כמה דוגמאות מהשיעור האחרון

דוגמה להסקה בעזרת רזולוציה.

הבעיה

בחדר נמצאים שלושה אנשים A, B ו C. A נשוי, ו C לא-נשוי. A מסתכל על B, ו B מסתכל על C.

תאר את הבעיה בעזרת פסוקים בצורה נורמלית.

הסק בעזרת רזולוציה שנמצא בחדר אדם נשוי שמביט על אדם לא-נשוי.

בסיס הידע

$T\rightarrow married(A)$

$married(C)\rightarrow F$

$T\rightarrow looks\_at(A,B)$

$T\rightarrow looks\_at(B,C)$

השאילתה

$\exists x.\exists y.\ looks\_at(x,y)\wedge\neg married(y)\wedge married(x)$

שלילת השאילתה

$\neg\exists x.\exists y.\ looks\_at(x,y)\wedge\neg married(y)\wedge married(x)$

$\forall x.\forall y.\ \neg looks\_at(x,y)\vee married(y)\vee\neg married(x)$

ובצורה נורמלית

$looks\_at(x,y)\wedge married(x)\rightarrow married(y)$

תהליך ההסקה

1. $T\rightarrow married(A)$
2. $married(C)\rightarrow F$
3. $T\rightarrow looks\_at(A,B)$
4. $T\rightarrow looks\_at(B,C)$
5. $looks\_at(x,y)\wedge married(x)\rightarrow married(y)$
6. (5,3) $married(A)\rightarrow married(B)$
7. (5,4) $married(B)\rightarrow married(C)$
8. (6,1) \married(B)
9. (7,2) $married(B)\rightarrow F$
10. (9,8) $T\rightarrow F$

=======================מתוך מטלה מסמסטר 2012 ב=================

שאלה 1 (20 נק׳)

התחתנתי עם אלמנה (W). לאשתי בת בוגרת (D). אבי (F), שהרבה לבקרנו, התאהב בבת ונשא אותה לאשה.

א. תארו את הנ״ל בלוגיקה מסדר ראשון.

ב. הוסיפו לבסיס הידע הגדרות רלבנטיות לקשרי משפחה.

ג. הסיקו בעזרת רזולוציה שאני סבא של עצמי.

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רזולוציה (1)

בסיס ידע:

למשה יש מחלת גבהים

חוקים:

מי שיש לו מחלת גבהים לא מטיס מטוס.

לכל מטוס יש טייס.

במטוס יש נוסעים וטייסים.

משה ודוד טסים במטוס "רום".

מטרה:

דוד הוא טייס של מטוס "רום"

א. החלף את המשפטים הנ"ל ל First Order Logic. (יש לזכור להגדיר את כל הפרדיקטים והקבועים)

ב. העבר את המשפטים שקבלת לצורת Conjunctive Normal Form.

ג. הוכח או הפרך את המטרה ע"י שימוש בחוקי הרזולוציה. הראה את פעולות האיחוד (unification) הנדרשות.

השתמשו בפרדיקטים:

MS (עבור מחלת גבהים), PT(עבור טייס), IP (במטוס), AP(מטוס), Pass(נוסע)

השתמשו בקבועים

M (עבור משה), D (עבור דוד), R("עבור מטוס "רום)

פתרון:

Predicates:

MS(x) – true iff x have Mountain Sickness

AP(x) – x is an airplane

Pt(x) – x is a pilot

IP(x,y) – x (an object) is in a plane named y

Pass(x) – x (a person) is a passenger.

Constants:

M – Moshe (person)

D – David (person)

R – Rom (an airplane)

Knowledge-Base:

1: $MS(M)$

Rules:

2: $\forall x(MS(x) \rightarrow \neg Pt(x))$

3: $\forall x \exists y(AP(x) \land IP(y,x)) \rightarrow (Pt(y))$

4: $\forall x \forall y(IP(x,y)) \rightarrow (Pt(x) \lor Pass(x)))$

5: $\forall x((AP(R) \land IP(R,x)) \rightarrow (=(x,\mathrm{D}) \lor =(x,\mathrm{M})))$

6: $AP(R) \rightarrow Pt(D)$

Transforming to CNF

1: $\{MS(M)\}$

2: $\forall x\big(MS(x) \rightarrow \neg Pt(x)\big)$

2: $\forall x(\neg MS(x) \vee \neg Pt(x))$

2: $(\neg \boldsymbol{MS}(\boldsymbol{x}) \vee \neg \boldsymbol{Pt}(\boldsymbol{x}))$

2: $\{\neg \boldsymbol{MS}(\boldsymbol{x}), \neg \boldsymbol{Pt}(\boldsymbol{x})\}$

3: $\forall x \exists y(AP(x) \wedge IP(y,x) \rightarrow Pt(y))$

3: $\forall x \exists y(\neg(AP(x) \wedge IP(y,x)) \vee Pt(y))$

3: $\forall x \exists y((\neg AP(x) \vee \neg IP(y,x)) \vee Pt(y))$

3: $\{\neg AP(x), \neg IP(f(x),x), Pt(f(x))\}$

4: $\forall x \forall y(IP(x,y)) \rightarrow (Pt(x) \vee Pass(x)))$

4: $\forall x \forall y(\neg IP(x,y)) \vee (Pt(x) \vee Pass(x)))$

4: $\{\neg IP(x,y)), Pt(x), Pass(x)\}$

5: $IP(M,R) \wedge IP(D,R)$

5a: $\{IP(D,R)\}$

5b: $\{IP(M,R)\}$

6: $\neg(AP(R) \rightarrow Pt(D))$ <u>בשלילה:</u>

6: $\neg(\neg AP(R) \vee Pt(D))$

6: $\neg(\neg AP(R) \vee Pt(D))$

6: $\neg(\neg AP(R) \vee Pt(D))$

6:$(AP(R) \wedge \neg Pt(D))$

$6a\colon \{AP(R)\}\ 6b\colon \{\neg Pt(D)\}$

Clause forms given in CNF:

1: $\{MS(M)\}$

2: $\{\neg MS(x_1), \neg Pt(x_1)\}$

3: $\{\neg AP(x), \neg IP(f(x),x), Pt(f(x))\}$

4: $\{\neg IP(x_3,y), Pt(x_3), Pass(x_3)\}$

5a: $\{IP(D,R)\}$

5b: $\{IP(M,R)\}$

$6a\colon \{AP(R)\}$

$6b\colon \{\neg Pt(D)\}$

Solution:

(1+2) $\{x_1/M\}$

7: $\{\neg Pt(M)\}$

(3+6a) $\{x_2\ /\ R\}$

8: $\{\neg IP(f(R),R), Pt(f(R))\}$

(5a+8) $\{M/f(R)\}$

9) $\{Pt(M)\}$

(7+9) $\{-/-\}$

12) { }

{ } Contradiction!

