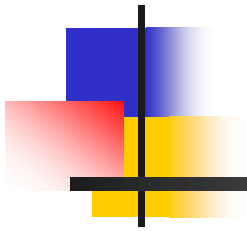
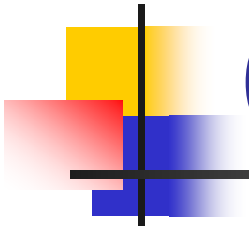


Chapter 4

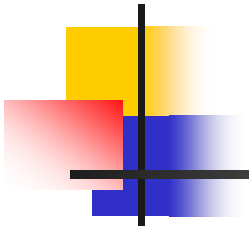
Methods of Inference

知識推論法

State and problem spaces (狀態與問題空間)



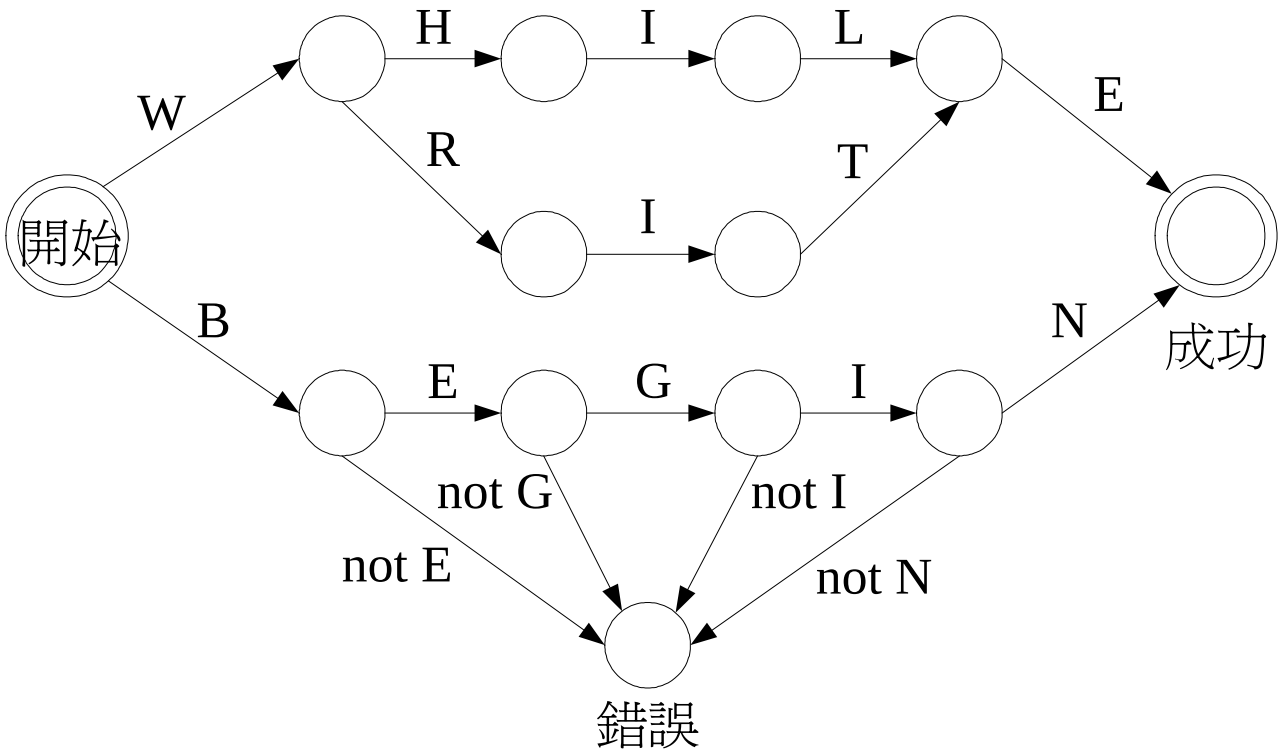
- **Tree**（樹狀結構）: nodes, edges
  - Directed or undirected
- **Digraph**（雙向圖）: a graph with directed edges
- **Lattice**（晶格）: a directed acyclic graph

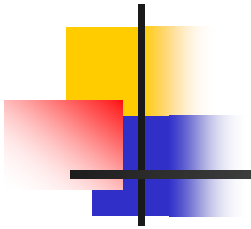


- A useful method of describing the behavior of an object is to define a graph called the state space. [state(狀態) and action(行動)]
  - Initial state
  - Operator
  - State space
  - Path
  - Goal test
  - Path cost

