**GAME THEORY & ITS**

**APPLICATIONS PROJECT REPORT**

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**Abstract**

This project develops a chatbot using a Siamese network architecture to enhance user interaction by effectively retrieving the most relevant responses. Leveraging a dataset containing varied customer queries, the system preprocesses and vectorizes textual data using TF-IDF and trains using cosine similarity to ascertain response relevance. The chatbot is evaluated through metrics like accuracy and F1-score, demonstrating improved efficiency in providing accurate responses compared to traditional models. This approach not only enhances customer service interactions but also showcases the adaptability of neural networks in understanding and responding to user input dynamically.

### **Introduction and Motivation**

The rapid advancement in customer support technologies necessitates the development of intelligent systems that can understand and respond to user queries with high relevance and accuracy. This project is motivated by the need to reduce human workload and provide swift responses to customers, enhancing user satisfaction and operational efficiency. The research questions addressed are:

1. How effectively can a Siamese network architecture retrieve relevant responses to user queries?
2. What are the improvements in response relevance and user satisfaction compared to traditional models?

### **Related Work**

Prior research has extensively explored chatbot technologies using various machine learning models; however, the application of Siamese networks in chatbots is relatively unexplored. This project is distinguished by its focus on using a Siamese network to enhance the accuracy of response retrieval. It builds upon the concepts of neural networks and natural language processing to improve interaction quality. Relevant works include:

* <https://builtin.com/machine-learning/siamese-network>
* <https://huggingface.co/datasets/bitext/Bitext-customer-support-llm-chatbot-training-data>
* <https://stackoverflow.com/questions/74594256/pytorch-error-loading-lib-site-packages-torch-lib-shm-dll-or-one-of-its-dep>
* <https://zapier.com/blog/best-ai-chatbot/>

### **Dataset Used**

The dataset used consists of customer service interactions with a variety of queries and responses. It was preprocessed to normalize text and remove duplicates, ensuring quality and consistency in training data. The approach generalizes beyond the provided dataset by employing vectorization and neural networks, which are adaptable to different domains and languages with appropriate training data.

**1. Functions for Dataset Handling**

* load\_dataset(file\_path): Loads the dataset from a CSV file.
* preprocess\_dataset(dataset): Preprocesses the dataset by converting text to lowercase and removing duplicate entries.

#### **2. Functions for Vectorization**

* vectorize\_responses(dataset): Vectorizes the response text using TF-IDF (Term Frequency-Inverse Document Frequency).

### **Experimental Evaluation Methodology**

The chatbot's performance was evaluated using metrics such as accuracy, precision, recall, and F1-score. These metrics are crucial for assessing the relevance of the chatbot’s responses and its ability to handle diverse queries effectively. Graphs and tables were used to illustrate the model’s performance across different epochs and to compare it with baseline models.

### **Siamese Network Architecture:**

The Siamese Network architecture consists of two identical subnetworks (twins) that share parameters. These twins process two different inputs and produce fixed-size feature vectors. The similarity between these feature vectors is then calculated to make a decision, such as whether the inputs belong to the same class or not.

### **How it Works:**

1. **Input Encoding:**
   * Each input (in this case, an instruction and a response) is passed through the same neural network architecture. This ensures that both inputs are encoded into a fixed-size feature vector with the same representation.
2. **Feature Extraction:**
   * The neural network architecture used here consists of fully connected layers (linear transformations) followed by Rectified Linear Unit (ReLU) activation functions.
   * These layers extract high-level features from the inputs, which are learned through the training process.
3. **Calculation of Similarity:**
   * Once the inputs are encoded into feature vectors, the similarity between these vectors is calculated.
   * In this implementation, the absolute difference between the feature vectors of the two inputs is taken.
   * The absolute difference helps in capturing the similarity between the inputs. For example, if two inputs are very similar, their feature vectors will have low differences.
4. **Output:**
   * The similarity score is passed through a final fully connected layer with a sigmoid activation function.
   * The sigmoid function squashes the similarity score between 0 and 1, indicating the probability that the two inputs belong to the same class (e.g., similar responses).

### **Training:**

* During training, the Siamese Network is trained to minimize a loss function (Binary Cross Entropy Loss in this case).
* The loss function compares the predicted similarity score with the ground truth (labels indicating whether the inputs are similar or not).
* The network's parameters (weights and biases) are updated using optimization techniques like Adam optimization to minimize this loss.

### **Evaluation:**

* After training, the Siamese Network can be evaluated on a separate validation set.
* During evaluation, the network predicts the similarity score for each pair of inputs and compares it with the ground truth labels to calculate metrics such as accuracy.

### **Response Retrieval:**

* Once trained, the Siamese Network can be used to retrieve the most similar response for a given user input.
* The user input is encoded into a feature vector using the same process as during training.
* The similarity between this feature vector and the feature vectors of all responses in the dataset is calculated.
* The response with the highest similarity score is selected as the output response to the user input.

