UE Artificial Intelligence

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Exercise 1 – Unification

- $MGU(Student(x), Student(y))$

Exercise 1 – Unification

- $MGU(Student(x), Student(y)) = \{x/y\}$

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- $MGU(Student(x), Student(y)) = \{x/y\}$
- $MGU(Student(passed(w), y), Student(z, grade(passed(u), v)))$

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  $= \{z/passed(w), y/grade(passed(u), v)\}$

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- $MGU(Student(enthusiastic(x), passed(x), owns(y)),$
  $Student(x, y, z, owns(z))\}$

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- $MGU(Student(enthusiastic(x), passed(x), owns(y)),$
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- $MGU(Student(y, enthusiastic(x), MATH),$
  $Student(AICOURSE, enthusiastic(x), y))$

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- $MGU(Student(y, enthusiastic(x), MATH),$
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  $= MGU(Student(y_1, enthusiastic(x_1), MATH),$
  $Student(AICOURSE, enthusiastic(x_2), y_2))$

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- $MGU(Student(y, enthusiastic(x), MATH),$
  $Student(AICOURSE, enthusiastic(x), y))$
  $= MGU(Student(y_1, enthusiastic(x_1), MATH),$
  $Student(AICOURSE, enthusiastic(x_2), y_2))$
  $= \{x_1/x_2, y_1/AICOURSE, y_2/MATH\}$

Exercise 1 – Unification

- $MGU(Student(grade(x, AICOURSE), x),$
  $Student(grade(z, u), genius(150, v)),$
  $Student(y, genius(v, MATH))\}$

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- $MGU(Student(grade(x, AICOURSE), x),$
  $Student(grade(z, u), genius(150, v)),$
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  Unify with 2 steps:

  1. $MGU(Student(grade(x, AICOURSE), x),$
     $Student(grade(z, u), genius(150, v)),$

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  Unify with 2 steps:

  1. $MGU(Student(grade(x, AICOURSE), x),$
     $Student(grade(z, u), genius(150, v)),$
     $= \{x/z, u/AICOURSE, z/genius(150, v)\}$

Exercise 1 – Unification

- $MGU(Student(grade(x, AICOURSE), x),$
  $Student(grade(z, u), genius(150, v)),$
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     $Student(grade(z, u), genius(150, v)),$
     $= \{x/z, u/AICOURSE, z/genius(150, v)\}$

  2. $MGU(Student(grade(genius(150, v), AICOURSE), genius(150, v)),$
     $Student(y, genius(v, MATH)))$

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     $Student(grade(z, u), genius(150, v)),$
     $= \{x/z, u/AICOURSE, z/genius(150, v)\}$
  2. $MGU(Student(grade(genius(150, v), AICOURSE), genius(150, v)),$
     $Student(y, genius(v, MATH)))$
     $MGU(Student(grade(genius(150, v_1), AICOURSE), genius(150, v_1)),$
     $Student(y, genius(v_2, MATH)))$

Exercise 1 – Unification

- $MGU(Student(grade(x, AICOURSE), x),$
  $Student(grade(z, u), genius(150, v)),$
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  Unify with 2 steps:

  1. $MGU(Student(grade(x, AICOURSE), x),$
     $Student(grade(z, u), genius(150, v)),$
     $= \{x/z, u/AICOURSE, z/genius(150, v)\}$

  2. $MGU(Student(grade(genius(150, v), AICOURSE), genius(150, v)),$
     $Student(y, genius(v, MATH)))$
     $MGU(Student(grade(genius(150, v_1), AICOURSE), genius(150, v_1)),$
     $Student(y, genius(v_2, MATH)))$
     $= \{y/grade(genius(150, v_1)), v_1/MATH, v_2/150\}$

Exercise 1 – Unification

- $MGU(Student(grade(x, y), genius(x)),$
  $Student(grade(enthusiastic(z), y), genius(enthusiastic(z)))\}$

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- $MGU(Student(grade(x, y), genius(x)),$
  $Student(grade(enthusiastic(z), y), genius(enthusiastic(z)))\}$
  $= MGU(Student(grade(x, y_1), genius(x)),$
  $Student(grade(enthusiastic(z), y_2), genius(enthusiastic(z)))\}$

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  $= \{x/enthusiastic(z), y_1/y_2\}$

