



Artificial & Computational Intelligence

AIML CZG557

M4 : Knowledge Representation using Logics

Indumathi V
Guest Faculty

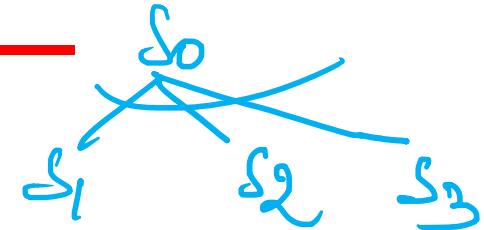
BITS - CSIS

BITS Pilani
Pilani Campus

Course Plan

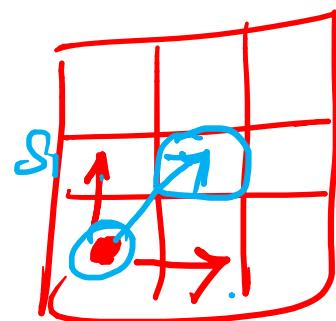
- M1 Introduction to AI
- M2 Problem Solving Agent using Search
- M3 Game Playing
- M4 Knowledge Representation using Logics
- M5 Probabilistic Representation and Reasoning
- M6 Reasoning over time
- M7 Ethics in AI

Certainty



Probability

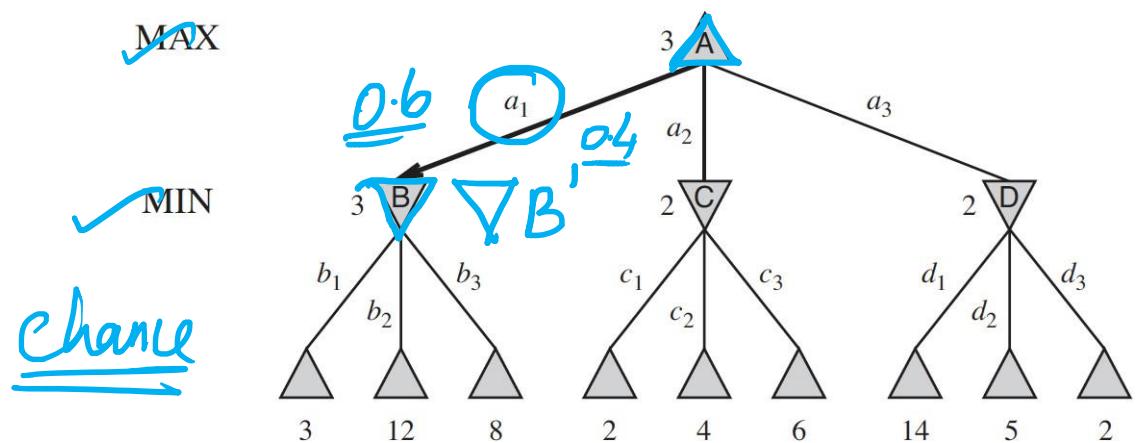
Gaming
(Imperfect Decisions) \nrightarrow uncertainty



4 possible actions

Computational Efficiency

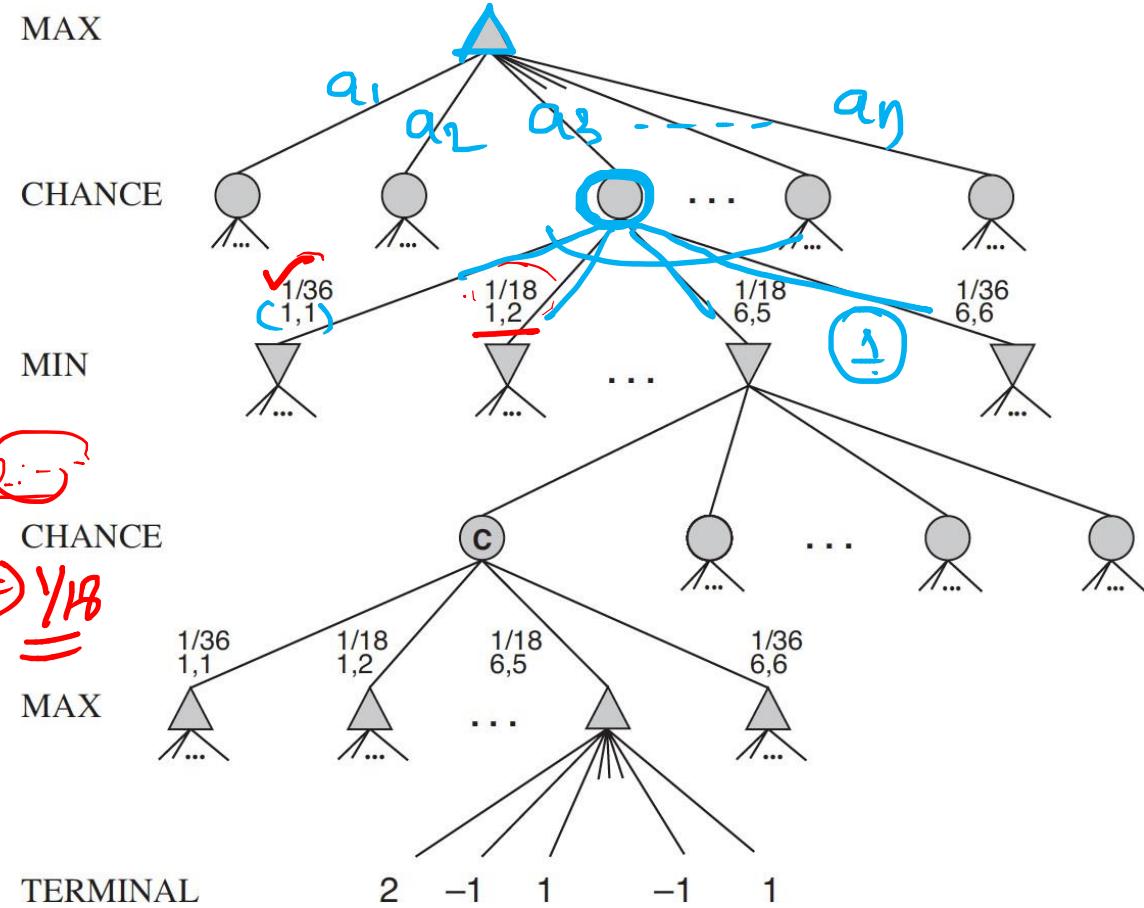
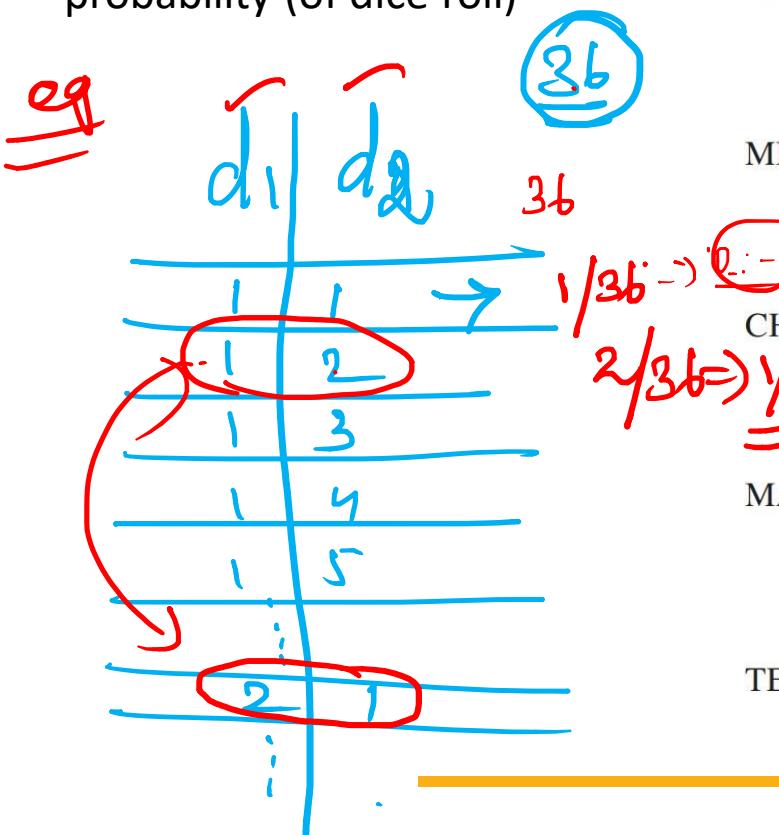
How games can be designed to handle imperfect decisions in real-time?