Finite State Machine
（有限狀態機器）

- Determining valid strings WHILE,WRITE, and BEGIN



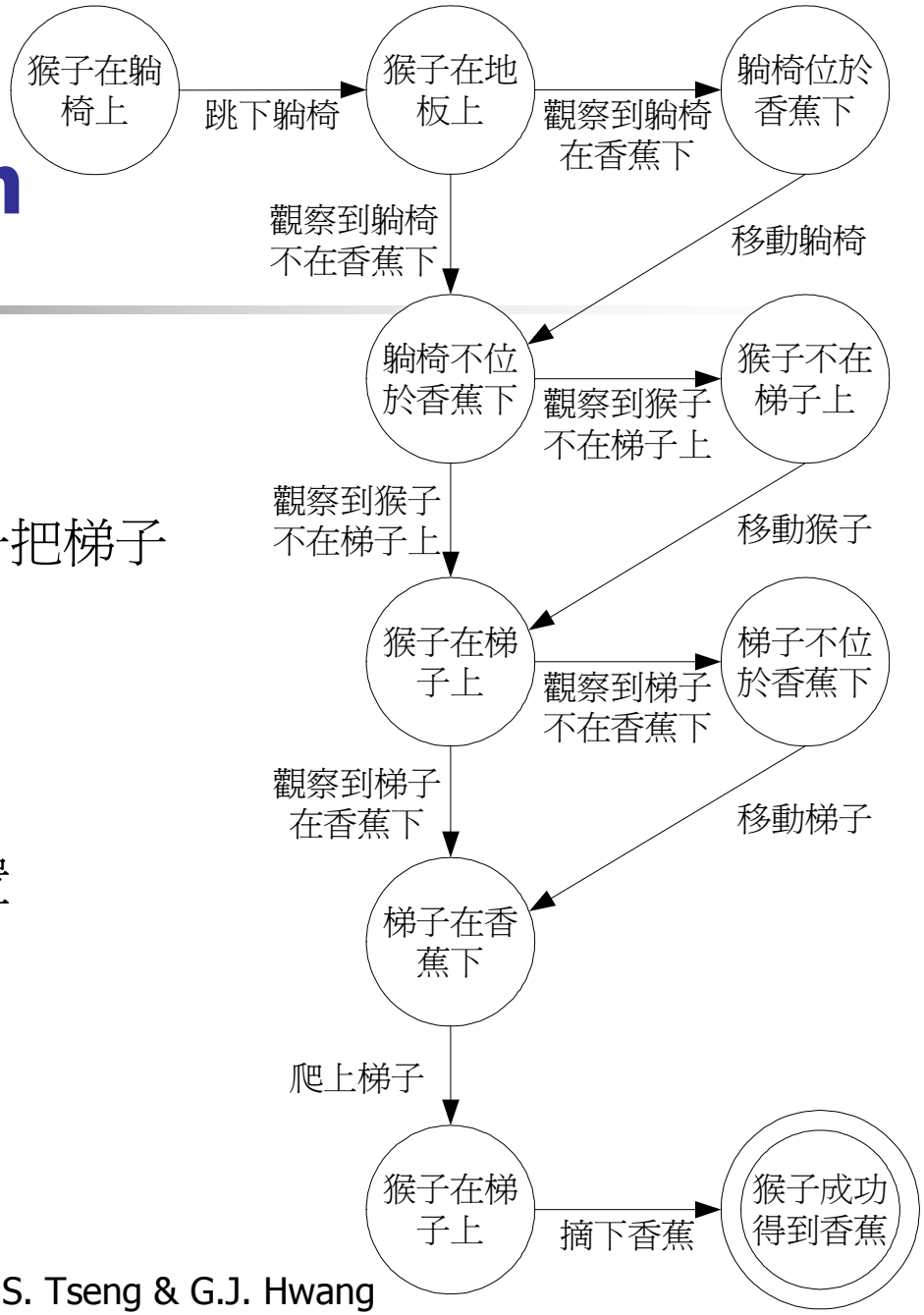


Finding solution in problem space

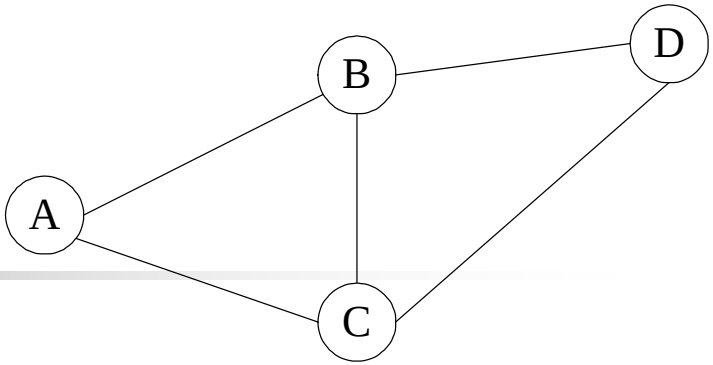
- State space（狀態空間） can be thought as a problem space（問題空間）.
- Finding the solution to a problem in a problem space involves finding a valid path from start to success(answer).
- The state space for the Monkey and Bananas Problem
- Traveling salesman problem（旅行推銷員問題）
- Graph algorithms, AND-OR Trees, etc.

Ex: Monkey and Bananas Problem

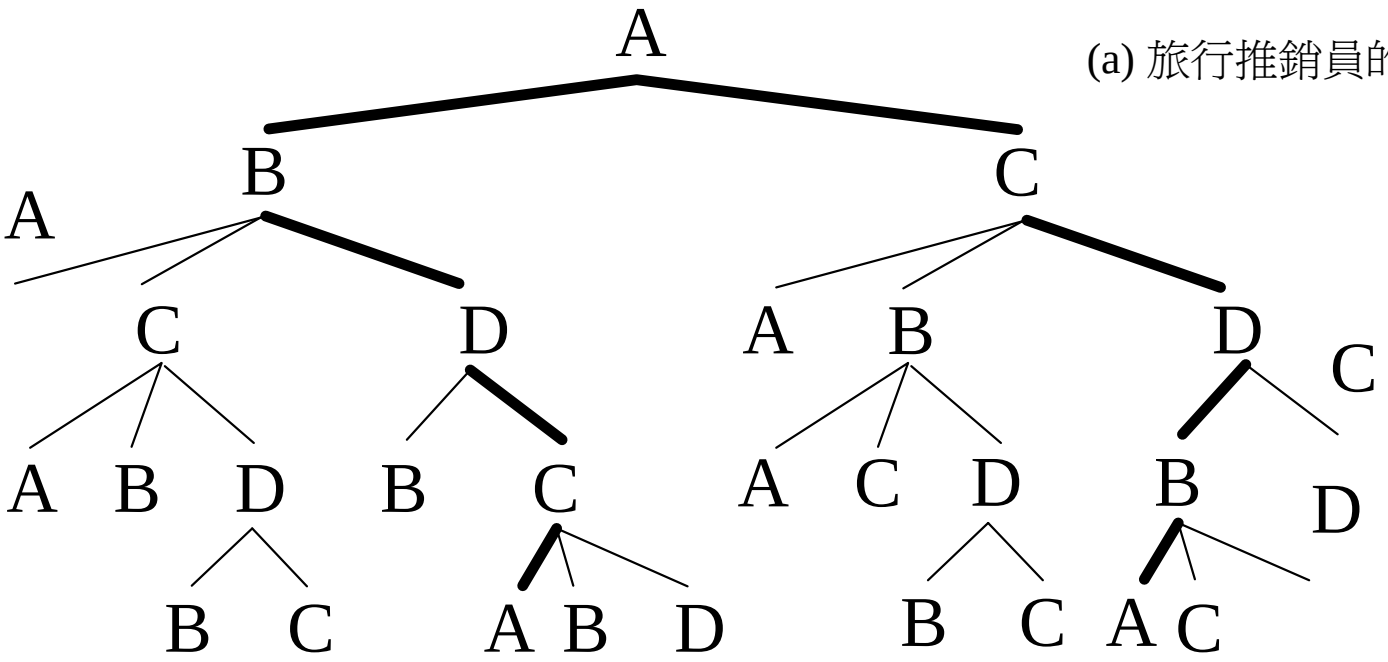
- 假設：
  - 房子裡有一懸掛的香蕉
  - 房子裡只有一張躺椅跟一把梯子
  - 猴子無法直接拿到香蕉
- 指示：
  - 跳下躺椅
  - 移動梯子
  - 把梯子移到香蕉下的位置
  - 爬上梯子
  - 摘下香蕉
- 初始狀態：
  - 猴子在躺椅上



