Unit-1- Introduction to AI

AI techniques, Problem solving with AI, AI Models, Data acquisition and learning aspects in AI, Problem solving- Problem solving process, formulating problems, Problem types and characteristics, Problem space

and search, Toy Problems – Tic-tac-toe problems, Missionaries and Cannibals Problem, Real World Problem – Travelling Salesman Problem

Problem-solving

Introduction to AI

- According to Rich and Knight,

  "AI is the study of how to make computers do things which at the moment, people do better"

- Branch of science which makes machine intelligent enough in comparable to people

- Involves the study of Psychology (human), giving human reactions to a machine and also mathematical modelling to optimize

Introduction to AI

- Horizon of AI includes,
  - Knowledge Transmission
  - Knowledge Representation
  - Automated Reasoning
- Machines should act rationally

What is AI?

"The exciting new effort to make computers think ... *machines with minds*, in the full and literal sense" (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning ..." (Bellman, 1978)	"The study of mental faculties through the use of computational models" (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act" (Winston, 1992)
"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better" (Rich and Knight, 1991)	"A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkoff, 1990) "The branch of computer science that is concerned with the automation of intelligent behavior" (Luger and Stubblefield, 1993)

Figure 1.1 Some definitions of AI. They are organized into four categories:

Systems that think like humans.	Systems that think rationally.
Systems that act like humans.	Systems that act rationally.

Stuart J. Russell, Peter Norwig , Artificial Intelligence –A Modern approach

SRM INSTITUTE OF SCIENCE & TECHNOLOGY
(Deemed to be University u/s 3 of UGC Act, 1956)

(ADVANTAGES OF AI)

Image and facial recognition

- It can help make data safer and more secure.
- For example, face authentication can ensure that only the appropriate person has access to sensitive information that is intended specifically for them.

Medical diagnosis

- Provides more exact diagnoses, detects hidden patterns in imaging investigations, and predicts how patients will respond to specific medications.
- This leads to better treatment strategies, fewer clinical errors, and more accurate diagnosis.

Customer service

- Customer service teams can get feedback from customers by using AI.
- For example, AI-powered information can provide agents with information on client intent, language, and sentiment so they are aware of how to approach an encounter.

Recommendation systems

- AI content recommendations help people stay engaged and informed.
- For example, Virtual(Siri and Alexa.), Personalized content on streaming platforms, Apps that suggest best routes based on traffic.

5 WHAT ARE THE DISADVANTAGES OF AI?

- Lack of Transparency → lying about using AI
- Bias and Discrimination → assumtion based of incorrect information
- Privacy Concerns
- Ethical Dilemmas →
- Security Risks
- Concentration of Power
- Dependence on AI
- Job Displacement

Artificial Intelligence VS. Robot

AI	Robot
Programmed to think	Programmed to do
Social Interaction	Low level interaction
Learns	Only as smart as program

Artificial Intelligence Tests

Turing Test

Developed by Alan Turing

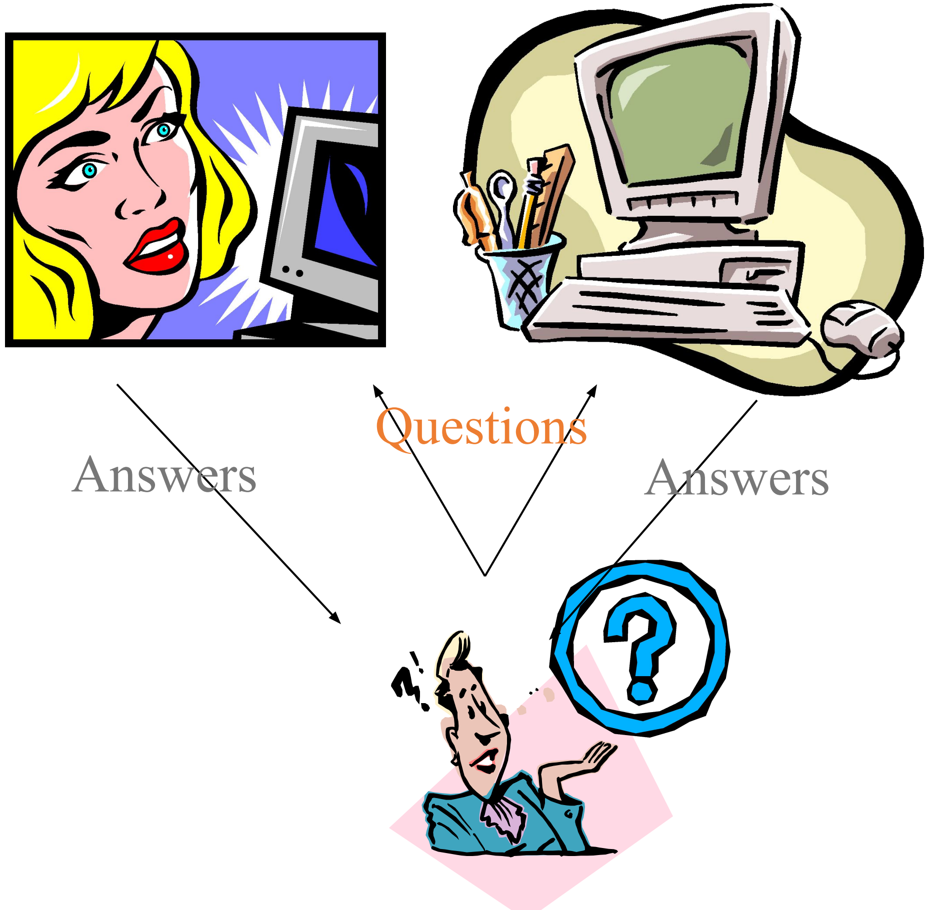
Involves an interpreter, a human, and a computer.

The computer and human have separate conversations with the interpreter.

If the interpreter can’t guess which is the computer or if the interpreter gets it wrong then the computer has Artificial Intelligence.

The Turing Test

- 1950 – Alan Turing devised a test for intelligence called the Imitation Game
  - Ask questions of two entities, receive answers from both
  - If you can't tell which of the entities is human and which is a computer program, then you are fooled and we should therefore consider the computer to be intelligent



Which is the person?
Which is the computer?

Problems with Symbolic AI Approaches

- Scalability
  - It can take dozens or more than-years to create a useful systems
  - It is often the case that systems perform well up to a certain threshold of knowledge (approx. 10,000 rules), after which performance (accuracy and efficiency) degrade
- Brittleness
  - Most symbolic AI systems are programmed to solve a specific problem, move away from that domain area and the system's accuracy drops rapidly rather than achieving a graceful degradation
    - this is often attributed to lack of common sense, but in truth, it is a lack of any knowledge outside of the domain area
  - No or little capacity to learn, so performance (accuracy) is static
- Lack of real-time performance

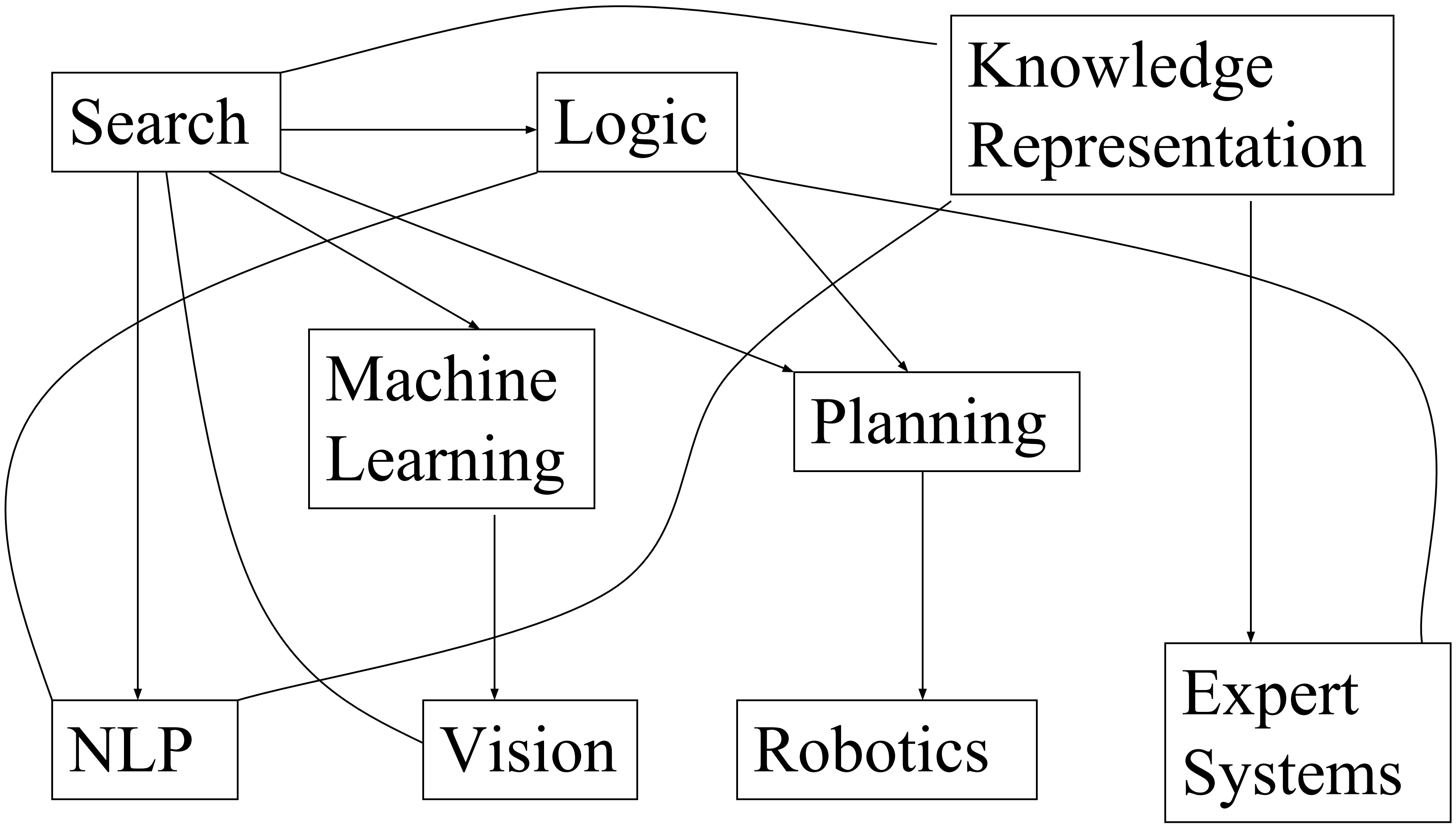
Problems with Connectionist AI Approaches

- No “memory” or sense of temporality
  - The first problem can be solved to some extent
  - The second problem arises because of a fixed sized input but leads to poor performance in areas like speech recognition
- Learning is problematic
  - Learning times can greatly vary
  - Overtraining leads to a system that only performs well on the training set and undertraining leads to a system that has not generalized
- No explicit knowledge-base
  - So there is no way to tell what a system truly knows or how it knows something
- No capacity to explain its output
  - Explanation is often useful in an AI system so that the user can trust the system’s answer

So What Does AI Do?

- Most AI research has fallen into one of two categories
  - Select a specific problem to solve
    - study the problem (perhaps how humans solve it)
    - come up with the proper representation for any knowledge needed to solve the problem
    - acquire and codify that knowledge
    - build a problem solving system
  - Select a category of problem or cognitive activity (e.g., learning, natural language understanding)
    - theorize a way to solve the given problem
    - build systems based on the model behind your theory as experiments
    - modify as needed
- Both approaches require
  - one or more representational forms for the knowledge
  - some way to select proper knowledge, that is, search

Areas of AI and Some Dependencies



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 ?
- the study of mental faculties through the use of computational models ?

What is Artificial Intelligence ?

- the study of computations that make it possible to perceive, reason and act ?
- a field of study that seeks to explain and emulate intelligent behaviour in terms of computational processes ?
- a branch of computer science that is concerned with the automation of intelligent behaviour ?
- anything in Computing Science that we don't yet know how to do properly ? (!)

ARTIFICIAL INTELLIGENCE EXAMPLES

- Manufacturing robots
- Self-driving cars
- Smart assistants
- Healthcare management
- Automated financial investing
- Virtual travel booking agent
- Social media monitoring
- Marketing chatbots

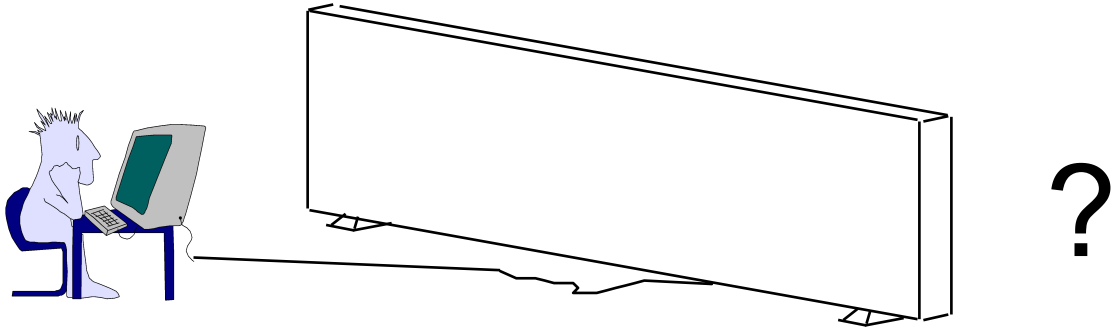
What is Artificial Intelligence ?

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

Systems that act like humans: Turing Test

- “The art of creating machines that perform functions that require intelligence when performed by people.” (Kurzweil)
- “The study of how to make computers do things at which, at the moment, people are better.” (Rich and Knight)

Systems that act like humans



- You enter a room which has a computer terminal. You have a fixed period of time to type what you want into the terminal, and 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, and at the end of the period you cannot reliably determine whether it is a system or a human, then the system is deemed to be intelligent.

Systems that act like humans

- The Turing Test approach
  - a human questioner cannot tell if
    - there is a computer or a human answering his question, via teletype (remote communication)
  - The computer must behave intelligently
- Intelligent behavior
  - to achieve human-level performance in all cognitive tasks

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

The total Turing Test

- Includes two more issues:
  - *Computer vision*
    - to perceive objects (seeing)
  - *Robotics*
    - to move objects (acting)

What is Artificial Intelligence ?

	HUMAN	RATIONAL
THOUGHT	Systems that think like humans	Systems that think rationally
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Systems that think like humans: cognitive modeling

- Humans as observed from 'inside'
- How do we know how humans think?
  - Introspection vs. psychological experiments
- Cognitive Science
- "The exciting new effort to make computers think … machines with *minds* in the full and literal sense" (Haugeland)
- "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning …" (Bellman)

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 ‘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’)
- “The study of mental facilities through the use of computational models” (Charniak and McDermott)
- “The study of the computations that make it possible to perceive, reason, and act” (Winston)

What is Artificial Intelligence ?

	HUMAN	RATIONAL
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Systems that act rationally: “Rational agent”

- Rational behavior: doing the right thing
- The right thing: that which is expected to maximize goal achievement, given the available information
- Giving answers to questions is ‘acting’.
- I don't care whether a system:
  - replicates human thought processes
  - makes the same decisions as humans
  - uses purely logical reasoning

Systems that act rationally

- Logic only *part* of a rational agent, not *all* of rationality
  - Sometimes logic cannot reason a correct conclusion
  - At that time, some *specific (in domain) human knowledge* or information is used
- Thus, it covers more generally different situations of problems
  - Compensate the incorrectly reasoned conclusion

Systems that act rationally

- Study AI as rational agent –

2 advantages:

  - It is more general than using logic only
    - Because: LOGIC + Domain knowledge
  - It allows extension of the approach with more scientific methodologies

Rational agents

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

$$[f: P^* \rightarrow A]$$

- For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- Caveat: computational limitations make perfect rationality unachievable
  - → design best program for given machine resources

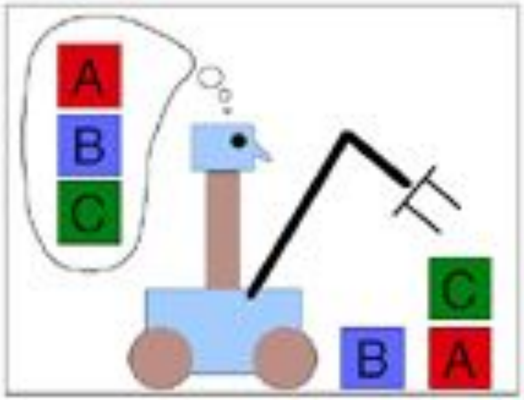
- Artificial
  - Produced by human art or effort, rather than originating naturally.
- Intelligence
- is the ability to acquire knowledge and use it" [Pigford and Baur]
- **So AI was defined as:**
  - AI is the study of ideas that enable computers to be intelligent.
  - AI is the part of computer science concerned with design of computer systems that exhibit human intelligence(From the Concise Oxford 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.

Goals of AI

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



The Foundation of AI

- ***Philosophy***
  - At that time, the study of human intelligence began with no formal expression
  - Initiate the idea of mind as a machine and its internal operations

The Foundation of AI

- Mathematics formalizes the three main area of AI: *computation*, *logic*, and *probability*
  - Computation leads to analysis of the problems that can be computed
    - *complexity theory*
  - Probability contributes the *"degree of belief"* to handle *uncertainty* in AI
  - *Decision theory* combines *probability theory* and *utility theory* (bias)

The Foundation of AI

- Psychology
  - How do humans think and act?
  - The study of human reasoning and acting
  - Provides reasoning models for AI
  - Strengthen the ideas
    - humans and other animals can be considered as information processing machines

The Foundation of AI

- Computer Engineering
  - How to build an efficient computer?
  - Provides the artifact that makes AI application possible
  - The power of computer makes computation of large and difficult problems more easily
  - AI has also contributed its own work to computer science, including: time-sharing, the linked list data type, OOP, etc.

The Foundation of AI

- **Control theory and Cybernetics**
  - How can artifacts operate under their own control?
  - The artifacts adjust their actions
    - To do better for the environment over time
    - Based on an objective function and feedback from the environment
  - Not limited only to linear systems but also other problems
    - as language, vision, and planning, etc.

The Foundation of AI

- Linguistics
  - For understanding natural languages
    - different approaches has been adopted from the linguistic work
  - Formal languages
  - Syntactic and semantic analysis
  - Knowledge representation

The main topics in AI

Artificial intelligence can be considered under a number of headings:

- Search (includes Game Playing).
- Representing Knowledge and Reasoning with it.
- Planning.
- Learning.
- Natural language processing.
- Expert Systems.
- Interacting with the Environment
  (e.g. Vision, Speech recognition, Robotics)

We won't have time in this course to consider all of these.

AI – History and Foundations

- AI entered mainstream before 60 years
- Defined as Statistics, Analysis of patterns and use of formal systems
- In 1940 **Zuse** developed artificial chess playing using high level language called Plankalkul.
- **Leibniz** developed a language for reasoning using symbols

AI – History and Foundations

- **Alan Turing**, British mathematician and WWII code-breaker, is widely credited as being one of the first people to come up with the idea of machines that think in 1950.

- He even created the Turing test, which is still used today, as a benchmark to determine a machine's ability to "think" like a human.

- Though his ideas were ridiculed at the time, they set the wheels in motion, and the term **"artificial intelligence"** entered popular awareness in the mid- 1950s, after Turing died.

