Project Title

Interactive Causal Analysis and Reasoning System for Large-Scale Conversational Data

Introduction

Large-scale conversational systems such as customer support chats and call-center dialogues generate massive volumes of multi-turn conversation transcripts between agents and customers. Many of these conversations are associated with critical outcome events such as escalations, complaints, refunds, or service failures. These outcomes are operationally costly and require deep analysis to improve service quality.

Existing systems mainly focus on detecting whether an outcome event has occurred. However, they fail to explain *why* the event occurred, which specific dialogue turns contributed to it, how conversational patterns evolved prior to the event, and whether similar causal patterns exist across multiple conversations.

This project aims to bridge this gap by designing a scalable system capable of performing **causal analysis and interactive reasoning over conversational data**, moving beyond simple event detection toward explainable and evidence-based insights.

Problem Statement

The causal factors within conversations that lead to outcome events are not directly observable. Although outcome labels are available at the conversation level, existing systems do not identify:

- The specific dialogue turns responsible for an outcome

- The evolution of conversational patterns leading to the event

- Recurrent conversational structures associated with similar outcomes

- Evidence-backed causal explanations traceable to transcript data

Additionally, current systems lack support for **multi-turn analytical interaction**, preventing users from exploring causal explanations through follow-up queries while maintaining contextual consistency.

Objectives

The primary objectives of this project are:

1. To design a system that generates **causally grounded explanations** for predefined outcome events in conversational transcripts.

2. To identify **dialogue-level causal factors** and extract supporting evidence from transcripts.

3. To enable **multi-turn, context-aware analytical interaction** for deeper exploration of causal insights.

4. To ensure scalability, interpretability, and faithfulness of explanations.

Task Description

Task 1: Query-Driven Causal Explanation with Evidence

Objective

To design a system that accepts a single natural language analytical query related to a predefined outcome event and produces an evidence-based causal explanation.

Description

Given a corpus of conversational transcripts with structured turns and speaker roles, along with conversation-level outcome labels, the system must:

- Analyze conversations associated with the queried outcome

- Identify causal dialogue-level factors

- Extract specific dialogue spans serving as evidence

- Generate a structured and interpretable explanation explicitly linking causes to outcomes

Constraints

- Explanations must be evidence-based

- Emphasis must be on causal reasoning rather than correlation

- Outputs must be interpretable and traceable

Task 2: Multi-Turn Context-Aware Query Handling

Objective

To extend the system to support multi-turn analytical interaction while maintaining contextual consistency.

Description

Given an initial query and system response, followed by dependent follow-up queries, the system must:

- Retain contextual information from earlier interactions

- Correctly interpret follow-up questions

- Generate responses consistent with previous causal reasoning

- Reuse and refine previously identified evidence

Constraints

- Context handling must be explicit and deterministic

- All responses must be grounded in the same conversational data

- Causal consistency must be preserved across interactions

System Architecture

The system follows a modular architecture consisting of the following components:

1. **Query Understanding Module** – Interprets user intent and outcome type

2. **Conversation Retrieval Module** – Retrieves relevant conversations

3. **Causal Analysis Engine** – Identifies causal factors using statistical and causal inference techniques

4. **Evidence Extraction Module** – Extracts dialogue turns supporting the explanation

5. **Explanation Generator** – Produces structured causal explanations

6. **Context Manager** – Maintains interaction history for multi-turn queries

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Technologies Used

Programming & Frameworks

- Python

- Flask / FastAPI

Data Processing

- Pandas

- NumPy

Natural Language Processing

- spaCy

- Sentence-BERT

- Transformer-based models

Machine Learning & Causal Inference

- Scikit-learn

- XGBoost

- DoWhy / EconML

Storage & Retrieval

- PostgreSQL / SQLite

- FAISS Vector Index

Frontend (Optional)

- React

- Chart.js

Dataset Description

The dataset consists of:

1. **Conversation Transcripts**

   o Speaker labels (agent/customer)

   o Turn ordering

   o Optional timestamps

2. **Outcome Labels**

   o Escalation

   o Complaint

   o Refund

3. **Derived Features**

   o Sentiment scores

   o Response delays

o   Politeness indicators

Evaluation Metrics

The system is evaluated using the following metrics:

- **IDRecall (Evidence Accuracy):** Measures whether retrieved conversation IDs match ground-truth evidence

- **Faithfulness:** Ensures explanations are strictly derived from retrieved transcript data

- **Relevancy:** Evaluates how well responses address user intent, especially in multi-turn interactions

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Deliverables

The final submission includes:

- Complete end-to-end system implementation for Task 1 and Task 2

- Source code with trained models

- requirements.txt listing all dependencies

- Query dataset in .csv format

- Technical report describing methodology and evaluation

- Well-structured and reproducible codebase

- Comprehensive README.md file with setup and execution instructions

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Conclusion

This project transitions conversational analytics from simple outcome detection to **causal explanation and interactive reasoning**. By identifying dialogue-level causal factors, grounding explanations in concrete evidence, and supporting multi-turn analysis, the system provides actionable insights for improving conversational systems at scale.

Team Name

THE 4 BITS

Team Members

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