CSP

- Melakukan konfirmasi struktur internal state yang memenuhi syarat goal test.
- Set variabel $x_1, x_2, \ldots, x_n$
  Set domain $D_1, D_2, \ldots, D_n$
  Set constrain $C_1, C_2, \ldots, C_n$
  - Unary (satu variabel)
  - Binary (perangan variabel)
  - Higher-order (>2 variabel)
  - Preference / SOFT constraint (pembobotan)
- Backtracking Search
  - Urutan pemilihan variabel
    -> Minimum Remaining Variable (MRV)
    pilih var dgn variasi kemungkinan paling sedikit
    jika >1, gunakan MCV
    -> Most Constraining Variable (MCV)
    pilih var yg punya jumlah constraint lebih banyak
  - Urutan pemilihan nilai dari variabel
    -> Least Constraining Value (LCV)
    pilih nilai var yg constraint lebih sedikit untuk variabel lain
    pilih nilai var yg membuat variabel lain memiliki kemungkinan pilihan lebih banyak

Bayes Classifiers

- Bayes Theorem

$$P(c|A) = \frac{P(A|C)P(c)}{P(A)}$$

- Misal ada 2 class : Mamals & Non
  1. Hitung P(A | Mammals)
  2. Hitung P(A | Non)
  3. Hitung (1) x P(Mammals)
  4. Hitung (2) x P(Non)
  5. Bandingkan hasil (3) dan (4) untuk menentukan class-nya.

Minimax

- Adversarial Search → ada agen lawan
- Minimax → algo backtracking
  Max → mencoba mendapat skor tertinggi
  Min → mencoba mendapat skor terendah
- Alpha-beta pruning (meractong)
  α → nilai terbaik maximizer
  β → nilai terbaik minimizer
- Function Max-Value ($v \rightarrow -\infty$)
- Function Min-Value ($v \rightarrow +\infty$)

First Order Logic

- syntax FOL
  - constants (KingJohn, NUS, ...)
  - predicates (Brother)
  - functions (sqrt, LeftLegOf, ...)
  - variables (a, b, x, y, ...)
  - Connectives ($\neg, \Rightarrow, \Leftrightarrow, \wedge, \vee$)
  - Equality ($=$)
  - Quantifiers ($\forall, \exists$)
- Universal Quantifiers ($\forall$)
  Everyone at NUS is smart → $\forall x\ At(x, NUS) \Rightarrow Smart(x)$
- Existential Quantifiers ($\exists$)
  Someone at NUS is smart → $\exists x\ At(x, NUS) \wedge Smart(x)$

- $\forall x \forall y = \forall y \forall x$; $\exists x \exists y = \exists y \exists x$; $\exists x \forall y \neq \forall y \exists x$
- Contoh FOL : Budi suka semua jenis Makanan
  $\forall x\ Suka(Budi, x)$
- Metode Forward-chaining
  botton to top (mulai dari facts)
- Metode Backward-chaining
  top to bottom (mulai dari goals)

- Konversi FOL → CNF

a) Eliminate biconditionals dan implications
   - Eliminate $\Leftrightarrow$, replacing $\alpha \Leftrightarrow \beta$ with $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$
   - Eliminate $\Rightarrow$, replacing $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$

b) Move negasi ke depan

$\neg(\forall x\ P) \equiv \exists x \neg P$; $\neg(\exists x\ P) \equiv \forall x \neg P$

$\neg(\alpha \vee \beta) \equiv \neg\alpha \wedge \neg\beta$; $\neg(\alpha \wedge \beta) \equiv \neg\alpha \vee \neg\beta$ → De Morgan

$\neg\neg\alpha \equiv \alpha$

c) Standardize variables apart by renaming them : each quantifier should use a diff. variable

d) Skolemize

Everyone has a heart $\forall x\ Person(x) \Rightarrow \exists y\ Heart(y) \wedge Has(x,y)$

menjadi $\forall x\ Person(x) \Rightarrow Heart(H(x)) \wedge Has(x, H(x))$

e) Drop Universal quantifiers

$\forall x\ Person(x)$ menjadi $Person(x)$

f) Distribute $\wedge$ over $\vee$

$(\alpha \wedge \beta) \vee \gamma \rightarrow (\alpha \vee \gamma) \wedge (\beta \vee \gamma)$