■

לוגיקה מסדר ראשון, צורה נורמלית ורזולוציה

תיאור המצב:

1. פרד הוא קולי.
2. סם הוא הבעלים של פרד.
3. היום שבת.
4. בשבת לא חם.
5. פרד מאולף.
6. ספניאלים הם כלבים טובים וגם קולי מאולפים הם כלבים טובים.
7. אם כלב הוא כלב טוב ויש לו בעלים אז הוא יימצא עם בעליו.
8. אם שבת וחם בשבת אז סם בפארק.
9. אם שבת ולא חם בשבת אז סם במוזיאון.

לוגיקה מסדר ראשון:

1. collie(Fred)
2. master(Fred, Sam)
3. day(Sat)
4. $\neg$warm(Sat)
5. trained(Fred)
6. $\forall$x [spaniel(x)$\vee$(collie(x)$\wedge$trained(x))]$\rightarrow$gooddog(x)
7. $\forall$x,y,z [gooddog(x)$\wedge$master(x,y)$\wedge$location(y,z)]$\rightarrow$location(x,z)
8. [day(Sat)$\wedge$warm(Sat)]$\rightarrow$location(Sam,Park)
9. [day(Sat)$\wedge\neg$warm(Sat)]$\rightarrow$location(Sam,Museum)

בסיס הידע בצורה נורמלית:

1. T$\rightarrow$collie(Fred)
2. T$\rightarrow$master(Fred, Sam)
3. T$\rightarrow$day(Sat)
4. warm(Sat)$\rightarrow$F
5. T$\rightarrow$trained(Fred)
6. spaniel(a)$\rightarrow$gooddog(a)
7. collie(b)$\wedge$trained(b)$\rightarrow$gooddog(b)
8. gooddog(c)$\wedge$master(c,d)$\wedge$location(d,e)$\rightarrow$location(c,e)
9. day(Sat)$\wedge$warm(Sat)$\rightarrow$location(Sam,Park)
10. day(Sat)$\rightarrow$warm(Sat)$\vee$location(Sam,Museum)

שאילתות

ננסה לענות על השאילתה: האם פרד במוזיאון?

בלוגיקה מסדר ראשון: location(Fred,Museum)

כדי לענות על השאילתה, נוסיף את השלילה שלה לבסיס הידע וננסה להסיק סתירה: T$\rightarrow$F.

השלילה של השאילתה: $\neg$ location(Fred,Museum)

ובצורה נורמלית: location(Fred,Museum)$\rightarrow$F

בסיס הידע כולל שלילת השאילתה:

1. T$\rightarrow$collie(Fred)
2. T$\rightarrow$master(Fred, Sam)
3. T$\rightarrow$day(Sat)
4. warm(Sat)$\rightarrow$F
5. T$\rightarrow$trained(Fred)
6. spaniel(a)$\rightarrow$gooddog(a)
7. collie(b)$\wedge$trained(b)$\rightarrow$gooddog(b)
8. gooddog(c)$\wedge$master(c,d)$\wedge$location(d,e)$\rightarrow$location(c,e)
9. day(Sat)$\wedge$warm(Sat)$\rightarrow$location(Sam,Park)
10. day(Sat)$\rightarrow$warm(Sat)$\vee$location(Sam,Museum)
11. location(Fred,Museum)$\rightarrow$F

תהליך ההסקה:

12. gooddog(Fred)$\wedge$master(Fred,f)$\wedge$location(f,Museum)$\rightarrow$F (11,8)
13. collie(Fred)$\wedge$trained(Fred)$\wedge$master(Fred,g)$\wedge$location(g,Museum)$\rightarrow$F (12,7)
14. trained(Fred)$\wedge$master(Fred,h)$\wedge$location(h,Museum)$\rightarrow$F (13,1)
15. master(Fred,i)$\wedge$location(i,Museum)$\rightarrow$F (14,5)

16. location(Sam,Museum)$\rightarrow$F (15,2)
17. day(Sat)$\rightarrow$warm(Sat) (16,10)
18. T$\rightarrow$warm(Sat) (17,3)
19. T$\rightarrow$F (18,4)

ננסה עכשיו לענות על השאילתה:

האם לכל כלב ובעליו מתקיים: אם הם באותו מקום אז היום שבת ?

בלוגיקה מסדר ראשון:

$\forall x,y,z \{[master(x,y) \wedge location(x,z) \rightarrow location(y,z)] \rightarrow day(Sat)\}$

נוסיף לבסיס הידע את שלילת השאילתה, וננסה להסיק $T \rightarrow F$:

$\neg \forall x,y,z \{[master(x,y) \wedge location(x,z) \rightarrow location(y,z)] \rightarrow day(Sat)\}$

ובצורה נורמלית:

$master(SK1,SK2) \wedge location(SK2,SK3) \rightarrow location(SK1,SK3)$

$day(Sat) \rightarrow F$

בסיס הידע כולל שלילת השאילתה:

1. $T \rightarrow collie(Fred)$
2. $T \rightarrow master(Fred, Sam)$
3. $T \rightarrow day(Sat)$
4. $warm(Sat) \rightarrow F$
5. $T \rightarrow trained(Fred)$
6. $spaniel(a) \rightarrow gooddog(a)$
7. $collie(b) \wedge trained(b) \rightarrow gooddog(b)$
8. $gooddog(c) \wedge master(c,d) \wedge location(d,e) \rightarrow location(c,e)$
9. $day(Sat) \wedge warm(Sat) \rightarrow location(Sam,Park)$
10. $day(Sat) \rightarrow warm(Sat) \vee location(Sam,Museum)$
11. $master(SK1,SK2) \wedge location(SK2,SK3) \rightarrow location(SK1,SK3)$
12. $day(Sat) \rightarrow F$

תהליך ההסקה:

13. $T \rightarrow F$ (12,3)

ננסה, לסיום, לענות על השאילתה: האם יש מקום שכולם בו?

בלוגיקה מסדר ראשון: $\exists x \forall y$ location(y,x)

נוסיף לבסיס הידע את שלילת השאילתה: $\neg\exists x \forall y$ location(y,x)

ובצורה נורמלית: location(sk-of(x),x)$\rightarrow$F

בסיס הידע כולל שלילת השאילתה:

1. T$\rightarrow$collie(Fred)
2. T$\rightarrow$master(Fred, Sam)
3. T$\rightarrow$day(Sat)
4. warm(Sat)$\rightarrow$F
5. T$\rightarrow$trained(Fred)
6. spaniel(a)$\rightarrow$gooddog(a)
7. collie(b)$\wedge$trained(b)$\rightarrow$gooddog(b)
8. gooddog(c)$\wedge$master(c,d)$\wedge$location(d,e)$\rightarrow$location(c,e)
9. day(Sat)$\wedge$warm(Sat)$\rightarrow$location(Sam,Park)
10. day(Sat)$\rightarrow$warm(Sat)$\vee$location(Sam,Museum)
11. location(sk-of(f),f)$\rightarrow$F

תהליך ההסקה:

12. gooddog(sk-of(h))$\wedge$master(sk-of(h),g)$\wedge$location(g,h)$\rightarrow$F (11,8)
13. spaniel(sk-of(j))$\wedge$master(sk-of(j),i)$\wedge$location(i,j)$\rightarrow$F (12,6)
14. collie(sk-of(l))$\wedge$trained(sk-of(l))$\wedge$master(sk-of(l),k)$\wedge$location(k,l)$\rightarrow$F (12,7)

והתהליך הסתיים בלי שהגענו לסתירה. אין הוכחה לשאילתה.

