State-Based Model (MCO2)

In Partial Fulfillment of the Requirements for the Course:

CSINTSY (Introduction to Artificial Intelligence)

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I. Brief Introduction

Artificial Intelligence has revolutionized various fields, especially Natural Language Processing (NLP) and other logic-based applications. One of the standard applications of integrated AI, such as chatbots, can simulate human-like conversations and provide information based on user queries. This project aims to create a chatbot that can comprehend and infer family relationships, which requires a deep understanding of logical inference and knowledge representation.

The primary objective of the specs is to design and conduct a chatbot that will understand, store, and infer family-related information using a logic-based inference system. With this, the specifications require PROLOG, a logic programming language well-suited for logic-based representation and inference, along with the interface of Python with the *pyswip* package. The chatbot will be able to process user inputs or prompts in the form of statements and questions following the knowledge base update to provide accurate responses based on family relationships. The program will provide the language's capability to represent facts and rules. For instance, the knowledge base and the logical queries make it a plausible decision to perform the provided objective. Python will be the platform to process inputs and manage the chatbot's interface.

To specify the features of the chatbot, it is designed to handle prompts. These prompts are the basis for inputting new information about family members according to their names and enable users to query the chatbot about the user's family relationships. The given project demonstrates the application of constructing a system to highlight the significance of logical inference.

II. Knowledge Base

The chatbot makes use of the following formulas that are encoded in the knowledge base:

1. $\exists X, Y\ male(X) \ \wedge \ father(X, Y)$
   - Some male X is the father of some Y.
2. $\exists X, Y\ male(X) \ \wedge \ brother(X, Y)$
   - Some male X is the brother of some Y.
3. $\exists X, Y\ male(X) \ \wedge \ son(X, Y)$
   - Some male X is the son of some Y.
4. $\exists X, Y\ male(X) \ \wedge \ uncle(X, Y)$
   - Some male X is the uncle of some Y.
5. $\exists X, Y\ male(X) \ \wedge \ grandfather(X, Y)$
   - Some male X is the grandfather of some Y.
6. $\exists X, Y\ female(X) \ \wedge \ mother(X, Y)$
   - Some female X is the mother of some Y.
7. $\exists X, Y\ female(X) \ \wedge \ sister(X, Y)$
   - Some female X is the sister of some Y.
8. $\exists X, Y\ female(X) \ \wedge \ daughter(X, Y)$
   - Some female X is the daughter of some Y.
9. $\exists X, Y\ female(X) \ \wedge \ aunt\ (X, Y)$
   - Some female X is the aunt of some Y.
10. $\exists X, Y\ female(X) \ \wedge \ grandmother\ (X, Y)$
    - Some female X is the grandmother of some Y.
11. $\exists Y, X\ sibling(Y, X) \ \wedge \ sibling(X, Y)$
    - Some Y is the sibling of some X, and some X is the sibling of Y.
12. $\exists X, Y\ relative(X, Y) \ \wedge \ parent(X, Y)$
    - Some X is the relative of some Y, and X is the parent of Y.
13. $\exists X, Y\ relative(X, Y) \ \wedge \ parent(Y, X)$
    - Some X is the relative of some Y, and Y is the parent of X.
14. $\exists X, Y\ relative(X, Y) \ \wedge \ sibling(X, Y)$
    - Some X is the relative of some Y, and X is the sibling of Y.

15. $\exists X, Y\ relative(X, Y) \wedge brother(X, Y)$
    - Some X is the relative of some Y, and X is the brother of Y
16. $\exists X, Y\ relative(X, Y) \wedge sister(X, Y)$
    - Some X is the relative of some Y, and X is the sister of Y
17. $\exists X, Y\ relative(X, Y) \wedge uncle(X, Y)$
    - Some X is the relative of some Y, and X is the uncle of Y
18. $\exists X, Y\ relative(X, Y) \wedge aunt(X, Y)$
    - Some X is the relative of some Y, and X is the aunt of Y
19. $\exists X, Y\ relative(X, Y) \wedge grandfather(X, Y)$
    - Some X is the relative of some Y, and X is the grandfather of Y
20. $\exists X, Y\ relative(X, Y) \wedge grandmother(X, Y)$
    - Some X is the relative of some Y, and X is the grandmother of Y

