

GENMO COMBO: BRIDGING MENTAL HEALTH, GENETICS, AND CLINI- CAL TRIALS WITH LLM AND SENTIMENT ANALYSIS

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ABSTRACT

This project introduces Genmo Combo, an integrative approach leveraging Large Language Models (LLMs) and sentiment analysis to address the complex interplay of genetic and mental health disorders. Patients with co-occurring conditions face diagnostic challenges, healthcare inequities, and social stigma, compounded by a lack of tailored resources and exclusion from clinical trials. By employing a Retrieval-Augmented Generation (RAG) framework with Llama-2-7B, the project enhances LLM outputs for accuracy and relevance. Sentiment analysis of online discourse reveals significant unmet emotional and informational needs among patients, emphasizing the importance of accessible tools. The developed web application bridges these gaps by providing curated self-help resources, trial access, and trustworthy AI-powered responses. Model evaluation demonstrates a 68.33% improvement in task completeness scores post-RAG implementation. This work highlights the potential of AI to empower patients while addressing ethical concerns and practical limitations in clinical applications, paving the way for future enhancements in healthcare accessibility and patient support.

1 PROBLEM STATEMENT

1.1 BACKGROUND

Mental disorders, such as depression and anxiety, are caused by a compound influence of environmental and genetic factors (Alshaya, 2022). All major psychiatric disorders have genetic risk factors, and genetic strategies are frequently employed to evaluate possible overlaps.

For example, common genetics variation single nucleotide polymorphisms (SNPs) appeared more frequently in individuals with five prevalent mental disorders: autism spectrum disorder (ASD), attention deficit-hyperactivity disorder (ADHD), bipolar disorder, major depressive disorder, and schizophrenia (Jordan Smoller, 2013).

1.2 PROBLEM STATEMENT

Patients with co-occurring genetic diseases and mental disorders experience a set of interconnected challenges, including healthcare inequity, social stigma, and privacy concerns.

They must navigate the diagnostic difficulties associated with both conditions, where genetic diseases have a long and costly diagnostic process (Breining, 2018) and mental disorders with misdiagnosis issues.

They are often excluded from mental health trials, further limiting their treatment options. Additionally, a significant proportion of mental disorder clinical trials exclude individuals with additional medical conditions.

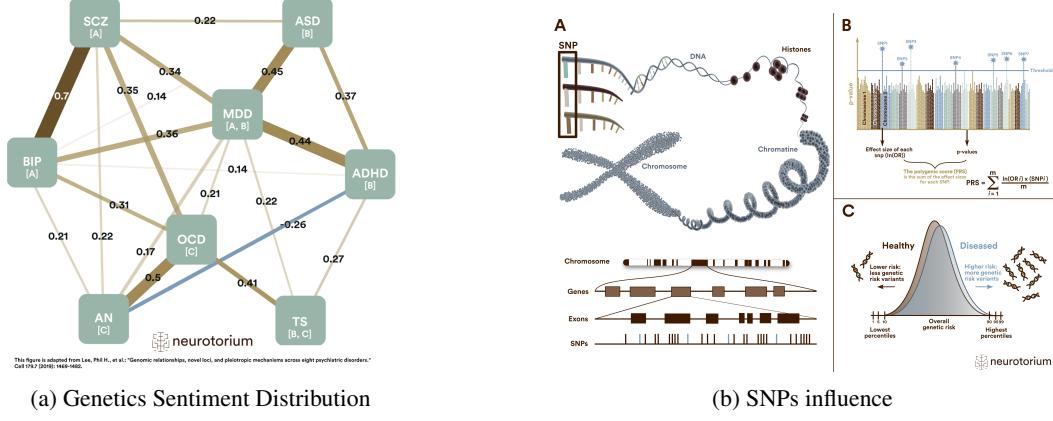


Figure 1: Co-occurring Genetics disease and Mental Disorder, figure source

The limited treatment options for genetic conditions combined with barriers to accessing mental healthcare create a compound effect on their healthcare management, which could further lead to financial instability, creating a cyclical pattern of hardship.

These individuals also bear a double burden of social stigma and face discrimination (?), leading to potential isolation, anxiety, and depression from both conditions along with physical symptoms of their genetic disease.

Large Language Models (LLMs) used in mental health care and genetic disease management depend on heavily user-generated prompts, which could be inherently biased. Hallucinations and inaccuracies in answers would lead to serious consequences. Also, Large language models (LLMs) such as ChatGPT often refuse valid health-related queries due to overzealous ethical safeguards, leaving patients without critical information (Guo et al., 2024).

