Introduction of AI

Text Book

- Stuart Russell and Peter Norvig
  - Artificial Intelligence - A Modern Approach, Prentice Hall, 3rd edition, 2011
- Elaine Rich and Kevin Knight:
  - Artificial Intelligence, Third Edition,
  - Tata McGraw, Hill, 2008

Suggestion for project

- A machine learning approach in financial markets
- Background Analysis and Design of an Agent-Based Operating System
- Intelligent Tourist Information System
- Classification of objects in images based on various object representations
- Visual Semantic Web Ontology based E-learning management system
- Controlling a Robot Hand in Simulation and Reality
- Face Detection by Image Discriminating
- An intelligent mobile robot navigation technique using RFID Technology
- Library Robot – Path Guiding Robotic System with AI using Microcontroller
- Wireless AI Based Fire Fighting Robot for Relief Operations
- Expert Systems

- Artificial
  - Produced by human art or effort, rather than originating naturally.
- Intelligence
  - The ability to acquire knowledge and use it
- **So AI was defined as:**
  - AI is the study of ideas that enable computers to be intelligent.
  - AI is the part of computer science concerned with
    - ✓Design of computer systems that exhibit human intelligence - Dictionary

From the above two definitions, we can see that AI has two major roles:

- Study the intelligent part concerned with humans.
- Represent those actions using computers.

What is Artificial Intelligence ?

- Making computers that think?
  - The automation of activities we associate with human thinking, like
  - Decision making, Learning ... ?
- The art of creating machines that
  - Perform functions that require intelligence when performed by people ?
- A field of study that seeks to explain and emulate
  - Intelligent behaviour in terms of computational processes ?

What is Artificial Intelligence ?

- A branch of computer science that is concerned
  - With the automation of intelligent behaviour ?
- The study of computations that make it possible
  - To perceive, reason and act ?
- The study of mental faculties through the use of computational models ?

State of Art with AI

- **Autonomous planning and scheduling:**
  - Hundred million miles from Earth,
  - NASA's Remote Agent program became the first on-board autonomous planning program
    - ✓To control the scheduling of operations for a spacecraft.
  - It monitored the operation of the spacecraft as the plans were executed
    - ✓Detecting, diagnosing, and recovering from problems.

State of Art with AI

- **Game playing :**
  - IBM's Deep Blue became the first computer program to defeat the world champion in a chess match when it bested Garry Kasparov by a score of 3.5 to 2.5 in an exhibition match.
  - A "new kind of intelligence" across the board
  - "The brain's last stand."

State of Art with AI

- **Autonomous control :**
  - The ALVINN computer vision system was trained to steer a car to keep it following a lane
  - NAVLAB computer-controlled minivan navigation across the United States-for 2850 miles
    - ✓Video cameras that transmit road images to ALVINN
    - ✓Alvinn computes the best direction to steer, based on experience from previous training runs.
  - It was in control of steering the vehicle 98%
    - ✓A human took over the other 2%, mostly at exit ramps

State of Art with AI

- Medical diagnosis programs
  - Based on probabilistic analysis have been able to perform at the level of an expert physician in several areas of medicine.
  - A leading expert on lymph-node pathology scoffs at a program's diagnosis of a difficult case
  - The machine points out the major factors influencing its decision and
    - ✓Explains the subtle interaction of several of the symptoms in this case

State of Art with AI

- **Logistics Planning :**
  - Persian Gulf crisis of 1991, U.S. forces deployed a Dynamic Analysis and Replanning Tool, DART.
  - 50,000 vehicles, cargo, and people at a time,
  - Account for starting points, destinations, routes, and conflict resolution among all parameters
  - Few hours vs. weeks
  - 30-year investment in AI paid off

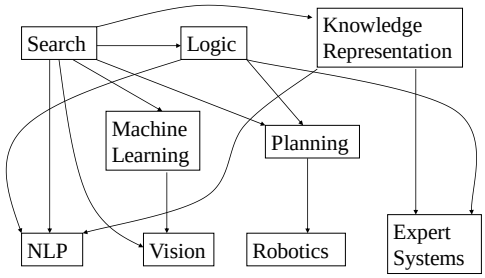
State of Art with AI

- **Robotics :**
  - HipNav is a system that uses computer vision techniques to create a three-dimensional model of a patient's internal anatomy
  - Uses robotic control to guide the insertion of a hip replacement prosthesis.
  - Many surgeons now use robot assistants in microsurgery.

