INTRODUCTION TO MACHINE LEARNING

Introduction to Machine Learning, Artificial Intelligence and Deep Learning

Session 02

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Agenda

- Alan Turing
- Turing Test & Associated Questions
- Agents
- Rational Agent
- Type of Agents
- PEAS

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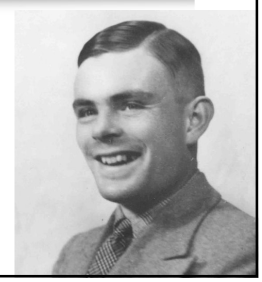
I propose to consider question: “ Can machines think?”
- Alan Turing - 1950
Great 20th Century Mathematician



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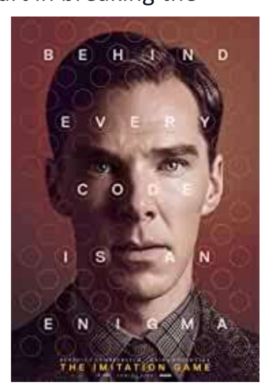
Alan Turing

- One of the rare figures in mathematics
- A mathematician, cryptographer, and a pioneer of computer science
- May best be known for his work at Bletchley Park during World War II, and his part in breaking the German Enigma code
- His idea of a 'Universal Machine', a hypothetical type of computer, resolved one of the most important problems in 20th century mathematics
- Movie “The Imitation Game”



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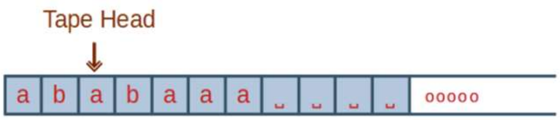
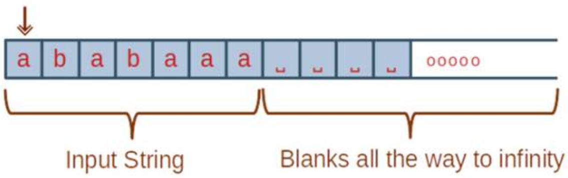
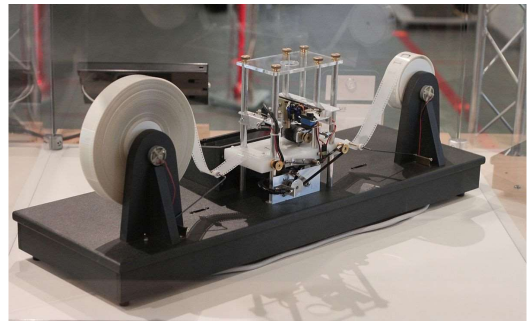
Turing Machine



- Tape Alphabets : Σ = {0, 1, a, b, x, Z0}
- The Blank ␣ is a special symbol and is not part of Σ and it is used to fill up the tape

- Initial Configuration





- Operations on the Tape
  - Read /Scan symbol at head location
    - Imagine that head is reading the tape
  - Update /Write a symbol using the head
  - Move Tape Head left or right
    - One space at a time

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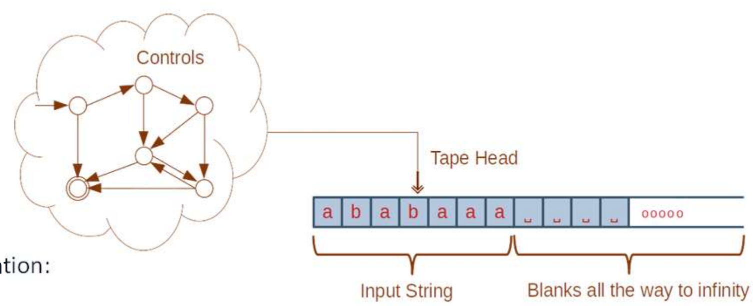
Turing Machine

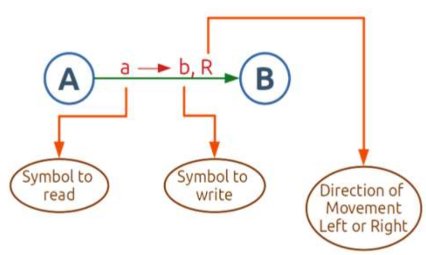
- Controls are similar
  - Finite State Machine
  - Pushdown Automata

- It is deterministic



- Rule 1: At each step of the computation:
  - Read the current symbol
  - Update it and move exactly one step left or right

- Rule 2:
  - Start from initial state and reach final state
  - Two Final States – Accept State and Reject State
  - Computations can either:
    - Halt and Accept
    - Halt and Reject
    - Loop (fails to Halt)



Turing Machine - Defined

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- A Turing Machine can be defined as a tuple of seven
- The tuple is $(Q, \Sigma, \Gamma, \delta, q_0, b\ , F)$, where
  - Q : A finite set of States – Non-empty only {A, B, C, D},
  - Σ(sigma) : A finite set of non-empty Symbols {1, 0, x, y}
  - Γ(gamma) : A finite Tape Symbols
  - δ(delta) : The transition Function, $Q\ x\ \Sigma\ \ \rightarrow\ \Gamma\ x\ (L/R)\ x\ Q$
  - q_0 : Initial State,
  - b : Blank Symbol,
  - F : set of Final State (Accept or Reject)
- Production Rule can be written as:
  - δ (q_0, α) → (q_1, γ, R)

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Turing Machine - Example

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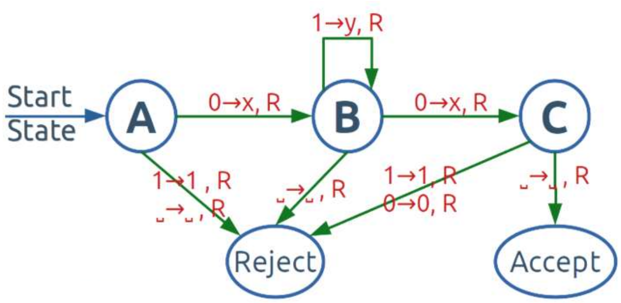
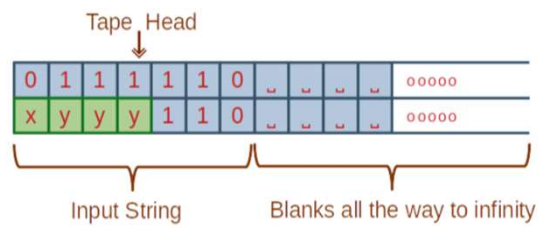
- Design a Turing Machine which recognizes language L = 01*0
  - Start with 0 thereafter there can be a number of 1s and end with 0





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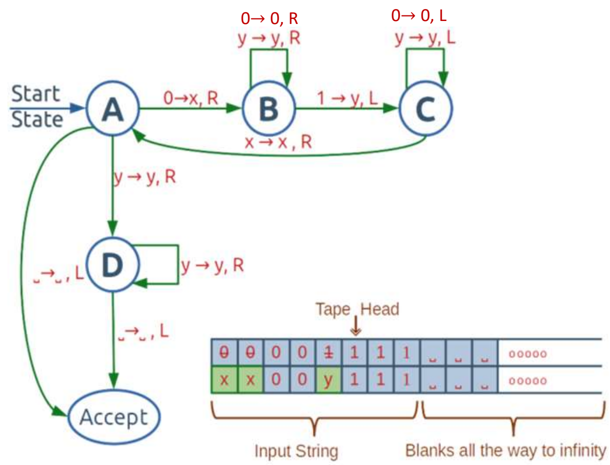
Turing Machine – Another Example