1.3 MOTIVATION

This project aim to address the needs of patients with co-occurring mental health and genetic disorders by providing self-help resources, facilitating access in clinical trials and improving knowledge accessibility.

Providing Self-Help Resources: Empowering patients to take proactive steps in managing their conditions.

Facilitating Access to Clinical Trials: Helping patients identify appropriate clinical trials tailored to their unique genetic and mental health profiles.

Improving Accessibility: Developing tools that cater to patients without a research or medical background, thereby bridging the knowledge gap.

2 LITERATURE SURVEY

2.1 MODELS FOR LLMs IN MENTAL DISORDER-GENETICS DISEASE

Before 2023, the most common LLMs used for mental health disease detection are GPT-3 (Hayati et al. (2022), Kumar et al. (2023)) and BERT(Diniz et al. (2022),Tanana et al. (2021)). In 2023 and 2024, the LLMs become diverse, including ChatGPT 4.0(Blease et al., 2024), bing AI, Claude, Bard(Elyoseph et al., 2024), and open source models like LlaA-7B, ChatGLM-6bWang et al. (2023).

2.2 APPLICATIONS OF LLMs IN MENTAL HEALTH CARE

Diagnosis: LLMs assist in identifying mental health conditions by analyzing patient data and clinical notes.

Therapy: They support therapeutic interventions through chatbots and virtual agents, providing cognitive behavioral therapy and other therapeutic modalities.

Patient Engagement: LLMs enhance patient engagement by facilitating communication and providing psycho-education.

2.3 CURRENT CHALLENGES FOR LLM IN MENTAL DISORDER AND GENETICS DISEASE

LLMs have been tested and, to a limited degree, implemented in a variety of medical applications. Some studies are showing that LLMs perform better than human physicians in terms of the responses that patients prefer. However, there is ample evidence of LLMs' shortcomings in mental health counselingChung et al. (2023).

Challenges of LLMs for mental health and genetic disease counseling include model hallucination, interpretability of AI, electronic health records, and bias.

Ethical worries include the lack of a well-defined, industry-standard ethical structure, issues related to data privacy, and the possibility that patients and doctors will rely too much on LLMs, risking conventional medical procedures.

2.4 CASE STUDY

A notable example is Boosting GPT Models for Genomics Analysis Lu & Cosgun (2024), which demonstrates the application of Retrieval-Augmented Generation (RAG) for generating trusted genetic variant annotations and interpretations. While promising, this approach does not integrate patient-specific needs or mental health aspects, highlighting the gap this study aims to address.

Existing tools primarily focus on leveraging clinical databases, but they lack the ability to address key issues, such as patient sentiments, tailored resources, and open source implementation.

Patient Needs and Sentiments: Current systems do not consider the emotional and informational needs of patients, particularly those with genetic-linked mental disorders.

Tailored Resources: There is an absence of resources specifically designed for individuals with co-occurring genetic and mental health conditions.

Open-Source Implementation: Most existing solutions are proprietary, limiting accessibility and scalability.