III. Chatbot implementation

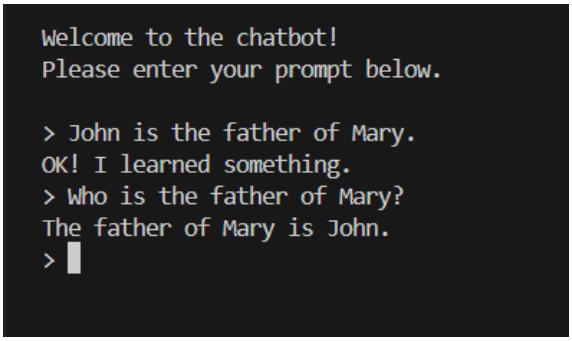
This chatbot uses the *PySWIP* library to connect Python and SWI-Prolog. The system can take in facts, process statements, infer new facts, and provide an answer given the base knowledge. The chatbot uses Prolog predicates, written as "*parent = Functor("parent," 2)*", making use of the Functor object in Python utilizing the *PySWIP* library. The chatbot interprets these statements similarly to how we would interpret predicate logic: "*parent(X, Y) indicates X is a parent of Y.*" The "*assertz*" predicate adds new facts to the knowledge base during runtime.

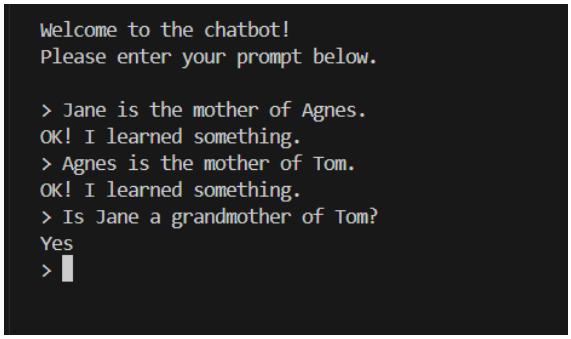
As stated earlier, the chatbot can infer facts from existing facts in the knowledge base. It employs logical rules to define relationships between facts, allowing new facts to arise from existing ones. The knowledge base gets updated while accounting for redundancy. The chatbot first processes statements using Python's *re* module for pattern matching. The statements then go under fact validation for logical consistency. After which, they are added using the "*assertz*" predicate. From there, the chatbot may use these new facts to infer more facts through rules. Lastly, a message is printed to show confirmation when the chatbot processes a statement.

For question processing, the chatbot uses Prolog queries from the *Pyswip Query* class to retrieve answers from the knowledge base. The chatbot is looped and will accept valid statements and questions from the user's input and promptly respond appropriately. For error handling, the chatbot can prevent contradicting statements and ensure valid relationships, keeping the logic in the knowledge base consistent with the facts going in and the ones already inside.

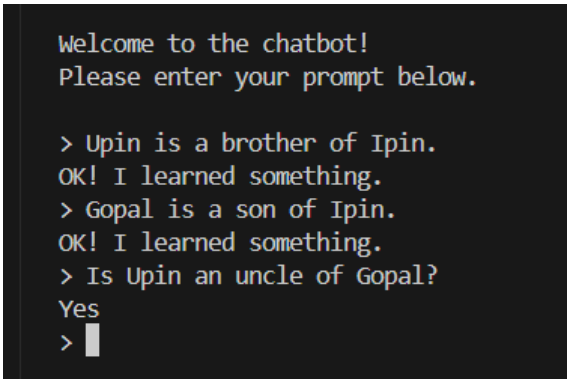
IV. Results

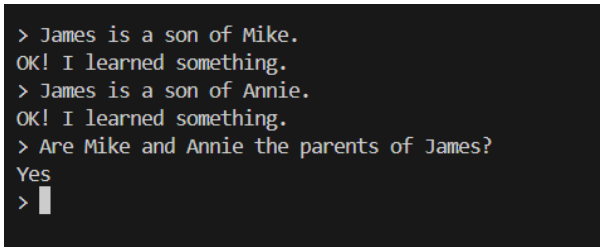
Simple relationships





Infer relationships





The chatbot has many strengths. First, it dynamically learns and grows the knowledge base from the user's inputs during runtime, so your answers can change for each iteration. It gets its results by making logical inferences based on the facts in the knowledge base. It also detects incorrect and invalid inputted statements and processes them accordingly. There are also many possible queries that the user can input. Finally, the chatbot can understand statements written in English/natural language and regular expressions as long as they follow the specific formats for querying and statements.

The chatbot also has some weaknesses. It only accepts a limited set of statements, so it can limit users' interactions with it. It also depends on predefined statement patterns for the program to understand what the user wants. The chatbot's logic can also be limited due to the predefined rules applied to it. Finally, speed, space, and scalability issues can present themselves when there are a lot of facts in the knowledge base.