- Design a Turing Machine to recognize language $L = \{ 0^n 1^n \mid n \in \mathbb{Z} \}$
- Algorithm
  - Replace 0 by ‘x’
  - Move right till you encounter 1
    - If None : “Reject”
  - Replace 1 to ‘y’
  - Move left till you encounter 0
  - Repeat till all 0s have been replaced by ‘x’
  - Validate if any 1 left still
    - No : “Accept”
    - Yes: “Reject”



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Turing Thesis

- Turing’s Thesis states that any computation that can be carried out by mechanical means can be performed by some Turing Machine
- Explanation
  - Anything that can be done on existing digital computer can also be done by Turing Machine
  - No one has yet been able to suggest a problem solvable by what we consider an algorithm, for which a Turing Machine Program cannot be written
- Recursively Enumerable Language
  - A language L with a set of input symbols Σ, is said to be recursively enumerable if there exists a Turing Machine that accepts it

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Turing Test and Associated Questions

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What is Intelligence?

- Intelligence:
  - Capacity to learn and solve problems
    - (Webster dictionary)
  - The ability to act rationally

- Hmm… Not so easy to define

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What is Artificial Intelligence?

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

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What is AI?

- Views of AI fall into four different perspectives --- two dimensions:
  - Thinking versus Acting
  - Human versus Rational

  (which is "easier"?)

	Human-like Intelligence	**"Ideal" Intelligent/ Pure Rationality**
Thought/ Reasoning ("modeling thought" "brain")	**2. Thinking humanly**	**3. Thinking Rationally**
Behavior/Actions "behaviorism", "mimics behavior"	**1. Acting Humanly**	**4. Acting Rationally**

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Acting Humanly

- Views of AI fall into four different perspectives --- two dimensions:
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	Human-like Intelligence	**"Ideal" Intelligent/ Pure Rationality**
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Acting Humanly: The Turing Test

- Turing (1950) "Computing machinery and intelligence"
  - "Can machines think?"; "Can machines behave intelligently?"
  - Operational test for intelligent behavior: the Imitation Game
- "Imitation Game"
  - Method
    - Three people play (man, woman, and interrogator)
    - Interrogator determines which of the other two is a woman by asking questions
      - Example: How long is your hair?
    - Questions and responses are typewritten or repeated by an intermediary
    - Turing Test: Machine takes the part of the man
  - AI system passes if interrogator cannot tell which one is the machine.
  - No computer vision or robotics or physical presence required!
  - Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- But, by scientific consensus, we are still several decades away from truly passing the Turing test (as the test was intended).

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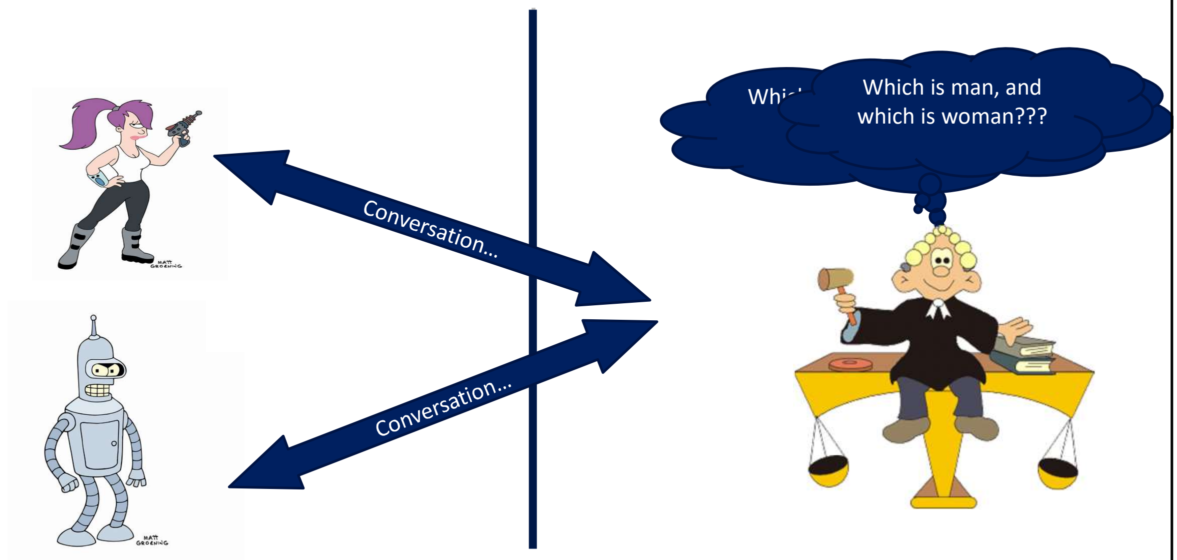
The Imitation Game



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Predictions

- In 1950, Turing predicted that 50 years later it will be possible to program a computer with ~100 Mb memory to pass TT 70% of the time, with 5 minute conversations.
- It will be natural to speak of computers 'thinking'.
- "[The machine] may be used to help in making up its own programs, or to predict the effect of alterations in its own structure."
- "We may hope that machines will eventually compete with men in all purely intellectual fields."

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Thinking Humanly

	Human-like Intelligence	"Ideal" Intelligent/ Pure Rationality
Thought/ Reasoning ("modeling thought" "brain")	**2. Thinking humanly** **➢ Cognitive Modeling**	**3. Thinking Rationally**
Behavior/Actions "behaviorism", "mimics behavior"	**1. Acting Humanly**	**4. Acting Rationally**

- Requires scientific theories of internal activities of the brain.
- Cognitive Science (top-down) computer models + experimental techniques from psychology
  - Predicting and testing behavior of human subjects
- Cognitive Neuroscience (bottom-up) : Direct identification from neurological data

Cognitive Science and Cognitive Neuroscience distinct disciplines
Cognitive Neuroscience has become very active.
Connection to AI: Neural Nets. (Large Google / MSR / Facebook AI Lab efforts.)

