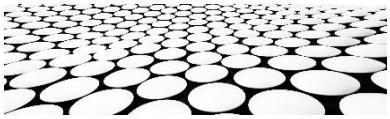
CSI4106 Introduction to Artificial Intelligence



ASSIGNMENT 3
Reasoning in Humans and AI

GOALS

This assignment is different from the previous two assignments, in the sense that there is no programming to do, but rather you have to do some reading/exploration to answer some questions.

The overall goal of this assignment is that you gain more insight into the different types of reasoning explored in class.

At the end of this assignment, you will have:

- Experimented on doing proofs in prepositional logic using rules of inference and equivalence
- Further understood how to translate from natural language to predicate logic (and see the expressiveness limitations of such logic)
- Learned about fuzzy logic to devise a simple fuzzy logic system.
- Explored different types of reasoning
- Explored different types of causal fallacies
- Tested a Large Language Model (with ChatGPT) with regards to its ability to perform different types of reasoning.

SUBMISSION INFORMATION

- Deadline:
  - Submission of your report: **Sunday, November 12, midnight**
- Groups:
  - You are expected to form groups of 2 and do a single submission per group. You first need to register your group in Brightspace (D3 groups) to later be able to do a group submission.
  - As I want to allow groups to change at each assignment (if you want), I need to create a new set of groups for each assignment. You therefore need to register again in D3 groups.
  - If you prefer to work alone, that is fine, but the requirements are not changed.
- Where to submit:
  - Your submission MUST be done in Brightspace in Assignment section (Assignment 3)
  - Do not send the reports by email.
  - If you do not see a submission link in Brightspace, it's because you have not registered your group (as D3 group).
- Submission format:
  - Your submission MUST be a pdf file.
  - Answer each question in order. Clearly indicate, in the report, which question is being answered to make the report easy to read.
  - In terms of the length required for each question, just use as much (or as little) space necessary to provide an answer that is clear and concise. There are no minimum required number of paragraphs per question. Nevertheless, it is expected that answers do provide explanations (and not just claims).

TUTORIALS/TECHNOLOGIES

This is not a programming assignment, so there are programming language nor software library to learn.

Nevertheless :

- You do have to review your course slides to perform this assignment. The material covered is from Week 7 – Logical Reasoning, and Week 9 – Reasoning.
- Some questions require additional reading (links provided).
- To answer the question on Fuzzy Logic, you need to watch the Fuzzy logic videos (3-part series) recorded in 2020 (as part of a previous version of the course CSI4106).

REQUIREMENTS

There are 7 questions to answer. The number of points for each question is given.

For each question, make sure you read the **TO DO**, which tells you what is expected of you for that question.

Q1 – Propositional logic and proofs (10 points)

This book, A Concise Introduction to Logic, by Craig DeLancey is freely available online.

https://milnepublishing.geneseo.edu/concise-introduction-to-logic/

Chapter 4 talks about proofs and is an easy read.

https://milnepublishing.geneseo.edu/concise-introduction-to-logic/chapter/4-proofs/

In 4.5, there are some exercises suggested.

e. Premises: **(S→¬Q)**, **(P→S)**, **¬¬P**. Show: **¬Q**.
f. Premises: **(T→P)**, **(Q→S)**, **(S→T)**, **¬P**. Show: **¬Q**.
g. Premises: **R, P, (P → (R → Q))**. Show: **Q**.
h. Premises: **((R→S)→Q)**, **¬Q**, **(¬(R→S)→V)**. Show: **V**.
i. Premises: **(P→(Q→R))**, **¬(Q→R)**. Show: **¬P**.
j. Premises: **(¬(Q→R)→P)**, **¬P**, **Q**. Show: **R**.
k. Premises: **P**, **(P→R)**, **(P→(R→Q))**. Show: **Q**.
l. Premises: **¬R**, **(S→R)**, **P**, **(P→(T→S))**. Show: **¬T**.
m. Premises: **P**, **(P→Q)**, **(P→R)**, **(Q→(R→S))**. Show: **S**.
n. Premises: **(P→(Q→R))**, **P**, **((Q→R)→¬S))**, **((T→V)→S)**. Show: **¬(T→V)**.

TO DO:

- Choose **4 proofs to do** (between e and n shown above) that you prove using rules of inferences and equivalence.
- Present each proof as we saw in class (*Week 7 – Logical reasoning - Slide 55*).
    - Start each proof by stating the premises and assign a different number to each one. You will be able to refer to each premise by its number later on.
    - In every intermediate step (step leading to the final conclusion), clearly state what is derived (either inferred or equivalent) and explain the specific rule used. Assign a unique number to each intermediate step so you can refer to that number in later steps of the proof.
    - If you use equivalence or inference rules from other resources than the slides presented in class (*Week 7 – logical reasoning, slides 46-50*), **you need to cite them and give the link**.
    - You can write the proofs with any edition software that you like, or write them on a paper and scan it. Make sure the correctors can read easily read what is written.

Q2 – Predicate logic (10 points)

Predicate logic has a certain expressive power. There are facts it can express and others it cannot. Its representation relies mostly on predicates (unary and binary) and on quantifiers (universal and existential).