State of Art with AI

- **Language understanding and problem solving**
  - PROVERB (Littman *et al.,* 1999) is a computer program
  - Solves crossword puzzles better than most humans, using constraints on possible word fillers,
  - A large database of past puzzles, dictionaries and
    - ✓Online databases such as a list of movies and the actors that appear in them

Areas of AI and Some Dependencies



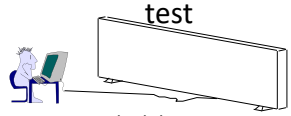
Definition

- Thought process
  - Thinks as human
  - Think rationally – Right thing given what it knows
    - ?? Do human think irrationally
- Action
  - Act as human
  - Rational way of acting
- Approaches as human
  - Hypothesis and confirmation by experimentation
- Approach as rational
  - Mathematics and engineering

What is Artificial Intelligence ?

THOUGHT	**Systems that think like humans**	**Systems that think rationally**
BEHAVIOUR	**Systems that act like humans**	**Systems that act rationally**
	HUMAN	**RATIONAL**

Systems that act like humans Turing test



?

- You enter a room which has a computer terminal.
  - You have a fixed period of time to type what you want into the terminal,
    - ✓Study the replies.
  - At the other end of the line is either a human being or a computer system.
- If it is a computer system
  - At the end of the period you cannot reliably determine whether it is a system or a human
    - ✓The system is deemed to be intelligent.

Systems that act like humans

- These cognitive tasks include
  - *Natural language processing*
    - ✓For communication with human
  - *Knowledge representation*
    - ✓To store information effectively & efficiently
  - *Automated reasoning*
    - ✓To retrieve & answer questions using the stored information
  - *Machine learning*
    - ✓ To adapt to new circumstances

What is Artificial Intelligence ?

THOUGHT	Systems that think like humans	Systems that think rationally
BEHAVIOUR	Systems that act like humans	Systems that act rationally
	HUMAN	RATIONAL

Systems that think like humans: cognitive modeling

- Humans as observed from 'inside'
- How do we know how humans think?
  - Introspection
  - Psychological experiments
  - Brain imaging
- Cognitive Science

What is Artificial Intelligence ?

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Systems that think 'rationally' "Laws of thought"

- Humans are not always 'rational'
- Rational - defined in terms of logic?
- Logic can't express everything (e.g. uncertainty)
- Logical approach is often not feasible
  - In terms of computation time
  - Needs 'guidance'

What is Artificial Intelligence ?

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BEHAVIOUR	Systems that act like humans	Systems that act rationally
	HUMAN	RATIONAL

Systems that act rationally: "Rational agent"

- Rational behavior?
  - Doing the right thing
- The right thing?
  - Expected to maximize goal achievement, given the available information
- Giving answers to questions is 'acting'.

Rational agents

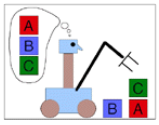
- This course is about designing rational agents
- An agent is an entity that
  - Perceives and Acts
- Abstractly, an agent is a function from percept histories to actions

  [f: P* → A]
- For any given class of environments and tasks,
  - We seek the agent with the best performance
    - Class of agents
  - Caveat: Computational limitations make perfect rationality unachievable

    → Design best program for given machine resources

Goals of AI

- To make computers more useful by letting them take over dangerous or tedious tasks from human
- Understand principles of human intelligence



