

4511W, Spring-2018

ASSIGNMENT 5:

**Assigned: 4/16/18 Due: Sunday 4/22/18 at 11:55 PM** Submit on moodle (in a zip if you have multiple files)

**Written/drawn:**

**Problem 1.** (20 points)

Convert the following sentence to conjunctive normal form (CNF).

$$\forall x (\forall y A(x) \wedge B(y) \iff C(x, y)) \Rightarrow (\exists y D(y) \wedge E(x, y))$$

Doing the steps on the slides:

$$1. \forall x (\forall y (A(x) \wedge B(y) \Rightarrow C(x, y)) \wedge (C(x, y) \Rightarrow A(x) \wedge B(y)) \Rightarrow (\exists y D(y) \wedge E(x, y))$$

$$\forall x \neg(\forall y (\neg(A(x) \wedge B(y)) \vee C(x, y)) \wedge (\neg C(x, y) \vee A(x) \wedge B(y)) \vee (\exists y D(y) \wedge E(x, y))$$

$$2. \forall x \neg(\forall y ((\neg A(x) \vee \neg B(y)) \vee C(x, y)) \wedge (\neg C(x, y) \vee A(x) \wedge B(y)) \vee (\exists y D(y) \wedge E(x, y))$$

$$\forall x (\exists y ((A(x) \wedge B(y)) \wedge \neg C(x, y)) \vee (C(x, y) \wedge (\neg A(x) \vee \neg B(y))) \vee (\exists y D(y) \wedge E(x, y))$$

$$3. \forall x (\exists y (A(x) \wedge B(y) \wedge \neg C(x, y)) \vee (C(x, y) \wedge (\neg A(x) \vee \neg B(y))) \vee (\exists z D(z) \wedge E(x, z)))$$

$$4. \forall x (A(x) \wedge B(Y(x)) \wedge \neg C(x, Y(x)) \vee (C(x, Y(x)) \wedge (\neg A(x) \vee \neg B(Y(x))) \vee (D(Z(x)) \wedge E(x, Z(x))))$$

$$5. (A(x) \wedge B(Y(x)) \wedge \neg C(x, Y(x)) \vee (C(x, Y(x)) \wedge (\neg A(x) \vee \neg B(Y(x))) \vee (D(Z(x)) \wedge E(x, Z(x))))$$

$$6. [(A(x) \vee C(x, Y(x)) \wedge (A(x) \vee \neg A(x) \vee \neg B(Y(x))) \wedge (B(Y(x)) \vee C(x, Y(x))) \wedge (B(Y(x)) \vee \neg A(x) \vee \neg B(Y(x))) \wedge (\neg C(x, Y(x)) \vee C(x, Y(x))) \wedge (\neg C(X, Y(x)) \vee \neg A(x) \vee \neg B(Y(x))))] \vee (D(Z(x)) \wedge E(x, Z(x)))$$

$$[(A(x) \vee C(x, Y(x)) \wedge (T) \wedge (B(Y(x)) \vee C(x, Y(x))) \wedge (T) \wedge (T) \wedge (\neg C(X, Y(x)) \vee \neg A(x) \vee \neg B(Y(x))))] \vee (D(Z(x)) \wedge E(x, Z(x)))$$

$$[(A(x) \vee C(x, Y(x)) \wedge (B(Y(x)) \vee C(x, Y(x))) \wedge (\neg C(X, Y(x)) \vee \neg A(x) \vee \neg B(Y(x))))] \vee (D(Z(x)) \wedge E(x, Z(x)))$$

$$(A(x) \vee C(x, Y(x) \vee D(Z(x))) \wedge (A(x) \vee C(x, Y(x) \vee E(x, Z(x))) \wedge (B(Y(x)) \vee C(x, Y(x)) \vee D(Z(x))) \wedge (B(Y(x)) \vee C(x, Y(x)) \vee E(x, Z(x))) \wedge (\neg C(X, Y(x)) \vee \neg A(x) \vee \neg B(Y(x)) \vee D(Z(x))) \wedge (\neg C(X, Y(x)) \vee \neg A(x) \vee \neg B(Y(x)) \vee E(x, Z(x)))$$