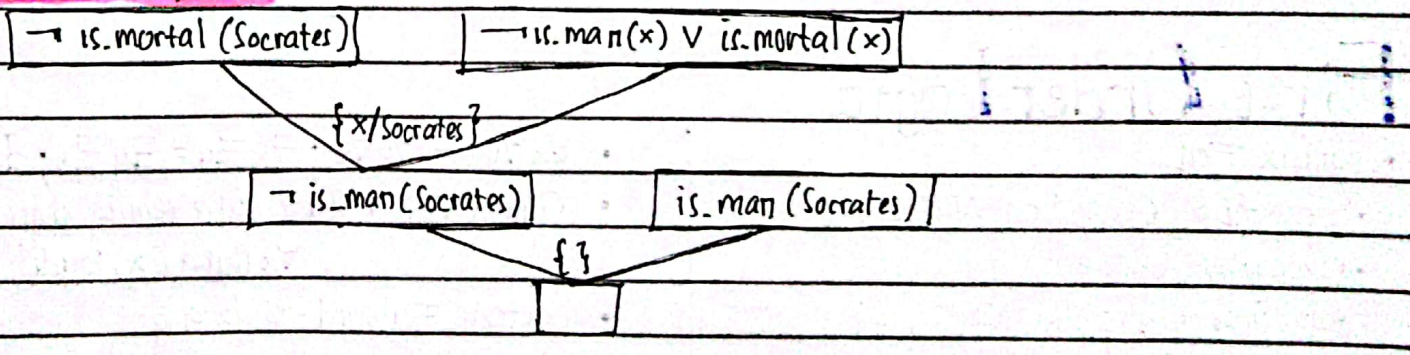
$(\neg B_{11} \vee P_{12} \vee P_{21}) \wedge ((\neg P_{12} \wedge \neg P_{21}) \vee B_{11}) \rightarrow (\neg B_{11} \vee P_{12} \vee P_{21}) \wedge ((\neg P_{12} \vee B_{11}) \wedge (\neg P_{21} \vee B_{11}))$

- Metode Resolution
  - mulai dari atas, negasi dari yang akan dibutuhkan/goal state
  - Cari hasil konversi yg dapat menghilangkan negasi pada hasil konversi hingga NULL $\square$ diikuti $\{x \mid y\}$ → jika var berbeda.
  - Contoh : Socrates is a man and all men are mortal. Therefore Socrates is mortal.

FOL :
- is_man (Socrates)
- $\forall x$ is_man $(x) \Rightarrow$ is_mortal (x)
- is_mortal (Socrates) → Goals

→ CNF :
- is_man (Socrates)
- $\neg$ is_man $(x) \vee$ is_mortal (x)
- $\neg$ is_mortal (Socrates) → negation goals

Resolution Proof Tree



EAS tahun 2021

1\|

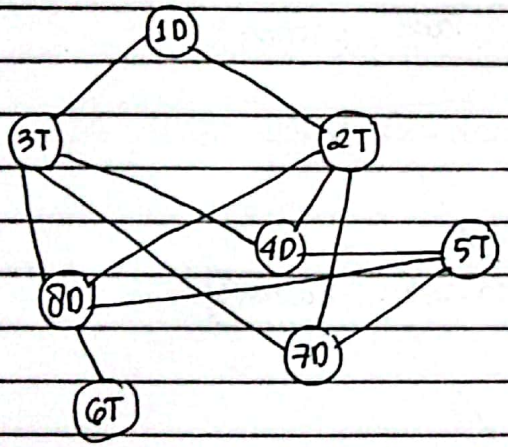
a. AFT	g. KEEL	m. SHEET
b. ALE	h. KNOT	n. STEER
c. EEL	i. LASER	o. TLE
d. HEEL	j. LEE	
e. HIKE	k. LINE	
f. HOSES	l. SAILS	

HOSES
A T
HIKE
A LEE
LASER
E

a)

Variabel	Domain	Constraint	
1D	filmn	1D[3] = 2T[1]	4D[3] = 5T[1]
2T	filmn	1D[5] = 3T[1]	5T[2] = 7D[2]
3T	filmn	2T[3] = 4D[2]	5T[3] = 8D[4]
4D	deghk	2T[4] = 7D[1]	6T[2] = 8D[5]
5T	deghk	2T[5] = 8D[3]	
6T	abcjo	3T[3] = 4D[4]	
7D	abcjo	3T[4] = 7D[3]	
8D	filmn	3T[5] = 8D[5]	

b)



c)