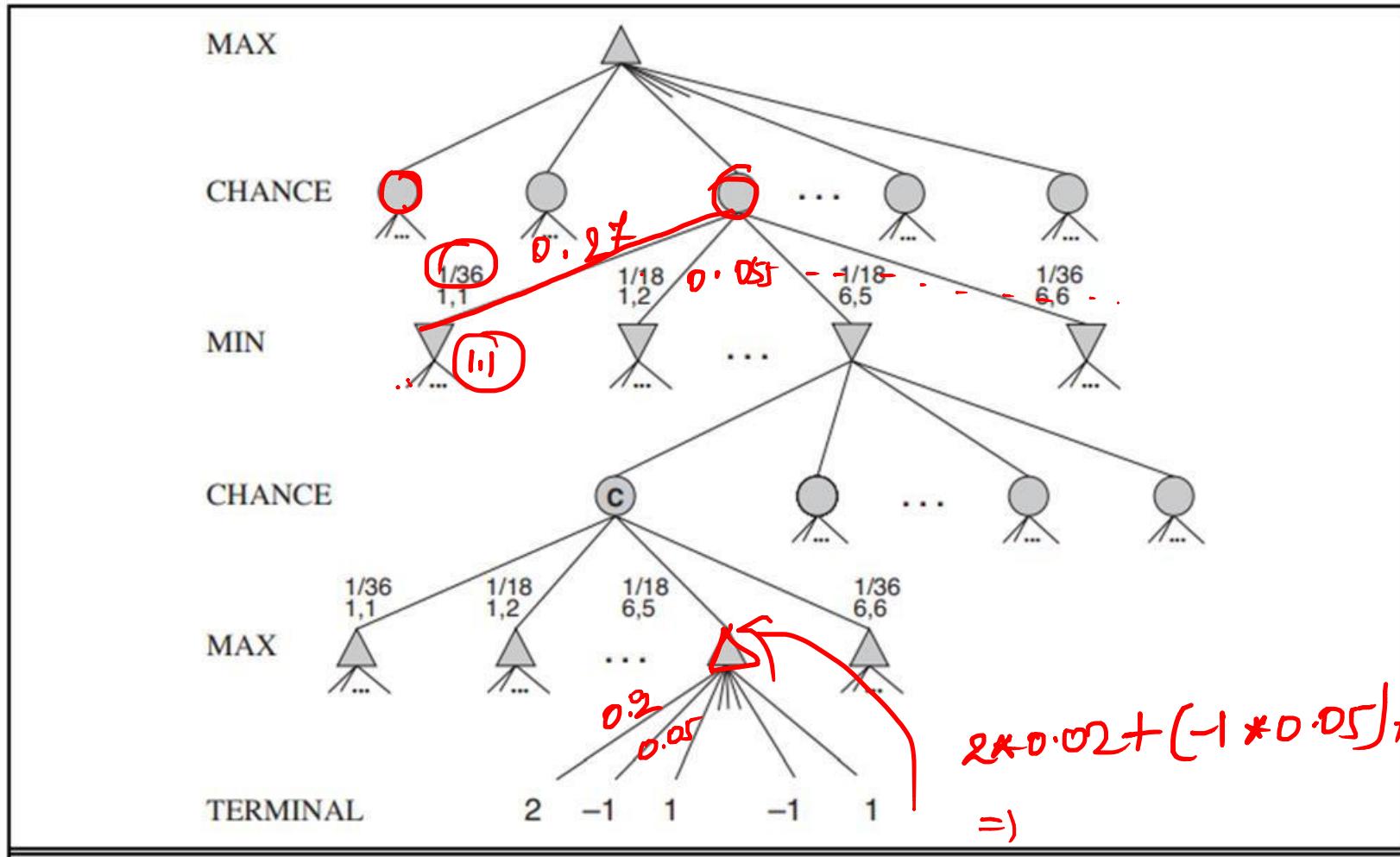
Computational Efficiency

Idea : Chance Node:

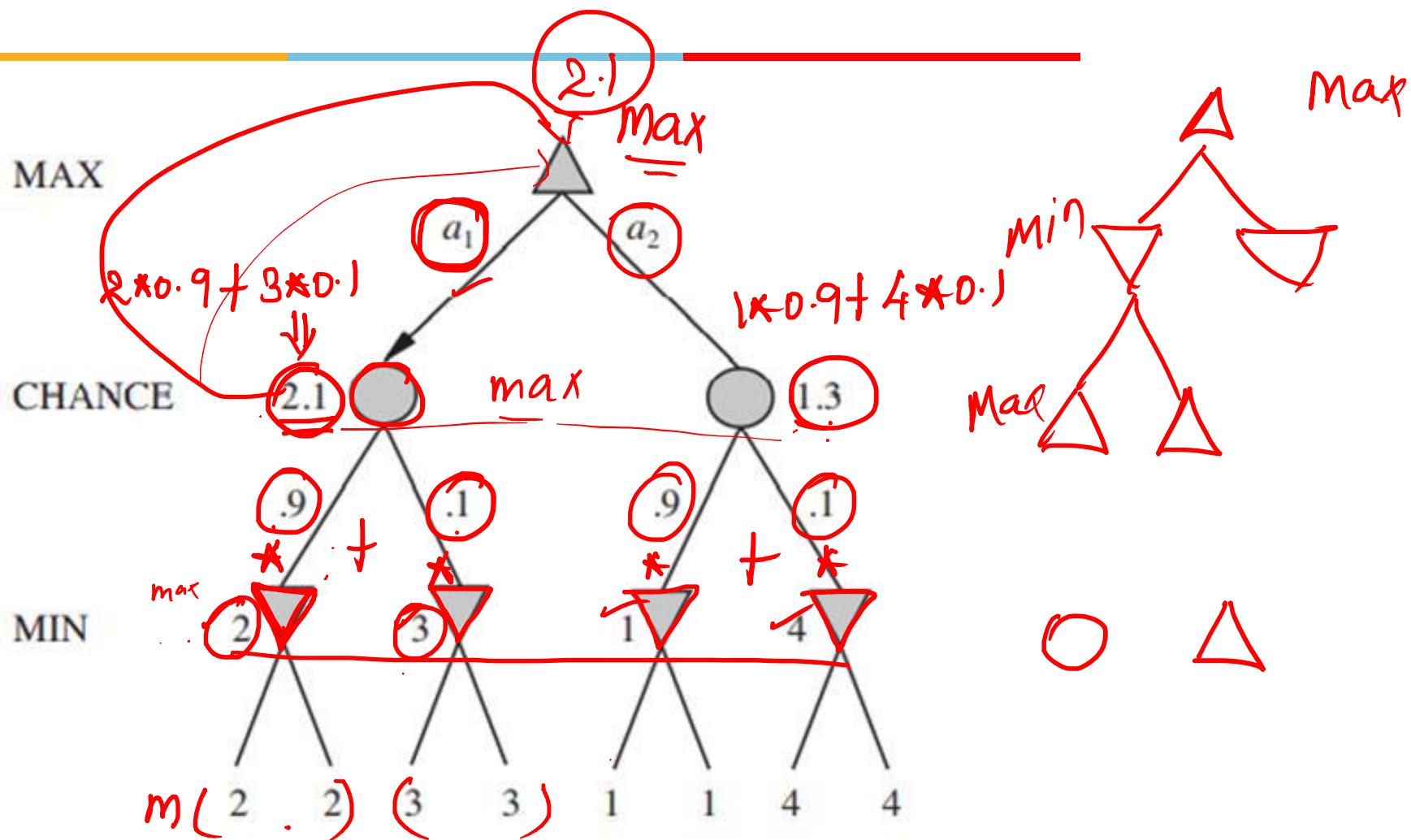
Holds the expected values that are computed as a sum of all outcomes weighted by their probability (of dice roll)

