Artificial Intelligence- Logical Agents

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Outline

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1. Knowledge-based Agents
2. Wampus world
3. Logic in general
4. Propositioanl Logic

Knowledge-Based Agents

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2. Each sentence represent some assertion about the world.
3. Tell method is a way to add new statements to KB.
4. Ask method is a way to query from KB.
5. Inference: deriving new sentences from old, using logic.

Knowledge-Based Agents, Cont

```
function KB-AGENT (percept) returns an action
  static KB, a knowledge base
         t, a counter initially 0

  TELL (KB,MAKE-PERCEPT-STATEMENT(percept,t))
  action= ASK(KB,MAKE-ACTION-QUERY(^))
  TELL (KB,MAKE-ACTION-SENTENCE(action,t))
  t= t+ 1
  return action
```

Knowledge-Based Agents, Cont

1. In Knowledge level:, one needs to specify what the agent knows and what its goals are.

Knowledge-Based Agents, Cont

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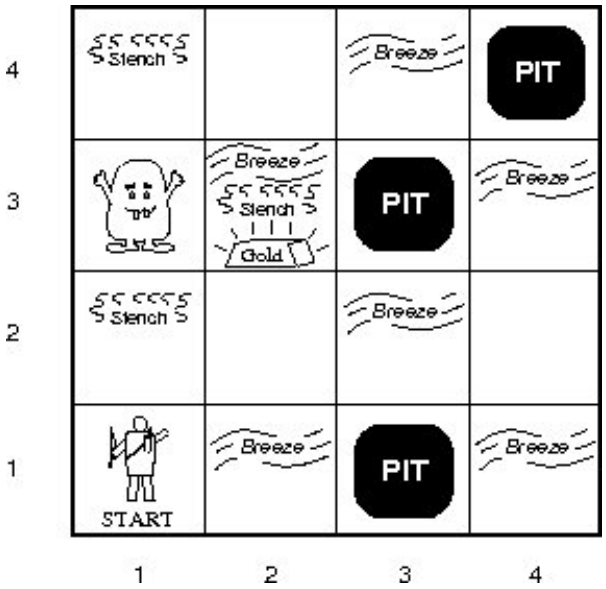
2. In Implementation Level:, one talks about data structures and algorithms used to work with statements.

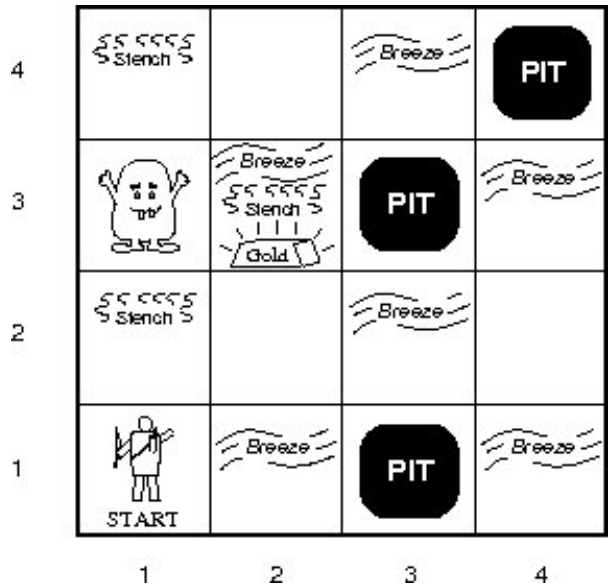
Wampus world, PEAS

1. Performance measure:
   . gold: +1000, death: -1000
   . -1 per step, -10 for using arrow.
2. Environment:
   . A 4x4 grid of rooms.
   . Agent starts in squeare [1,1].
   . There may be a pit in each square.
   . etc.
3. Actuators: Turn left, Turn right, Forward
   . Forward, Grab, Release, Shoot
4. Sensors: Stench, Breeze, Glitter, Bump, Scream