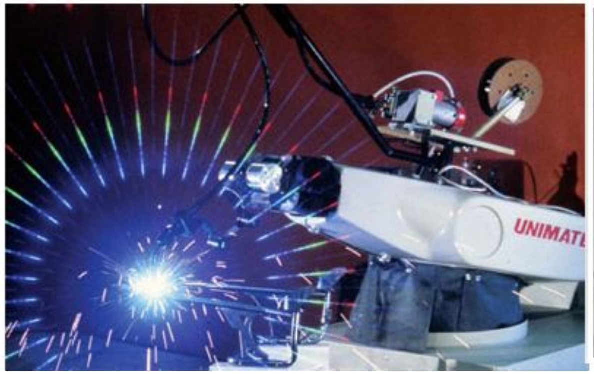
AI – History and Foundations

- **Isaac Asimov**, was an American writer and professor of biochemistry at Boston University.
- The Three Laws of Robotics. The rules were introduced in his 1950 short story "Runaround" and "I,Robot“

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

AI – History and Foundations

- 1951 – First AI based program was written
  - a checkers-playing program written by Christopher Strachey and a chess-playing program written by Dietrich Prinz.
- 1955 – First self learning game playing
  - competing against human players in the game of Checkers
- 1959 – MIT – AI based lab setup
- 1961 – First Robot is introduced into GM's assembly line



AI – History and Foundations

- 1964 – First demo of AI program which understand natural language
- 1965 – First chat bot Eliza was invented
- 1974 – First Autonomous vehicle is created
- 1989 – Carnegie Mellon created the first autonomous vehicle using neural networks
  - ALVINN, which stands for Autonomous Land Vehicle In a Neural Network

AI – History and Foundations

- 1996 – IBM's deep blue – chess playing game
  - Deep Blue won its first game against world champion Garry Kasparov in game one of a six-game match on 10 February 1996.
- 1999 – Sony introduces AIBO – self learning entertaining robot

AI – History and Foundations

- 1999 – MIT AI lab – first emotional AI is demonstrated
- 2004 – DARPA – introduce first vehicle challenge
- 2009 – Google – stared to build a self driving car
- 2010 – Narrative Science AI demonstrate ability to write reports
- 2011 – IBM watson beats jeopardy champions – quiz game
    - the Watson computer system competed on Jeopardy against champions Brad Rutter and Ken Jennings, winning the first place prize of $1 million.

AI – History and Foundations

- 2011 – Google now and Cortana becomes mainstream
- 2016 – Stanford issues the AI 100 reports
- 2016 – UC Berkley launces the centre for human compatible AI

AI – History and Foundations

- AI was started long back

- This is made as possible currently
    - Big data
    - Computing Power

Birth of AI

- Initially, AI dealt with simple reasoning and reaction problems. It requires only very less knowledge base

- Over the period of time, domains like speech recognition, image processing and medical image diagnosis had been added under AI

- Later, AI started to handle complex task with more knowledge base

Examples

- Building intelligent systems,
  - Water tap

    When tank gets filled, switch off

  - Washing machines

    Stops water after reaching particular level

    Fuzzy logic takes necessary amount of water only

  - Traffic control

    Automatically, dynamically adjust signal timing, info to nearby signals, etc…

Examples

- So, the basics of AI,
  - **Machine has to learn**
  - **Machine learn from given knowledge**
  - **Knowledge should be properly represented**

Advantages of Artificial Intelligence

- more powerful and more useful computers
- new and improved interfaces
- solving new problems
- better handling of information
- relieves information overload
- conversion of information into knowledge

The Disadvantages

- increased costs
- difficulty with software development - slow and expensive
- few experienced programmers
- few practical products have reached the market as yet.

AI Techniques

- Types of problem solved,
  - Various day to day problems
  - Identification and Authentication in security
  - Various classification problems in decision making
  - Interdependent and cross domain problem

Data Acquisition and Learning Aspects in AI

- Knowledge discovery
  - Data Mining
  - Machine learning
- Computational learning theory
  - Study and analyse of algorithms
  - Lot of mathematical models
- Neural and Evolutionary computation
  - Neural: mimics the neural behaviour of human beings
  - Evolutionary: Biological behaviours
- Intelligent agents and multi-agent systems
  - Agent: a software which is flexible and supports users

Problem solving

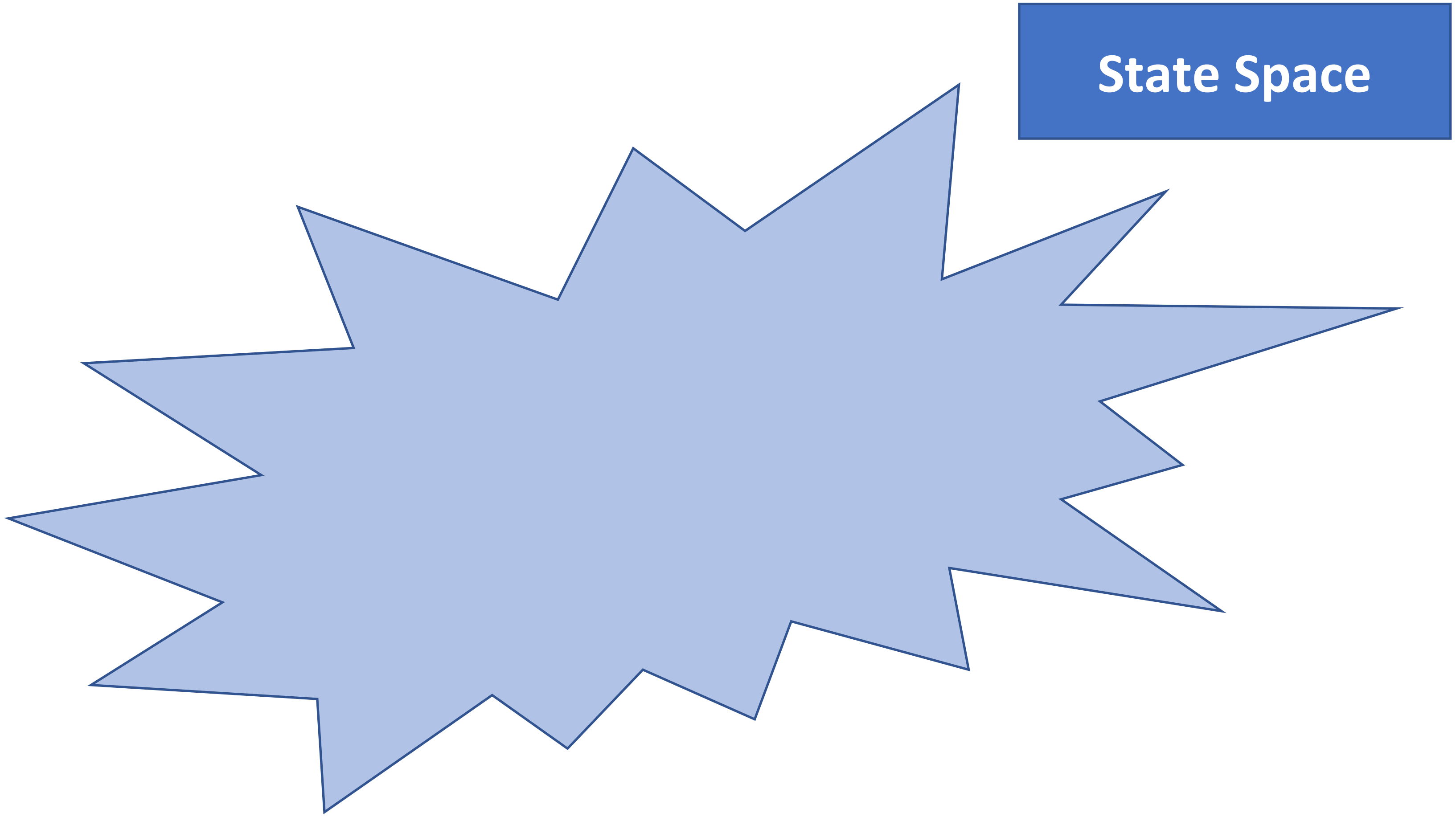
- Given situation -> Desired situation

- Task of AI – to perform series of action to move from given situation to desired situation