- Machine
  - Something that acts mechanically
  - Acts on well defined rules
  - Laws of physics
- Is computer machine – SPC?
- Is Human Machine?
- Freewill, Emotions
- Emotional machine - Marvin Minsky
  - Memories – labels – State
  - Dog – Cat – Mosquito, bacterias , Viruses,
  - Intuition
    - Can it be defined by rules

- Chinese room and translation
  - Is it really intelligence
  - Addition, Fourier , Laplace transform
  - Neural network
- Language vs. Thought
  - Noam Chomsky – Universal Grammar
  - Human are born with UG and learn language as per their environment

Goal of AI

- Build a machine with mind of its own.
- For an intelligent agent
  - We need it have a mind that can represent world in a way that it can manage representation efficiently.
  - Operate in world
  - Do something useful for itself and achieve its goal.
- Our thoughts are reflection of what is out there
- What is out there is reflection of our thought.

CAPTcHA

➢"Completely Automated Public Turing test to tell Computers and Humans Apart,"

Cognitive modeling

- Self-examination
- Behavior analysis
- Brain Imaging

AI types

Criteria based AI

Strong AI

- Uses clustering and association
- Eg: Chess is a strong AI

Weak AI

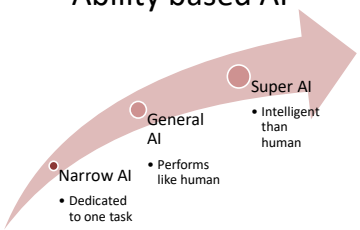
- Uses keyword or request
- Eg: Coffee machine switches on whenever your voice is enabled

Criteria based AI

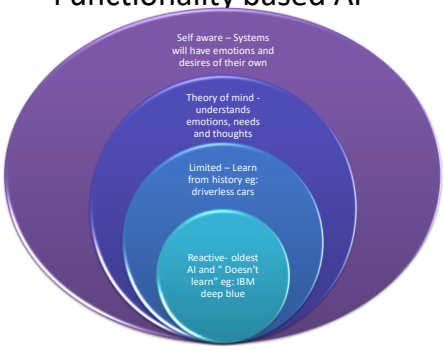
Strong AI

Weak AI

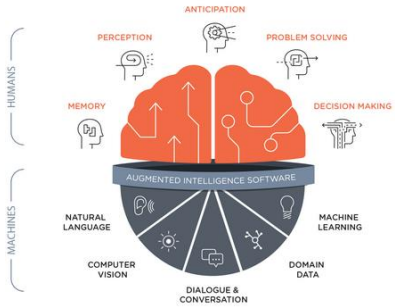
Ability based AI



Functionality based AI



Human Intelligence Vs Artificial Intelligence



AI-100%correct

- Paperless in invoicing
- Job applications
- Automated testing
- Online marketing & sales
- Automatic updates
- Importing and Exporting data