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- $MGU(Student(y, passed(x), MATH, z),$
  $Professor(x, AICOURSE, enthusiastic(x), y)\}$

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- $MGU(Student(passed(x), grade(passed(u), v)),$
  $Student(passed(grade(w, v)), grade(z, w))\}$

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  $Student(grade(enthusiastic(z), y), genius(enthusiastic(z)))\}$
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  $Student(passed(grade(w, v)), grade(z, w))\}$
  $= MGU(Student(passed(x), grade(passed(u), v_1)),$
  $Student(passed(grade(w, v_2)), grade(z, w))\}$

Exercise 1 – Unification

- $MGU(Student(grade(x, y), genius(x)),$
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- $MGU(Student(y, passed(x), MATH, z),$
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- $MGU(Student(passed(x), grade(passed(u), v)),$
  $Student(passed(grade(w, v)), grade(z, w))\}$
  $= MGU(Student(passed(x), grade(passed(u), v_1)),$
  $Student(passed(grade(w, v_2)), grade(z, w))\}$
  $= \{x/grade(w, v_2), z/passed(u), v_1/w\}$

Exercise 2 – Probabilistic Inference

1. $P(hungry)$
2. $P(\neg cold \mid hungry \wedge cold)$
3. $P(excited \vee \neg excited)$
4. $P(hungry \wedge cold \mid crying)$
5. $P(\neg crying)$
6. $P(cold \mid hungry)$
7. $P(cold \mid excited \wedge \neg hungry)$
8. $P(crying \vee excited)$
9. $P(excited \wedge \neg hungry)$
10. $P((excited \wedge cold) \vee (\neg crying \wedge hungry))$

Exercise 2 – Probabilistic Inference

		crying		¬ crying	
		cold	¬ cold	cold	¬ cold
excited	hungry	0.02	0.01	0.02	0.06
	¬ hungry	0.01	0.01	0.05	0.12
¬ excited	hungry	0.05	0.03	0.06	0.14
	¬ hungry	0.03	0.01	0.1	0.28

Exercise 2 – Notation

$$P(a, b) \triangleq P(a \land b)$$

$$\sum_A P(A, b) \triangleq P(a, b) + P(\neg a, b)$$

Exercise 2 – Rules

- Marginalisation:

$$P(a) = \sum_{B,C} P(a, B, C)$$

- Conditional Probability:

$$P(a \mid b) = \frac{P(a, b)}{P(b)}$$

- "Or"-Rule:

$$P(a \vee b) = P(a) + P(b) - P(a, b)$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(h) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(h) = \sum_{E,Co,Cr} P(E, Co, Cr, h) = 0.39$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(\neg c \mid h, c) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(\neg c \mid h, c) = 0$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(e \vee \neg e) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(e \vee \neg e) = 1$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(h, co \mid cr) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(h, co \mid cr) = \frac{P(h, co, cr)}{P(cr)} =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(h, co \mid cr) = \frac{P(h, co, cr)}{P(cr)} = \frac{\sum_E P(E, h, co, cr)}{\sum_{E,H,Co} P(E, H, Co, cr)} \approx 0.41$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(\neg cr) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(\neg cr) = \sum_{E,H,Co} P(E, H, Co, \neg cr) = 0.83$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(co \mid h) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(co \mid h) = \frac{P(co, h)}{P(h)} =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(co \mid h) = \frac{P(co, h)}{P(h)} = \frac{\sum_{E,Cr} P(E, Cr, co, h)}{\sum_{E,Cr,Co} P(H, Cr, Co, h)} \approx 0.38$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(co \mid e, \neg h) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(co \mid e, \neg h) = \frac{P(co, e, \neg h)}{P(e, \neg h)} =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(co \mid e, \neg h) = \frac{P(co, e, \neg h)}{P(e, \neg h)} = \frac{\sum_{Cr} P(Cr, co, e, \neg h)}{\sum_{Cr,Co} P(Cr, Co, e, \neg h)} \approx 0.32$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(cr \vee e) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(cr \vee e) = P(cr) + P(e) - P(cr, e) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(cr \vee e) = P(cr) + P(e) - P(cr, e) = 0.42$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P(e, \neg h) = \sum_{Cr,Co} P(Cr, Co, e, \neg h) = 0.19$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P((e \wedge co) \vee (\neg cr \wedge h)) =$$