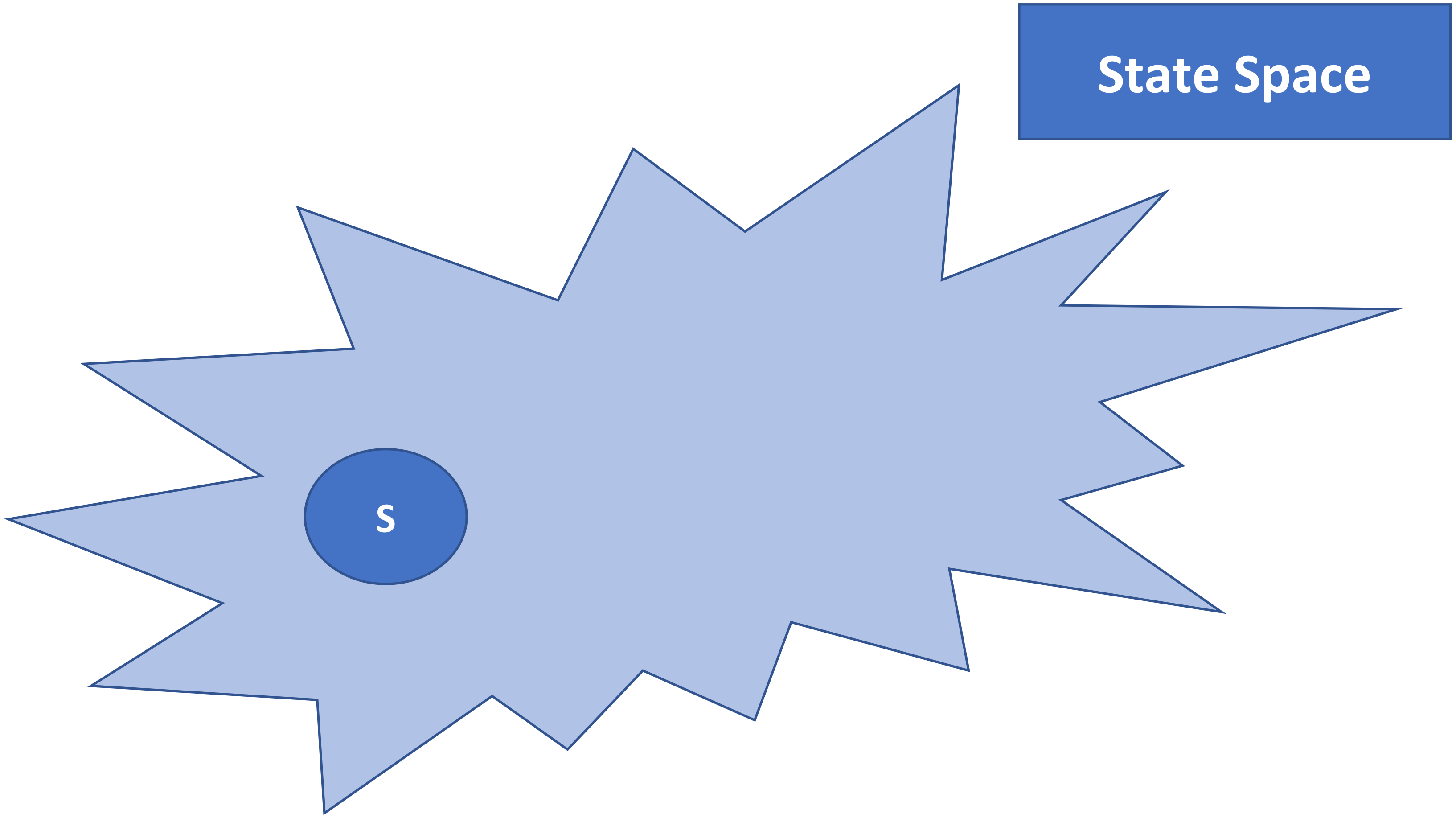
Types of problem solving

- Knowledge based
  - Memory based
  - Rule based
- Search based

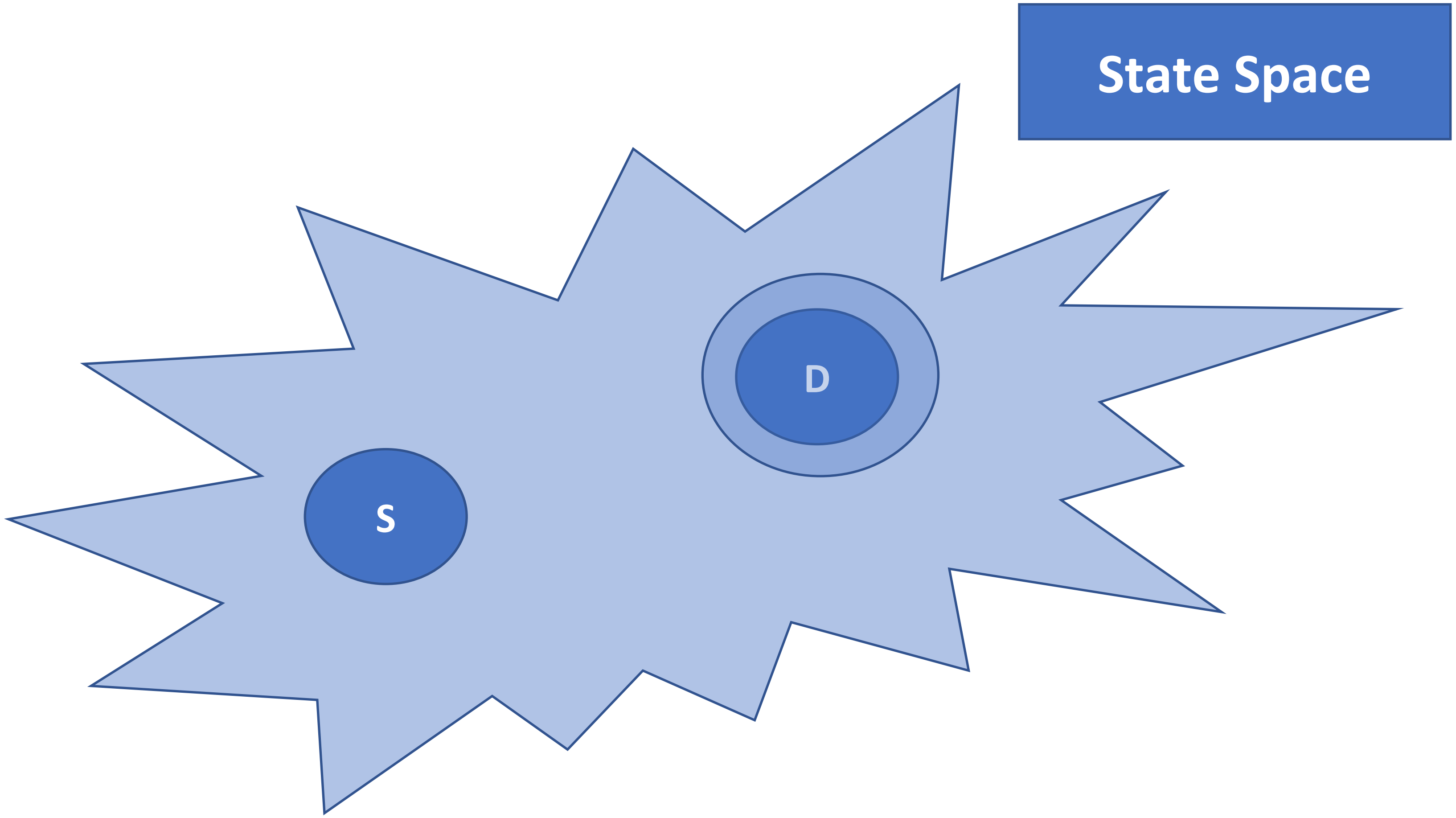
Search based method – state space



Search based method – state space

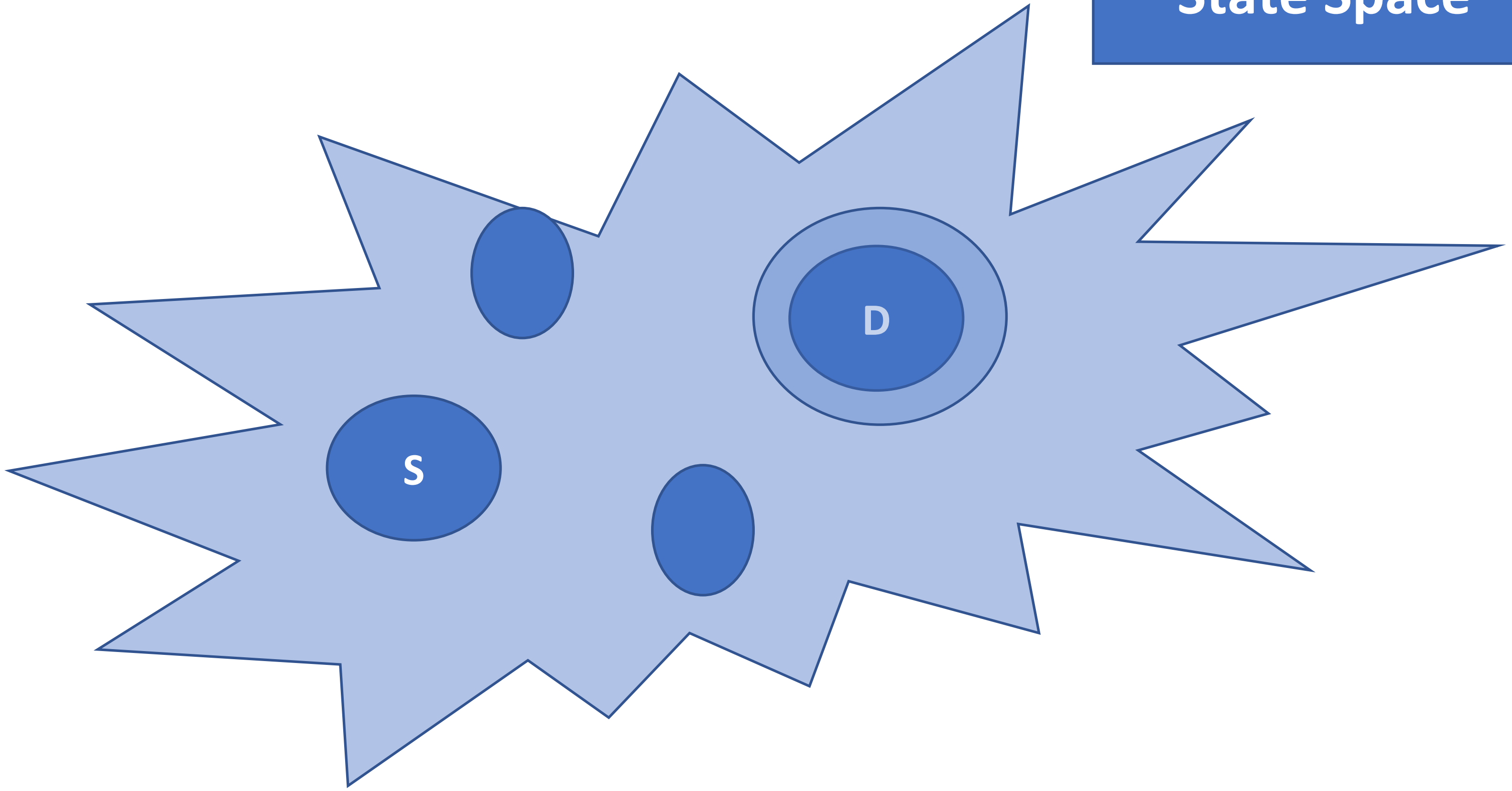


Search based method – state space

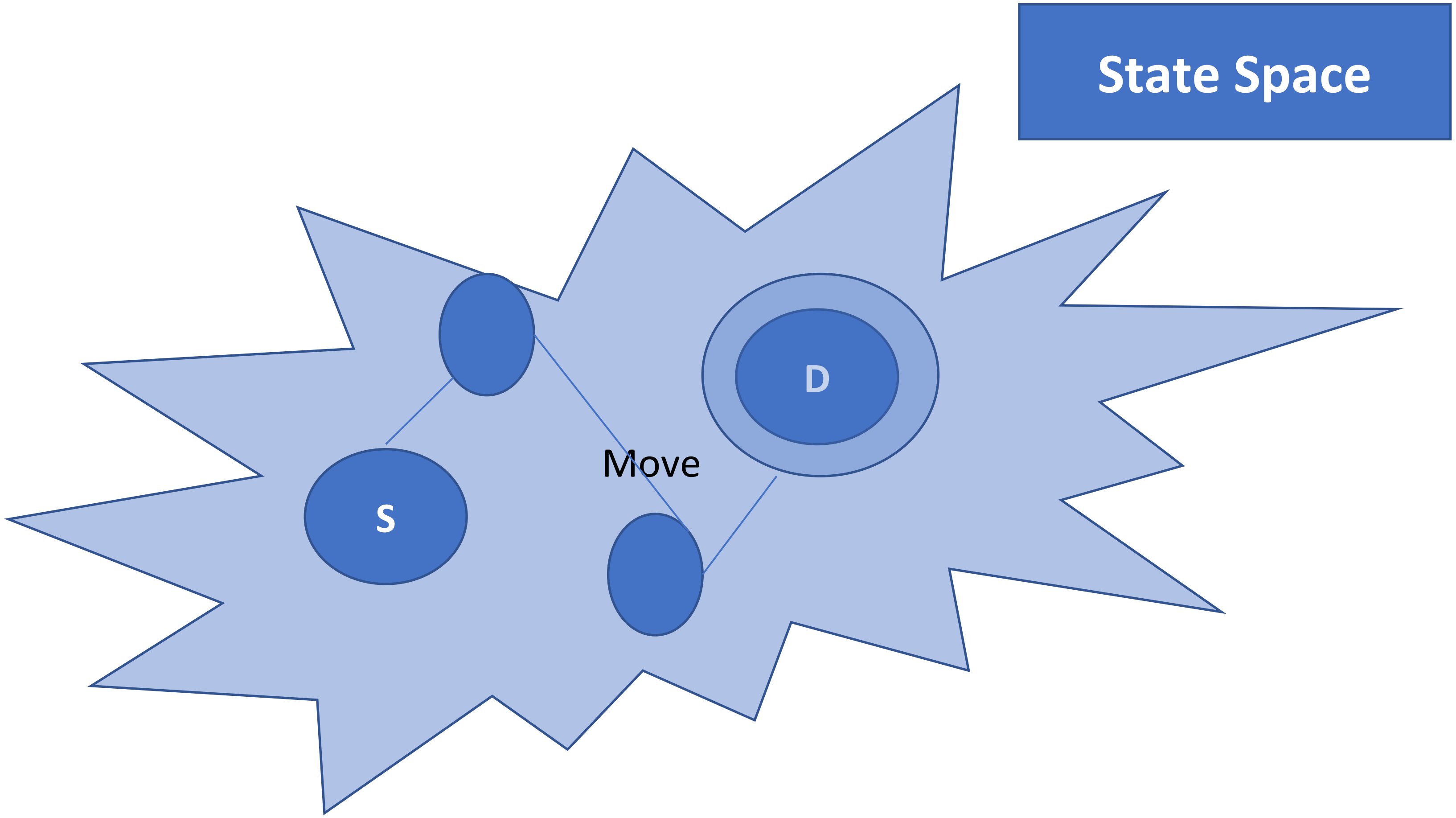


Search based method – state space

State Space

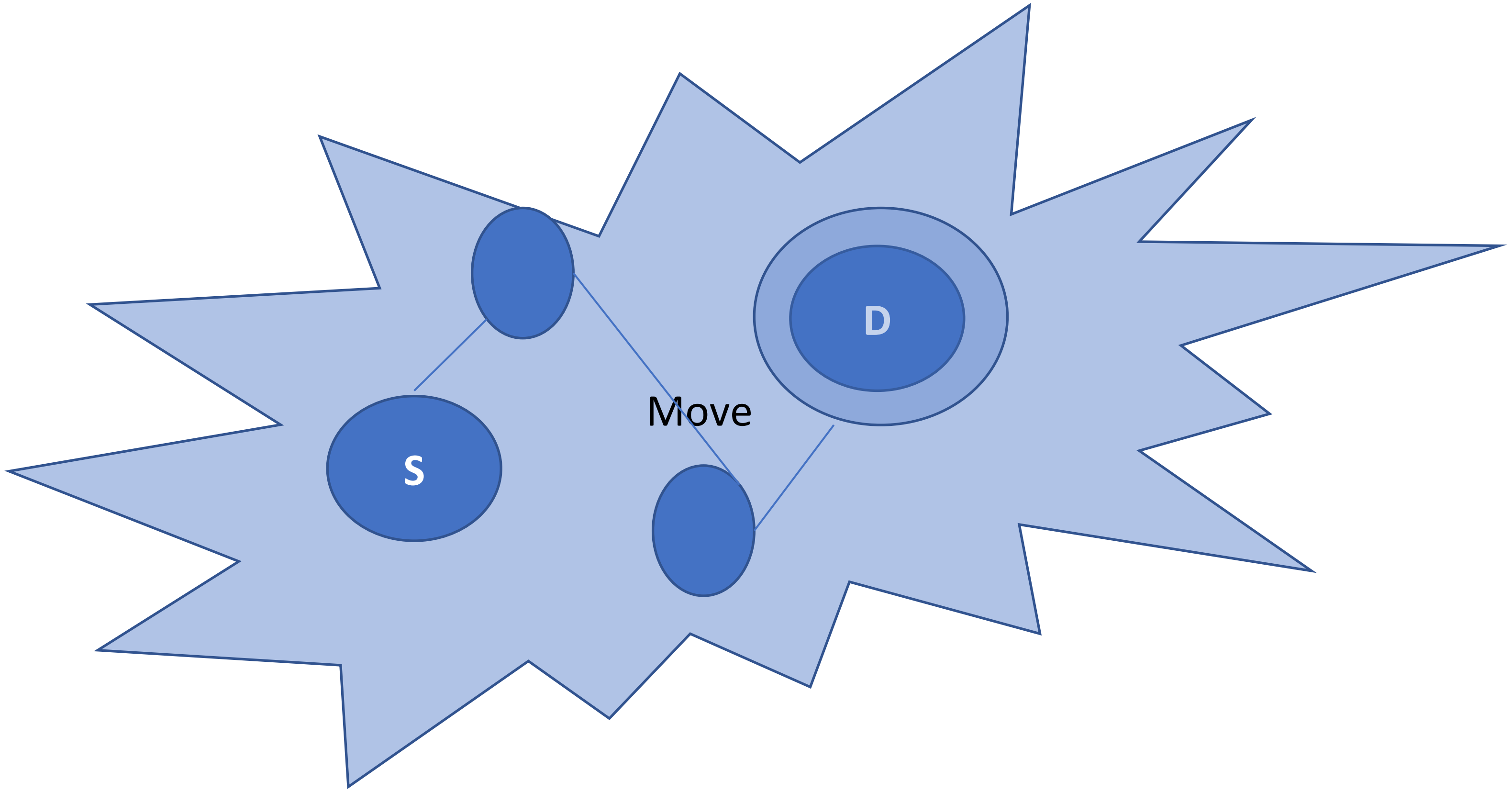


Search based method – state space



Search based method – state space

- Movegen(S) – find all possible neighbours

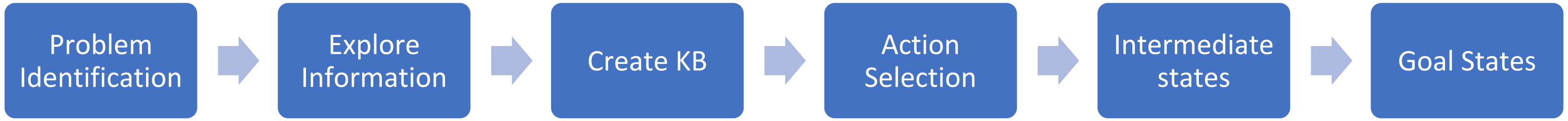


PROBLEM SOLVING

- Problem solving – area of finding answers for unknown situation
  - Understanding
  - Representation
  - Formulation
  - Solving
- Types,
  - Simple – Can be solved using deterministic approach
  - Complex – Lack of full information
- Humans?
  - Able to perceive, learn, use statistical methods, mathematical modelling to solve
  - AI do the same for the machine

PROBLEM SOLVING PROCESS

- Problem? – desired objective is not obvious
- Problem solving?
  - process of generating solution for given situation
  - Sequence of well defined methods that can handle doubts, inconsistency, uncertainty and ambiguity



Vacuum Cleaner – problem solving

Introduction

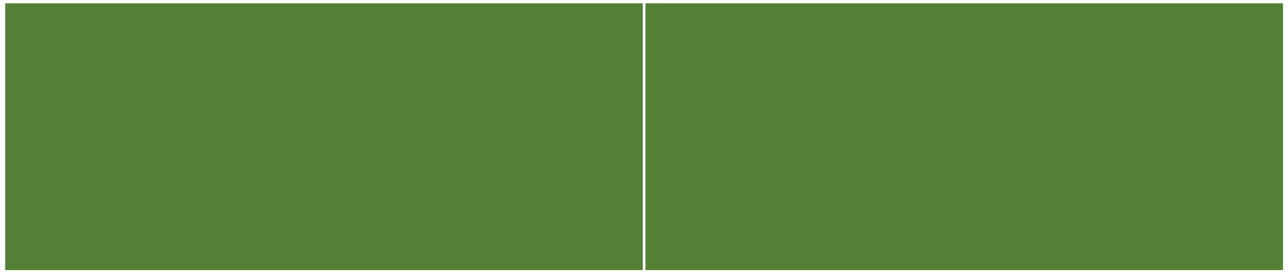
- well-known search problem for an agent which works on Artificial Intelligence
- our vacuum cleaner is our agent
- Goal – clean up the whole area

Understanding

- Two rooms and one vacuum cleaner
- Dirt in both rooms – to be cleaned
- Vacuum cleaner present in any one room
- Goal – clean both rooms

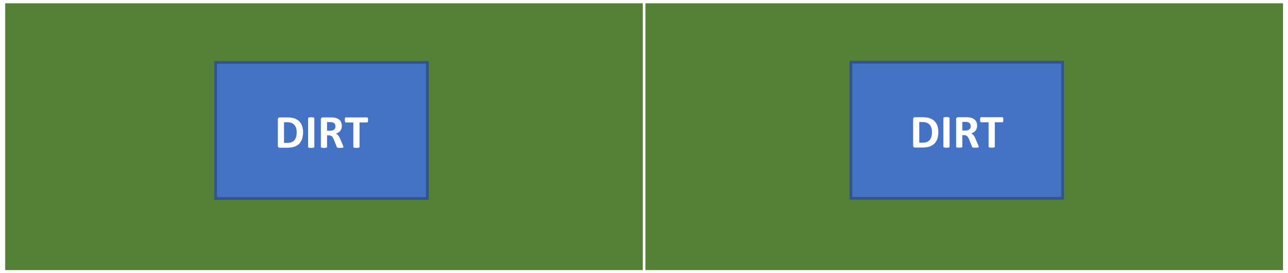
Representation

- Two rooms



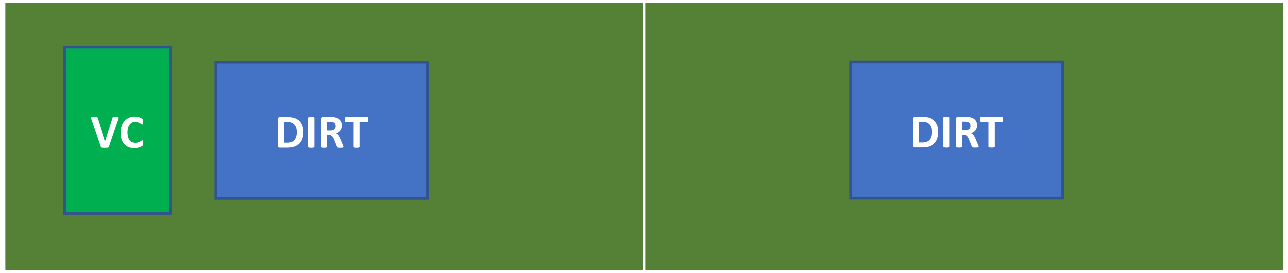
Representation

- Two rooms – with dirt



Representation

- Two rooms – with dirt

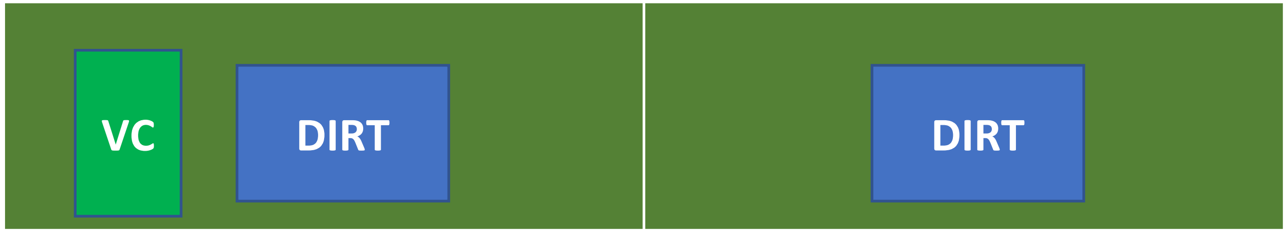


- Vacuum cleaner in any one room

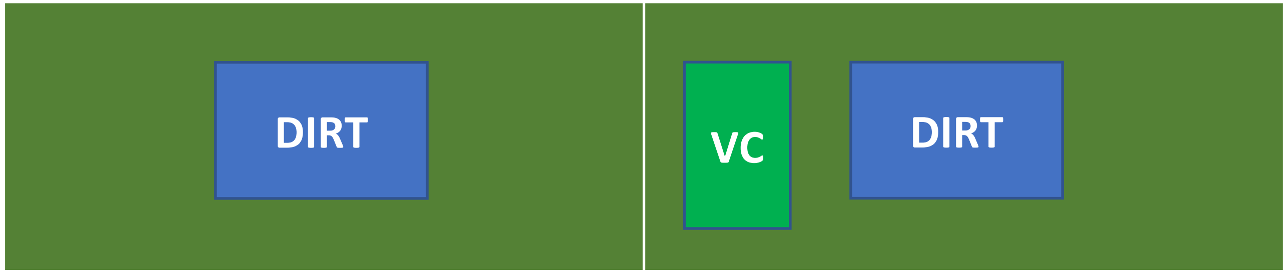
- **State representation**

8 possible states

1 – Dirt – both rooms – Vacuum cleaner – Left room



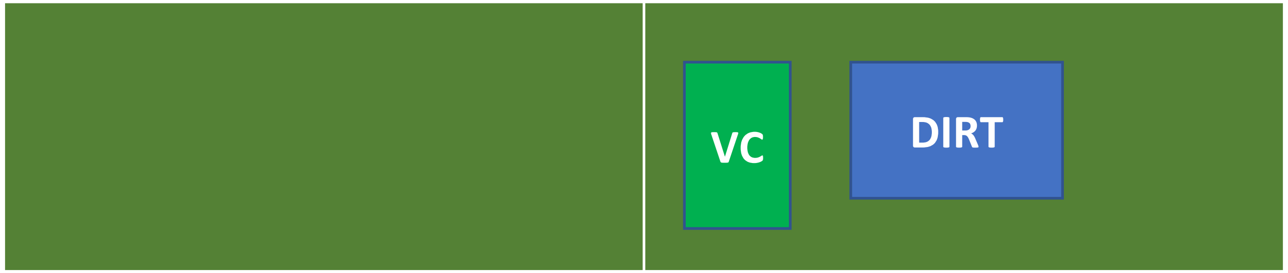
2 – Dirt – both rooms – Vacuum cleaner – Right room



8 possible states

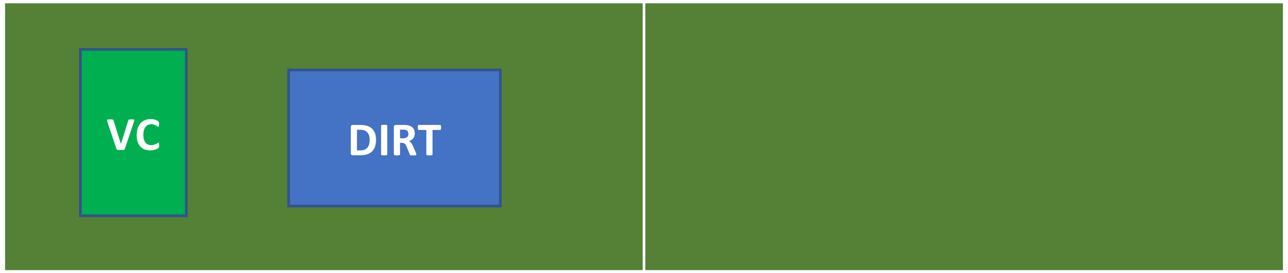
3 – Dirt - right room – Vacuum cleaner – Left room

