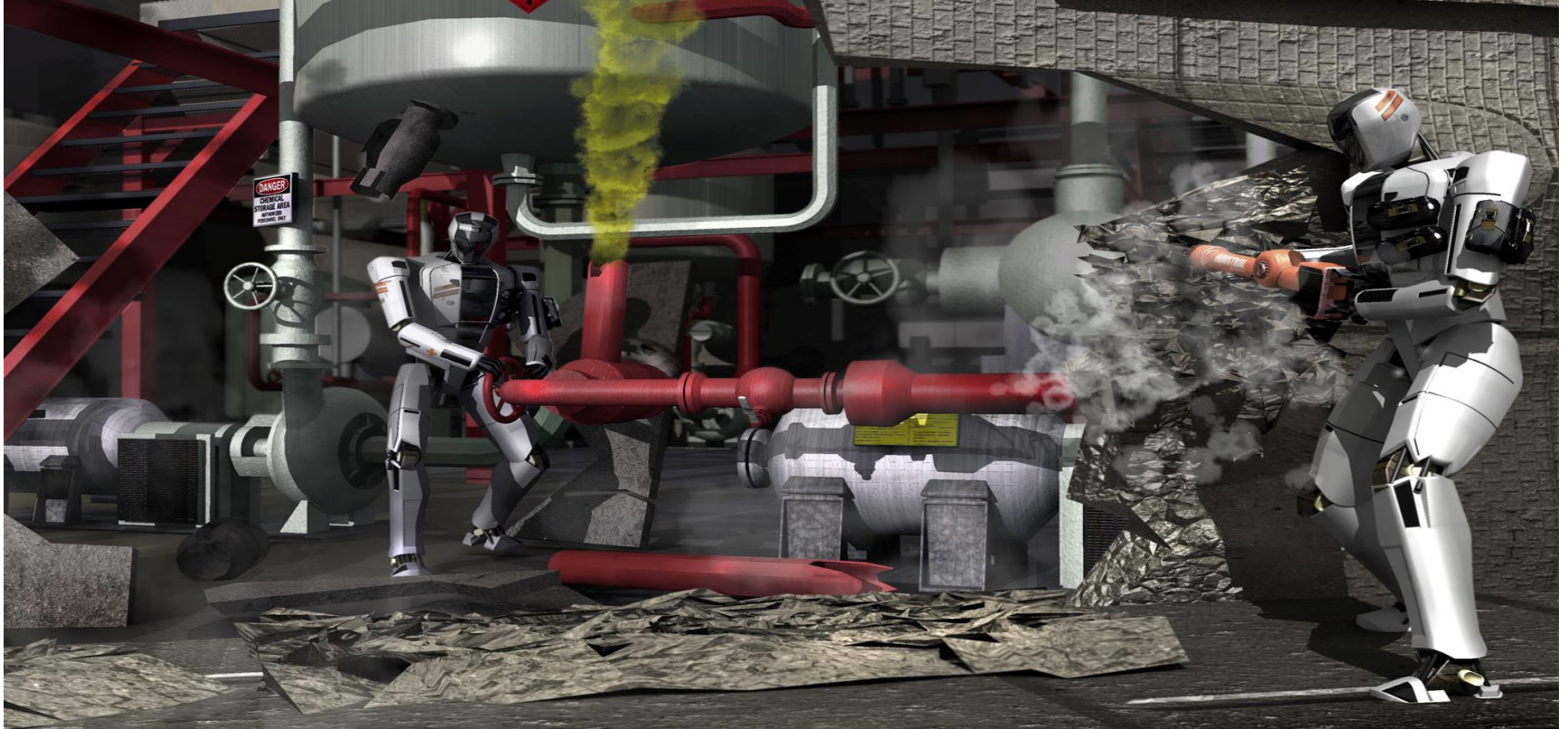


You're right, it wouldn't be ethical for me to complete your homework for you. However, I can certainly help you understand the material and work through the problems on your own. This can be a more effective and rewarding way to learn, and it will also help you develop the skills and confidence you need to succeed in your studies and future endeavors. Do you have a specific question or topic that you would like help with?





DARPA Robotics Challenge





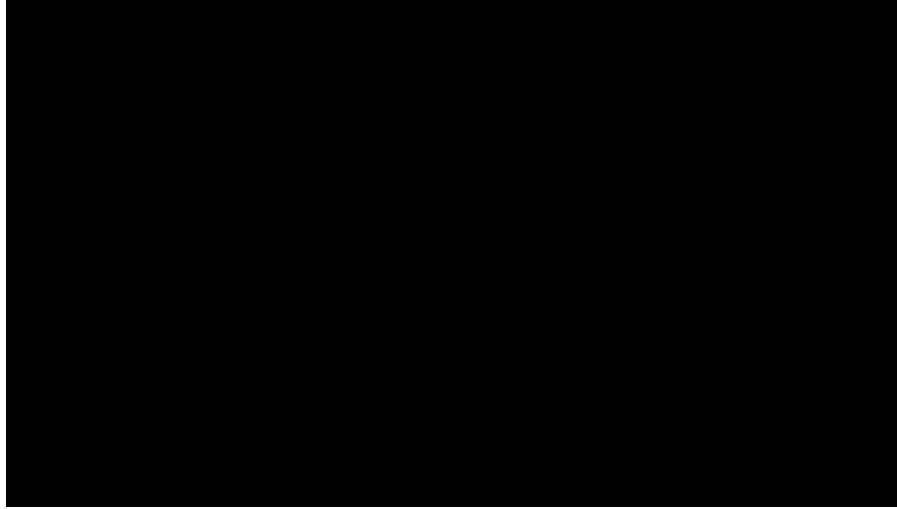
Biped Humanoid Robot DRC-Hubo

Wearable computing

Google glass



Microsoft Hololens,
Apple vision pro



Zypad



Humane AI pin



What is AI?