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2. הנתונים הבאים אמורים להיות מוזנים לרובוט:

1) כל החבילות שבחדר מס' 1 קטנות ממש מכל החבילות שבחדר מס' 2.

2) חבילה A נמצאת בחדר מס' 1 או בחדר מס' 2.

3) B היא חבילה הנמצאת בחדר מס' 1.

4) חבילה B איננה קטנה מחבילה A.

א. בצעו תהליך קונספטואליזציה עבור הנתונים הנ"ל (כלומר, הציעו שפה מסדר ראשון לייצוג הנתונים לרובוט, ותארו את מרכיביה).

ב. הצרינו את ארבע הטענות הנ"ל בשפה שהצעתם בסעיף א'.

ג. יצגו את הטענות שבסעיף ב' בצורה פסוקית (כלומר: אם Γ היא קבוצת הנוסחאות של סעיף ב', מצאו קבוצת פסוקיות Clause(Γ) שספיקה אמ"מ Γ ספיקה).

ד. לאיזה חדר על הרובוט ללכת על מנת לאסוף את חבילה A? הוכיחו את תשובתכם ברזולוציה המבוססת על ההנחות (1)-(4) לעיל.
(יש לתאר את עץ ההוכחה ברזולוציה. סמנו בברור אילו פסוקיות מעורבות בכל שלב, ומהן ההצבות הנדרשות להפעלת כלל הרזולוציה).

<u>אובייקטים</u>

A – חבילה

B – חבילה

Room1

Room2

<u>פרדיקטים</u>

1. smaller(X,Y) // X is smaller the Y
2. in(X,Y) // X is in Y

<u>חוקים</u>

1. $\forall$x,y (in(x,Room1)$\wedge$in(y,Room2) $\rightarrow$smaller(x,y)
2. in(A,Room1) $\vee$ in(A,Room2)
3. in(B,Room1)
4. $\neg$smaller(B,A)

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<u>צ"ל</u>

in(A,Room1)

כדי להוכיח נניח כי

5. $\neg$ in(A,Room1)

<u>הוכחה:</u>

6. in(B,Room1) // לפי חוק 3
7. $\neg$ in(A,Room1) // לפי חוק 5
8. in(A,Room1) $\vee$ in(A,Room2) // לפי חוק 2
9. in(A,Room2) // לפי חוק 7 ו 8
10. $\forall$x,y (in(x,Room1)$\wedge$in(y,Room2) $\rightarrow$smaller(x,y) // לפי חוק 1
11. smaller(B,A)//לפי חוק 6 ו 9 ו 1
12. $\neg$smaller(B,A)
13. T=F מ.ש.ל

<u>ההוכחה האונטולוגית של אנסלם לקיום האל.</u>

הנחות היסוד:

1. אלוהים הוא הדבר הגדול ביותר שניתן להעלות על הדעת.

2. דבר קיים גדול יותר מאותו דבר בדמיון.

בלוגיקה מסדר ראשון:

$\forall$x exist(real-of(God))$\rightarrow$ bigger(real-of(God),x)

$\forall$x $\neg$exist(real-of(God))$\rightarrow$bigger(img-of(God),x)

$\forall$x $\neg$bigger(img-of(x),real-of(x))

בצורה נורמלית:

exist(real-of(God))$\rightarrow$ bigger(real-of(God),a)

T$\rightarrow$exist(real-of(God))$\vee$bigger(img-of(God),b)

bigger(img-of(c),real-of(c))$\rightarrow$F

נוסיף שאילתא:

exists(real-of(God))$\rightarrow$F

שאלה 1 (25 נק׳)

התחתנתי עם אלמנה (W). לאשתי בת בוגרת (D). אבי (F), שהרבה לבקרנו, התאהב בבת ונשא אותה לאשה.

א. תארו את הנ״ל בלוגיקה מסדר ראשון.

ב. הוסיפו לבסיס הידע הגדרות רלבנטיות לקשרי משפחה.

ג. הסיקו בעזרת רזולוציה שאני סבא של עצמי.

תשובה:

א. הנ״ל בלוגיקה מסדר ראשון

אישויות: I , W, D, F.

יחסים: Married(x,y), Mother(x,y), Father(x,y), Parent(x,y), GrandFather (x,y), FatherInLaw(x,y), StepFather (x,y),

1. Married (I,W)
2. Mother(W,D)
3. Father(F,I)
4. Married (D,F)

ב. הוסיפו לבסיס הידע הגדרות רלבנטיות לקשרי משפחה

5. $\forall x \forall y\ ((\exists z\ \text{Father}(x,z) \wedge \text{Parent}(z,y) \Rightarrow \text{GrandFather}(x,y))$

6. $\forall x \forall y\ (\exists z\ \text{Father}(x,z) \wedge \text{Married}(z,y) \Rightarrow \text{FatherInLaw}(x,y))$

7. $\forall x \forall y\ (\exists z\ (Married\ (x,z) \wedge Mother\ (z,y) \Rightarrow StepFather\ (x,y)))$
8. $\forall x \forall y\ (FatherInLaw\ (x,y) \vee StepFather(x,y) \Rightarrow Father\ (x,y))$
9. $\forall x \forall y\ (Father\ (x,y) \vee Mother\ (x,y) \Rightarrow Parent\ (x,y))$

ג. הסיקו בעזרת רזולוציה שאני סבא של עצמי.

נעביר לCNF:

5a. $\forall x1 \forall y1\ (\neg(Father\ (x1,F(x1)) \wedge Parent(F(x1),y1)) \vee GrandFather\ (x1,y1))$

5b. $\forall x2 \forall y2\ (\neg Father\ (x2,F(x2)) \vee \neg Parent(F(x2),y2)) \vee GrandFather\ (x2,y2))$

5c. $\boldsymbol{\{\neg Father\ (x3,F(x3)) \vee \neg Parent(F(x3),y3) \vee GrandFather\ (x3,y3)\}}$

6a. $\forall x4 \forall y4\ ((Father\ (x4, F(x4) \wedge Married\ (F(x4),y4) \Rightarrow FatherInLaw(x4,y4))$

6b. $\forall x5 \forall y5(\neg(Father\ (x5, F(x5) \wedge Married\ (F(x5),y5) \vee FatherInLaw(x5,y5))$

6c. $\forall x6 \forall y6(\neg Father\ (x6, F(x6) \vee \neg Married\ (F(x6),y6) \vee FatherInLaw(x6,y6))$

6d. $\boldsymbol{\{\neg Father\ (x7, F(x7) \vee \neg Married\ (F(x7),y7) \vee FatherInLaw(x7,y7)\}}$

