Tutorial 05 for Fundamentals of Artificial Intelligence

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Problem 1 – Part i

1. Answer the following questions:
(a)What is Knowledge-based Agent? What about its two main components? (L6: P5-6)
(b)Please explain the following definitions: 1) Syntax; 2) Semantics, and 3) Sentence in Propositional Logic. (L6: P17-18)
(c)How to understand two different domains: Domain-specific content for Knowledge Base and Domain-Independent algorithms for Inference Engine? (L6: P24)

Knowledge-based Agent

- A knowledge-based agent includes a Knowledge Base and an Inference Engine.
- A knowledge base is a set of representations of facts of the world.
- Each individual representation is called a **sentence**.
- The sentences are expressed in a **knowledge representation language**.
- The agent operates as follows:
  - It TELLs the knowledge base what it perceives.
  - It ASKs the knowledge base what action it should perform.
  - It performs the chosen action.

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Two Different Domains

- **Domain-specific content** for Knowledge Base
  - ¬ : Knowledge should be related to the environment of the current agent, not applied to other agents, so is domain-specific.
- **Domain-Independent algorithms** for Inference Engine
  - ¬ : Inference algorithms are based on some universal principles, like the Propositional Logic, which are independent to the domain.

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Some Definitions for Logic in General

- Logics are formal languages for representing information such that conclusions can be drawn.
- **Syntax** defines the sentences in the language
- **Semantics** define the "meaning" of sentences.
- **Sentence in Propositional Logic**: A sentence is formed by combining sentences with one of the five logical connectives:
  - $\neg$: negation
  - $\vee$: conjunction
  - $\wedge$: disjunction
  - $\Rightarrow$: implication
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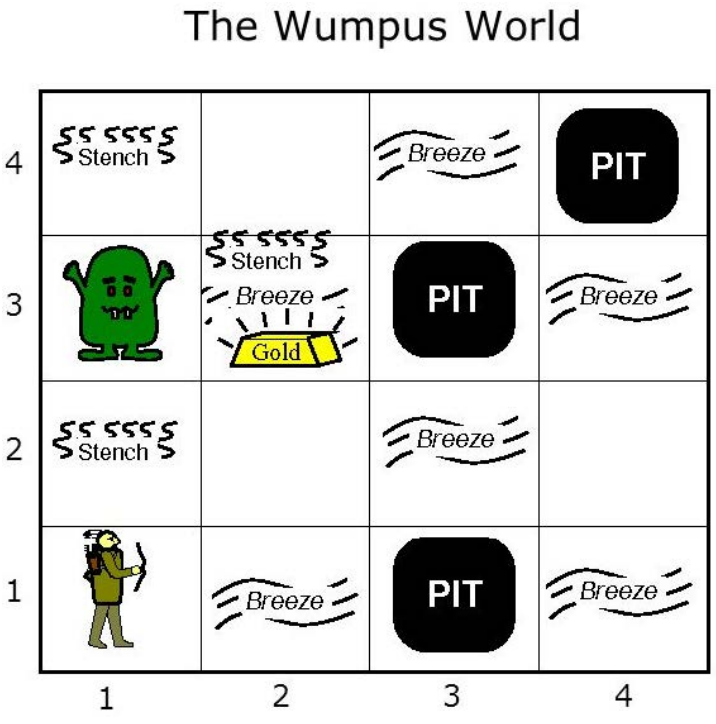
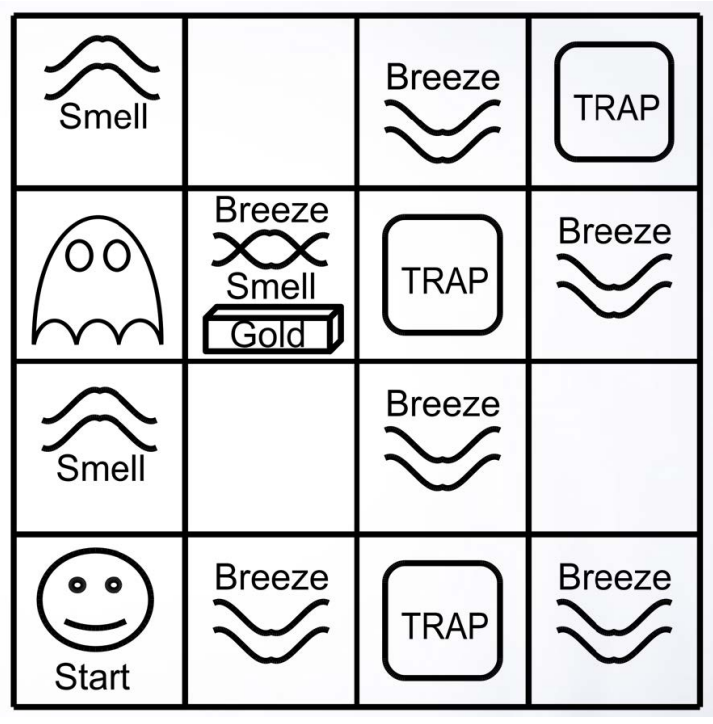
Problem 1 – Part ii