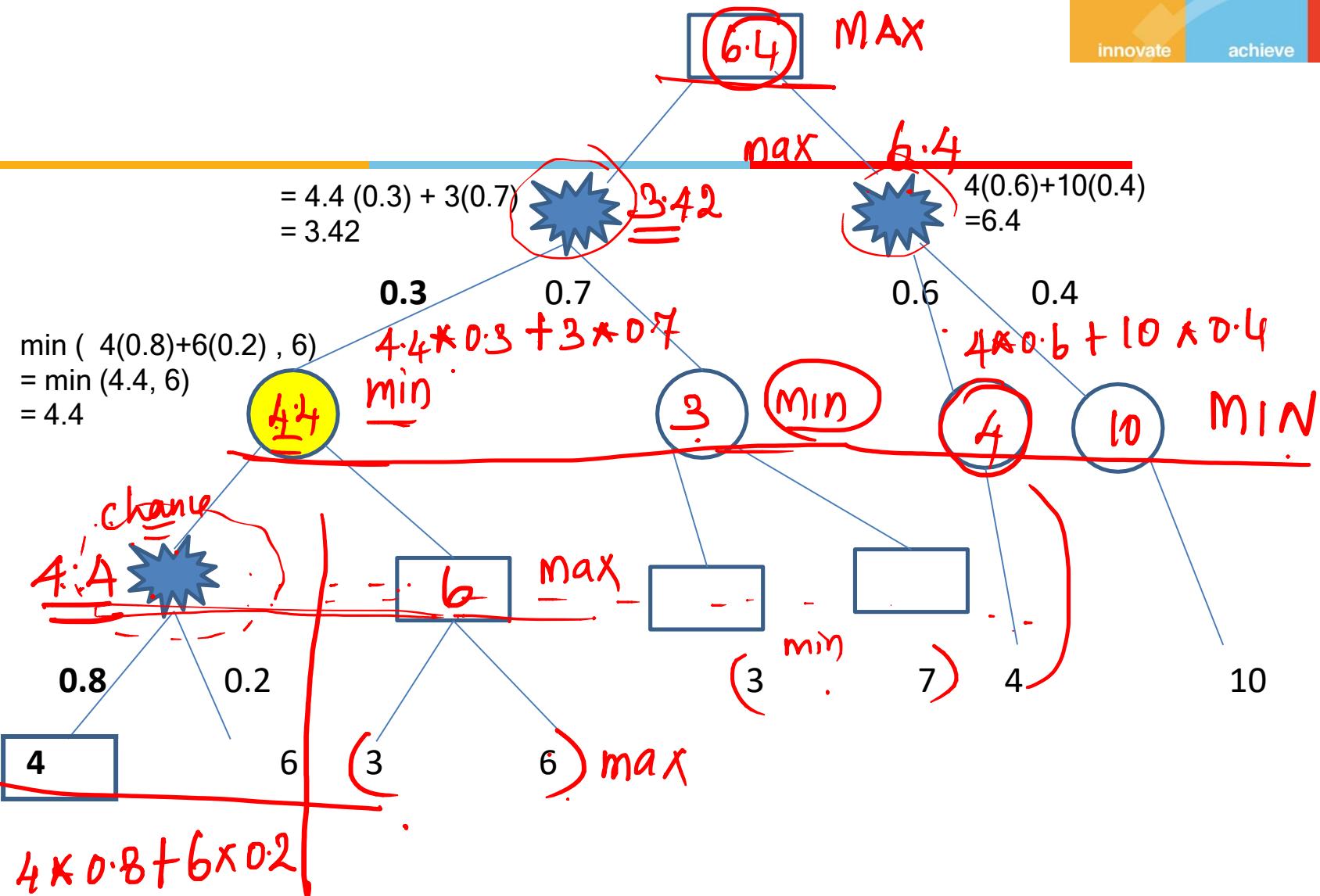


Expecti Mini Max Algorithm

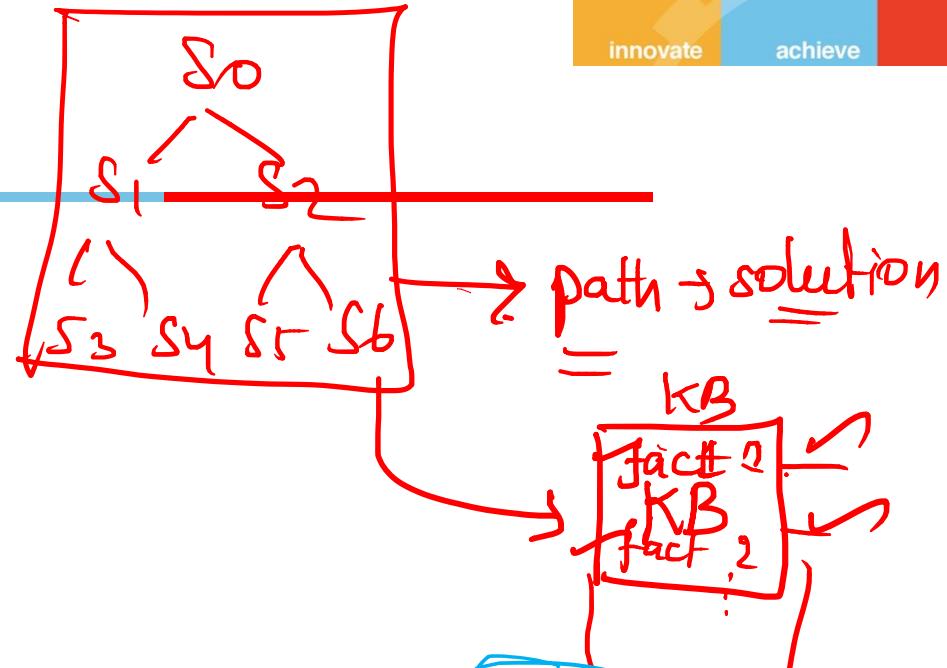


Expecti Min! Max Algorithm





- ① uninformed search
- ② Informed "
- ③ Local "
- ④ Adversarial search



M4 Knowledge Representation Using Logics

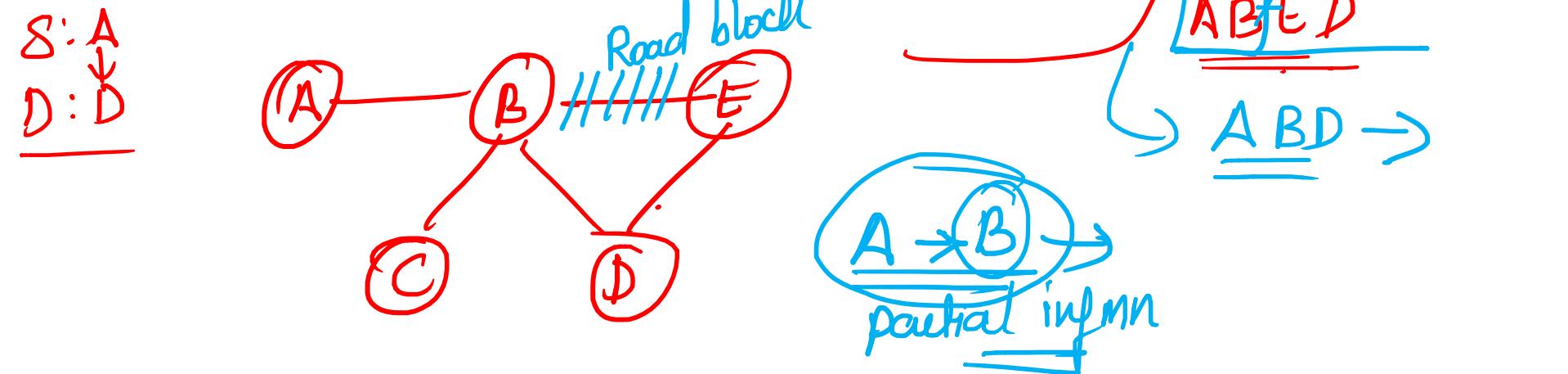
Large Prob → more info → generated → KB → Large KB