7a. $\forall x8 \forall y8\ ((Married\ (x8, F(x8)) \wedge Mother\ (,F(x8),y8)) \Rightarrow StepFather\ (x8, y8))$

7b. $\forall x9 \forall y9\ (\neg(Married\ (x9, F(x9)) \wedge Mother\ (F(x9),y9)) \vee StepFather\ (x9, y9))$

7c. $\forall x10 \forall y10\ (\neg Married\ (x10, F(x10) \vee \neg Mother\ (F(x10),y10) \vee StepFather\ (x10, y10))$

7d. $\boldsymbol{\{\neg Married\ (x11, F(x11) \vee \neg Mother\ (F(x11),y11) \vee StepFather\ (x11, y11)\}}$

8a. $(\neg FatherInLaw\ (x112,y112) \wedge \neg StepFather(x112,y112)) \vee Father\ (x112,y112)$

8b. $(\neg FatherInLaw\ (x113,y113) \vee Father\ (x113,y113)) \wedge (\neg StepFather(x113,y113) \vee Father\ (x113,y113))$

8c. $\boldsymbol{\{\neg FatherInLaw\ (x114,y114) \vee Father\ (x114,y114)\}}$

8d. $\boldsymbol{\{\neg StepFather(x115,y115) \vee Father\ (x115,y115)\}}$

9a. $\forall x13 \forall y13$ ((Father (x13,y13) ∨Mother (x13,y13)) => Parent (x13,y13))

9b. $\forall x14 \forall y14$ (¬(Father (x14,y14) ∨Mother (x14,y14)) ∨ Parent (x14,y14))

9c. $\forall x15 \forall y15$ (¬Father (x15,y15) ∧¬Mother (x15,y15)) ∨ Parent (x15,y15))

9d. (¬Father (x16,y16) ∧¬Mother (x16,y16)) ∨ Parent (x16,y16))

9e. (¬Father (x16,y16) ∨ Parent (x16,y16))∧(¬Mother (x16,y16)) ∨ Parent (x16,y16))

9f. {¬Father (x17,y17) ∨ Parent (x17,y17)}

9g{¬Mother (x18,y18)) ∨ Parent (x18,y18)}

הנחת שלילה :

10. ¬GrandFather (I,I)

הוכחה :

11. From(1,2, **7d**) :

    Married (I,W)

    Mother(W,D)

    { ¬Married (x11, F(x11) ∨¬Mother (F(x11),y11)∨StepFather (x11, y11) }

    Get: **StepFather (I, D)**

12. From(8d, 11):

    {¬StepFather(x112,y112) ∨Father (x112,y112)}

    StepFather (I, D)

Get: **Father (I,D)**

13. From(6d , 12, 4):

{¬Father (x7, F(x7) ∨¬Married (F(x7),y7) ∨ FatherInLaw(x7,y7)}

Father (I,D)

Married (D,F)

Get: **FatherInLaw**(I,F)

14. From(8c , 13):

{**¬FatherInLaw (x114,y114) ∨Father (x114,y114)}**

FatherInLaw(I,F)

Get: **Father** (I,F)

15. From(3,9f):

Father(F,I)

{¬Father (x17,y17) ∨ Parent (x17,y17)}

Get: **Parent** (F,I)

16. From(5c,14,15):

{ ¬Father (x3,F(x3)) ∨¬Parent(F(x3),y3) ∨GrandFather (x3,y3)}

Father (I,F)

Parent (F,I)

Get: **GrandFather** (I,I)

17.From (10, 16):

¬GrandFather (I,I)

GrandFather (I,I)

Get :{}

שאלה 2 (20 נק׳)

ברזולוצית קלט (input resolution) מרשים שימוש בכלל הרזולוציה רק אם לפחות אחת משתי הפסוקיות המשתתפות ברזולוציה שייכת לפסוק המקורי. (כלומר, לא מרשים שימוש בכלל הרזולוציה אם שתי הפסוקיות המשתתפות בגזירת הרזולוציה אינן שייכות לפסוק המקורי).
האם רזולוצית קלט שלמה להפרכה? הוכיחו.
רמז: התבוננו בשלב האחרון של גזירת הפסוקית הריקה מן הפסוק המקורי.

תשובה:

נירה דוגמה שלא ניתן לקבל ממנה קבוצה רעקה ברזולוציה קלט:

$F = \{\{A, B\}, \{A, \neg B\}, \{\neg A, B\}, \{\neg A, \neg B\}\}.$

במקרה זה כל שלב רזולוציה יתן פסוקית עם ליטרל בודד, אך מליטרל בודד ואחד הפסוקיות מקוריות לא ניתן לקבל קבוצה רקה, משל.

שאלה 3 (35 נק׳)

גיל, רונן והדר שייכים למועדון הספורטאים. כל חבר במועדון זה הוא גולש סקי או מטפס הרים או שניהם. אין מטפס הרים שאוהב גשם וכל הגולשים אוהבים שלג. הדר אינה אוהבת את כל מה שגיל אוהב ואוהבת את כל מה שגיל אינו אוהב. גיל אוהב גשם ושלג.

הוכיחו באמצעות רזולוציה כי "הדר היא מטפסת הרים אך אינה גולשת סקי". לצורך כך:

א. תרגמו את המשפטים שלעיל לפסוקים בלוגיקה מסדר ראשון.

ב. המירו לצורת CNF.

ג. השתמשו בכלל הרזולוציה ובהאחדה (היכן שצריך) כדי להוכיח את המטרה: " הדר היא מטפסת הרים אך אינה גולשת סקי".

תשובה

א. תרגמו את המשפטים שלעיל לפסוקים בלוגיקה מסדר ראשון.

אישטיות: G(גיל), R(רונן), H(הדר) , Snow(שלג) , Rain (גשם)

קשרים: ClubMember (x) חבר במועגון, Skier(x) – גולש סקי, Mountaineer(x) - מטפס הרים, Like (x,y).

לפסוקים בלוגיקה מסדר ראשון:

1. ClubMember (G)
2. ClubMember (R)
3. ClubMember (H)
4. ∀x ClubMember(x) => Skier(x) ∨Mountaineer(x)
5. ∀x Mountaineer(x) => ¬Like(x,Rain)
6. ∀x Skier (x) => Like (x,Snow)
7. ∀x Like (G,x) => ¬Like (H,x)
8. ∀x ¬Like (G,x) => Like (H,x)
9. Like (G, Snow)
10. Like (G, Rain)

ב. המירו לצורת CNF.