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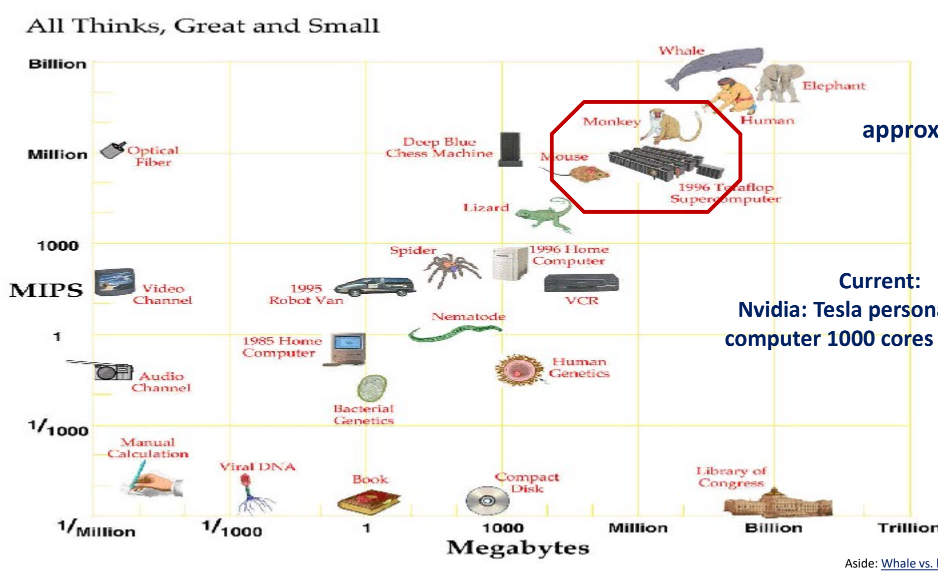
Computer vs. Brain



approx. 2025

Current:
Nvidia: Tesla personal super-computer 1000 cores 4 teraflop

Aside: Whale vs. human brain

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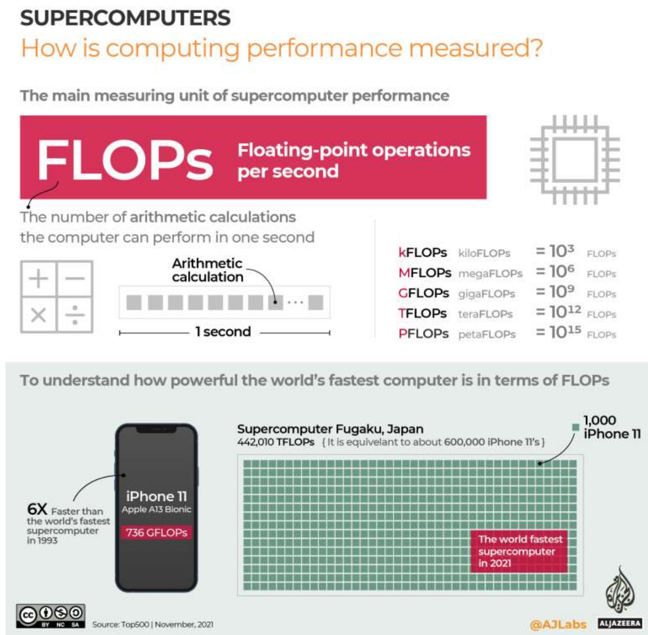
Super – Computer



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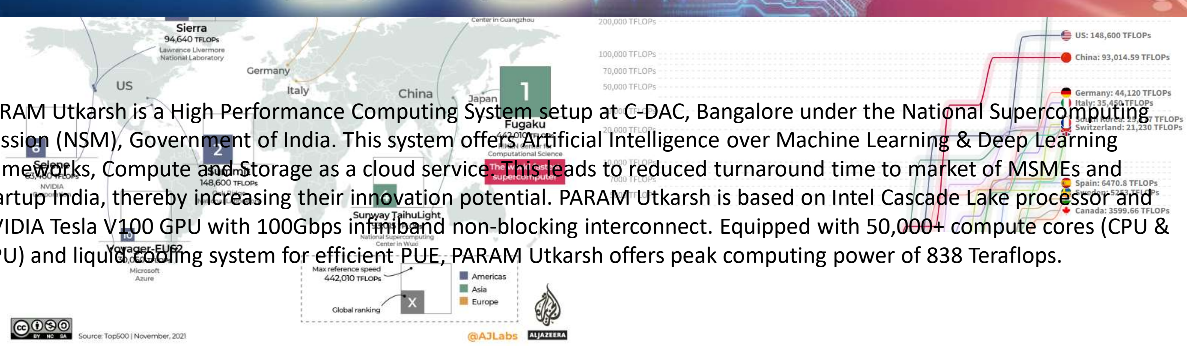
Top 10 Super – Computer



PARAM Utkarsh is a High Performance Computing System setup at C-DAC, Bangalore under the National Supercomputing Mission (NSM), Government of India. This system offers Artificial Intelligence over Machine Learning & Deep Learning frameworks, Compute and Storage as a cloud service. This leads to reduced turnaround time to market of MSMEs and Startup India, thereby increasing their innovation potential. PARAM Utkarsh is based on Intel Cascade Lake processor and NVIDIA Tesla V100 GPU with 100Gbps infiniband non-blocking interconnect. Equipped with 50,000+ compute cores (CPU & GPU) and liquid cooling system for efficient PUE, PARAM Utkarsh offers peak computing power of 838 Teraflops.

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Safe to assume

- In near future, we can have computers with as many processing elements as our brain, but:
  - Far fewer interconnections (wires or synapses)
  - Then again, much faster updates
- Fundamentally different hardware may be require ➔ fundamentally different algorithms!
  - Still an open question.
  - Neural net research - Can a digital computer simulate our brain?

Likely: Church-Turing Thesis
(But, might we need quantum computing?)
(Penrose; consciousness; free will?)

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Thinking Rationally

	Human-like Intelligence	"Ideal" Intelligent/ Pure Rationality
Thought/ Reasoning ("modeling thought" "brain")	2. Thinking humanly	3. Thinking Rationally ➢ formalizing "Laws of Thought"
Behavior/Actions "behaviorism", "mimics behavior"	1. Acting Humanly	4. Acting Rationally

- Logic: Making the right inferences!
  - Remarkably effective in science, math, and engineering.
- Several Greek schools developed various forms of logic: notation and rules of derivation for thoughts.
- Aristotle: what are correct arguments/thought processes? (characterization of "right thinking").
  - Socrates is a man, All men are mortal ➔ Therefore, Socrates is mortal

Can we mechanize it? (syntactic; strip interpretation)
Use: legal cases, diplomacy, ethics etc. (?)

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Acting Rationally

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- An agent is an entity that perceives and acts in the world (i.e. an "autonomous system" (e.g. self-driving cars) / physical robot or software robot (e.g. an electronic trading system))
- Current focus of AI is about designing rational agents
- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance

Caveat: computational limitations may make perfect rationality unachievable design best program for given machine resources "Limited rationality"

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Building Intelligent Machines

Focus I
Building exact models of human cognition view from psychology, cognitive science, and neuroscience

Focus II
Developing methods to match or exceed human performance in certain domains, possibly by very different means

Main focus of current AI.

But, Focus I often provides inspiration for Focus II. Also, Neural Nets blur the separation.

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Acting Rationally

Good judgment comes from experience, and a lot of that comes from bad judgment.

- For **each percept sequence** does whatever action is expected to maximize its performance measure **on the basis of evidence perceived so far** and built-in knowledge.
- Were all your past decisions correct?
- Do you regret them?
- Includes acting on the basis of what you know and what you have learnt!

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What is AI?

- Views of AI fall into four different perspectives --- two dimensions:
  - Thinking versus Acting
  - Human versus Rational (which is "easier"?)

