Interactive math tutoring with Reinforcement Learning and Storytelling: A Multi-Agent Approach

Name : Monzer Wael Sakaw

Supervised by : Dr Ghada Khoriba

Abstract : this paper is introducing innovative method for math tutoring by using reinforcement learning (RL) techniques with multi-agent architecture, enhanced by adding storytelling element. The system is designed to provide interactive dialogue based tutoring sessions, its goal is to improve students' math skills and problem solving skills. The proposed framework works by two agents: the first one is the Tutor Agent, responsible for generating and asking questions and providing feedback, and he second is the Student Agent, who is tasked and asked with solving questions and improving his performance by RL. The main unique feature here for this approach is the integration of a narrative component (storytelling part) , where students must solve math problems in order to proceed through (continue) the story. If they failed to pass a level the results will appear in a negative story telling or negative way, motivating students to improve their performance. This study demonstrates the effectiveness of the approach through experiments conducted on a dataset of math problems.

Project Objective:

The primary main objective of this project is to develop an intelligent teaching system being able to be facilitating math learning through interactive dialogues and storytelling. By employing RL technology, the project aims to offer personalized learning experiences tailored to what individual student needs. In Addition to, the project is looking forward to evaluate the system's performance and compare it with all traditional tutoring methods to prove its efficacy in improving students' math skills in solving hard arithmetic equations while maintaining engagement through a compelling narrative stories.

Data Preparation and Methodology:

The dataset which is used in this project comprises math problems covering a lot of topics in arithmetic problems, finding the sum of 2 numbers, finding the difference between 2 numbers (subtracting), finding the product of them and division . Each problem is generated with its correct solution, and additional metadata such as difficulty level and topic category are included for analysis., the data is divided into easy, medium, and hard-level questions to can run through training and testing across different proficiency (math solving skills levels). The RL model, implemented using TensorFlow and Keras, consists of an LSTM-based neural network trained on the tokenized question sequences.

Model Architecture and Training:

The neural network model architecture consists of embedding layer with one or more LSTM layer and a dense layer with a sigmoid or softmax activation function. This model is compiled using

Interactive math tutoring with Reinforcement Learning and Storytelling: A Multi-Agent Approach

appropriate loss functions (e.g., binary cross-entropy for binary classification tasks) and optimizers (e.g., Adam optimizer). Training is performed using the padded question sequences and corresponding binary or categorical responses, with the model trained over multiple epochs which are 10 epochs in order to optimize its performance. Hyperparameter tuning techniques such as the grid searching or other random search can be added and used to apply fine tuning on the model's parameters.

Agent Interaction and Reinforcement Learning:

The interaction between the Tutor Agent and the Student Agent occurs in a simulated tutoring environment, where the Tutor Agent generates math questions based on the student's proficiency level and the Student Agent tries to solve them. The RL framework enables the Student Agent to learn from its interactions with the Tutor Agent, with rewards provided for correct answers and penalties for incorrect responses. Additionally, a storytelling component is integrated, where the student's progress through the story depends on their ability to solve math problems. Passing a level allows the student to continue the story, while failure results in a negative story element, encouraging the student to improve. Various RL algorithms such as Q-learning, SARSA, and deep Q-networks (DQN) may be explored to optimize the student's learning process. Curriculum learning techniques may be incorporated to adaptively adjust the difficulty level of questions based on the student's performance.

Conclusion:

The proposed multi-agent RL framework with storytelling demonstrates promising potential for math tutoring applications, offering personalized and adaptive learning experiences. By linking RL techniques and adding a narrative element, the system effectively engages students through interactive dialogue based tutoring sessions, leading to improved math comprehension and problem solving skills. Future research directions may include the integration of natural language processing (NLP) techniques to enhance the conversational capabilities of the Tutor Agent, as well as the exploration of ensemble learning methods to further improve the system's performance.