A → B → Query → DB → result

Learning Objective

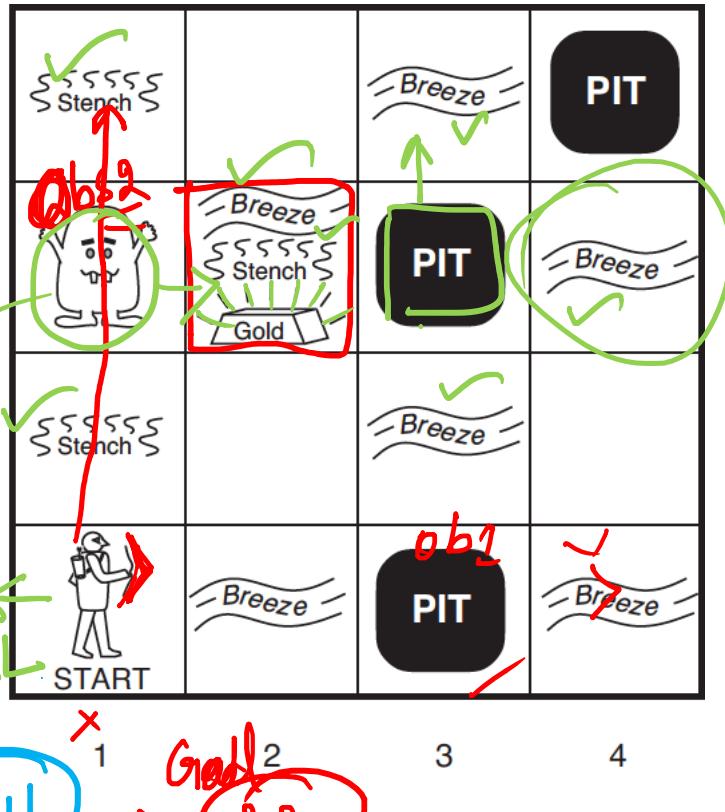
At the end of this class , students Should be able to:

1. Represent a given knowledge base into logic formulation
2. Infer facts from KB using Resolution
3. Infer facts from KB using Forward Chaining
4. Infer facts from KB using Backward Chaining



Knowledge based Agent : Model & Represent

Concepts, logic Representation of a sample agent



Wumpus World Problem:

PEAS:

Performance Measure:

- +1000 for climbing out with gold,
- 1000 for falling into a pit or being eaten by Wumpus,
- 1 for each action taken and
- 10 for using an arrow

Environment: 4x4 grid of rooms. Always starts at [1, 1] facing right.

The location of Wumpus and Gold are random. Agent dies if entered a pit or live Wumpus.

① Env : static

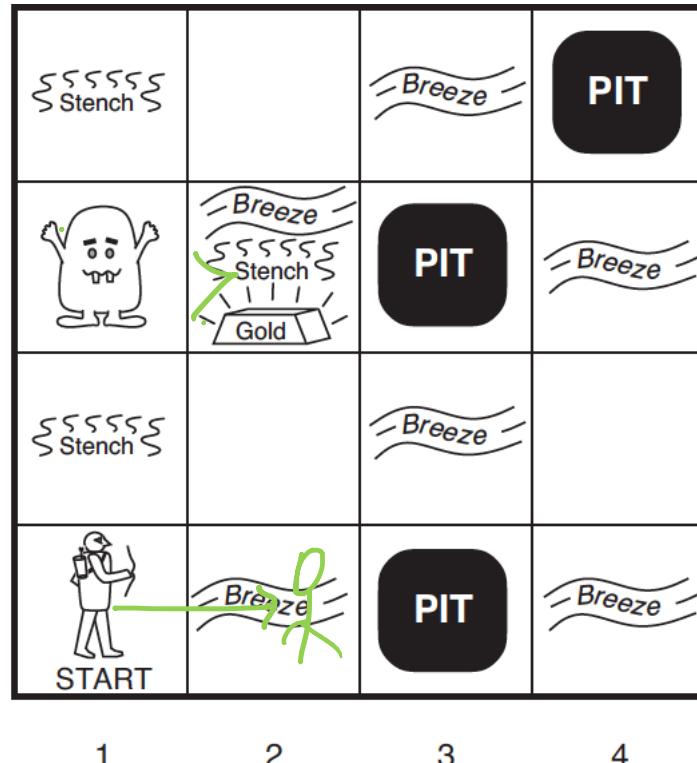
② Agent:
st, Br → evidences
4° free.

2 → PIT
Wumpus → Restart the game

Knowledge based Agent : Model & Represent



Concepts, logic Representation of a sample agent

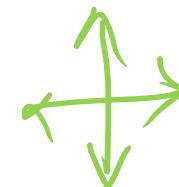


Wumpus World Problem:

PEAS:

Actuators –

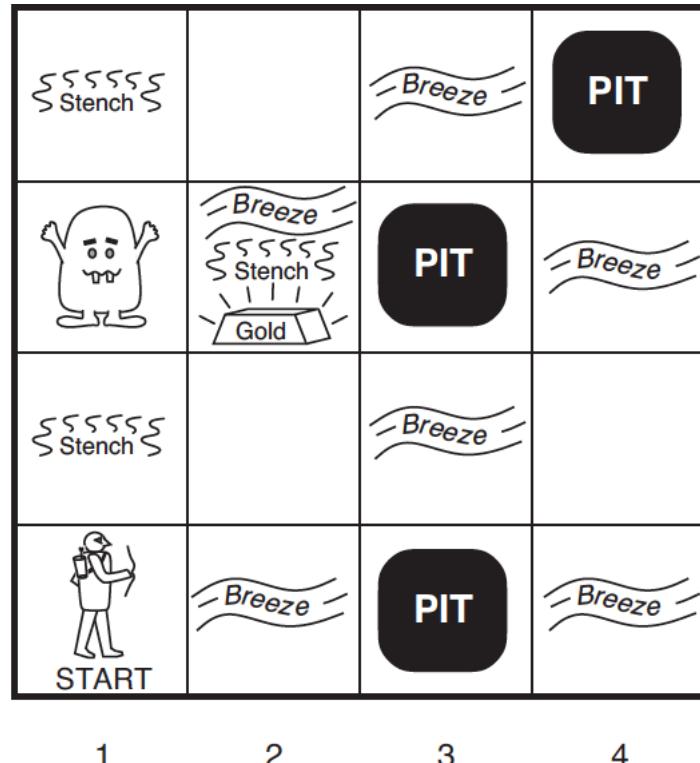
- ~~Forward~~, ML
- ~~TurnLeft by 90,~~ MR
- ~~TurnRight by 90,~~ MU, MD
- ✓ Grab – pick gold if present,
- ✓ Shoot – fire an arrow, it either hits a wall or kills wumpus. Agent has only one arrow.
- Climb – Used to climb out of cave, only from [1, 1]