Ex: Travel Salesman Problem（旅行推銷員問題）



(a) 旅行推銷員的問題描述



(b) 搜尋路徑(粗線是解答路徑)

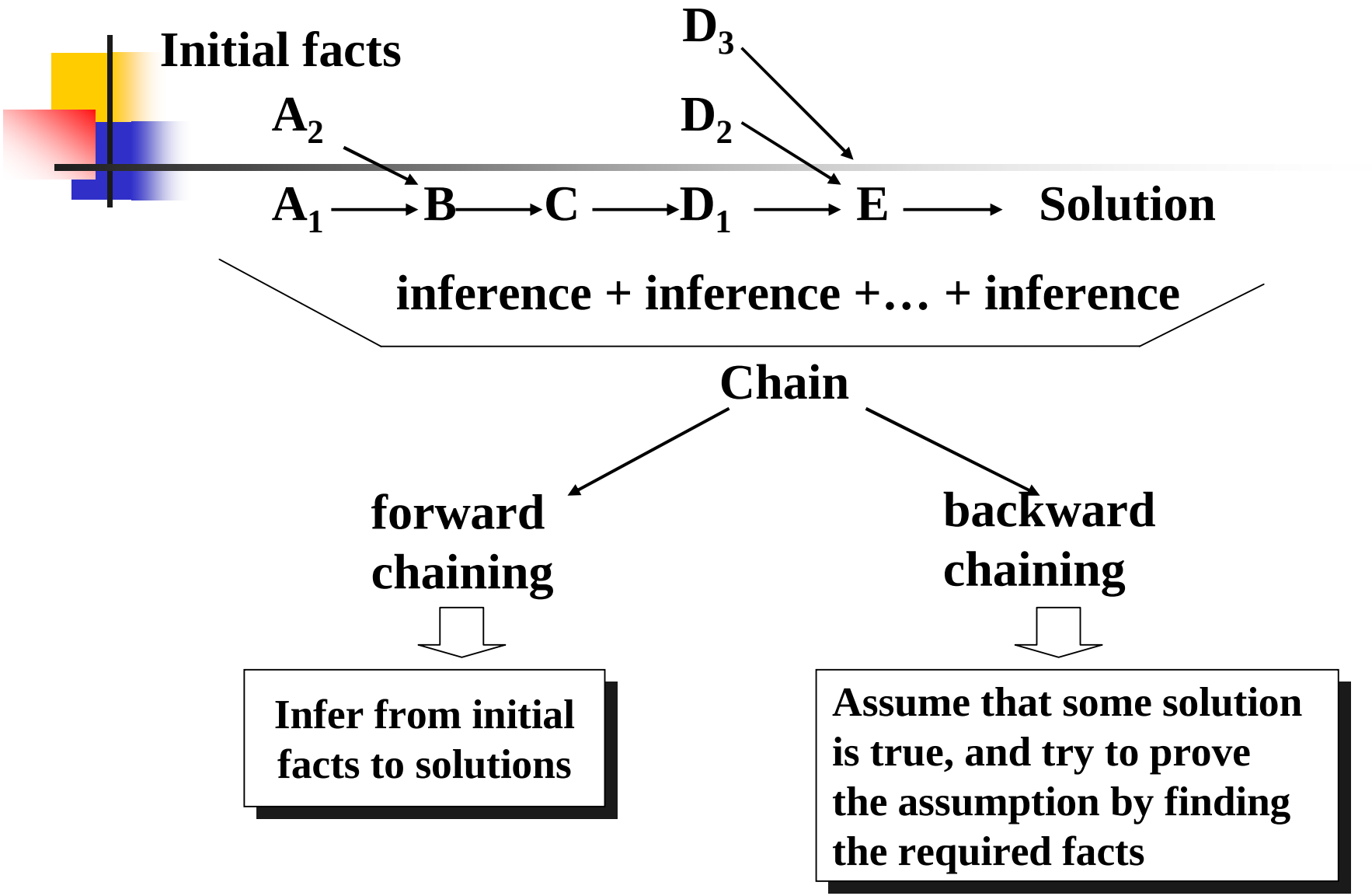
Ill-structured problem (非結構化問題)

- Ill-structured problems have uncertainties associated with it.
  - Goal not explicit
  - Problem space unbounded
  - Problem space not discrete
  - Intermediate states difficult to achieve
  - State operators unknown
  - Time constraint

Ex:旅遊代理人

特徵	客戶的反應
目標不明顯	我在想到底要去哪裡
問題空間範圍未被介定	我不確定要去哪裡
問題狀態不是離散的	我只是想去旅遊，目的地並不重要
中間的狀態不易實行	我沒有足夠的錢去
狀態的可用運算元未知	我不知道怎麼可以籌到錢
時間限制	我必須儘快出發

Inference Chain (推斷鏈)



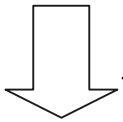
- **Forward Chaining（前向鏈結）:**

Rule1: elephant(x)→ mammal(x)

Rule2: mammal(x) → animal(x)

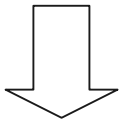
Fact：John is an elephant.

elephant (John) is true



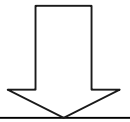
X=John (Unification)

elephant(x) → mammal(x) → **Mammal(John) is true**



X'=X=John

mammal(x') → animal(x')



animal(John) is true

- **Unification（變數替代）**

The process of finding substitutions for variables to make arguments match.

Forward Chaining（前向推論）

Rule1：$\underline{A_1}$ **and** $\underline{B_1}$ → C_1

Rule2：$\underline{A_2}$ **and** C_1 → D_2

Rule3： $\underline{A_3}$ **and** $\underline{B_2}$ → D_3

Rule4：C_1 **and** D_3 → G

Facts：A_1 **is true,** A_2 **is true ,** A_3 **is true,** B_1 **is true,** B_2 **is true**

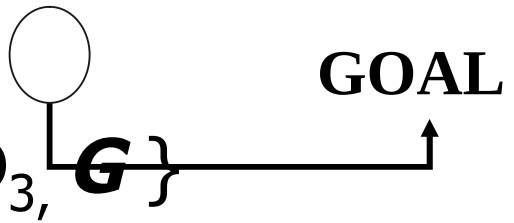
$\{A_1, A_2, A_3, B_1, B_2\}$ → **match** $\{r_1, r_3\}$

fire r_1 $\{A_1, A_2, A_3, B_1, B_2, \underline{\boldsymbol{C_1}}\}$ →**match** $\{\underline{r_1}, r_2, r_3\}$

fire r_2 $\{A_1, A_2, A_3, B_1, B_2, C_1, \boldsymbol{D_2}\}$ →**match**$\{\underline{r_1}, \underline{r_2}, r_3\}$

fire r_3 $\{A_1, A_2, A_3, B_1, B_2, C_1\ D_2, \boldsymbol{D_3}\}$ → **match**$\{\underline{r_1}, \underline{r_2}, r_3, r_4\}$