4a. ∀x1 ¬ClubMember(x1) ∨ Skier(x1) ∨Mountaineer(x1)

4b. {¬ClubMember(x2) ∨ Skier(x2) ∨Mountaineer(x2)}

5a. $\forall x3\ \neg Mountaineer(x3) \lor \neg Like(x3,Rain)$

5a. $\{\neg Mountaineer(x4) \lor \neg Like(x4,Rain)\}$

6a. $\forall x5\ \neg Skier\ (x5) \lor Like\ (x5,Snow)$

6b. $\{\neg Skier\ (x6) \lor Like\ (x6,Snow)\}$

7a. $\{\neg Like\ (G,x7)\ \lor \neg Like\ (H,x7)\}$

8a. $Like\ (G,x8)\ \lor Like\ (H,x8)$

ג. " הדר היא מטפסת הרים אך אינה גולשת סקי":

11. $\neg\ (Mountaineer(H) \land \neg\ Skier(H))$

11a. $\neg\ Mountaineer(H) \lor\ Skier(H))$

הוכחה:

12. from (1, 4b,11a)

ClubMember (G)

$\{\neg ClubMember(x2) \lor Skier(x2) \lor Mountaineer(x2)\}$

$\neg\ Mountaineer(H) \lor\ Skier(H))$

Get: Skier(H)

13. from (9,7a)

Like (G, Snow)

$\{\neg Like\ (G,x7)\ \lor \neg Like\ (H,x7)\}$

Get: ¬Like (H, Snow)}

14. from (6b,13)

$\{\neg Skier\ (x6) \lor Like\ (x6,Snow)\}$

¬Like (H, Snow)}

Get: ¬Skier (H)

14. from (12,14)

Get: {}

שאלה 4 (20 נק')

לכל זוג של פסוקים אטומים שלהלן, מצאו את המאחד הכללי ביותר (MGU), אם הוא קיים:

א. $P(A, B, B), \quad P(x, y, z)$

תשובה:

1. $P(x, y, z) = P(A, B, B)$
2. $x=A,\ y=B\ ,z=B$

MGU: {x/A, y/B, z/B}

Result: $P(A, B, B)$,

ב. $Q(y, G(A, B)), \quad Q(G(x, x), y)$

תשובה:

1. $Q(G(x, x), y) = Q(y, G(A, B))$
2. $G(x, x) = \mathrm{y},\ y = G(A, B)$
3. $G(x, x) = G(A, B)$

falue

ג. $Older(Father(y), y), \quad Older(Father(x), John)$

תשובה:

1. $Older(Father(y), y) = Older(Father(x), John)$
2. $Father(y)= Father(x)$, y= $John$
3. $Father(John)= Father(x)$, y= $John$
4. x= $John$,y= $John$

MGU:{y/John, x/John}

Result: $Older(Father(\text{John}), \text{John})$

ד. $Knows(Father(y), y)\ Knows(x, x)$

תשובה:

1. $Knows(Father(y), y) = Knows(x, x)$
2. $Father(y)= x,\ y =x$

   falue

שאלה 1

הראה שהקשר ∩ והקשר ¬ מספיקים כדי לבטא כל ביטוי בתחשיב הפרדיקטים.

מדוע, אם כן להשתמש בארבעה קשרים?

שאלה 2

א. יהיו M מודל, ו p פסוק בלוגיקה מסדר ראשון.
הראה ש p מתקיים ב M או ש ¬p מתקיים ב M.

ב. מה הטעות בטיעונים הבאים:
כדי לבדוק האם $p \models q$, נשלב נסיונות להוכחת q ו ¬q.

אם הוכחת q מצליחה, q נובע מ p.

אם הוכחת ¬q מצליחה, q לא נובע מ p.

בכל מקרה בעיית ההסקה היא כריעה.

שאלה 3

א. אם f הוא סתירה, הוכח ש $D \models q$ שקול ל $D\cup\{\neg q\} \models f$.

ב. הוכח שמודוס פוננס שלם בבסיסי נתונים המורכבים רק מפסוקי הורן.

שאלה 4

א. מה המשמעות של: $p(a) \models \forall x.p(x)$

ב. מה המשמעות של: $p(a) \models \neg p(a)$

שאלה 5

כמה קשרים בינאריים קיימים?

שאלה 6

האם לדעתך קיים אלגוריתם להוכחת הנאותות של כלל היסק?

שאלה 7.

מצא קשר בינארי באמצעותו אפשר לבטא כל פסוק בתחשיב הפרדיקטים.

Example:

Consider the following axioms:

1. All hounds howl at night.
2. Anyone who has any cats will not have any mice.
3. Light sleepers do not have anything which howls at night.
4. John has either a cat or a hound.
5. (Conclusion) If John is a light sleeper, then John does not have any mice.

The conclusion can be proved using Resolution as shown below. The first step is to write each axiom as a well-formed formula in first-order predicate calculus. The clauses written for the above axioms are shown below, using LS(x) for `light sleeper'.

1. *&forall x (HOUND(x) &rarr HOWL(x))*
2. *&forall x &forall y (HAVE (x,y) &and CAT (y) &rarr ¬ &exist z (HAVE(x,z) &and MOUSE (z)))*
3. *&forall x (LS(x) &rarr ¬ &exist y (HAVE (x,y) &and HOWL(y)))*
4. *&exist x (HAVE (John,x) &and (CAT(x) &or HOUND(x)))*
5. *LS(John) &rarr ¬ &exist z (HAVE(John,z) &and MOUSE(z))*

The next step is to transform each wff into Prenex Normal Form, skolemize, and rewrite as clauses in conjunctive normal form; these transformations are shown below.

1. *&forall x (HOUND(x) &rarr HOWL(x))*

   ¬ HOUND(x) &or HOWL(x)

2. *&forall x &forall y (HAVE (x,y) &and CAT (y) &rarr ¬ &exist z (HAVE(x,z) &and MOUSE (z)))*

   &forall x &forall y (HAVE (x,y) &and CAT (y) &rarr &forall z ¬ (HAVE(x,z) &and MOUSE (z)))

   &forall x &forall y &forall z (¬ (HAVE (x,y) &and CAT (y)) &or ¬ (HAVE(x,z) &and MOUSE (z)))

   ¬ HAVE(x,y) &or ¬ CAT(y) &or ¬ HAVE(x,z) &or ¬ MOUSE(z)

3. *&forall x (LS(x) &rarr ¬ &exist y (HAVE (x,y) &and HOWL(y)))*

   &forall x (LS(x) &rarr &forall y ¬ (HAVE (x,y) &and HOWL(y)))

   &forall x &forall y (LS(x) &rarr ¬ HAVE(x,y) &or ¬ HOWL(y))

   &forall x &forall y (¬ LS(x) &or ¬ HAVE(x,y) &or ¬ HOWL(y))

   ¬ LS(x) &or ¬ HAVE(x,y) &or ¬ HOWL(y)

4. *&exist x (HAVE (John,x) &and (CAT(x) &or HOUND(x)))*

   HAVE(John,a) &and (CAT(a) &or HOUND(a))

5. *¬ [LS(John) &rarr ¬ &exist z (HAVE(John,z) &and MOUSE(z))] (negated conclusion)*

   ¬ [¬ LS (John) &or ¬ &exist z (HAVE (John, z) &and MOUSE(z))]

   LS(John) &and &exist z (HAVE(John, z) &and MOUSE(z)))

   LS(John) &and HAVE(John,b) &and MOUSE(b)

The set of CNF clauses for this problem is thus as follows:

1. ¬ *HOUND(x) &or HOWL(x)*
2. ¬ *HAVE(x,y) &or ¬ CAT(y) &or ¬ HAVE(x,z) &or ¬ MOUSE(z)*
3. ¬ *LS(x) &or ¬ HAVE(x,y) &or ¬ HOWL(y)*
4.
    1. *HAVE(John,a)*
    2. *CAT(a) &or HOUND(a)*
5.
    1. *LS(John)*
    2. *HAVE(John,b)*
    3. *MOUSE(b)*

Now we proceed to prove the conclusion by resolution using the above clauses. Each result clause is numbered; the numbers of its parent clauses are shown to its left.