The exciting new effort to make computers think ... machines with minds, in the full and literal sense"
(Haugeland 1985)

"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990)

Systems that think like humans

Systems that act like humans

"The study of mental faculties through the use of computational models"
(Charniak et al. 1985)

A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes"
(Schalkol, 1990)

Systems that think rationally

Systems that act rationally

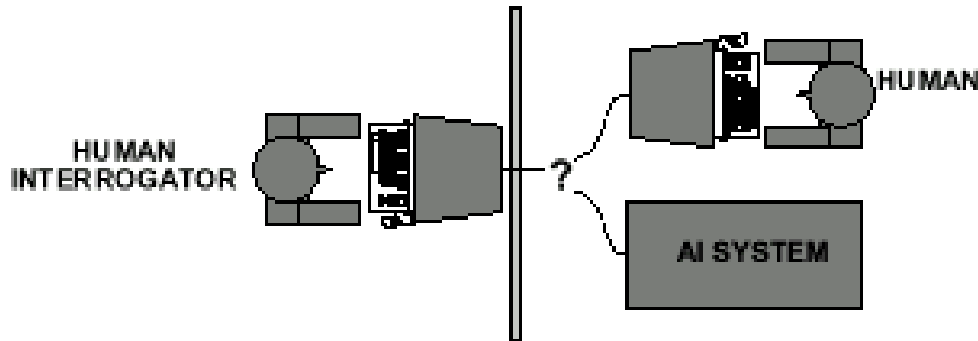
Acting Rationally: The Rational Agent



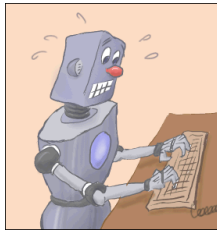
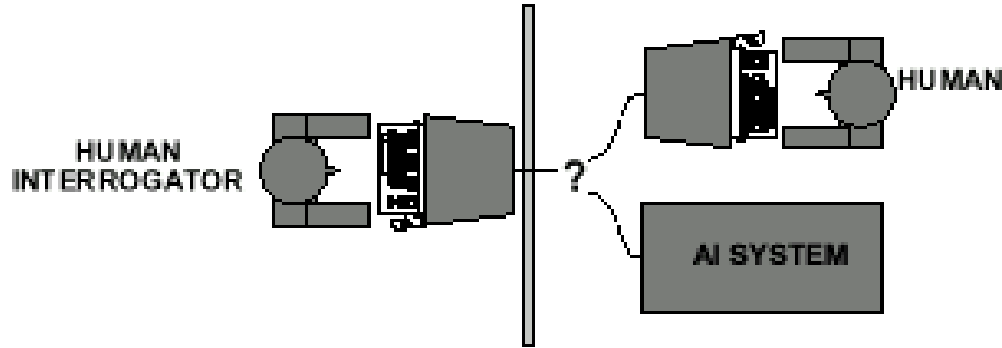
- Rational behavior: Doing the right thing!
- The right thing: That which is expected to maximize the expected return
- Provides the most general view of AI because it includes:
 - Correct inference (“Laws of thought”)
 - Uncertainty handling
 - Resource limitation considerations (e.g., reflex vs. deliberation)
 - Cognitive skills (NLP, AR, knowledge representation, ML, etc.)
- Advantages:
 - 1) More general
 - 2) Its goal of rationality is well defined

Acting Humanly: The Turing Test

- Alan Turing's 1950 article Computing Machinery and Intelligence discussed conditions for considering a machine to be intelligent
- "Can machines think?" □□ "Can machines behave intelligently?"
- The Turing test (The Imitation Game): Operational definition of intelligence.



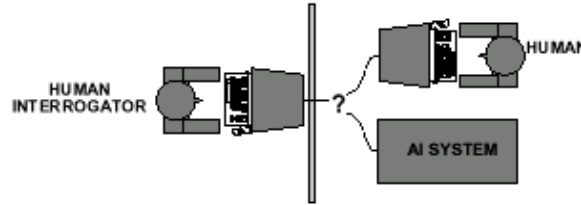
Acting Humanly: The Turing Test



- Computer needs to possess: Natural language processing, Knowledge representation, Automated reasoning, and Machine learning
- Are there any problems/limitations to the Turing Test?

Acting Humanly: The Full Turing Test

- Alan Turing's 1950 article Computing Machinery and Intelligence discussed conditions for considering a machine to be intelligent
 - "Can machines think?" □ "Can machines behave intelligently?"
 - The Turing test (The Imitation Game): Operational definition of intelligence.

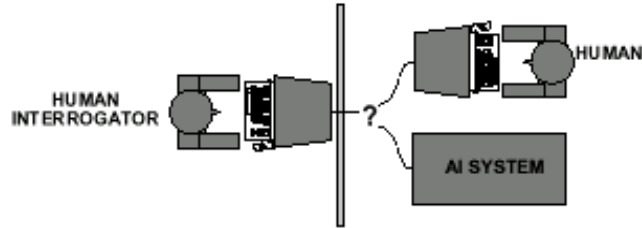


- Computer needs to possess: Natural language processing, Knowledge representation, Automated reasoning, and Machine learning
- **Problem:** 1) Turing test is not reproducible, constructive, and amenable to mathematic analysis. 2) What about physical interaction with interrogator and environment?
- **Total Turing Test:** Requires physical interaction and needs perception and actuation.

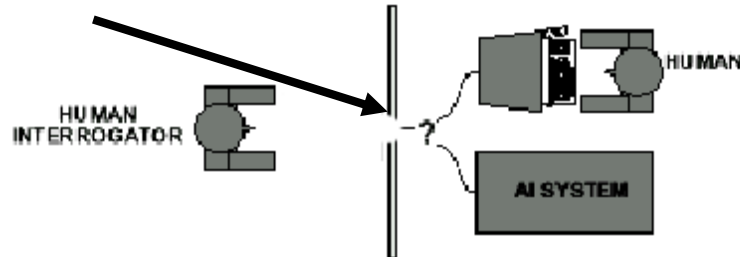
Acting Humanly: The Full Turing Test

Problem:

- 1) Turing test is not reproducible, constructive, and amenable to mathematic analysis.
- 2) What about physical interaction with interrogator and environment?



Trap door



What would a computer need to pass the Turing test?

- **Natural language processing:** to communicate with examiner.
- **Knowledge representation:** to store and retrieve information provided before or during interrogation.
- **Automated reasoning:** to use the stored information to answer questions and to draw new conclusions.
- **Machine learning:** to adapt to new circumstances and to detect and extrapolate patterns.