1. Answer the following questions:
(d) What is P.E.A.S. description in the Wumpus World? (L6: P9-12)
(e) Inference rules: 1) Contraposition; 2) de Morgan; 3) Distributivity of $\wedge$ over $\vee$; 4) Distributivity of $\vee$ over $\wedge$. (L6: P28)
(f) Inference rules: 1) Modus Ponens\Implication Elimination; 2) Biconditional Elimination; 3) And-Elimination; 4) Full Resolution (L6: P27-34)
(g) What are Validity and Satisfiability? What are Deduction Theorem and Refutation Theorem? (L6: P29)

Partially Observable Environment
The WUMPUS World





- To well-define The WUMPUS World problem
  - PEAS description in Lecture 2 is used
  - **P**erformance, **E**nvironment, **A**ctuators, **S**ensors
- Let's go to L6: P10-12

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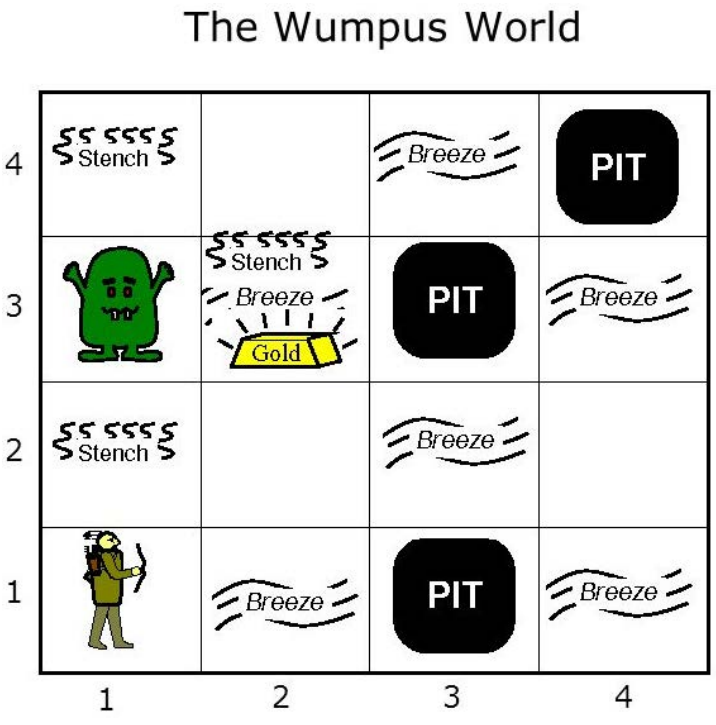