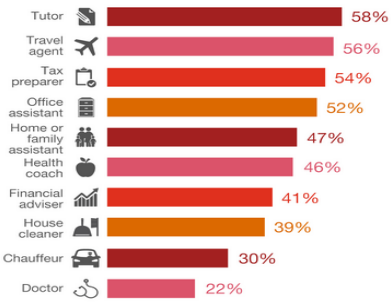
Consequences of AI

- Efficiency
- Safer working condition
- Precision and accuracy

Drawbacks of AI

- Lack of cognitive function
- Limits to memory capabilities

AI- Statistics for 2020

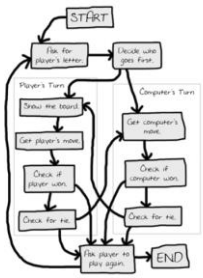


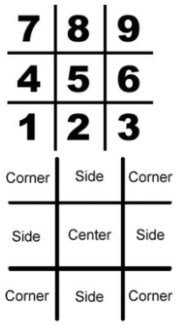
Tools

AI - Future

- Cognitive Science
  - –Robot can dream, get angry

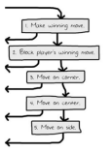
Tic-Tac-Toe





The AI's algorithm

- 1 see if there's a move the computer can make that will win the game.
  - If there is, take that move. Otherwise, go to step 2
- 2 See if there's a move the player can make that will cause the computer to lose the game.
  - If there is, move there to block the player. Otherwise, go to step 3.
- 3 Check if any of the corner spaces
  - (spaces 1, 3, 7, or 9) are free. If so, move there.
  - If no corner piece is free, then go to step 4.
- 4 Check if the center is free.
  - If so, move there. If it isn't, then go to step 5.
- 5 Move on any of the side pieces
  - (spaces 2, 4, 6, or 8). There are no more steps, because if the execution reaches step 5 the side spaces are the only spaces left.



Functions

- ToTboardDraw
  - Nine spaces for each
  - Test it
  - Coins as list/array
- Playerinput
  - Check for X, O as chosen by player
- Fullboard
- winner
- Computermove
  - Iterate AI algo for computer win
  - Iterate AI algo for blocking player
  - Occupy one of the corner..
- Random_selection
  - X, O
  - One in list, corners
- playagain
- winner

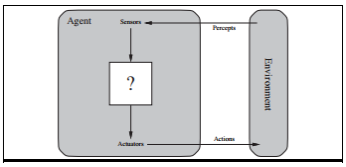
Design Principles

- Building successful agents-systems that can reasonably be called **intelligent**
  - **Agents and environment**
  - Notion of an agent is meant to be a tool
    - ✓For analyzing systems.
- How well an agent can behave
  - Depends on the nature of the environment
  - Some environments are more difficult than others.
- A rational agent
  - One that behaves as well as possible.

Stuart J . Russell and Peter Norvig, Artificial Intelligence: A Modern Approach

Agent and Environment

- *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.*



Stuart J. Russell and Peter Norvig, Artificial Intelligence: A Modern Approach

Agent

- An agent is anything that can be viewed as
  - Perceiving its environment through sensors
    - ✓Human - Ears, Eyes, Touch, Mouth
    - ✓Robot - Camera, Infrared sensors
    - ✓Software Agent – Key strokes, Files, Network Packets
  - Acting upon that environment through actuators
    - ✓Human- Hands, Legs, Fingers, Sound
    - ✓Robot - Motor – Movements, Holding, Horn, Music, Display systems, Pneumatic, Hydraulic
    - ✓Software Agent – Display systems , Files, Network Packets,
- Notion of an agent is meant to be
  - A tool for analyzing systems.

Stuart J. Russell and Peter Norvig, Artificial Intelligence: A Modern Approach

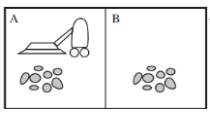
Percept

- The agent's perceptual inputs at any given instant.
- An PERCEPT SEQUENCE
  - agent's **percept sequence** is the complete history of everything the agent has ever perceived.
  - In general, *an agent's choice of action at any given instant can depend on the entire percept sequence observed to date*
  - Specify the agent's choice of action for every possible percept sequence

Stuart J. Russell and Peter Norvig, Artificial Intelligence: A Modern Approach

Agent Behaviour

- An agent's behavior is AGENT FUNCTION
  - It maps any given percept sequence to an action.
- Describe an agent by
  - Tabulating its function – May be a large table
  - Percept sequence -> Action
    - ✓The agent function is an abstract mathematical description
  - External characterization
- Internally – Implementation
  - An agent program, algorithm, data, data structure.



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, Clean]	Right
[A, Clean], [A, Clean], [A, Dirty]	Suck
⋮	⋮

- What is the rightway to fill the table?
- How you describe an agent
  - Good, Bad, Intelligent, Stupid

- AI operates at the most interesting end of the spectrum,
  - where the artifacts, agents, have significant computational resources
  - The task environment requires
    - ✓nontrivial decision making.