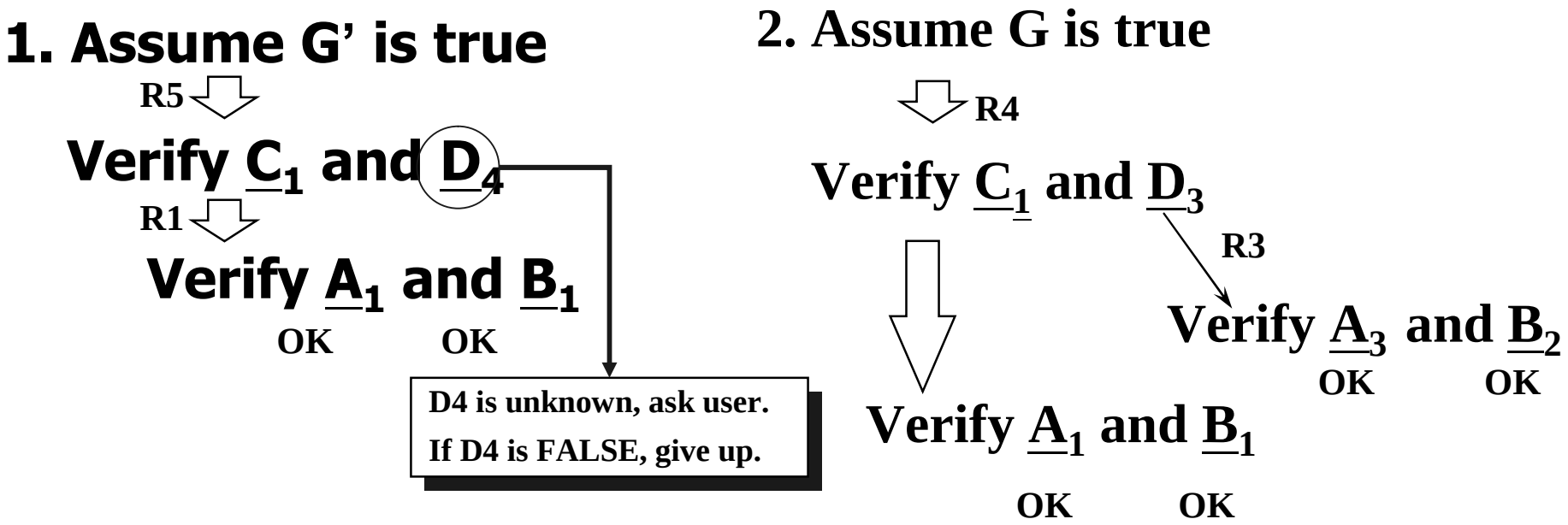
fire r_4 $\{A_1, A_2, A_3, B_1, B_2, C_1\ D_2, D_3, \boldsymbol{G}\}$

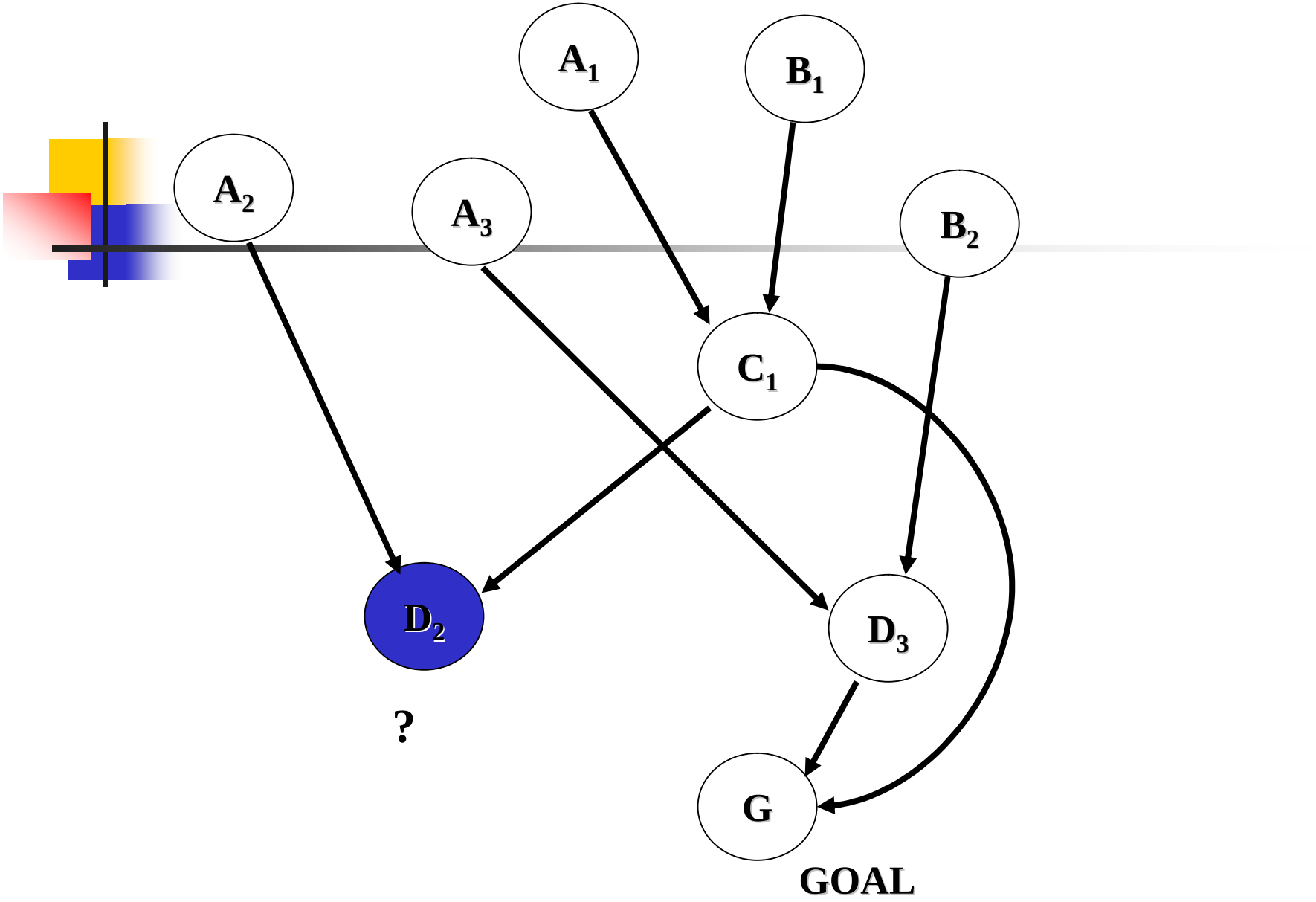


Backward Chaining (反向推論)