Exercise 2 – Probabilistic Inference

		cr		¬ cr	
		co	¬ co	co	¬ co
e	h	0.02	0.01	0.02	0.06
	¬ h	0.01	0.01	0.05	0.12
¬ e	h	0.05	0.03	0.06	0.14
	¬ h	0.03	0.01	0.1	0.28

$$P((e \wedge co) \vee (\neg cr \wedge h)) = P(e, co) + P(\neg cr, h) - P(e, co, \neg cr, h) = 0.36$$

Exercise 3 – Knowledge Representation, FWD/BCK Chaining

- **Unicorns, jackalopes and hippocamps are mammals.**
- An offspring of a unicorn is a unicorn.
- HappyRainbowDancer is a unicorn.
- HappyRainbowDancer is Greenyboony's parent.
- Offspring and parent are inverse relations.

Exercise 3 – Knowledge Representation, FWD/BCK Chaining

- $Unicorn(x) \rightarrow Mammal(x)$
- $Jackalope(x) \rightarrow Mammal(x)$
- $Hippocamp(x) \rightarrow Mammal(x)$
- **An offspring of a unicorn is a unicorn.**
- HappyRainbowDancer is a unicorn.
- HappyRainbowDancer is Greenyboony's parent.
- Offspring and parent are inverse relations.

Exercise 3 – Knowledge Representation, FWD/BCK Chaining

- $Unicorn(x) \rightarrow Mammal(x)$
- $Jackalope(x) \rightarrow Mammal(x)$
- $Hippocamp(x) \rightarrow Mammal(x)$
- $Unicorn(y) \wedge Offspring(x, y) \rightarrow Unicorn(x)$
- **HappyRainbowDancer is a unicorn.**
- HappyRainbowDancer is Greenyboony's parent.
- Offspring and parent are inverse relations.

Exercise 3 – Knowledge Representation, FWD/BCK Chaining

- $Unicorn(x) \rightarrow Mammal(x)$
- $Jackalope(x) \rightarrow Mammal(x)$
- $Hippocamp(x) \rightarrow Mammal(x)$
- $Unicorn(y) \wedge Offspring(x, y) \rightarrow Unicorn(x)$
- $Unicorn(HappyRainbowDancer)$
- **HappyRainbowDancer is Greenyboony's parent.**
- Offspring and parent are inverse relations.

Exercise 3 – Knowledge Representation, FWD/BCK Chaining

- $Unicorn(x) \rightarrow Mammal(x)$
- $Jackalope(x) \rightarrow Mammal(x)$
- $Hippocamp(x) \rightarrow Mammal(x)$
- $Unicorn(y) \wedge Offspring(x, y) \rightarrow Unicorn(x)$
- $Unicorn(HappyRainbowDancer)$
- $Parent(HappyRainbowDancer, Greenyboony)$
- **Offspring and parent are inverse relations.**

Exercise 3 – Knowledge Representation, FWD/BCK Chaining

- $Unicorn(x) \rightarrow Mammal(x)$
- $Jackalope(x) \rightarrow Mammal(x)$
- $Hippocamp(x) \rightarrow Mammal(x)$
- $Unicorn(y) \land Offspring(x, y) \rightarrow Unicorn(x)$
- $Unicorn(HappyRainbowDancer)$
- $Parent(HappyRainbowDancer, Greenyboony)$
- $Offspring(x, y) \rightarrow Parent(y, x)$
- $Parent(x, y) \rightarrow Offspring(y, x)$

Exercise 3 – Standardising Apart

1. $U(x) \rightarrow M(x)$
2. $J(x) \rightarrow M(x)$
3. $H(x) \rightarrow M(x)$
4. $U(y) \land O(x,y) \rightarrow U(x)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(x,y) \rightarrow P(y,x)$
8. $P(x,y) \rightarrow O(y,x)$

Exercise 3 – Standardising Apart

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$

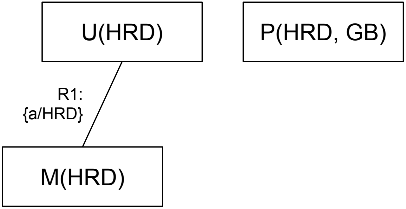
Exercise 3 – Forward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$