1D	2T	3T	4D	5T	6T	7D	8D
f	lmn	lmn	deghk	deghk	abcjo	abcjo	ilmn
f	l	mn	ek	dgh	abcjo	j	imn
f	l	m	e	dg	abcjo	j	x
f	l	n	e	g	a	j	i

2\|

2.1) Proposisi : a, b, e

2.2) a) $\exists x (\forall y$ bermain $(x, y))$

b) $\neg \forall y (suka(y, Matematika Diskrit) \wedge suka(y, Kalkulus))$

c) $Coco(x) \Leftrightarrow$ Pudel Kuning (x)

3\|

makanan (x)	x adalah makanan
suka (x,y)	x suka y
makan (x,y)	x makan y
hidup (x)	x hidup
terbunuh (x)	x terbunuh
Andi, Budi, Cika	individu

FOL

Budi menyukai semua jenis makanan

$\forall x (makanan(x) \Rightarrow suka(x, Budi))$

Apapun yg dimakan siapa saja & tidak terbunuh adalah makanan

$\forall x (\forall y\ makan(x,y) \wedge \neg terbunuh(x) \Rightarrow makanan(x))$

Andi makan kacang dan tetap hidup

makan (Andi, kacang) ∧ hidup (Andi)

Cika makan semua yang anda makan

$\forall x$ makan (Andi, x) $\Rightarrow$ makan (Cika, x)

Semua yang hidup jika dan hanya jika tidak terbunuh

$\forall x$ (hidup (x) $\Leftrightarrow$ $\neg$ terbunuh (x))

FOL → CNF

1. $\neg$ makanan (x) ∨ suka (Budi, x) ✓
2. $\neg$ makan (y, x) ∨ terbunuh (y) ∨ makanan (x) ✓
3. makan (Andi, kacang) ✓
4. hidup (Andi)
5. $\neg$ makan (Andi, x) ∨ makan (Cika, x)

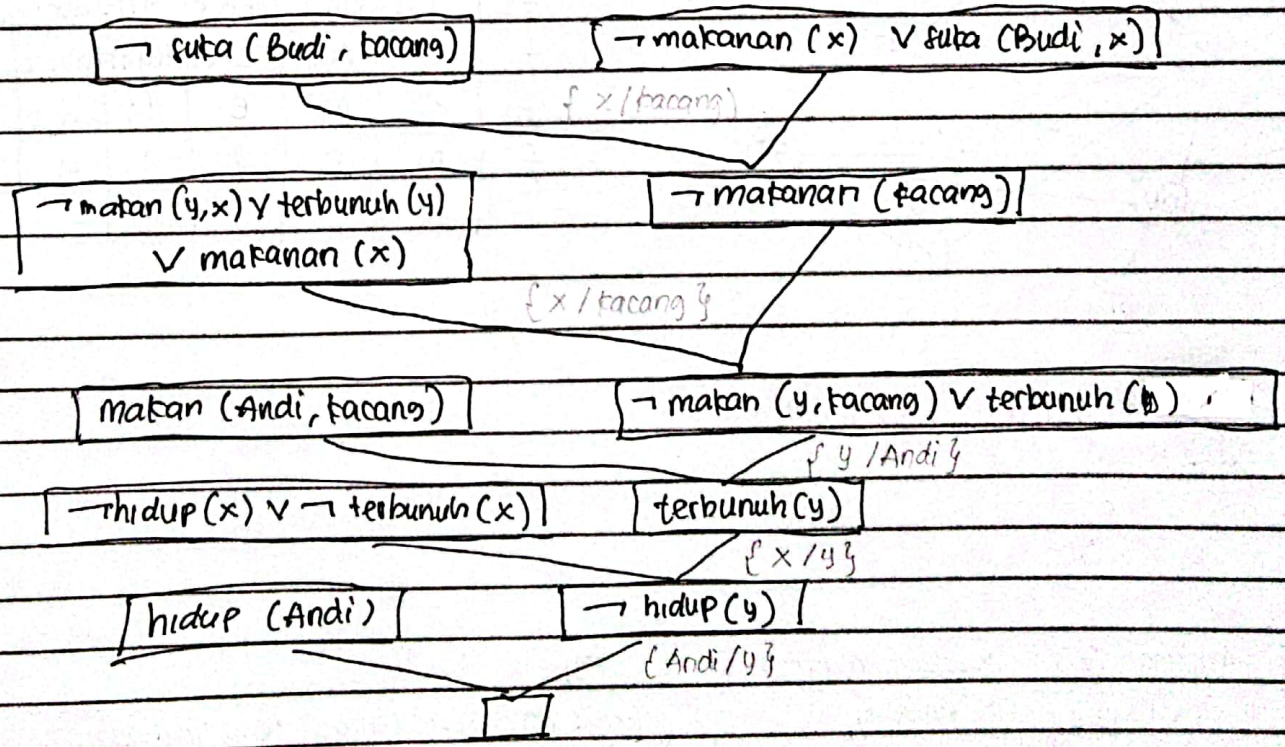
(hidup (x) $\Rightarrow$ $\neg$ terbunuh) ∧ ($\neg$ terbunuh $\Rightarrow$ hidup (x))