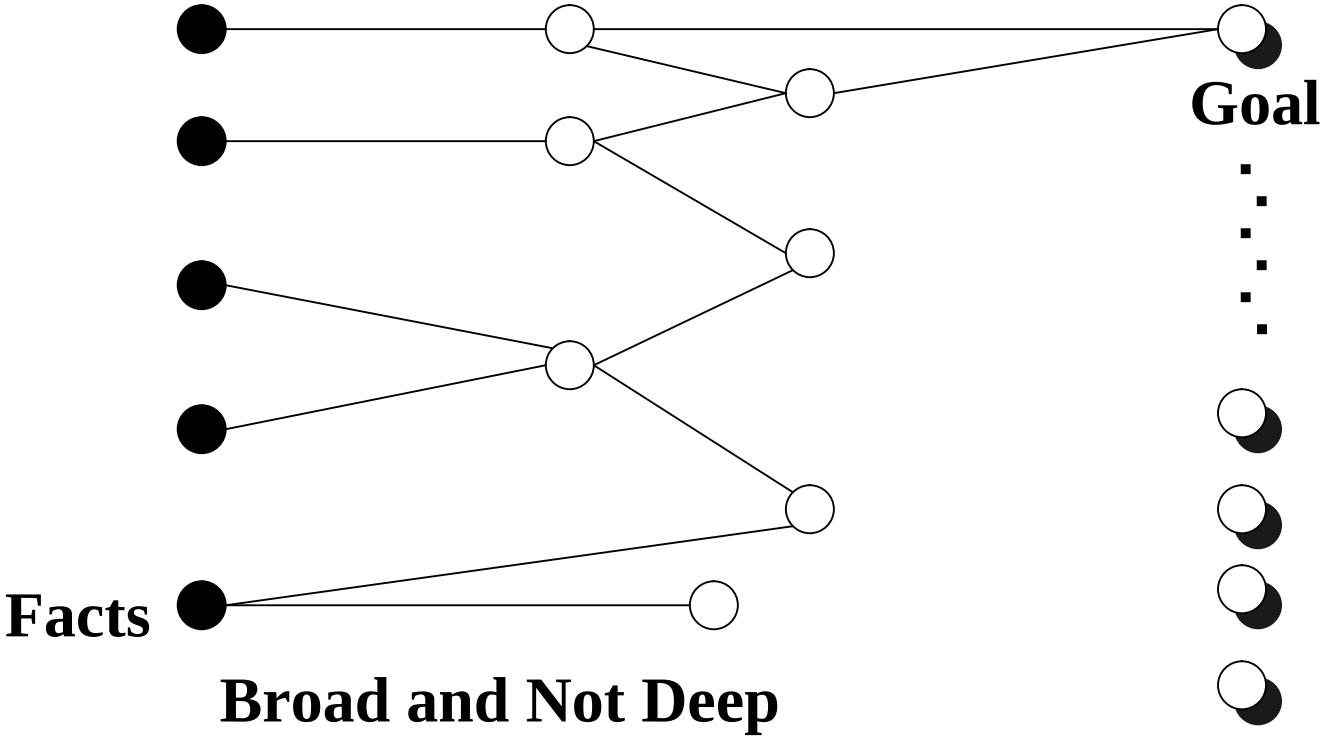
rule1 : A_1 and B_1 ⟶ C_1
rule2 : A_2 and C_1 ⟶ D_2
rule3 : A_3 and B_2 ⟶ D_3
rule4 : C_1 and D_3 ⟶ G
rule5 : C_1 and D_4 ⟶ G'