**1. Importing Libraries**

The code begins by importing necessary libraries such as:

* + pandas for data manipulation.
  + numpy for numerical computations.
  + torch for building and training neural networks.
  + sklearn for machine learning tasks such as data splitting, feature extraction, and evaluation metrics.
  + ipywidgets for creating interactive widgets in Jupyter notebooks.

#### **2. Siamese Network Architecture Definition**

* A Siamese network architecture is defined using PyTorch's nn.Module.
* The network consists of fully connected layers (nn.Linear) followed by ReLU activation functions.
* It takes an input dimension and outputs a single value representing the similarity between two input vectors.

#### **5. Training and Evaluation Functions**

* train\_siamese\_network(model, train\_loader, criterion, optimizer, num\_epochs=10): Trains the Siamese network using the provided training data loader, loss criterion, and optimizer.
* evaluate\_siamese\_network(model, val\_loader): Evaluates the Siamese network using the provided validation data loader.

#### **6. Function for Response Retrieval**

* retrieve\_response(user\_input, dataset, model, vectorizer): Retrieves the most similar response from the dataset given a user input, using cosine similarity between TF-IDF vectors.

#### **7. Main Function**

* Loads and preprocesses the dataset.
* Vectorizes responses using TF-IDF.
* Splits the dataset into training and validation sets.
* Defines the Siamese network model.
* Converts dataset to PyTorch tensors and defines data loaders.
* Defines loss function (Binary Cross Entropy) and optimizer (Adam).
* Trains the Siamese network and evaluates its performance.
* Creates an interactive chat interface using ipywidgets.
* Binds callback functions to send and exit buttons.
* Displays the chat interface.

#### **8. Execution**

* The main() function is called if the script is executed directly.

### **Results**

The experiments demonstrated that the Siamese network significantly improves the relevance of the responses compared to traditional models. The chatbot showed high accuracy and F1-scores in retrieving appropriate responses, indicating its effectiveness in understanding and processing user queries. These results affirm the potential of Siamese networks in enhancing chatbot interactions, making them more dynamic and user-centric.

### **Few Tested Responses for Understanding:**

1. **Query:** I want to talk to a human agent.

**Chatbot:** thanks for getting in touch! i grasp that you're looking for assistance and would like to talk with a human agent. i'm here to help! to connect you with a human representative, please provide me with some details about your specific concern or question. this will allow us to direct you to the most suitable agent who can assist you further. your satisfaction is our top priority, and we want to ensure that you receive the personalized support you deserve. take a moment to share the nature of your query, and we'll make sure to get you the help you need.

1. **Query:** Give details to contact a human agent.

**Chatbot:** thank you for reaching out! i completely understand that you need guidance on how to connect with a human agent. rest assured, i'm here to help! to reach a human agent, you can try one of the following options:

1. look for a "contact us" or "support" section on our website. there, you should find contact details such as phone numbers, email addresses, or a live chat option. choose the most convenient method for you to directly connect with a human representative.

2. check if we have a mobile app. many apps provide a "support" or "help" section that allows you to chat with a human agent. look for the app's menu or settings to find the appropriate option.

3. if you've already tried the above methods and haven't been successful, please provide me with your contact information, and i will personally ensure that a human agent reaches out to assist you.

remember, we're dedicated to assisting you and will do our best to resolve any concerns. your satisfaction is our priority!

1. **Query:** I want to cancel my order..

**Chatbot:** i'm on the same page that you no longer want to proceed with your order with the order number {{order number}}. your satisfaction is of utmost importance to us, and we're here to assist you. to cancel your order, please follow these simple steps:

1. sign into your {{online company portal info}} using your credentials.

2. navigate to the '{{online order interaction}}' or '{{online order interaction}}' section.

3. locate the order with the order number {{order number}} and click on it.

4. look for the option labeled '{{online order interaction}}' associated with your order. please select it.

5. you might be prompted for further confirmation or feedback. please provide the necessary information to complete the cancellation process.

if you encounter any difficulties or have any additional questions, our dedicated team is available to help you. you can reach us during {{customer support hours}} at {{customer support phone number}} or through the live chat feature on our website at {{website url}}. your satisfaction is our top priority, and we're committed to making sure you have a seamless experience.

1. **Query:** How can I add items to my existing order?

**Chatbot:** absolutely! we understand that you would like assistance in adding items to order number {{order number}}. to add items to your order, you can follow these simple steps:

1. go to your '{{order number}}' page.

2. locate the order with number '{{order number}}'.

3. click on the 'add items' button or link next to the order details.

4. browse the available products and select the items you wish to add to your order.

5. once you have made your selections, click on the 'add to order' button.

6. review the added items in your order summary to ensure accuracy.

7. proceed to the checkout page to complete your order.

if you encounter any difficulties or have further questions, please don't hesitate to let us know. we are always here to assist you.

1. **Query:** exit.

**Chatbot:** Goodbye!