($\neg$ hidup (x) ∨ $\neg$ terbunuh (x)) ∧ (terbunuh (x) ∨ hidup (x))

⑥ ✓ ⑦

Proof by Resolution

Budi menyukai kacang ⇝ $\neg$ suka (Budi, kacang)



41 a) Jamur ke-9

$P(A \mid Class = 0) = 2/5 \times 2/5 \times 3/5 \times 2/5 = 24/625$

$P(A \mid Class = 0)\, P(Class = 0) = 24/625 \times 5/8 = 0{,}024$

$P(A \mid Class = 1) = 1/3 \times 1/3 \times 1/3 \times 1/3 = 1/81$

$P(A \mid Class = 1)\, P(Class = 1) = 1/81 \times 3/8 = 0{,}005$

$P(A \mid Class = 0)\, P(Class = 0) > P(A \mid Class = 1)\, P(Class = 1)$

$0{,}024 > 0{,}05$

Tidak Dapat dimakan

b) Jamur ke 10

$P(A|class:0) = 3/5 \times 3/5 \times 3/5 \times 3/5 = 81/625$

$P(A|class:0)\,P(class:0) = 81/625 \times 5/8 = 405/5000 = 0,081$

$P(A|class:1) = 2/3 \times 2/3 \times 1/3 \times 2/3 = 8/81$

$P(A|Class:1)\,P(class:1) = 8/81 \times 3/8 = 0,037$

Tidak Dapat dimakan

c) Jamur ke - 11

$P(A|class:0) = 3/5 \times 3/5 \times 2/5 \times 3/5 = 54/625$

$P(A|class:0)\,P(class:0) = 54/625 \times 5/8 = 0,054$

$P(A|class:1) = 2/3 \times 2/3 \times 2/3 \times 2/3 = 16/81$

$P(A|class:1)\,P(class:1) = 16/81 \times 3/8 = 0,074$

~~Tidak~~ dapat dimakan

Latihan Soal

1.

1. Ant
2. Ape
3. Big
4. Bus
5. Car
6. Has
7. Bard
8. Book
9. Buys
10. Hold
11. Lane
12. Year
13. Rant
14. Browns
15. Ginger
16. Symbol
17. Syntax

Variabel	Domain
1D	1, 2, 3, 4, 5, 6
1T	7, 8, 9, 10, 11, 12, 13
2T	14, 15, 16, 17
3D	7, 8, 9, 10, 11, 12, 13
4D	1, 2, 3, 4, 5, 6

Contraint

1D[1] = 1T[1]
1D[3] = 2T[1]
2T[3] = 3D[3]
2T[5] = 4D[1]
1T[3] = 3D[1]

1D	1T	2T	3D	4D
1,2,3,4,5,6	7,8,9,10,11,12,13	14,15,16,17	7,8,9,10,11,12,13	1,2,3,4,5,6
1	X			
2	X			
3	7,8,9	15	11,13	X
3	7,8,9	X		
4	7,8,9	16,17	11,13	12
4	7	17	13	1

3.

