TFCS Assignment Test

Semester 2, 2015

**Time:** 70 minutes plus 5 minutes of reading time. During reading time you may make notes on this question paper but may not write in your answer booklet.

**Total Marks:** 64 (Marked out of 60)

**Instructions:** Attempt all questions. Write your answers in the answer booklet. This question paper will not be marked and you can keep it after the test.

This is a closed-book test. No calculators or other materials are allowed. Make sure that your telephones are turned off and remove all non-essential items from your table.

# Question 1 (10 Marks)

The controller for a railroad crossing light receives input from a senor on the railway line some distance away. Once per five seconds, the pressure pad sends a digit to the controller; 1 if a train has been sensed passing and 0 if all is clear. Normally the controller is in the ‘inactive’ state, meaning that the boom gates are up and the alerts are turned off. When a 1 is received in such a state, the controller switches to a ‘warning’ state causing alerts to sound. Five seconds later the controller switches to a ‘closed’ state, meaning that the boom gate lowers while the alerts continue. After 30 seconds in the ‘closed state’ in which no 1s have been received, the controller returns to ‘inactive’ state, causing the boom gate to raise and the alarms to stop. And 1s received during the ‘closed’ state cause the 30 second countdown to reset.

1. If you assume that the input will eventually halt (the line goes down for maintenance on occasion) and that there is a way to observe the state in the machine, what is the classification (tier) of this problem? **(2 marks)**
2. Give a machine that decides the problem under the assumptions from a) above.

**(5 marks)**

1. What is the language of this problem? Depending on your answer to b) a rough description may be appropriate. **(2 marks)**
2. If we did not make the assumption that the input was finite, how would this affect the classification (tier) of the problem? Justify your answer. **(2 marks)**

# Question 2 (16 Marks)

A conspiracy theorist has decided that Garfield cartoons form a secret code. The idea is that each panel in each cartoon is assigned a ‘character number’, which is the number of main characters (Garfield, Odie and Jon) who are clearly visible in that panel. The character numbers then form a string, which is then translated into binary and hence into English.

A linguistics expert has pointed out that if such a code were to exists, certain groupings would naturally occur more than any other. In particular, the sequence 011 would occur roughly three times as often as 030 and twice as often as 020.

The problem is to write a program that checks a string of ‘character numbers’ to see if the expected frequency is upheld.

1. Classify this problem. **(2 marks)**
2. Give a machine that decides the problem (and show that it is a decider, if in Tier **(7 marks)**

AND

1. Prove that the problem is not at a lower level. **(7 marks)**

OR

1. Prove that this machine is not decidable using reduction from ATM **(14 marks)**

# Question 3 (5 Marks)

A Sudoku buff has just come across Addoku for the first time. Sometimes referred to as “sum doku” or “killer Soduko”, this game involves a 3x3 grid of 3x3 cells much like Soduko. Unlike Soduko, there are no numbers pre-inserted in the squares, but instead each square is part of exactly one contiguous grouping of cells and each such grouping has its sum given. The buff had heard that Sudoku is NP-Hard (although he doesn’t know what it means) and asks you whether that is true and whether this new game might be even harder.

Classify this problem and briefly explain the reasoning behind your classification. You do not need to give any proofs.

# Question 4 (7 Marks)

A computing lecturer who is keen on setting high standards asks his students to not only learn about Bayesian networks, but to actually write a program to infer the value of the hidden variables of any network given as input; formally the task is to compute the exact probabilistic inference of the Bayesian network.

Classify this problem. If the problem is in P, give an algorithm that decides the problem and show that it is polynomial in time. If the problem is in NP but not P, prove this (you do not need to give full details of this proof). If the problem is classified as NP-Complete or NP-Hard, state the classification and give a rough sketch of the proof (no details are required, but you must state what problem you are reducing to/from).

# Question 5 (17 Marks)

A machine is to be designed that automatically adjusts the alignment of the Square Kilometre Array of radio dishes to focus on more interesting phenomena. Two new circuits are added, one for north-south adjustment and one for east-west adjustment. Your job is to design the ‘focus east’ part of the circuit for the latter.

Your part of the circuit will receive inputs from classifiers that determine whether enough interesting events have occurred to move the focus of the array eastwards. The classifiers send a two-bit binary string that is 00 when nothing interesting has occurred, 10 when something interesting has occurred in the eastern section of the array, 01 when something interesting has occurred in the western section and 11 when something interesting has occurred in the northern or southern sections.

The exact problem is to determine whether there have been at least twice as many interesting events in the eastern section as there have been events in the other two sections combined.

Classify this problem and prove its classification in the usual way.

# Question 6 (5 Marks)

As part of creating an AI programming machine, your team is tasked with writing a universal syntax checker. The program should load a set of syntax specifications for a programming languages (such as C or Java) and a program, and test to see whether the program meets the syntax specification.

State the classification of this problem and briefly outline how you would prove this classification. You do not need to give any details; one or two sentences should be enough to show that you know how to build a machine and/or perform the reduction.

# Bonus Question (4 Marks)

True Quantified Boolean Formula Problem (QBF) is defined as the generalization of SAT by the addition of quantifiers. This problem has been shown to be PSPACE-Complete. Describe this complexity class.

**Note:** The marks from this question are bonus marks that raise the possible marks obtainable above 60.