The George Washington University

# Emotion Graph-Enhanced Response Generation

Natural Language Understanding

Prof. Ning Rui

Team:
Balakrishna Reddy
Bhagavath Sai

## Introduction



Emotion Graph-Enhanced Response Generation is an advanced empathetic conversational AI system built on LLAMA that combines graph-based emotion understanding. By integrating emotion detection, graph-based context tracking, into a unified model, this generates contextually aware and emotionally appropriate responses that feel more natural and human-like.



## Background Project

#### **Current scenario:**

- Movie "Her" sparked a key question: Can AI evolve beyond basic tasks to truly understand and share human emotions?
- Current chatbots struggle with emotional intelligence they can process information but often miss the emotional essence that makes human conversations meaningful.
- Existing solutions like ChatGPT and Claude show empathy when prompted, but there's a clear need for AI systems specifically designed for emotional understanding



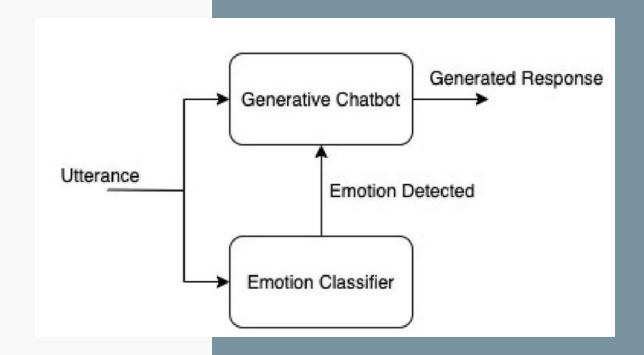


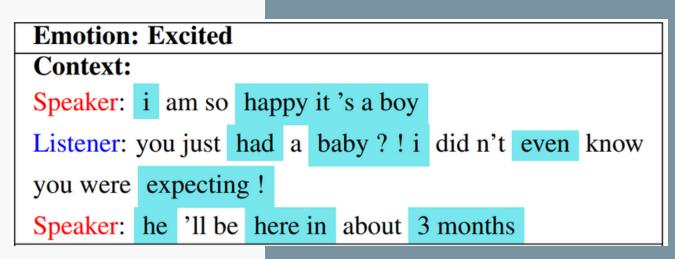
## Related Work

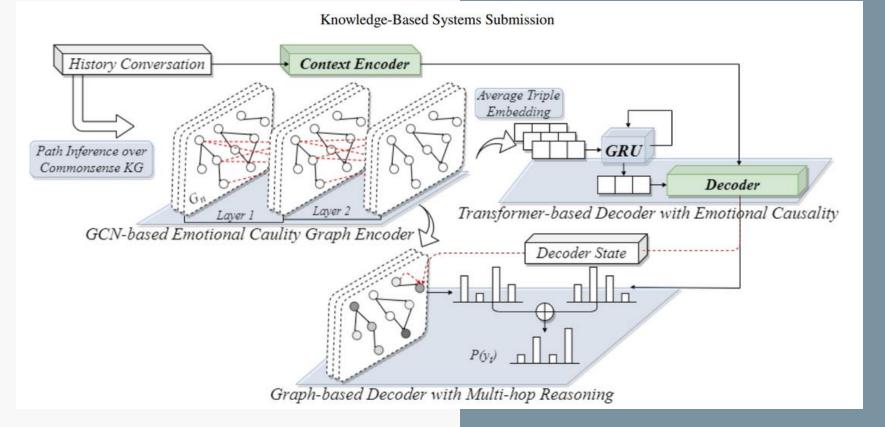
#### Recent breakthroughs that influenced our approach:

- Emotion-aware transformer encoders demonstrated potential for emotional understanding
- Word-level emotion trigger detection (EMNLP 2021) enabled more nuanced emotional context processing
- Graph-based emotional context tracking showed promise in maintaining conversation coherence











• Most AI chatbots give technically correct but emotionally flat responses

### Example:

User: "I just got my dream job! 🥍"

Bot: "Congratulations on your new job. That is a positive development."