U(HRD)	P(HRD, GB)

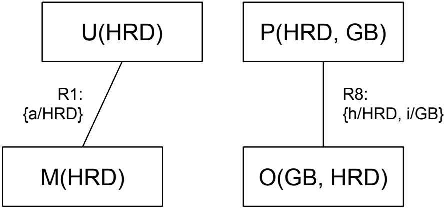
Exercise 3 – Forward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$



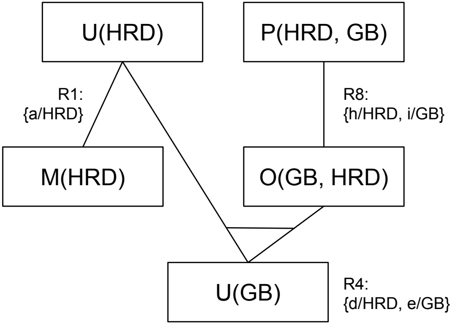
Exercise 3 – Forward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \land O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$



Exercise 3 – Forward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$



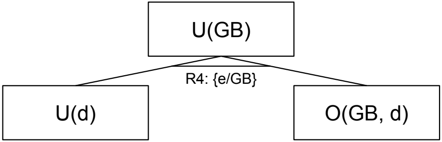
Exercise 3 – Backward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$

$\boxed{\text{U(GB)}}$

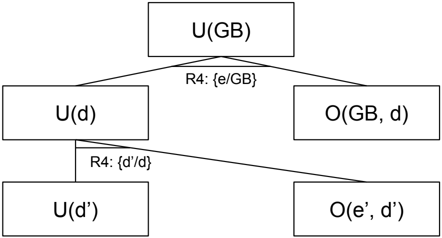
Exercise 3 – Backward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$



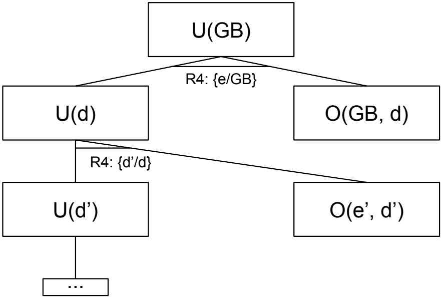
Exercise 3 – Backward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$



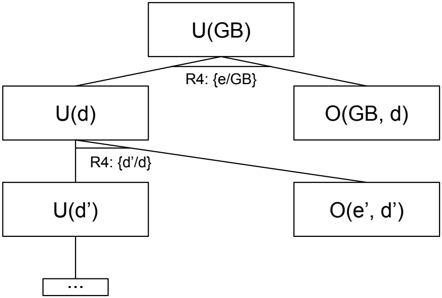
Exercise 3 – Backward Chaining: $U(GB)$

1. $U(a) \to M(a)$
2. $J(b) \to M(b)$
3. $H(c) \to M(c)$
4. $U(d) \wedge O(e,d) \to U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f,g) \to P(g,f)$
8. $P(h,i) \to O(i,h)$



Exercise 3 – Backward Chaining: $U(GB)$

1. $U(a) \rightarrow M(a)$
2. $J(b) \rightarrow M(b)$
3. $H(c) \rightarrow M(c)$
4. $U(d) \wedge O(e, d) \rightarrow U(e)$
5. $U(HRD)$
6. $P(HRD, GB)$
7. $O(f, g) \rightarrow P(g, f)$
8. $P(h, i) \rightarrow O(i, h)$



To prevent the loop, just switch rule 4 and 5.

Exercise 4 – FWD/BCK Chaining

1. $Horse(x) \wedge Fish(x) \rightarrow Hippocamp(x)$
2. $Horse(x) \wedge Horned(x) \rightarrow Unicorn(x)$
3. $Rabbit(z) \wedge Horned(z) \rightarrow Jackalope(z)$
4. $Unicorn(x) \wedge Jackalope(y) \rightarrow Friendlier(x, y)$
5. $Jackalope(y) \wedge Hippocamp(z) \rightarrow Friendlier(y, z)$
6. $Friendlier(x, y) \wedge Friendlier(y, z) \rightarrow Friendlier(x, z)$
7. $Horse(Steve)$
8. $Horse(Greenyboony)$
9. $Horned(Greenyboony)$
10. $Jackalope(Bob)$
11. $Fish(Steve)$