What would a computer need to pass the Turing test?

- Natural language processing: to communicate with examiner.
- Knowledge representation: to store and retrieve information provided before or during interrogation.
- Automated reasoning: to use the stored information to answer questions and to draw new conclusions.
- Machine learning: to adapt to new circumstances and to detect and extrapolate patterns.

Core focus in this course



What would a computer need to pass the Turing test?

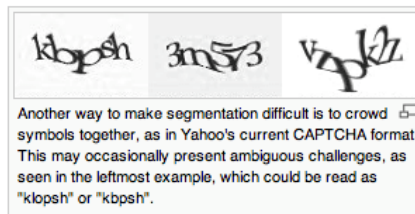
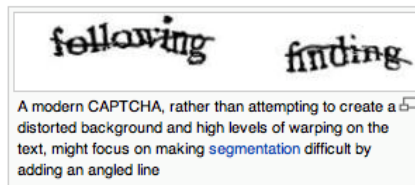
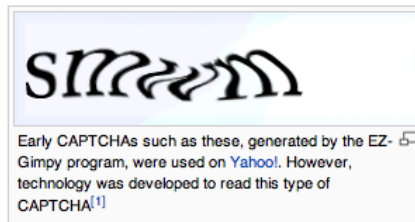


- **Vision** (for Total Turing test): to recognize the examiner's actions and various objects presented by the examiner.
- **Motor control** (total test): to act upon objects as requested.
- **Other senses** (total test): such as audition, smell, touch, etc.

We will cover this briefly too!

CAPTCHAs or “reverse Turing tests”

- **Vision** is a particularly difficult one for machines...
- Gave rise to “Completely Automated Public Turing test to tell Computers and Humans Apart” (CAPTCHA)



AI Prehistory

Philosophy	logic, methods of reasoning mind as physical system foundations of learning, language, rationality
Mathematics	formal representation and proof algorithms computation, (un)decidability, (in)tractability probability
Psychology	adaptation phenomena of perception and motor control experimental techniques (psychophysics, etc.)
Linguistics	knowledge representation grammar
Neuroscience	physical substrate for mental activity
Control theory	homeostatic systems, stability simple optimal agent designs

AI History



- 1943 McCulloch & Pitts: Boolean circuit model of brain
- 1950 Turing's "Computing Machinery and Intelligence"
- 1952–69 Look, Ma, no hands!
- 1950s Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
- 1956 Dartmouth meeting: "Artificial Intelligence" adopted
- 1965 Robinson's complete algorithm for logical reasoning
- 1966–74 AI discovers computational complexity
Neural network research almost disappears
- 1969–79 Early development of knowledge-based systems
- 1980–88 Expert systems industry booms
- 1988–93 Expert systems industry busts: "AI Winter"
- 1985–95 Neural networks return to popularity
- 1988– Resurgence of probabilistic and decision-theoretic methods
Rapid increase in technical depth of mainstream AI
"Nouvelle AI": ALife, GAs, soft computing

AI State of the art



- Have the following been achieved by AI?
 - Pass the Turing test
 - World-class chess or go playing
 - Playing table tennis
 - Autonomous cross-country driving
 - Solving mathematical problems
 - Discovering and proving mathematical theories
 - Engaging in a meaningful conversation
 - Understanding spoken language
 - Observing and understanding human emotions
 - Expressing emotions
 - ...

AI State of the art



Technology

Computer AI passes Turing test in 'world first'

🕒 9 June 2014 | [Technology](#)