4 – Dirt – right room – Vacuum cleaner – Right room

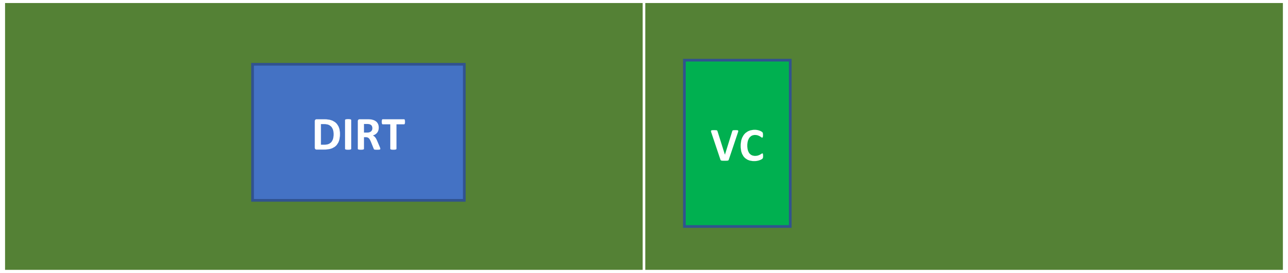


8 possible states

5 – Dirt – left room – Vacuum cleaner – Left room

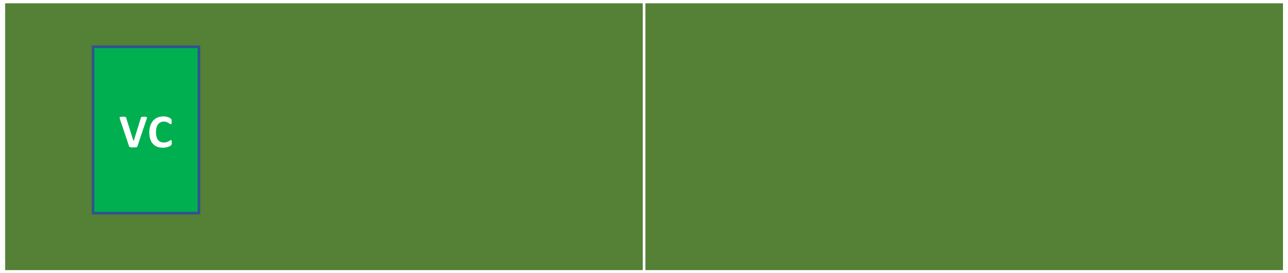


6 – Dirt – left room – Vacuum cleaner – Right room

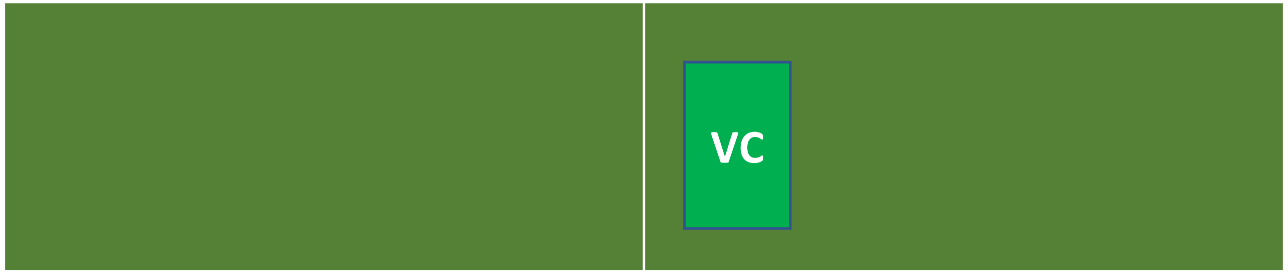


8 possible states

7 – No Dirt – both rooms – Vacuum cleaner – Left room

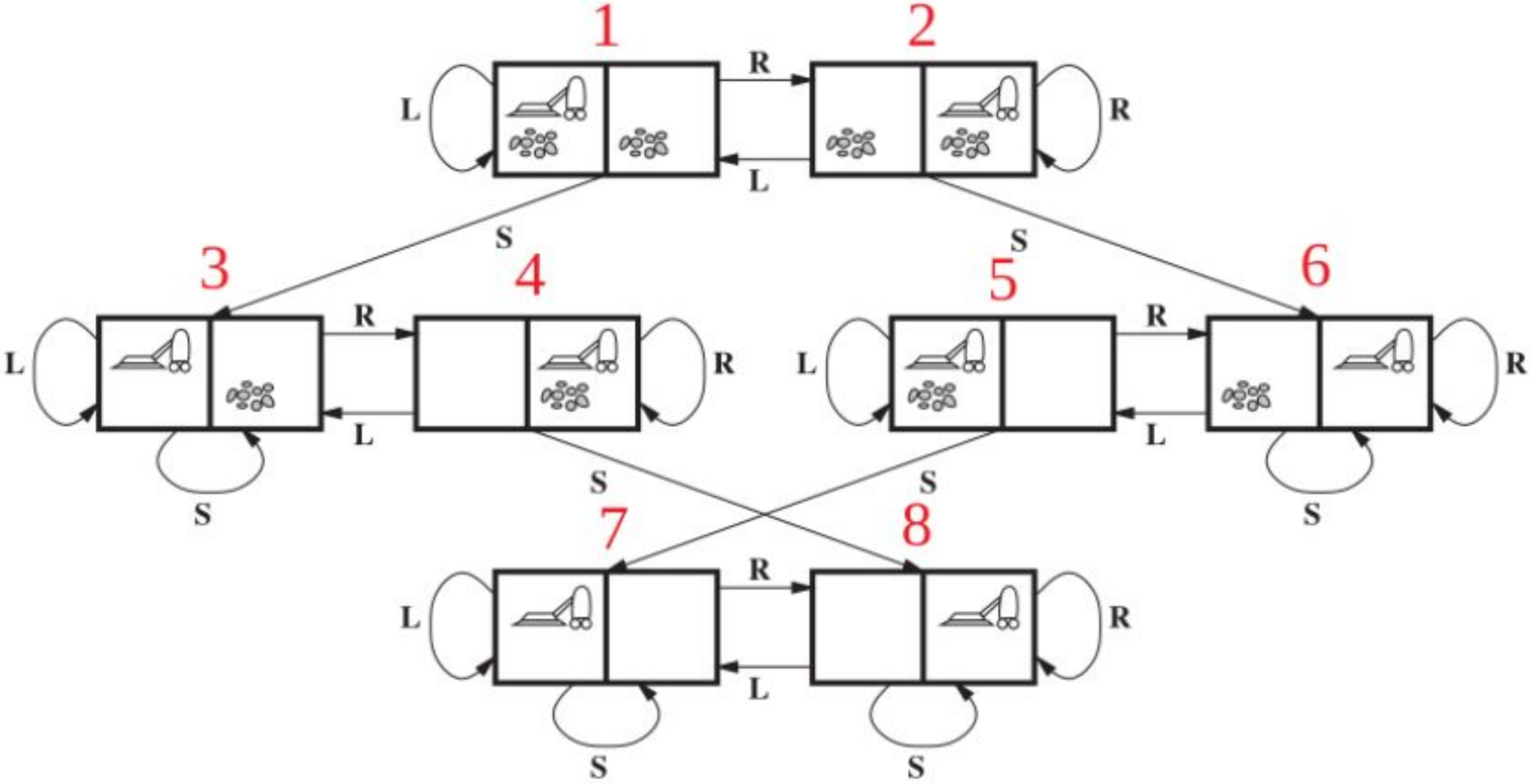


8 – No Dirt – both rooms – Vacuum cleaner – Right room



Formulation

- Possible action
    - Move Left
    - Move Right
    - Clean Dirt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Solving

Solving

–Move Left

–Move Right

–Clean Dirt

Solving

VC - Already Left
- Move Left
- Move Right
- Clean Dirt

Solving

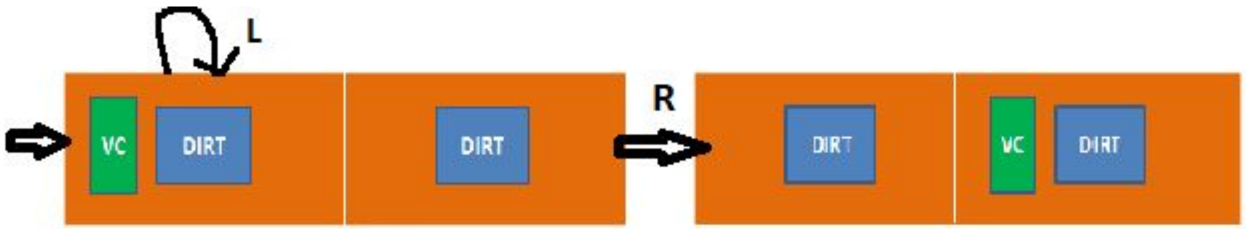
VC - Already Left
- Move Left
- Move Right
- Clean Dirt