Exercise 4 – FWD/BCK Chaining

1. $Hs(x) \wedge F(x) \rightarrow Hi(x)$
2. $Hs(x) \wedge Hn(x) \rightarrow U(x)$
3. $R(z) \wedge Hn(z) \rightarrow J(z)$
4. $U(x) \wedge J(y) \rightarrow F(x, y)$
5. $J(y) \wedge Hi(z) \rightarrow F(y, z)$
6. $F(x, y) \wedge F(y, z) \rightarrow F(x, z)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$

Exercise 4 – FWD/BCK Chaining

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$

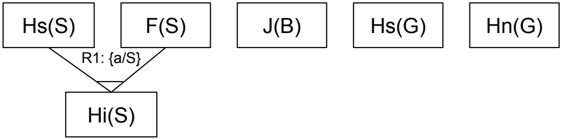
Exercise 4 – Forward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$

$\boxed{Hs(S)}$ $\boxed{F(S)}$ $\boxed{J(B)}$ $\boxed{Hs(G)}$ $\boxed{Hn(G)}$

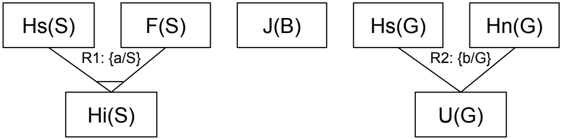
Exercise 4 – Forward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



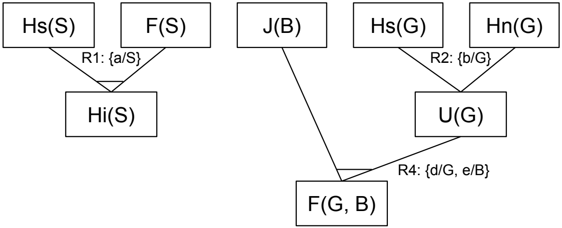
Exercise 4 – Forward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



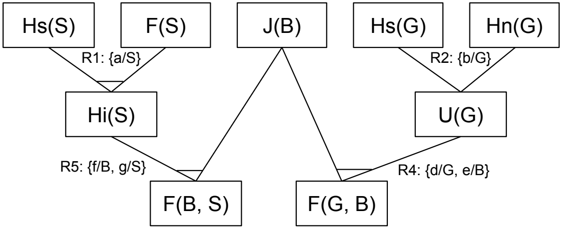
Exercise 4 – Forward Chaining $F(G, S)$

1. $Hs(a) \land F(a) \rightarrow Hi(a)$
2. $Hs(b) \land Hn(b) \rightarrow U(b)$
3. $R(c) \land Hn(c) \rightarrow J(c)$
4. $U(d) \land J(e) \rightarrow F(d, e)$
5. $J(f) \land Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \land F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



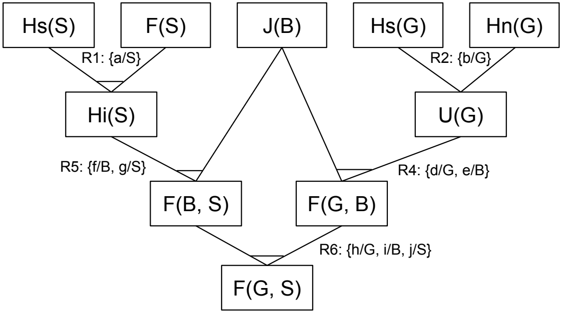
Exercise 4 – Forward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



Exercise 4 – Forward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



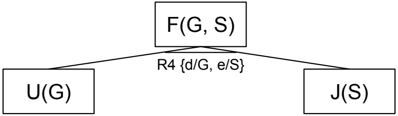
Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$

$\boxed{F(G, S)}$

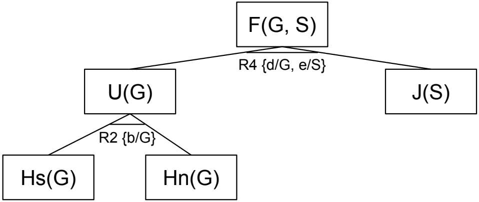
Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