facts : A_1, A_2, B_1, B_2, A_3




A1
B1
A2
A3
B2
C1
D2
D3
?
G
GOAL

Good applications of forward chaining

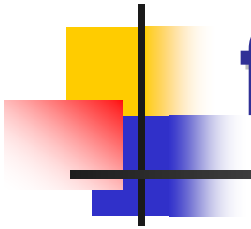


Broad and Not Deep

or

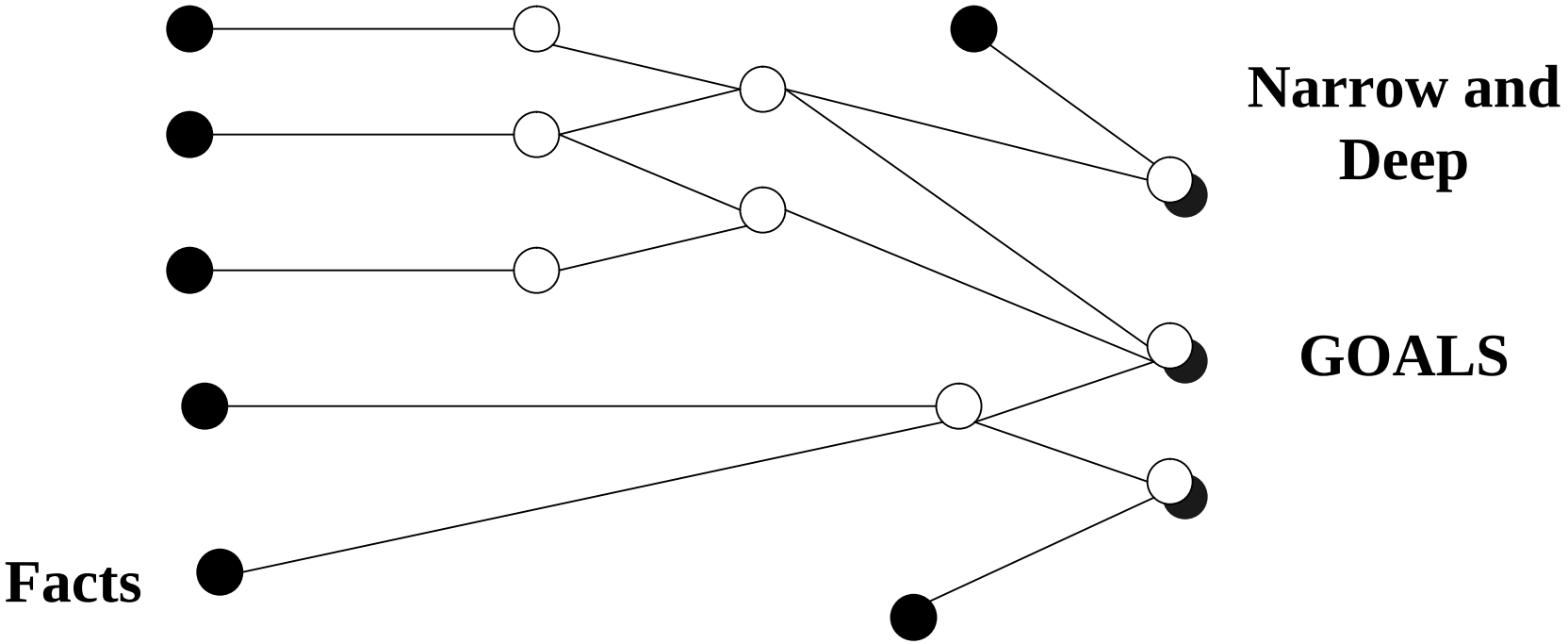
too many possible goals

Good applications of forward chaining

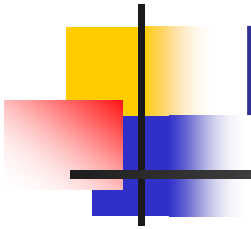


- Planning
- Monitoring
- Control
- Data-driven
- Explanation not facilitated

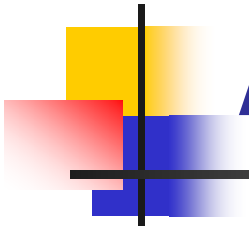
Good applications of backward chaining



Good applications of backward chaining



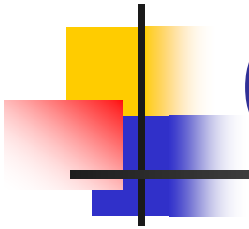
- **Diagnosis**
- **Goal-driven**
- **Explanation facilitated**



Analogy

- Try to relate old situations as guides to new ones
- Consider tic-tac-toe with values as a magic square (15 game)
  - 6 1 8
  - 7 5 3
  - 2 9 4
- 18 game from set {2,3,4,5,6,7,8,9,10}
- 21 game from set {3,4,5,6,7,8,9,10,11}

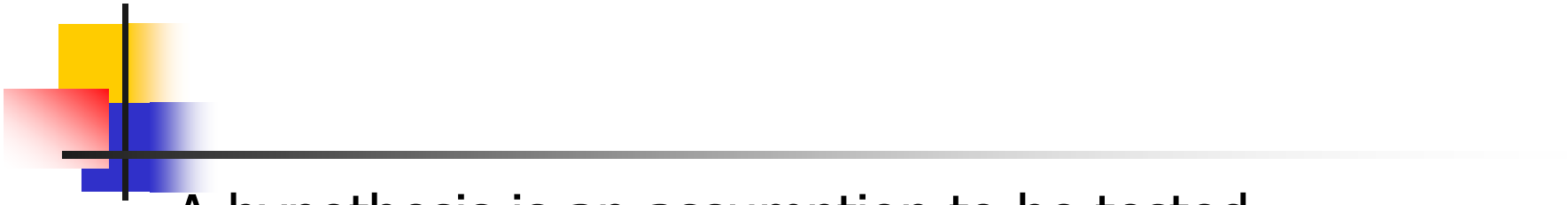
Reasoning Under Uncertainty (不確定性推論)



- Uncertainty can be considered as the lack of adequate information to make a decision.
- Classical probability, Bayescian probability, Dempster-Shafer theory, and Zadeh's fuzzy theory.
- In the MYCIN and PROSPECTOR systems conclusion are arrived at even when all the evidence needed to absolutely prove the conclusion is not known.

Many different types of error can contribute to uncertainty

Example	Error	Reason
Turn the value off	Ambiguous	What value?
Turn value-1	Incomplete	Which way?
Turn value-1 off	Incorrect	Correct is on
Value is stuck	False positive	Value is not stuck
Value is not stuck	False negative	Value is stuck
Turn value-1 to 5	Imprecise	Correct is 5.4
Turn value-1 to 5.4	Inaccurate	Correct is 9.2
Turn value-1 to 5.4 or 6 or 0	Unreliable	Equipment error
Value-1 setting is 5.4 or 5.5 or 5.1	Random error	Statistical fluctuation
Value-1 setting is 7.5	Systematic error	Miscalibration
Value-1 is not stuck because it's never been stuck before	Invalid induction	Value is stuck
Output is normal and so value-1 is in good condition	Invalid deduction	Value is stuck in open position



- A hypothesis is an assumption to be tested.
- Type 1 error (false positive) means acceptance of a hypothesis when it is not true.
- Type 2 error (false negative) means rejection of a hypothesis when it is true.
- Error of measurement
  - Precision
    - The millimeter ruler is more precise than centimeter ruler.
  - accuracy

Error & Induction

The process of induction is the opposite of deduction

The fire alarm goes off (響起)

∴ There is a fire.

An even stronger argument is

The fire alarm goes off & I smell smoke

∴ There is a fire.

Although this is a strong argument, it is not proof that there is a fire.