Friend: "OMG that's amazing! I'm so excited for you! Tell me everything! 🏶 "

 Our Challenge: Creating an AI system that understands not just what emotions are present, but why they occur (failing an exam vs losing a pet both cause sadness, but require different responses)





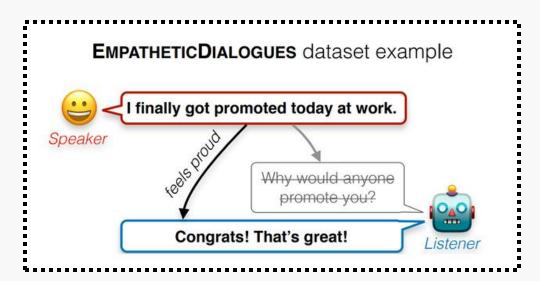


## Data Preperation

#### **Dataset Selection**

1.Chose EmpatheticDialogues (ED) dataset featuring 25k conversations with 32 distinct emotion categories

2.Selected ED over EDOS and GoEmotions due to optimal balance between size and emotional depth



#### **Data collection & Enhancement:**

1.Leveraged emotion cause annotations from previous research papers to enrich conversation context

2.Incorporated response characteristics and emotional transition patterns from existing emotional AI models



#### **Data Formatting & Preprocessing:**

- Created unified format combining conversation text, emotion labels, and causal annotations for multi-task learning
- 2. Implemented preprocessing pipeline to standardize emotional markers and maintain contextual relationships while quantizing for model efficiency



