"AIMA slides" chapter 9

Example knowledge base

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.

Prove that Col. West is a criminal

① $\forall x,y,z \ American(x) \wedge Sell(x,y,z) \wedge Weapon(y) \wedge Hostile(z) \rightarrow Criminal(x)$
x sell y ให้ z

② $\forall x \quad Enemy(x, American) \rightarrow Hostile(x)$

③ $\exists y \quad Sell(Col.West, y, Nono) \wedge Missile(y)$

④ $\forall x \ Missile(x) \rightarrow Weapon(x)$

แปลงเป็น CNF

① $\neg American(x) \vee \neg Sell(x,y,z) \vee \neg Weapon(y) \vee \neg Hostile(z) \vee Criminal(x)$

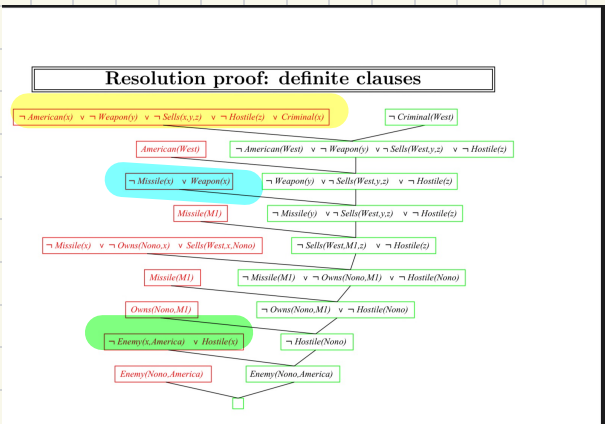
② $\neg Enemy(x, America) \vee Hostile(x)$

③ $Sell(West, M_1, Nono) \wedge Missile(m_1)$

④ $\neg Missile(x) \vee Weapon(x)$

$\alpha = Criminal(West)$

$\neg\alpha = \neg Criminal(West)$



$\forall x,y,z$ American$(x) \wedge$ Sell$(x,y,z) \wedge$ Weapon$(y) \wedge$ Hostile$(z) \rightarrow$ Criminal(x)

CNF

① แปลง $\rightarrow$, $\leftrightarrow$

$\forall x,y,z \neg [\text{American}(x) \wedge \text{Sell}(x,y,z) \wedge \text{Weapon}(y) \wedge \text{Hostile}(z)] \vee \text{Criminal}(x)$