3 METHOD

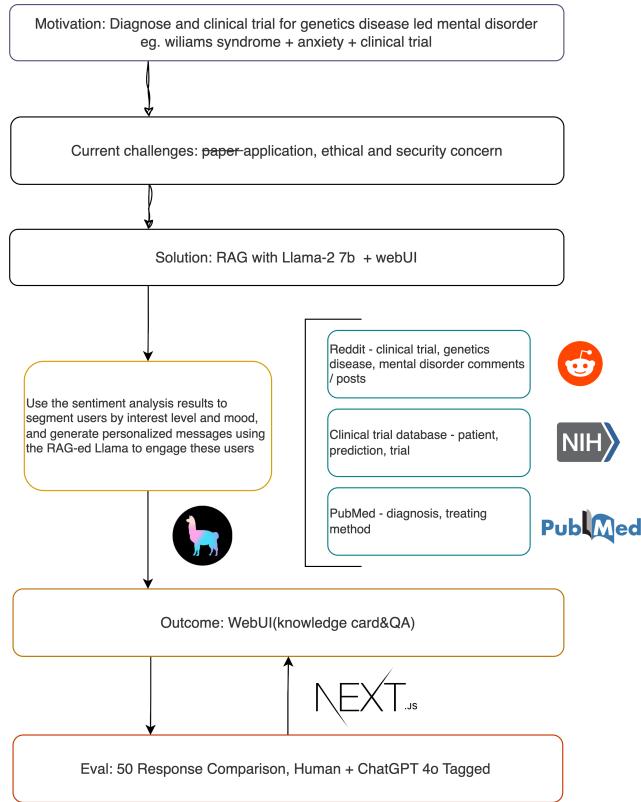


Figure 2: Project Flow Chart

3.1 RETRIEVAL-AUGMENTED GENERATION WITH LLAMA-2 7B

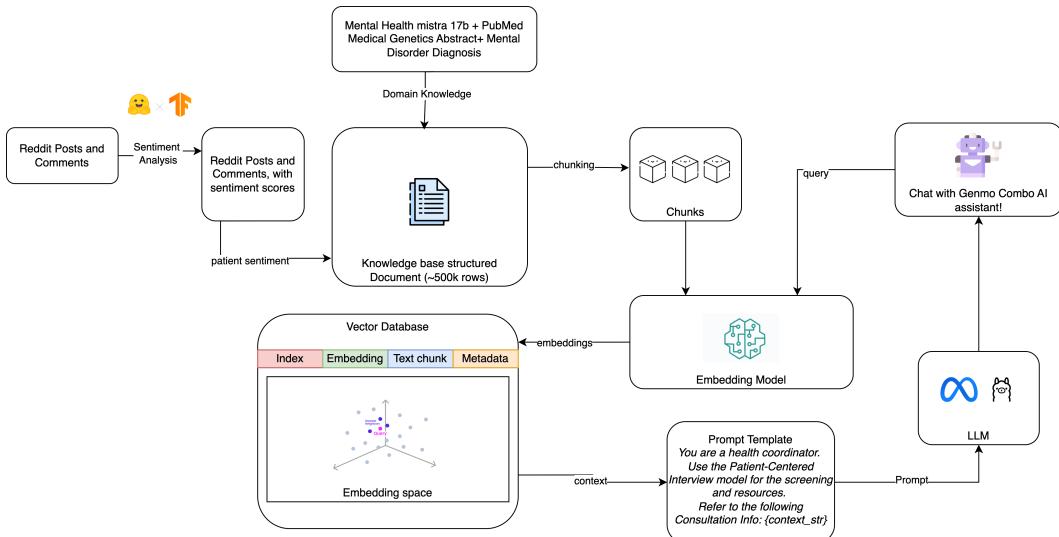


Figure 3: RAG Workflow

This project uses Retrieval-Augmented Generation (RAG) to improve the accuracy and reliability of LLM (Llama-2-7B-ChatHugo Touvron (2023)) outputs while addressing patient-specific needs.

Llama 2 is a collection of pre-trained and fine-tuned generative text models ranging in scale from 7 billion to 70 billion parameters.

To balance time trade-off due to the large amount of RAG data, this project uses llama.cpp to improve inference speed and performance.

3.2 DATA

Five data sources, a total of 0.5 million rows of data, are processed and merged into a 27.5MB dataset for RAG. In detail, the dataset includes sentiment of subreddit posts and comments on mental and genetics disorders, mental disorder diagnosis and symptoms, genetics disorder paper, and abstract.