Knowledge based Agent : Model & Represent



Concepts, logic Representation of a sample agent



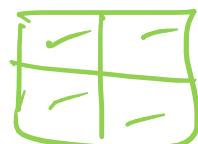
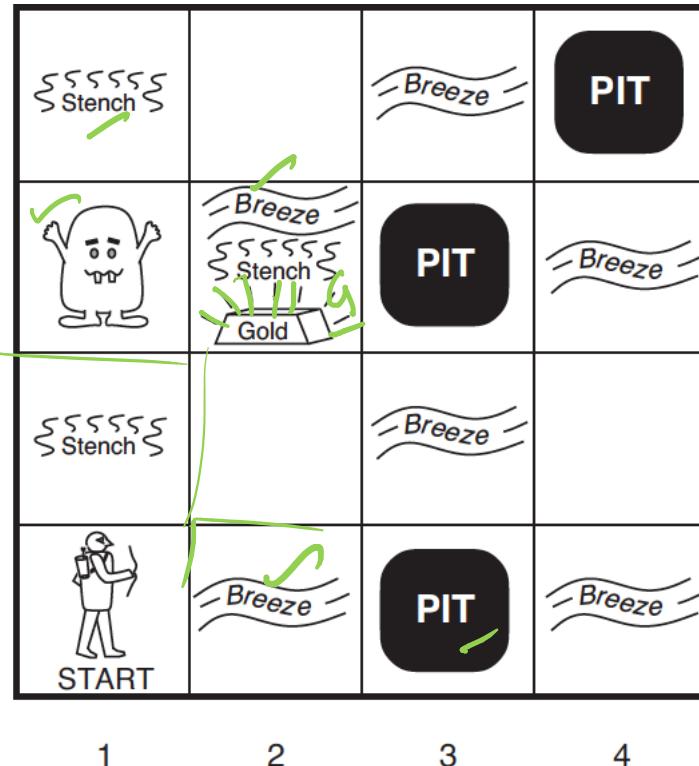
Why do we need Factored representation

- To reason about steps
- To learn new knowledge about the environment
- To adapt to changes to the existing knowledge
- Accept new tasks in the form of explicit goals
- To overcome partial observability of environment

Knowledge based Agent : Model & Represent

[St, G, B] →

Concepts, logic Representation of a sample agent



Wumpus World Problem:

PEAS:

Sensors. The agent has five sensors

Stench: In all adjacent (but not diagonal) squares of Wumpus

Breeze: In all adjacent (but not diagonal) squares of a pit

Glitter: In the square where gold is

Bump: If agent walks into a wall

Scream: When Wumpus is killed, it can be perceived everywhere

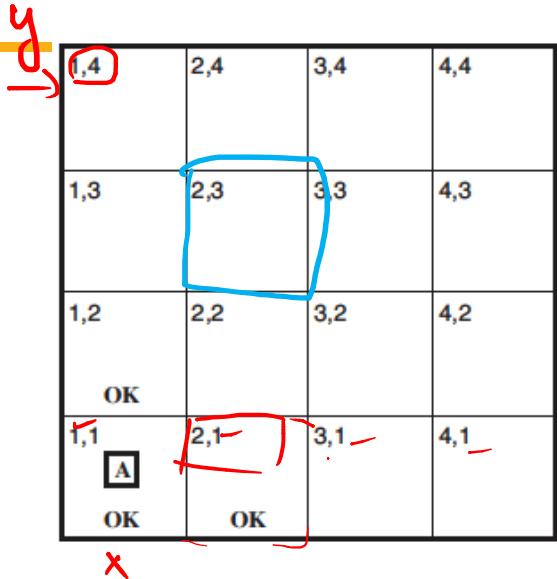
Percept Format:

[Stench?, Breeze?, Glitter?, Bump?, Scream?]

E.g., [Stench, Breeze, None, None, None]

Percept 1: [None, None, None, None, None]

Action: Forward



A 4x4 grid world state diagram. The axes are labeled x and y. Cells are labeled with values (e.g., 1,4; 2,4; 3,4; 4,4) or status (OK). A robot is at (1,1) with a sensor range of 1 unit. A pit is at (4,4). A gold coin is at (3,3). A stench source is at (1,4). A breeze source is at (2,3).

$S <^T_F \Rightarrow S_{x,y}$

$S_{1,4} \rightarrow \text{True}$

$S_{1,1} \rightarrow \text{False} \rightarrow \neg S_{1,1}$

$B_{x,y} \Rightarrow [B_{2,1}] \rightarrow \text{True}$

$B_{2,2} \rightarrow \text{False}$

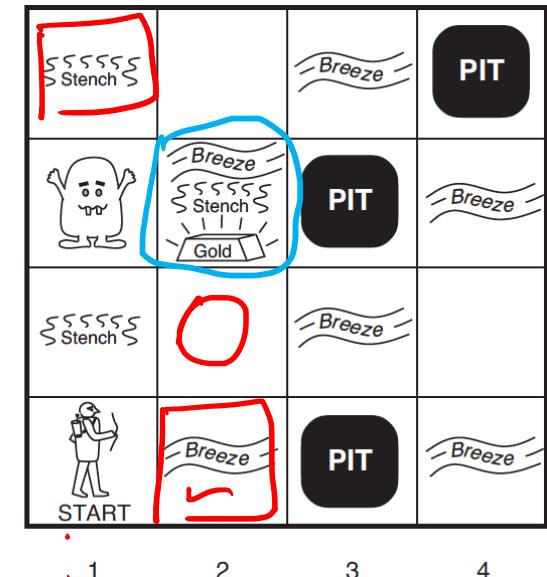
$\neg B_{2,2} \rightarrow B_{2,2}$

$B, S, b,$

Percepts?