TO DO:

Express the following statements in **predicate logic**. If you think the statement cannot be expressed in predicate logic, explain why.

1. All graduate students have an undergraduate degree.
2. Anyone with an undergraduate degree studied in at least one university.
3. A university, at any particular year, delivers courses to many students.
4. For a professor to teach a course, there must be at least a student registered in it.
5. A class is called a large class if at least 100 students are part of it.
6. Classmates are students taking the same course.
7. A graduate student takes less courses than an undergraduate student.

You can write the predicate logic expressions with any edition software that you like, or write them on a paper and scan it. Make sure the correctors can read easily read what is written.

You can look at (*Week 7 – Logical reasoning – Slide 61*) for examples of Natural Language to predicate logic translations.

Q3 – Fuzzy logic (15 points)

For this question, you will need to watch 3 videos, recorded in 2020, presenting fuzzy logic in more details. Those videos are available on Brightspace. After watching these videos, you will have the necessary knowledge to answer the question.

You have to develop a fuzzy logic system for representing the impact of stress level and leisure time on quality of sleep. I know we are not expert in the field… but each of you can make up their own fuzzy sets and rules based on their experience. *The purpose of the question is to practice developing a fuzzy logic system, not on its accuracy*.

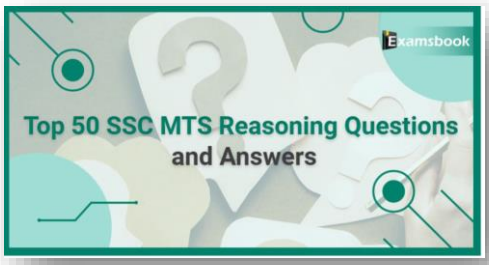
TO DO:

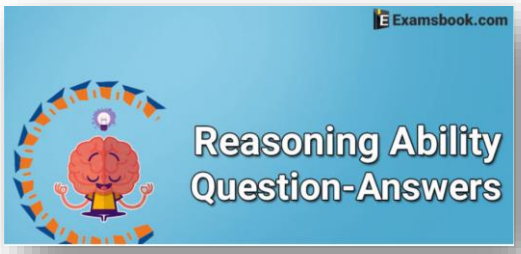
- Define 3 linguistic variables for sleep, leisure and stress. For each one, define its name, range (min/max values) and fuzzy subsets. For example, stress level can range from 1 to 15 and there could be 4 subsets (Calm, Moderate, Intense, Extreme). Each fuzzy subset should define the membership degrees associated with them. For doing so, draw a membership graph which provides the degree of membership of each value in your range to each subset defined. You should have 3 graphs. Remember, **subsets should (at least in part) overlap**.
- Define 3 fuzzy rules which use in different combinations the fuzzy sets defined (e.g. *if stress level is Intense and leisure is minimal then sleep quality is poor*). In those rules, stress and leisure are the antecedents, and sleep is the consequence. Each of your rules should be expressed as IF… THEN…
- Show an example of using fuzzy inference with your rules to establish a sleep quality (consequence) based on leisure time and stress level (antecedent). For doing so:
    - define an actual input (e.g. stress = 9 and leisure = 2 hours)
    - transform such input into membership values to your subsets
    - apply your 3 fuzzy rules to obtain membership values to the output set
    - transform the membership value of sleep to an actual number within the range that you decided.

ATTENTION: This situation is totally hypothetical, and you can make the linguistic variables and the rules as you like. Just try to make the system a bit realistic (e.g. if stress level if "very high", the sleep quality should not be "very good").

Q4 – Reasoning (10 points)

We looked at different questions in class (*Week 9 – Reasoning*) related to different types of reasoning. These questions were taken from tests available at different sources (*Week 9 – Reasoning – Part 1 – Slide 14*). Here are 2 examples of sources.





TO DO:

Within these sources (or others that you may find), find additional examples for each of the following type of reasoning:

- constraint-based reasoning
- inductive reasoning
- analogical reasoning
- temporal reasoning
- spatial reasoning

For each type of reasoning:

- Show the example and cite its source
- Explain why it's a good example of that type of reasoning
- Explain if there are other types of reasoning intertwined with the main type
- Show how to solve it (just give a few main steps) and discuss required knowledge to do so
- In class, we discussed the distinction between what is problem specific and what is generic enough to be transferable from one problem to another (within the same type of reasoning). Mention, for your example, what is specific and generic.

Q5 – Causal fallacies (10 points)

We saw in class (*Week 9 – Reasoning – Part 1*) how causal reasoning is not trivial, and texts (newspapers) are sometimes full of causal fallacies.

