### Class 21BIT – Term II/2023-2024

### Course: CS300 – Artificial Intelligence

Homework 03

***Submission Notices:***

* *Conduct your homework by filling answers into the placeholders given in this file (in Microsoft Word format). Questions are shown in black color, instructions/hints are shown in italic and blue color, and your content should use any color that is different from those.*
* *After completing your homework, prepare the file for submission by exporting the Word file (filled with answers) to a PDF file, whose filename follows the following format,*

*<StudentID-1>\_<StudentID-2>\_HW02.pdf (Student IDs are sorted in ascending order)*

*E.g.,* ***2152001\_2152002\_HW02.pdf***

*and then submit the file to Moodle directly WITHOUT any kinds of compression (.zip, .rar, .tar, etc.).*

* *Note that you will get zero credit for any careless mistake, including, but not limited to, the following things.*
  1. *Wrong file/filename format, e.g., not a pdf file, use “-” instead of “\_” for separators, etc.*
  2. *Disorder format of problems and answers*
  3. *Conducted not in English.*
  4. *Cheating, i.e., copying other students’ works or let the other student(s) copy your work.*

**Problem 1. (3pts)** Let’s consider a propositional language where

*A =“An comes to the party”,*

*B =“Binh comes to the party”,*

*C =“Chi comes to the party”,*

*D =“Dung comes to the party”.*

Formalize the following sentences*:*

*1. If Dung comes to the party then Binh and Chi come too.*

*2. Chi comes to the party only if An and Binh do not come.*

*3. If Dung comes to the party, then, if Chi doesn’t come then An comes.*

*4. Chi comes to the party provided that Dung doesn’t come, but, if Dung comes, then Binh doesn’t come.*

*5. A necessary condition for An coming to the party, is that, if Binh and Chi aren’t coming, Dung comes.*

*6. An, Binh and Chi come to the party if and only if Dung doesn’t come, but, if neither An nor Binh come, then Dung comes only if Chi comes.*

Please write your answers to the following table.

|  |  |
| --- | --- |
| *1 (0.5pt)* | *D→(B∧C)* |
| *2 (0.5pt)* | *C→(¬A∧¬B)* |
| *3 (0.5pt)* | *D→(¬C→A)* |
| *4 (0.5pt)* | *C↔¬D∧(D→¬B)* |
| *5 (0.5pt)* | *A→(¬B∧¬C→D)* |
| *6 (0.5pt)* | *(A∧B∧C)↔¬D∧(¬A∧¬B→(C→D))* |

**Problem 2. (4pts)** Consider the following statement.

*“(1) Either taxes are increased or if expenditures rise then the debt ceiling is raised. (2) If taxes are increased, then the cost of collecting taxes rises. (3) If a rise in expenditures implies that the government borrows more money, then if the debt ceiling is raised, then interest rates increase. (4) If taxes are not increased and the cost of collecting taxes does not increase then if the debt ceiling is raised, then the government borrows more money. (5) The cost of collecting taxes does not increase. (6) Either interest rates do not increase, or the government does not borrow more money.* Prove by resolution that *(7)* Either the debt ceiling is not raised, or expenditures do not rise.*”*

Let T be taxes are increased C be cost of collecting taxes rises

E be expenditures rise G be government borrows more money

D be debt ceiling is raised I be interest rates increase

*Note that you do not need to handle* [*the exclusiveness of the grammar structure “either…or”*](https://www.merriam-webster.com/dictionary/either-or)*, just consider them as simple “or”.*

(2pts) Translate the English sentences into propositional logic sentences

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.** | Sentences | **No.** | Sentences | **No.** | Sentences |
| 1 | T∨(E→D) | 4 | (¬T∧¬C)→(D→G) | 7 | Not needed |
| 2 | T→C | 5 | ¬C | 8 | ¬(D∨E) |
| 3 | (E→G)→(D→I) | 6 | ¬I∨¬G | 9 | ¬(D∨E) |

(1pt) Convert propositional logic sentences into CNF.

|  |  |  |
| --- | --- | --- |
| No. | Sentences | Notes the sentence’s sources. |
| 1 | T∨(¬E∨D) | From 1 |
| 2 | ¬T∨C | From 2 |
| 3 | ¬E∨G∨D∨¬I | From 3 |
| 4 | T∨C∨G∨¬D | From 4 |
| 5 | ¬C | From 5 |
| 6 | ¬I∨¬G | From 6 |
| 7 | Not needed |  |
| 8 | ¬D∧¬E | Negated goal |
| 9 | ¬D∧¬E | Negated goal |

(1pt) Prove by resolution that either the debt ceiling is not raised, or expenditures do not rise.

|  |  |  |
| --- | --- | --- |
| No. | Sentences | Notes the sentence’s sources. |
| 10 | ¬D | From 5, 8 (resolution) |
| 11 | ¬E | From 5, 8 (resolution) |
| 12 | ¬G | From 4, 11 (resolution) |
| 13 | ¬T | From 2, 5 (resolution) |
| 14 | C | From 2, 5 (resolution) |
| 15 | ¬T | From 1, 9 (resolution) |
| 16 | ¬D | From 1, 9 (resolution) |

Conclusion: ¬D∨¬E Disjunction of resolved literals

**Problem 3. (3pts)** Given a chess board with 4 rows and 4 columns (4x4) as below.

|  |  |  |  |
| --- | --- | --- | --- |
| A black chess piece on a white background  Description automatically generated |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

* + 1. (1pt) Place 4 queens on the board so that they are not able to attack each other.

*Please fill your answer in the given table below*

|  |  |  |  |
| --- | --- | --- | --- |
|  | A black chess piece on a white background  Description automatically generated |  |  |
|  |  |  | A black chess piece on a white background  Description automatically generated |
| A black chess piece on a white background  Description automatically generated |  |  |  |
|  |  | A black chess piece on a white background  Description automatically generated |  |

* + 1. (2pts) Assign a Boolean variable to each cell of the board as below (*1, 2, 3, etc. are variable names*)

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 |

If a variable is True, then there is a queen on the corresponding cell and vice versa.

Use CNF clauses to describe constraints to place a queen on cell no. 1 (*use -1 to denote NOT 1*).

*Hint: if there is a queen on cell no. 1, then there mustn’t any queens on cell no. 2, 3, etc.*

*Please fill your answer in the table below (add more rows as needed)*

|  |  |  |
| --- | --- | --- |
|  | −1∨−2 |  |
|  | −1∨−3 |  |
|  | −1∨−4 |  |
|  | −1∨−5 |  |
|  | −1∨−6 |  |
|  | −1∨−7 |  |
|  | −1∨−8 |  |
|  | −1∨−9 |  |
|  | −1∨−10 |  |
|  | −1∨−11 |  |
|  | −1∨−12 |  |
|  | −1∨−13 |  |
|  | −1∨−14 |  |
|  | −1∨−15 |  |
|  | −1∨−16 |  |