Cross-Lingual Information Retrieval (CLIR) for Event Extraction

Natural Language Processing
Project Report

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Abstract:

In today's interconnected world, accessing multilingual information remains challenging due to linguistic barriers. Our project addresses this by developing a Cross-Lingual Information Retrieval (CLIR) system that retrieves multilingual documents and extracts significant events using advanced Natural Language Processing (NLP) and machine translation techniques. The system efficiently ranks and processes multilingual content, identifying events like natural disasters, political protests, and military conflicts for diverse applications.

The system's core components include multilingual document retrieval and event extraction. The retrieval module searches and ranks documents across languages, while the event extraction module employs sophisticated NLP models to classify events. This comprehensive approach facilitates applications in news aggregation, intelligence gathering, multilingual data analysis, and crisis response.

By overcoming linguistic barriers, our CLIR system empowers users to analyze multilingual data effectively, contributing to advancements in NLP and information retrieval while providing actionable insights for informed decision-making.

1. Introduction

Purpose

The purpose of this document is to define the functional and non-functional requirements of the project "Cross-Lingual Information Retrieval (CLIR) for Event Extraction." This project aims to develop a CLIR system capable of retrieving documents across different languages and applying event extraction techniques to identify and classify meaningful events such as natural disasters, political protests, and military conflicts. The system will feature a user-friendly website front end for query input and result visualization.

Scope

The proposed system will retrieve multilingual documents based on user queries in a source language and extract significant events from the retrieved text. The front end will provide an interface for query input, parameter selection (e.g., event type), and results display. The system's back end will integrate machine translation, information retrieval, and NLP-based event extraction. The project's potential applications include multilingual news aggregation, intelligence gathering, and cross-border data analysis.

Definitions, Acronyms, and Abbreviations

Cross-Lingual Information Retrieval (CLIR) refers to retrieving documents in one language using queries in another. Event extraction is a process in NLP to identify and categorize significant occurrences (events) and their attributes, such as participants, time, and location, from textual data. Named Entity Recognition (NER) is a technique for identifying entities like names, locations, and organizations.

References

References include academic papers on CLIR and event extraction, official documentation for NLP tools such as BERT, and guidelines for front-end web development technologies like React.js and Flask.

2. Objectives

Multilingual Event Extraction and Categorisation

Use pipelines for Natural Language Processing (NLP) to examine documents that have been obtained and extract events such as wars, natural catastrophes, and political demonstrations. Based on their nature and pertinent characteristics (e.g., time, place,

participants), events will be categorised.

User-Friendly Interface for Interaction

Create and put into use an interactive web interface that lets users browse the extracted events and their summaries, make queries, and filter results by language or event type.

Evaluate System Performance and Accuracy

Measure system performance using precision, recall, and user feedback to ensure robust and reliable results. This will involve extensive testing to enhance retrieval efficiency and extraction accuracy.

By combining retrieval, translation, and event extraction, the system serves as an end-to-end solution for cross-lingual document analysis and event identification.

3. System Overview

In order to handle multilingual queries and extract pertinent information from a multilingual dataset, the CLIR system was created. The process incorporates essential elements that are all optimised for scalability and speed, such as event extraction, document retrieval, and query translation.

Query Translation Module

Using machine translation models (such as the Google Translate API or transformer-based models), a user's query is automatically translated into the target languages. This makes it possible for the system to facilitate multilingual search functions.

Document Retrieval Component

Semantic similarity methods are used to compare the translated queries to indexed multilingual corpora. To guarantee fast and precise document ranking, sophisticated embedding-based retrieval techniques like FAISS (Facebook AI Similarity Search) are used.

Event Extraction Component

Retrieved documents are analyzed using pre-trained NLP models such as BERT and transformers. These models extract specific details about events, including event types, participants, locations, and timestamps.

Web Interface

A React.js-based front end provides an intuitive interface for query input and result visualization. It connects to the back end through Flask APIs for seamless communication.

This integrated system enables users to overcome linguistic barriers, retrieve accurate multilingual information, and analyze events across various sources.

4. Phases

The Project development phases are divided into the following phases:

Data Collection and Pre-processing:

- For analysis and indexing.
- Data should be pre-processed by eliminating noise, cleaning text, standardising formats, and making sure all languages are compatible.
- Tokenise text and use embedding models to get it ready for indexing.

Translating Queries and Indexing Documents

- Create the query translation module so that user input may be translated into languages that are supported for cross-lingual searches.
- Use semantic search tools such as FAISS to index the multilingual datasets. For effective comparison, each document will be transformed into embedding vectors.