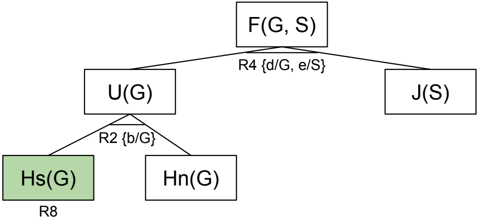
Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



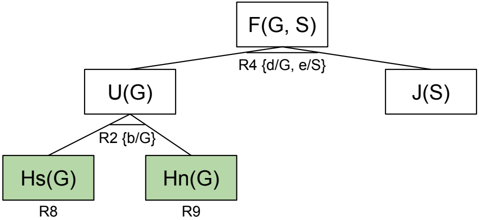
Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
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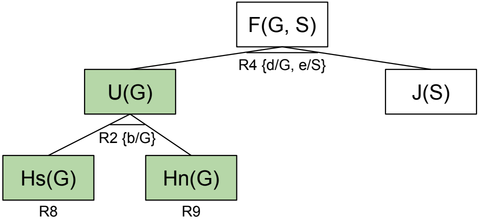
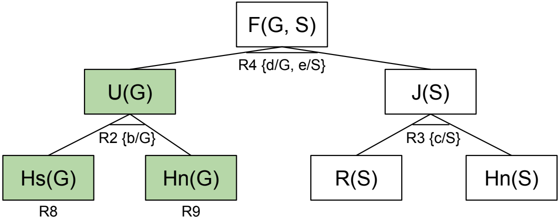
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \land F(a) \rightarrow Hi(a)$
2. $Hs(b) \land Hn(b) \rightarrow U(b)$
3. $R(c) \land Hn(c) \rightarrow J(c)$
4. $U(d) \land J(e) \rightarrow F(d, e)$
5. $J(f) \land Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \land F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
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6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
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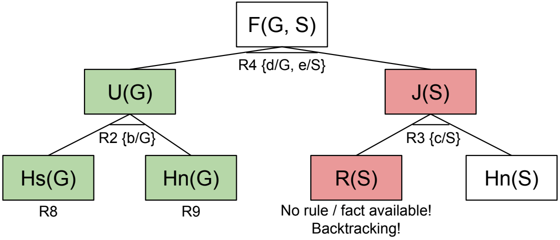

Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
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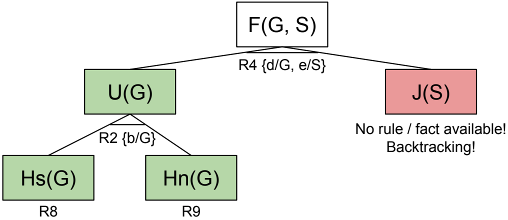
10. $J(B)$
11. $F(S)$



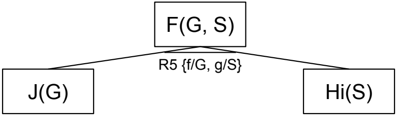
Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \land F(a) \to Hi(a)$
2. $Hs(b) \land Hn(b) \to U(b)$
3. $R(c) \land Hn(c) \to J(c)$
4. $U(d) \land J(e) \to F(d, e)$
5. $J(f) \land Hi(g) \to F(f, g)$
6. $F(h, i) \land F(i, j) \to F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$

$\boxed{F(G, S)}$

Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
11. $F(S)$



Exercise 4 – Backward Chaining $F(G, S)$

1. $Hs(a) \wedge F(a) \rightarrow Hi(a)$
2. $Hs(b) \wedge Hn(b) \rightarrow U(b)$
3. $R(c) \wedge Hn(c) \rightarrow J(c)$
4. $U(d) \wedge J(e) \rightarrow F(d, e)$
5. $J(f) \wedge Hi(g) \rightarrow F(f, g)$
6. $F(h, i) \wedge F(i, j) \rightarrow F(h, j)$
7. $Hs(S)$
8. $Hs(G)$
9. $Hn(G)$
10. $J(B)$
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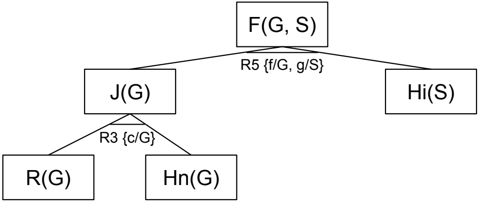