Google DeepMind
Challenge Match
8 - 15 March 2016

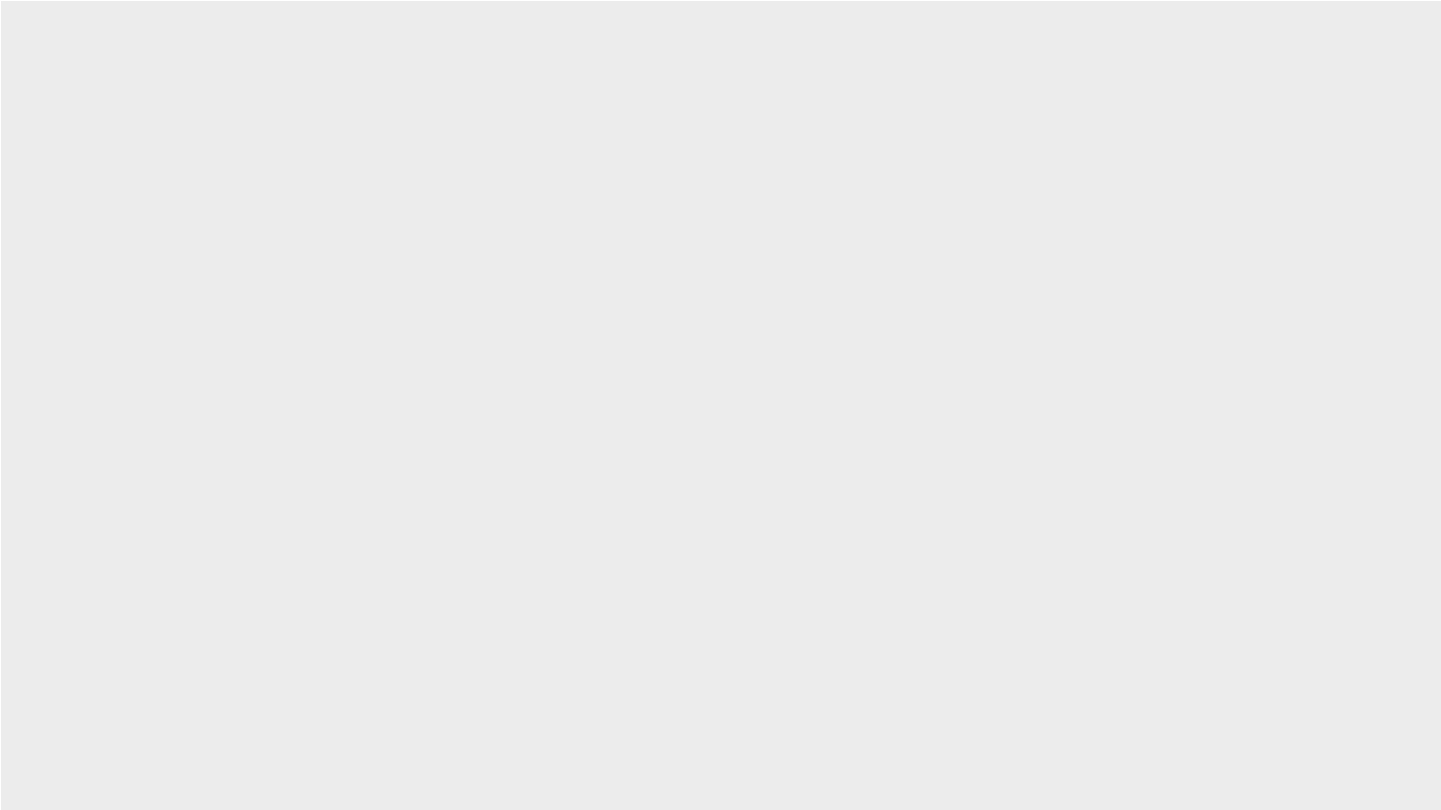


AlphaGo

Lee Sedol



AI State of the art



AI State of the art



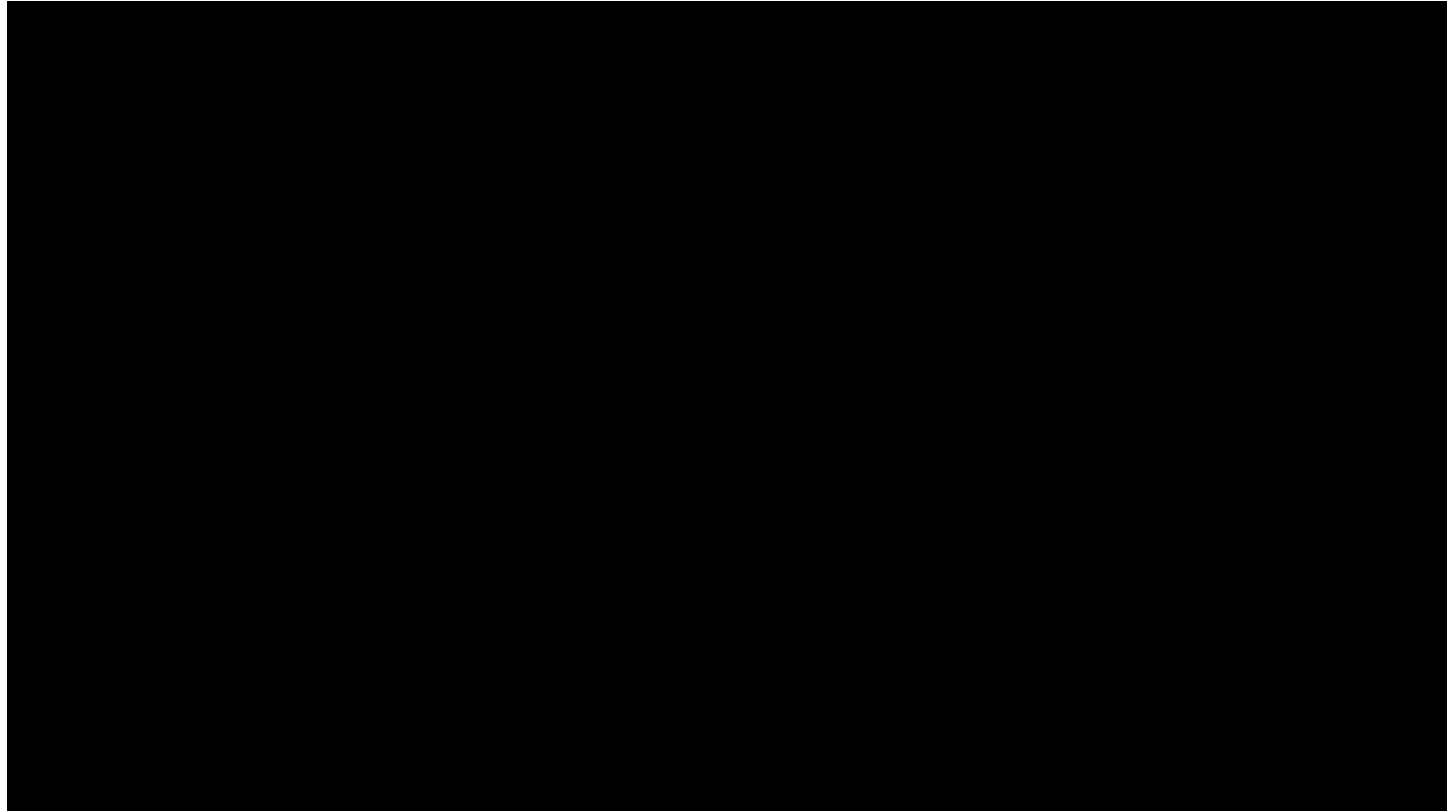
DARPA
Grand
Challenge

March, 2004

BOSTON DYNAMICS



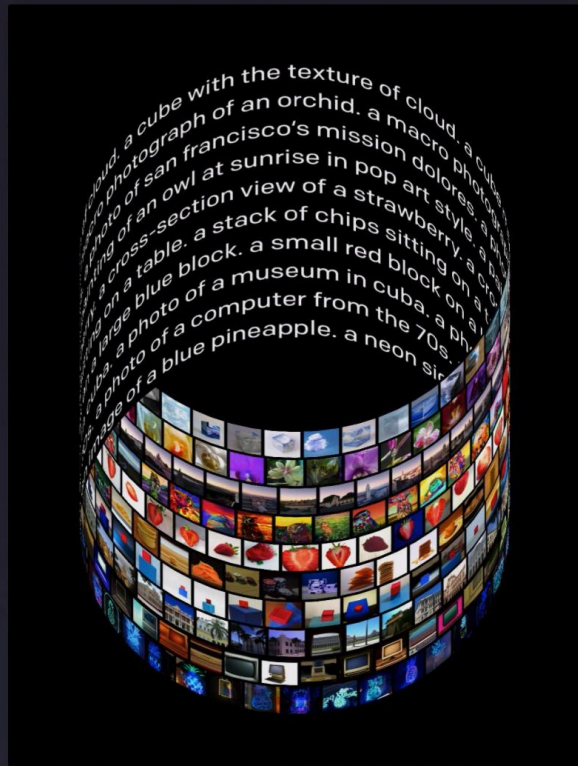
AI State of the art



DALL·E: Creating Images from Text

We've trained a neural network called DALL·E that creates images from text captions for a wide range of concepts expressible in natural language.