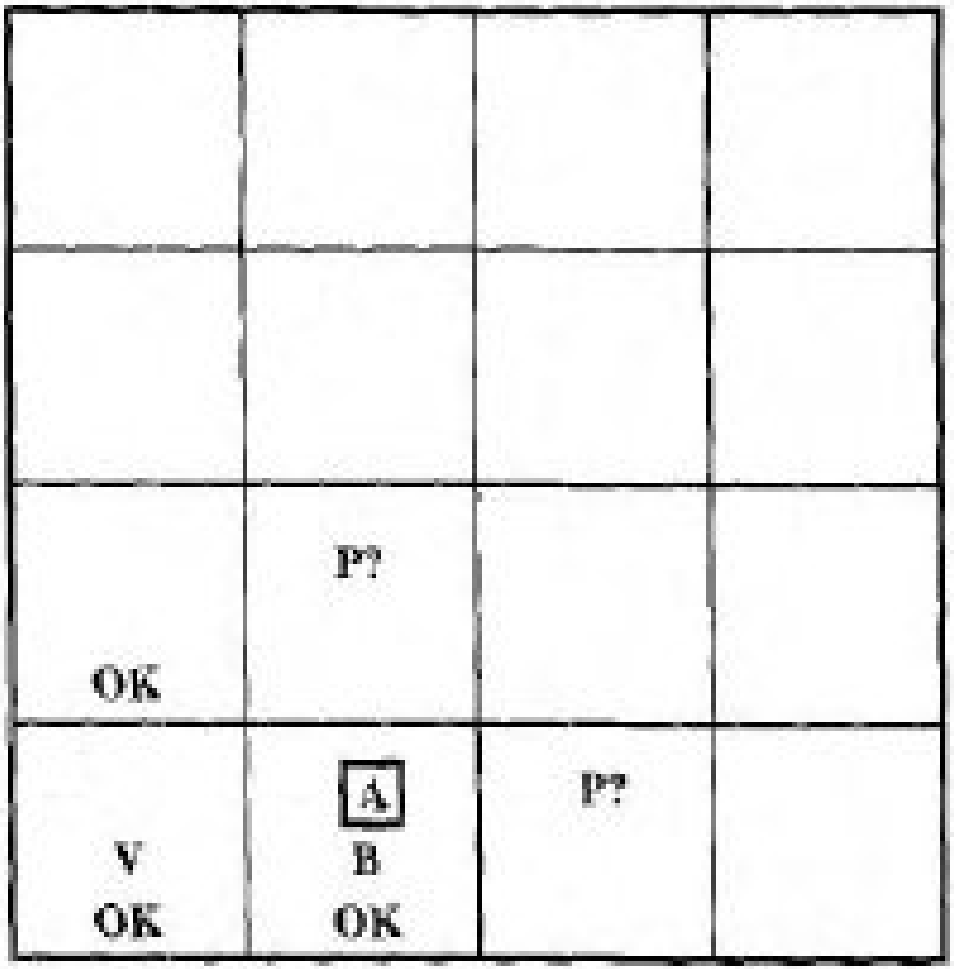
Wampus world, exploration

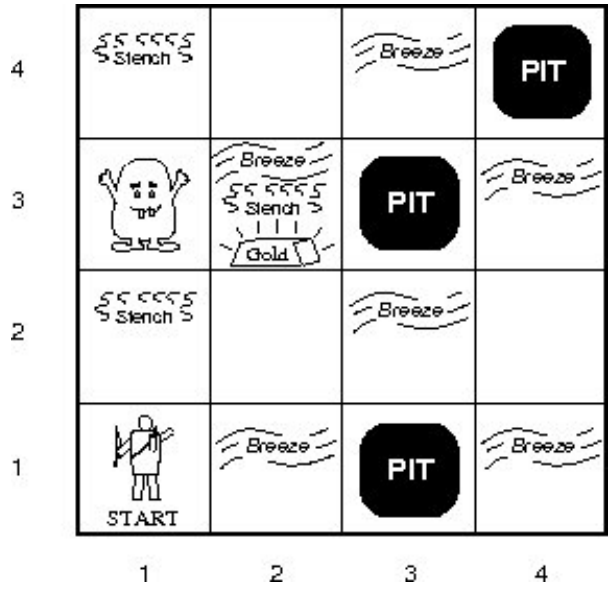
OK			
OK A	OK		



A: [-,-,-,-,-]