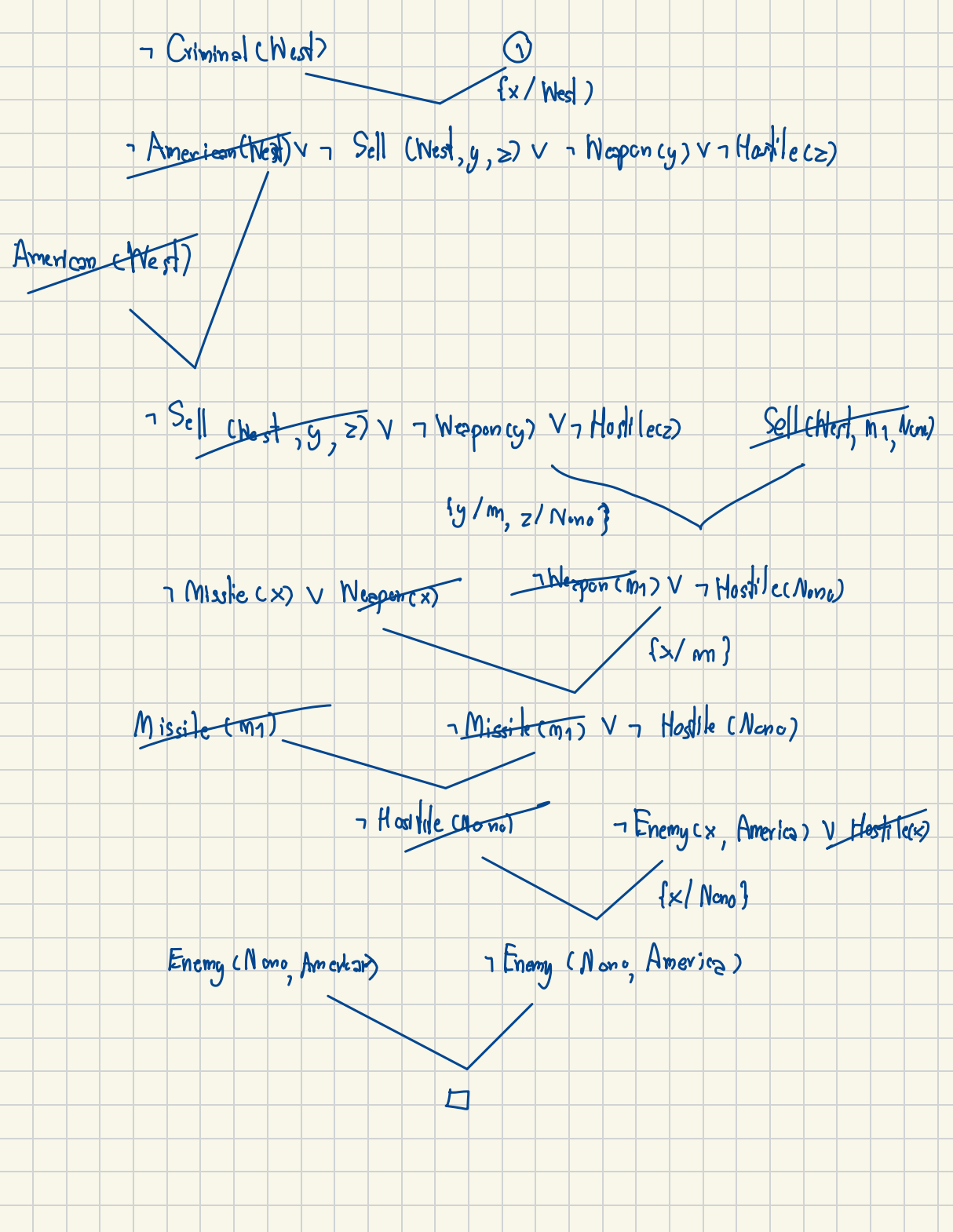
② กระจาย $\neg$

$\forall x,y,z [\neg \text{American}(x) \vee \neg \text{Sell}(x,y,z) \vee \neg \text{Weapon}(y) \vee \neg \text{Hostile}(z)] \vee \text{Criminal}(x)$

③ กำจัด $\exists x$

④ กำจัด $\forall x$

⑤ กระจาย $\vee$, $\wedge$


¬ Criminal (West)
1
{x / West}
¬ American (West) ∨ ¬ Sell (West, y, z) ∨ ¬ Weapon (y) ∨ ¬ Hostile (z)
American (West)
¬ Sell (West, y, z) ∨ ¬ Weapon (y) ∨ ¬ Hostile (z)
Sell (West, m1, None)
{y / m, z / None}
¬ Missile (x) ∨ Weapon (x)
¬ Weapon (m1) ∨ ¬ Hostile (None)
{x / m}
Missile (m1)
¬ Missile (m1) ∨ ¬ Hostile (None)
¬ Hostile (None)
¬ Enemy (x, America) ∨ Hostile (x)
{x / None}
Enemy (None, America)
¬ Enemy (None, America)
□

สำหรับทุกคนที่รักสัตว์ทุกตัวจะถูกรักโดยใครบางคน

$$\forall x\,[\,\forall y\ Animal(y) \longrightarrow Loves(x,y)\,] \rightarrow \exists y\ Loves(y,x)$$

CNF

① เปลี่ยน $\rightarrow$, $\leftrightarrow$ ตัวเชื่อมหลัก

$$\forall x\ \neg\,[\,\forall y\ Animal(y) \rightarrow Loves(x,y)\,] \vee \exists y\ Loves(y,x)$$

$$\forall x\ \neg\,[\,\forall y\ \neg Animal(y) \vee Loves(x,y)\,] \vee \exists y\ Loves(y,x)$$