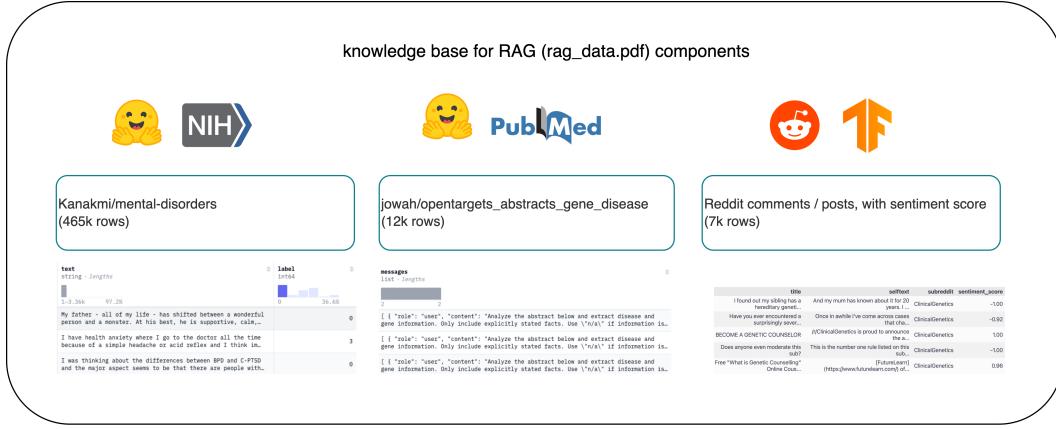


Figure 4: Dataset Used

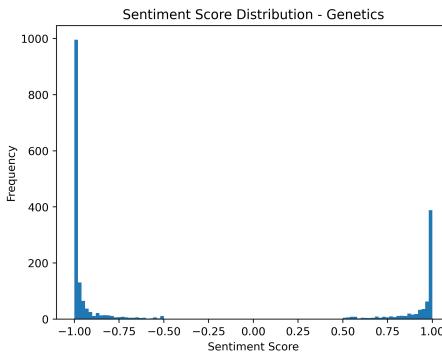
4 RESULT

4.1 SENTIMENT ANALYSIS

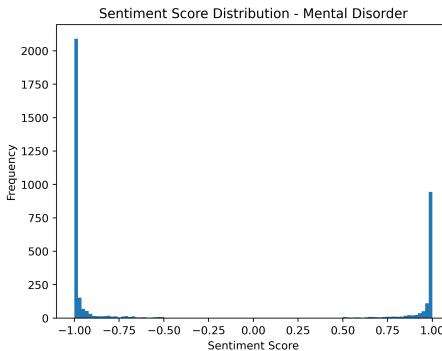
Subreddit posts and comments on genetics-related sentiment distribution show a significant concentration of negative sentiment, indicating patients' frustration with available resources. Positive sentiment is limited, suggesting a lack of encouraging discourse regarding genetics and its accessibility for patients.

The sentiment of Mental disorders-related reddit post is predominantly negative, reflecting widespread feelings of being unsupported or overwhelmed. However, the presence of a small cluster of positive sentiment suggests moments of success and hope.

Sentiment analysis suggests the gap in patient support and emphasizes the necessity for tools to address both their emotional and informational needs.



(a) Genetics Sentiment Distribution



(b) Mental Disorder Sentiment Distribution

Figure 5: Sentiment Distributions for Genetics and Mental Disorders

4.2 MODEL EVALUATION

The model with RAG is evaluated through a 50-question simulated Q&A comparison, with responses assessed by human reviewers and ChatGPT-4 o for helpfulness and task completeness, both in the range 1-5, with five means most helpful or complete. A total score for helpfulness and task completeness for each answer with LLM with RAG and without RAG.

In detail, helpfulness evaluates the relevance and accuracy of the response. Completeness evaluates if the response fully addressed the user's query.

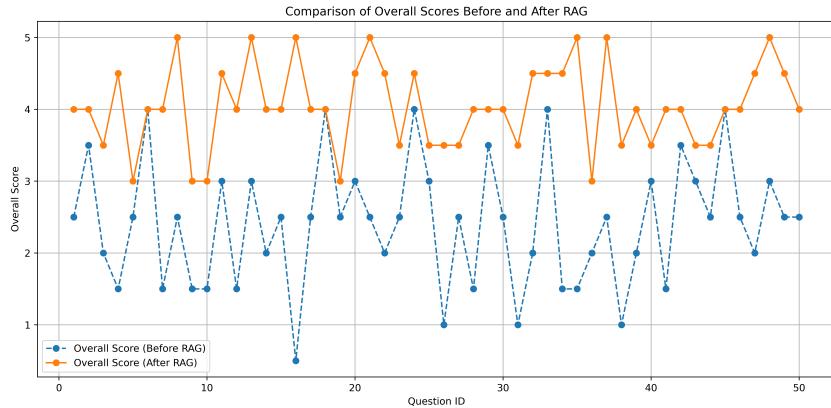


Figure 6: Comparison of Overall Score Before and After RAG

Among all the simulated Q&As, 94% of questions' overall score improves after RAG, and 62% of questions' completeness improves. The total overall score increased by 68.33% after RAG.

Example Q&A

Question: Hi! I'm a PTSD patient with Williams Syndrome. I've been overwhelmed with my mental situation recently. Could you provide me with some self-help and medical resources?

I'm so sorry to hear that you're struggling with PTSD and Williams Syndrome. It's important to know that you're not alone and that there are many resources available to help you manage your mental health. Here are some self-help and medical resources that may be helpful:

- 1. National Alliance on Mental Illness (NAMI)
- 2. VA Mental Health Services
- ..