Hap(x) → x happy dgn hidupnya
Wira(x) → x wirausaha
Art(x) → x artis
Anak(x,y) → x anak y
Bobi → individu

a) FOL

1. $\forall x (\forall y \text{ anak}(y,x) \Rightarrow \text{Wira}(y)) \Rightarrow \text{Hap}(x)$
2. $\forall x \text{ Anak}(x, \text{Bobi}) \Rightarrow \text{Art}(x)$
3. $\forall x \text{ Art}(x) \rightarrow \text{Wira}(x)$

b) CNF

1. $\forall x (\forall y \neg \text{anak}(y,x) \vee \text{Wira}(y)) \Rightarrow \text{Hap}(x)$

$\forall x \neg (\forall y \neg \text{anak}(y,x) \vee \text{Wira}(y)) \vee \text{Hap}(x)$

$(\text{anak}(y,x) \wedge \neg \text{wira}(y)) \vee \text{Hap}(x)$

$(\text{anak}(y,x) \vee \text{Hap}(x)) \wedge (\neg \text{Wira}(y) \vee \text{Hap}(x))$

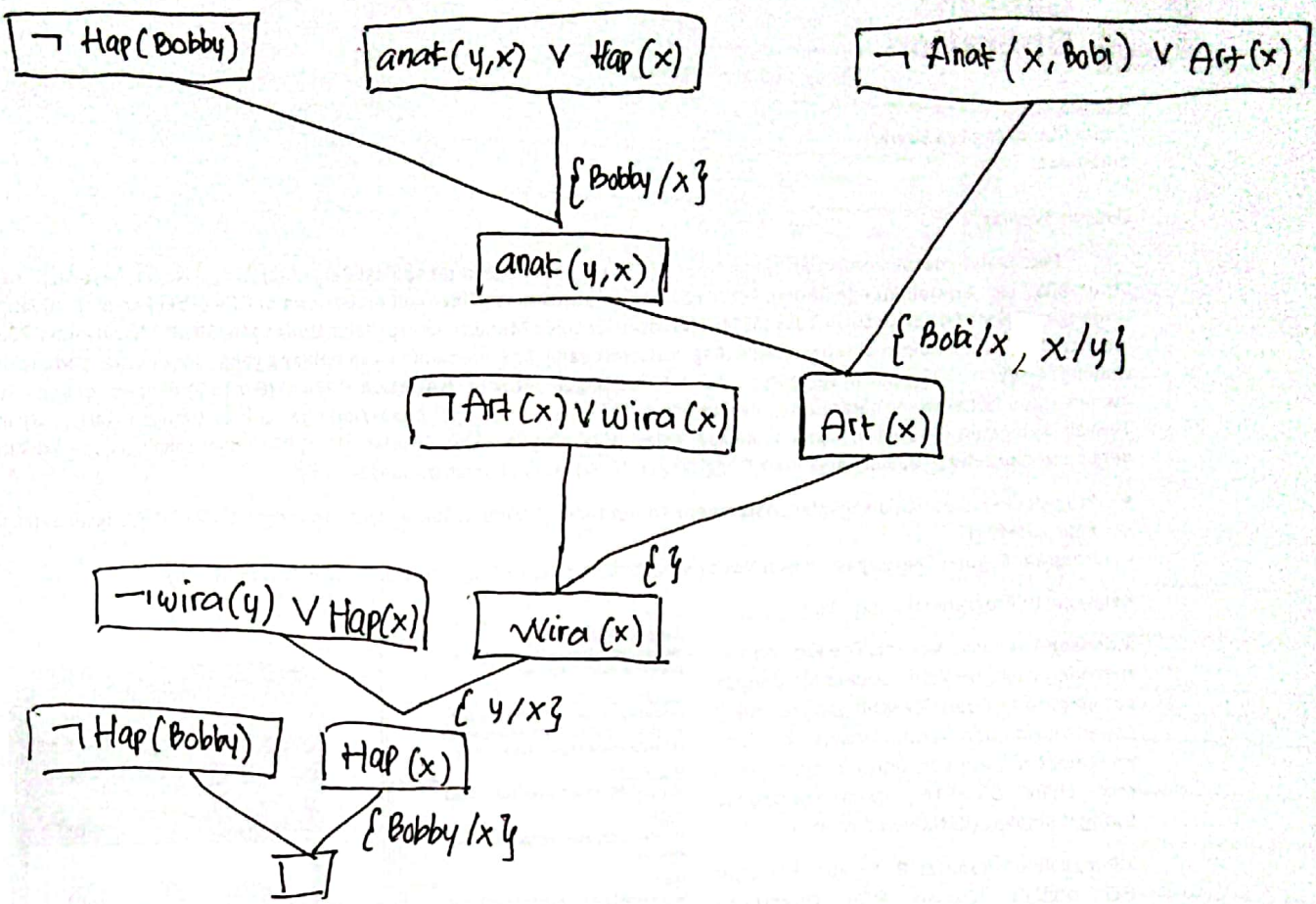
- $(\text{anak}(y,x) \vee \text{Hap}(x))$
- $\neg \text{Wira}(y) \vee \text{Hap}(x)$