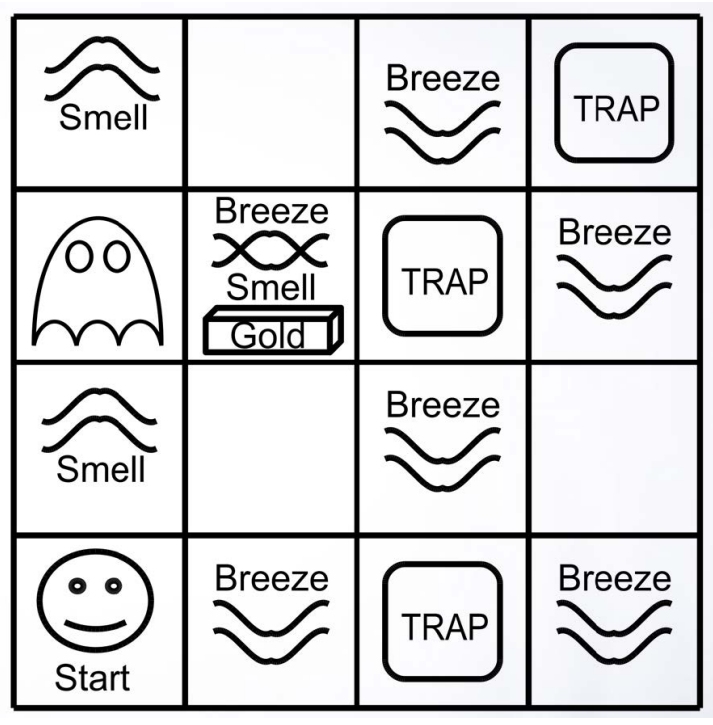

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- Let's go to L6: P10-12

Inference Rules

$$(\alpha \wedge \beta) \equiv (\beta \wedge \alpha) \quad \text{commutativity of } \wedge$$
$$(\alpha \vee \beta) \equiv (\beta \vee \alpha) \quad \text{commutativity of } \vee$$
$$((\alpha \wedge \beta) \wedge \gamma) \equiv (\alpha \wedge (\beta \wedge \gamma)) \quad \text{associativity of } \wedge$$
$$((\alpha \vee \beta) \vee \gamma) \equiv (\alpha \vee (\beta \vee \gamma)) \quad \text{associativity of } \vee$$
$$\neg(\neg\alpha) \equiv \alpha \quad \text{double-negation elimination}$$
$$(\alpha \Rightarrow \beta) \equiv (\neg\beta \Rightarrow \neg\alpha) \quad \text{contraposition}$$
$$(\alpha \Rightarrow \beta) \equiv (\neg\alpha \vee \beta) \quad \text{implication elimination}$$
$$(\alpha \Leftrightarrow \beta) \equiv ((\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)) \quad \text{biconditional elimination}$$
$$\neg(\alpha \wedge \beta) \equiv (\neg\alpha \vee \neg\beta) \quad \text{de Morgan}$$
$$\neg(\alpha \vee \beta) \equiv (\neg\alpha \wedge \neg\beta) \quad \text{de Morgan}$$
$$(\alpha \wedge (\beta \vee \gamma)) \equiv ((\alpha \wedge \beta) \vee (\alpha \wedge \gamma)) \quad \text{distributivity of } \wedge \text{ over } \vee$$
$$(\alpha \vee (\beta \wedge \gamma)) \equiv ((\alpha \vee \beta) \wedge (\alpha \vee \gamma)) \quad \text{distributivity of } \vee \text{ over } \wedge$$

Inference Rules

- Modus Ponens/Implication Elimination
  - $(\alpha \Rightarrow \beta) \equiv (\neg\alpha \vee \beta)$

Modus Ponens or **Implication-Elimination**: (From an implication and the premise of the implication, you can infer the conclusion.)

$$\frac{\alpha \Rightarrow \beta, \quad \alpha}{\beta}$$

premise

conclusion

If a proposition α entails a proposition β, and α is true, then β is true.

Inference Rules

- Biconditional Elimination
  - $(\alpha \Leftrightarrow \beta) \equiv ((\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha))$

Inference Rules

- And-Elimination

And-Elimination: (From a conjunction, you can infer any of the conjuncts.)

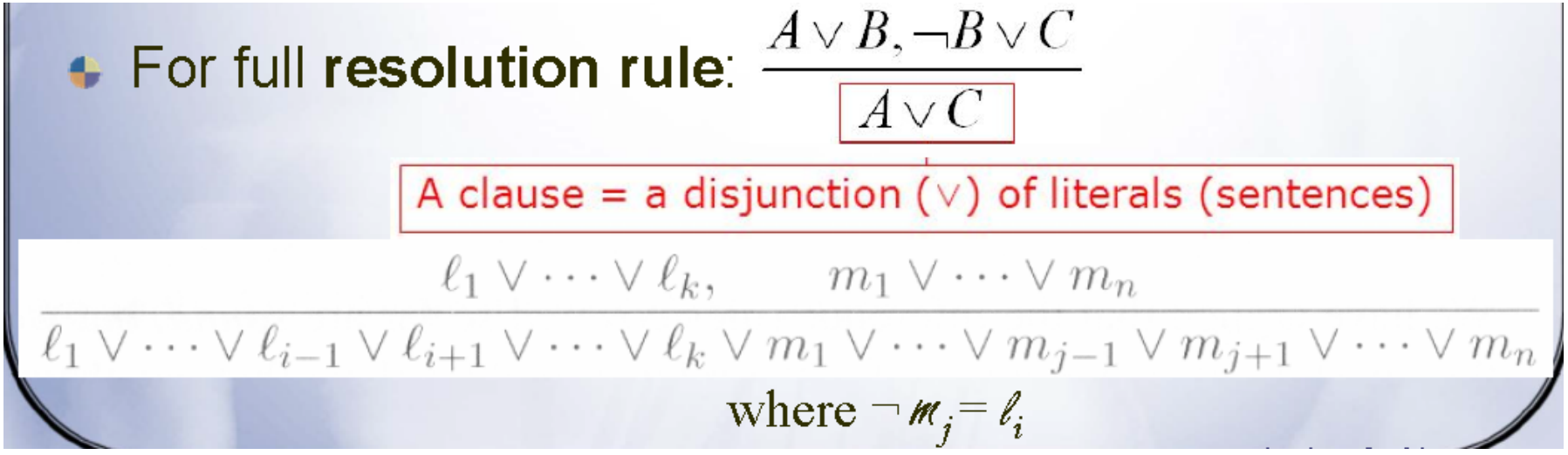
$$\frac{\alpha_1 \wedge \alpha_2 \wedge \ldots \wedge \alpha_n}{\alpha_i}$$

premise

conclusion

Inference Rules

- Full Resolution



Validity and Satisfiability

- Let's go to L6: P29

Problem 1 – Part iii

1. Answer the following questions:
(h)Please list a few examples for the following definitions: 1) Positive/Negative Literals, and 2) Pure Horn Clauses/Negative Clauses/Non-Horn Clauses. (L6: P39)
(i)What about resolution algorithm, including Unit Resolution and Resolution Rule? (L6: P33-35)