January 5, 2021
27 minute read



Defining intelligent agents

- Intelligent Agents (IA)
- Environment types
- IA Behavior
- IA Structure
- IA Types

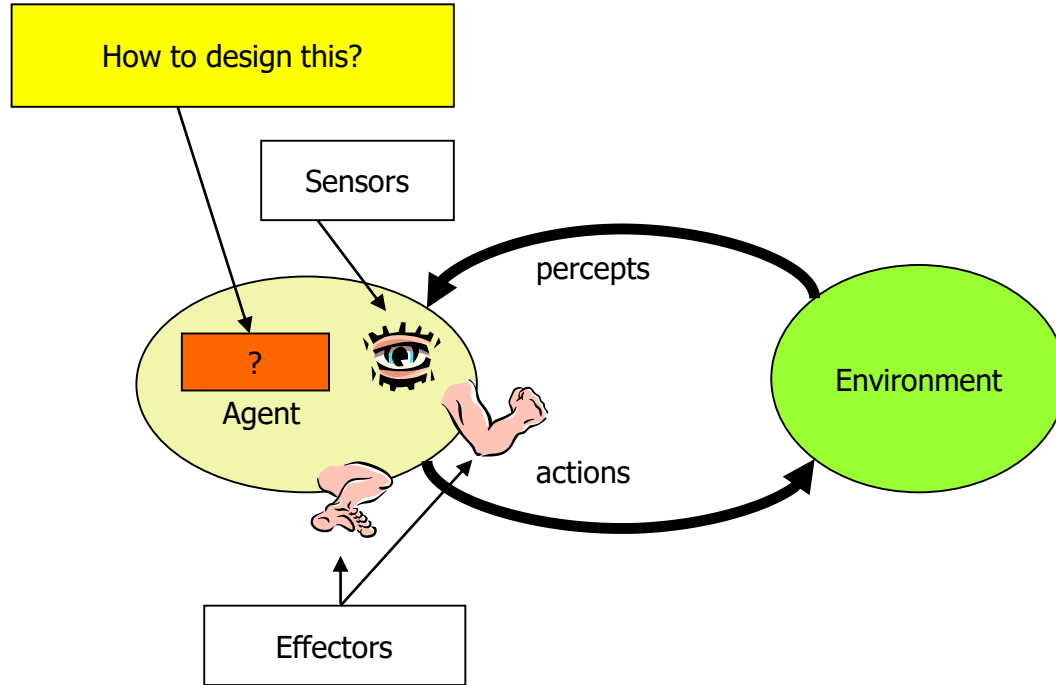
What is an (Intelligent) Agent?

- An over-used, over-loaded, and misused term.
- Anything that can be *viewed as* **perceiving** its **environment** through **sensors** and **acting** upon that environment through its **effectors** to maximize progress towards its **goals**.

What is an (Intelligent) Agent?

- **PAGE** (Percepts, Actions, Goals, Environment)
- Task-specific & specialized: well-defined goals and environment
- The notion of an agent is meant to be a tool for analyzing systems, It is not a different hardware or new programming languages

Rational Agents



A Windshield Wiper Agent

How do we design a agent that can wipe the windshields when needed?

- Goals?
- Percepts?
- Sensors?
- Effectors?
- Actions?
- Environment?

A Windshield Wiper Agent (Cont'd)

- Goals: Keep windshields clean & maintain visibility
- Percepts: Raining, Dirty
- Sensors: Camera (moist sensor)
- Effectors: Wipers (left, right, back)
- Actions: Off, Slow, Medium, Fast
- Environment: Inner city, freeways, highways, weather ...

Interacting Agents

Collision Avoidance Agent (CAA)

- Goals: Avoid running into obstacles
- Percepts ?
- Sensors?
- Effectors ?
- Actions ?
- Environment: Freeway

Lane Keeping Agent (LKA)

- Goals: Stay in current lane
- Percepts ?
- Sensors?
- Effectors ?
- Actions ?
- Environment: Freeway

Interacting Agents

Collision Avoidance Agent (CAA)

- Goals: Avoid running into obstacles
- Percepts: Obstacle distance, velocity, trajectory
- Sensors: Vision, proximity sensing
- Effectors: Steering Wheel, Accelerator, Brakes, Horn, Headlights
- Actions: Steer, speed up, brake, blow horn, signal (headlights)
- Environment: Freeway

Lane Keeping Agent (LKA)

- Goals: Stay in current lane
- Percepts: Lane center, lane boundaries
- Sensors: Vision
- Effectors: Steering Wheel, Accelerator, Brakes
- Actions: Steer, speed up, brake
- Environment: Freeway

Conflict Resolution by Action Selection Agents

- **Override:** CAA overrides LKA
- **Arbitrate:** if Obstacle is Close then CAA
else LKA
- **Compromise:** Choose action that satisfies both agents
- Any combination of the above
- **Challenges:** Doing the right thing

The Right Thing = The Rational Action

- **Rational Action:** The action that maximizes the expected value of the performance measure given the percept sequence to date
 - Rational = Best ?
 - Rational = Optimal ?
 - Rational = Omniscience ?
 - Rational = Clairvoyant ?
 - Rational = Successful ?