2. $\neg \text{Anak}(x, \text{Bobi}) \vee \text{Art}(x)$
3. $\neg \text{Art}(x) \vee \text{Wira}(x)$

c) Resolusi

Goals : Hap (Bobby)

→ negasi Goals : ¬ Hap (Bobby)



4) X = (Age : Senior, Income : High, Student : No, Credit_rating : Fair)

$$P(C|A) = \frac{P(A|C)\,P(C)}{P(A)}$$

$$P(c|\text{class}:\text{Yes}) = \frac{3}{9} \times \frac{2}{9} \times \frac{3}{9} \times \frac{6}{9}$$

$$= \frac{1}{3} \times \frac{2}{9} \times \frac{1}{3} \times \frac{2}{3}$$

$$= \frac{4}{243}$$

$$P(c|\text{class}:\text{Yes})\,P(\text{class}:\text{Yes}) = \frac{4}{243_{27}} \times \frac{9}{14}$$

$$= 0{,}011$$

$$P(c|\text{class}:\text{No}) = \frac{2}{5} \times \frac{2}{5} \times \frac{4}{5} \times \frac{2}{5}$$

$$= \frac{32}{625}$$

$$P(c|\text{class}:\text{No})\,P(\text{class}:\text{No}) = \frac{32}{625_{125}} \times \frac{5}{14}$$

$$= 0{,}018$$

$$P(c|\text{class}:\text{Yes})\,P(\text{class}:\text{Yes}) < P(c|\text{class}:\text{No})\,P(\text{class}:\text{No})$$

$$0{,}011 < 0{,}018$$

Keputusan untuk membeli komputer adalah "No"

Latihan PPT 10.

Logical Agents

$\forall x$ is_gardeners(x) $\Rightarrow$ Likes(x, rum)

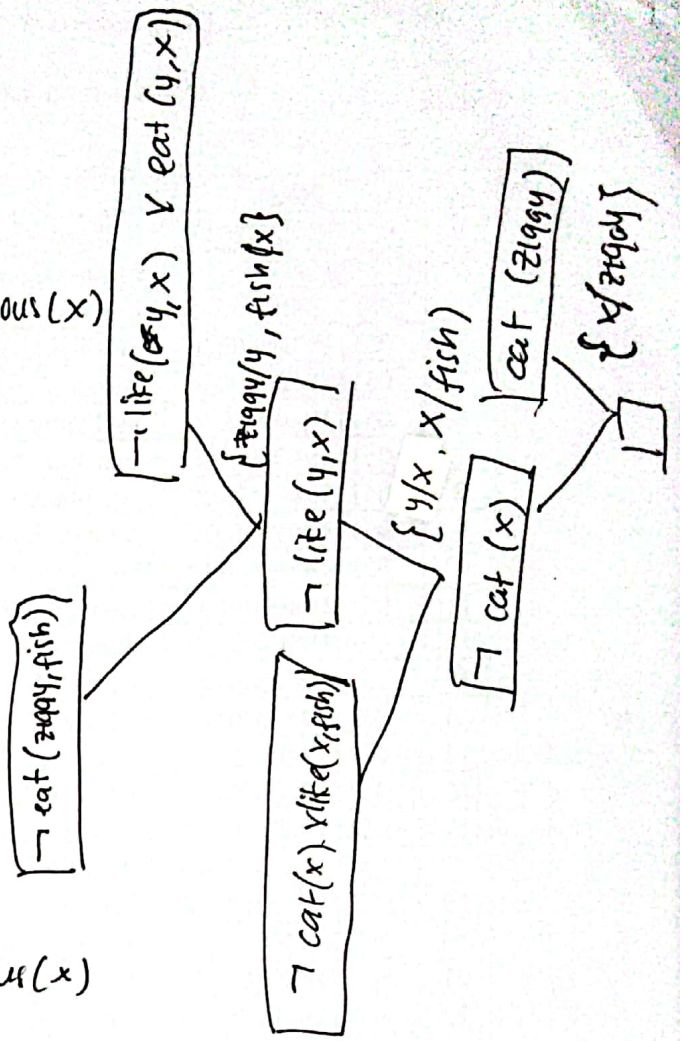
$\forall x$ is_purplemushrooms(x) $\Rightarrow$ poisonous(x)