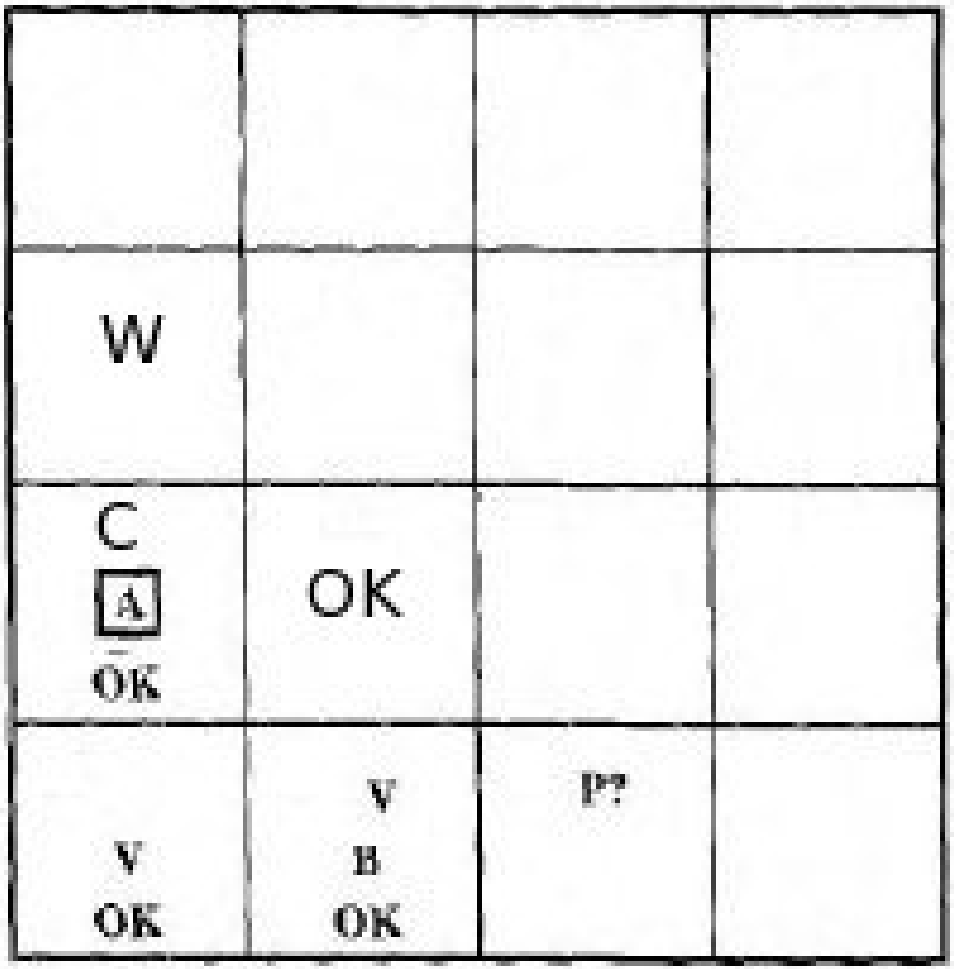
Wampus world, exploration

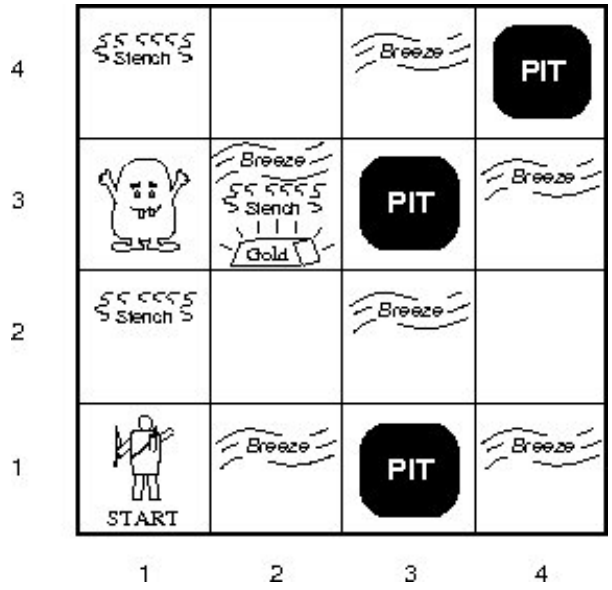




B: [-,B,-,-,-]

Wampus world, exploration





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   - Wampus wasn't there ⇒ safe

Logic in general

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4. Semantic defines the meaning of sentences.

Entailment

1. A Entails B (informally) means that B follows logically from B.
2. $KB \models \alpha$ (Knowledge base KB entails α)
   . if and only if
   α is true in all worlds(models) where KB is true.