Rational agent

- A **rational agent** is one that does the right thing ?? measure
  - Performance measure
    - ✓The RA generates a sequence of actions according to the percepts it receives.
    - ✓This sequence of actions causes the environment to go through a sequence of states.
    - ✓If the sequence is desirable, then the agent PERFORMANCE MEASURE has performed well.
  - Emphasis on environment state and not agent state
  - A designer need to devise one appropriate one as PM
    - ✓For a vacuum cleaner - The amount dirt cleaned in a hour
    - ✓Sour grapes

Rational agent

- *It is better to design performance measures according to*
  - What one actually wants in the environment, rather than according to how one thinks the agent should behave
  - What is clean floor? Need philosophy
    - ✓*Average cleanliness*
    - ✓*Mediocre* job all the time
    - ✓High energy to clean the floor – long break
    - ✓Average rich/poor
    - ✓Rich and Poor combination

Rational agent

- Rational at any given time depends on
  - The performance measure that defines the criterion of success.
  - The agent's prior knowledge of the environment.
  - The actions that the agent can perform.
  - The agent's percept sequence to date.
    - ✓*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.*

Rational agent

- Omniscience agent knows the *actual* outcome of its actions and can act accordingly.
  - Omniscience is impossible in reality
    - ✓Perfection in performance
  - Rationality is not the same as perfection
  - Rationality maximizes *expected* performance,
    - ✓while perfection maximizes *actual* performance
- **Information gathering** is an important part of rationality.
  - Doing actions *in order to modify future percepts*

Rational agent

- We haven't inadvertently allowed the agent to
  - Engage in **under intelligent** activities.
- Gather information and also Learn
  - The agent's initial configuration could reflect some prior knowledge of the environment,
  - As the agent gains experience this may be modified and augmented.
  - Beetle, Female Sphex wasp

Rational agent

- Autonomy
  - If an agent relies on the prior knowledge of its designer
    - ✓Not on its own percepts, we say that the agent lacks **autonomy**.
  - An AI agent with some initial knowledge and an ability to learn.
    - ✓After sufficient experience of its environment, the behavior of a rational agent can become effectively *independent* of its prior knowledge.
  - VCA – When and where additional dirt appears
  - Clock - No input (percepts)
    - ✓Run only but its own algorithm (prior knowledge)
    - ✓No learning, no experience, etc.

Rational agent

- Same agent would be irrational under different circumstances.
  - For example, once all the dirt is cleaned up, the agent will oscillate needlessly back and forth;
  - A better agent for this case would do
    - ✓ Do nothing, once it is sure that all the squares are clean.
    - ✓ If clean squares can become dirty again, the agent should occasionally check and re-clean them.
    - ✓ If the geography of the environment is unknown, the agent will need to explore it rather than stick to squares A and B.

The Structure of Intelligent Agents

- The agent function maps from percept histories to actions:
  - $f : P* \rightarrow A$
- Agent's structure can be viewed as
  - Agent = Architecture + Agent Program
  - Architecture = the machinery that an agent executes on.
  - Agent Program = an implementation of an agent function.
  - The agent program runs on the physical architecture to produce *f*.

Specification of Task environment

- Task environments are the problems.
  - Rational agents are solution to the problems
- Task environment is specified by
  - Performance
  - Environment
  - Actuators
  - Sensors
    - ✓ In designing an agent, the first step must always be to specify the task environment as fully as possible.
- The flavor of the task environment
  - Directly affects the appropriate design for the agent program.