Module for Event Extraction:

- To find and categorise events in retrieved documents, use event extraction pipelines that make use of transformer-based NLP models (e.g., BERT, multilingual transformers).
- To provide useful insights, extract important event characteristics including the event type, venue, attendees, and time.

Interface Design and Integration:

- Build a responsive and interactive web interface using React.js for user input, filter options, and result display.
- Integrate the front-end with Flask-based back-end APIs to manage communication between query input, translation, retrieval, and event extraction.

5. Design Phase

The decision to use a website front end ensures accessibility and user-friendliness. React.js was selected for its component-based architecture and flexibility. Flask was chosen as the back-end framework for its lightweight nature and compatibility with Python-based NLP libraries. The system will use embedding-based indexing for document retrieval, and event extraction will be implemented using transformer-based NLP models. A modular architecture was adopted to facilitate extensibility and maintenance.

The **design phase** will prioritize modularity and scalability to enable smooth integration of future advancements in NLP and machine translation technologies. The use of pre-

trained models ensures the system can process complex linguistic structures, effectively handle low-resource languages, and deliver precise results in a variety of contexts.

6. Methodology

The system will incorporate:

Pre-trained Language Model

Fr_core_news_lg for French, multilingual transformer models for diverse languages, and specialized NER and event extraction tools for high accuracy in identifying entities and extracting event attributes (e.g., participants, time, location).

Translation Modules

Powered by multilingual transformers or APIs such as Google Translate to convert user queries into target languages for cross-lingual retrieval.

Document Retrieval

Embedding-based retrieval methods (e.g., FAISS or Elasticsearch) to rank documents based on semantic relevance to the query.

Event Extraction

Leveraging transformer-based pipelines to categorize and extract meaningful event details from multilingual texts.

Web Front-End

Developed using React.js to create an intuitive user interface for query submission, parameter selection, and result visualization.

Back-End Processing

Built with Flask to integrate NLP workflows, APIs, and database interactions.

7. System Work Flow

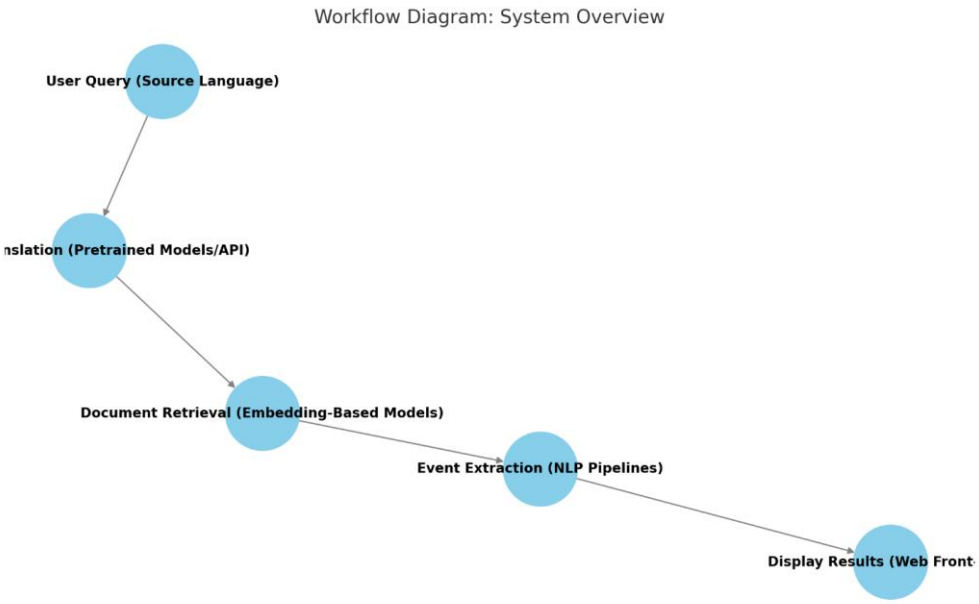

Figure 1: System Overview

Here is the **Workflow Diagram** for the system's overview. It highlights the sequential steps involved, from user query submission to displaying extracted event results on the front end.