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   α is true in all worlds(models) where KB is true.
3. $KB = \{\text{It is cold, It is raining}\} \models \text{It is cold and rainy.}$

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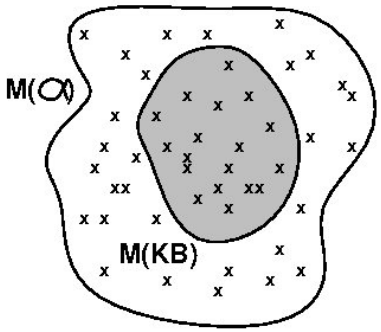
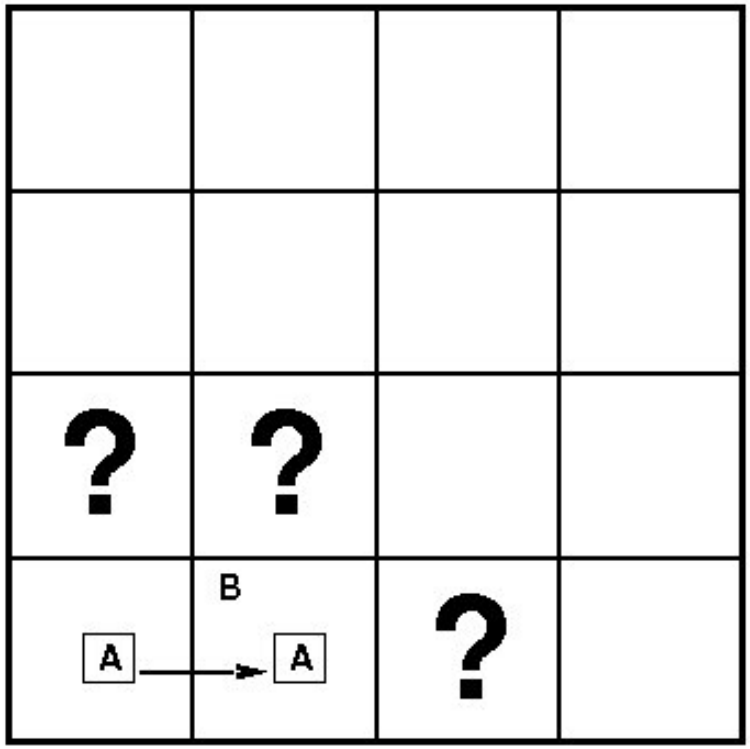


Wampus models



1. Nothing detected in [1,1], and breeze in [2,1].

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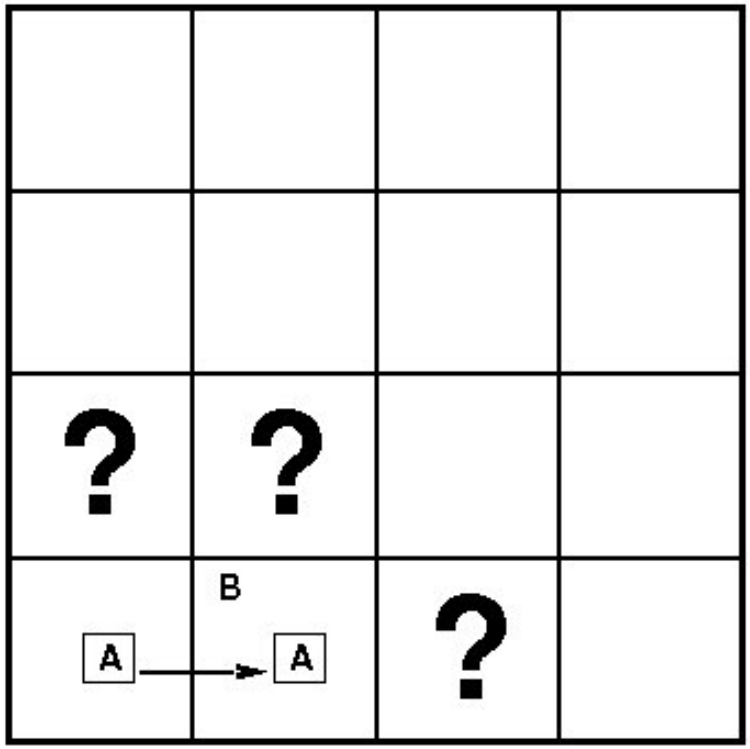

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2. We want to find out if ? are pit or not.