My clothes are burning

Deductive errors

$p \rightarrow q$

q

$\therefore p$

If John is a father, than John is a man

John is a man

$\therefore$ John is a father

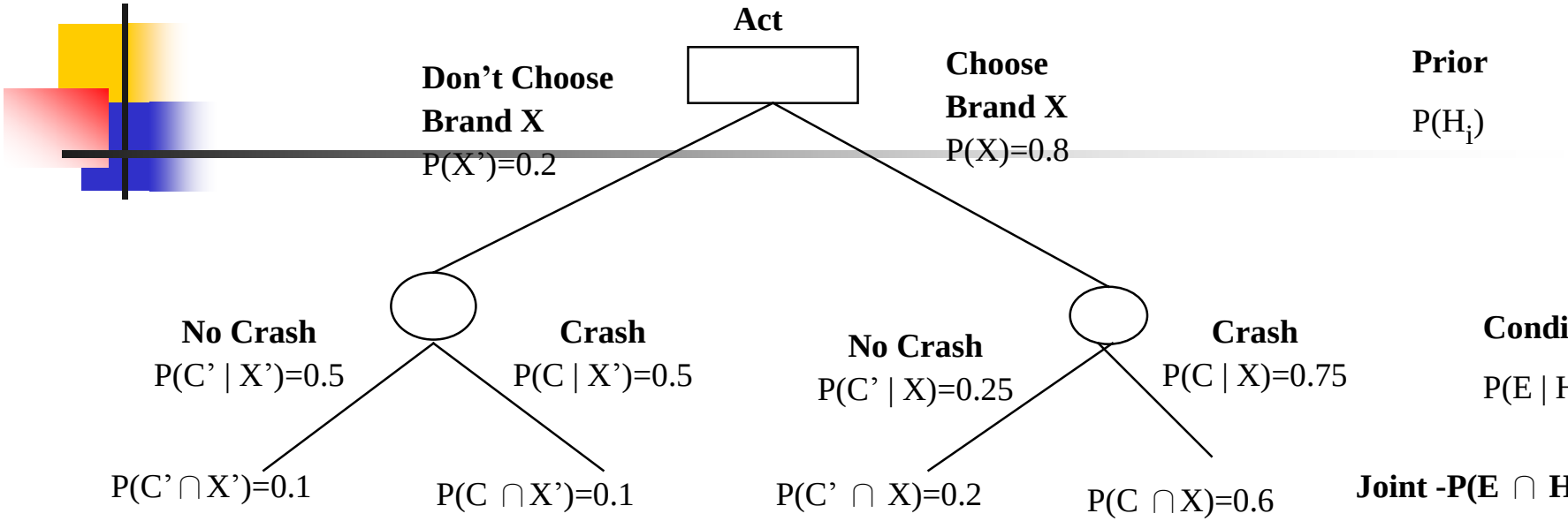
Baye's Theorem
（貝氏定理）

- Conditional probability（條件機率）, P(A | B) , states the probability of event B occurred. Crash= Brand X(0.6)+ Not X(0.1)=0.7
- P(X|C) =

$$\frac{P(C \mid X)\,P(X)}{P(C)} = \frac{(0.75)(0.8)}{0.7} = \frac{6}{7}$$

- Suppose you have a drive and don't know its brand, what is the probability that if it crashes, it is Brand X? non-Brand X?

Decision Tree for the Disk drive Crashes



$$P(X' \mid C') = \frac{0.1}{0.1+0.2} = 1/3 \qquad P(X' \mid C) = \frac{0.1}{0.1+0.6} = 1/7$$

$$P(X \mid C') = \frac{0.2}{0.2+0.1} = 2/3 \qquad P(X \mid C) = \frac{0.6}{0.6+0.1} = 6/7$$

Posterior

$$P(H_i \mid E) = \frac{P(E \cap Hi)}{\sum_i P(E \cap Hi)}$$

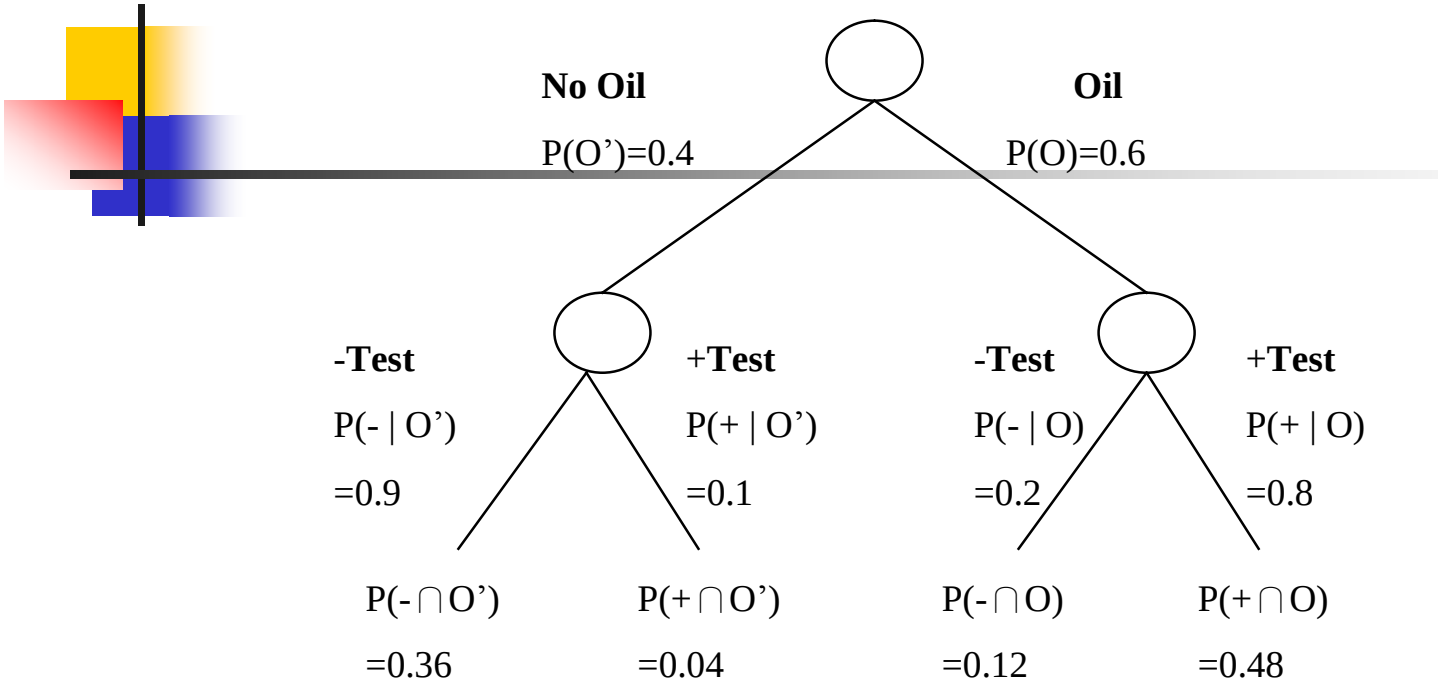
$$P(Hi \mid E) = \frac{P(E \cap Hi)}{\sum_j P(E \cap Hj)} = \frac{P(E \mid H\,i)\,P(Hi)}{\sum_j P(E \mid Hj)\,P(Hj)}$$

$$= \frac{P(E \mid Hi)P(Hi)}{P(E)}$$

- Bayes' Theorem（貝氏定理） is commonly used for decision tree analysis of business and the social science.

- Used in Prospector expert system to decide favorite sites of mineral exploration

Hypothetical Reasoning and Backward Induction.