Solving

–Move Right

–Clean Dirt

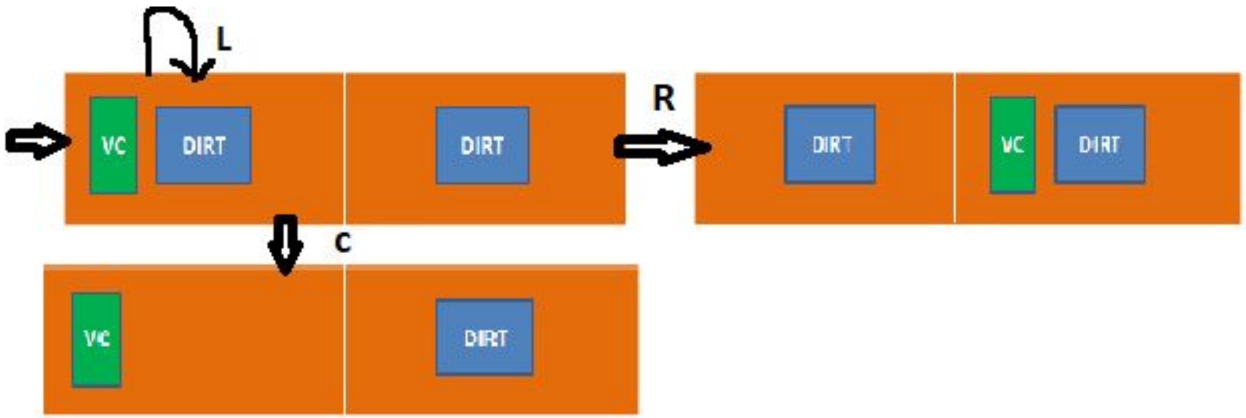
Solving



$\boxed{\text{–Move Right}}$

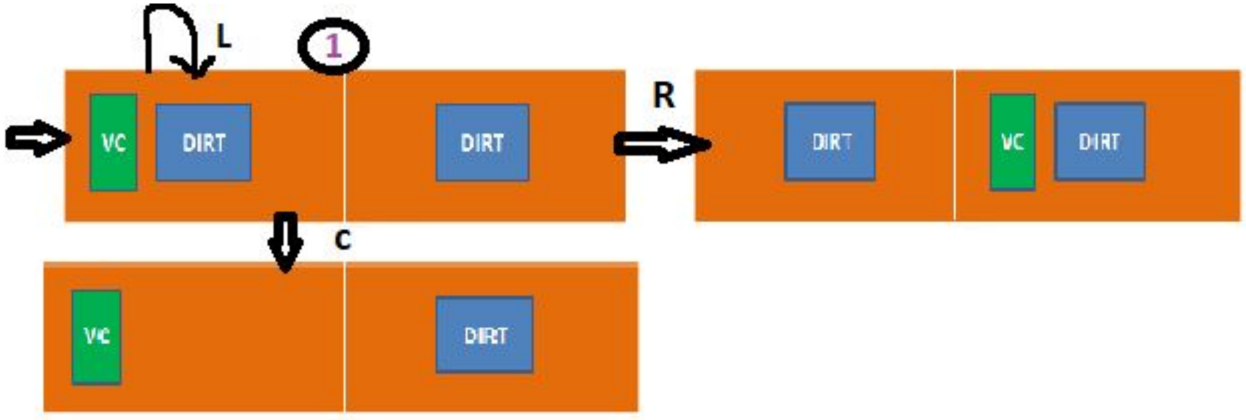
–Clean Dirt

Solving

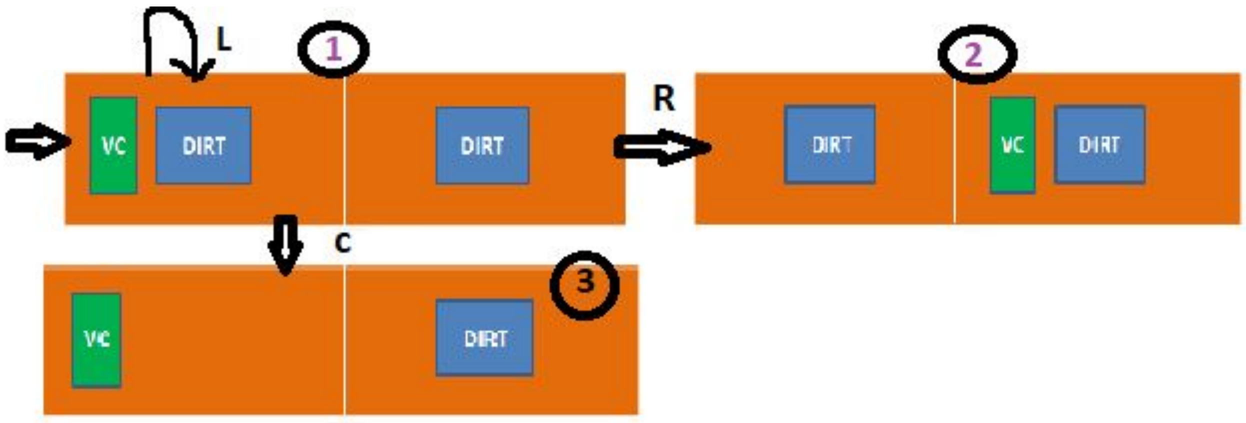


–Clean Dirt

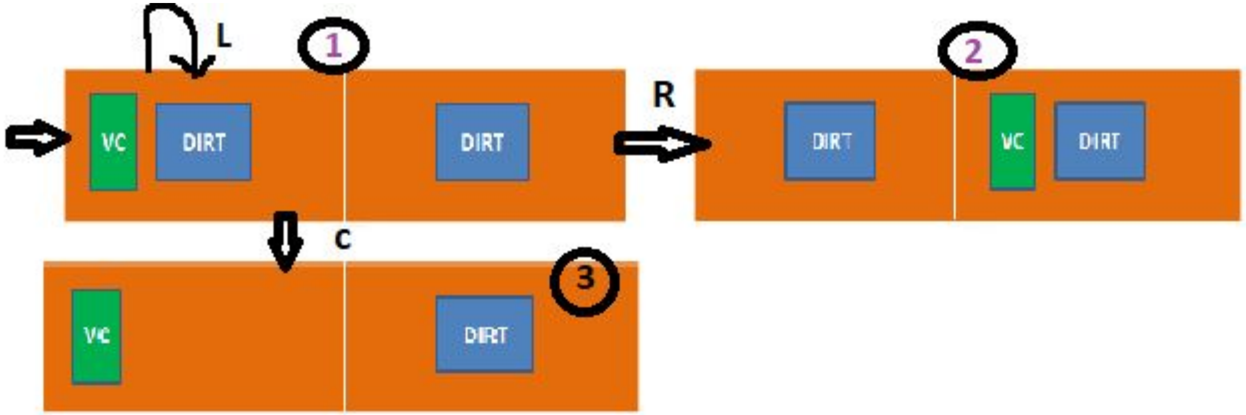
Solving



Solving



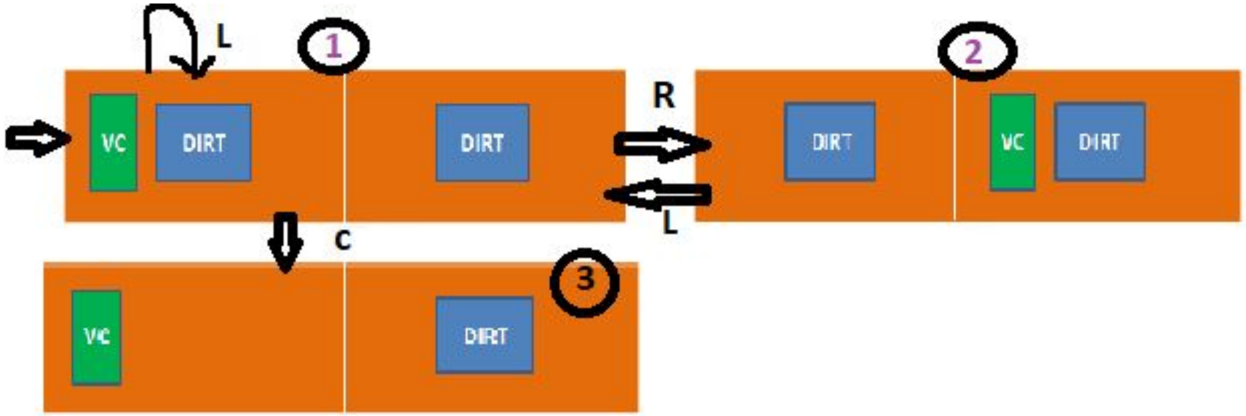
Solving



State 2

- move left
- move right
- clean dirt

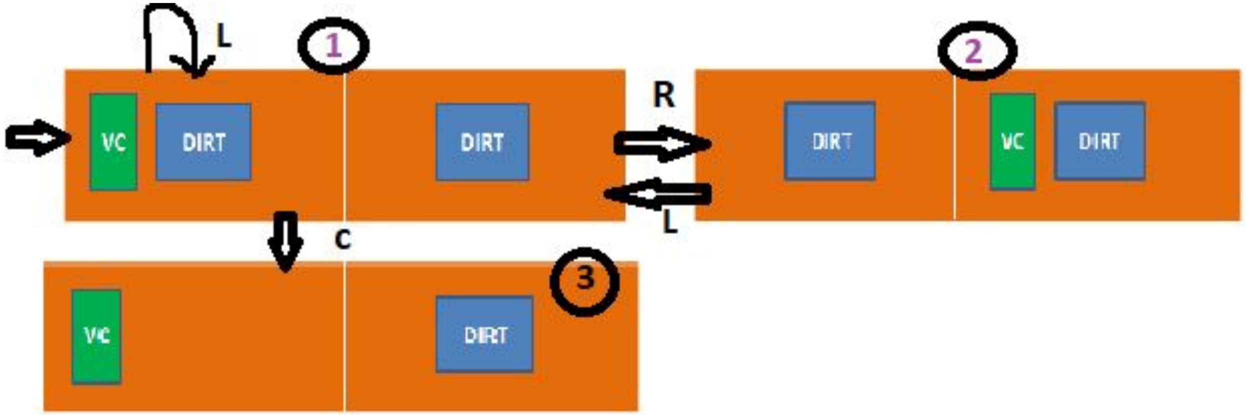
Solving



State 2

- $\boxed{\text{move left}}$
- move right
- clean dirt

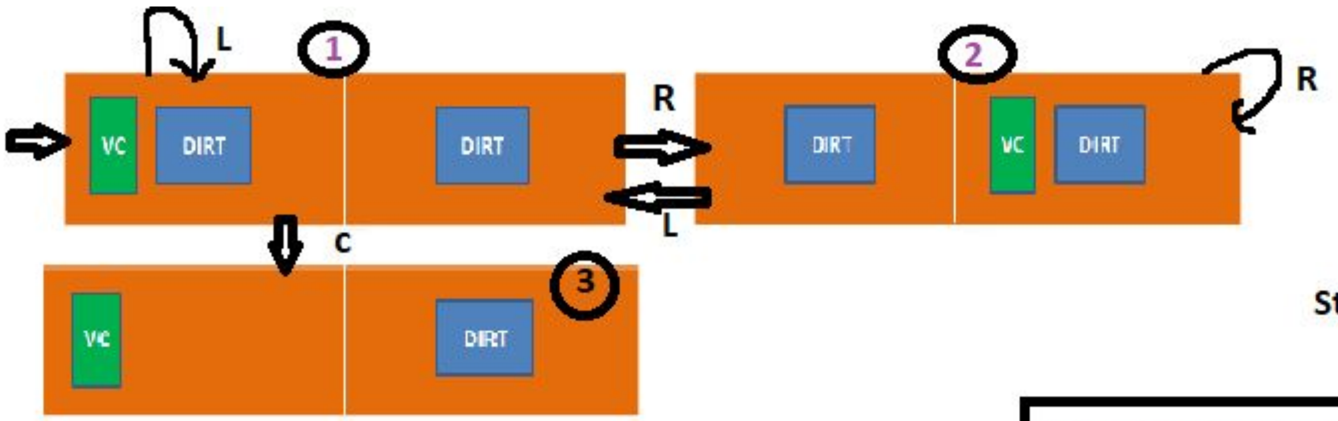
Solving



State 2

Already in right - move right
- clean dirt

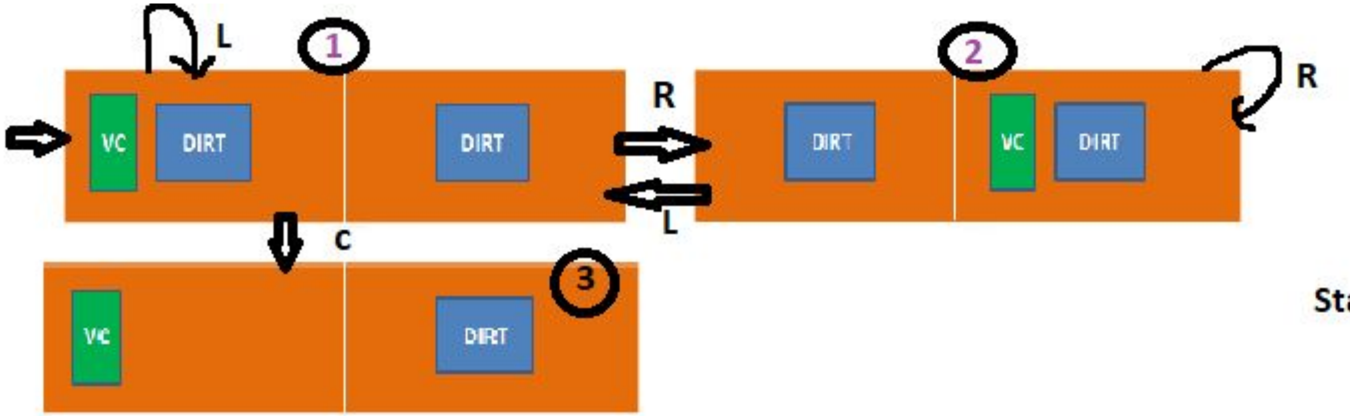
Solving



State 2

Already in right - move right
- clean dirt

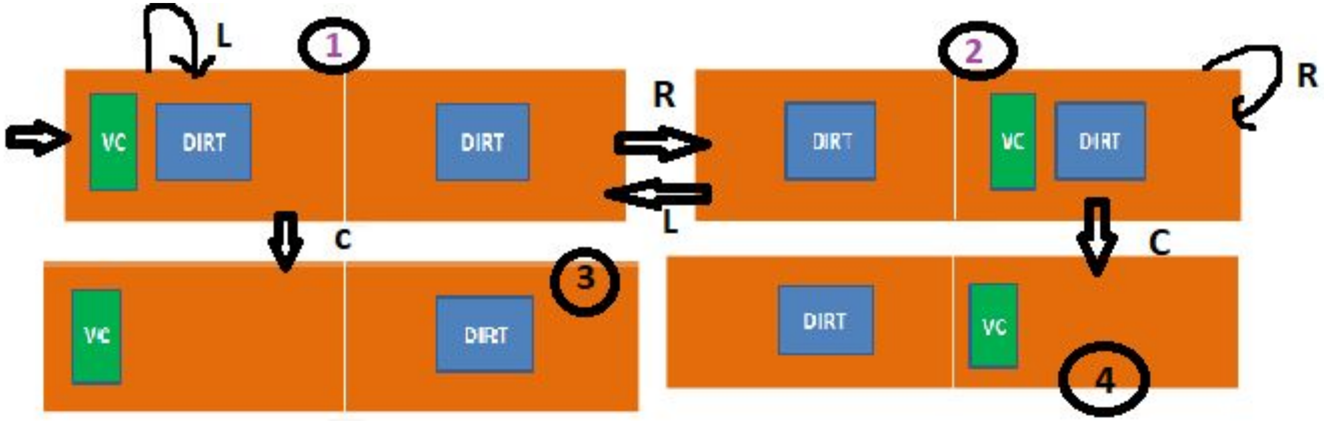
Solving



State 2

- clean dirt

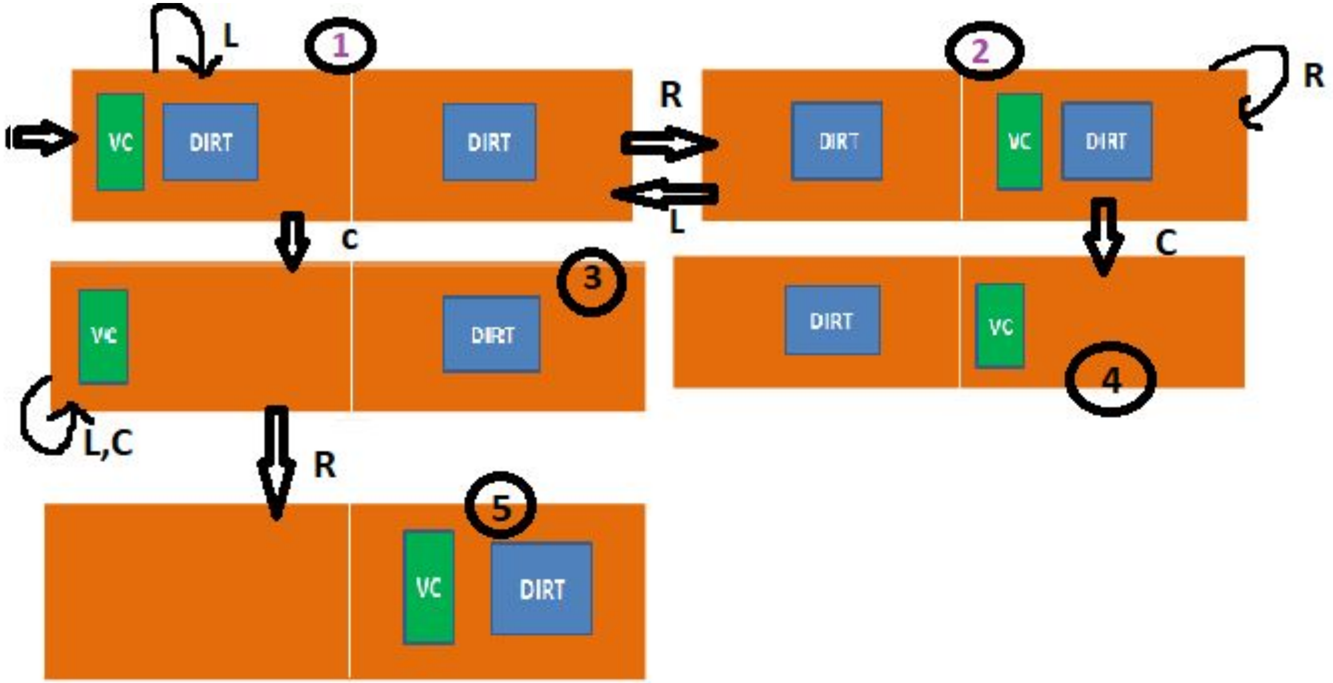
Solving



State 2

Clean dirt

Solving



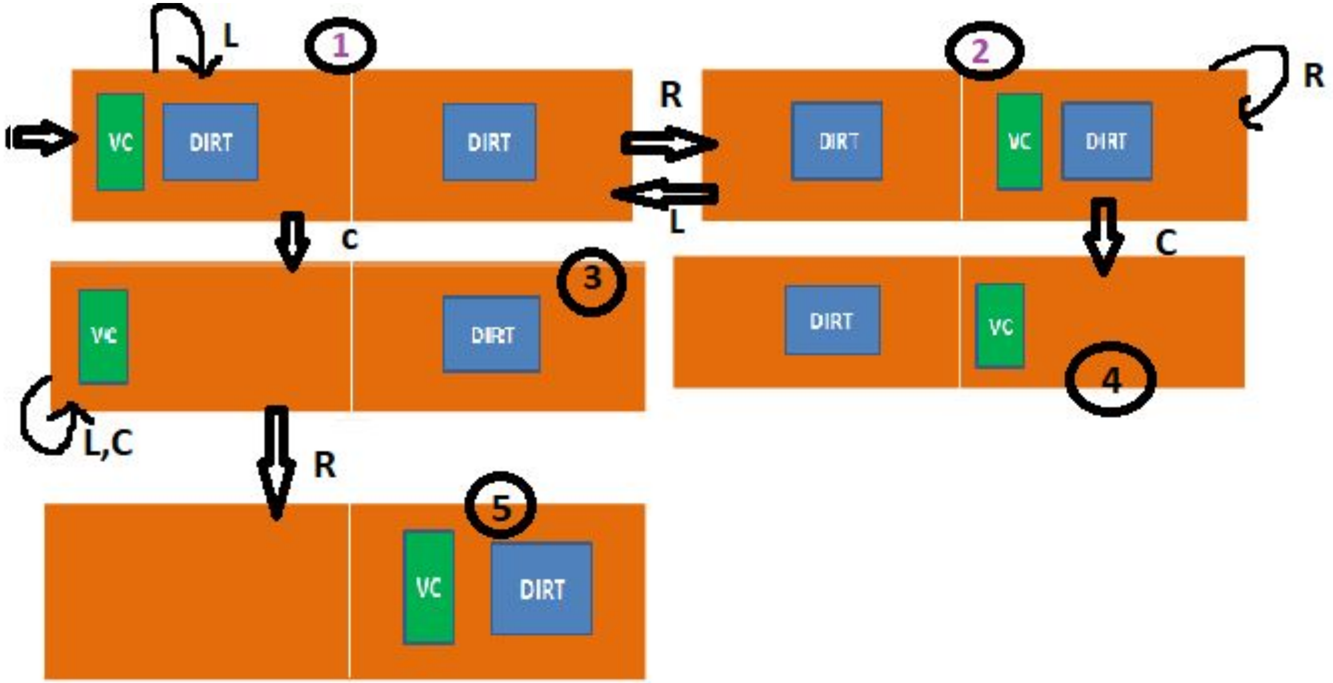
State 3

Move left - 3

Move right - 5

Clean Dirt - 3

Solving



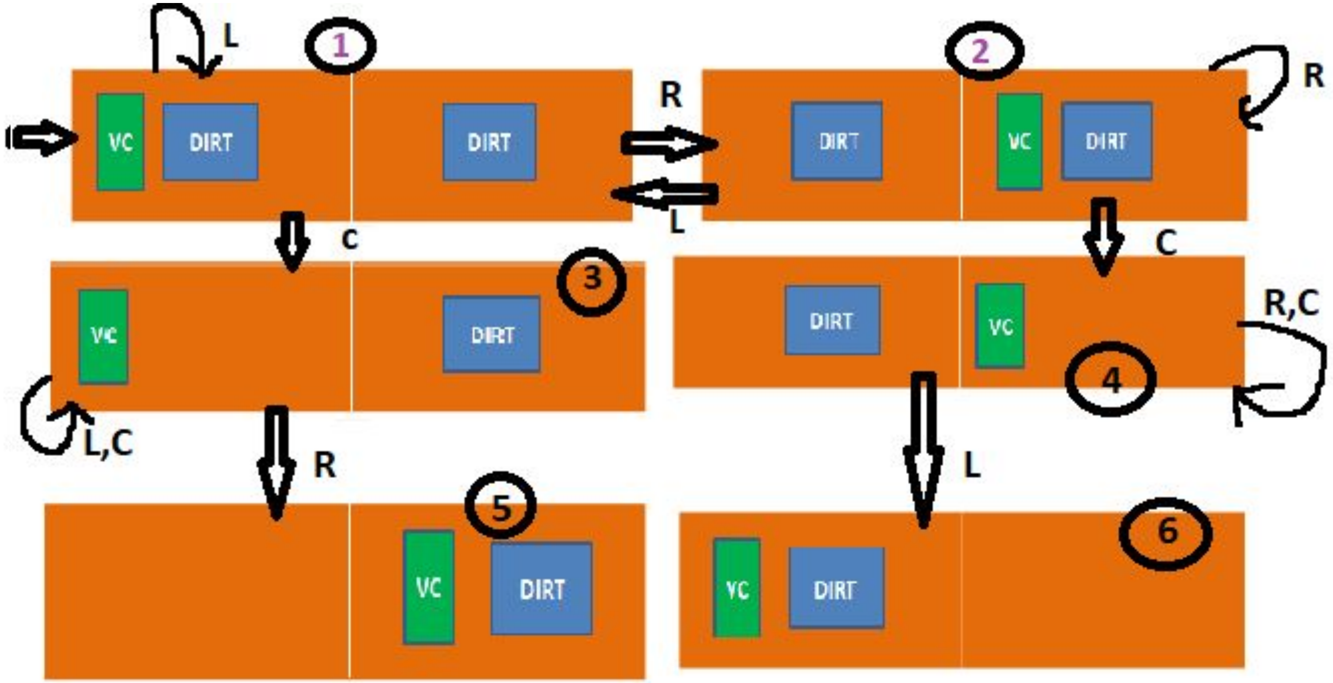
State 4

Move left - 6

Move right - 4

Clean Dirt - 4

Solving



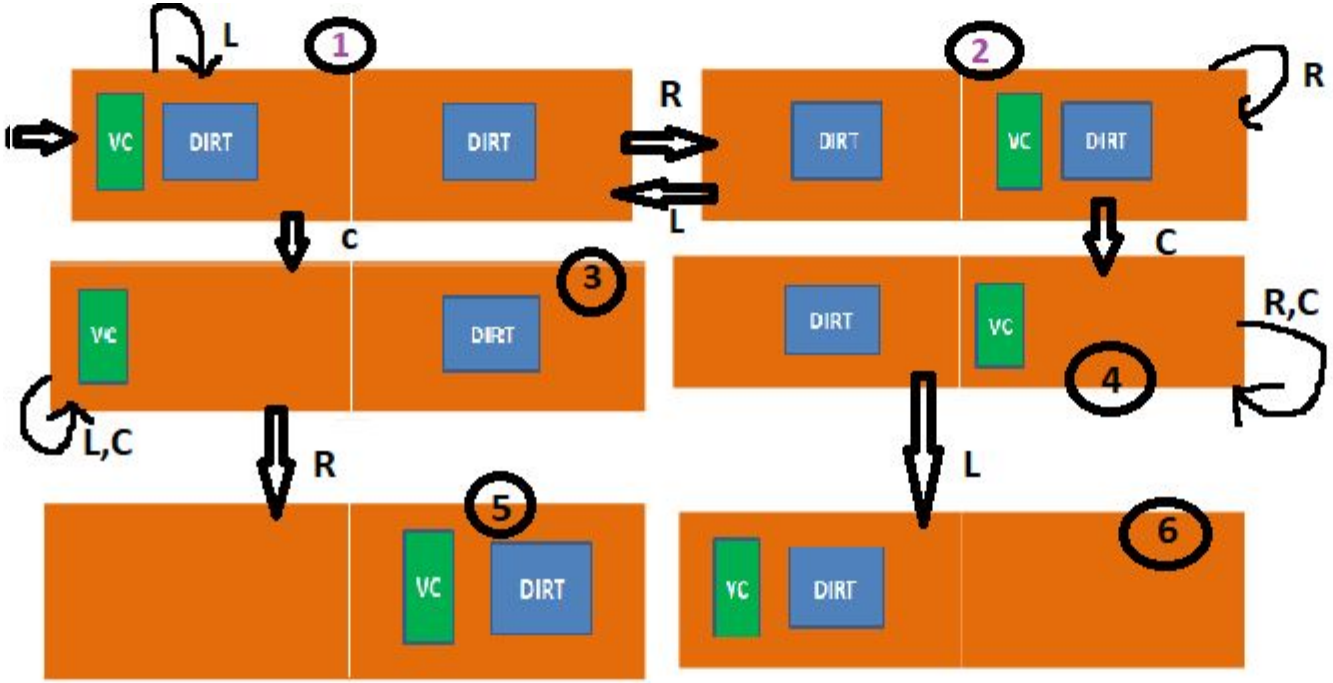
State 4

Move left - 6

Move right - 4

Clean Dirt - 4

Solving



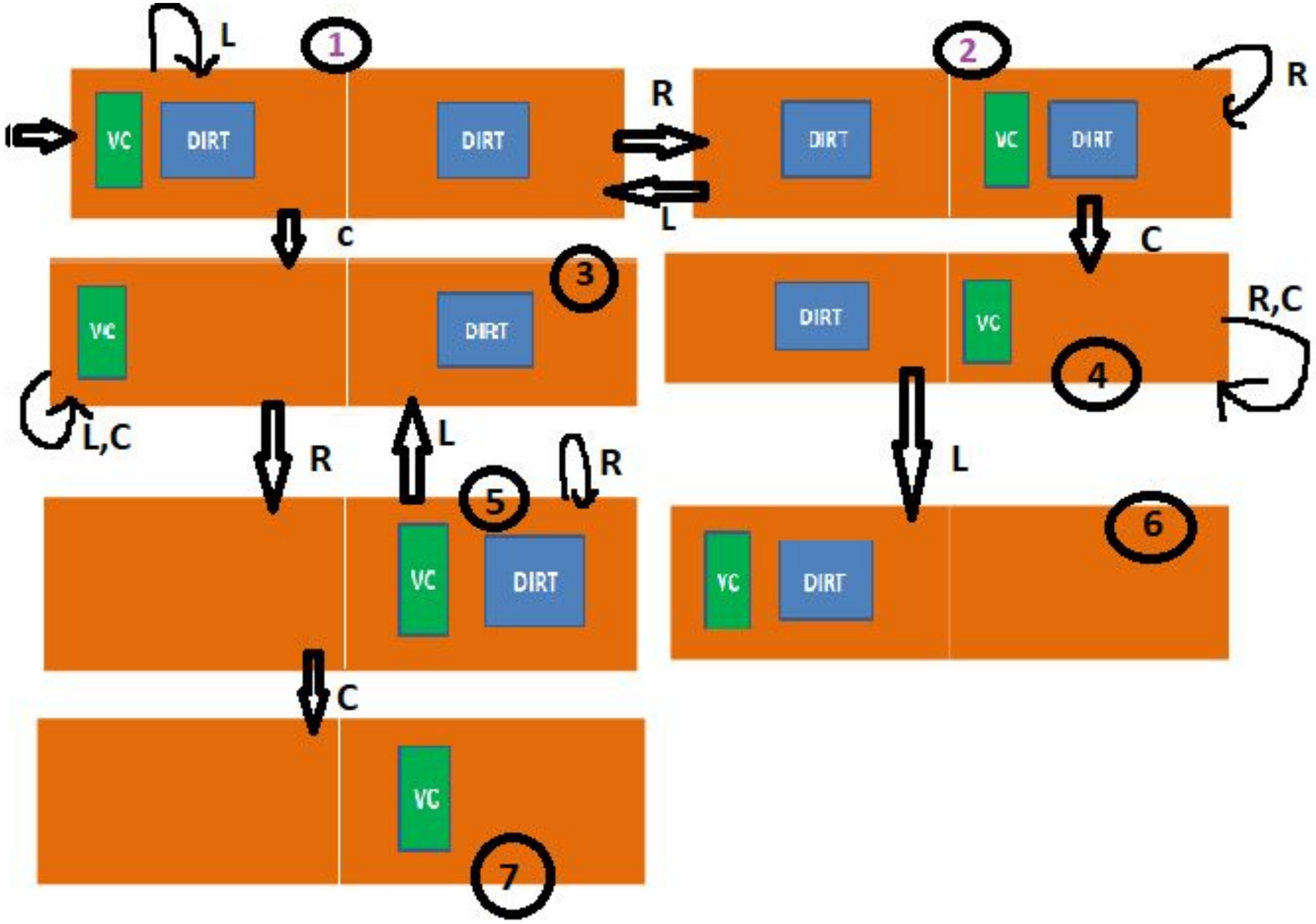
State 5

Move left - 3

Move right - 5

Clean Dirt - 7