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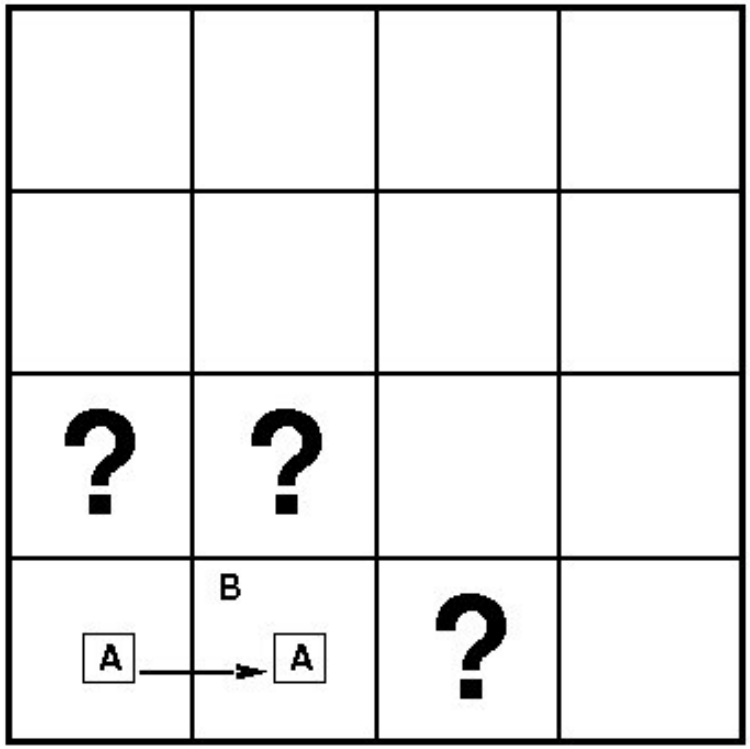
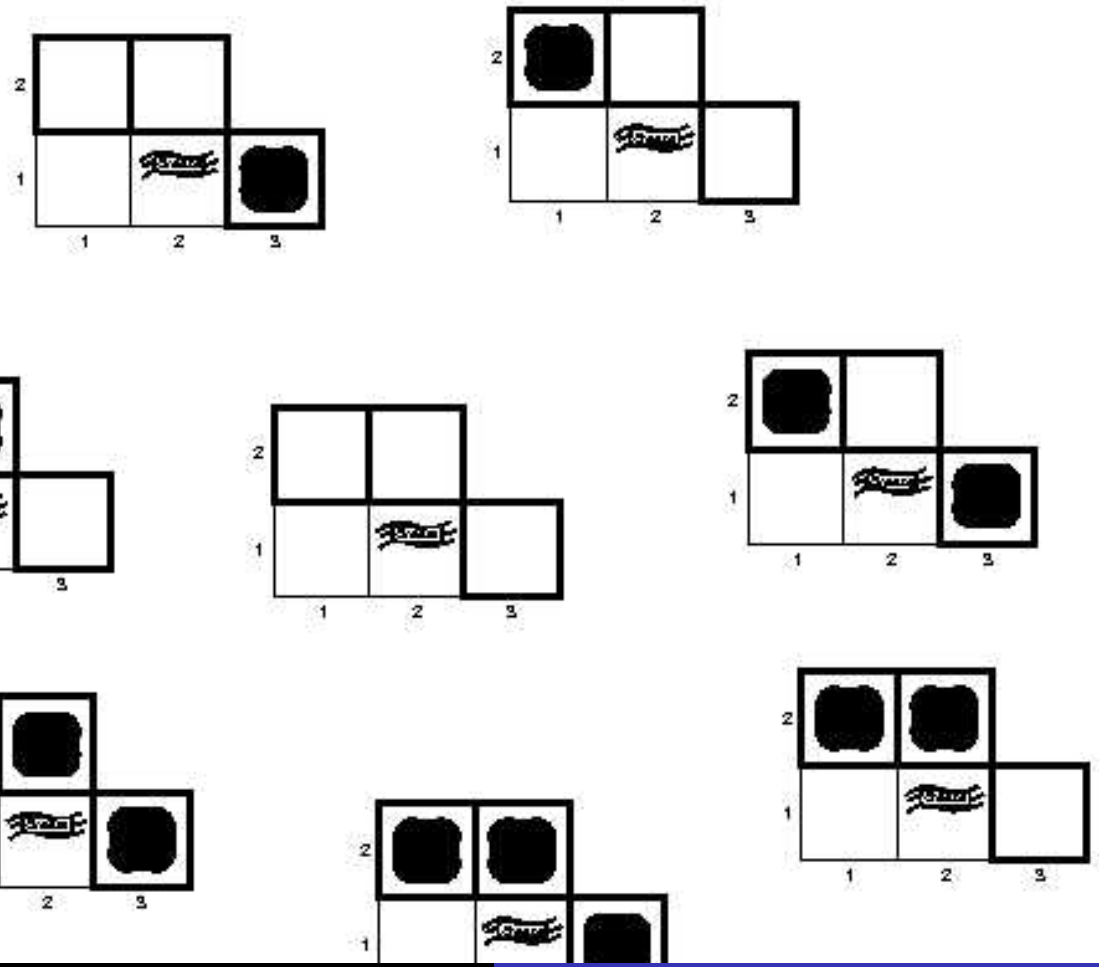
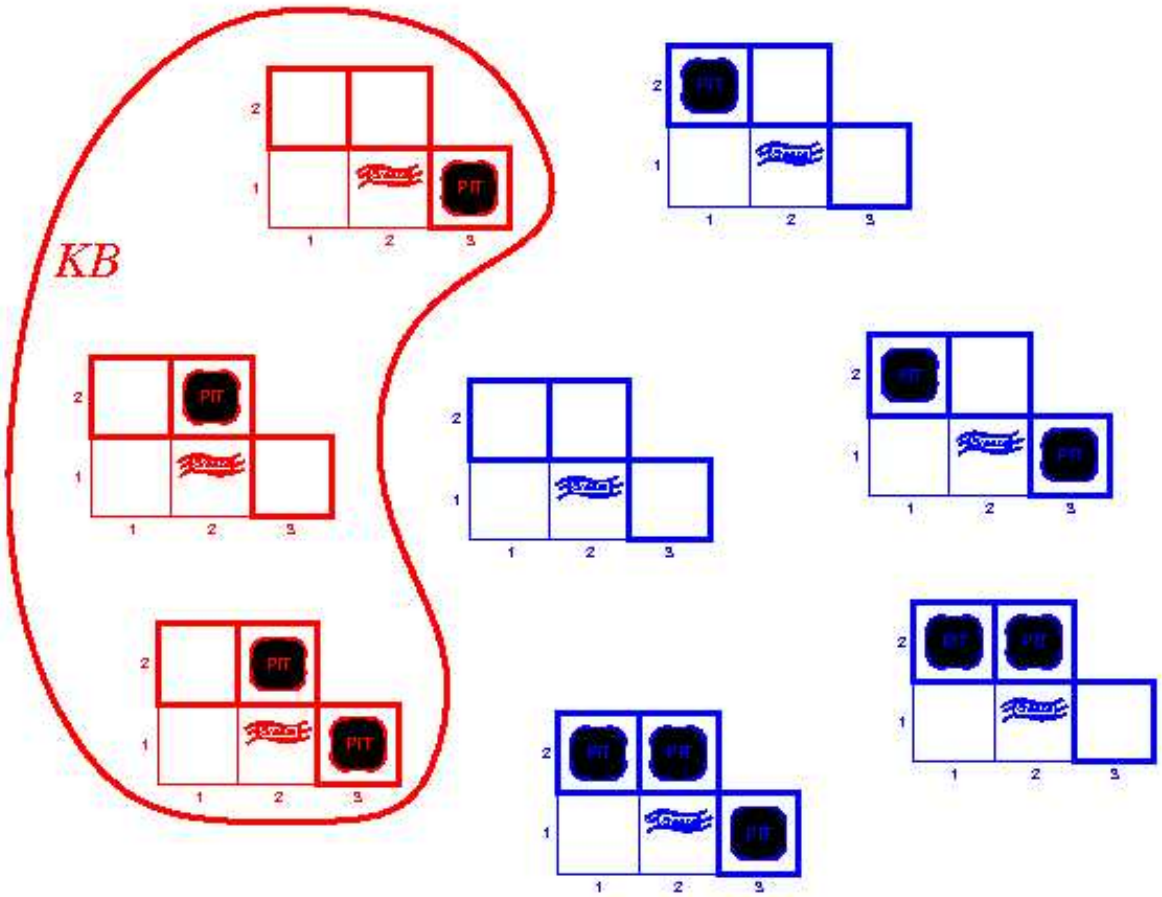