V. Limitations and Challenges

The program demonstrated a practical implementation of a logic-based inference system in managing family relationships; it is essential to recognize and consider its limitations about any large language model (LLM) based chatbots like Gemini or ChatGPT. The fundamental limitations of the chatbot and its challenges will be underscored when considering developing a logic-based platform such as AI.

Inputting Prompts

The program intends to integrate a chatbot in comprehending family connections based on a predefined set of sentence patterns. However, it cannot respond to queries that fall outside these patterns. For example, it cannot handle complex or ambiguous statements or questions that do not fit the specified formats; otherwise, it will produce an error for the program. Challenges like this may need to expand a dynamic range of algorithms to modify the knowledge base and inference rules significantly. Despite the program's complexity, such as handling ambiguities, context-dependent meanings may be time-consuming and labor-intensive.

Natural Language Understanding (NLU)

While the chatbot requires a strict string statement for prompts, it may not have the same capability of using Natural Language Understanding (NLU) compared to other LLM platforms. NLU is another branch of Natural Language Processing (NLP) that tends to comprehend human interaction by understanding various words, synonyms, or contextual nuances [1]. This limitation makes having more natural and flexible interactions unnecessary due to specified formats. For future preferences, if the program can integrate NLU capabilities, it would necessitate advanced knowledge in logic-based techniques, models, and algorithms, which would be beyond the scope of the logic-based inference system. Adapting to these ideas will enhance the chatbot's ability to handle large databases and employ logic-based algorithms to understand human-like responses.

Comparative Analysis with LLM Chatbots

Comparing other LLM chatbots, such as ChatGPT, Gemini, or any other AI platform, to the basis of this project and the required specifications is different from its advanced features in logic-based models. While these AIs possess LLM, their features have advanced NLU capabilities to generate human-like intelligence for a wide range of queries [2]. Bridging the gap between the specifications and LLM-based chatbots would require broader structures and capabilities, such as integrating NLP techniques, advanced machine learning algorithms, and scalability training on diverse databases.

VI. Conclusion

Implementing a logic-based chatbot capable of comprehending and inferring family relationships has been a tremendous project. The project has not only implied applying theoretical knowledge of logic-based models and NLP, but it has also provided several insights to consider in building intelligent human-like conversations using Python and ProLog.

In conducting the significance of learning LLM platforms such as ChatGPT, it is essential to highlight the use of inference engines in managing and inferring complex relationships or any other types of systems to store databases. As part of the project, the group was able to utilize ProLog's abilities and proven invaluable results to represent facts and rules in a knowledge base and logical queries. However, several highlights are needed for such an intelligent chatbot, such as implementing a distinct representation of natural language processing techniques. Parsing user inputs, responding to impossible or inconsistent information, and translating inputs into appropriate Prolog queries was a challenging and complex task crucial for maintaining the integrity of the knowledge base. That is why learning this project was a starting point for making accurate and efficient logic-based inference systems.

While the chatbot effectively demonstrated the capabilities of a logic-based system, some points should be considered since the project is only limited to inferring family relationships. For instance, some prompts should be input manually to perform appropriate family connections; otherwise, they will provide false results. Since the chatbot's comprehension is limited to a predefined set of sentence patterns, it also lacks the capabilities of NLU. With this, future improvements, such as enhancing logic-based techniques, should be made.

In conclusion, implementing the chatbot has been a great learning experience in learning logic-based models and applying them by constructing that includes inferring relationships. The insights and realizations obtained throughout the process have not only optimized the group's understanding of logic-based inference systems but have also provided a solid foundation for future endeavors that will be utilized in the field of Artificial Intelligence and Machine Learning.

References

[1] Gillis, A. S. *What is natural language understanding (NLU)?* Search Enterprise AI. https://www.techtarget.com/searchenterpriseai/definition/natural-language-understanding-NLU (accessed Nov. 27, 2024).

[2] Lacy, L. *What is an LLM and how does it relate to AI chatbots? Here's what to know. CNET*. https://www.cnet.com/tech/services-and-software/what-is-an-llm-and-how-does-it-relate-to-ai-chatbots-heres-what-to-know/ (accessed Nov. 27, 2024).

Table of Contributions

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Dwight Daryl J. Astrero	• Python • ProLog Logic • Debugging
Andrei Zarmin D. De Jesus	• Python • ProLog Logic • Debugging
Rafael Luis L. Navarro	• Chatbot Implementation • Results • Debugging
John Cristian N. Sayat	• Brief Introduction • Limitation and Challenges • Conclusion
Matthew Gavin A. Tiopes	• Knowledge Base • Results