If the above is too parenthesis happy for you, here is a dumbed-down version:

$$(A \wedge B \wedge C) \vee (C \wedge (\neg A \vee \neg B)) \dots \vee (D \wedge E)$$

$$\begin{aligned}
 & (A \vee C) \wedge (A \vee \neg A \vee \neg B) \wedge (B \vee C) \wedge (B \vee \neg A \vee \neg B) \wedge (\neg C \vee C) \wedge (\neg C \vee \neg A \vee \neg B) \dots \vee (D \\
 & \wedge E) \\
 & (A \vee C) \wedge (B \vee C) \wedge (\neg C \vee \neg A \vee \neg B) \dots \vee (D \wedge E) \\
 & (A \vee C \vee D) \wedge (A \vee C \vee E) \wedge (B \vee C \vee D) \wedge (B \vee C \vee E) \wedge (\neg C \vee \neg A \vee \neg B \vee D) \wedge (\neg C \vee \neg A \vee \neg B \vee E)
 \end{aligned}$$

**Problem 2. (20 points)**

Apply resolution on the following KB to determine if:  $KB \models \alpha$

You must show what variables you are unifying/substituting to make resolution possible between parts/clauses.

KB:

$$(A(cat) \vee C(x, y))$$

$$\wedge (\neg B(x, y) \vee C(x, y))$$

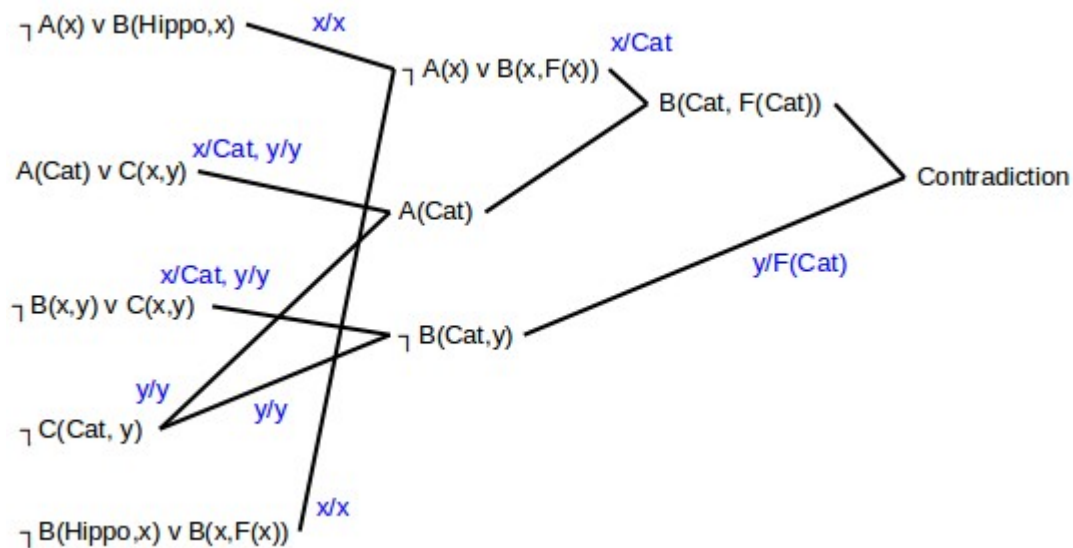
$$\wedge (\neg A(x) \vee B(hippo, x))$$

$\neg \alpha$ : (Note: this is already negated)

$$(\forall x \neg B(hippo, x) \vee B(x, F(x)))$$

$$\wedge (\forall y \neg C(cat, y))$$

There are a couple of ways to do this. You could have started with resolving the 1<sup>st</sup> and 3<sup>rd</sup> sentences in the KB, but here is the way I assume most people did it. Note: You must show proper unification.