[1.,4.(b):]	6.	*CAT(a) &or HOWL(a)*
[2,5.(c):]	7.	¬ *HAVE(x,y) &or ¬ CAT(y) &or ¬ HAVE(x,b)*
[7,5.(b):]	8.	¬ *HAVE(John,y) &or ¬ CAT(y)*
[6,8:]	9.	¬ *HAVE(John,a) &or HOWL(a)*
[4.(a),9:]	10.	*HOWL(a)*
[3,10:]	11.	¬ *LS(x) &or ¬ HAVE(x,a)*
[4.(a),11:]	12.	¬ *LS(John)*
[5.(a),12:]	13.	□

Exercises:

1. Unify (if possible) the following pairs of predicates and give the resulting substitutions. *b* is a constant.

a. $P(x, f(x), z)$
$\neg P(g(y),f(g(b)),y)$

b. $P(x, f(x))$
$\neg P(f(y), y)$

c. $P(x, f(z))$
$\neg P(f(y), y)$

2. Consider the following axioms:

1. Every child loves Santa.
2. Everyone who loves Santa loves any reindeer.
3. Rudolph is a reindeer, and Rudolph has a red nose.
4. Anything which has a red nose is weird or is a clown.
5. No reindeer is a clown.
6. Scrooge does not love anything which is weird.
7. (Conclusion) Scrooge is not a child.

Represent these axioms in predicate calculus; skolemize as necessary and convert each formula to clause form. (Note: `has a red nose' can be a single predicate. Remember to negate the conclusion.) Prove the unsatisfiability of the set of clauses by resolution.

3. Consider the following axioms:

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
2. Every dog chases some rabbit.
3. Mary buys carrots by the bushel.
4. Anyone who owns a rabbit hates anything that chases any rabbit.
5. John owns a dog.
6. Someone who hates something owned by another person will not date that person.
7. (Conclusion) If Mary does not own a grocery store, she will not date John.

Represent these clauses in predicate calculus, using only those predicates which are necessary. For example, you need not represent `person', and phrases such as `who buys carrots by the bushel' may be represented by a single predicate. Negate the conclusion and convert to clause form, skolemizing as necessary. Prove the unsatisfiability of the resulting set of clauses by resolution.

4. Consider the following axioms:

1. Every Austinite who is not conservative loves some armadillo.
2. Anyone who wears maroon-and-white shirts is an Aggie.
3. Every Aggie loves every dog.
4. Nobody who loves every dog loves any armadillo.
5. Clem is an Austinite, and Clem wears maroon-and-white shirts.
6. (Conclusion) Is there a conservative Austinite?

5. Consider the following axioms:

1. Anyone whom Mary loves is a football star.
2. Any student who does not pass does not play.
3. John is a student.
4. Any student who does not study does not pass.
5. Anyone who does not play is not a football star.
6. (Conclusion) If John does not study, then Mary does not love John.

6. Consider the following axioms:

1. Every coyote chases some roadrunner.
2. Every roadrunner who says ``beep-beep'' is smart.
3. No coyote catches any smart roadrunner.

4. Any coyote who chases some roadrunner but does not catch it is frustrated.
5. (Conclusion) If all roadrunners say ``beep-beep'', then all coyotes are frustrated.

7. Consider the following axioms:

1. Anyone who rides any Harley is a rough character.
2. Every biker rides [something that is] either a Harley or a BMW.
3. Anyone who rides any BMW is a yuppie.
4. Every yuppie is a lawyer.
5. Any nice girl does not date anyone who is a rough character.
6. Mary is a nice girl, and John is a biker.
7. (Conclusion) If John is not a lawyer, then Mary does not date John.

8. Consider the following axioms:

1. Every child loves anyone who gives the child any present.
2. Every child will be given some present by Santa if Santa can travel on Christmas eve.
3. It is foggy on Christmas eve.
4. Anytime it is foggy, anyone can travel if he has some source of light.
5. Any reindeer with a red nose is a source of light.
6. (Conclusion) If Santa has some reindeer with a red nose, then every child loves Santa.

9. Consider the following axioms:

1. Every investor bought [something that is] stocks or bonds.
2. If the Dow-Jones Average crashes, then all stocks that are not gold stocks fall.
3. If the T-Bill interest rate rises, then all bonds fall.
4. Every investor who bought something that falls is not happy.
5. (Conclusion) If the Dow-Jones Average crashes and the T-Bill interest rate rises, then any investor who is happy bought some gold stock.

10. Consider the following axioms:

1. Every child loves every candy.
2. Anyone who loves some candy is not a nutrition fanatic.
3. Anyone who eats any pumpkin is a nutrition fanatic.
4. Anyone who buys any pumpkin either carves it or eats it.
5. John buys a pumpkin.
6. Lifesavers is a candy.
7. (Conclusion) If John is a child, then John carves some pumpkin.

11. Consider the following axioms:

1. Every tree that is an oak contains some grackle.
2. If anyone walks under any tree that contains any grackle, then he hates every grackle.
3. For every building, there is some tree that is beside it.
4. Taylor Hall is a building.
5. Every CS student visits Taylor Hall.
6. If anyone visits any building, then he walks under every tree that is beside that building.
7. (Conclusion) If some CS student does not hate some grackle, then there is some tree beside Taylor Hall that is not an oak.

12. Consider the following axioms:

1. Every child sees some witch.
2. No witch has both a black cat and a pointed hat.
3. Every witch is good or bad.
4. Every child who sees any good witch gets candy.
5. Every witch that is bad has a black cat.
6. (Conclusion) If every witch that is seen by any child has a pointed hat, then every child gets candy.

13. Consider the following axioms:

1. Every boy or girl is a child.
2. Every child gets a doll or a train or a lump of coal.
3. No boy gets any doll.
4. No child who is good gets any lump of coal.
5. (Conclusion) If no child gets a train, then no boy is good.

14. Consider the following axioms:

1. Every child who finds some [thing that is an] egg or chocolate bunny is happy.
2. Every child who is helped finds some egg.
3. Every child who is not young or who tries hard finds some chocolate bunny.
4. (Conclusion) If every young child tries hard or is helped, then every child is happy.

15. Consider the following axioms:

1. Anything that is played by any student is tennis, soccer, or chess.
2. Anything that is chess is not vigorous.
3. Anyone who is healthy plays something that is vigorous.
4. Anyone who plays any chess does not play any soccer.
5. (Conclusion) If every student is healthy, then every student who plays any chess plays some tennis.