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Seems to be a Good Idea

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Rational Agent

- An agent should strive to do right thing,
  - Based on what it can perceive and the actions it can perform
- Right action is one which makes agent to be most successful
- Performance measure: An objective criterion for success of an agents behavior
- Imagine you are trying to design a vacuum-cleaner
  - Amount of dirt gathered
  - Time taken in doing so
  - Electricity consumed
  - Noise generated
  - etc…

Lets look at Agents…

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Agents

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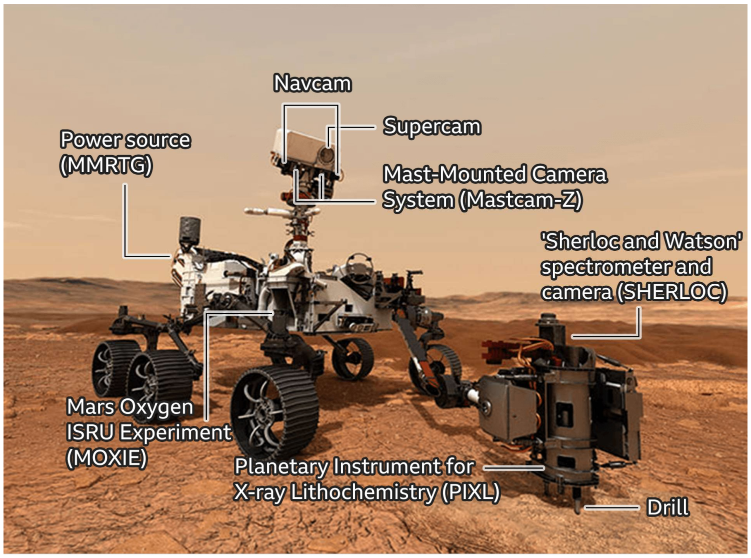
Mars Rover Perseverance



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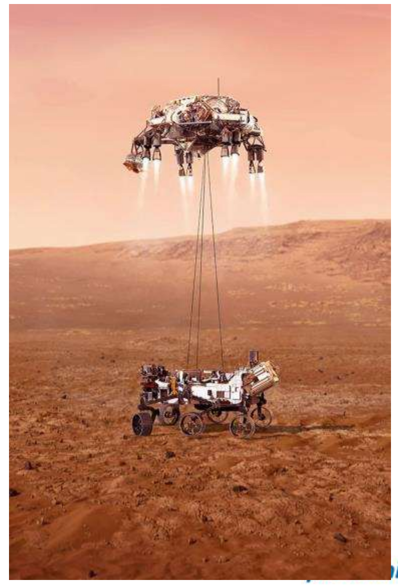

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Agent

- We sense the world around us
  - Create notion of a world in our head
  - Convert it to symbols
- These symbols and their interaction we try to define by known law of physics
- That's the idea of Agent
- Agent: anything that can be viewed as:
  - Perceiving its environment through sensors and
  - Acting upon that environment through actuators

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Agent

- Human agent has:
  - eyes, ears, and other organs for sensors and hands, legs, vocal tract, and so on for actuators.
- Robotic agent might have:
  - cameras and infrared range finders for sensors and various motors for actuators
- Software agent receives:
  - keystrokes, file contents, and network packets as sensory inputs and acts on the environment by displaying on the screen, writing files, and sending network packets
- Percept: The agent's perceptual inputs at any given instant
- Percept Sequence : complete history of everything the agent has ever perceived.
  - An agent's choice of action at any given instant can depend on the entire percept sequence observed to date, but not on anything it hasn't perceived
- Agent Function: describes agent's behavior that maps any given percept sequence to an action

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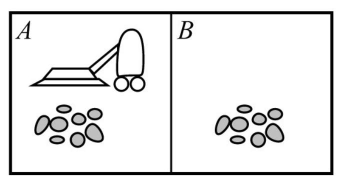
Toy Vacuum World

- Two Locations : squares A and B
- The vacuum agent perceives:
  - Which square it is in
  - Whether there is dirt in the square
- Actions: move left, move right, suck up the dirt, or do nothing
- Agent function:
  - if the current square is dirty, then suck;
  - otherwise, move to the other square
- A partial tabulation of this agent function is shown here
  - various vacuum-world agents can be defined by filling in the right-hand column in various ways
- Question: What is the right way to fill out the table?
  - what makes an agent good or bad, intelligent or stupid?



Percept Sequence	Action
[A, Clean]	Right
[A, Dirty]	Suck
[B, Clean]	Left
[B, Dirty]	Suck
[A, Clean], [A, Clean]	Right
[A, Clean], [A, Dirty]	Suck
…	…
[A, Clean], [A, Clean], [A, Dirty]	Suck
[A, Clean], [A, Clean], [A, Clean]	Right

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Agent

- An agent is something that:
  - Acts in an environment and does something
- Agents include everything:
  - Dogs, thermostats, airplanes, robots, humans, companies, and countries
- We are interested in what an agent does; that is, how it acts
- An agent acts intelligently when:
  - What it does is appropriate for its circumstances and its goals,
  - It is flexible to changing environments and changing goals,
  - It learns from experience, and
  - It makes appropriate choices given its perceptual and computational limitations.
- An agent typically cannot observe the state of the world directly;
  - It has only a finite memory and it does not have unlimited time to act

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Agents Situated in Environments

- Imagine Agent as worker bee!

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Agents Situated in Environments

- AI agents deal with knowledge (data)
  - Facts (believe & observe knowledge)
  - Procedures (how to knowledge)
  - Meaning (relate & define knowledge)
- Right representation is crucial
  - Early realisation in AI
  - Wrong choice can lead to project failure
  - Active research area

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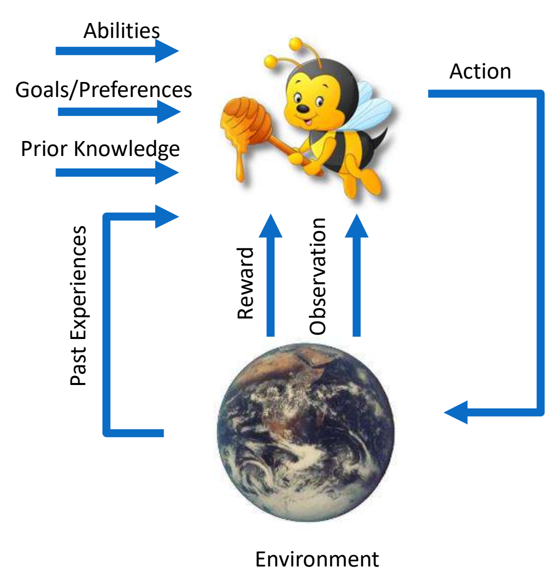
Agents Situated in Environments

- Abilities, which are the primitive actions it is capable of carrying out
- Goals that it must try to achieve or preferences over states of the world; and
- Prior knowledge about the agent and the environment;
- Rewards it gets on achieving the goal
- History of interaction with the environment, which is composed of
  - Observations of the current environment and
  - Past experiences of previous actions and observations, or other data, from which it can learn;