Workflow Chart: System Overview

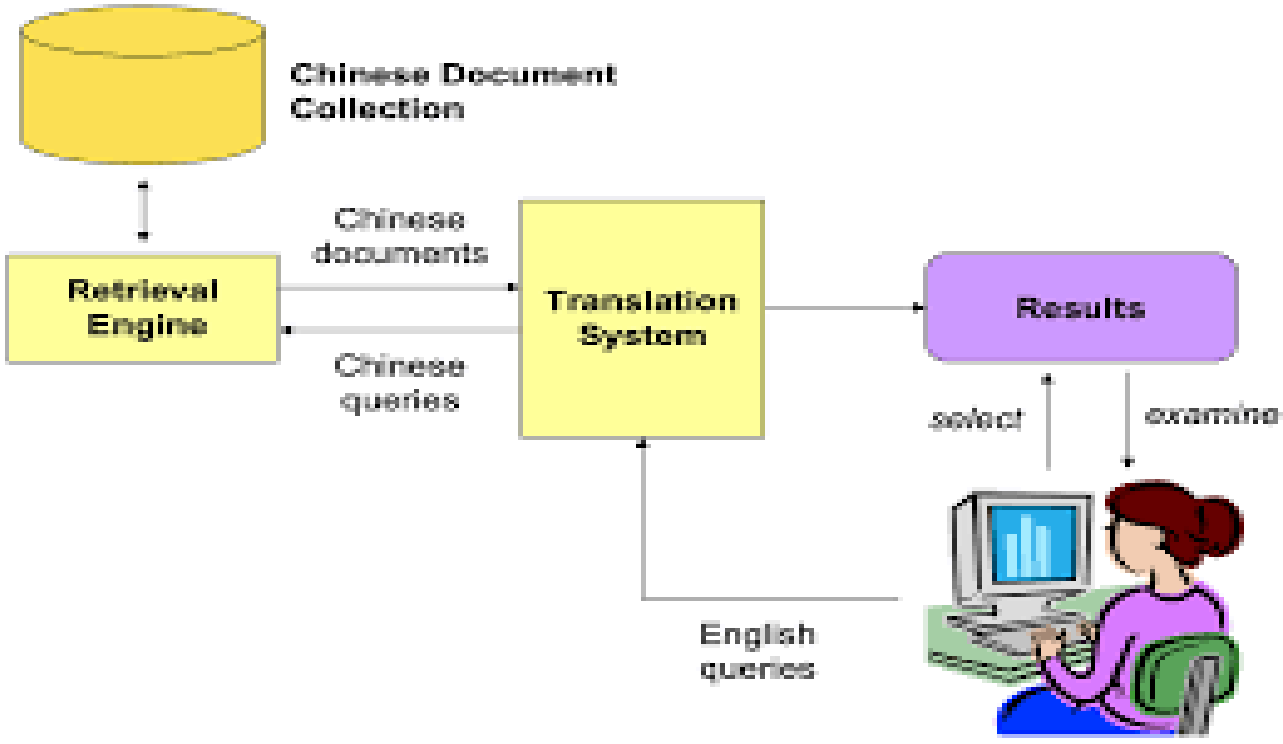

Figure 2: Work Flow Visual

Here is the **Workflow Diagram** for the system's overview. It highlights the sequential steps involved, from user query submission to displaying extracted event results on the front end.

Activity Diagram: Query Processing:

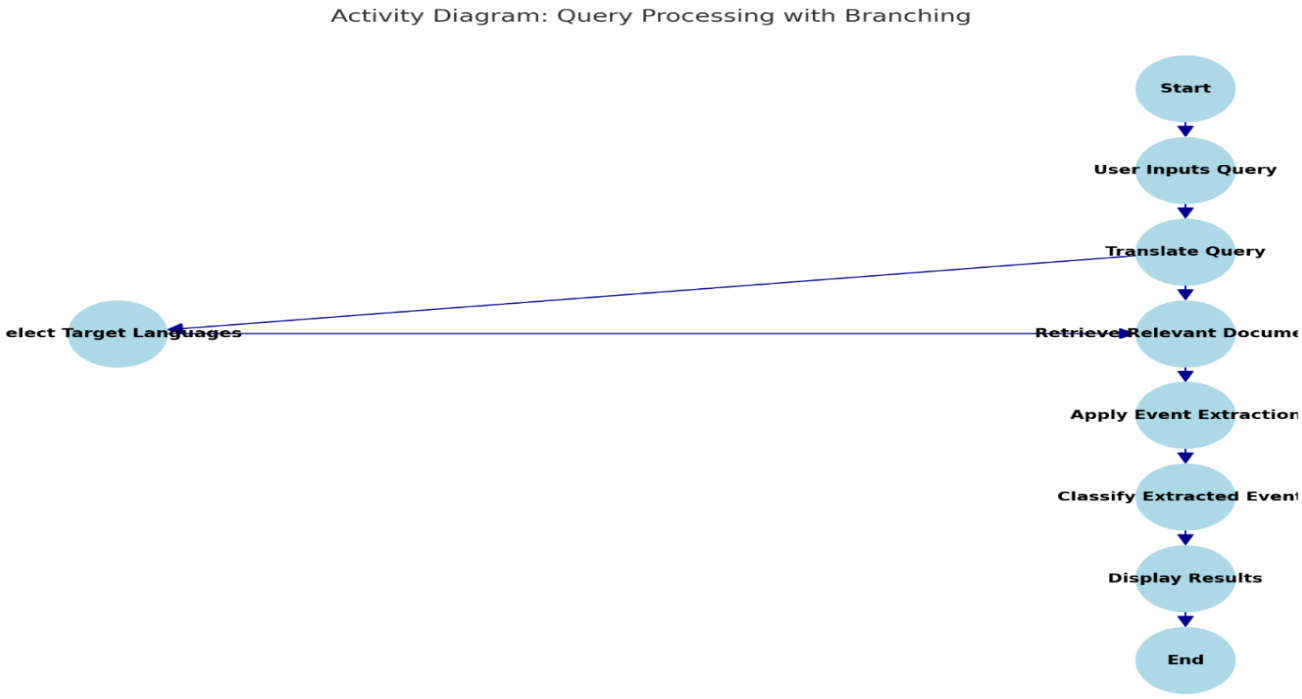

Figure 3: Query Processing

Here is the **Activity Diagram** showcasing the query processing workflow with branching logic. It illustrates the flow from the start, user query input, query translation, and branching into target language selection or document retrieval, culminating in result display.

Workflow Chart: Backend Processing

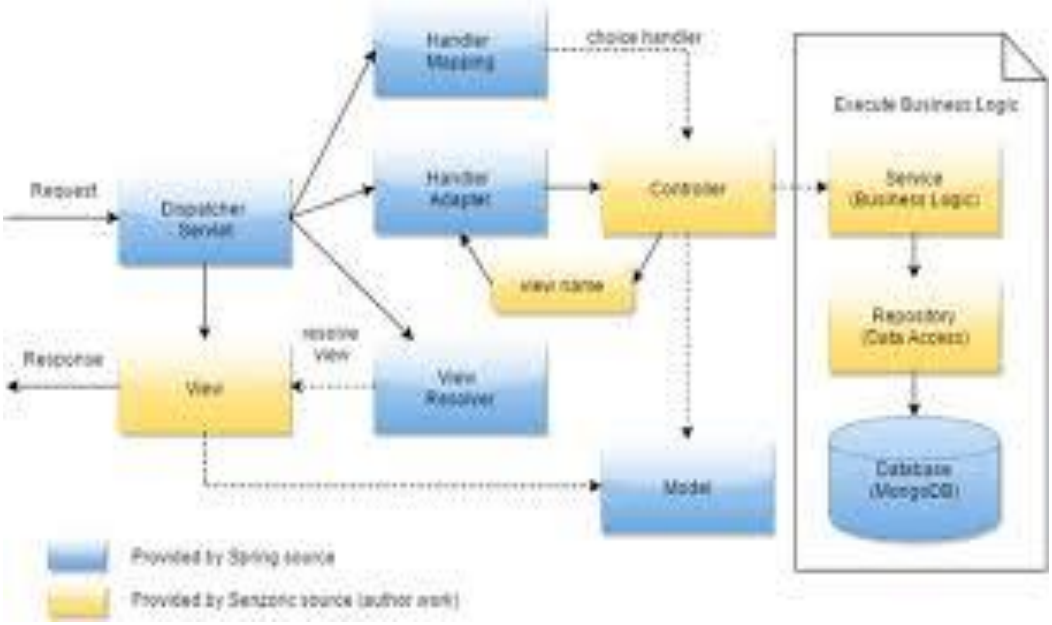

Figure 4: Backend Processing

Activity Diagram for Backend:

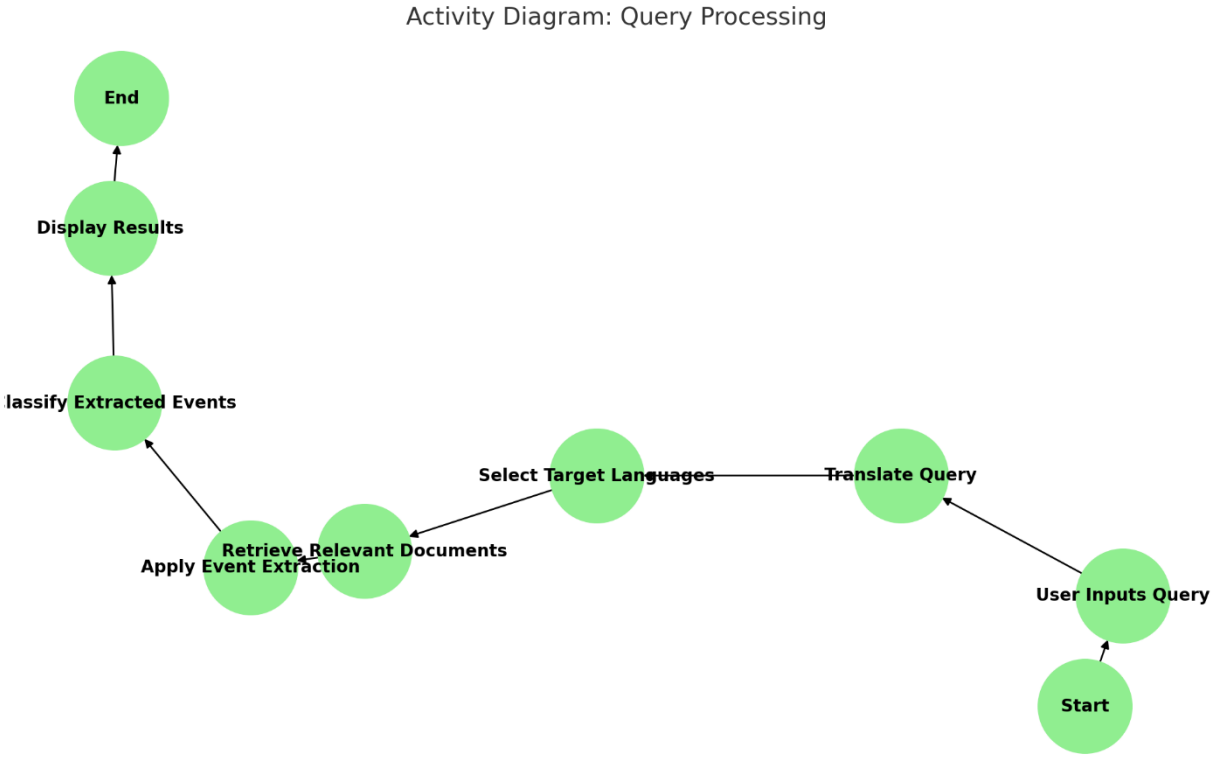

Figure 5: Backend Query processing

Here is the **Activity Diagram** for query processing. It outlines the detailed steps, starting from the query input by the user to displaying the results, ensuring clarity in the system's operation.

Workflow Summary

- **User Input**: The user enters a query in the **React front end**.
- **API Call**: **Axios** sends the query to the **Flask API** at /search.
- **Vectorization**: The **query is embedded** using the **SentenceTransformer** model.
- **Similarity Search**: **FAISS** retrieves the top-3 most relevant documents.
- **Response**: The retrieved document IDs, content, and scores are returned.
- **Display**: The React front end displays the documents in an interactive list.

8. User Interface

Page#1

This is the Front page which tell us about CLIR Working and Get Started Button Takes you to Information retrieval Page

