COMP4418, 2013 – Assignment 1

Questions 1 & 2 Due: 11:59:59am Wednesday 28 August (Late penalty: 10 marks per day)
Questions 3 & 4 Due: 11:59:59am Wednesday 4 September (Late penalty: 10 marks per day)

Worth: $\frac{1}{3}$.

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1. [**10 Marks**] (Propositional Inferences)
   Prove that the following inferences hold in propositional logic using the truth table method.

   (a) $\models \neg p \vee p$

   (b) $p \models q \rightarrow p$

   (c) $(p \wedge q) \wedge r \models p \wedge (q \wedge r)$

   (d) $p \leftrightarrow q \models (q \leftrightarrow r) \rightarrow (p \leftrightarrow r)$

   (e) $p \leftrightarrow q \models (p \wedge q) \vee (\neg p \wedge \neg q)$

   Prove that the following inferences hold in propositional logic using resolution.

   (f) $\neg(p \vee q) \vdash \neg p$

   (g) $p \vdash p \vee q$

   (h) $p \leftrightarrow q \vdash \neg(p \leftrightarrow \neg q)$

   (i) $\vdash (\neg p \wedge \neg q) \rightarrow (p \leftrightarrow q)$

   (j) $p \rightarrow q,\ \neg r \rightarrow \neg q \vdash p \rightarrow r$

2. [**20 Marks**] (Logic Puzzle)
   Donald and Daisy Duck took their nephews aged 4, 5 and 6 on an outing. Each boy wore a tee-shirt with a different design on it and of a different colour. You are also given the following information:

   - Huey is younger than the boy in the green tee-shirt
   - The five year-old wore the tee-shirt with the camel design
   - Dewey's tee-shirt was yellow
   - Louie's tee-shirt bore the giraffe design
   - The panda design was not featured on the white tee-shirt

   (a) Represent these facts as sentences in first-order logic.

   (b) Using your formalisation in part (2a), is it possible to conclude the age of each boy together with the colour and design of the tee-shirt they're wearing? Show semantically how you determined your answer.

   (c) If your answer to part (2b) was 'no', indicate what further sentences you would need to add to your formalisation so that you could conclude the age of each boy together with the colour and design of the tee-shirt they're wearing.

3. [**20 Marks**] (Knowledge Representation and Reasoning)
Select a method for knowledge representation and reasoning that we have not covered in lectures and write 1–2 pages addressing the following:

   (a) briefly describe how the method represents knowledge and include an example;

   (b) briefly describe the inference procedure(s) adopted by the method for reasoning; and,

   (c) identify some importance issues in using the method (try and assess both advantages and shortcomings).

   In answering this question some sources you might consult include:

   - Ronald Brachman and Hector Levesque, *Knowledge Representation and Reasoning*, Morgan Kaufmann, 2004.
   - Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, Third Edition, Prentice Hall, 2010.
   - The *Principles of Knowledge Representation and Reasoning* conference series (`www.kr.org`).
   - The *Association for the Advancement of Artificial Intelligence* conference series (`www.ijcai.org`).
   - The *International Joint Conference on Artificial Intelligence* series (`www.aaai.org`).

4. [**50 Marks**] (Satisfiability)
Determining whether a set of clauses is satisfiable or not is a fundamental problem in knowledge representation and reasoning (and in artificial intelligence and computer science where it was the problem considered in describing the notion of NP-complete problems). In order to better understand the computational nature of the satisfiability problem, researchers have investigated various instances of the problem. One well studied instance is 3-SAT which focusses on the satisfiability of sets of clauses (i.e., disjunctions of literals) which have exactly three literals. For example, $\{p \vee q \vee r, p \vee \neg s \vee t\}$. 3-SAT is known to be NP-complete.

   It is also known that 3-SAT exhibits an *easy-hard-easy* computational pattern. Determining the satisifiability of sets of clauses that are small in relation to the total number of distinct propositional variables in the set is usually easy because there are fewer constraints in assigning truth values to the propositional variables. Determining the satisifiability of sets of clauses that are large in relation to the total number of distinct propositional variables in the set is usually easy because there are too many constraints to assign truth values to the propositional variables and the set is unsatisfiable. Somewhere in between these two extremes the satisfiability problem becomes hard.

   Your task in this question is to determine empirically at what point the satisfiability problem becomes difficult. More specifically, you are to determine, approximately, a constant value C for number of propositional variables n at which $C.n$ clauses constitutes a hard satisifiability problem.

   To help you in this task, the satisfiablity solver `minisat` is available on the CSE machines from:

   ```
   ~morri/bin/minisat
   ```

   You can run this program as follows:

   ```
   ~morri/bin/minisat file.cnf
   ```

   where `file.cnf` is a file containing clauses in CNF in DIMACS format. DIMACS format consists of three types of lines:

   - lines beginning with the letter `c` are comments;
   - one line with the format `p cnf` *variables clauses* where *variables* is the number of propositional variables and *clauses* is the number of clauses;

- lines specifying clauses where a positive literal is specified by a number (identifying the literal) and a negative literal is specified by the corresponding negative number; each line is terminated by the number `0`.

For example, the set of clauses $\{p \vee q \vee r, p \vee \neg s \vee t\}$ would be represented DIMACS formart as:

```
c example CNF file with 5 propositional variables and 2 clauses
p cnf 5 2
1 2 3 0
1 -4 5 0
```

While you can write your own satisfiability solver and are welcome to do so, your task is to write a program to randomly generate test files containing clauses and to use these test files to empirically determine the value C explained above.

You are then to write a report explaining your empirical results and how you determined the value C. The use of tables and graphs to support your results is desirable.

For this question you must submit your report and any source code files used in answering this question.

Submission

There are two parts to your assignment submission.

- Your answers to Questions 1 and 2 in a PDF file which can be submitted using the command:

  `give cs4418 a1_1 file.pdf`

  The deadline for this submission is 11:59:59am Wednesday 28 August.

- Your answers to Questions 3 and 4 in a PDF file along with any source code files used in answering Question 4 can be submitted using the command:

  `give cs4418 a1_2 file.pdf other-files`

  The deadline for this submission is 11:59:59am Wednesday 4 September.