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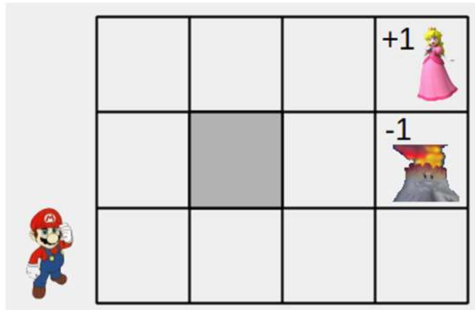
Rational Agent

- Has clear preference
  - Action for every possible sequence is clearly programmed
  - Every entry in the table for the agent function is filled out correctly
- Acts in a way to maximize its performance measure with all possible actions
- A rational agent is said to perform the right things
- AI is about creating rational agents to use for various real-world scenarios
- For an AI agent, the rational action is most important
  - For each best possible action, agent gets the positive reward
  - For each wrong action, an agent gets a negative reward



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Rational Agent Models Uncertainty

- A rational agent not only gathers information but also learns as much as possible from what it perceives
- The agent's initial configuration could reflect some prior knowledge of the environment, but as the agent gains experience this may be modified and augmented.
- An agent that does not perceive or learn is fragile!
- Dung Beetle
  - A lowly dung beetle, after digging its nest and laying its eggs, it fetches a ball of dung from a nearby heap to plug the entrance.
  - If the ball of dung is removed from its grasp en route, the beetle continues its task and pantomimes plugging the nest with the nonexistent dung ball, never noticing that it is missing
- Sphex Wasp (slightly more intelligent)
  - The female sphex will dig a burrow, go out and sting a caterpillar and drag it to the burrow, enter the burrow again to check all is well, drag the caterpillar inside, and lay its eggs.
  - The caterpillar serves as a food source when the eggs hatch.
  - So far so good, but if an entomologist moves the caterpillar a few inches away while the sphex is doing the check, it will revert to the "drag" step of its plan and will continue the plan without modification, even after dozens of caterpillar-moving interventions.
  - The sphex is unable to learn that its innate plan is failing, and thus will not change it.

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Rationality

- A rational agent should be autonomous—it should learn what it can to compensate for partial or incorrect prior knowledge.
  - For example, a vacuum-cleaning agent that learns to foresee where and when additional dirt will appear will do better than one that does not
- Complete autonomy from the start is not needed
  - Act random initially and learn as you go!
- Rationality is relative to a performance measure
- Judge rationality based on:
  - The performance measure that defines the criterion of success
  - The agent prior knowledge of the environment
  - The possible actions that the agent can perform
  - The agent’s percept sequence to date
- Agent can become irrational
  - For example, once all the dirt is cleaned up, the agent will oscillate needlessly back and forth
  - If the performance measure includes a penalty of one point for each movement left or right, the agent will fare poorly
  - A better agent for this case would do nothing once it is sure that all the squares are clean

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Distinguish between Rationality and Omniscience

- Rational behavior - maximizes expected performance
  - Look both ways while crossing the road, cross if no approaching vehicle
- Omniscience (state of knowing everything) – maximizes actual performance
  - Person crossing a road killed by flying hoarding? (Rational but not Omniscience)
  - Impossible to design agent for Omniscience
- Definition of rationality does not require omniscience
  - Because the rational choice depends only on the percept sequence to date
- Doing actions in order to modify future percepts—sometimes called information gathering—is an important part of rationality (Exploration)

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Rational Agents

- An autonomous entity :
  - Act upon an environment using sensors and actuators for achieving goals
  - May learn from the environment to achieve their goals
  - A thermostat is an example
- Following are the main four rules for an AI agent:
  - Rule 1: An AI agent must have the ability to perceive the environment
  - Rule 2: The observation must be used to make decisions
  - Rule 3: Decision should result in an action
  - Rule 4: The action taken by an AI agent must be a rational action
- Well-behaved agents
  - For each possible percept sequence, a rational agent should select an action that is expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has

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Type of agents

- Five classes based on their degree of perceived intelligence and capability
- All these agents can improve their performance and generate better action over the time
  - Simple Reflex Agent
  - Model-based Reflex Agent
  - Goal-based Agents
  - Utility-based Agent
  - Learning Agent

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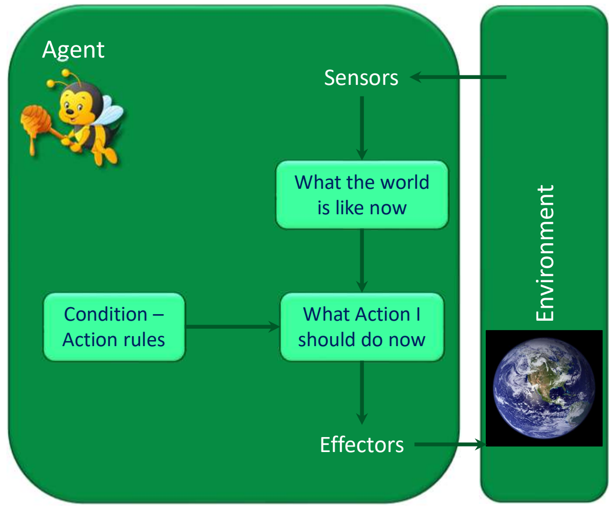
Simple Reflex Agent

- Agents take decisions on the basis of the current percepts and ignore the rest of the percept history
- Successful in the fully observable environment only
- No percepts history considered
- Works on “Condition – Action” rule
  - Maps the current state to action
    - If hand is in fire, pull it out
    - Reflex action / muscle memory similar to humans
  - Example: Room Cleaner agent
    - There is dirt in the room ➔ pick it up.



https://www.doc.ic.ac.uk/project/examples/2005/163/g0516334/sra.html

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Limitation of Simple Reflex agent

- They have very limited intelligence
- They do not have knowledge of non-perceptual parts of the current state
  - Take example of a mars lander designed to collect a rocks
  - A simple reflex agent will keep collecting rocks even if same rock is found again
  - It doesn't take into account that it already picked up this type of rock
- Not adaptive to changes in the environment

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Model-based Reflex Agent

- Can work in a partially observable environment, and track the situation

- Two important factors:
  - Model: It is knowledge about "how things happen in the world," so it is called a Model-based agent
  - Internal State: It is a representation of the current state based on percept history

- These agents have the model, "which is knowledge of the world" and based on the model they perform actions
  - Mars Lander after picking up its first sample, it stores this in the internal state of the world around it so when it come across the second same sample it passes it by and saves space for other samples

- Updating the agent state requires information about:
  - How the world evolves
  - How the agent's action affects the world
    - If our mars Lander took a sample under a precarious ledge it could displace a rock and it could be crushed