**Problem 3.** (20 points)

Use backward chaining on the following sentences to determine whether:  $\exists x \text{ Traps}(\text{Felicidad}, x)$

$$\exists x \text{ Troll}(x)$$

$$\forall x \text{ Troll}(x) \Rightarrow \text{Large}(x)$$

$$\exists x \text{ Troll}(x) \wedge \text{Aggressive}(x)$$

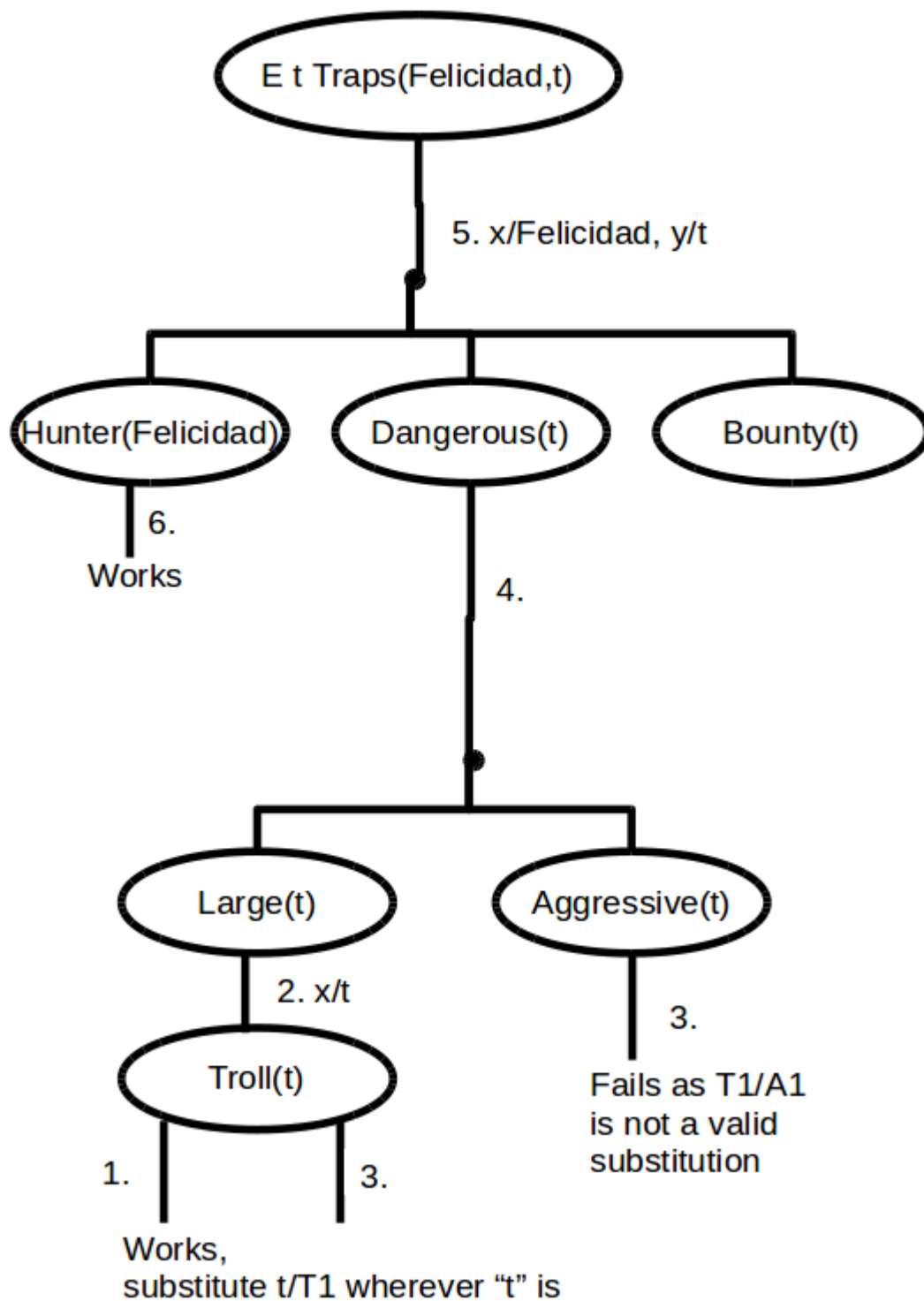
$$\forall x \text{ Large}(x) \wedge \text{Aggressive}(x) \Rightarrow \text{Dangerous}(x)$$

$$\forall x, y \text{ Hunter}(x) \wedge \text{Dangerous}(y) \wedge \text{Bounty}(y) \Rightarrow \text{Traps}(x, y)$$