$L_{2,3} \rightarrow B_{2,3} \wedge \neg B_{3,3} \wedge G_{1,2,3}$

$L_{2,1} \rightarrow B_{2,1} \wedge \neg S_{2,1} \wedge \neg G_{1,2,1}$



$S_r \rightarrow \text{True}$
ignore M

Percept Format: $[S, B, G, Bump, Scream]$

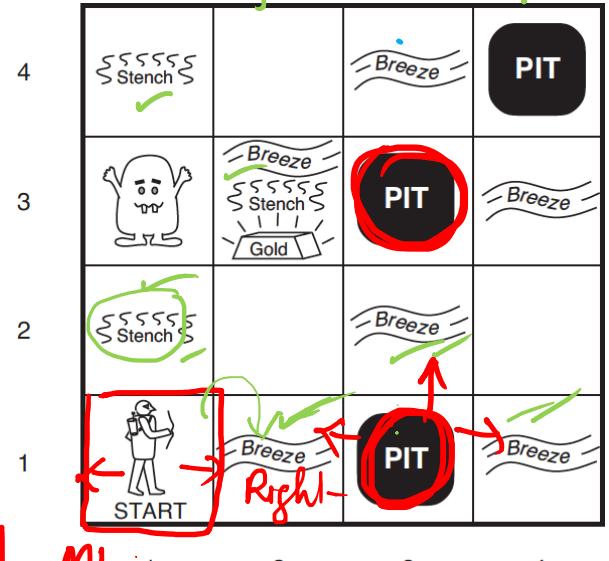
$S \quad B \quad G \quad Bump \quad Scream$

Percept 1: [None, None, None, None, None]

Action: Forward



1,4	2,4	3,4	4,4
1,3	2,3	B	PIT
1,2	2,2	B	B
1,1	A	OK	OK
2,1	OK	OK	



conjunction
and

if P_{xy} $\rightarrow B_{x+1,y}^3 \wedge B_{x,y+1}^3 \wedge B_{x-1,y}^3 \wedge B_{x,y-1}^3$
 $\wedge B_{4,3} \wedge B_{3,4} \wedge B_{2,3} \wedge B_{3,2}$

Rule System (2)

if $W_{x,y}$ $\rightarrow S_{x+1,y} \wedge S_{x,y+1} \wedge S_{x-1,y} \wedge S_{x,y-1}$

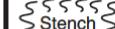
$\wedge S_{2,3} \wedge S_{1,4} \wedge S_{3,3} \wedge S_{1,2}$

Percept Format:
 [Stench?, Breeze?, Glitter?, Bump?, Scream?]
 No No No No No

Percept 1: [None, None, None, None, None]

Action: Forward

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
1,1 OK A OK	2,1 PIT Fr OK	3,1	4,1

4	 Stench	 Breeze	PIT
3	 Breeze	 Stench	PIT
2	 Stench	 Breeze	
1	 START	 Breeze	PIT

$$\begin{aligned}
 B_{x,y} &\rightarrow P_{x+1,y} \vee P_{x,y+1} \quad \text{OR} \\
 S_{x,y} &\rightarrow W_{x+1,y} \vee W_{x,y+1} \vee W_{x-1,y} \vee W_{x,y-1} \rightarrow \text{Rule 3} \\
 \neg B_{1,1} &\rightarrow \neg P_{1,2} \quad \neg P_{2,1} \\
 \neg S_{1,1} &\rightarrow \neg W_{1,2} \quad \neg W_{2,1}
 \end{aligned}$$

declared facts

PIT free

Percept Format:

[Stench?, Breeze?, Glitter?, Bump?, Scream?]

Monshee free

Safe cell

Percept 3: [Stench, None, None, None, None] Breeze

Action: Move to [2, 2]

Remembers (2,2) as possible PIT and no Stench.

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
1,1	A	2,1	3,1
OK	OK	OK	OK

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
1,1	A	2,1	3,1
OK	OK	OK	OK

fact
 $Loc_{2,1} \Rightarrow B_{21} \wedge \neg S_{21}$

$B_{21} \rightarrow P_{11} \vee P_{22} \vee P_{31}$

$\neg S_{21} \rightarrow \neg W_{11} \wedge \neg W_{21} \wedge \neg W_{31}$

$P_{11} \vee P_{22} \vee P_{31}$

$\neg P_{11}$

$P_{22} \vee P_{31}$

2 Risk \rightarrow Randomly
 backtrace \rightarrow alternate path.

Stench		Breeze	PIT
Breeze		Stench	PIT
		Gold	
			Breeze
		✓	
			Breeze
START		Breeze	PIT
			Breeze

KB

Percept 3: [Stench, None, None, None, None]

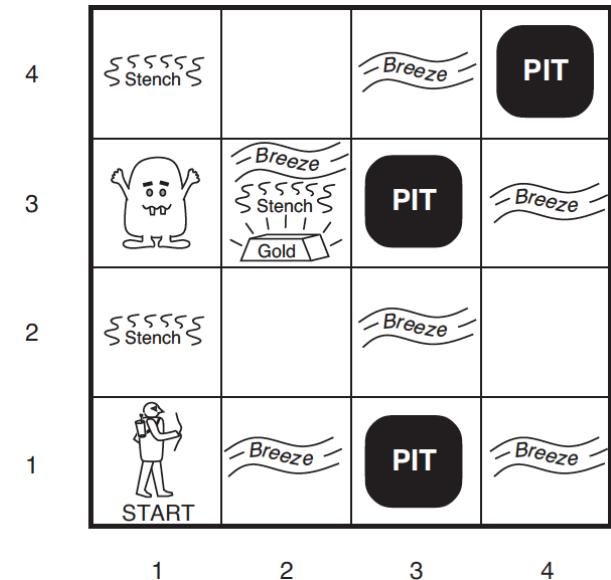
Action: Move to [2, 2]

Remembers (2,2) as possible PIT and no Stench.

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
OK			
1,1 A	2,1	3,1	4,1
OK	OK		



1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2 P?	3,2	4,2
OK			
1,1 V OK	2,1 A B OK	3,1 P?	4,1



Percept 3: [Stench, None, None, None, None]

Action: Move to [2, 2]

Remembers (2,2) as possible PIT and no Stench.