② กระจาย $\neg$

$$\forall x\,[\,\exists y\ Animal(y) \wedge \neg Loves(x,y)\,] \vee \exists y\ Loves(y,x)$$

③ กำจัด $\exists$ โดย Skolem constant หรือ Skolem function

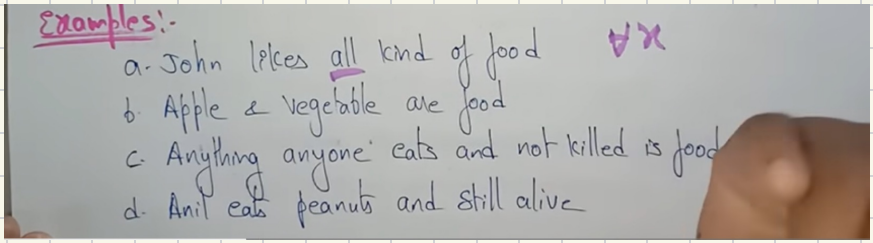
$$\forall x\,[\,Animal(F(x)) \wedge \neg Loves(x,F(x))\,] \vee Loves(G(x),x)$$

④ กำจัด $\forall x$

$$(\,Animal(F(x)) \wedge \neg Loves(x,F(x))\,) \vee Loves(G(x),x)$$

⑤ กระจาย $\vee$, $\wedge$ ในรูป $(\vee\vee)\wedge(\vee\vee)$

$$(\,Animal(F(x)) \vee Loves(G(x),x)) \wedge (Loves(x,F(x)) \vee Loves(G(x),x)\,)$$



e. Harry eats everything that Anil eats

∝. John like peanut

แปลงเป็น FOL

a. $\forall x\ [\ food(x) \rightarrow like(John, x)]$

b. $food(Apple) \wedge food(Vegetable)$

c. $\forall x \forall y\ [eat(x,y) \wedge \neg killed(x)] \rightarrow food(y)$

d. $eats(Anil, peanuts) \wedge alive(Anil)$

e. $\forall x\ [eats(Anil, x) \rightarrow eats(Harry, x)]$

∝. $like(John, peanuts)$ $\quad \neg\alpha = \neg like(John, peanuts)$

แปลงเป็น CNF

① เปลี่ยนตัวเชื่อมหลัก $\rightarrow$, $\leftarrow$

a. $\forall x\ \neg food(x) \vee like(John, x)$

b. $food(Apple) \wedge food(Vegetable)$

c. $\forall x \forall y\ \neg[(eat(x,y) \wedge \neg killed(x))] \vee food(y)$

d. $eats(Anil, peanuts) \wedge alive(Anil)$

e. $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$

② กระจาย $\neg$

a. $\forall x \neg food(x) \vee like(John, x)$

b. $food(Apple) \wedge food(Vegetable)$

c. $\forall x \forall y [\neg eat(x,y) \vee killed(x)] \vee food(y)$

d. $eats(Anil, peanuts) \wedge alive(Anil)$

e. $\forall x \neg eats(Anil, x) \vee eats(Harry, x)$

③ ลบ $\exists$, $\forall$ + ④ กระจาย $\vee \wedge$ ในรูป $(\wedge \wedge) \vee (\wedge \wedge)$

a. $\neg food(x) \vee like(John, x)$ ✓

b. $food(Apple) \wedge food(Vegetable)$

c. $\neg eat(x,y) \vee killed(x) \vee food(y)$ ✓

d. $eats(Anil, peanuts) \wedge alive(Anil)$ ✓

e. $\neg eats(Anil, x) \vee eats(Harry, x)$

∝. $\neg like(John, Peanuts)$ ✓

f. $\neg killed(x) \rightarrow alive(x)$ } add predicate

g $alive(x) \rightarrow \neg killed(x)$ } add predicate

Refutation by Resolution