제5강
추론하는 기계

<인공지능 입문> 강의 노트

장 병 탁
서울대학교 컴퓨터공학부 &
인지과학/뇌과학 협동과정
http://bi.snu.ac.kr/~btzhang/

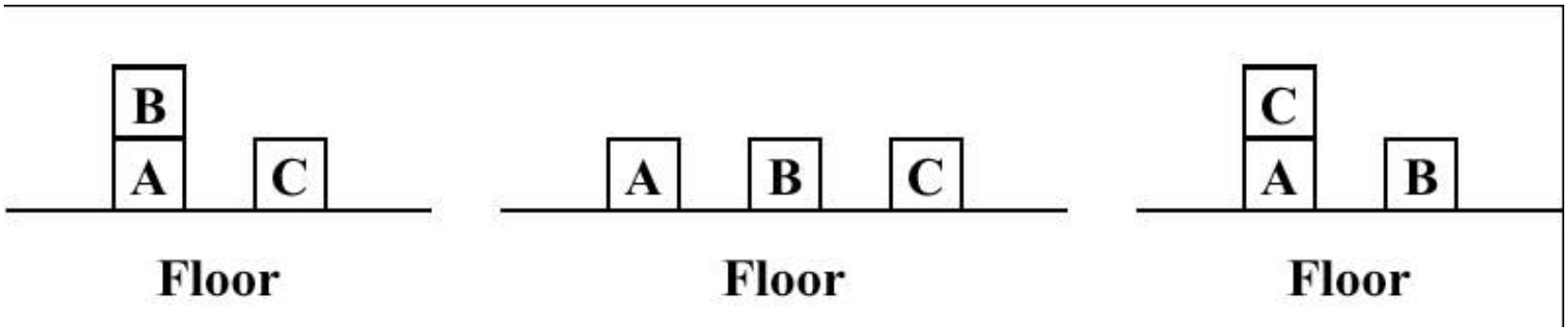
Version: 20180402 → 20180403

목차

제5강

현실과 모델

- 현실 세계



현실 세계 1　　현실 세계 2　　현실 세계 3

- 논리언어 모델

세계 1:

Clear(B) ∧ On(B, A) ∧ Clear(C) ∧ Floor(A) ∧ Floor(C)

세계 2:

Clear(A) ∧ Clear(B) ∧ Clear(C) ∧ Floor(A) ∧ Floor(B) ∧ Floor(C)

세계 3:

Clear(C) ∧ On(C, A) ∧ Clear(B) ∧ Floor(A) ∧ Floor(B)

제5강

기호 논리와 추론

- 기호 논리
  - 명제 논리(propositional logic), 술어 논리(predicate logic)
- 술어 논리
  - 상수(constants): 객체, 관계, 함수의 이름 — A, B, On, Clear, Floor
  - 술어(predicates): 참/거짓 값을 갖는 관계 — On(A, B), Clear(B), Floor(A)
  - 연결자(connectives): ∧, ∨, ¬, → — On(A, B) ∧ Clear(B)
- 논리와 지식 표현

  Parent(x, y) → Child(y, x)

  Parent(x, y) → Father(x, y) ∨ Mother(x, y)

  Father(x, y) → Male(x) ∧ Adult(x)

  Mother(x, y) → Female(x) ∧ Adult(x)

  Brother(x, y) → Sibling(x, y)

  Sister(x, y) → Sibling(x, y)

  Father(x, y) ^ Father(y, z) → GrandFather(x, z)
- 지식 표현과 추론 →

Given: John is a parent of Brian.
Question: Is John an adult?

Given: Tom is a grandfather of Brian.
John is father of Brian.
Question: Is Tom father of John?

제5강

추론 규칙

- 명제논리/술어논리 공통 추론 규칙
  - *modus ponens*: w_1 and $w_1 \rightarrow w_2 \models w_2$
  - $\wedge$ introduction: w_1 and $w_2 \models w_1 \wedge w_2$
  - commutativity $\wedge$: w_1 and $w_2 \models w_2 \wedge w_1$
  - $\wedge$ elimination: $w_1 \wedge w_2 \models w_1$
  - $\vee$ introduction: either from w_1 or from $w_2 \models \quad w_1 \vee w_2$
  - $\neg$ elimination: $\neg (\neg w_1) \models w_1$
- 술어논리 추론 규칙
  - Universal instantiation
    - Example: $(\forall x)P(x, f(x), B) \rightarrow P(A, f(A), B)$
  - Existential generalization
    - Example: $(\forall x)Q(A, g(A), x) \rightarrow (\exists y)(\forall x)Q(y, g(y), x)$