1. Nothing detected in [1,1], and breeze in [2,1].
2. We want to find out if ? are pit or not.
3. There are 8 modals.

Wampus models, Cont

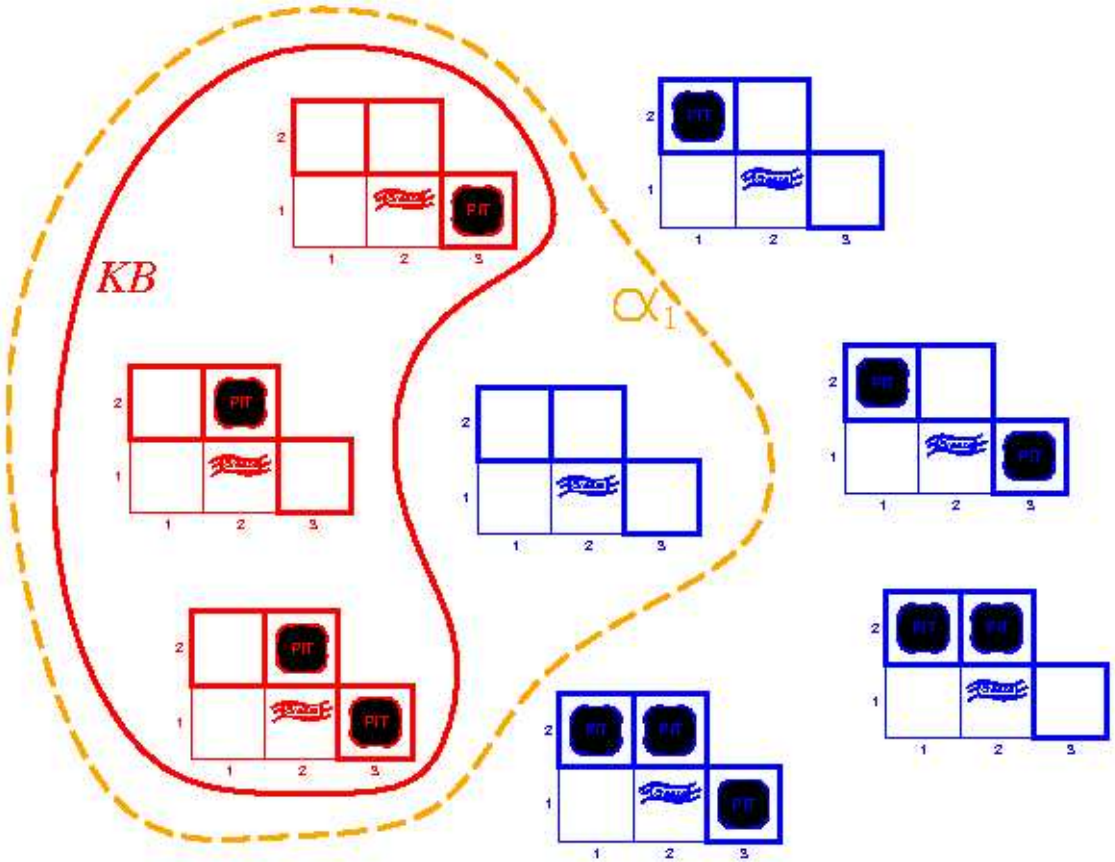


Wampus models, Cont



KB= wumpus-world rules + observations

Wampus models, Cont



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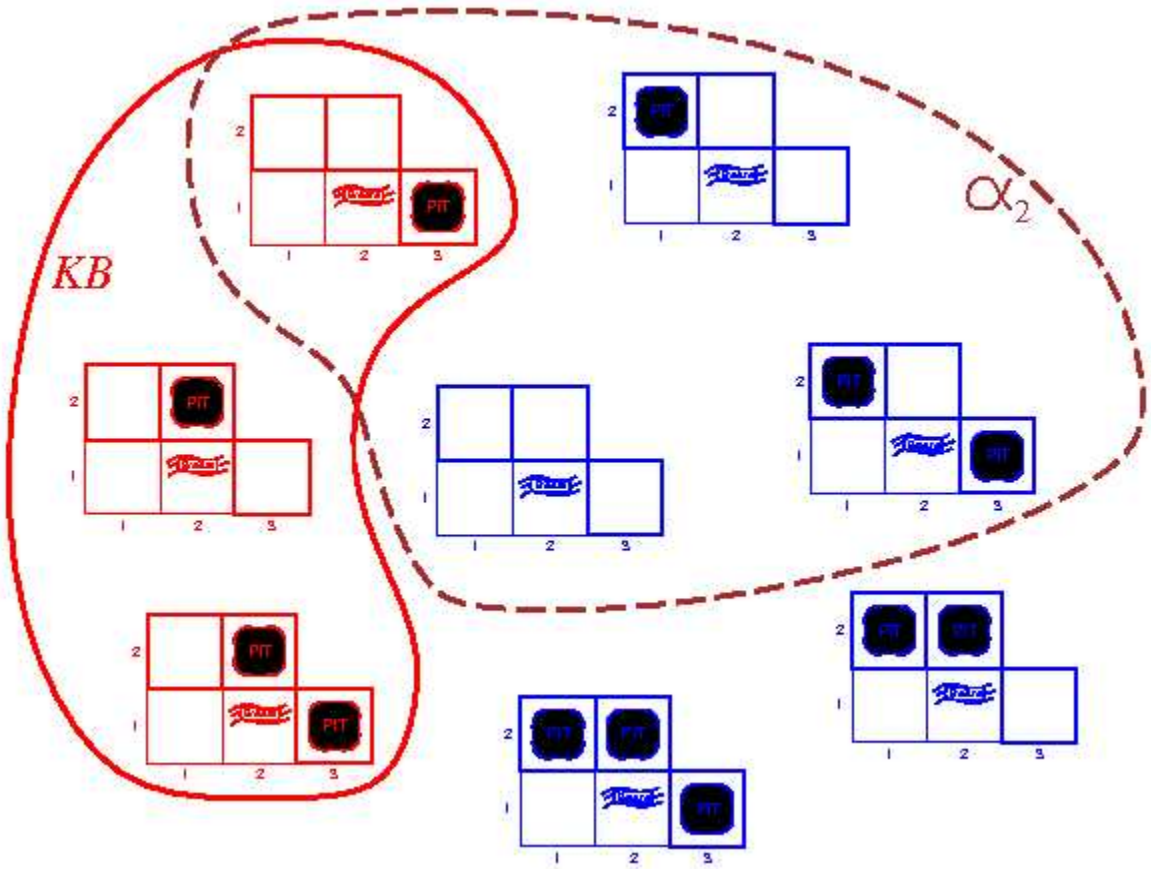

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α_2 = [2,2] is safe.

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3. A Complete and Sound inference procedure will answer any question whose answer follows from what is known by the KB.

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3. Symbol $\longrightarrow$ P|Q|R|$\cdots$
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5. $S_1 \Rightarrow S_2$ is true iff S_1 is true and S_2 is false.
6. $S_1 \Leftrightarrow S_2$ is true iff $S_1 \Rightarrow S_2$ is true and $S_1 \Rightarrow S_2$ is true.