The Right Thing = The Rational Action

- **Rational Action:** The action that maximizes the expected value of the performance measure given the percept sequence to date

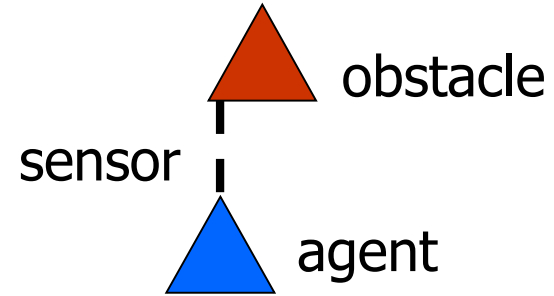
- Rational = Best Yes, to the best of its knowledge
- Rational = Optimal Yes, to the best of its abilities (incl. its constraints)
- Rational \neq Omniscience
- Rational \neq Clairvoyant
- Rational \neq Successful

Behavior and performance of IAs

- **Perception** (sequence) to **Action Mapping**: $f: P^* \rightarrow A$
 - **Ideal mapping**: specifies which actions an agent ought to take at any point in time
 - **Implementation**: Look-Up-Table, Closed Form, Algorithm, etc.
- **Performance measure**: a *subjective* measure to characterize how successful an agent is (e.g., speed, power usage, accuracy, money, etc.)
- (degree of) **Autonomy**: to what extent is the agent able to make decisions and take actions on its own?

Look up table

Distance	Action
10	No action
5	Turn left 30 degrees
2	Stop



Closed form

- Output (degree of rotation) = $F(\text{distance})$
- E.g., $F(d) = 10/d$ (distance cannot be less than $1/10$)

How is an Agent different from other software?

- Agents are **autonomous**, that is, they act on behalf of the user
- Agents contain some level of **intelligence**, from fixed rules to learning engines that allow them to adapt to changes in the environment
- Agents don't only act **reactively**, but sometimes also **proactively**
- Agents have **social ability**, that is, they communicate with the user, the system, and other agents as required
- Agents may also **cooperate** with other agents to carry out more complex tasks than they themselves can handle
- Agents may **migrate** from one system to another to access remote resources or even to meet other agents

Environment Types

- Characteristics
 - Accessible vs. inaccessible
 - Deterministic vs. nondeterministic
 - Episodic vs. nonepisodic
 - Hostile vs. friendly
 - Static vs. dynamic
 - Discrete vs. continuous

Environment Types

- Characteristics

- Accessible vs. inaccessible

- Accessible: sensors give access to **complete** state of the environment.

- Deterministic vs. nondeterministic

- Deterministic: the next state can be determined based on the current state and the action.

- Episodic vs. nonepisodic (Sequential)

- Episode: each perceive and action pairs
 - In episodic environments, the quality of action does not depend on the previous episode and does not affect the next episode.
 - Example: Episodic: mail sorting system; non-episodic: chess

Environment Types

- Characteristics
 - Hostile vs. friendly
 - Static vs. dynamic
 - Dynamic if the environment changes during deliberation
 - Discrete vs. continuous
 - Chess vs. driving

Environment types

Environment	Accessible	Deterministic	Episodic	Static	Discrete
Operating System					
Virtual Reality					
Office Environment					
Mars					

Environment types

Environment	Accessible	Deterministic	Episodic	Static	Discrete
Operating System	Yes	Yes	No	No	Yes
Virtual Reality	Yes	Yes	Yes/no	No	Yes/no
Office Environment	No	No	No	No	No
Mars	No	Semi	No	Semi	No

The environment types largely determine the agent design.

Structure of Intelligent Agents

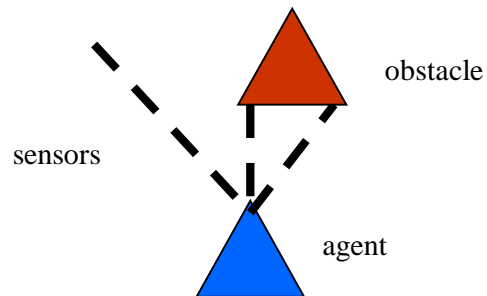
- Agent = architecture + program
- **Agent program:** the implementation of $f: \mathcal{P}^* \rightarrow \mathcal{A}$, the agent's perception-action mapping

```
function Skeleton-Agent(Percept) returns Action  
    memory  $\leftarrow$  UpdateMemory(memory, Percept)  
    Action  $\leftarrow$  ChooseBestAction(memory)  
    memory  $\leftarrow$  UpdateMemory(memory, Action)  
return Action
```

- **Architecture:** a device that can execute the agent program (e.g., general-purpose computer, specialized device, beobot, etc.)

Using a look-up-table to encode $f: \mathcal{P}^* \rightarrow \mathcal{A}$

- **Example:** Collision Avoidance
 - Sensors: 3 proximity sensors
 - Effectors: Steering Wheel, Brakes
- How to generate?
- How large?
- How to select action?



Using a look-up-table to encode $f: \mathcal{P}^* \rightarrow \mathcal{A}$

- **Example:** Collision Avoidance

- Sensors: 3 proximity sensors
- Effectors: Steering Wheel, Brakes

- **How to generate:** for each $p \in \mathcal{P}_\ell \times \mathcal{P}_m \times \mathcal{P}_r$
generate an appropriate action, $a \in S \times \mathcal{B}$

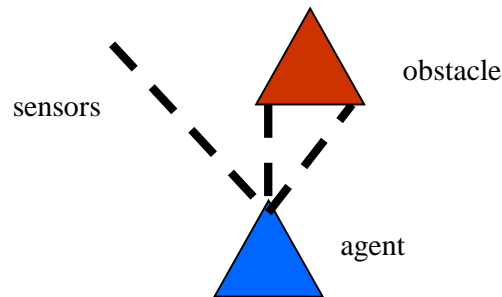
- **How large:** size of table = # possible percepts times # possible actions = $|\mathcal{P}_\ell| |\mathcal{P}_m| |\mathcal{P}_r| |S| |\mathcal{B}|$

E.g., $P = \{\text{close, medium, far}\}^3$

$A = \{\text{left, straight, right}\} \times \{\text{on, off}\}$

then size of table = 27 rows

- Total possible combinations (ways to fill table): $27 \times 3 \times 2 = 162$



Agent types

- Reflex agents
- Reflex agents with internal states
- Goal-based agents
- Utility-based agents
- Learning agents