In this source (https://www.slideserve.com/Gabriel/argument-reasoning), Cause-Effect reasoning is presented starting on slide 16 (after discussing deductive and inductive reasoning). On slides 18-20, a few types of fallacies are mentioned:

- Glittering generality
- Card Stacking
- Bandwagon Appeal
- Unrelated Testimonial
- Name Calling

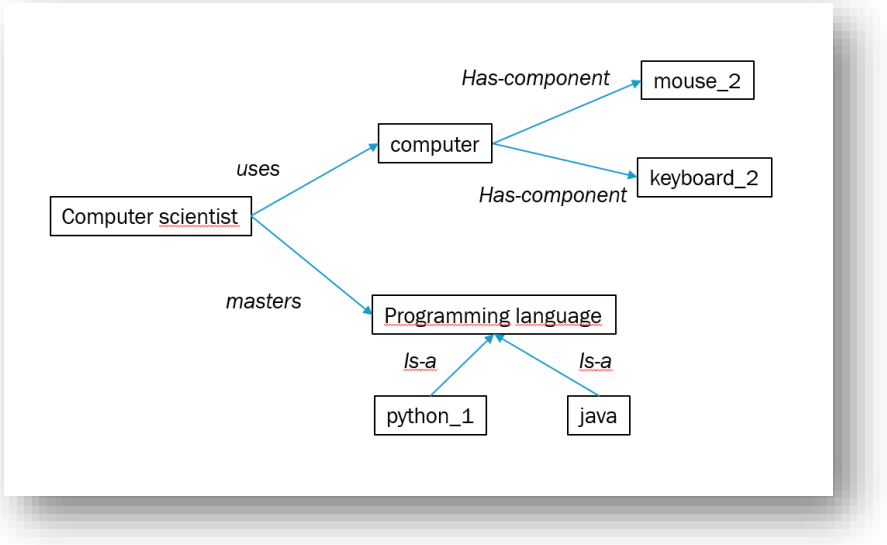
TO DO:

- Find examples in newspapers (or blogs, or social media) for the 5 different types of fallacies mentioned above. If you prefer, use 3 of the above and use 2 other types of fallacies seen in the lecture (Slide 42, e.g. appeal to ignorance, hasty generalization, etc).
- For each example, explain why it is a good example of the type of error, and provide the source (where does the example come from).

Q6 – Knowledge Representation (15 points)

We saw in class (*Week 9 – Reasoning – Part 2*) how to build semantic networks, including various types of relations (is-a, has-component, attribute, other relations).

For example:



TO DO:

- Create a small semantic network representing a bit of "you". The network can include your friends, your home, your family, your meals, your activities… anything around you in your daily life.
- Your semantic network should contain at least 10 concepts/entity and show relations between subsets of these concepts.
- Your small semantic network should not include the entities provided in the figure above.
- Make sure the names given to the relations clearly expresses that relation.
- Make sure your network contains some is-a, part-of, attribute, and other relations.
- Show the network as a graph, depicting concepts as nodes and relations as directed edges (see figure above).
- If the graph is too big to fit on a page, you can provide a link to it. For example, a good tool is Draw.io (https://www.drawio.com/). Add the graph to the report (as well as you can) and provide a link as well. Make sure the corrector can access the link if you provide one.

Q7 – ChatGPT's reasoning capabilities (15 points)

We discussed in class (*Week 9 – Reasoning*) 10 different types of reasoning, as shown below.

1. Mathematical Reasoning
2. Deductive reasoning
3. Constraint-Based Reasoning
4. Causal reasoning
5. Inductive reasoning / Abstract reasoning

6. Similarity-based Reasoning
7. Analogical reasoning
8. Spatial Reasoning
9. Temporal Reasoning
10. Commonsense reasoning

Many people these days are interested in "putting to the test" large language models, like ChatGPT, in terms of their reasoning capabilities.

If you've never used ChatGPT, first experiment a bit with it, at https://chat.openai.com/auth/login

TO DO:

- Choose 5 types of reasoning, and for each one, define some tests to validate if ChatGPT can demonstrate such type of reasoning.
- Describe your tests. Describe the results. Where does ChatGPT it succeed? Where does it fail (or has issues)?
- Since ChatGPT is a non-deterministic system, it will answer differently every time. So submit it to the same test at least twice for each type of reasoning chosen. Discuss the consistency (or inconsistency) observed.
- What do you think?? Is ChatGPT "general AI" in the sense that it can perform all the reasoning tested?

☆☆☆ EVALUATION (on 100 points))

- Overall effort in the report (15 points)
  - Writing in a clear and descriptive style that will allow the corrector to easily read/understand what was done, how and why
  - Each question is clearly identified
  - The report has been check for typographic errors (*proof reading*)

- Answers to questions (85 points)
  - Q1 – Proofs in Propositional Logic (10 points)
  - Q2 – Predicate Logic from NL – expressive power (10 points)
  - Q3 – Fuzzy logic world (15 points)
  - Q4 – Examples of reasoning in human tests (10 points)
  - Q5 – Causal fallacies (10 points)
  - Q6 – Knowledge Representation (15 points)
  - Q7 – ChatGPT as "reasoner" (15 points)

QUESTIONS

- You can ask your questions within the Assignment topic of the discussion forum on Brightspace.
- You can also send an email to Baharin (balia034@uottawa.ca), but using the forum is a much preferred way as fellow students will benefit from your questions and Baharin's answers.