추론 규칙 적용 예

- Modus Ponens
  - w_1 and $w_1 \rightarrow w_2 \models w_2$

  w_1: NoBattery(x)

  w_2: NoBattery(x) → Doesn'tStart(x)

- Universal Instantiation

  x = MyCar

  w_1: NoBattery(MyCar)

  w_2: NoBattery(MyCar) → Doesn'tStart(MyCar)

  NoBattery(MyCar)

  → Doesn'tStart(MyCar)

제5강

PROLOG: 논리 프로그래밍

❑ PROLOG

- Programming in logic
- 1차 술어 논리
- Horn clause: 최대 1개의 positive literal을 갖는 절(clause)

A

A → B

A ^ B → C

```
A :-
B :- A
C :- A, B
```

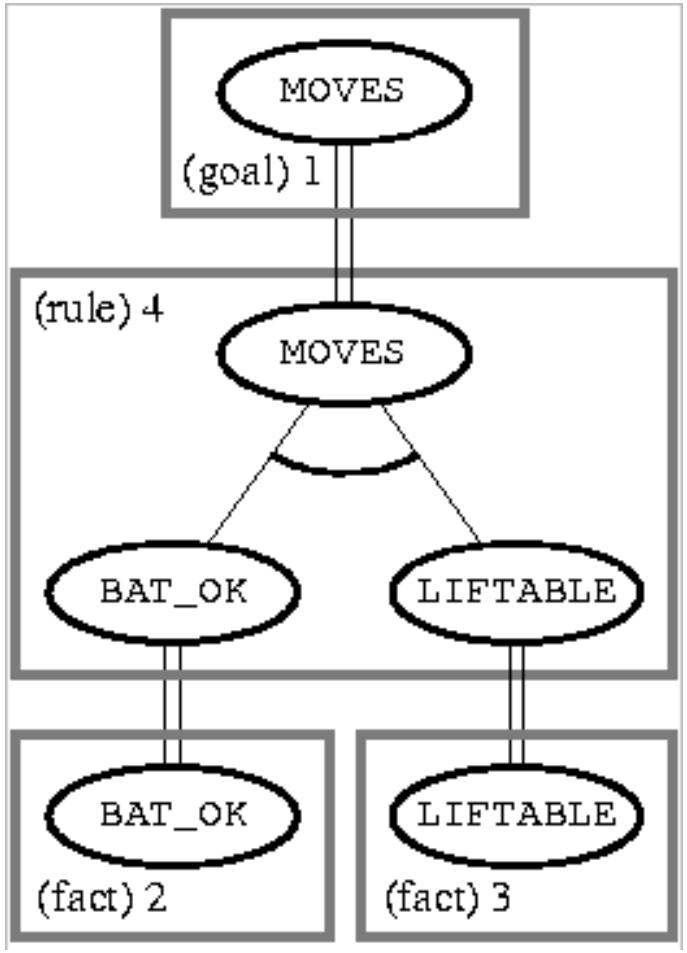
❑ Prolog 프로그램의 문법

- Goal
- Fact
- Rule

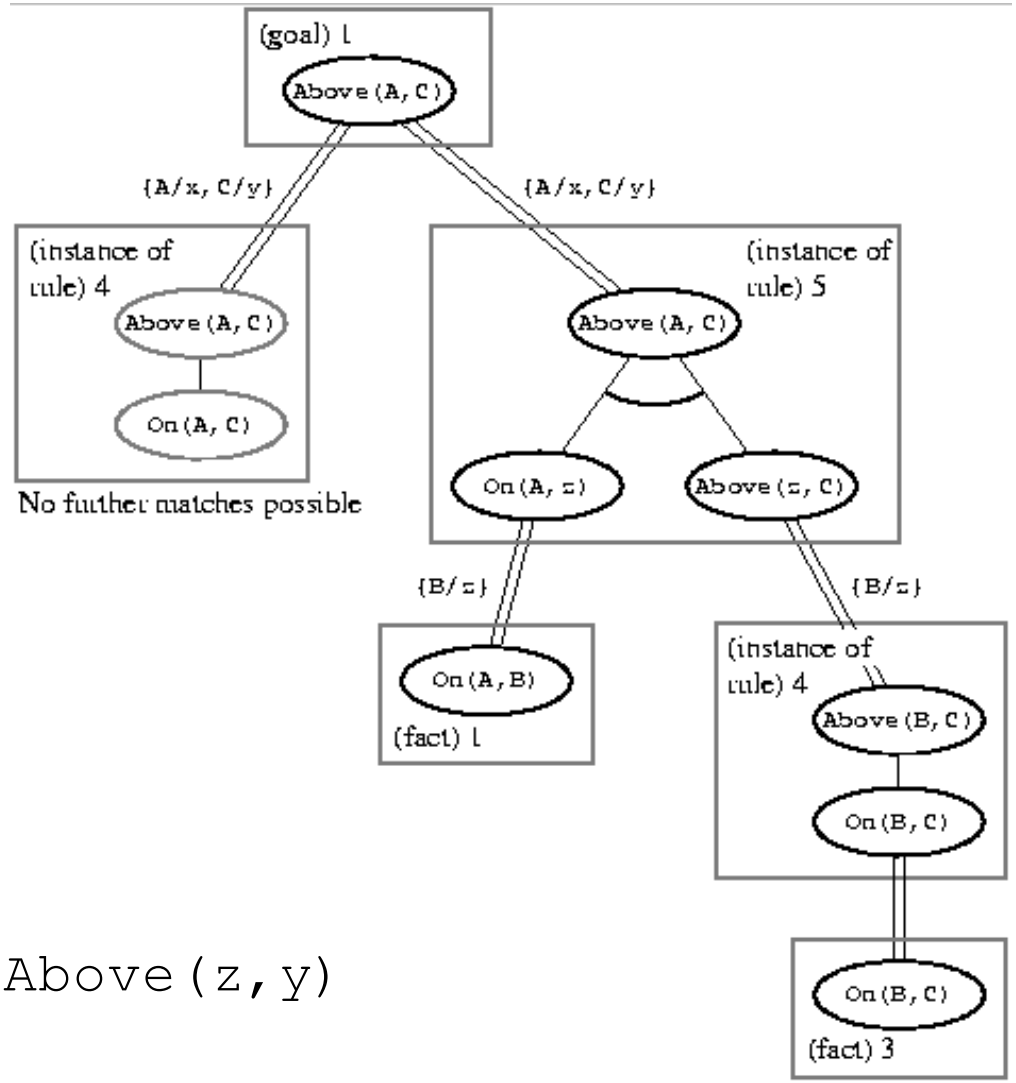
```
1. :- MOVES
2. BAT_OK :-
3. LIFTABLE :-
4. MOVES :- BAT_OK, LIFTABLE
```

증명 트리(Proof Tree)

```
1. :- MOVES
2. BAT_OK :-
3. LIFTABLE :-
4. MOVES :- BAT_OK, LIFTABLE
```



증명 트리




```
1. :- Above(A,C)
2. On(A,B) :-
3. On(B,C) :-
4. Above(x,y) :- On(x,y)
5. Above(x,y) :- On(x,z), Above(z,y)
```

제5강

정리 증명

소포 배달 로봇 문제

- 로봇은 27번 방에 있는 모든 소포는 28번 방에 있는 모든 소포 보다 작다는 것을 알고 있다고 하자(주어진 지식).

  1. $(\forall\, x, y)\{Package(x) \wedge Package(y) \wedge Inroom(x, 27) \wedge Inroom(y, 28)\} \rightarrow Smaller(x, y)$

  2. $\neg P(x) \vee \neg P(y) \vee \neg I(x, 27) \vee \neg I(y, 28) \vee \neg S(x, y)$