Solving



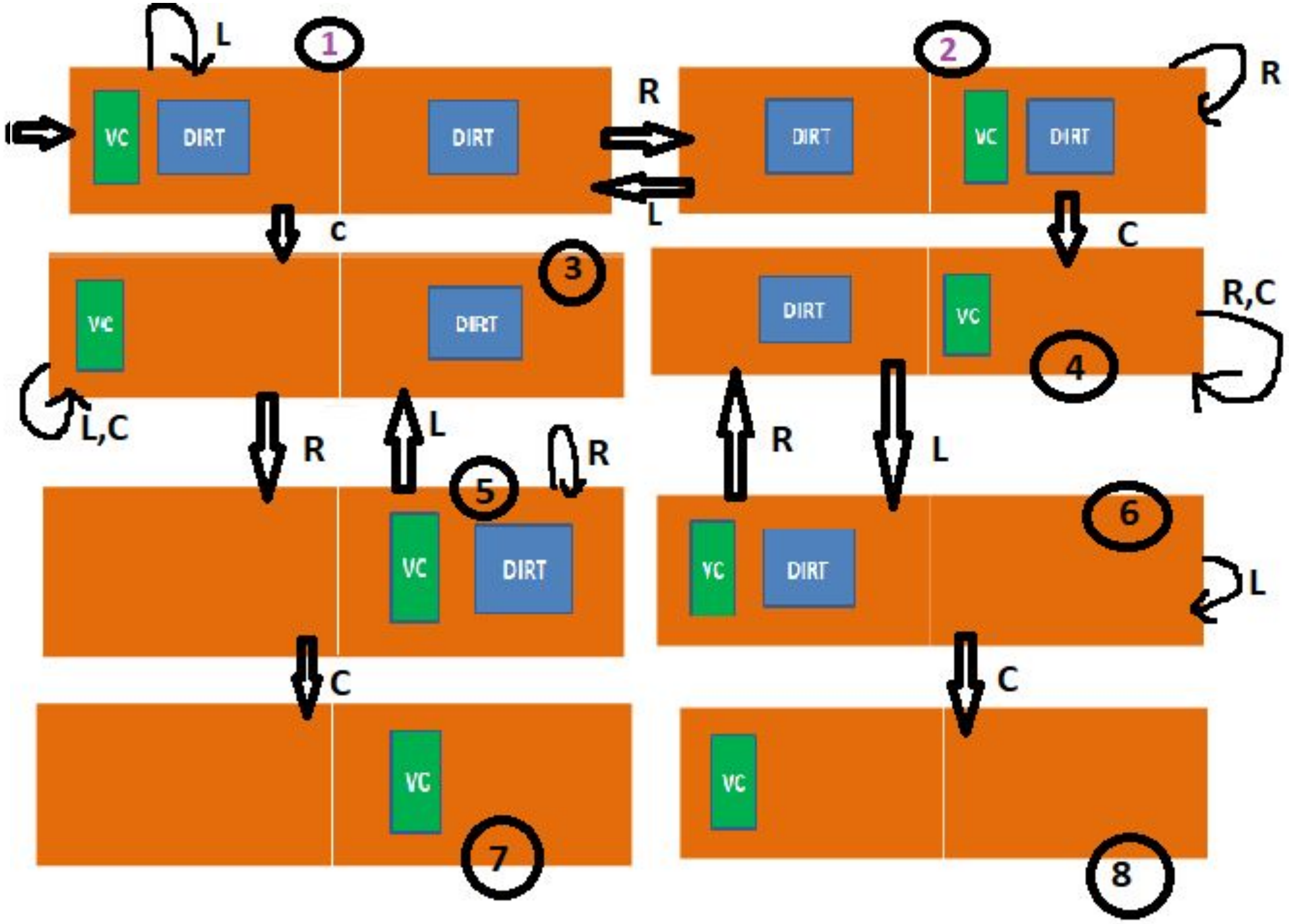
State 5

Move left - 3

Move right - 5

Clean Dirt - 7

Solving



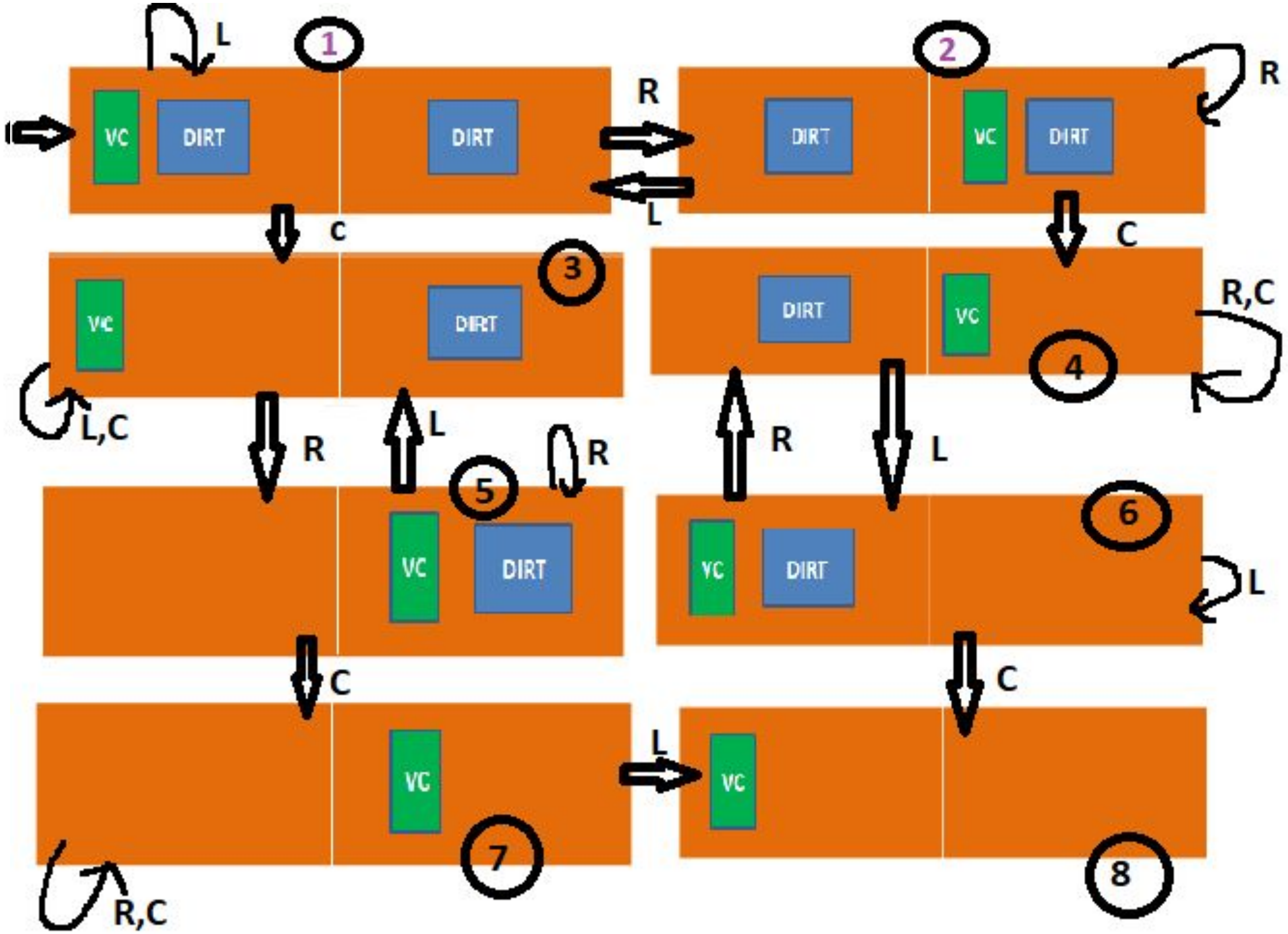
State 6

Move left - 6

Move right - 4

Clean Dirt - 8

Solving



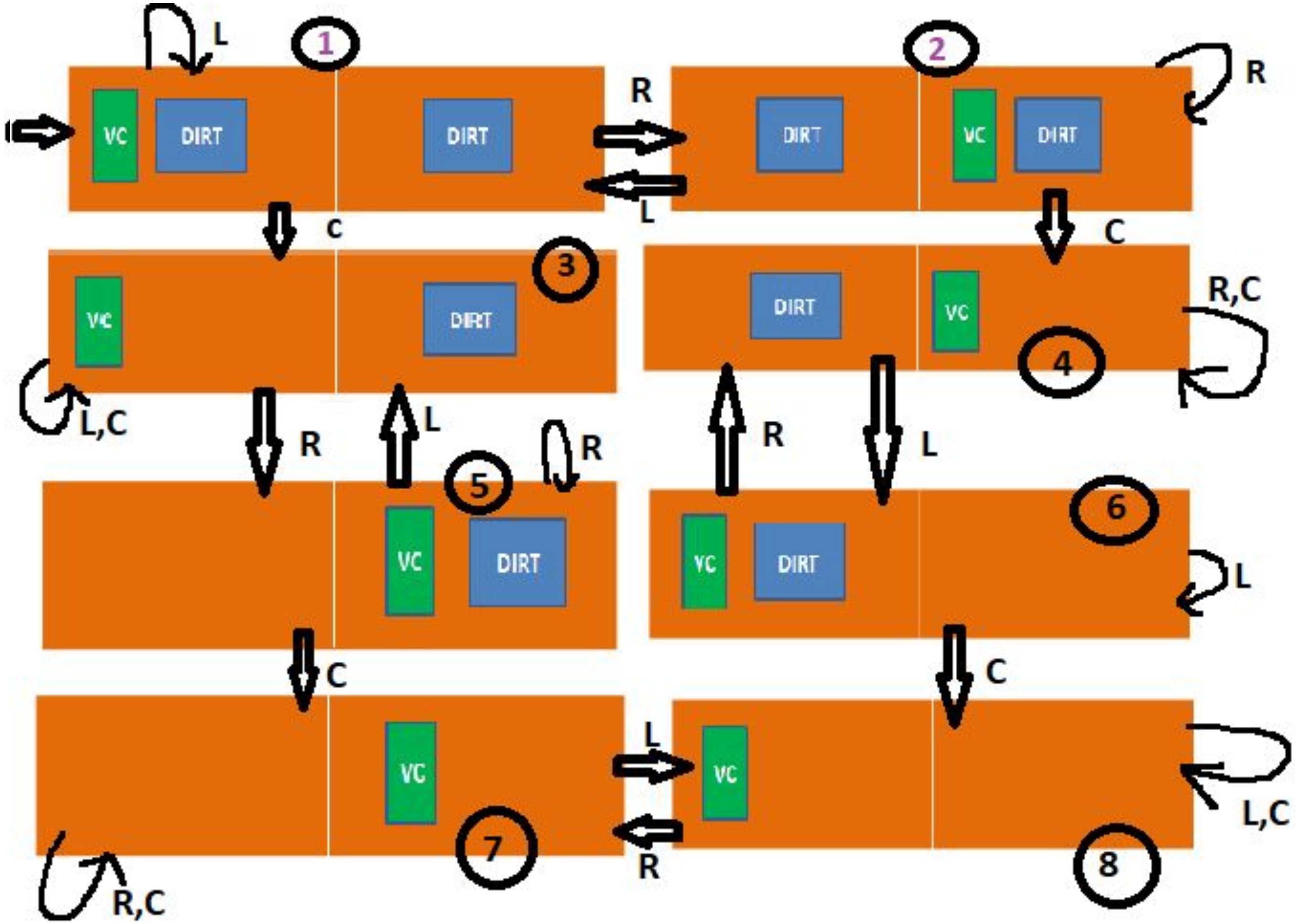
State 7

Move left - 8

Move right - 7

Clean Dirt - 7

Solving



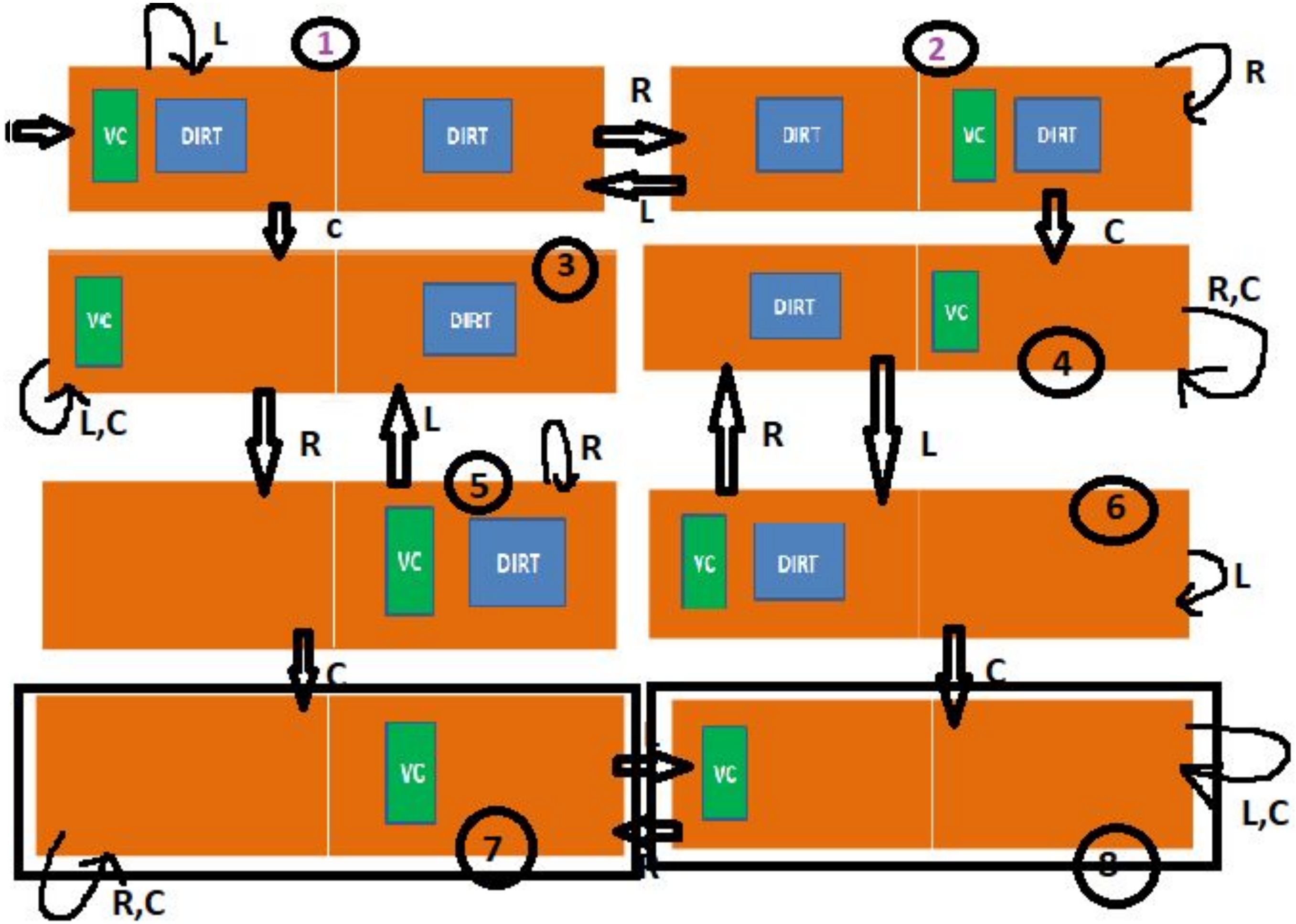
State 8

Move left - 8

Move right - 7

Clean Dirt - 8

Solving



Problem

- In AI, formally define a problem as
  - a space of all possible configurations where each configuration is called a state
  - The ***state-space*** is the configuration of the possible states and how they connect to each other e.g. the legal moves between states.
  - an initial state
  - one or more goal states
  - a set of rules/operators which move the problem from one state to the next
- In some cases, we may enumerate all possible states
  - but usually, such an enumeration will be overwhelmingly large so we only generate a portion of the state space, the portion we are currently examining
  - we need to search the state-space to find an optimal path from a start state to a goal state.

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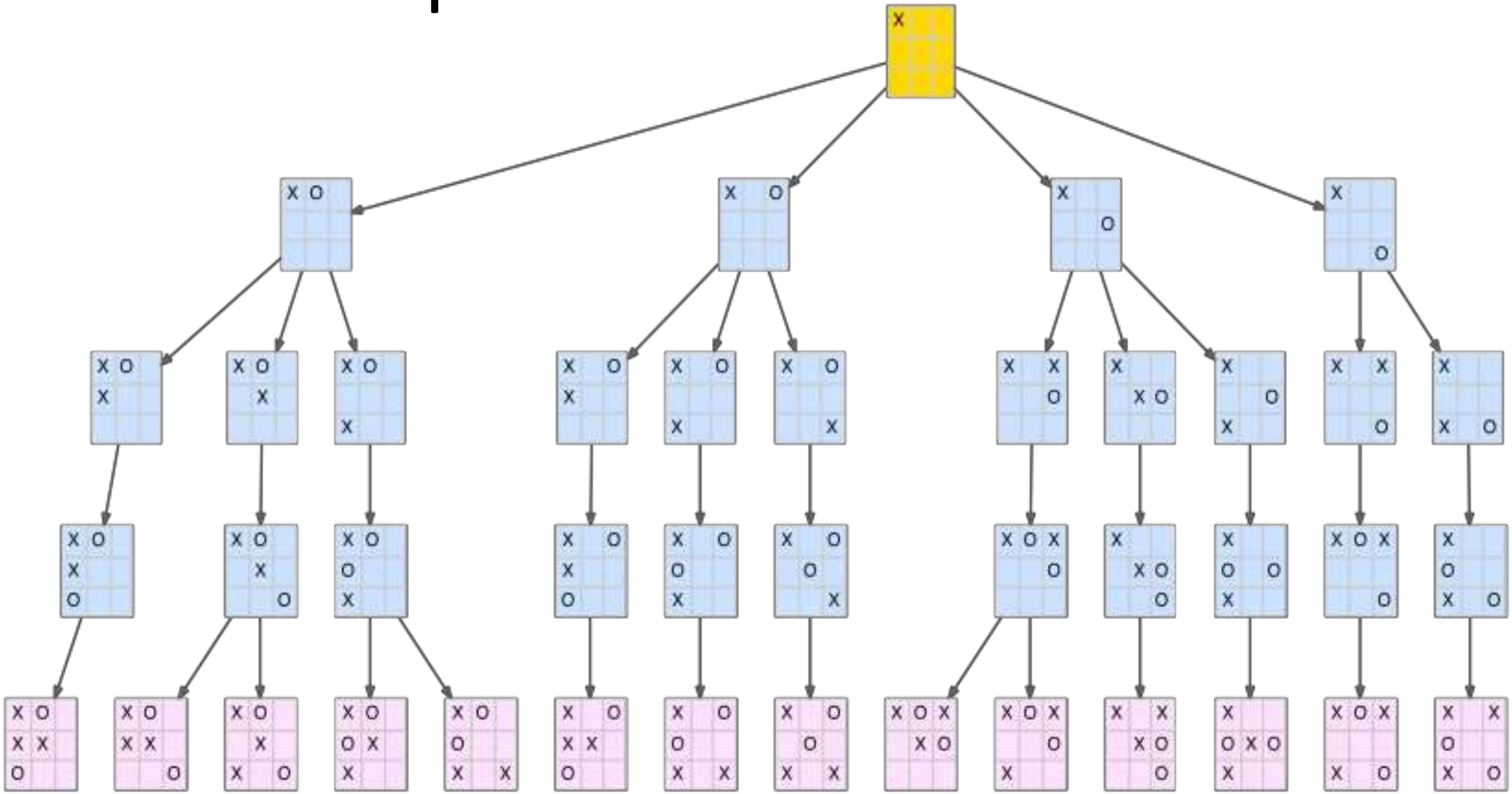
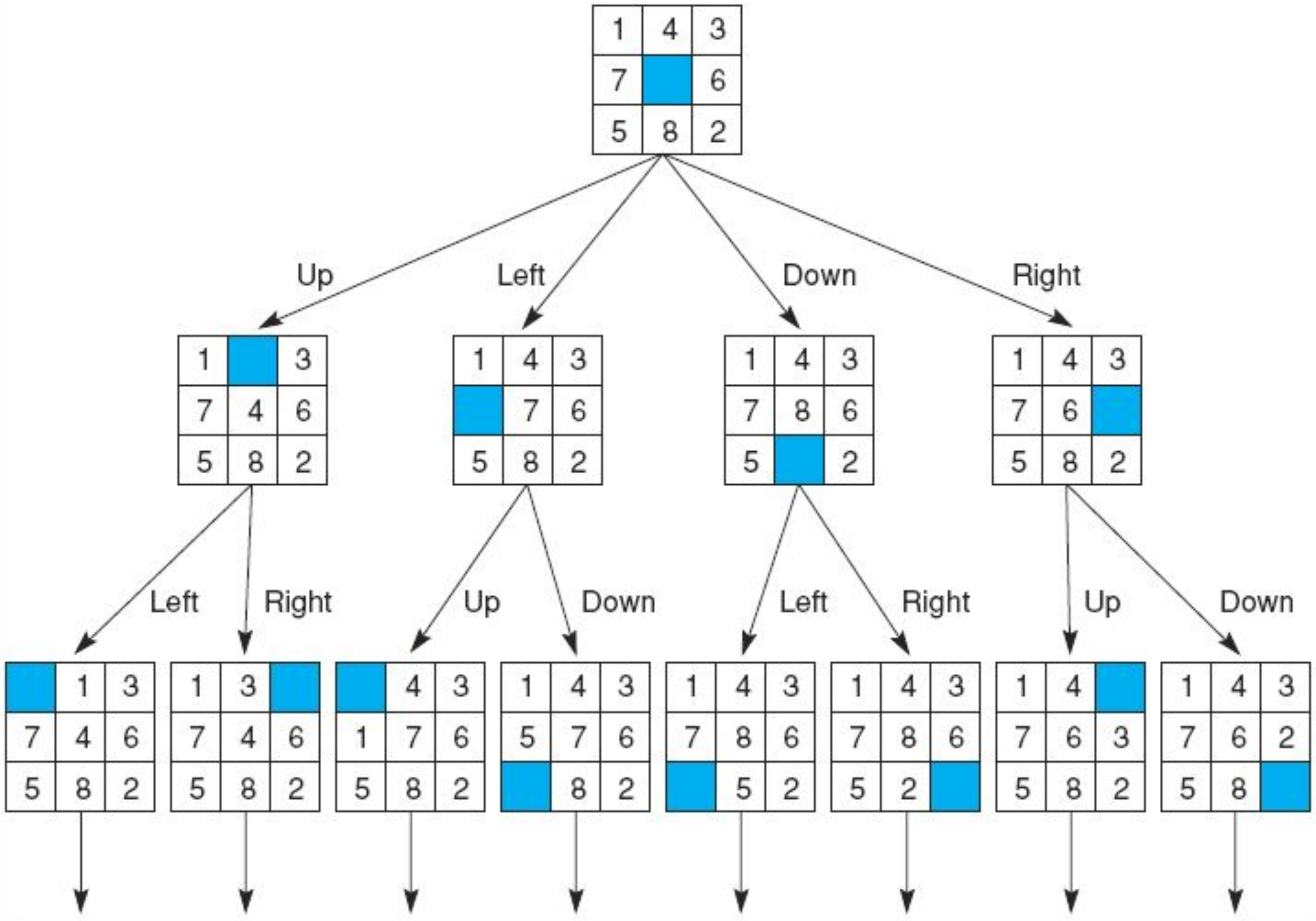
State space: Tic-Tac-Toe