PEAS

- Automated Taxi
  - Performance measure: Be safe, reach destination, maximize profits, fast, Comfortable, obey laws, …
  - Environment: Urban streets, freeways, other traffic, pedestrians, stray animals, roadworks, police cars, puddles, weather, customers, left drive, right drive …
  - Actuators: Steering wheel, accelerator, brake, Signal, Display, Communicate to customer, other vehicles, horn
  - Sensors: Camera, Sonar, odometer, keyboard, accelerometers, gauges, engine sensors, GPS, …

PEAS

- A medical diagnosis system
  - **Performance measure:** Healthy patient, minimal costs, no lawsuits, …
  - **Environment:** Patient, doctors, nurses, hospital, pharmacy, equipment, …
  - **Actuators:** Screen display (questions, tests), diagnoses, treatments, referrals, …
  - **Sensors:** Keyboard , File, Network packets
    - ✓ entry of symptoms, findings, patient's answers, …

PEAS

- Internet Shopping agent
  - **Performance measure:** Price, quality, appropriateness, efficiency, …
  - **Environment:** Current and future Web sites, vendors, shippers, …
  - **Actuators:** Display to user, follow URL, fill in form
  - **Sensors:** Web pages (text, graphics, scripts …

PEAS

- Vacuum Machine
  - Performance - one point for each clean square at each time step
  - Environment – Known a priori, The Left and Right actions move the agent left and right
    - ✓Except when this would take the agent outside the environment, → the agent remains where it is
  - Actions - Left, Right, and Suck
  - Sensor - Agent correctly perceives its location and whether that location contains dirt

Task environment

- The environment may be
  - Real or artificial
  - Behavior of the agent
    - ✓The percept sequence generated by the environment,
    - ✓The performance measure.
    - ✓The complexity of the relationship

Task environment

- A softbot Web site operator
  - – Designed to scan Internet news sources and
  - – Show the interesting items to its users,
  - – While selling advertising space to generate revenue.
  - ✓Needs NLP,
  - ✓Learns what each user and advertiser is interested in,
  - ✓Change its plans dynamically

Task environment

- The Internet is an environment
  - Complexity equal to the physical world
  - Inhabitants include many artificial and human agents
- The range of task environments that might arise in AI is vast.
  - Small number of dimensions along which task environments can be categorized .

Properties of Environment

- The environment has multifold properties
  - Few of the categorization
- **Fully / Partially Observable /Unobservable**–
  - If it is possible to determine the complete state of the environment at each time point from the percepts
  - If the sensors detect all aspects that are *relevant* to the choice of action
    - ✓relevance, in turn, depends on the performance measure.
  - Noisy, Inaccurate sensors → partially observable.
    - ✓Local dirt sensor of the cleaner cannot tell if the squares are clean/dirty?

Properties of Environment

- **Single agent / Multiple agents** –
  - The environment may contain other agents which may be of the same or different kind as that of the agent.
  - Agent vs Object
    - ✓B's behavior is best described as maximizing a performance measure whose value depends on agent A's behavior.
  - Competitive multi agent - Chess
  - Cooperative multi agent – Automated Taxi
    - ✓Parking space
  - Communication
  - Randomized behavior

Properties of Environment

- **Deterministic / Non-deterministic (stochastic)**
  - If the next state of the environment is completely determined by
    - ✓The current state and
    - ✓the actions of the agent, then the environment is deterministic
  - If the environment is partially observable, then it could *appear* to be stochastic.

Properties of Environment

- **Stochastic**
  - implies that uncertainty about outcomes is quantified in terms of probabilities;
  - VAC, Automated taxi may become stochastic
    - ✓Some unobservable aspects such as Noise, Unknown.
- **Nondeterministic**
  - Actions are characterized by their *possible* outcomes, but no probabilities are attached to them.
  - Nondeterministic environment descriptions are usually associated with performance measures that require the agent to succeed for *all possible* outcomes of its actions

Properties of Environment

- **Deterministic / Non-deterministic (stochastic)**
  - Most real situations are so complex that it is impossible to keep track of all the unobserved aspects
    - ✓For practical purposes, they must be treated as stochastic.
    - ✓VC- randomly appearing dirt and an unreliable suction mechanism
    - ✓Traffic