  $A \rightarrow B \Leftrightarrow \neg A \vee B$

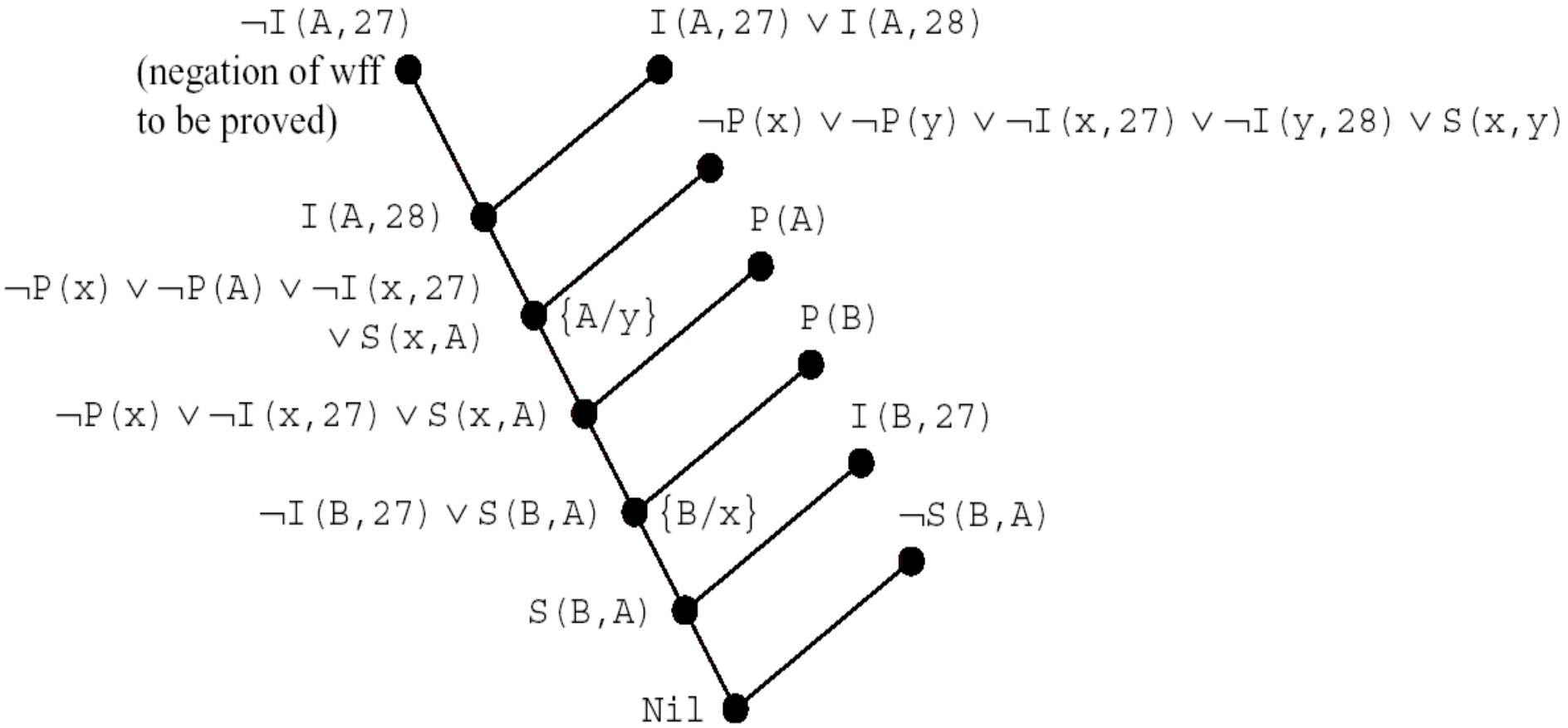
- 로봇이 다음 사항도 알고 있다고 하자(로봇이 관측한 사실들).

  3. *P*(*A*)
  4. *P*(*B*)
  5. *I*(*A*, 27) $\vee$ *I*(*A*,28) // package A is either in room 27 or in room 28 (but not which)
  6. *I*(*B*, 27) // package B is in room 27
  7. $\neg$*S*(*B*, *A*) // package B is not smaller than package A.

- 질문: 소포 *A*는 27번 방에 있는가? *I*(*A*, 27)?

제5강

정리 증명 방법: Resolution



제5강

상식적 지식
(Commonsense Knowledge)