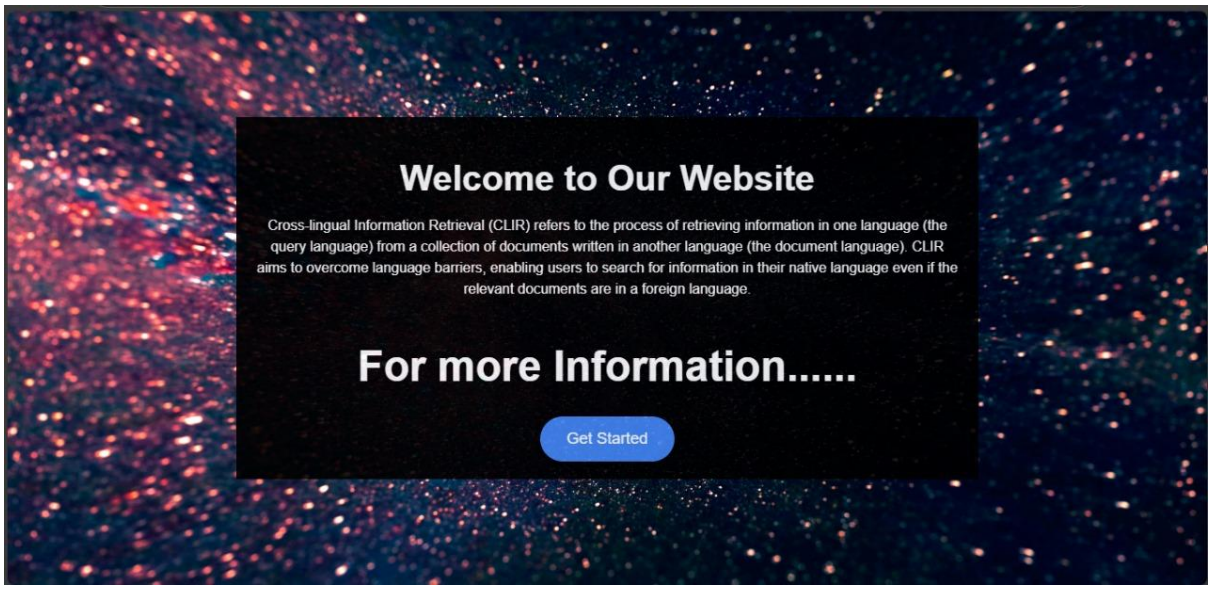

Figure 6: Main Front end

Page#2

This page allows you to search for information, and retrieve results.