16. Consider the following axioms:

1. Every student who makes good grades is brilliant or studies.
2. Every student who is a CS major has some roommate. [Make ``roommate'' a two-place predicate.]
3. Every student who has any roommate who likes to party goes to Sixth Street.
4. Anyone who goes to Sixth Street does not study.
5. (Conclusion) If every roommate of every CS major likes to party, then every student who is a CS major and makes good grades is brilliant.

17. Consider the following axioms:

1. Everyone who aces any final exam studies or is brilliant or is lucky.
2. Everyone who makes an A aces some final exam.
3. No CS major is lucky.
4. Anyone who drinks beer does not study.
5. (Conclusion) If every CS major makes an A, then every CS major who drinks beer is brilliant.

18. Consider the following axioms:

1. Anyone who loves any lottery is a gambler.
2. Everyone who favors the lottery proposition loves some lottery.
3. Everyone favors the lottery proposition or opposes the lottery proposition.
4. If every Baptist votes and opposes the lottery proposition, then the lottery proposition does not win.
5. Every Baptist who is faithful is not a gambler.
6. (Conclusion) If every Baptist votes and the lottery proposition wins, then some Baptist is not faithful.

19. Consider the following axioms. Hint: the predicates WHITE, SNOWY, HAPPY, and GETS should each have a ``time'' argument.

1. Anyone who owns any sled is happy when it is snowy.
2. When it is white, it is snowy.
3. If Santa is happy at Christmas, then every child who is good gets some toy at Christmas.
4. Any child who gets a toy at any time is happy at that time.
5. Santa owns a sled.
6. (Conclusion) If it is white at Christmas and every child who is not good owns some sled, then every child is happy at Christmas.

20. Consider the following axioms.

1. Anyone who is on Sixth Street and is not a police officer has some costume.
2. No CS student is a police officer.
3. Every costume that is good is a robot costume.
4. For anyone, if they are on Sixth Street and are happy, then every costume they have is good or they are drunk.
5. (Conclusion) If no CS student is drunk and every CS student on Sixth Street is happy, then every CS student on Sixth Street has some costume that is a robot costume.

21. Consider the following axioms.

1. For every mall, there is some Santa who is at the mall.
2. Every child who visits anywhere talks with every Santa who is at the place visited. [Don't make a predicate for ``the place visited''; it should just be a variable.]
3. Every child who is a city child visits some mall.
4. Every child who is good or who talks with some Santa gets some toy.

5. (Conclusion) If every child who is not a city child is good, then every child gets some toy.

22. Consider the following axioms.

1. Everyone who feels warm either is drunk, or every costume they have is warm.
2. Every costume that is warm is furry.
3. Every AI student is a CS student.
4. Every AI student has some robot costume.
5. No robot costume is furry.
6. (Conclusion) If every CS student feels warm, then every AI student is drunk.

23. Consider the following axioms.

1. Every bird sleeps in some tree.
2. Every loon is a bird, and every loon is aquatic.
3. Every tree in which any aquatic bird sleeps is beside some lake.
4. Anything that sleeps in anything that is beside any lake eats fish.
5. (Conclusion) Every loon eats fish.

24.``Schubert's Steamroller'', for the ambitious. (See C. Walther, AAAI-84, p. 330.)

Wolves, foxes, birds, caterpillars, and snails are animals, and there are some of each of them. Also there are some grains, and grains are plants. Every animal either likes to eat all plants or all animals much smaller than itself that like to eat some plants. Caterpillars and snails are much smaller than birds, which are much smaller than foxes, which in turn are much smaller than wolves. Wolves do not like to eat foxes or grains, while birds like to eat caterpillars but not snails. Caterpillars and snails like to eat some plants. Therefore there is an animal that likes to eat a grain-eating animal.

Resolution Exercise Solutions

2. Consider the following axioms:

1. Every child loves Santa.
   &forall x (CHILD(x) &rarr LOVES(x,Santa))
2. Everyone who loves Santa loves any reindeer.
   &forall x (LOVES(x,Santa) &rarr &forall y (REINDEER(y) &rarr LOVES(x,y)))
3. Rudolph is a reindeer, and Rudolph has a red nose.
   REINDEER(Rudolph) &and REDNOSE(Rudolph)
4. Anything which has a red nose is weird or is a clown.
   &forall x (REDNOSE(x) &rarr WEIRD(x) &or CLOWN(x))
5. No reindeer is a clown.
   ¬ *&exist x (REINDEER(x) &and CLOWN(x))*
6. Scrooge does not love anything which is weird.
   &forall x (WEIRD(x) &rarr ¬ LOVES(Scrooge,x))
7. (Conclusion) Scrooge is not a child.
   ¬ *CHILD(Scrooge)*

3. Consider the following axioms:

1. Anyone who buys carrots by the bushel owns either a rabbit or a grocery store.
   &forall x (BUY(x) &rarr &exist y (OWNS(x,y) &and (RABBIT(y) &or GROCERY(y))))
2. Every dog chases some rabbit.
   &forall x (DOG(x) &rarr &exist y (RABBIT(y) &and CHASE(x,y)))
3. Mary buys carrots by the bushel.
   BUY(Mary)
4. Anyone who owns a rabbit hates anything that chases any rabbit.
   &forall x &forall y (OWNS(x,y) &and RABBIT(y) &rarr &forall z &forall w (RABBIT(w) &and CHASE(z,w) &rarr HATES(x,z)))
5. John owns a dog.
   &exist x (DOG(x) &and OWNS(John,x))
6. Someone who hates something owned by another person will not date that person.
   &forall x &forall y &forall z (OWNS(y,z) &and HATES(x,z) &rarr ¬ DATE(x,y))
7. (Conclusion) If Mary does not own a grocery store, she will not date John.
   ((¬ &exist x (GROCERY(x) &and OWN(Mary,x))) &rarr ¬ DATE(Mary,John))

4. Consider the following axioms:

1. Every Austinite who is not conservative loves some armadillo.
   &forall x (AUSTINITE(x) &and ¬ CONSERVATIVE(x) &rarr &exist y (ARMADILLO(y) &and LOVES(x,y)))

2. Anyone who wears maroon-and-white shirts is an Aggie.
   &forall x (WEARS(x) &rarr AGGIE(x))
3. Every Aggie loves every dog.
   &forall x (AGGIE(x) &rarr &forall y (DOG(y) &rarr LOVES(x,y)))
4. Nobody who loves every dog loves any armadillo.
   ¬ &exist x ((&forall y (DOG(y) &rarr LOVES(x,y))) &and &exist z (ARMADILLO(z) &and LOVES(x,z)))
5. Clem is an Austinite, and Clem wears maroon-and-white shirts.
   AUSTINITE(Clem) &and WEARS(Clem)
6. (Conclusion) Is there a conservative Austinite?
   &exist x (AUSTINITE(x) &and CONSERVATIVE(x))

```
( ( (not (Austinite x))  (Conservative x)  (Armadillo (f x)) )
  ( (not (Austinite x))  (Conservative x)  (Loves x (f x)) )
  ( (not (Wears x))  (Aggie x) )
  ( (not (Aggie x))  (not (Dog y))  (Loves x y) )
  ( (Dog (g x))  (not (Armadillo z))  (not (Loves x z)) )
  ( (not (Loves x (g x)))  (not (Armadillo z))  (not (Loves x z)) )
  ( (Austinite (Clem)) )
  ( (Wears (Clem)) )
  ( (not (Conservative x))  (not (Austinite x)) ) )
```