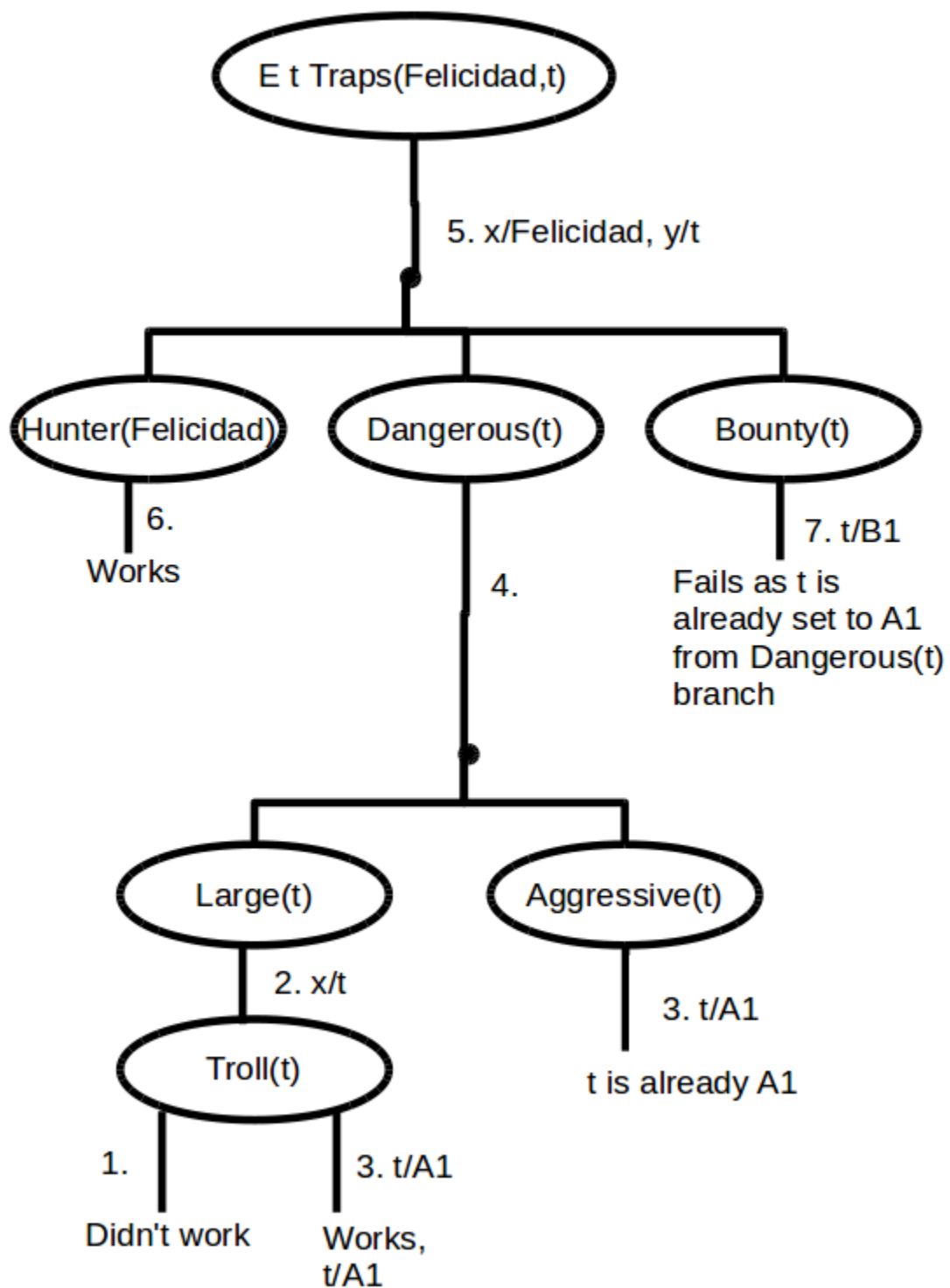
$$\text{Hunter}(\text{Felicidad})$$

$$\exists x \text{ Troll}(x) \wedge \text{Bounty}(x)$$

First we search using DFS (left branches first) until this point:



... Then we have to go back and try the other branch of  $Troll(t)$  in our DFS:



This is all the possible substitutions and none of them work (we cannot assume the troll with the bounty is the aggressive one).

**Problem 4.** (10 points)

Use forward-search to solve the following planning problem. Use a breadth-first-search to approach for searching the space until a goal is found. Show all possible states at the depth the goal was found as well.

Initial =  $\neg Study \wedge \neg Passed$

Goal =  $Study \wedge Passed$