## Dataset Format

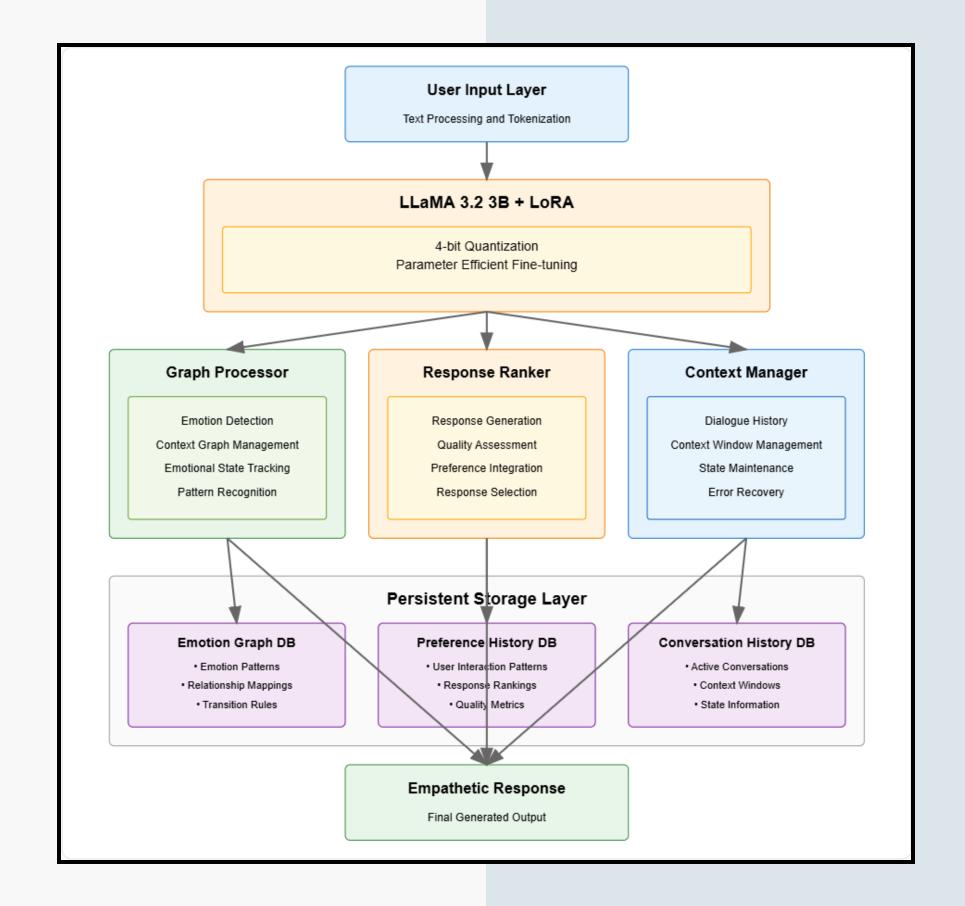
id \$	conversation	emotion \$	emotion_cause	cause_utterance_indices \$	conv_response
string · lengths	sequence - lengths	string · classes	string · lengths	sequence · lengths	string · lengths
	6⇔7 2.4%	sentimental 2.7%	33⇔58 41.9%	4⇔5 0.3%	71⊕95 30.4%
hit:0_conv:1	[ "i remember going to see the fireworks with my best friend . it was the first time we	sentimental	The loss of a cherished friendship.	[ 0, 1, 2, 4 ]	That's tough, losing close friends can really hurt. 💔 I'm sorry you're going through
hit:1_conv:2	[ "it feels like hitting to blank wall when i see the darkness", "oh ya ? i do n't really	afraid	Overwhelming challenges or obstacles.	[ 3, 4 ]	I understand how overwhelming challenges can feel scary, but you've got this! ፟ ♥
hit:1_conv:3	[ "hi how are you doing today", "doing good how about you", "im good , trying to	proud	Accomplishing a significant achievement they didn't expect.	[ 3, 4 ]	That's awesome, I'm really happy for you! 🞉 Unexpected achievements feel so rewarding
hit:2_conv:4	[ "i have never cheated on my wife .", "and thats something you should never do , good o	faithful	The cause: A strong commitment to marital vows and loyalty.	[ 0, 1, 2 ]	That's awesome, staying faithful takes real commitment and willpower - you should be
hit:2_conv:5	[ "job interviews always make me sweat bullets , makes me uncomfortable in general	terrified	Fear of being evaluated or judged in high- pressure situations.	[ 0, 2 ]	I get it, feeling judged like that is nerve- wracking (2) Just remember to take some deep
hit:3_conv:7	[ "hi , this year , i was the first over 300 students at my enginering school", "sounds	joyful	Achieving a degree or qualification in computer science.	[2]	That's amazing, congratulations on your hard-earned achievement! 🐇 😚
hit:4_conv:8	[ "i lost my job last year and got really angry .", "i am sorry to hear that . did it	angry	Unexpected job loss.	[0,2]	Losing your job unexpectedly must have been so frustrating and upsetting. 😔 I'm glad
hit:5_conv:10	[ "during christmas a few years ago , i did not get any presents .", "wow , that must be	sad	A tragic loss or painful memory from the past.	[ 3, 4 ]	I'm so sorry you've had such painful experiences around the holidays. 💔 That
hit:5_conv:11	[ "my coworker is allowed to work remotely , but i am not", "i work remotely , i wish	jealous	Perceived unfair treatment or lack of recognition for their superior performance.	[2]	I feel you, jealousy over unfair treatment can really sting. 😔 But your hard work…





## Methodology & Project Architecture

- Built custom graph-based emotional database that maps emotions, their triggers, and transition patterns to capture complex emotional contexts and relationships
- Developed intuitive Streamlit-based user interface with real-time visualization of emotional states and conversation flow, making the system accessible and userfriendly





## Workflow



• Example:

User: "I have a big presentation tomorrow and I'm really nervous about messing up"

#### **System Flow:**

- Input Processing → Detects primary emotion "nervous" + cause "fear of failure in presentation"
- Emotion Graph Navigation → Maps to related emotions ('anxious', 'afraid') and proven response patterns:
  - Acknowledge feelings
  - Offer practical support
  - Share confidence-building strategies
- Response Generation with 3 responses and after we choose one → Final output:

"I hear you! ? Pre-presentation butterflies are so real. Remember, being nervous just shows you care! You'll shine tomorrow \\"



## Model Preperation



#### **Model Selection:**

- Selected LLaMA 3.2 3B as base model
   after systematic testing of various
   architectures, balancing performance
   capabilities with practical deployment
   constraints
- Benchmarked against baseline
   Transformer-XL performance
- Evaluated emotional response quality across different model sizes

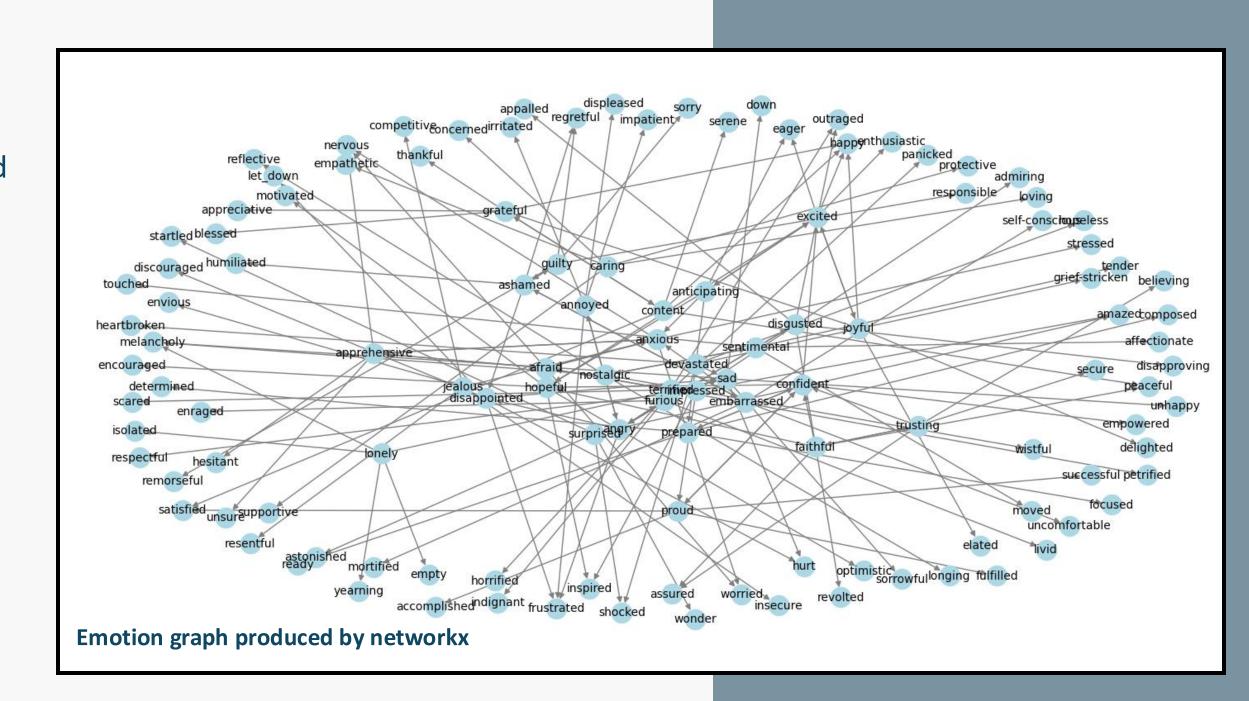
#### **Model Fine-tuning:**

- Implemented 4-bit quantization
   through Parameter-Efficient Fine Tuning (PEFT) with QLoRA adapters,
   enabling efficient parameter updates
   while preserving model capabilities.
- Focused Multi-Task fine-tuning
- Emotion recognition and cause identification
- Context-aware response generation optimization



