CIS 730 Artificial Intelligence
CIS 530 Introduction to Artificial Intelligence
Fall 2018

Homework 7 of 10: Machine Problem
Reasoning and Learning, Part I: Clausal Form Concluded;
Intro to Probabilistic Reasoning (Hugin) & Machine Learning (WEKA)

Assigned: Sun 28 Oct 2018
Due: Mon 05 Nov 2018

The purpose of this assignment is to exercise your knowledge of clausal form (conjunctive normal form) and the INSEUDOR transformation. You will also practice using some concepts we have just covered: basic probabilistic reasoning (inference and causality) using the Hugin Lite and TETRAD software packages, and the Waikato Environment for Knowledge Analysis (WEKA).

This homework assignment is worth a total of 100%.
Each problem is worth 20% for both CIS 530 and 730 students.

References

***TETRAD V*:** http://www.phil.cmu.edu/projects/tetrad/
Hugin Lite: https://www.hugin.com/index.php/hugin-lite/
WEKA: http://www.cs.waikato.ac.nz/ml/weka/

Conjunctive Normal Form (CNF) converter

Recall the following specification from MP5-1 & MP5-2.

```
# The hash mark denotes comments (ignore the entire line).
# The first non-comment line contains the number of sentences.
3
# The second non-comment line starts the sentences.
# Syntax:
#     \A denotes UNIVERSAL QUANTIFICATION (\forall)
#     \E denotes EXISTENTIAL QUANTIFICATION (\exists)
#     => denotes IMPLICATION (\rightarrow)
#     & denotes CONJUNCTION, i.e., AND
#     | denotes DISJUNCTION, i.e., OR (\vee)
#     ! denotes NEGATION, i.e., NOT (\not)
#     = denotes EQUALITY (NOTE: this is OPTIONAL in the regular MP)
#     . separates each quantified variable from its scoped expression
# Conventions:
#     - All variables are lowercase
#     - All constants are alphanumeric names in ALL CAPS
#     - All predicates contain alphanumeric characters or _, begin with
#       a capital letter, and enclose their arguments in parentheses
#     - All functions contain alphanumeric characters or _, begin with
#       a lowercase letter, and enclose their arguments in parentheses
#     - Use C/C++ precedence for & and |
\A x . \A y . P(x, y) => \E z . Q(x, z) & !R(y, z)
Husband_Of (JOE1, SUSAN)
Longer (left_leg_of(RICHARD), left_leg_of(JOHN)) & (Foo() | bar = baz)
```

```
# Correct answers:
# 1. {!P(x_1, y_1), Q(x_1, sf1(x_1, y_1))},
#    {!P(x_2, y_2), !R(x_2, sf1(x_2, y_2))}
# 2. {Husband_Of (JOE1, SUSAN)}
# 3. {{Longer (left_leg_of(RICHARD), left_leg_of(JOHN))},
#     {Foo(), bar = baz}}
```

1. **(530/730) Implications, De Morgan's Theorem, and Standardizing Variables Apart.**

   730 students: Perform the "UDOR" part of the "INSEUDOR" procedure for conversion to clausal (conjunctive normal) form. Print the resulting intermediate version of expressions given as standard input. Turn in `mp7_1`, a revised version of your scanner/parser code or spec.

   530 students: Perform the full conversion of the first example above by hand using INSEUDOR (not the textbook's procedure). Show your work on all eight (8) INSEUDOR steps. Explain where any step is vacuous, i.e., results in the same output as the input with no change, and explain what would cause work to be done in this step with a concrete example. You may complete the 730 part above for extra credit (25%) by the due date of Homework 9.

2. **(530/730) TETRAD.** Download TETRAD v5.3 from **http://bit.ly/tetrad-download-current** and refer to the manual (under Help → TETRAD Manual).

   Create the following Bayesian networks, including CPTs, using TETRAD:

   a) The murder trial BN specified in Section 2.2 of "Fusion, Propagation, and Structuring in Belief Networks" by Judea Pearl (see http://bit.ly/pearl-bayesnets-1986 and the Handouts directory in Canvas).
   b) The Asia network (see http://bit.ly/asia-bayesnet).

   Save the networks and turn in `ps7_2a.tet` and `ps7_2b.tet`. In your final homework, you will use TETRAD to implement Bayesian network structure learning from data.

3. **(530/730) Hugin.** Download Hugin Lite for your platform from **http://bit.ly/hugin-lite-demo**, install it, and use it to construct the Bayesian network for the Apple Tree tutorial, following the instructions in **http://bit.ly/hugin-tutorial-build-bn**. Turn `ps7_3.zip`, an archive containing screenshots of your demo as you step through the construction and running of the model. **What kind of temporal Bayesian network representation does the network implement?**

4. **(530/730) WEKA.** Download WEKA v3.8.3 from **http://bit.ly/weka-download** (the stable version, v3.8.3, will also suffice), install it, and run it in Explorer mode. Run decision tree induction (J48) on the Mushroom data set, in the Classify tab. Turn `ps7_4.txt`, the classifier output including the accuracy and other performance measures, and the confusion matrix. What is the average validation set accuracy?

5. **(730 only) Influence Diagrams (Decision Networks) in Hugin.** Complete the Apple Tree influence diagram tutorial as well, as we discussed in class.

Extra Credit (25%)

530:

a) Complete the CIS 730 part of MP7-1 by the due date of Homework 9 **or**

b) Write a short essay (a couple of paragraphs to a page) discussing the relative merits (pros and cons) of bounded cutset conditioning, junction tree, and variable elimination algorithms for Bayesian network inference that we discussed in class.

730: Complete MP7-EC(b), the short essay, above.

Class Participation (required)

Post to the MP7 discussion thread on Canvas any questions about any part of this assignment, about probabilistic reasoning and machine learning, or about your term project.

Coming Up Next (note revised due dates)

Problem Set 8 (due Fri 09 Nov 2018) – Reasoning and Learning, Part II: Probabilistic Reasoning (Inference and Causality), Version Spaces, and Decision Trees; The Waikato Environment for Knowledge Analysis (WEKA). You will solve some Bayesian network reasoning and learning tasks and a few classification problems to simulate the behavior of supervised inductive learning algorithms, and continue working with classification models in WEKA.

Machine Problem 9 (due Fri 16 Nov 2018) – Perception and Understanding, Part I: Artificial Neural Networks (ANNs) and Genetic and Evolutionary Computation (GEC). You will apply ANN and GEC to a pattern recognition or obstacle avoidance task for a simple mobile robot.

Problem Set 10 (due Fri 30 Nov 2018) – Perception and Understanding, Part II: Natural Language Processing (NLP), and Vision. You will solve problems and answer some discussion questions about perception and understanding. (This will include some practice final exam questions.)