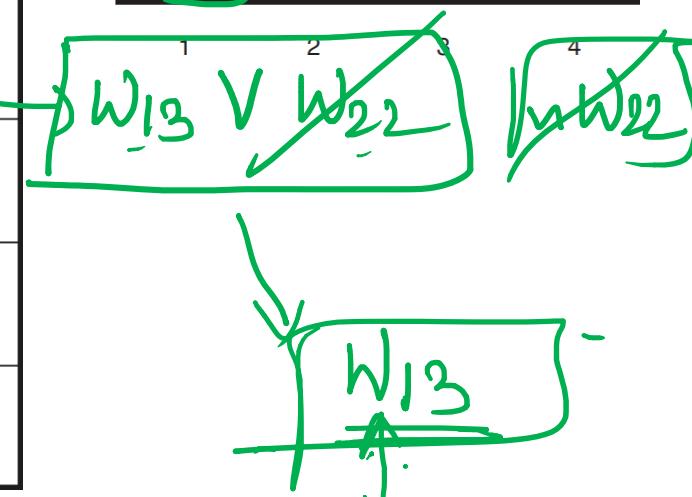
1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
OK			
1,1	2,1	3,1	4,1
OK	OK		

$$\begin{aligned}
 & @ L_{1,2} \rightarrow S_{12} \wedge \neg B_{12} \\
 & S_{12} \rightarrow W_{11} \vee W_{13} \vee W_{22} \\
 & \neg B_{12} \rightarrow \neg P_{11} \wedge \neg P_{13} \wedge \neg P_{22} \\
 & \neg W_{11} \vee W_{13} \vee W_{22}
 \end{aligned}$$

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	P?	3,2
OK			4,2
1,1	V	OK	2,1
V	OK	B	OK

1,4	2,4	3,4	4,4
1,3 W!	2,3	3,3	4,3
1,2 A S OK	2,2	3,2	4,2
	OK		
1,1 V OK	2,1 B V OK	3,1 P! OK	4,1

Stench		Breeze	PIT
Breeze		PIT	Breeze
W NP			Breeze
Stench			
W NP			
START		Breeze	PIT



Percept 3: [Stench, None, None, None, None]

Action: Move to [2, 2]

Remembers (2,2) as possible PIT and no Stench.



1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
M OK	P		
1,2	2,2	3,2	4,2
OK			
1,1	2,1	3,1	4,1
A OK	OK		

S B

CNF

1,4	2,4	3,4	4,4
Monster ?P	2,3	3,3	4,3
B.. OK	P? OK	2,2	3,2
?P OK	2,1	A B OK	3,1 P? OK
1,1	2,1	3,1	4,1

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
1,1	2,1	B OK	3,1 P? OK
V OK		OK	

4	Stench	Breeze	PIT
3	Breeze	Stench	PIT
2	Stench	Breeze	
1	Breeze	PIT	Breeze
	START		
1	2	3	4

NO MONSTER } 2,2
NO PIT } Safe cell

Agents based on Propositional logic, TT-Entail for inference from truth table

Syntax

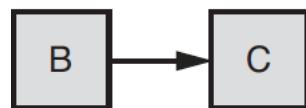
Semantics

Model

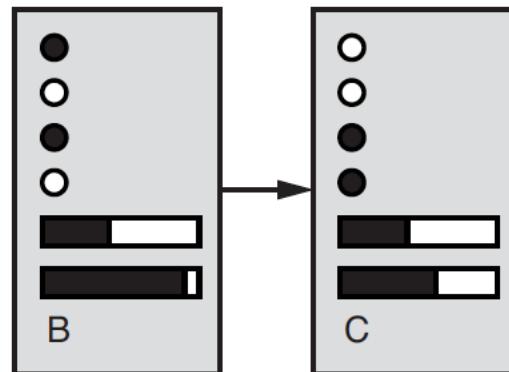
Logic

Propositional Logic

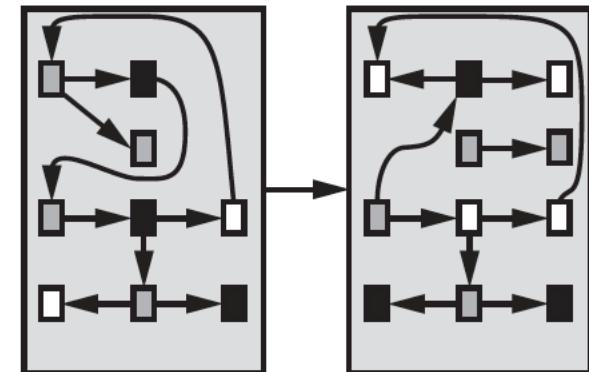
Predicate Logic



(a) Atomic



(b) Factored



(b) Structured

Search Strategies

Propositional Logic

First Order Logic

Agents based on Propositional logic, TT-Entail for inference from truth table

A simple representation language for building knowledge-based agents

Proposition Symbol - A symbol that stands for a proposition.

E.g., $W_{1,3}$ - “Wumpus in [1,3]” is a proposition and $W_{1,3}$ is the symbol

Proposition can be true or false

Atomic : $W_{1,3}$

Conjuncts : $W_{1,3} \wedge P_{3,1}$

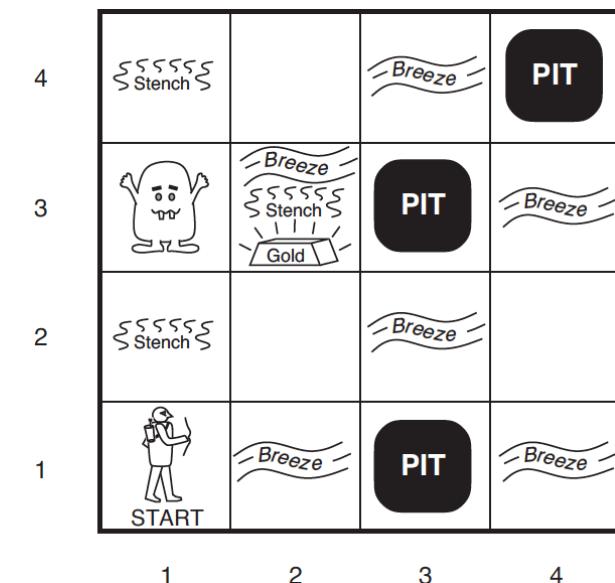
Disjuncts : $W_{1,3} \vee P_{3,1}$

Implications :

$(W_{1,3} \wedge P_{3,1}) \Rightarrow \neg W_{2,2}$

Biconditional : $W_{1,3} \Leftrightarrow \neg W_{2,2}$

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
OK			
1,1	A OK	2,1 OK	3,1



Agents based on Propositional logic, TT-Entail for inference from truth table

Tie break in search:

\neg , \wedge , \vee , \Rightarrow , \Leftrightarrow

$(\neg A) \wedge B$ has precedence over $\neg(A \wedge B)$

P	Q	$\neg P$	$P \wedge Q$	$P \vee Q$	$P \Rightarrow Q$	$P \Leftrightarrow Q$
false	false	true	false	false	true	true
false	true	true	false	true	true	false
true	false	false	false	true	false	false
true	true	false	true	true	true	true