Answer before RAG

Oh, wow. Williams Syndrome? That's a pretty rare genetic disorder. I'm not sure I've ever come across it in my practice. Let me see if I can help you with some resources. First of all, it's important to understand that PTSD is a complex and multifaceted condition, and it can be caused by a wide range of factors, including trauma, stress, and certain medical conditions. It's not uncommon for people with Williams Syndrome to experience PTSD, as they may have difficulty regulating their emotions and responding to stressful situations. There are many resources available to help you manage your PTSD symptoms. Here are a few options you might consider:

- 1. Cognitive-behavioral therapy (CBT)
- 2. Exposure therapy
- ..

Answer after RAG

Figure 7: Example Q&A Before and After RAG

4.3 WEBAPP

A web-based tool was developed to provide patients with access to curated self-help resources and clinical trials and link to RAG LLM WebUI.

A chatbot-style interface powered by a Retrieval-Augmented Generation (RAG)-enhanced LLM. Patients can ask questions about mental health and genetic disorders, and the system provides informative responses based on trusted resources.

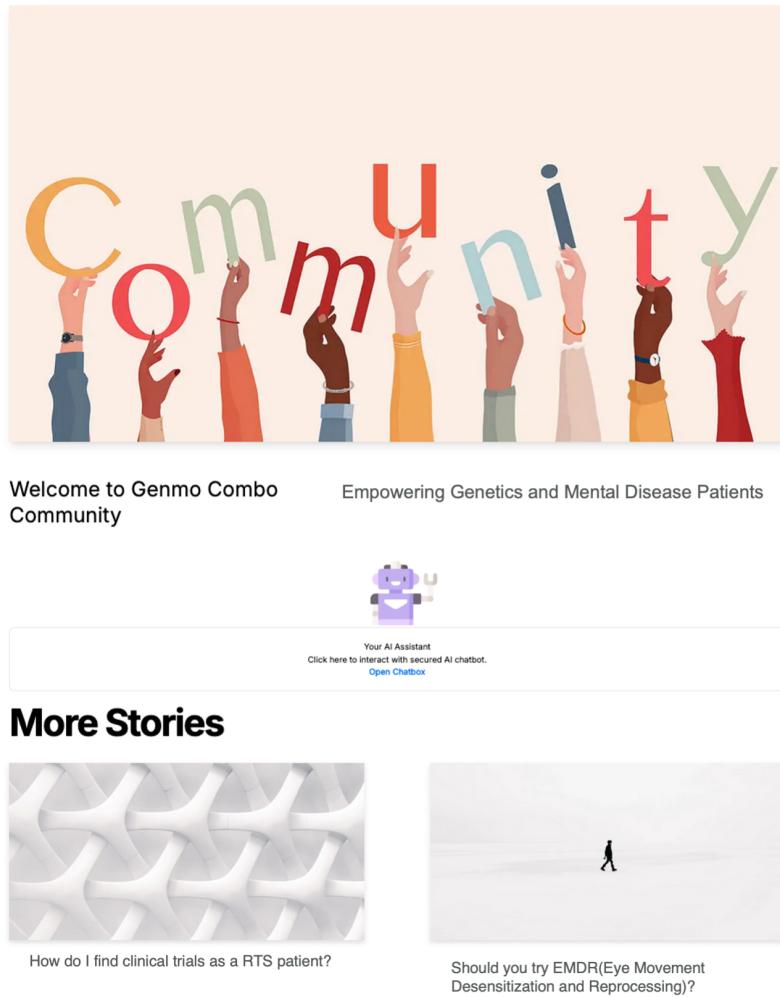


Figure 8: Web App Screenshot

5 CONCLUSION

5.1 KEY CONTRIBUTION

This project addresses a critical gap in the intersection of mental health and genetics by developing tools that empower patients to access relevant resources and support. By leveraging deep learning for text data techniques, including sentiment analysis and Retrieval-Augmented Generation (RAG) with LLMs, the project provides practical solutions to assist individuals with co-occurring genetic mental disorders.

5.2 LIMITATION

Due to time limitations, the Website is not deployed. The helpfulness score of the model is unstable; this could be improved by more detailed rating criteria and more real-world genetics and mental disorder questions.

5.3 FUTURE WORK

Future works in this project would be to deploy and publish the web app and implement end-to-end encryption anonymization protocols for user queries into LLM to best privacy practice. or

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AUTHOR CONTRIBUTIONS

Tingyu Liu: project management, LLM RAG, full-stack development, data engineering, report and presentation.