Properties of Environment

- **Episodic / Non-episodic** –
  - In an episodic environment, each episode consists of the agent perceiving and then acting.
  - The quality of its action depends just on the episode itself.
  - Subsequent episodes do not depend on the actions in the previous episodes.
  - Episodic environments are much simpler because the agent does not need to think ahead.
  - In sequential environments, the current decision could affect all future decisions
    - ✓Taxi driving, Chess

Properties of Environment

- **Static / Dynamic** –
  - If the environment does not change while an agent is deliberating (acting), then it is static;
  - The agent need not keep looking at the world while it is deciding on an action,
    - ✓It need not worry about the passage of time.
    - ✓Destination
- Dynamic – Environment
  - Always changing – Number of people in street
  - continuously asking the agent what it wants to do
    - ✓ If it hasn't decided yet, that counts as deciding to do nothing

Properties of Environment

- **Semi dynamic**
  - If the environment itself does not change with the passage of time but the performance score of agent changes.
- **Discrete / Continuous** –
  - There are a limited number of distinct, clearly defined, states of the environment
    - ✓Chess
  - 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.
    - ✓Driving

Properties of Agent

- **Known** vs. **unknown**
  - A known environment, the outcomes for all actions are given,
  - For stochastic - outcome probabilities
- Unknown - the agent will have to learn how it works in order to make good decisions
  - *known* environment and *partially* observable
    - ✓Solitair
  - *Unknown* environment and *Fully* observable
    - ✓New Video game

Properties of Environment

- The hardest case is
  - *partially observable*,
  - *Multi agent*,
  - *stochastic*,
  - *sequential*,
  - *dynamic*,
  - *continuous*, and
  - *unknown*.

Properties of Environment

- **Accessible / Inaccessible** –
  - If the agent's sensory apparatus can have access to the complete state of the environment, then the environment is accessible to that agent.

Environment example

Crossword puzzle	Crossword puzzle
Observable:	Observable: Fully
Agents:	Agents: Single
Deterministic:	Deterministic: Deterministic
Episodic:	Episodic: Sequential
Static:	Static: Static
Discrete:	Discrete: Discrete

Environment example

Taxi driving	Taxi driving
Observable:	Observable: Partially
Agents:	Agents: Multi
Deterministic:	Deterministic: Stochastic
Episodic:	Episodic: Sequential
Static:	Static: Dynamic
Discrete:	Discrete: Continuous

Environment example

English tutor:	English tutor:
Observable:	Observable: Partially
Agents:	Agents: Multi (why?)
Deterministic:	Deterministic: Stochastic
Episodic:	Episodic: Sequential
Static:	Static: Dynamic
Discrete:	Discrete: Discrete

Environment example

Image analysis:	Image analysis:
Observable:	Observable: Fully
Agents:	Agents: Single
Deterministic:	Deterministic: Deterministic
Episodic:	Episodic: Episodic
Static:	Static: Semi
Discrete:	Discrete: Continuous

Table driven Agent

- Designers must construct a table
  - Contains the appropriate action for every possible percept sequence.
  - Number of Percept – P → Look up table size $\sum_{t=1}^{T} |\mathcal{P}|^t$
  - Life Time of agent t
    - ✓Total number of percepts received

function TABLE-DRIVEN-AGENT(*percept*) **returns** an action
persistent: *percepts*, a sequence, initially empty
table, a table of actions, indexed by percept sequences, initially fully specified

append *percept* to the end of *percepts*
action ← LOOKUP(*percepts*, *table*)
return *action*

Table driven Agent

- Playing Chess
  - P = 10
  - T = 150
  - Need a table of 10^{150} entries

Table driven Agent

- No physical agent in will have the space to store the table,
- The designer would not have time to create the table
- No agent could ever learn all the right table entries from its experience,
- Even if the environment is simple enough
  - To yield a feasible table size,
    - ✓the designer still has no guidance about how to fill in the table entries.

