Problem assignment 6  
Due: Thursday, October 16, 2014

Propositional Logic

Problem 1. Inference with propositional rules.

Assume a simplified animal identification problem due to P. Winston. The knowledge needed for the problem consists of the following set of rules:

1. If the animal has hair then it is a mammal
2. If the animal gives milk then it is a mammal
3. If the animal has feathers then it is a bird
4. If the animal flies and it lays eggs then it is a bird
5. If the animal is a mammal and it eats meat then it is a carnivore
6. If the animal is a mammal and it has pointed teeth and it has claws and its eyes point forward then it is a carnivore
7. If the animal is a mammal it has hoofs then it is an ungulate
8. If the animal is a mammal and it chews cud then it is an ungulate
9. If the animal is a mammal and it chews cud then it is even-toed
10. If the animal is a carnivore and it has a tawny color and it has dark spots then it is a cheetah
11. If the animal is a carnivore and it has a tawny color and it has black strips then it is a tiger
12. If the animal is an ungulate and it has long legs and it has a long neck and it has a tawny color and it has dark spots then it is a giraffe
13. If the animal is an ungulate and it has a white color and it has black stripes then it is a zebra
14. If the animal is a bird and it does not fly and it has long legs and it has a long neck and it is black and white then it is an ostrich,
15. If the animal is a bird and it does not fly and it swims and it is black and white then it is a penguin
16. If the animal is a bird and it is a good flyer then it is an albatross.
The above set of rules can be represented in the propositional logic using implications of the form \( A_1 \land A_2 \land \cdots \land A_k \rightarrow B \), that is, all the statements are in the Horn form. Recall that inferences with modus ponens for KB in the Horn normal form are both sound and complete.

Assume a set of initial facts: the animal gives milk, it chews cud, it has long legs, long neck, tawny cloor and dark spots are all TRUE for the animal we want to identify. Assume the following set of theorems:

- Theorem 1: the animal is a giraffe;
- Theorem 2: the animal is a penguin;
- Theorem 3: the animal is a mammal.

Decide using the repeated application of the modus ponens inference rule whether Theorems 1-3 hold. For every theorem proved give a sequence of rules (their numbers) used to derive the conclusion.

**Implementation of logical inference with propositional rules**

The inferences with propositional rules are not that hard to implement. Two procedures for making logical inferences with propositional rules are: forward and backward chaining.

For the sake of simplicity we assume that the knowledge base is represented using two knowledge components:

- **rule-base** (RB) that consists of a set of rules;
- **fact base** (FB) that consists of a set of statements (facts) that are known to be true in the actual world.

The definition of a knowledge base and its components: rule base (RB) and fact base (FB) can be found in *kb.h*. Both the rule and the fact base are represented using simple list structures. Facts are represented as strings of characters. Rules are more complex and consist of:

- an antecedent (if part) represented by a list of facts that need to be satisfied;
- a consequent (then part) that corresponds to a simple fact that becomes true whenever the antecedent is true.
Part b. Forward chaining of propositional rules

Write a forwardchain procedure that takes a knowledge base (with rules and initial facts) and the theorem to be proved. It returns true if the theorem can be proved and false if it cannot. Your forward chaining procedure should:

- repeatedly scan rules with consequents that are not in the fact base;
- check whether the antecedent of a rule is satisfied: if yes, add the fact in the consequent of the rule to the fact base (and print the rule);
- report success if the theorem is in the fact base;
- report failure if no new fact was added during the last scan cycle.

Hint: Use functions: isin_RL_if, isin_RL_then, isin_KB, and equal functions to do testing and add_a_fact_to_KB to update the fact base.

Include the forward chaining procedure in file main6b.c. In addition, main6b.c should load the animal identification problem and run the forward chaining algorithm on three theorems THEOREM1, THEOREM2 and THEOREM3. To initialize the knowledge base and load the animal identification problem use the following functions: initialize_KB to initialize the KB structures, load_rules to load the rule base and load_facts to load the initial set of facts. The rules are in rules.txt and facts in facts.txt.

Part c. Backward chaining of propositional rules

The forward chaining procedure scans the rules “blindly” in the order in which they were defined. For more complex knowledge bases it may keep inferring facts that are not helping in proving the target theorem. An alternative inference technique, called backward chaining, alleviates this difficulty.

The backward chaining works on the proof backwards: it starts from the theorem. It checks all rules with antecedents equal to the theorem to see whether their antecedents are satisfied. If at least one of the rules is satisfied the fact is proved and added to the fact base. If not, the facts that are not known in the rule premise become new theorems to be proved and the backward chaining procedure is called recursively on new theorems. Note that there may be many rules with the same antecedent so before saying that the fact cannot be proved make sure that all rules are exhausted and cannot be used to prove the theorem.

Write a backwardchain procedure that takes a knowledge base and the theorem to be proved. It returns true if the theorem can be proved and false if it cannot. The procedure should print every rule that was satisfied and used to infer its consequent. Include the
forward chaining procedure in the file `main6c.c`. Similarly to part b. `main6c.c` should load the problem and run the forward chaining algorithm on three theorems THEOREM1, THEOREM2 and THEOREM3. Hint: Use list structures and functions for facts and rules to implement the procedure.

**First-order Logic**

**Problem 2**

Do exercise 8.9. from page 316 of the RN textbook.

**Problem 3**

Do exercise 8.10 from page 317 of the RN textbook.