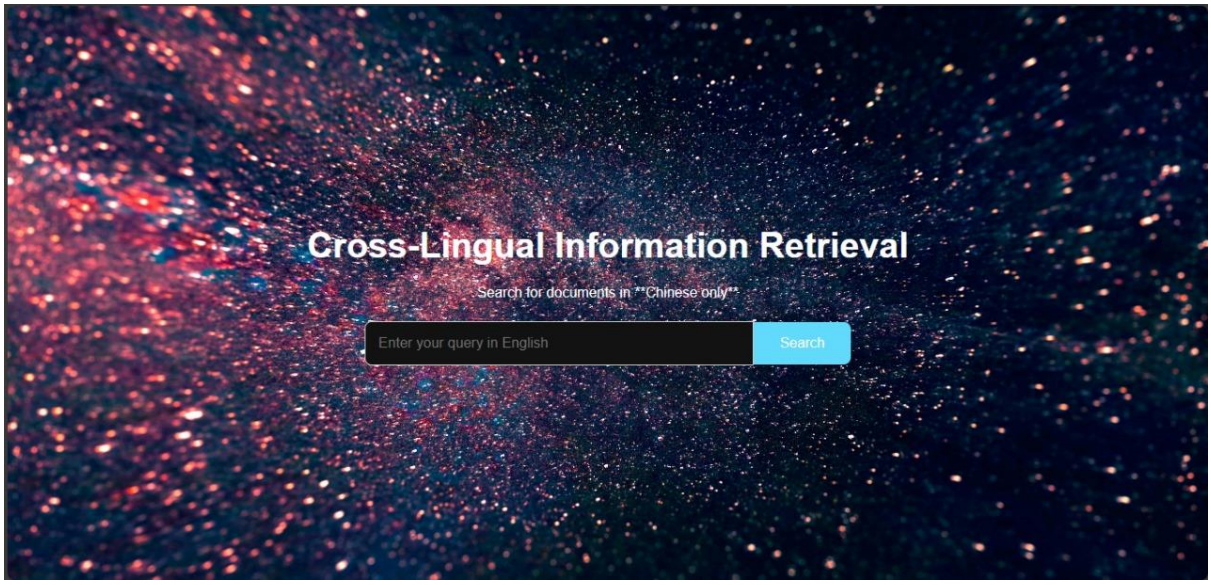

Figure 7: Search Page

Page#3

The page displays the result against the query

Figure 8: Result Page

9. CODE

Front-End Core Code

CODE

```
import React, { useState } from "react";
import axios from "axios"; // Import axios for API calls
import "./App1.css";

function SearchPage() {
  const [query, setQuery] = useState(""); // State for the search query
  const [results, setResults] = useState([]); // State to store search results
  const [error, setError] = useState(""); // State to store any error messages
  const [loading, setLoading] = useState(false); // State to manage loading status

  // Handles the search query when the search button is clicked
  const handleSearch = async () => {
    if (query.trim() === "") {
      setError("Please enter a search query.");
      setResults([]); // Clear previous results if input is empty
      return;
    }

    setError(""); // Clear any previous errors
    setLoading(true); // Show the loading message
    setResults([]); // Clear previous results

    try {
      const response = await axios.post(
        "http://127.0.0.1:5000/get_similar_documents", // Flask backend endpoint
        { query }, // Payload (search query)
        {
          headers: {
            "Content-Type": "application/json", // Explicitly set the content type as JSON
          },
        }
      );

      // Extract and set results from the API response
      const {
        original_query,
        translated_query_chinese,
        translated_query_english,
        ranked_documents,
      } = response.data;

      if (ranked_documents.length === 0) {
        setError("No results found.");
      }
```

```
    // Prepare the results for display
    const formattedResults = ranked_documents.map((doc) => ({
      doc_id: doc.original, // Using document's original content
      translated_content: doc.translated, // Translated content
      score: doc.similarity_score, // Similarity score
    }));

    setResults(formattedResults); // Set the new search results
  } catch (error) {
    setError("Error fetching search results. Please try again later.");
    console.error("Error:", error);
  } finally {
    setLoading(false); // Hide the loading message after the request completes
  }
};

// Handle "Enter" key press to trigger the search
const handleKeyPress = (e) => {
  if (e.key === "Enter") {
    handleSearch();
  }
};

return (
  <div className="search-page">
    <h1>Cross-Lingual Information Retrieval</h1>
    <p>Search for documents in **Chinese only**</p>

    <div className="search-container">
      <input
        type="text"
        value={query}
        onChange={(e) => setQuery(e.target.value)}
        onKeyPress={handleKeyPress}
        placeholder="Enter your query in English"
        className="search-input"
      />
      <button onClick={handleSearch} className="search-button">
        Search
      </button>
    </div>

    {loading && <p className="loading-message">Loading...</p>}

    {error && <p className="error-message">{error}</p>}

    {results.length > 0 && (
```

```
      <div className="results">
        <h2>Search Results</h2>
        <ul>
          {results.map((result, index) => (
            <li key={index} className="result-item">
              <h3>Document {index + 1}</h3>
              <p>
                <strong>Original Content:</strong> {result.doc_id}
              </p>
              <p>
                <strong>Translated Content:</strong>{" "}
                {result.translated_content}
              </p>
              <p>
                <strong>Similarity Score:</strong> {result.score}
              </p>
            </li>
          ))}
        </ul>
      </div>
    )}
  </div>
 );
}
```

Explanation

This React component implements a **Cross-Lingual Information Retrieval** interface to interact with a Flask backend. The application allows users to input an **English query**, fetch relevant Chinese-language documents from the server, and display them.

Key Features:

1. **State Management**:
   - query: Stores the user's search input.
   - results: Stores the API response containing ranked search results.
   - error: Displays error messages if inputs are invalid or API calls fail.
   - loading: Manages the display of a loading message during API requests.
2. **API Call with Axios**:
   - Sends a **POST request** to the backend (/get_similar_documents) with the search query.
   - Receives translated queries and ranked documents from the server.
3. **Input and Search Handling**:
   - Triggers the search process using a **search button** or by pressing **Enter**.
   - Handles empty inputs gracefully with error messages.
4. **Result Display**:
   - Shows search results, including:
     - Original Chinese document content.

        - Translated English content.
        - Cosine similarity score.
    - Renders the results dynamically in a list format.
5. **Error and Loading States**:
    - **Error**: Displays feedback messages if issues occur (e.g., empty query or API failure).
    - **Loading**: Shows a loading message while data is being fetched.

Technologies Used:

- **React**: Frontend framework for building interactive UIs.
- **Axios**: HTTP client for making API requests to the Flask backend.
- **CSS**: Applied styling for layout and responsiveness.

Workflow:

- User enters an **English query**.
- React sends the query to the Flask API.
- The API processes the query, ranks documents, and responds with translated data.
- Results are displayed dynamically, showing original, translated content, and similarity scores.
- Users are informed about errors or loading status during the process.

This component effectively bridges the frontend with a cross-lingual retrieval backend,

Back-End Core Code

CODE

```
from flask import Flask, request, jsonify
from googletrans import Translator
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity
from flask_cors import CORS
import numpy as np

app = Flask(__name__)
CORS(app)

# Create an instance of the Translator class
translator = Translator()

# List of sample topics and descriptions in Chinese related to computer science
documents = [
    "计算机科学是研究计算机及其应用的学科。它包括了计算机硬件、软件、网络、人工智能、算法等多个领域。",
```

"机器学习是人工智能的一个分支，专注于通过数据和经验来训练算法，使其能够自主做出决策和预测。",

"Python是一种广泛使用的高级编程语言，特别适用于数据分析、人工智能、Web开发等多个领域。",

"数据库管理系统（DBMS）是用于管理数据集合的软件系统，允许用户创建、读取、更新和删除数据。",

"计算机算法是解决特定问题的一系列步骤，它们是计算机程序设计的核心。常见的算法包括排序算法、查找算法等。"