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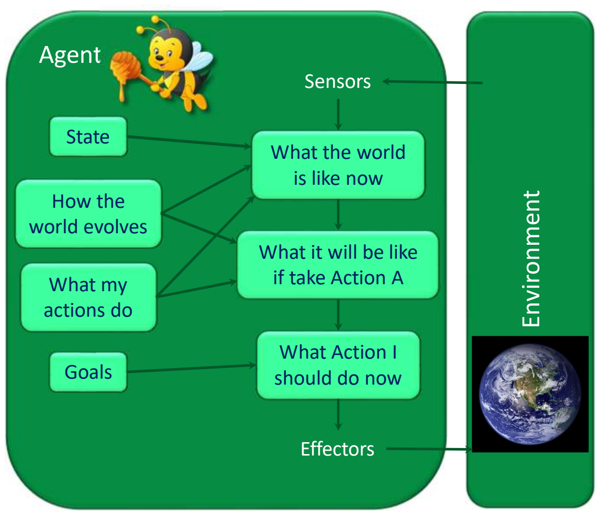
Goal Based Agents

- Agent having a set of goals with desirable situations

- Agent uses these goals with a set of actions to move towards the goal
  - Predicted outcomes to see which action(s) achieve our goal(s) better
  - For achieving the goals, can take an action or many actions

- Two subfields devoted to finding sequences of actions to achieve goals
  - Search
  - Planning

- Before acting the agent:
  - Reviews many actions
  - Chooses the one which come closest to achieving its goals
  - Whereas the reflex agents just have an automated response for the situations



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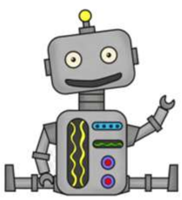
Goal based agents are Always learning

- Much more flexible because the knowledge used for decision making is represented explicitly and can be modified
- For example if our mars Lander needed to get up a hill the agent can update its knowledge on how much power to put into the wheels to gain certain speeds, through this all relevant behaviors will now automatically follow the new knowledge on moving
- Still these agents are not measuring and storing their efficiency



- Please welcome Utility Based agents

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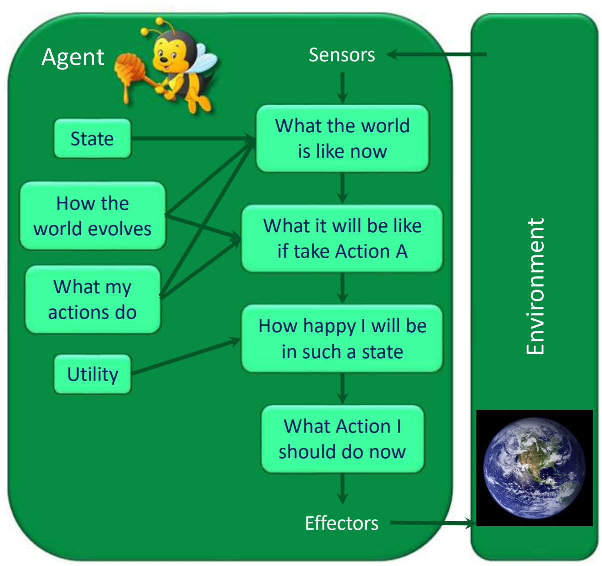
Utility-based Agents

- Just having goals is not enough, the agents need to also achieve these goals in best possible way
- They an extra component of utility measurement
  - Utilization provides a measure of success at a given state
  - E.g. how many steps to achieve the goal
- Utility-based agent act based not only goals but also the best way to achieve the goal
- The Utility-based agent is useful when there are multiple possible alternatives, and an agent has to choose in order to perform the best action



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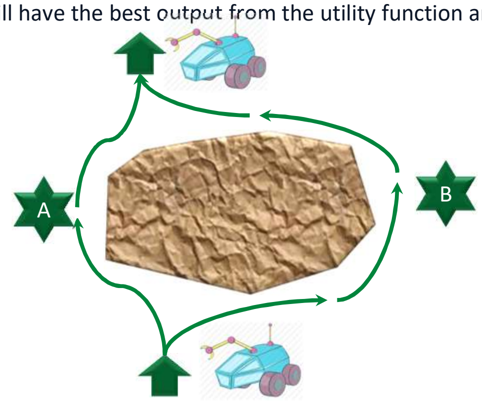
Utility-based agents

- The utility function maps each state to a real number to check how efficiently each action achieves the goals
- For example let's show our mars Lander on the surface of mars with an obstacle in its way.
  - In a goal based agent it is uncertain which path will be taken by the agent
  - some are clearly not as efficient as others
  - Utility based agent the best path will have the best output from the utility function and that path will be chosen



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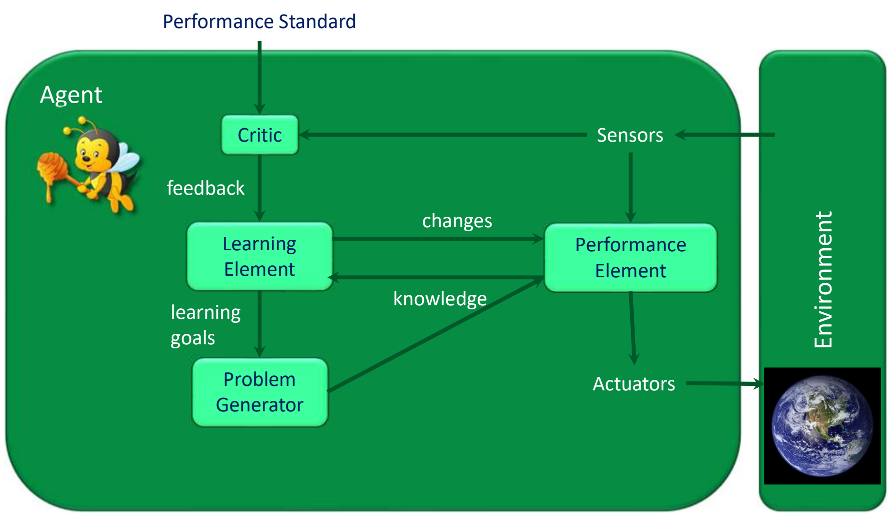
A Learning Agent

- Has four broad parts



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A Learning Agent - Critic

- Responsible for improvements this can make a change to any of the knowledge components in the agents
- Observe pairs of successive states in the percept sequence;
- From this the agent can learn how the world evolves
- For utility based learning agents an external performance standard is needed to tell the critic if the agent's action has a good or a bad effect on the world.

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A Learning Agent - Performance element

- Responsible for selecting external actions
- Agent gains feedback from the critic on how well the agent is doing
- Determines how the performance element (actions) should be modified if at all to improve the agent
- For example , in this course
  - You would do a test it would be marked
  - The test is the critic
  - The teacher would mark the test and see what could be improved and instructs you how to do better next time, the teacher is the learning element
  - You are the performance element

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A Learning Agent - Problem Generator

- So far our agents are doing task they have learned to do well
- We need a way of getting the agent to experience new situations,
- Mechanism to encourage agent to exploit
- This way the agent keeps on learning
- For example: While idling on a red light, you would see various recommendations
  - Switch off your engine
  - Take your foot off the paddle
  - Don't idle with clutch pressed , etc….