5. Consider the following axioms:

1. Anyone whom Mary loves is a football star.
   &forall x (LOVES(Mary,x) &rarr STAR(x))
2. Any student who does not pass does not play.
   &forall x (STUDENT(x) &and ¬ PASS(x) &rarr ¬ PLAY(x))
3. John is a student.
   STUDENT(John)
4. Any student who does not study does not pass.
   &forall x (STUDENT(x) &and ¬ STUDY(x) &rarr ¬ PASS(x))
5. Anyone who does not play is not a football star.
   &forall x (¬ PLAY(x) &rarr ¬ STAR(x))
6. (Conclusion) If John does not study, then Mary does not love John.
   ¬ STUDY(John) &rarr ¬ LOVES(Mary,John)

6. Consider the following axioms:

1. Every coyote chases some roadrunner.
   &forall x (COYOTE(x) &rarr &exist y (RR(y) &and CHASE(x,y)))
2. Every roadrunner who says ``beep-beep'' is smart.
   &forall x (RR(x) &and BEEP(x) &rarr SMART(x))
3. No coyote catches any smart roadrunner.
   ¬ &exist x &exist y (COYOTE(x) &and RR(y) &and SMART(y) &and CATCH(x,y))
4. Any coyote who chases some roadrunner but does not catch it is frustrated.
   &forall x (COYOTE(x) &and &exist y (RR(y) &and CHASE(x,y) &and ¬ CATCH(x,y)) &rarr FRUSTRATED(x))
5. (Conclusion) If all roadrunners say ``beep-beep'', then all coyotes are frustrated.
   (&forall x (RR(x) &rarr BEEP(x)) &rarr (&forall y (COYOTE(y) &rarr FRUSTRATED(y)))

```
( ( (not (Coyote x))  (RR (f x)) )
  ( (not (Coyote x))  (Chase x (f x)) )
  ( (not (RR x))  (not (Beep x))  (Smart x) )
  ( (not (Coyote x))  (not (RR y))  (not (Smart y))  (not (Catch x y)) )
  ( (not (Coyote x))  (not (RR y))  (not (Chase x y)) (Catch x y)
    (Frustrated x) )
  ( (not (RR x))  (Beep x) )
  ( (Coyote (a)) )
  ( (not (Frustrated (a))) ) )
```

7. Consider the following axioms:

1. Anyone who rides any Harley is a rough character.
   &forall x ((&exist y (HARLEY(y) &and RIDES(x,y))) &rarr ROUGH(x))
2. Every biker rides [something that is] either a Harley or a BMW.
   &forall x (BIKER(x) &rarr &exist y ((HARLEY(y) &or BMW(y)) &and RIDES(x,y)))
3. Anyone who rides any BMW is a yuppie.
   &forall x &forall y (RIDES(x,y) &and BMW(y) &rarr YUPPIE(x))
4. Every yuppie is a lawyer.
   &forall x (YUPPIE(x) &rarr LAWYER(x))
5. Any nice girl does not date anyone who is a rough character.
   &forall x &forall y (NICE(x) &and ROUGH(y) &rarr ¬ DATE(x,y))

6. Mary is a nice girl, and John is a biker.
   NICE(Mary) &and BIKER(John)
7. (Conclusion) If John is not a lawyer, then Mary does not date John.
   ¬ LAWYER(John) &rarr ¬ DATE(Mary,John)

8. Consider the following axioms:

1. Every child loves anyone who gives the child any present.
   &forall x &forall y &forall z (CHILD(x) &and PRESENT(y) &and GIVE(z,y,x) &rarr LOVES(x,z)
2. Every child will be given some present by Santa if Santa can travel on Christmas eve.
   TRAVEL(Santa,Christmas) &rarr &forall x (CHILD(x) &rarr &exist y (PRESENT(y) &and GIVE(Santa,y,x)))
3. It is foggy on Christmas eve.
   FOGGY(Christmas)
4. Anytime it is foggy, anyone can travel if he has some source of light.
   &forall x &forall t (FOGGY(t) &rarr (&exist y (LIGHT(y) &and HAS(x,y)) &rarr TRAVEL(x,t)))
5. Any reindeer with a red nose is a source of light.
   &forall x (RNR(x) &rarr LIGHT(x))
6. (Conclusion) If Santa has some reindeer with a red nose, then every child loves Santa.
   (&exist x (RNR(x) &and HAS(Santa,x))) &rarr &forall y (CHILD(y) &rarr LOVES(y,Santa))

9. Consider the following axioms:

1. Every investor bought [something that is] stocks or bonds.
   &forall x (INVESTOR(x) &rarr &exist y ((STOCK(y) &or BOND(y)) &and BUY(x,y)))
2. If the Dow-Jones Average crashes, then all stocks that are not gold stocks fall.
   DJCRASH &rarr &forall x ((STOCK(x) &and ¬ GOLD(x)) &rarr FALL(x))
3. If the T-Bill interest rate rises, then all bonds fall.
   TBRISE &rarr &forall x (BOND(x) &rarr FALL(x))
4. Every investor who bought something that falls is not happy.
   &forall x &forall y (INVESTOR(x) &and BUY(x,y) &and FALL(y) &rarr ¬ HAPPY(x))
5. (Conclusion) If the Dow-Jones Average crashes and the T-Bill interest rate rises, then any investor who is happy bought some gold stock.
   (DJCRASH &and TBRISE) &rarr &forall x (INVESTOR(x) &and HAPPY(x) &rarr &exist y (GOLD(y) &and BUY(x,y)))

10. Consider the following axioms:

1. Every child loves every candy.
   &forall x &forall y (CHILD(x) &and CANDY(y) &rarr LOVES(x,y))
2. Anyone who loves some candy is not a nutrition fanatic.
   &forall x ((&exist y (CANDY(y) &and LOVES(x,y))) &rarr ¬ FANATIC(x))
3. Anyone who eats any pumpkin is a nutrition fanatic.
   &forall x ((&exist y (PUMPKIN(y) &and EAT(x,y))) &rarr FANATIC(x))
4. Anyone who buys any pumpkin either carves it or eats it.
   &forall x &forall y (PUMPKIN(y) &and BUY(x,y) &rarr CARVE(x,y) &or EAT(x,y))
5. John buys a pumpkin.
   &exist x (PUMPKIN(x) &and BUY(John,x))
6. Lifesavers is a candy.
   CANDY(Lifesavers)
7. (Conclusion) If John is a child, then John carves some pumpkin.
   CHILD(John) &rarr &exist x (PUMPKIN(x) &and CARVE(John,x))