Goal: Arrange in horizontal or vertical or diagonal to win

State space: 8 Puzzle



The 8 puzzle search space consists of 8! states (40320)

Categories of problems

Structured problems –goal state defined

Unstructured problems- goal state not known

Linear problems- based on dependent variable

Non linear problems- no dependency between variables

Problem Types

1. Deterministic or observable (single-state)
2. Non-observable (multiple-state)
3. Non-deterministic or partially observable
4. Unknown state space

Problem Types

1. Deterministic or observable(Single-state problems)

- Each state is fully observable and it goes to one definite state after any action.
- Here , the goal state is reachable in one single action or sequence of actions.
- Deterministic environments ignore uncertainty.
- *Ex- Vacuum cleaner with sensor.*

Problem Types

2. Non-observable(Muliple-state problems) / conformant problems

- **Problem – solving agent does not have any information about the state.**
- **Solution may or may not be reached.**
- *Ex- In case of vacuum cleaner , the goal state is to clean the floor rather clean floor. Action is to suck if there is dirt. So , in non-observable condition , as there is no sensor , it will have to suck the dirt , irrespective of whether it is towards right or left . Here , the solution space is the states specifying its movement across the floor.*

Problem Types

3. Non-deterministic(partially observable) / contingency problem

- **The effect of action is not clear.**
- **Percepts provide new information about the current state.**
- *Ex- If we take Vacuum cleaner , and now assume that the sensor is attached to it , then it will suck if there is dirt. Movement of the cleaner will be based on its current percept.*

Problem Types

4. Unknown state space problems

- **Typically exploration problems**
- **States and impact of actions are not known**
- ***Ex- online search that involves acting without compete knowledge of the next state or scheduling without map.***

Problem Solving with AI
" Formulate , Search , Execute " design for agent

```
function SIMPLE-PROBLEM-SOLVING-AGENT(percept) returns an action
  persistent: seq, an action sequence, initially empty
              state, some description of the current world state
              goal, a goal, initially null
              problem, a problem formulation

  state ← UPDATE-STATE(state, percept)
  if seq is empty then
     goal ← FORMULATE-GOAL(state)
     problem ← FORMULATE-PROBLEM(state, goal)
     seq ← SEARCH(problem)
     if seq = failure then return a null action
  action ← FIRST(seq)
  seq ← REST(seq)
  return action
```

A simple problem-solving agent. It first formulates a goal and a problem, searches for a sequence of actions that would solve the problem, and then executes the actions one at a time. When this is complete, it formulates another goal and starts over.

Searching for solution

- Searching for AI problems involves performing an action to go to one proper state among possible numerous states of agents

- Thus the process of finding solution can be searching of the best among all the possible states

Characteristics of AI

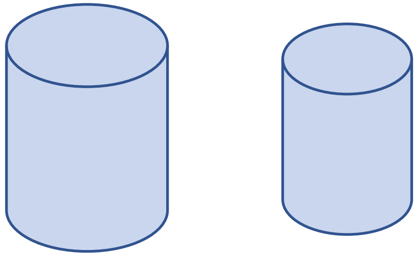
- AI problems have large number of combination of solution
- AI program manipulate large number of Symbolic information
- AI problem uses heuristic search to cope with the combination of exploration of solution
- Ability to learn
- AI problems can be solved with or without the use of AI technique

Water Jug problem

- A Water Jug Problem:

You are given two jugs, a 4-gallon one and a 3-gallon one, a pump which has unlimited water which you can use to fill the jug, and the ground on which water may be poured. Neither jug has any measuring markings on it. How can you get exactly 2 gallons of water in 4-gallon jug?

(x,y)	(x,y)
(0,0)	(4,0)
(0,3)	(1,3)
(3,0)	(1,0)
(3,3)	(0,1)
(4,2)	(4,1)
	(2,3)



With out AI

- First pour 3l water in 2nd jug
  - X=0,y=3
- Pour 3l water in 2nd jug to x
  - X=3,y=0
- Pour the extra water from outside in 2nd jug
  - X=3,y=3
- The total capacity of jug 1 is 4 ,so fill the remaining in jug 1 So
  - x=4,y=2
- Here 2l water is filled in jug 2

Representation

- State Representation and Initial State
- we will represent a state of the problem as a
- tuple (x, y) where x represents the amount of water in the 4-gallon jug and y represents the amount of water in the 3-gallon jug.
- Note $0 \leq x \leq 4$, and $0 \leq y \leq 3$. Our initial state: (0,0)

Production rules - Formulation

1. Fill 4-gal jug (x,y) → (4,y) where ,x < 4

2. Fill 3-gal jug (x,y) → (x,3) where, y < 3

Production rules - Formulation

3. Empty 4-gal jug on ground $(x,y) \rightarrow (0,y)$ where, $x > 0$

4. Empty 3-gal jug on ground $(x,y) \rightarrow (x,0)$ where, $y > 0$

Production rules - Formulation

5.Empty some water in 3 gallon jug $(x,y) \rightarrow (x,y-d)$ where, $y>0$

6. Empty some water in 4 gallon jug $(x,y) \rightarrow (x-d,y)$ where, $x>0$

Production rules - Formulation

7. Pour water from 3-gal jug $(x,y) \rightarrow (4, y - (4 - x))$ to fill 4-gal jug $x+y \geq 4$ and $y > 0$

8. Pour water from 4-gal jug $(x,y) \rightarrow (x - (3-y), 3)$ to fill 3-gal-jug $x+y \geq 3$ and $x > 0$

Production rules - Formulation

9. Pour all of water from 3-gal jug $(x,y) \rightarrow (x+y, 0)$ into 4-gal jug $0 < x+y \leq 4$ and $y \geq 0$

10. Pour all of water from 4-gal jug $(x,y) \rightarrow (0, x+y)$ into 3-gal jug $0 < x+y \leq 3$ and $x \geq 0$

One solution

Gals in 4-gal jug	Gals in 3-gal jug	Rule Applied
0	0	
		1. Fill 4
4	0	
		8. Pour 4 into 3 to fill
1	3	
		4. Empty 3
1	0	
		10. Pour all of 4 into 3
0	1	
		1. Fill 4
4	1	
		8. Pour into 3
2	3	

Problem types

- single-state problem-Agent knows exactly what each of its actions does and it can calculate exactly which state it will be in after any sequence of actions.
- multiple-state problem-when the world is not fully accessible, the agent must reason about sets of states that it might get to, rather than single states.
- contingency problem-the agent may be in need to now calculate a whole tree of actions, rather than a single action sequence in which each branch of the tree deals with a possible contingency that might arise.
- exploration problem-the agent learns a "map“ of the environment, which it can then use to solve subsequent problems.

Problem Characteristics

- To choose the most appropriate method
- Its necessary to analyse the problem

Problem Characteristics

1. Is the problem Decomposable?
2. Can solution steps to be ignored or undone?
3. Is the problem’s universe predictable?
4. Is the good solution is absolute or relative?
5. Is the solution a state or a path?
6. What is the role of knowledge?
7. Does the task require interaction with a person?

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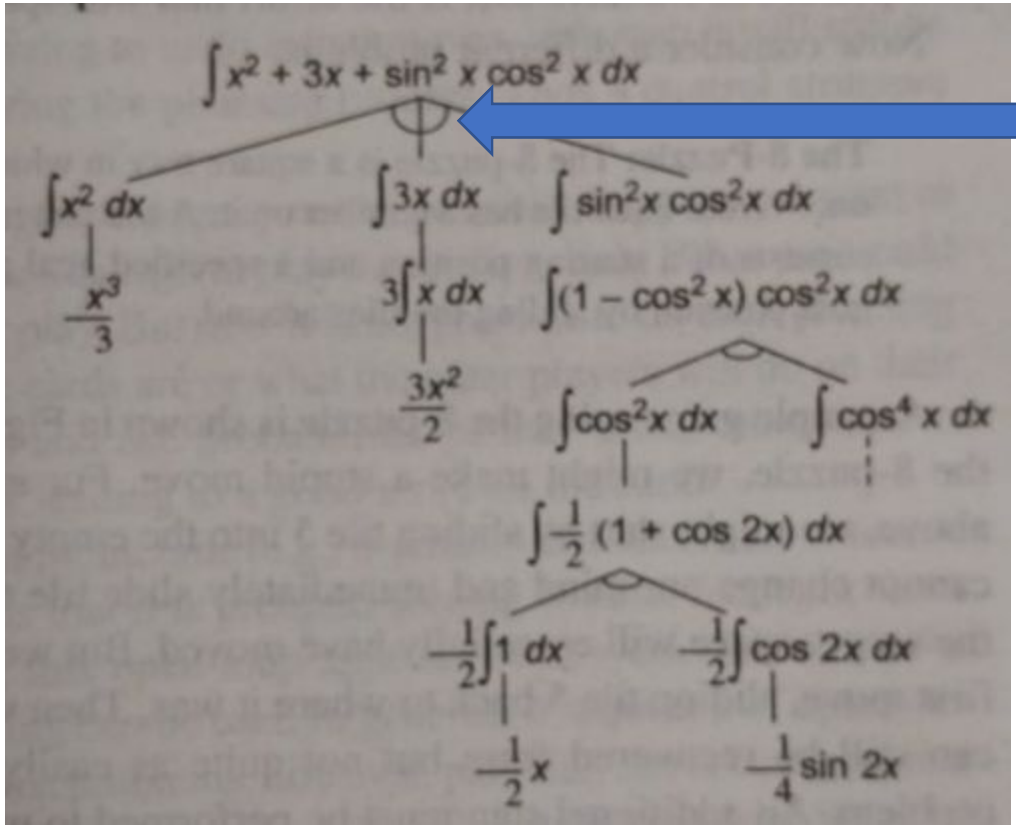
Is the problem Decomposable?

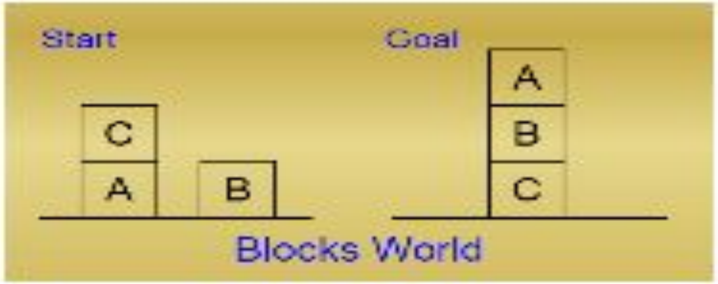
- Decomposable problem:



AND logic

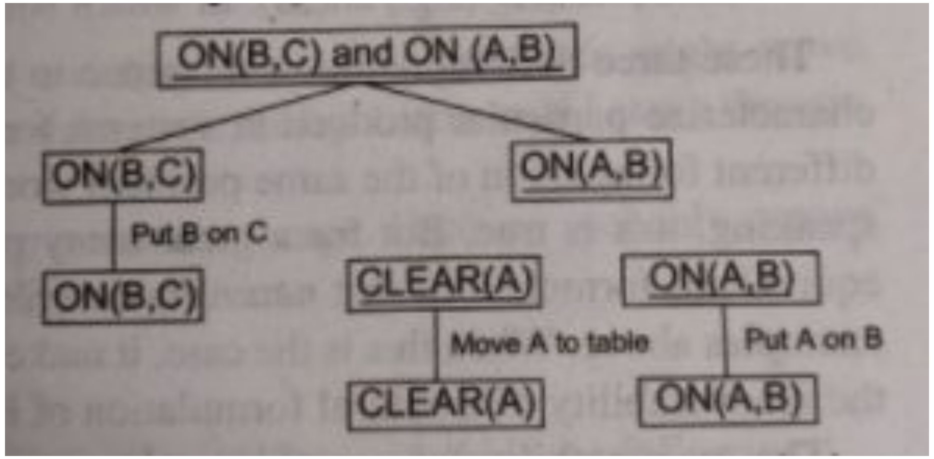
Is the problem Decomposable?

- Non - Decomposable problem:



Is the problem Decomposable?

- Non - Decomposable problem:



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Can solution steps to be ignored or undone?

- Consider following 3 problems

1: proving a theorem or lemma

– some steps can be ignored

– logically derives to a solution

Can solution steps to be ignored or undone?

- Consider following 3 problems

2: 8 puzzle problem

1	3	4
8	6	2
7		5

Initial State

1	3	4
8	6	2
7	5	

1	3	4
8	6	
7	5	2

1	2	3
8		4
7	6	5

Goal State

- Recoverable problem

Can solution steps to be ignored or undone?

- Consider following 3 problems

3: chess problem

- Irrecoverable problem

Can solution steps to be ignored or undone?

- Proving a theorem or lemma
  - Ignorable
- 8 puzzle problem
  - Recoverable
- Chess game
  - Irrecoverable

Recovery of the problem plays an important role in determining the complexity of the control structure

Problem Characteristics

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Is the problem’s universe predictable?

- 8 puzzle problem – next step is always predictable – normal planning - certain outcome

1	3	4
8	6	2
7		5

1	3	4
8	6	2
7	5	

- Card game – next st ility for finding – uncertain problem

Problem Characteristics

1. Is the problem Decomposable?
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Is the good solution is absolute or relative?

- Consider this example: Given some facts

1. Deena is a man.
2. Deena is a worker in a company.
3. Deena was born in 1905.
4. All men are mortal.
5. All workers in a factory died when there was an accident in 1952.
6. No mortal lives longer than 100 years.

"Is Deena alive"

Is the good solution is absolute or relative?

1. Deena is a man.
2. Deena is a worker in a company.
3. Deena was born in 1905.
4. All men are mortal.
5. All workers in a factory died when there was an accident in 1952.
6. No mortal lives longer than 100 years.

"Is Deena alive"

Solution 1:
1. Deena is a man.
2. Deena was born in 1905.
3. All men are mortal.
4. Now it is 2020, so Siva's age is 105 years.
5. No mortal lives longer than 100 years.

Solution 2:
1. Deena is a worker in the company.
2. All workers in the company died in 1952.

Any path problem – Relative solutions

Is the good solution is absolute or relative?

Consideration 2 : Travelling Salesman problem

Travelling salesman problem: Goal : shortest path from source city to destination city – visiting all cities one by one

Solution : Shortest path – to visit all cities

Best path problem – Absolute solutions

Is the good solution is absolute or relative?

Solution:

Any path problem – Relative solution

Best path problem – Absolute Solution

Problem Characteristics

1. Is the problem Decomposable?
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5. Is the solution a state or a path?
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7. Does the task require interaction with a person?

Is the solution a state or a path?

Consideration 1: Inference from the statement

"The bank president ate a dish of pasta salad with the fork"

Inference: pasta salad was a dish , pasta salad was eaten, pasta salad consists of pasta....

Solution: state

Is the solution a state or a path?

Consideration 2 : Path problem

Water jug problem: Goal : (2,0)

Solution : path taken to reach goal state from initial state

Solution: path taken from (0,0) – (2,0)

Problem Characteristics

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7. Does the task require interaction with a person?

What is the role of knowledge?

- **Chess playing**

  – rules for determining legal moves + some simple control mechanisms

- **News paper story**

  – scan all daily newspapers + how many supports Modi jee + how many supports Soina jee for upcoming election

Problem Characteristics

1. Is the problem Decomposable?
2. Can solution steps to be ignored or undone?
3. Is the problem's universe predictable?
4. Is the good solution is absolute or relative?
5. Is the solution a state or a path?
6. What is the role of knowledge?
7. Does the task require interaction with a person?

Does the task require interaction with a person?

- **Solitary**:
  - Computer is given with a problem description
  - no intermediate communication
  - no demand for an explanation
- **Conversational**:
  - Intermediate conversations between person to computer
  - User need to provide additional information
  - Robotics

Problem Characteristics

1. Is the problem Decomposable?
2. Can solution steps to be ignored or undone?
3. Is the problem’s universe predictable?
4. Is the good solution is absolute or relative?
5. Is the solution a state or a path?
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- https://youtu.be/iaAbUhqXmNo

Problem Analysis and Representation

Solution:

- Two water jugs are there with 5 litre and 2 litre capacity and there is no measurements available
- The allowed operations are filling the jug and pouring out water from the jug
- initial state: (5,2)
- goal state: (1,0)
- **Sequence of operations:**

  i) empty big(remove water from big jug)

  ii) empty small(remove water from small jug)

  iii) big is empty(pour water from small jug to big jug)

  iv) small is empty(pour water from big jug to small jug)

  actions of sequence: 2,4,2,4,2

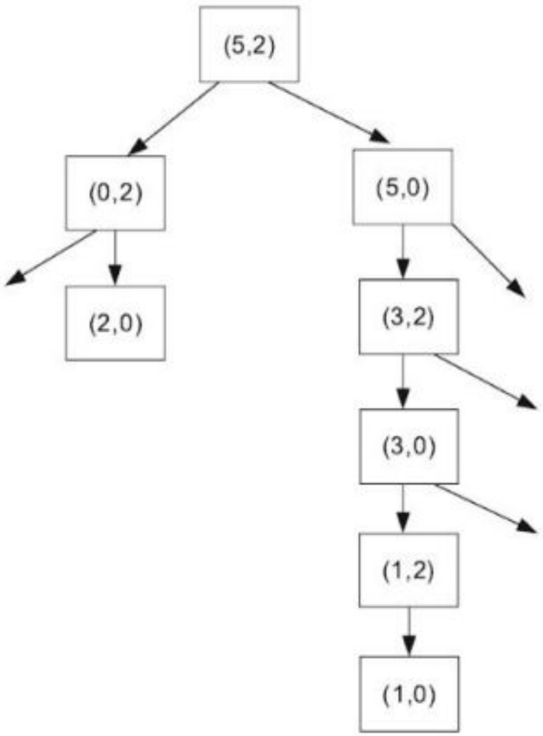


Figure 2.7 Water jug problem.