Probabilities

Prior

Subjective Opinion of Site - P (Hi)

Conditional

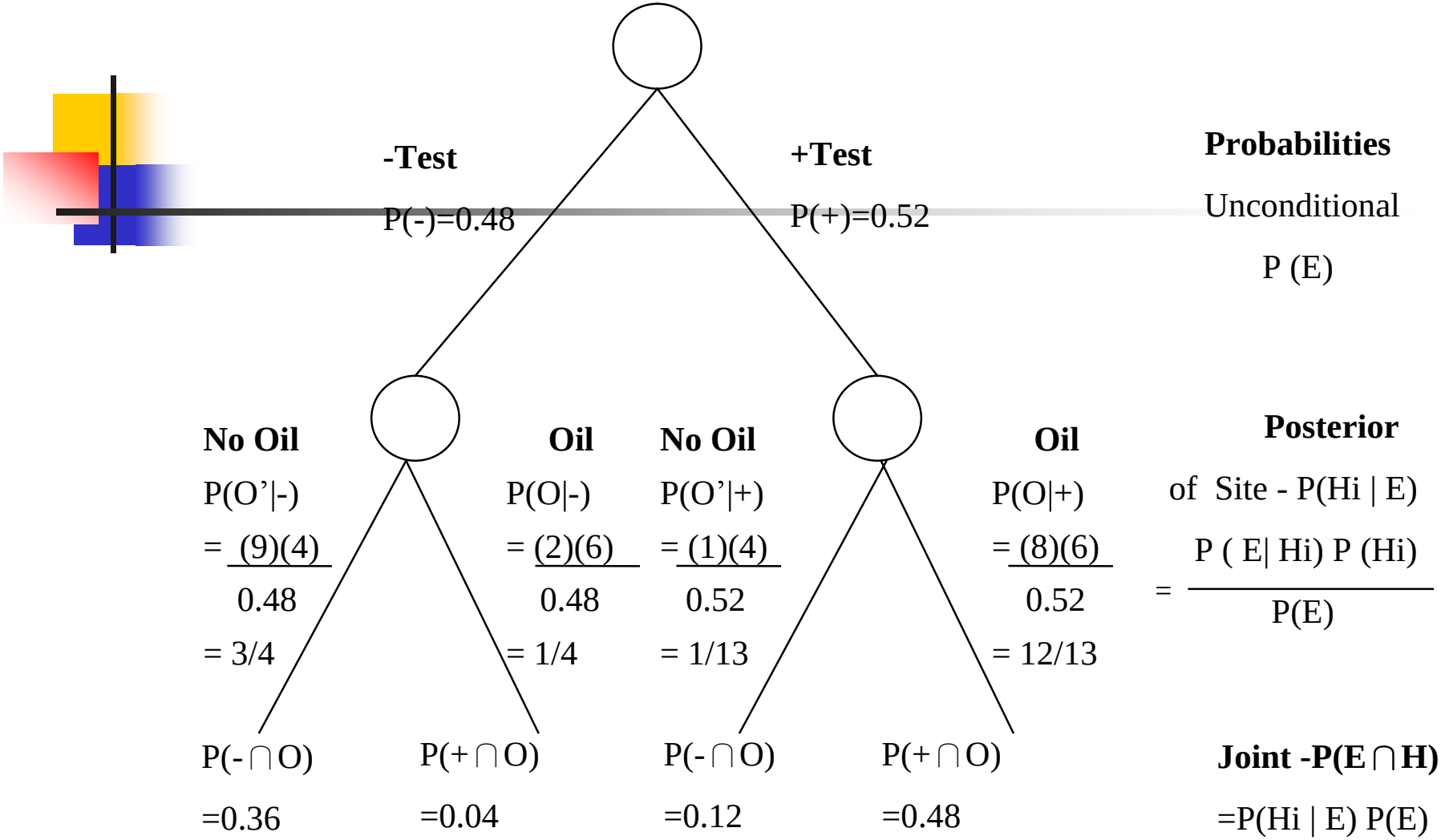
Seismic Test Result

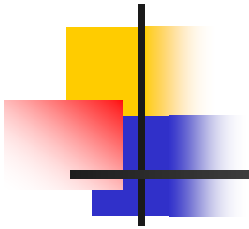
Joint - P(E∩H)

=P(E | Hi) P(Hi)

$$P(+)=P(+\cap O)+P(+\cap O')=0.48+0.04=0.52$$

$$P(-)=P(-\cap O)+P(-\cap O')=0.12+0.36=0.48$$


-Test
P(-)=0.48
+Test
P(+)=0.52
Probabilities
Unconditional
P (E)
No Oil
P(O'|-)
= (9)(4)
0.48
= 3/4
Oil
P(O|-)
= (2)(6)
0.48
= 1/4
No Oil
P(O'|+)
= (1)(4)
0.52
= 1/13
Oil
P(O|+)
= (8)(6)
0.52
= 12/13
Posterior
of Site - P(Hi | E)
= P (E| Hi) P (Hi) / P(E)
P(- ∩ O)
=0.36
P(+ ∩ O)
=0.04
P(- ∩ O)
=0.12
P(+ ∩ O)
=0.48
Joint -P(E ∩ H)
=P(Hi | E) P(E)



- Oil release , if successful $1250000
- Drilling expense -$200000
- Seismic survey -$50000
- Expected payoff (success)
  - 846153=1000000 *12/13 – 1000000*1/13
- Fail
  - -500000= 1000000*1/4- 1000000*3/4
- Expected payoff (total)
  - 416000= 846153*0.52 – 50000 * 0.48

Uncertainty in inference chains

- Uncertainty may be presented in rules, evidence used by the rules, or both.
  - The child has high fever (CF 0.8)
  - The child has red spots (CF 0.7)
  - IF high fever and read spots THEN the disease is measles (CF 0.9)

  →The child has measles (CF=0.8×0.7×0.9)

Systems with Forward chaining and backward chaining

- Forward chaining: OPS5, CLIPS, DRAMA
- Backward chaining:EMYCIN, PROLOG
- Both: ART,KEE
- Depends on the problem domain
- Diagnostic problem –backward
- Prognosis, monitoring, control -forward

Exercise

- 針對以下的事實與規則，說明前向及後向鏈結的推論過程。

事實: A1, A2, A3, A4, B1, B2

規則: R1: A1 and A3 --> C2

R2: A1 and B1 --> C1

R3: A2 and C2 --> D2

R4: A3 and B2 --> D3

R5: C1 and D2 --> G1

R6: B1 and B2 --> D4

R7: A1 and A2 and A3 --> D2

R8: C1 and D3 --> G2

R9: C2 and A4 --> G3

目標: G1, G2 and G3