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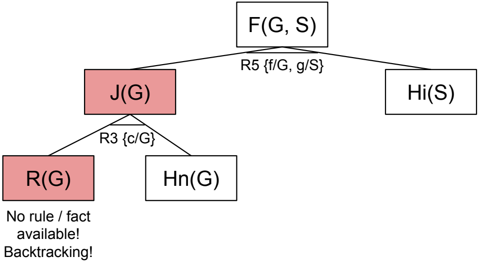

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$\boxed{F(G, S)}$

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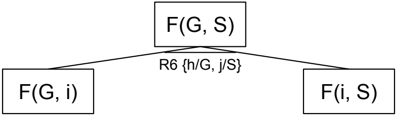

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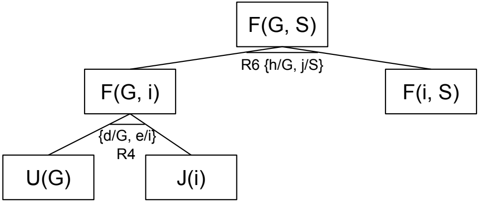

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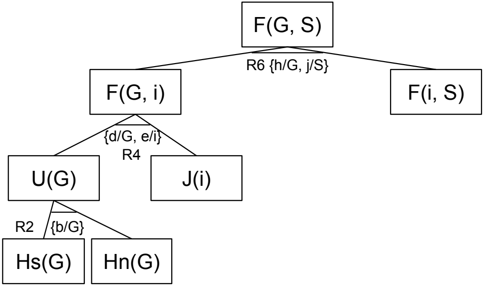

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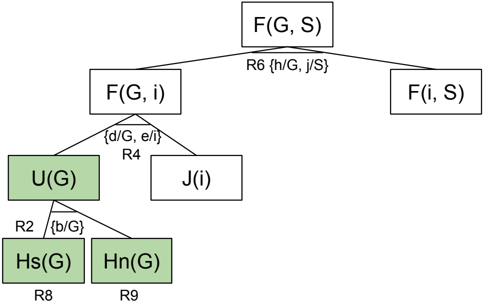

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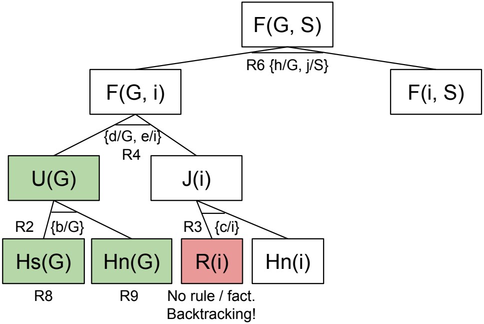

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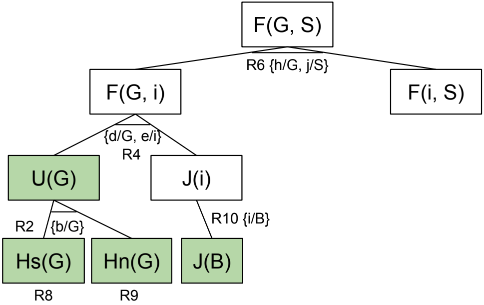

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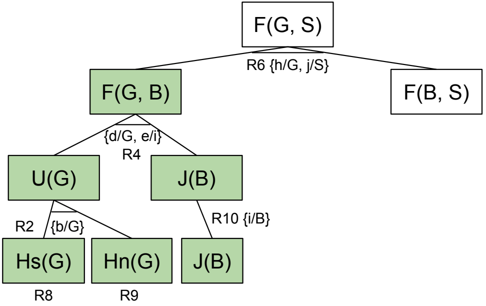

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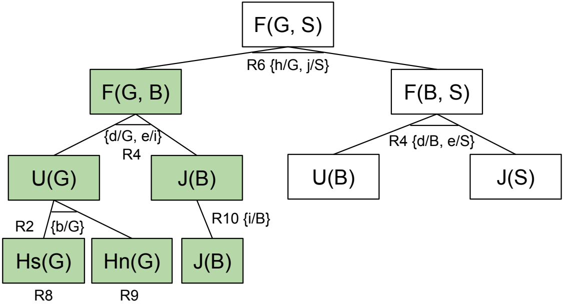