Problem Analysis and Representation

- Problem definition must satisfy these criteria:

1. **Compactness:** Solution space should be clearly defined
2. **Utility:** Compatible with existing systems
3. **Soundness:** Should not raise false alarm
4. **Completeness:** Should have all the past details
5. **Generality:** Able to handle all similar events
6. **Transparency:** Reasoning should be visible to the user

Performance Measuring

- Various factors needs to be considered in problem solving
- Three outcomes of problem solver
    - Finding a solution
    - Terminating with failure after search space is exhausted
    - Terminating after certain number of iterations
- Reward: if the problem is solved but the amount of time and resource used needs to be considered

Performance Gain

- Performance gain,
  - Problem: Well defined problem or poorly defined
  - Time: Time taken to arrive at the solution
  - Resource: Storage cost, hardware cost, etc.…
  - Result: Success or Failure

Problem Space and Search

- Problem is represented as state space
- Search is a general algorithm for finding path in state space
- The identified path will either lead to solution or dead end
- Search algorithm makes use of control strategy like forward or backward search
    - forward search(data directed)
        - Starts search from initial state towards goal state.
        - Ex: locating a city from current location
- backward search(goal directed)
    - Search stars from goal state towards a Solvable initial state
    - Ex: start from target city

Problem Space and Search

- Strategies to explore the states
  - Informed search – No guarantee for solution but high probability of getting solution
    -heuristic approach is used to control the flow of solution path
    -heuristic approach is a technique based on common sense, rule of thumb, educated guesses or intuitive judgment
  - Uninformed search – generates all possible states in the state space and checks for the goal state.
    - time consuming due to large state space
    - used where error in the algorithm has severe consequences

- Parameters for search evaluation
  i) completeness: Guaranteed to find a solution within finite time
  ii) space and time complexity: memory required and time factor needed
  iii) optimality and admissibility: correctness of the solution

Informed Search

- Does not guarantee a solution
- But it ensures high probability of arriving at solution
- Heuristic is a problem specific knowledge or guidance used to constrain the search and lead to the goal
- Heuristic is based on common sense or rule of thumb, educated guesses or intuitive judgement
- It helps us to choose the right path when multiple path exist for a problem

Uninformed Search

- Uninformed search is also referred as blind search
- Generates all possible states in state space and checks for goal state
- It will always find a solution if it exists
- But the method is time consuming since search space is huge
- It is used to benchmark results of other algorithms

Problems in design of search programs

- State representation and identifying relationships between states

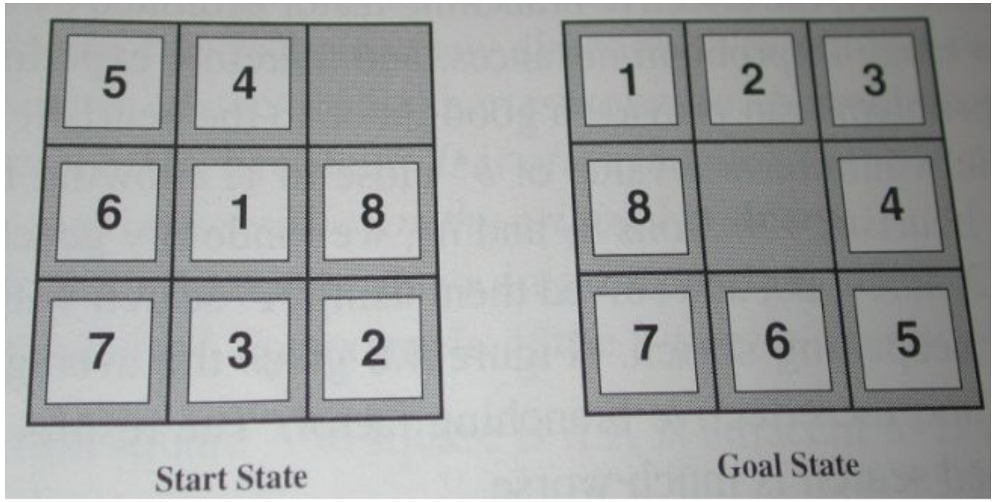
- Proper selection of forward and backward movement to determine optimal path

- Rule selection

Toy problems

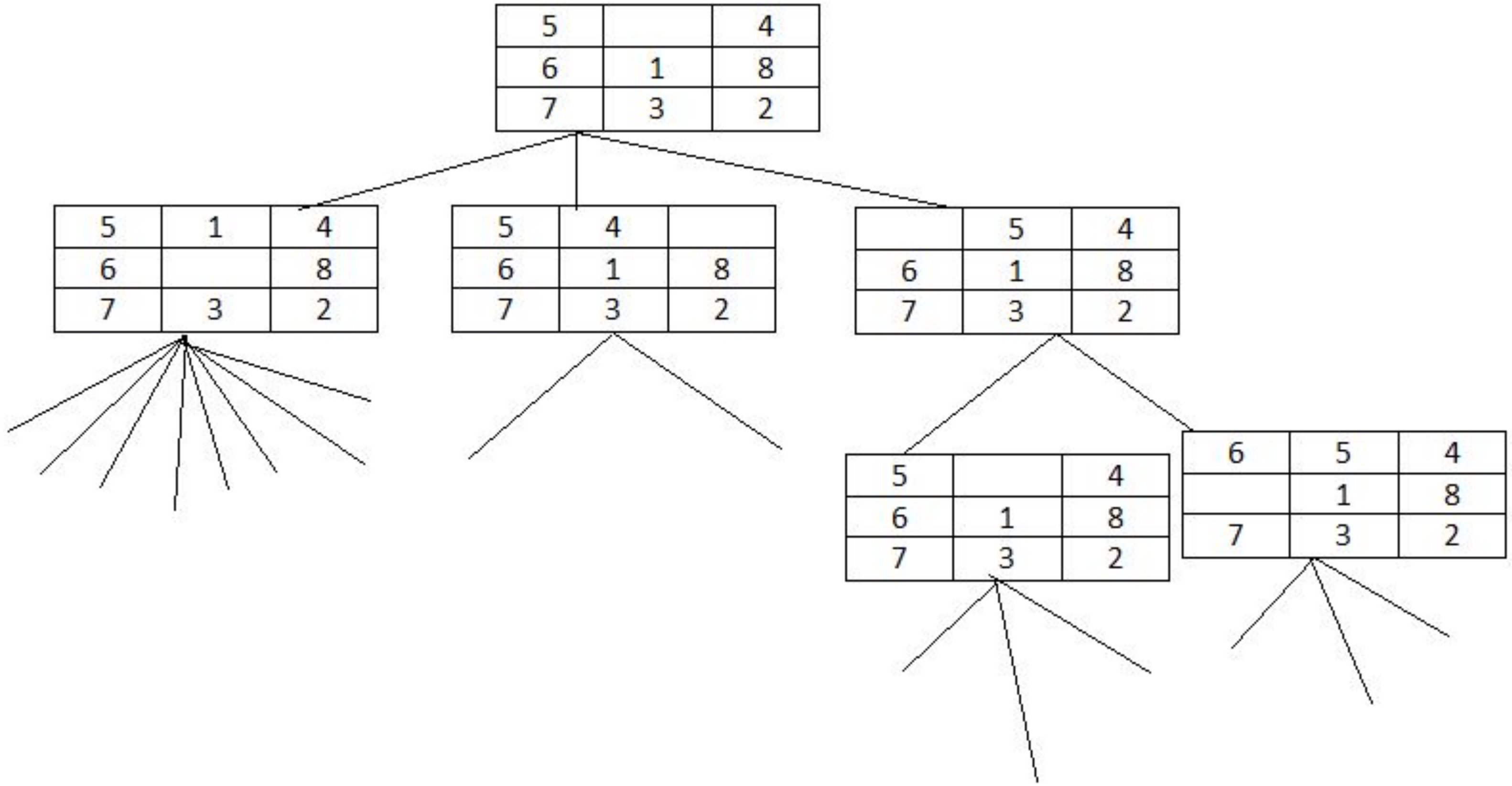
1. 8 puzzle problem

- 3x3 board with eight numbered tiles and a blank space.
- A tile adjacent to the blank space can slide into the space.
- objective-to reach the configuration shown on the right of the figure.



Toy problems

1. 8 puzzle problem – search space



Toy problems

1. 8 puzzle problem

Problem formulation:

• **States:** a state description specifies the location of each of the eight tiles in one of the nine squares. For efficiency, it is useful to include the location of the blank.

• **Initial state:** Numbers are not arranged in clockwise order

• **Operators:** blank moves left, right, up, or down.

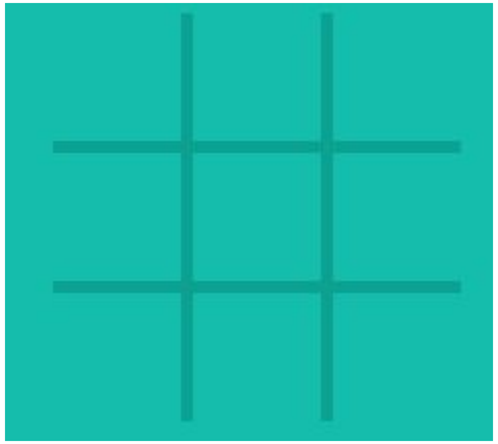
• **Goal state:** state matches the goal configuration shown in previous Figure

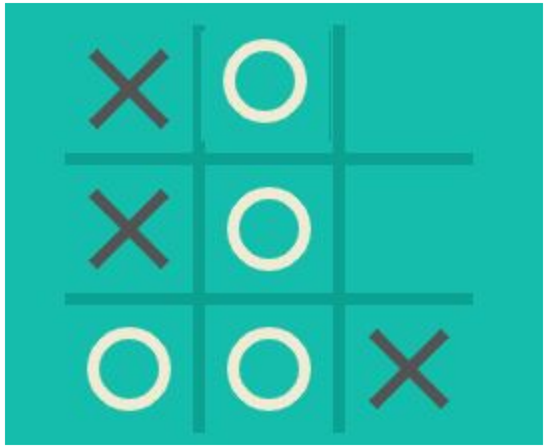
• **Path cost:** each step costs 1, so the path cost is just the length of the path.

Toy problems

2. Tic-tac-toe problem

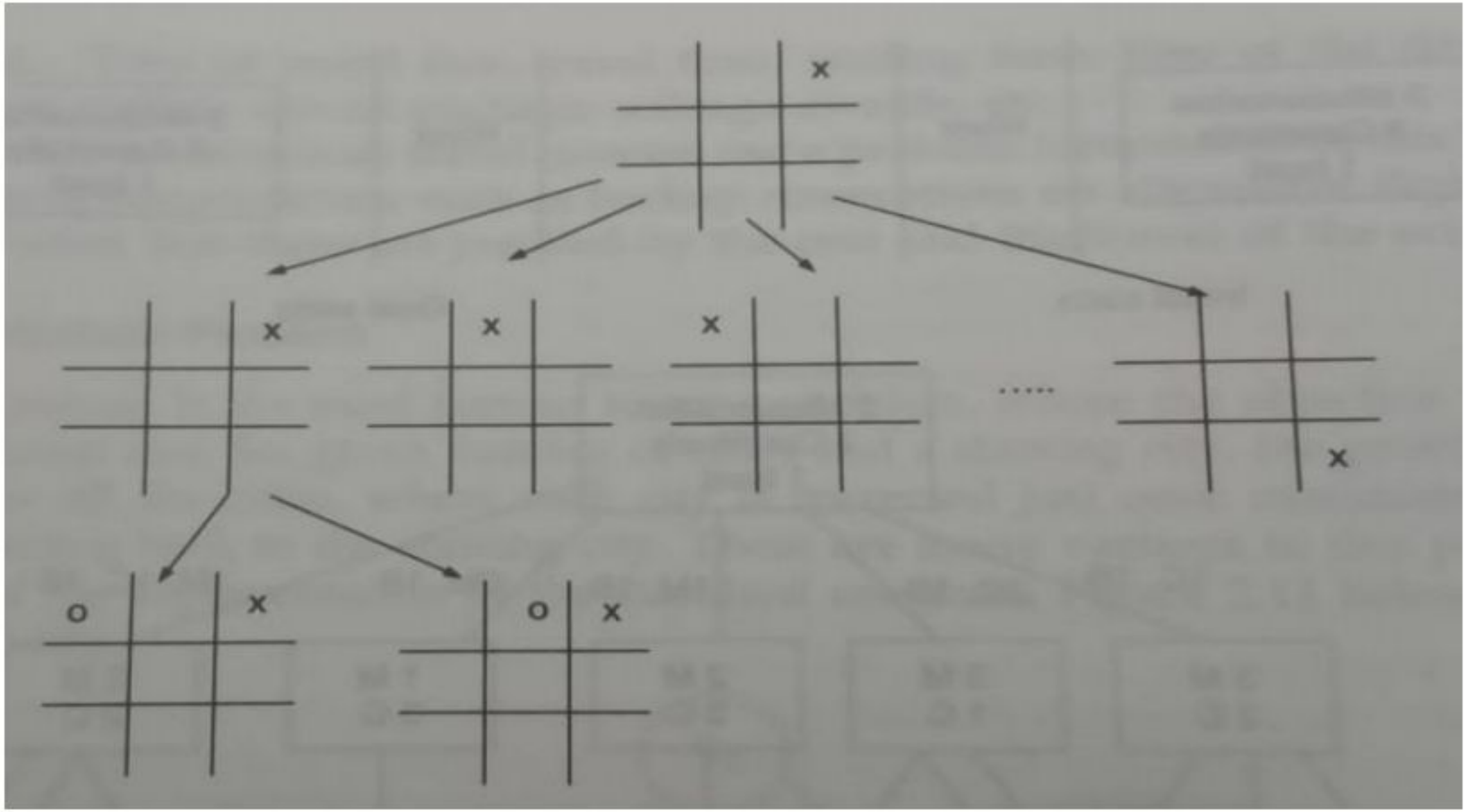
- Each player marks a 3*3 grid by 'x' and 'o' in turn.
- The player who puts respective mark in a horizontal, vertical or diagonal line wins the game
- If both players fail to reach above criteria and all boxes in the grid are filled, then the game is draw





Toy problems

2. Tic-tac-toe problem



Toy problems

2. Tic-tac-toe problem

Formulating Tic-tac-toe problem

- **Initial state** – state in previous figure
- **States** – Next figure with 'x' and 'o' positions constitutes the states in space
- **Operators** – Adding 'x' or 'o' in cells one by one
- **Goal** – To reach final/winning position
- **Path cost** – Each step costs 1 so that path cost is length of path

Toy problems

3. Missionaries and Cannibals

- Three missionaries and cannibals
- Need to move all the six people from one bank of river to the other
- The boat has a capacity of one of two people

Toy problems

3. Missionaries and Cannibals

Formulating the problem in state space search

• States – sequence of 3 numbers representing number of missionaries, cannibals and boat.

•Goal state - missionaries and cannibals have reached other side of river (3,3,1)

•Initial state - (3,3,0)

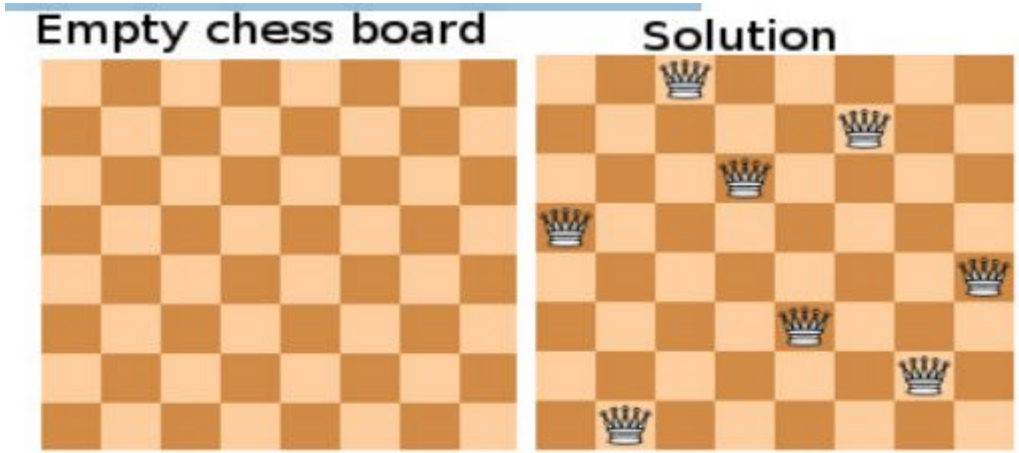
•Operator - Putting missionary and cannibal in boat such that cannibal does not outnumber missionary and one/two people in boat

• Path cost – number of crossings

Toy problems

4. The 8-queens problem

- Place eight queens on a chessboard such that no queen attacks any other.
- There are two main kinds of formulation
- The incremental formulation involves placing queens one by one
- The complete-state formulation starts with all 8 queens on the board and moves them around.
- Goal test: 8 queens on board, none attacked



Toy problems

4. The 8-queens problem

Formulating the problem in state space search

Consider the following for incremental formulation:

- States: Any arrangement of 0 to 8 queens on board.
- Initial state: No queens in the board
- Goal state: Queens in each column without targeting other queens
- Operators: add a queen to any square.
- Path cost: Number of moves

Toy problems

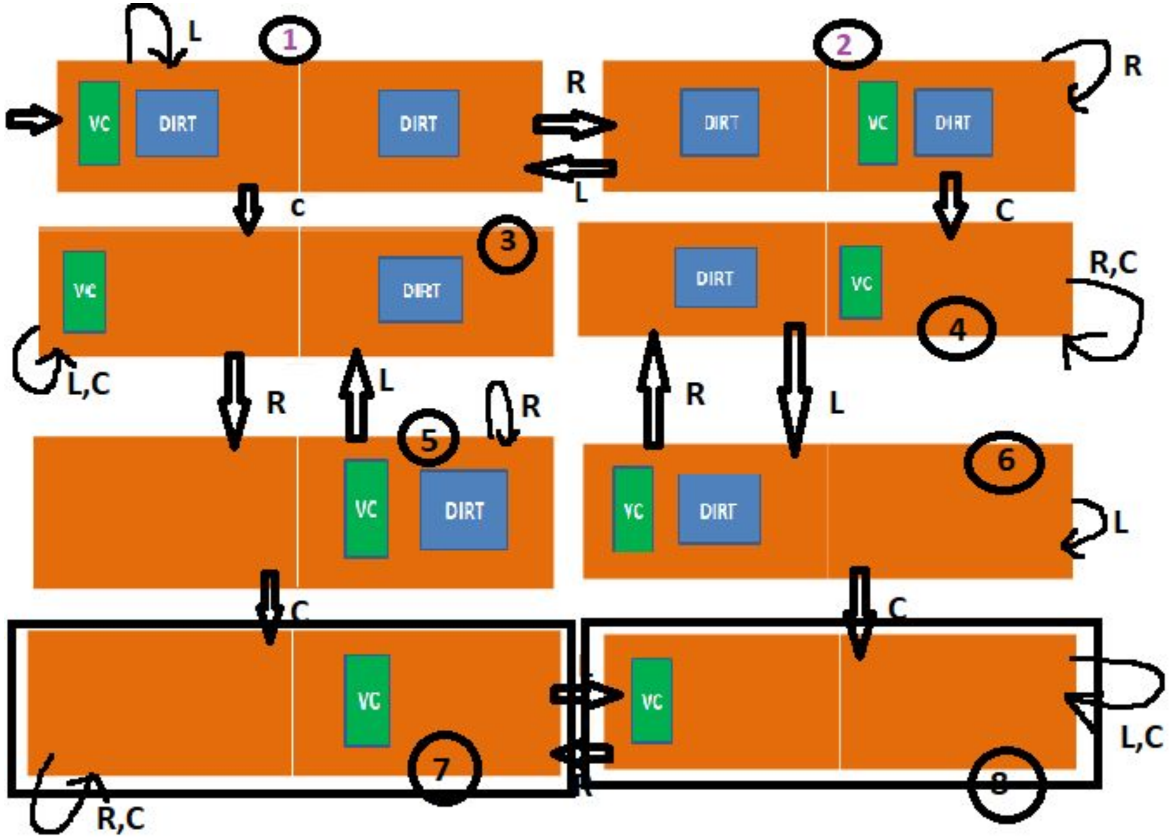
5. Vacuum cleaner problem

Assume that the agent knows its location and the locations of all the pieces of dirt, and the suction is still in good working order.

- States: It is based on Vacuum cleaner location and dirt location
- Initial state: Any state can be assumed as initial state
- Operators: move left, move right, suck.
- Goal state: no dirt left in any square.
- Path cost: each action costs 1.

Toy problems

5. Vacuum cleaner problem



Real-world problems

- **Route finding:**
- Defined in terms of locations and transitions along links between them
- Applications: routing in computer networks, automated travel advisory systems, airline travel planning systems

Real-world problems

- **Touring and traveling salesperson problems:**
- "Visit every city on the map at least once and end in Bucharest"
- Needs information about the visited cities
- Goal: Find the shortest tour that visits all cities
  - NP-hard, but a lot of effort has been spent on improving the capabilities of TSP algorithms

Real-world problems

- **VLSI layout:**
  - Place cells on a chip so they don't overlap and there is room for connecting wires to be placed between the cells
- **Robot navigation:**
  - Generalization of the route finding problem
  - No discrete set of routes
  - Robot can move in a continuous space
  - Infinite set of possible actions and states

Real-world problems

- **Assembly sequencing:**
  - Automatic assembly of complex objects
  - The problem is to find an order in which to assemble the parts of some object