Wampus world with propositional logic

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4. $B_{1,1} \Leftrightarrow (P_{1,2} \vee P_{2,1})$
5. $B_{2,1} \Leftrightarrow (P_{1,1} \vee P_{2,2} \vee P_{3,1})$

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3. $R_3 : B_{2,1}$
4. $R_4 : B_{1,1} \Leftrightarrow (P_{1,2} \vee P_{2,1})$

Wampus world with propositional logic, Cont

1. $R_1 : \neg P_{1,1}$
2. $R_2 : \neg B_{1,1}$
3. $R_3 : B_{2,1}$
4. $R_4 : B_{1,1} \Leftrightarrow (P_{1,2} \vee P_{2,1})$
5. $R_5 : B_{2,1} \Leftrightarrow (P_{1,1} \vee P_{2,2} \vee P_{3,1})$

Inference by enumeration

```
function TT-ENTAILS? (KB, a) returns true or false
 symbols= list of the symbols in KB and a.
 return TT-CHECK-ALL (KB, a, symbols, []);

 function TT-CHECK-ALL (KB, a, symbols, models)
                        returns true or false
   if Empty(symbols) then
     if PL-TRUE?(KB,models) then return PL-TRUE?(a,models)
     else return false;
   else
     P= FIRST(symbols); rest= REST(symbols);
     return TT-CHECK-ALL(KB,a,rest,EXTEND(P,true,modal))
      and TT-CHECK-ALL(KB,a,rest,EXTEND(P,false,modal))
```

Some concepts in propositional logic

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6. $(\neg(\neg a)) = a$ double-negation elimination

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6. $(\neg(\neg a)) = a$ double-negation elimination
7. $(\neg(a \wedge b)) \equiv (\neg a \vee \neg b)$ De Morgan
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8. $(\neg(a \vee b)) \equiv (\neg a \wedge \neg b)$ De Morgan
9. $(a \wedge (b \vee c)) \equiv (a \wedge b) \vee (a \wedge c)$ distributivity of $\wedge$ over $\vee$
10. $(a \vee (b \wedge c)) \equiv (a \vee b) \wedge (a \vee c)$ distributivity of $\vee$ over $\wedge$

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2. Satisfiablity: P is satisfiable if it is true in some models.
3. Unsatisfiablity: P is unsatisfiable if it is true in no models.
4. $KB \models \alpha$ if and only if $KB \wedge \neg\alpha$ is unsatifiable.

Reasoning patterns in propositional logic

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5. And-Elimination: $\frac{\alpha \wedge \beta}{\alpha}$

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3. $R_7 : ((P_{1,2} \vee P_{2,1}) \Rightarrow B_{1,1}))$ from R_6.
4. $R_8 : (\neg B_{1,1} \Rightarrow \neg(P_{1,2} \vee P_{2,1})))$ from R_7.

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3. $R_7 : ((P_{1,2} \vee P_{2,1}) \Rightarrow B_{1,1}))$ from R_6.
4. $R_8 : (\neg B_{1,1} \Rightarrow \neg(P_{1,2} \vee P_{2,1})))$ from R_7.
5. $R_9 : \neg(P_{1,2} \vee P_{2,1})))$ from R_8, R_2 by MP.

Reasoning patterns in propositional logic, Cont

1. $P_{1,2}$??
2. $R_6 : ((B_{1,1} \Rightarrow (P_{1,2} \vee P_{2,1})) \wedge ((P_{1,2} \vee P_{2,1}) \Rightarrow B_{1,1}))$ from R_4.
3. $R_7 : ((P_{1,2} \vee P_{2,1}) \Rightarrow B_{1,1}))$ from R_6.
4. $R_8 : (\neg B_{1,1} \Rightarrow \neg(P_{1,2} \vee P_{2,1})))$ from R_7.
5. $R_9 : \neg(P_{1,2} \vee P_{2,1})))$ from R_8, R_2 by MP.
6. $R_{10} : (\neg P_{1,2} \wedge \neg P_{2,1})$ from R_9.

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5. $R_9 : \neg(P_{1,2} \vee P_{2,1})))$ from R_8, R_2 by MP.
6. $R_{10} : (\neg P_{1,2} \wedge \neg P_{2,1})$ from R_9.
7. $R_{11} : \neg P_{1,2}$ from R_{10}.

Reasoning patterns in propositional logic, Cont

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2. Finding a proof is a search problem.
3. Problem Statement: ?
4. Goal Statement: ?
5. Successor Function: ?
6. Path Cost: ?

Reasoning patterns in propositional logic, Cont

1. A Horn clause: is disjunction of literals of which atmost one is positive.
2. $\neg l_1 \vee \neg l_2 \cdots \neg l_k \vee l_{k+1} \equiv l_1 \wedge l_2 \cdots \wedge l_k \Rightarrow l_{k+1}$

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4. Deciding entailment with Horn clauses can be done in linear time.

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Forward Chaining, Cont

```
function FC-ENTAILS?(KB, q) returns true or false

 while agenda is not empty do
  p= POP(agenda)
  unless inferred [p] do
   inferred [p]= true
   foreach c in whose promises p appears do
    Dec (count[c])
    if count[c]= 0 then
     if HEAD[c]=q then
      return true;
     push(HEAD[c],agenda);
 return false
```

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4. Resolution is sound and complete for propositional logic.

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3. If an empty clause generated, returns true.

Resolution, Cont

```
function Resolution?(KB, q) returns true or false

 clauses= set of clauses in the CNF format of KB^ not a
 loop
  new= {}
  for each Ci, Cj in clauses do
   resolvants=RESOLVE(Ci,Cj);
   if resolvants contains empty cluases then
    return true
   new= new U resolvants
  if new is a subset of clauses return false;
  clauses= clauses U new
```

Resolution, Cont

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3. Resolution+ complete search algorithm: complete inference algorithm.

