CSC384

Introduction to Artificial Intelligence: Knowledge Representation and Reasoning

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October 20, 2014 1 / 1

Introduction

- Today we cover converting first order knowledge bases into CNF
- We now move into material from chapter 9 next lecture will start from 9.2: unification

Converting to CNF clauses

An 8 step procedure for converting a first order knowledge base into CNF clauses:

- Eliminate implications
- Ove ¬ inwards
- Standardize variables
- Skolemize
- Onvert to prenix form
- Oisjunctions over conjunctions
- Ilatten nested conjunctions and disjunctions
- Onvert to clauses

Converting to CNF clauses

Step 1: Eliminate Implications

• $A \rightarrow B \mapsto \neg A \lor B$

3

Converting to CNF clauses

Step 2: Move Negations inwards

•
$$\neg (A \land B) \mapsto \neg A \lor \neg B$$

• $\neg (A \lor B) \mapsto \neg A \land \neg B$
• $\neg \forall X.f(X) \mapsto \exists X.\neg f(X)$
• $\neg \exists X.f(X) \mapsto \forall X.\neg f(X)$
• $\neg \neg A \mapsto A$

Step 3 Standardize variables

Rename variables such that each quantified variable is unique

• $\forall X.f(X) \land (\forall X.g(X)) \mapsto \forall X.f(X) \land (\forall Y.g(Y))$

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Step 4 Skolemize

Remove existential quantifiers by adding constants and functions:

• $\exists X.f(X) \mapsto f(a)$ for a new constant a

If there is universal quantification, instead of a constant you must use a new function which refers to all universally quantified variables

• $\forall XY \exists Z.f(X, Y, Z) \mapsto \forall XY.f(X, Y, g'(X, Y))$ where g' is a new function

Converting to CNF clauses

Step 5 Standardize variables

Bring all universal quantifiers to the front

•
$$\forall X.f(X) \land (\forall Y.g(Y) \land (\forall Z.h(Z))) \mapsto \forall XYZ.f(X) \land (g(Y) \land (h(Z))))$$

Steps 3 and 4 make this possible

Converting to CNF clauses

Step 6 Disjunctions over conjunction

•
$$A \lor (B \land C) \mapsto (A \lor B) \land (A \lor C)$$

Step 7 Flatten nested conjunctions and disjunctions

•
$$A \land (B \land C) \mapsto A \land B \land C$$

• $A \lor (B \lor C) \mapsto A \lor B \lor C$

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Step 8 Convert to clauses

Remove quantifiers, break conjunctions to individual clauses

•
$$\forall XY.(f(X) \lor g(Y)) \land (\neg f(X) \lor g(X) \lor h(Y)) \mapsto (f(X), g(Y)) (\neg f(X), g(X), h(Y))$$

All variables are now implicitly universally quantified