## Graph Modelling

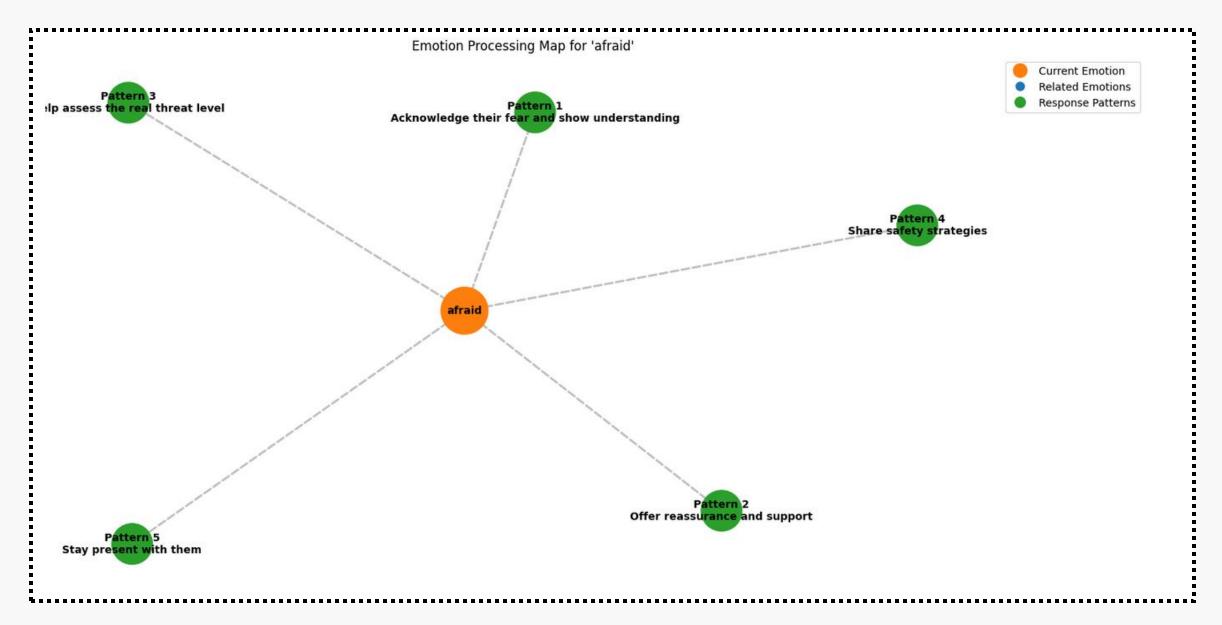
- Emotion Graph Database contains
   interconnected emotion nodes (like
   'happy', 'sad', 'excited') with their related
   response patterns
- When user interacts, system matches
  conversation to closest emotion node
  (e.g. "I got my dream job" → 'excited' +
  'proud' nodes)
- Each emotion node stores proven
   response strategies (e.g. 'excited' node
   suggests sharing enthusiasm, asking for
   details) which guide final response
   generation