Principle of intelligent system

- Simple reflex agents;
- Model-based reflex agents;
- Goal-based agents; and
- Utility-based agents.

Simple reflex agents

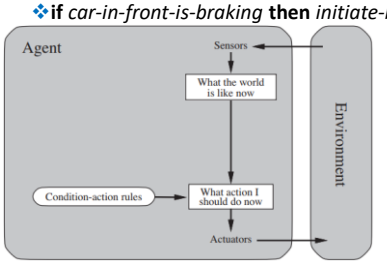
- Select actions on the basis of
  - The *current* percept,
  - Ignoring the rest of the percept history
  - VC agent's Decision is based only on
    - ✓Whether that location contains dirt and The current location and . 4^T vs. 4

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*

Simple reflex agents

- **Condition–action rule**
  - **if** *car-in-front-is-braking* **then** *initiate-braking*



Simple reflex agents

- A general-purpose interpreter for
  - Condition– action rules
  - INTERPRET-INPUT function
    - ✓Percept → Current state
  - Limited intelligence
    - ✓Decision only if correct percept

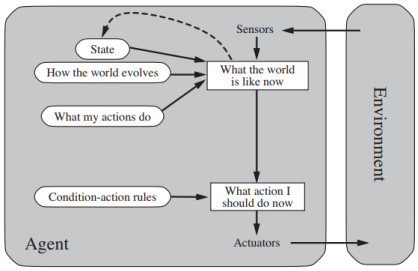
function SIMPLE-REFLEX-AGENT(*percept*) **returns** an action
  persistent: *rules*, a set of condition–action rules

  state ← INTERPRET-INPUT(*percept*)
  rule ← RULE-MATCH(*state*, *rules*)
  action ← *rule*.ACTION
  return *action*

Model-based reflex agents

- The most effective way to handle partial observability
  - For the agent to keep track of the part of the world it can't see now.
  - Internal state – Model of the world
    - ✓Depends on the percept history and
    - ✓It reflects at least some of the unobserved aspects of the current state.
    - ✓How the world evolves independently of the agent?
    - ✓How the agent's own actions affect the world ?

Model-based reflex agents



Model-based reflex agents

- What is the change from Simple reflex agent?

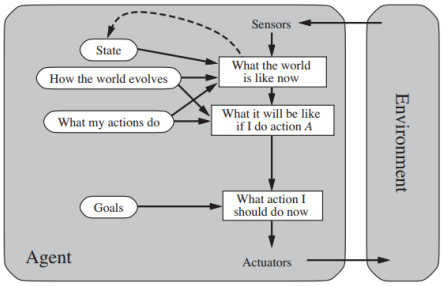
function MODEL-BASED-REFLEX-AGENT(*percept*) **returns** an action
  persistent: *state*, the agent's current conception of the world state
    model, a description of how the next state depends on current state and action
    rules, a set of condition–action rules
    action, the most recent action, initially none

  state ← UPDATE-STATE(*state*, *action*, *percept*, *model*)
  rule ← RULE-MATCH(*state*, *rules*)
  action ← *rule*.ACTION
  return *action*

Goal based agent

- Knowing something about the current state of the environment
  - is not always enough to decide what to do.
  - At a junction correct decision depends on
    - ✓Where the taxi is trying to go / get to.
  - Goal – describes situations that are desirable from agents perspective
  - Agent need to combine goal with Model
  - Simple vs. Complex action for a goal
    - ✓Search and Planning subfields of AI

Goal based agent



Goal based agent

- Decision making
  - Involves consideration of the future— Following Two
    - ✓What will happen if I do such-and-such?"
    - ✓Will that make me reach goal / Happy?
    - ✓Different from rule based as in Simple Reflex agent
    - ✓Series of actions and not one action
    - ✓Break vs. Slow down
    - ✓Appears less efficient, but it is more flexible
      - Knowledge that supports its decisions is represented explicitly and can be modified
      - Application of brake during Rain,
      - One destination vs. Many