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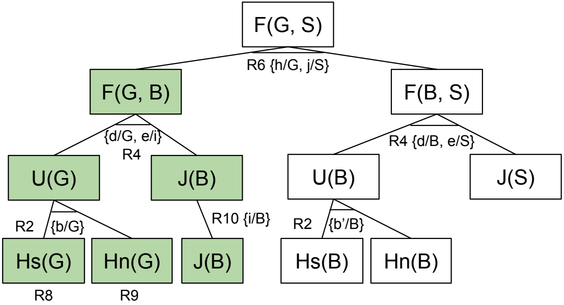

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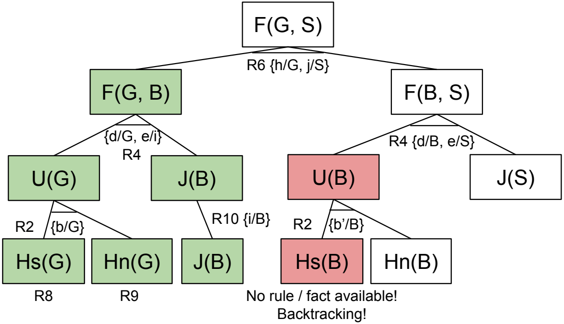

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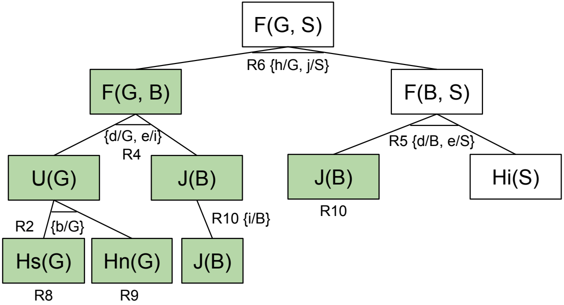

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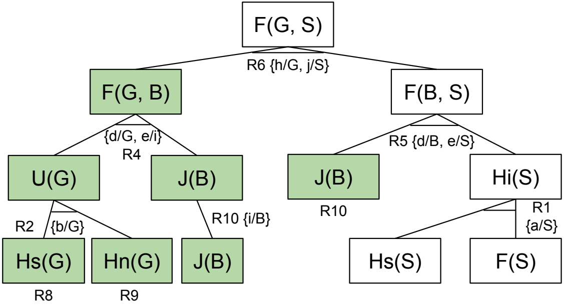

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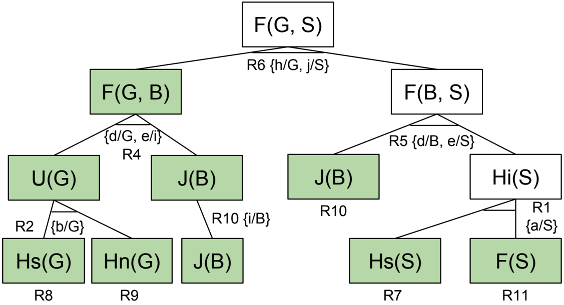

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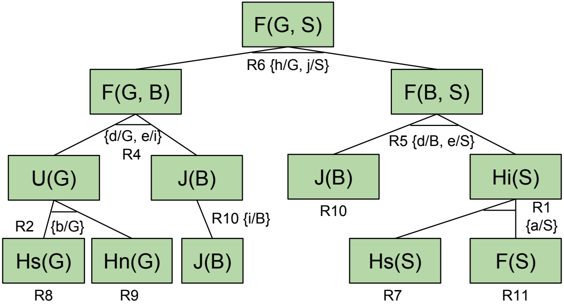

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Imagine many descriptions of individuals in the KB, like $Rabbit(Bugs)$, $Horse(FuManchu)$. Which algorithm would you use?

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- Forward Chaining first determines the "species" of each individual, then establishes relations.

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- Until now, Backward Chaining seemed wasteful: Runs into many dead ends.
- Forward Chaining first determines the “species” of each individual, then establishes relations.
- If we have many individuals, FC would unnecessarily expand all of them, even if they are unrelated to the query.
- **Backward Chaining** would focus the search!

Questions

?

Assignment 4 – Bayesian Nets, Reinforcement Learning

Topics

- Construct a Bayesian Net from a textual description of a domain.
- Write an algorithm that **learns** to play a (simple) game.

Deadline

- 25th of January 2016, 23:55
- You can even submit after the exam!