$\forall x \, (\exists y \, fool(x,y)) \Rightarrow$

$\forall x \, (\exists y \, fool(you, y, x))$

$\exists x \, (\forall y \, fool(you, y, x))$

$\forall x$ is_purplemushrooms(x) $\Rightarrow \neg$ poisonous(x)



$\forall x$ Cat(x) $\Rightarrow$ Like(x, fish) $\rightarrow$ CNF: $\neg$ cat(x) $\vee$ Like(x, fish)

Cat(ziggy) cat(ziggy)

$\neg$ Eat(ziggy, fish)

$\neg$ Like(Cats, x) $\vee$ Eat(y, x)

$\forall x$ Eat(x) $\Rightarrow$ Eat

$\forall y. \, (\forall x \, Like(y, x)) \Rightarrow$ Eat(y, x)

FOL

Contoh : "The Law says that it is a crime for an American to sell weapons to hostile nations. The country Nono, an enemy of America, has some missiles, and all of its missiles were sold to it by Colonel West, who is American."

Buktikan bahwa Colonel West is a criminal.

1. It is a crime for an American to sell weapons to hostile nations.

   $American(x) \wedge Weapons(y) \wedge sell(x,y,z) \wedge hostile(z) \Rightarrow Criminal(x)$

2. Nono has some missiles

   $\exists x\ Owns(Nono, x) \wedge Missiles(x)$

3. All of its missiles were sold to it by Colonel West

   $\forall x\ Missiles(x) \wedge Owns(Nono, x) \Rightarrow sell(West, x, Nono)$

4. Missiles is a weapon

   $Missiles(x) \Rightarrow Weapon(x)$

5. Enemy of America counts as hostile

   $Enemy(x, America) \Rightarrow Hostile(x)$

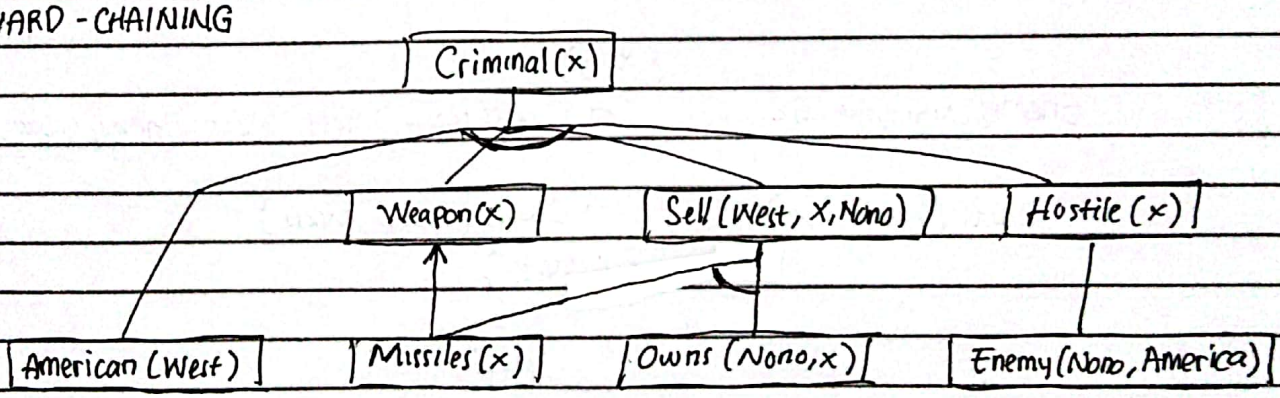
6. Colonel West, who is American

   $American(West)$

7. The country Nono, an enemy of America

   $Enemy(Nono, America)$

FORWARD-CHAINING



Convert to CNF

1. $\neg [American(x) \wedge Weapons(y) \wedge sell(x,y,z) \wedge hostile(z)] \vee Criminal(x)$

   $\neg American(x) \vee \neg Weapons(y) \vee \neg sell(x,y,z) \vee \neg hostile(z) \vee Criminal(x)$

2. $Owns(Nono, x)$ $Missiles(x)$

3. $\neg Missiles(x) \vee \neg Owns(Nono, x) \vee sell(West, x, Nono)$

4. $\neg Missiles(x) \vee Weapon(x)$

5. $\neg Enemy(x, America) \vee Hostile(x)$

6. $American(West)$

7. $Enemy(Nono, America)$

Goals : $\neg Criminal(West)$