Action = *Cram*,

Precondition:

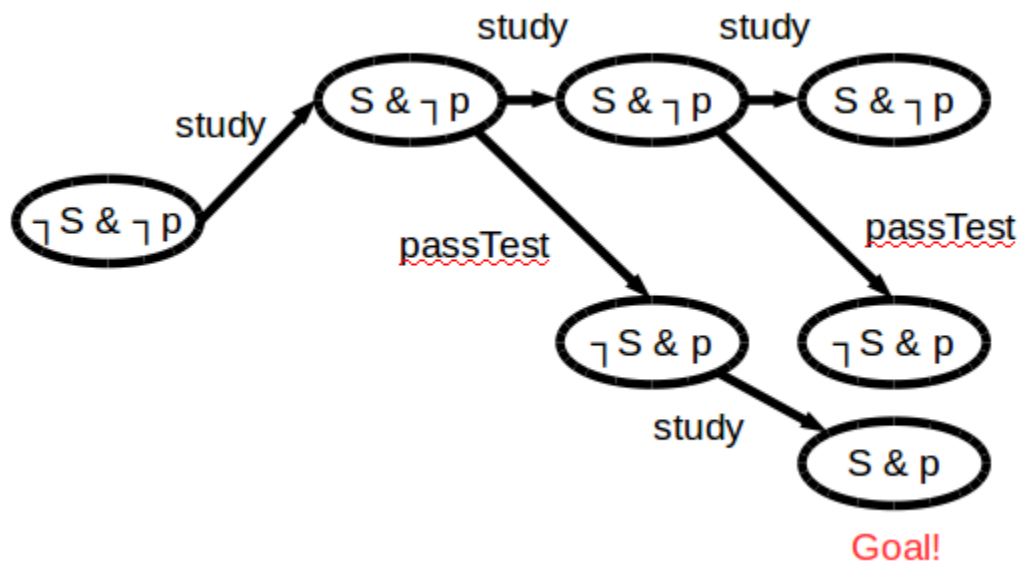
Effect: *Study*

Action = *PassTest*,

Precondition: *Study*

Effect:  $\neg Study \wedge Passed$

Here is the search tree:

**Problem 5.** (30 points)

Apply graph-plan to the following problem until the mutexes converge (i.e. the mutexes stop changing between levels). **Note:** there was initially an error in action “W” that is fixed now.

Initial:  $A \wedge \neg B \wedge \neg C$

Action( W,  
Preconditions:  $A$   
Effects:  $\neg B \wedge C$ )

Action( X,  
Preconditions:  $C$   
Effects:  $\neg C$ )

Action( Y,  
Preconditions:  $A \wedge C$   
Effects:  $\neg A \wedge B$ )

Action( Z,  
Preconditions:  $B \wedge \neg C$   
Effects:  $\neg B \wedge C$ )