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Structure of an AI Agent

- Architecture: Architecture is machinery that an AI agent executes on
- Agent Function: Agent function is used to map a percept to an action
- Agent program: Agent program is an implementation of agent function. An agent program executes on the physical architecture to produce function f
- PEAS Representation
  - **P:** Performance measure
  - **E:** Environment
  - **A:** Actuators
  - **S:** Sensors

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PEAS

- Performance:
  - Safety, time Legal drive and comfort
- Environment:
  - Roads, other cars, pedestrians, road signs and everything else
- Actuators:
  - Steering, accelerator, brake, signal, horn
- Sensors:
  - Camera, sonar, GPS, Speedometer, odometer, accelerometer, engine sensors, keyboard

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PEAS

- Performance:
  - Cleanness, efficiency: distance traveled to clean, battery life, security
- Environment:
  - Room, table, wood floor, carpet, different obstacles
- Actuators:
  - Wheels, different brushes, vacuum extractor
- Sensors:
  - Camera, dirt detection sensor, cliff sensor, bump sensors, infrared wall sensors.

iRobot Roomba 675

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Reflect

#	Agent	Example
1	Simple Reflex Agent	• Thermostat, • Atari console with left/ right move and fire button
2	Model-based Reflex Agent	• Traffic Camera taking pic of speeding vehicle • Atari console forcing you to remain within a lane while you drive
3	Goal Based Agents	• Google's Waymo driverless cars • Programmed with an end destination, or goal • The car will then "think" and make the right decisions in order to reach the destination • Still only thinking of Goal. Not too worried about time it is taking to reach there
4	Utility-based Agents	• Route recommendation system which solves the '*best*' route to reach a destination
5	A Learning Agent	• Human : Can learn to ride a bicycle, even though, at birth, no human possesses this skill

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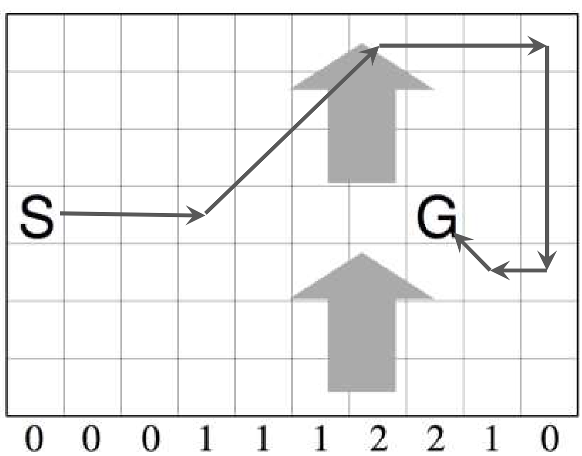
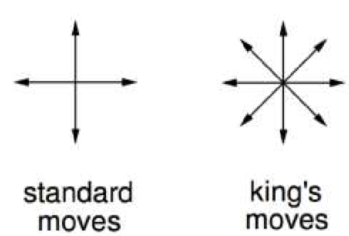
Learning Agent: Windy Gridworld Example

- Agent can move one step at a time
- Reward = -1 per time-step until reaching goal





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Properties of Task Environments

- Fully observable vs. partially observable
- Single agent vs. multi-agent
- Deterministic vs. stochastic
- Episodic vs. sequential
- Static vs. dynamic
- Discrete vs. continuous
- Known vs. unknown

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Properties of Task Environments

- Range of task environments is vast;
- Need to reduce number of dimensions to some manageable number
- What dimensions to consider?

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Fully Observable vs. Partially Observable

- Fully observable
  - An agent's sensors give it access to the complete state of the environment at each point in time
  - The sensors detect all aspects that are relevant to the choice of action; relevance, in turn, depends on the performance measure
- Fully observable environments are convenient because the agent need not maintain any internal state to keep track of the world
- An environment might be partially observable because:
  - Noisy and inaccurate sensors
  - Parts of the state are simply missing from the sensor data
- Examples
  - A vacuum agent with only a local dirt sensor cannot tell whether there is dirt in other squares
  - An automated taxi cannot see what other drivers are thinking
- The agent has no sensors at all then the environment is unobservable
  - The agent's goals may still be achievable, sometimes with certainty

Single Agent vs. Multi-agent

- Fairly Straight forward
  - An agent solving a crossword puzzle by itself is clearly in a single-agent environment, whereas an agent playing chess is in a two agent environment
- In most cases we struggle to classify
  - How an entity may be viewed as an agent?
  - Do we know which entities must be viewed as agents.
  - Does an agent A (the taxi driver for example) have to treat an object B (another vehicle) as an agent, or can it be treated merely as an object behaving according to the laws of physics, analogous to waves at the beach or leaves blowing in the wind?
  - Are they part of the environment?
- The key distinction:
  - Whether B's behavior is best described as maximizing a performance measure whose value depends on agent A's behavior.

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Single Agent vs. Multi-agent

- Competitive multi-agent environment – chess
  - The opponent entity B is trying to maximize its performance measure,
  - Minimizes agent A's performance measure
- Partially cooperative multi-agent environment - taxi-driving environment
  - Avoiding collisions maximizes the performance measure of all agents
  - It is also partially competitive because, for example, only one car can occupy a parking space.
- The agent-design problems in multi-agent environments are often quite different from those in single-agent environments
  - Communication often emerges as a rational behavior in multi-agent environments;
  - In some competitive environments, randomized behavior is rational because it avoids the pitfalls of predictability

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Deterministic vs. Stochastic

- If the next state of the environment is completely determined by:
  - The current state and the action executed by the agent → the environment is deterministic; otherwise, it is stochastic
  - The Toy Vacuum World is deterministic
- Most real situations are so complex that it is impossible to keep track of all the unobserved aspects;
  - Must be treated as stochastic.
  - Taxi driving is clearly stochastic in this sense, because one can never predict the behavior of traffic exactly; moreover, one's tires blow out and one's engine seizes up without warning.
  - Variations can include stochastic elements such as randomly appearing dirt and an unreliable suction mechanism
- An environment is uncertain if it is not fully observable or not deterministic
- In our case, a non-deterministic environment is one in which actions are characterized by their possible outcomes, but no probabilities are attached to them
  - Behavior of other drives are non-deterministic.
- Nondeterministic environment descriptions are usually associated with performance measures that require the agent to succeed for all possible outcomes of its actions.

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Episodic vs. Sequential

- Episodic task environment – the agent's experience is divided into atomic episodes
  - In each episode the agent receives a percept and then performs a single action or sequence of actions
  - The next episode does not depend on the actions taken in previous episodes
  - Many classification tasks are episodic
- For example
  - An agent that has to spot defective parts on an assembly line bases each decision on the current part, regardless of previous decisions
  - The current decision doesn't affect whether the next part is defective
- Sequential environments – the current decision could affect all future decisions
  - Chess and taxi driving are sequential: in both cases, short-term actions can have long-term consequences
- Episodic environments are much simpler than sequential environments because the agent does not need to think ahead.