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Propositional Inference based on Model Checking

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   - Backtracking search
   - Local search

Complete backtracking search (Davis-Putnam)

```
function DPLL(clauses,sybmols,model) return true or false
 if every clauses is true in model return true
 if some clauses is false in model return false
 P,v=FIND-PURE-SYMBOL(symbols,clauses,model)
 if P!=null return DPLL(clauses,symbols-P,model+(P,v))
 P,value= FIND-UNIT-SYMBOL(clauses,model)
 if P!=null return DPLL(clauses,symbols-P,model+(P,v))
 P=FIRST(symbols);rest=REST(symbols);
 return DPLL(clauses,rest,model+(P,true)) or
        DPLL(clauses,rest,model+(P,false))
```

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5. Various forms of randomness are required.

Local-search algorithm- Cont

```
function WALKSAT(clauses,p,max-flips)returns a model or fai

 model=random assignment of true/false to symbols in clause
 for i:= 1 to max-flip do
  if model satisfies clauses then return model
  clause= a randomly selected clause
                that is false in model.
  with prob. p:
   flip value of randomly selected symbol from clause
  else
   flip symbol in clause which maximizes no. of
                satisfied clauses.
```

Local-search algorithm, Cont

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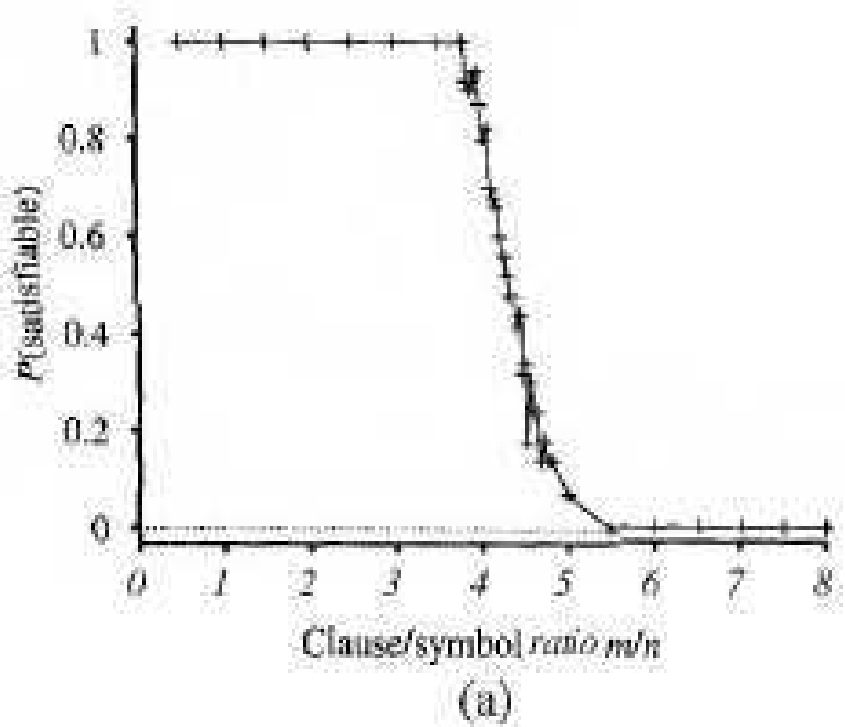
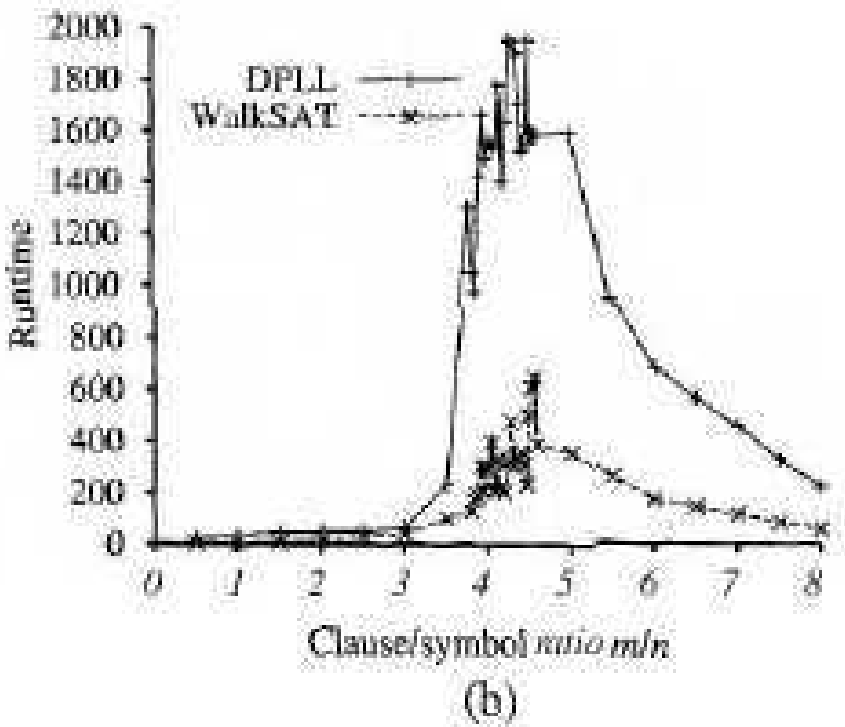
Local-search algorithm, Cont

1. WALKSAT may returns a model if one exists.
2. It can not tell whether the statement is unsatisfiable.
3. But, WALKSAT can tell us a statement my be unsatisfiable.
4. Satisfiability may be a hard problem (depending on $\frac{No.\ of\ symbols}{No.\ of\ clauses}$)

Local-search algorithm, Cont





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5. Problem has 64 symbols and 155 statements.

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