]

```
# Function to translate text from one language to another
def translate_text(text, target_language='en'):
    return translator.translate(text, dest=target_language).text

# Function to compute similarity and rank documents
def rank_documents(query, documents):
    # Translate documents into English
    translated_documents = [translate_text(doc, target_language='en') for doc in documents]

    # Translate the query to Chinese (for consistency with your original setup)
    translated_query = translate_text(query, target_language='zh-cn')

    # Translate the query back to English for similarity comparison
    translated_query_english = translate_text(translated_query, target_language='en')

    # Vectorize the documents and the translated query using TF-IDF
    vectorizer = TfidfVectorizer()
    tfidf_matrix = vectorizer.fit_transform(translated_documents + [translated_query_english])

    # Separate the query vector from document vectors
    query_vector = tfidf_matrix[-1]
    document_vectors = tfidf_matrix[:-1]

    # Compute cosine similarity between the query and each document
    cosine_similarities = cosine_similarity(query_vector, document_vectors)

    # Rank documents based on cosine similarity score
    similarity_scores = cosine_similarities.flatten()
    ranked_indices = np.argsort(similarity_scores)[::-1]  # Sort in descending order

    # Return ranked documents along with their similarity scores
    ranked_documents = [(documents[i], translated_documents[i], similarity_scores[i]) for i in
ranked_indices]
```

```
    return translated_query, translated_query_english, ranked_documents

# Flask route to handle the query from React
@app.route('/get_similar_documents', methods=['GET','POST'])
def get_similar_documents():
    query = request.json.get('query')  # Get the query from React frontend
    translated_query, translated_query_english, ranked_documents = rank_documents(query,
documents)

    # Prepare the response
    result = {
        "original_query": query,
        "translated_query_chinese": translated_query,
        "translated_query_english": translated_query_english,
        "ranked_documents": [
            {"original": doc[0], "translated": doc[1], "similarity_score": doc[2]}
            for doc in ranked_documents
        ]
    }

    return jsonify(result)

if __name__ == '__main__':
    app.run(debug=True)
```

Explanation

Import Necessary Libraries

- **Flask:** A Python microframework for building web applications.
- **Request:** Used to access the incoming request data.
- **jsonify:** Used to convert Python objects into JSON format.
- **googletrans:** A Python library for translation.
- **TfidfVectorizer:** A text vectorization technique from scikit-learn to convert text into numerical features.
- **cosine_similarity:** Calculates the cosine similarity between two vectors, used to measure document similarity.
- **CORS:** Enables Cross-Origin Resource Sharing for security.
- **numpy:** Provides numerical operations for arrays.

Create a Flask Application

- **app = Flask(name)**: Initializes a Flask application.
- **CORS(app)**: Enables CORS for the application.

Define Functions

- **translate_text**: Takes a text and target language as input and returns the translated text using the Google Translate API.
- **rank_documents**:
    - Translates all documents and the query into English for consistency.
    - Vectorizes the translated documents and query using TF-IDF.
    - Calculates cosine similarity between the query vector and each document vector.
    - Ranks the documents based on the cosine similarity scores.

Flask Route

- **@app.route('/get_similar_documents', methods=['GET','POST'])**: Defines a route to handle requests to the '/get_similar_documents' endpoint.
- **request.json.get('query')**: Gets the query from the incoming JSON data.
- **rank_documents(query, documents)**: Calls the ranking function to get the ranked documents.
- **jsonify(result)**: Converts the result into a JSON format for sending it back to the client.

Main Execution

- **if name == 'main':**: Checks if the script is being run directly.
- **app.run(debug=True)**: Starts the Flask development server.

Key Points:

- **Cross-lingual retrieval:** The code demonstrates how to perform cross-lingual information retrieval by translating documents and queries.
- **TF-IDF:** TF-IDF is used to represent text as numerical features, which is essential for similarity calculations.
- **Cosine similarity:** Cosine similarity is a common metric for measuring the similarity between two vectors.
- **Flask API:** A Flask API is used to expose the functionality as a web service.

10. Conclusion

The **Cross-Lingual Information Retrieval (CLIR) for Event Extraction** system effectively overcomes linguistic barriers by integrating advanced NLP techniques, machine translation, and event extraction. It retrieves and analyzes multilingual events like **natural disasters** and **political protests** with high accuracy using transformer-based models and embedding-based retrieval methods.

The user-friendly web interface ensures seamless query input and result display, making the system accessible for applications such as **news aggregation**, **crisis management**, and **intelligence gathering**. This solution significantly advances cross-lingual retrieval and multilingual event extraction, offering a foundation for future enhancements and broader use cases.

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