Examples

- Positive Literals:
  - $L_{1,1}, B_{1,1}, Breeze$
- Negative Literals:
  - $\neg L_{1,1}, \neg B_{1,1}, \neg Breeze$
- Pure Horn Clauses:
  - $\neg L_{1,1} \vee \neg B_{1,1} \vee Breeze$, $\neg Male \vee \neg Child \vee Boy$
- Negative Clauses:
  - $\neg L_{1,1} \vee \neg B_{1,1} \vee \neg Breeze$, $\neg Male \vee \neg Child \vee \neg Boy$
- Non-Horn Clauses:
  - $L_{1,1} \vee \neg B_{1,1} \vee Breeze$, $Male \vee Child \vee Boy$

Examples

- Positive Literals:
  - $L_{1,1}, B_{1,1}, Breeze$
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- Non-Horn Clauses:
  - $L_{1,1} \vee \neg B_{1,1} \vee Breeze$, $Male \vee Child \vee Boy$

Resolution Algorithm

- Unit Resolution and Full Resolution Rule

$$\frac{\alpha \vee \beta, \neg\beta}{\alpha}$$

$$\frac{\alpha \vee \beta, \neg\beta \vee \gamma}{\alpha \vee \gamma} \quad \text{or} \quad \frac{\alpha \vee \beta, \beta \Rightarrow \gamma}{\alpha \vee \gamma}$$

Example:

α: "The weather is dry"

β: "The weather is rainy"

γ: "I carry an umbrella"

Problem 2

2. Complete the truth table. (L6: P20)

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

Problem 2

2. Complete the truth table. (L6: P20)

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

Problem 3

3. Determine whether the following proposition is TRUE or FALSE.
(a) $1 + 1 = 3$ if and only if $2 + 2 = 3$.
(b) If $1 + 1 = 2$ or $1 + 1 = 3$, then $2 + 2 = 3$ and $2 + 2 = 4$.
(c) $1 + 2 = 5 \Rightarrow 2 + 3 = 5$.

Problem 3

3. Determine whether the following proposition is TRUE or FALSE.

(a) $1 + 1 = 3$ if and only if $2 + 2 = 3$. True

(b) If $1 + 1 = 2$ or $1 + 1 = 3$, then $2 + 2 = 3$ and $2 + 2 = 4$. False

(c) $1 + 2 = 5 \Rightarrow 2 + 3 = 5$. True

Problem 4

4. Write the statements.
(a) Using c for "it is cold" and d for "it is dry", write "It is neither cold nor dry" in symbols.
(b) Using c for "it is cold", r for "it is rainy", and w for "it is windy", write "It is rainy only if it is windy and cold" in symbols.

Problem 4

4. Write the statements.
(a) Using c for "it is cold" and d for "it is dry", write "It is neither cold nor dry" in symbols.

$$\neg c \wedge \neg d$$

(b) Using c for "it is cold", r for "it is rainy", and w for "it is windy", write "It is rainy only if it is windy and cold" in symbols.

$$r \Rightarrow (w \wedge c)$$

Problem 5

5. Convert the following formulas into Conjunctive Normal Form (CNF). (L6: P35)

(a) $(p \Leftrightarrow q) \Rightarrow (\neg p \wedge r)$

(b) $(p \Rightarrow q) \Leftrightarrow (p \Rightarrow r)$

Problem 5

5. Convert the following formulas into Conjunctive Normal Form (CNF). (L6: P35)

(a) $(p \Leftrightarrow q) \Rightarrow (\neg p \wedge r)$

$$(p \vee q \vee r) \wedge (\neg p \vee \neg q \vee r) \wedge (\neg p \vee \neg q)$$

(b) $(p \Rightarrow q) \Leftrightarrow (p \Rightarrow r)$

$$(\neg q \vee \neg p \vee r) \wedge (\neg r \vee \neg p \vee q)$$

Problem 6

6. Please use the inference rules to prove if the following sentence is TRUE.

(a) $A \wedge \neg A$

(b) $A \vee \neg A$

(c) $A \Rightarrow A$

(d) $(A \wedge (A \Rightarrow B)) \Rightarrow A$