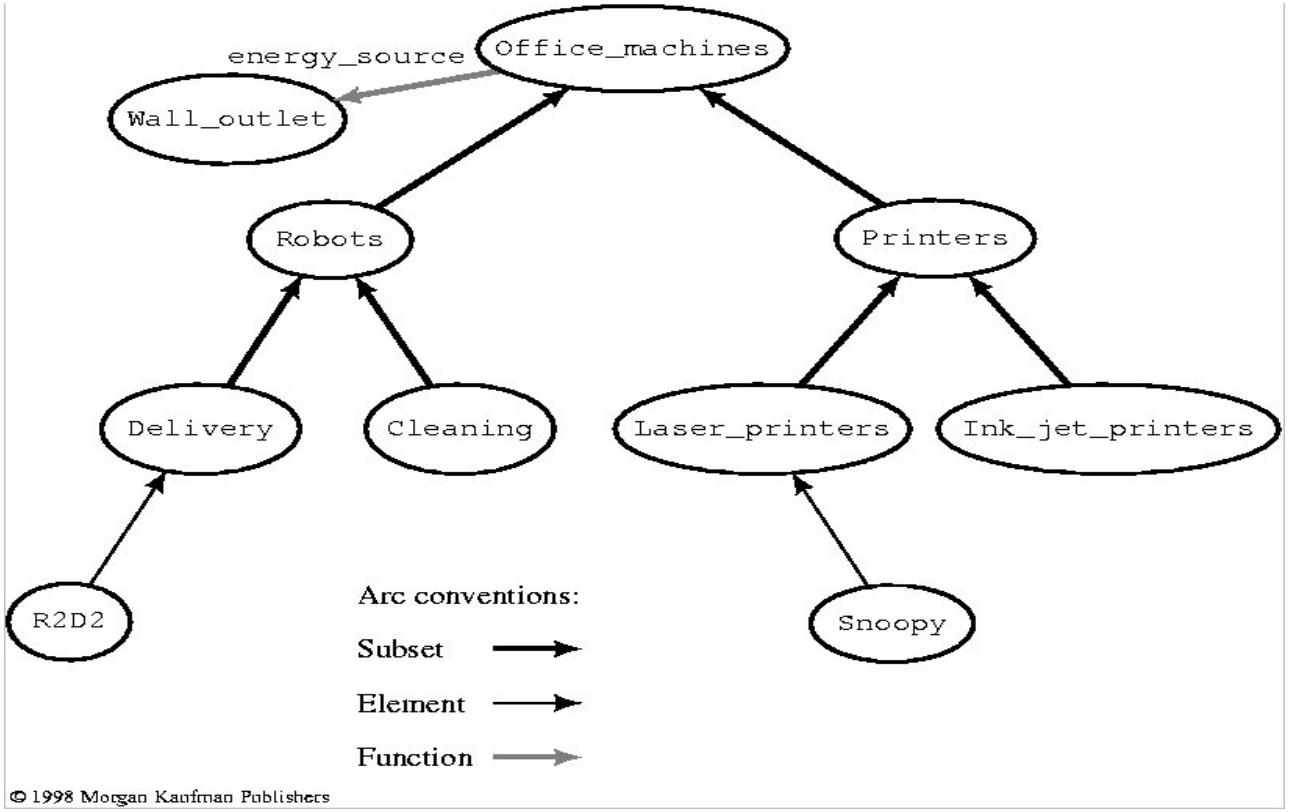
다음과 같은 상식적인 지식을 기계가 어떻게 표현할 것인가?

- 컵이 넘어지면 물이 나온다.
- 물체를 공중에서 놓으면 땅으로 떨어진다.
- 사람은 태어나기 전에는 존재하지 않는다.
- 물고기는 물에서 살며 물 밖으로 나오면 죽는다.
- 빵은 빵가게에서 산다.
- 사람들은 주로 저녁에 잠을 잔다.
- 운전시 교통 법규를 어기면 벌금이 나온다.