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Static vs. Dynamic

- If the environment can change while an agent is deliberating, then we say the environment is dynamic for that agent; otherwise, it is static
- Static environments are easy to deal with because the agent need not keep looking at the world while it is deciding on an action, nor need it worry about the passage of time
- Dynamic environments are continuously asking the agent what it wants to do; if it hasn't decided yet, that counts as deciding to do nothing
- If the environment itself does not change with the passage of time but the agent's performance score does, then we say the environment is semi-dynamic
- Taxi driving is clearly dynamic: the other cars and the taxi itself keep moving while the driving algorithm dithers about what to do next
- Chess, when played with a clock, is semi-dynamic
- Crossword puzzles are static

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Discrete vs. Continuous

- The discrete/continuous distinction applies to the state of the environment
  - The way time is handled,
  - To the percepts and actions of the agent
- For example, the chess environment has a finite number of distinct states
  - Chess also has a discrete set of percepts and actions
- Taxi driving is a continuous-state and continuous-time problem:
  - the speed and location of the taxi and of the other vehicles sweep through a range of continuous values and do so smoothly over time
  - Taxi-driving actions are also continuous (steering angles, etc.)
- Input from digital cameras is discrete, strictly speaking, but is typically treated as representing continuously varying intensities and locations.

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Known vs. Unknown

- Strictly speaking, this distinction refers not to the environment itself but to the agent's (or designer's) state of knowledge about the "laws of physics" of the environment
- Known Environment – the outcomes (or outcome probabilities if the environment is stochastic) for all actions are given
- Unknown Environment – the agent will have to learn how it works in order to make good decisions
- The distinction between known and unknown environments is not the same as the one between fully and partially observable environments
- It is quite possible for a known environment to be partially observable—for example, in solitaire card games
  - Rules are known, still unable to see the cards that have not yet been turned over
  - Conversely, an unknown environment can be fully observable – in a new video game, the screen may show the entire game state but I still don't know what the buttons do until I try them

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Rented car – new country – unfamiliar geography and traffic laws

Task Environment	Observable	Agents	Deterministic	Episodic	Static	Discrete
Crossword puzzle	Fully	Single	Deterministic	Sequential	Static	Discrete
Chess with a clock	Fully	Multi	Deterministic	Sequential	Semi	Discrete
Poker	Partially	Multi	Stochastic	Sequential	Static	Discrete
Backgammon	Fully	Multi	Stochastic	Sequential	Static	Discrete
Taxi driving	Partially	Multi	Stochastic	Sequential	Dynamic	Continuous
Medical diagnosis	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Image analysis	Fully	Single	Deterministic	Episodic	Semi	Continuous
Part-picking robot	Partially	Single	Stochastic	Episodic	Dynamic	Continuous
Refinery controller	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Interactive English tutor	Partially	Multi	Stochastic	Sequential	Dynamic	Discrete

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Reflect…

- An agent is something that perceives and acts in an environment.
- The agent function for an agent specifies the action taken by the agent in response to any percept sequence
- The performance measure evaluates the behavior of the agent in an environment.
- A rational agent acts so as to maximize the expected value of the performance measure, given the percept sequence it has seen so far
- A task environment specification includes the performance measure, the external environment, the actuators, and the sensors.
- In designing an agent, the first step must always be to specify the task environment as fully as possible

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Reflect…

- Task environments vary along several significant dimensions.
- Environments can be fully or partially observable, single-agent or multi-agent, deterministic or stochastic, episodic or sequential, static or dynamic, discrete or continuous, and known or unknown
- The agent program implements the agent function. There exists a variety of basic agent-program designs reflecting the kind of information made explicit and used in the decision process.
- The designs vary in efficiency, compactness, and flexibility. The appropriate design of the agent program depends on the nature of the environment
- Simple reflex agents respond directly to percepts, whereas model-based reflex agents maintain internal state to track aspects of the world that are not evident in the current percept.
- Goal-based agents act to achieve their goals, and utility-based agents try to maximize their own expected “happiness.”
- All agents can improve their performance through learning

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Reflect…

- ________ are used for perceiving and _____ are used for acting upon the environment?
  - Sensors and Actuators
  - Sensors
  - Perceiver
  - None of the above
- What is meant by agent’s percept sequence?
  - Used to perceive the environment
  - Complete history of actuator
  - Complete history of perceived things
  - None of the above
- What is the function of an artificial intelligence “Agent”?
  - Mapping of goal sequence to an action
  - Work without the direct interference of the people
  - Mapping of precept sequence to an action
  - Mapping of environment sequence to an action
- What is the rule of simple reflex agent?
  - Simple-action rule
  - Condition-action rule
  - Simple & Condition-action rule
  - None of the above

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Reflect…

- The composition for agents in artificial intelligence are _______
  - Program only
  - Architecture only
  - Both Program and Architecture
  - None of the above
- In which agent does the problem generator is present?
  - Learning agent
  - Observing agent
  - Reflex agent
  - None of the above
- Which agent deals with happy and unhappy states?
  - Simple reflex agent
  - Model based agent
  - Learning agent
  - Utility based agent
- What is an 'agent'?
  - Perceives its environment through sensors and acting upon that environment through actuators
  - Takes input from the surroundings and uses its intelligence and performs the desired operations
  - A embedded program controlling line following robot
  - All of the above

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Reflect…

- Agents behavior can be best described by ____________
  - Perception sequence
  - Agent function
  - Sensors and Actuators
  - Environment in which agent is performing
- Rational agent is the one who always does the right thing.
  - True
  - False
- Performance Measures are fixed for all agents.
  - True
  - False
- An omniscient agent knows the actual outcome of its actions and can act accordingly; but omniscience is impossible in reality
  - True
  - False
- Rational Agent always does the right thing; but Rationality is possible in reality.
  - True
  - False
- The Task Environment of an agent consists of ____________
  - Sensors
  - Actuators
  - Performance Measures
  - All of the mentioned

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Reflect…

- Categorize Crossword puzzle in Fully Observable / Partially Observable.
  - Fully Observable
  - Partially Observable
  - All of the mentioned
  - None of the mentioned
- The game of Poker is a single agent.
  - True
  - False
- What is called an exploration problem?
  - State and actions are unknown to the agent
  - State and actions are known to the agent
  - Only actions are known to agent
  - None of the mentioned

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Reflect…

- Fine-tuned model from one field may not work in other field
  - True
  - False
  - Don't know
- A.M. Turing developed a technique for determining whether a computer could or could not demonstrate the artificial Intelligence, Presently, this technique is called ___________
  - Turing Test
  - Algorithm
  - Boolean Algebra
  - Logarithm
- What was originally called the "imitation game" by its creator?
  - The Turing Test
  - LISP
  - The Logic Theorist
  - Cybernetics
- Which programming language is most used for AI?
  - Python
  - Java
  - Lisp
  - R
  - Prolog

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Reflect…

- Bottom Up Approach focuses on ____
  - on action and behavior
  - on action and function
  - on representation and function
  - on representation and behavior

- Recursively Enumerable Language
  - A language L with a set of input symbols Σ, is said to be recursively enumerable if there exists a Turing Machine that accepts it

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Reflect…

- Categorize Crossword puzzle in Fully Observable / Partially Observable.
  - Fully Observable
  - Partially Observable
  - All of the mentioned
  - None of the mentioned

- The game of Poker is a single agent.
  - True
  - False

- What is called an exploration problem?
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