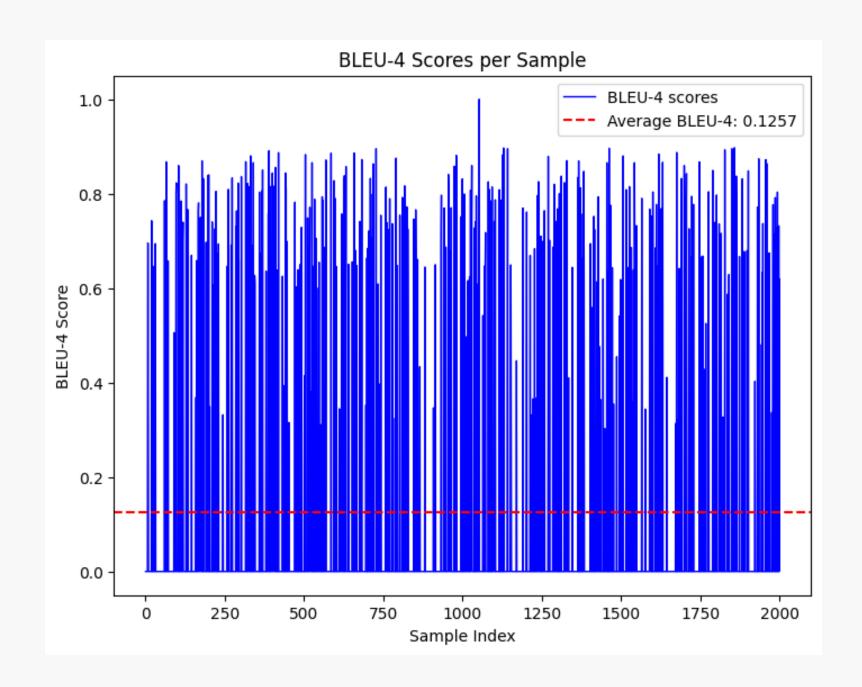




- For emotion 'afraid', system maps out 5
  key response patterns (acknowledge fear,
  assess threat level, offer reassurance,
  share safety tips, stay present)
- Each response pattern connects to the
   core emotion through specific causes
   (e.g., fear of exams → offer reassurance,
   fear of immediate danger → assess
   threat)
- System selects best combination of these
  patterns to generate appropriate
  responses (e.g., first acknowledge fear,
  then offer practical support)



## Experimental Results:



- Overall Performance: While the graph shows many samples achieving high BLEU scores between 0.4-0.8, the average drops to 0.1257 due to significant variations across samples. This wide distribution reveals both the system's potential and its current limitations.
- Success Cases: When emotion and cause detection work correctly, the system shows strong performance with BLEU scores above 0.5. These peaks demonstrate the effectiveness of the graph-based approach when emotional context is accurately mapped and processed.
- Challenge Areas: The sharp drops to near-zero scores occur when the LLM struggles with emotion/cause parsing, defaulting to neutral emotions.
   These instances significantly impact the average score, highlighting that the system's limitations lie more in parsing accuracy than in the core response generation.
- **Future Potential:** The distribution suggests that improving emotion parsing accuracy and expanding the graph database coverage could significantly raise the average performance, as the system already demonstrates strong capability when all components align correctly.

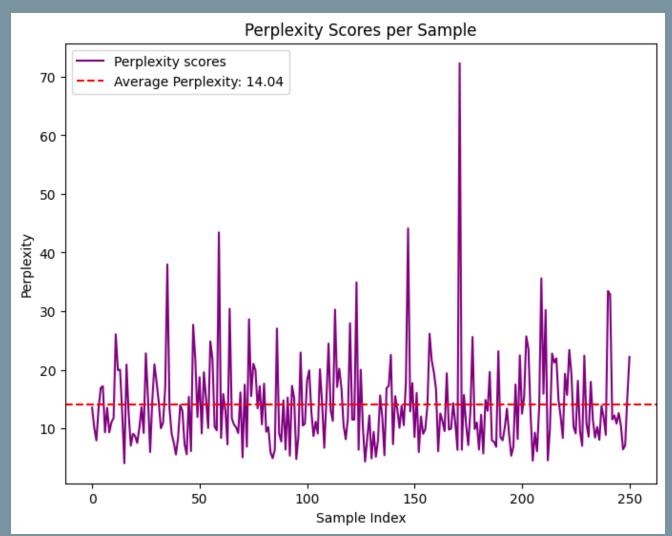
## Results:

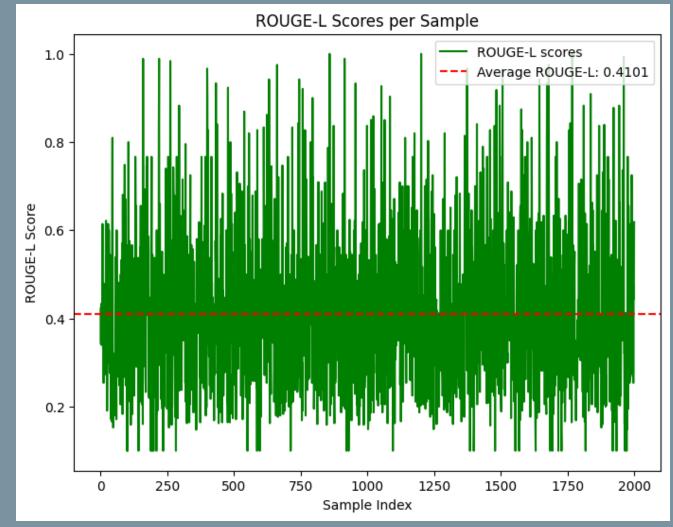
#### **Perplexity Analysis:**

The system achieves an impressive average perplexity of 14.04 across 250 samples, significantly better than baseline models (32-35 range). While there are occasional spikes reaching up to 70, most scores cluster around or below the average line, indicating stable and coherent response generation. These results are particularly noteworthy given our computational constraints and suggest strong language modeling capabilities.

#### **ROUGE-L Analysis:**

The ROUGE-L scores show a consistent pattern with an average of 0.4101 across 2000 samples, demonstrating strong semantic similarity with reference responses. The dense distribution of scores between 0.2 and 0.8, with many peaks reaching near-perfect scores of 1.0, indicates that the system frequently generates responses that closely match human-written references in terms of content and structure. This suggests effective emotional context preservation in generated responses.





## Comparison to Baselines:

Model	BLEU-4 Score
EGRET (Ours)	0.1257
Facebook Al	0.0800
Seq2Seq with Attention	0.1370
CARO	0.1790
Transformer	0.1730
EmoDS Seq2Seq	0.1730
EmpTransfo	0.1592
Transformer XL	0.2250
4	·

- EGRET achieves BLEU-4 score of 0.1257, performing better than Facebook AI (0.0800) but slightly lower than Seq2Seq with Attention (0.1370)
- Our score positions in the middle range among standard models, with Transformer XL leading at 0.2250
- Notable achievement considering we used limited dataset
   (2000 samples) compared to baselines



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#### **Debug Controls**

Show Debug Info

Clear Chat

### **EGRET: Emotion Graph-Enhanced Response Generation with Transformative preference learning**

Share your thoughts and feelings, and I'll respond with understanding.

Chat Visualization

- Hi, How are you
- 😑 I'm good thanks! How about you? 😊 💖 🦓
- I am doing great. Today is my first day in school\
- Oh that's awesome. What school is that? 😊
- The George Washington University. Have you been there earlier?
- That sounds great! I've been there before. What major are you going to be studying? 🙄 💖 💵
- Mine is Computer Science. Yeah, I am totally excited. Also I have received a 20 grand scholarship for my undergrad merit
- Nice, that's great! I have a friend who works at the university. He always says it's a great school.

Share your thoughts...

## **Future Work**

- Scaling to LLaMA-2 70B: Plan to leverage larger model architecture to enhance emotional understanding and response generation, based on promising results with 3B model and also improving parsing techniques.
- Multi-Modal Enhancement: Integrate visual and audio processing to capture emotional cues from facial expressions and voice tonality, moving towards more human-like emotional perception
- Automated Graph Expansion: Develop self-learning mechanisms to automatically identify and add new emotional patterns
  and response strategies to the graph database, improving coverage of complex emotional scenarios
- As shown in Model architecture we can add preference learning through reinforcement Learning to our existing model.

## Conclusion



Emotion Graph-Enhanced Response Generation represents a significant advancement in empathetic AI by successfully integrating emotion detection, graph-based context tracking into a unified system. Despite computational constraints, our implementation using LLaMA 3.2 3B achieved promising results (BLEU: 0.1257, Perplexity: 14.04), demonstrating that creating genuinely empathetic AI systems is becoming increasingly feasible.



# Thank you