제5강

의미망과 추론

- 의미망(semantic network): 노드(객체)와 아크(관계)로 구성된 그래프 구조

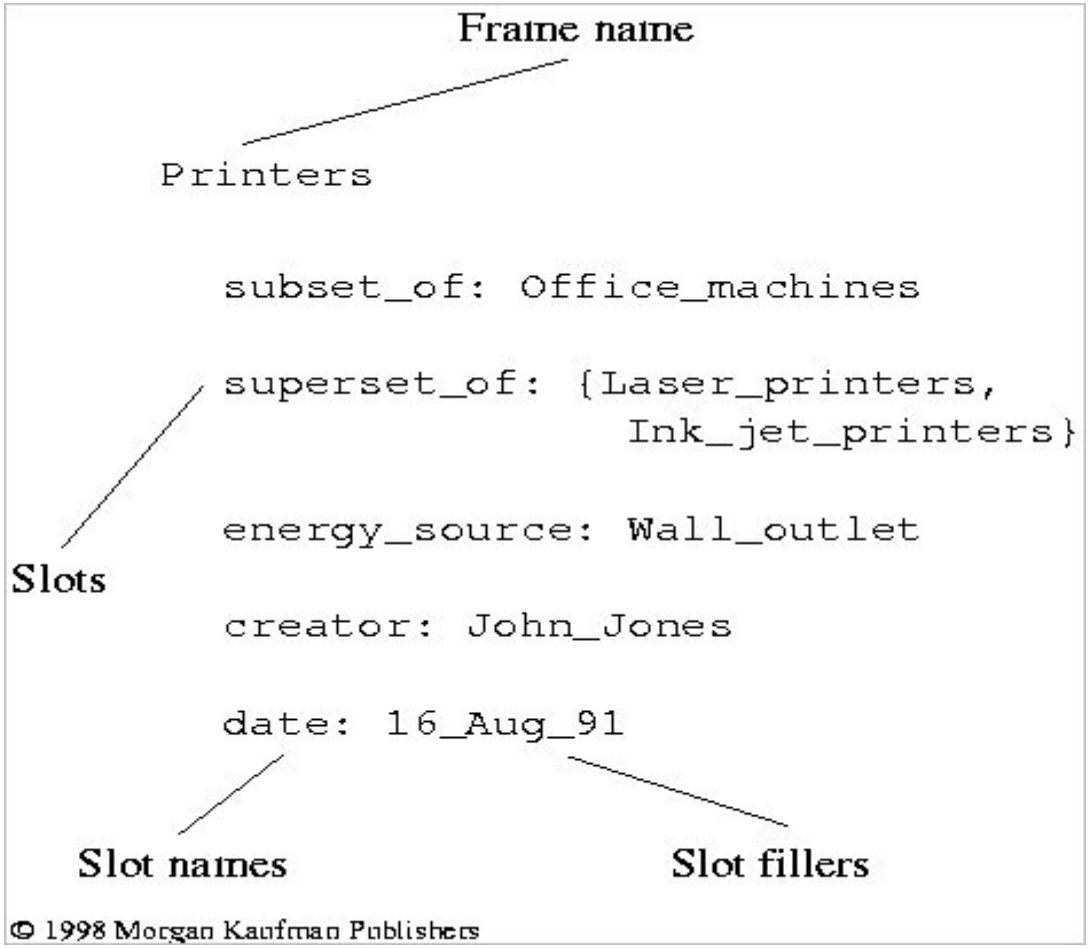



```
Laser_printer(Snoopy)
(∀x)[Laser_printer(x) ⊃ Printer(x)]
(∀x)[Printer(x) ⊃ Office_machine(x)]
```

제5강

프레임과 상식 추론

- 슬럿(속성)과 필러(속성값)로 구성된 자료 구조. 의미망의 노드에 해당.



Assignment 1/2

[Russell & Norvig, 2010] Problem 8.9: Consider a vocabulary with the following symbols:

Occupation(p, o): Predicate. Person *p* has occupation *o.*
Customer(p1, p2): Predicate. Person *p1* is a customer of person *p2*.
Boss(p1, p2): Predicate. Person p1 is a boss of person p2.
Doctor, Surgeon, Lawyer, Actor: Constants denoting occupations.
Emily, Joe: Constants denoting people.

Use these symbols to write the following assertions in first-order logic:

a. Emily is either a surgeon or a lawyer.
b. Joe is an actor, but he also holds another job.
c. All surgeons are doctors.
d. Joe does not have a lawyer (i.e., is not a customer of any lawyer).
e. Emily has a boss who is a lawyer.
f. There exists a lawyer all of whose customers are doctors.
g. Every surgeon has a lawyer.

Assignment 2/2

[Russell & Norvig, 2010] 8.31 Consider a first-order logical knowledge base that describes worlds containing people, songs, albums (e.g., "Meet the Beatles") and idsks (i.e., particular physical instances of CDs). The vocabulary contains the following symbols:

CopyOf(*d, a*): Predicate. Disk *d* is a copy of album *a*.
Owns(*p, d*): Predicate. Person *p* owns disk *d*.
Sings(*p, s, a*): Album *a* includes a recording of song *s* sung by person *p*.
Wrote(*p, s*): Person *p* wrote song *s*.
McCartney, Gershwin, BHoliday, Joe, EleanorRigby, TheManILove, Revolver: Constants with the obvious meanings.

Express the following statements in first-order logic:

a. Gershwin write "The Man I Love."
b. Gershwin did not write "Eleanor Rigby."
c. Either Gershwin or McCartney wrote "The Man I Love."
d. Joe has written at least one song.
e. Joe owns a copy of Revolver.
f. Every song that McCartney sings on Revolver was written by McCartney.
g. Gershwin did not write any of the songs on Revolver.
h. Every song that Gershwin wrote has been recorded on some album. (Possibly different songs are recorded on different albums.)
i. There is a single album that contains every song that Joe has written.
j. Joe owns a copy of an album that has Billie Holiday singing "The Man I Love."
k. Joe owns a copy of every album that has a song sung by McCartney (Of course, each different album is instantiated in a different physical CD.)
l. Joe owns a copy of every album on which all the songs are sung by Billie Holiday.