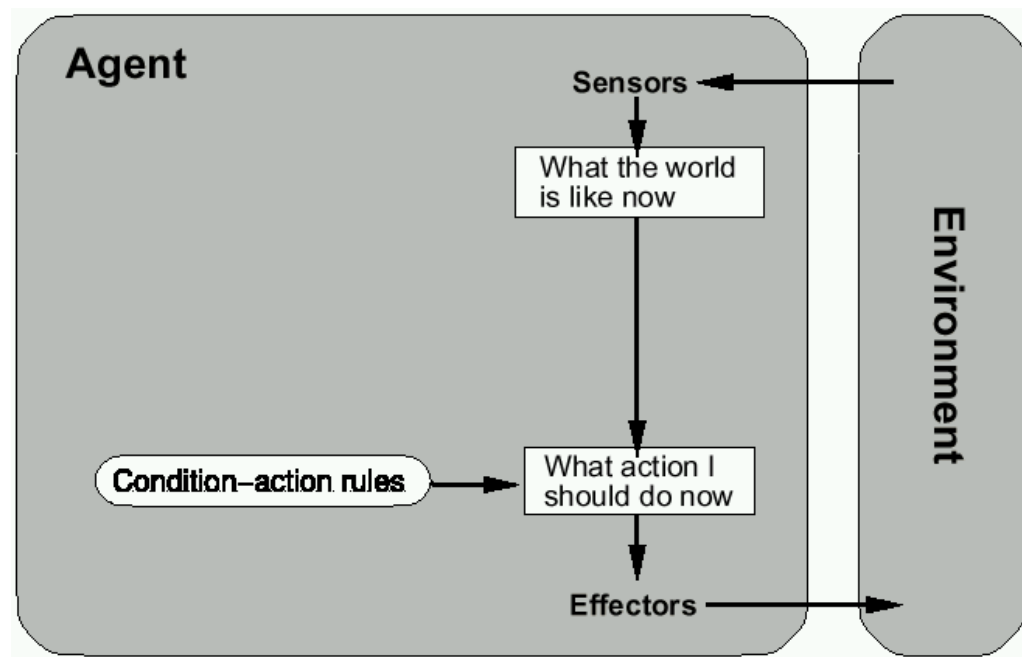
Agent types

- Reflex agents
 - Reactive: No memory
- Reflex agents with internal states
 - W/o previous state, may not be able to make decision
 - E.g. brake lights at night.
- Goal-based agents
 - Goal information needed to make decision

Agent types

- Utility-based agents
 - How well can the goal be achieved (degree of happiness)
 - What to do if there are conflicting goals?
 - Speed and safety
 - Which goal should be selected if several can be achieved?
- Learning agents
 - How can I adapt to the environment?
 - How can I learn from my mistakes?

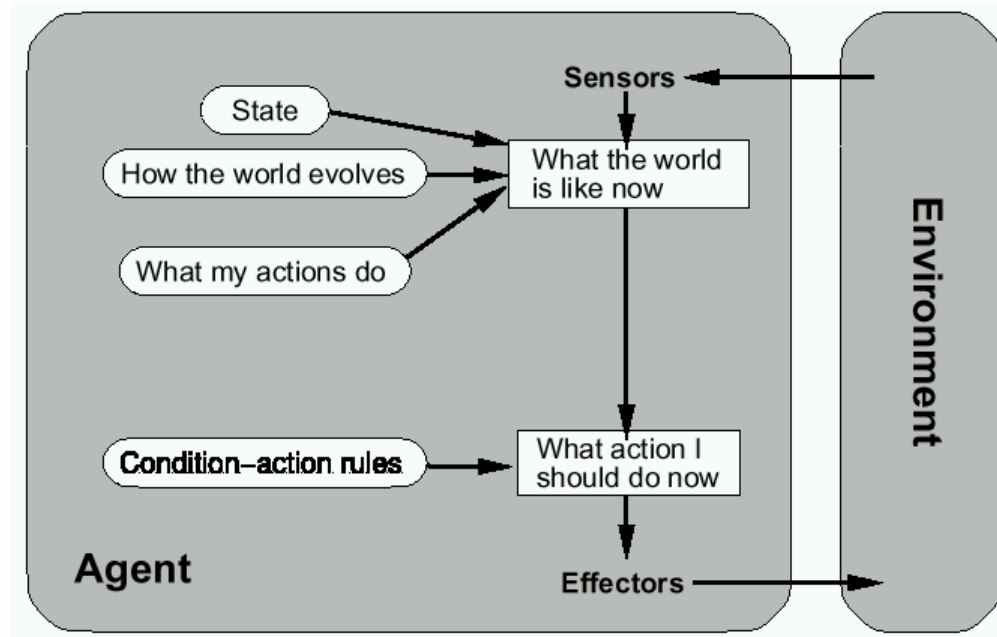
Reflex agents



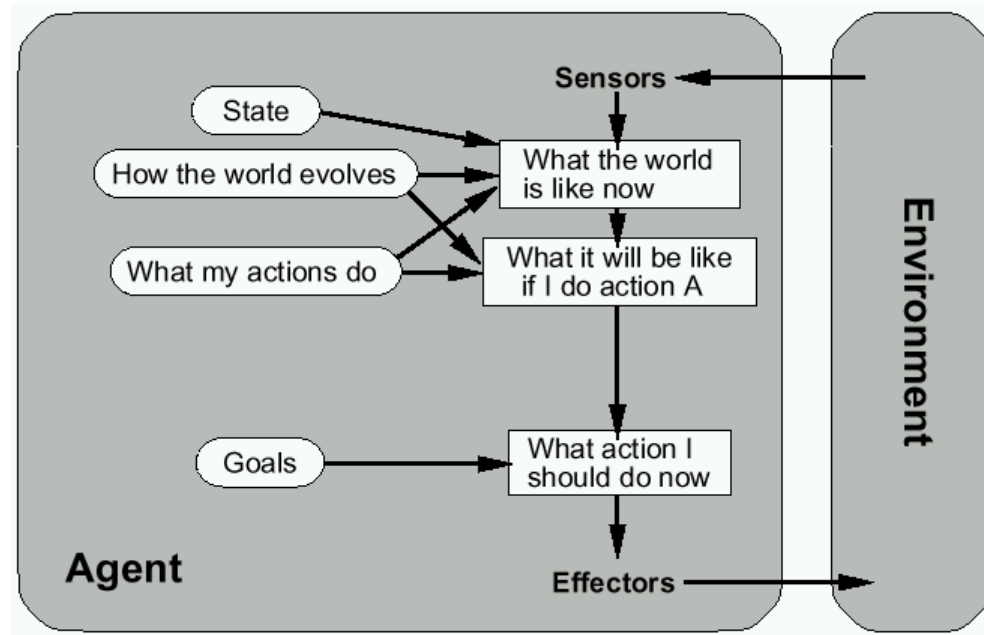
Reactive agents

- Reactive agents do not have internal symbolic models.
 - Act by stimulus-response to the current state of the environment.
 - Each reactive agent is simple and interacts with others in a basic way.
 - Complex patterns of behavior emerge from their interaction.
-
- **Benefits:** robustness, fast response time
 - **Challenges:** scalability, how intelligent?
and how do you debug them?

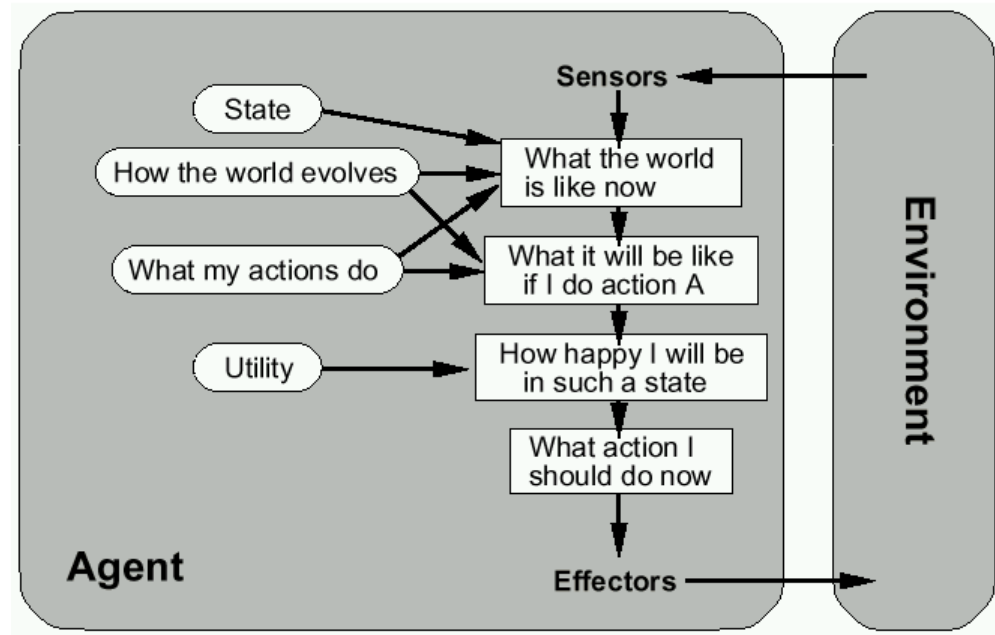
Reflex agents w/ state



Goal-based agents



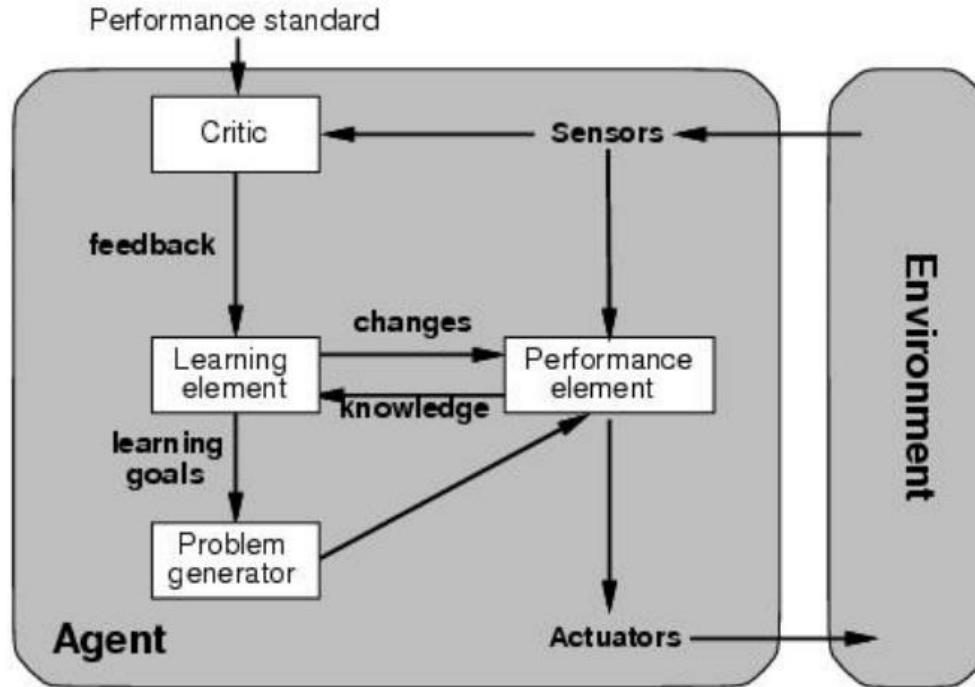
Utility-based agents



Learning agents

Critic: Determines outcomes of actions and gives feedback

Learning element:
Takes feedback from critic and improves performance element



Problem generator: creates new experiences to promote learning

Summary on intelligent agents

- **Intelligent Agents:**

- Anything that can be *viewed as* **perceiving** its **environment** through **sensors** and **acting** upon that environment through its **effectors** to maximize progress towards its **goals**.
- PAGE (Percepts, Actions, Goals, Environment)
- Described as a Perception (sequence) to Action Mapping: $f: \mathcal{P}^* \rightarrow \mathcal{A}$
- Using look-up-table, closed form, etc.

- **Agent Types:** Reflex, state-based, goal-based, utility-based, learning

- **Rational Action:** The action that maximizes the expected value of the performance measure given the percept sequence to date