IDENTIFYING AND PREDICTING / DIAGNOSING COMMON MENTAL DISORDERS BY DIGITAL PHENOTYPING USING A MOBILE APP

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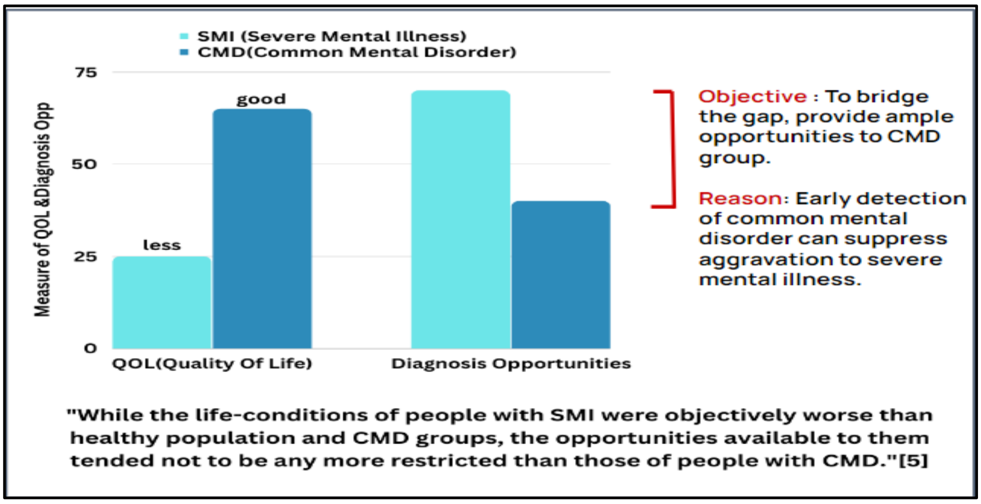
Introduction

Amidst the global challenges posed by the COVID-19 pandemic, mental health has risen to the forefront of concerns, particularly in India where 60 to 70 million individuals grapple with various mental illnesses. The World Health Organization (WHO) projects staggering economic costs, estimating a USD 1.03 trillion burden from mental health disorders between 2012 and 2030. Recognizing this critical juncture, our project, 'Identifying and Diagnosing/Predicting Common Mental Disorders By Digital Phenotyping', aims to bridge the vast treatment and diagnosis gaps prevalent in common mental disorders.

In light of these challenges, there is a pressing need to bridge the gap in treatment and diagnostic resources for individuals with common mental disorders (CMD). This need has spurred the conception of our major project titled 'Identifying And Diagnosing/Predicting Common Mental Disorders By Digital Phenotyping'. Our project aims to leverage digital phenotyping techniques to enhance early detection, diagnosis, and prediction of CMD, thus offering timely interventions and support to those in need. Through innovative approaches and advanced technologies, we aspire to contribute to the holistic well-being and mental health resilience of individuals in India and beyond.

Objectives

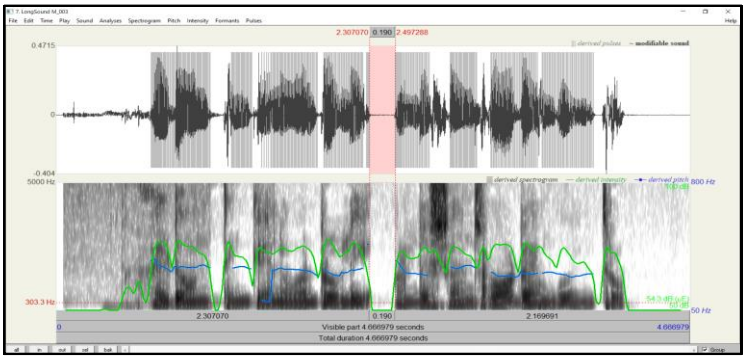
The objective of the project is to develop a comprehensive digital phenotyping framework for the early prediction and diagnosis of common mental disorders, such as anxiety and depression. This initiative aims to bridge the gap in mental health care by providing ample opportunities for early detection and intervention for individuals with common mental disorders (CMD). By focusing on early detection, the project seeks to prevent the progression of CMD into severe mental illness (SMI), thereby improving overall mental health outcomes and reducing the burden on healthcare systems.



Methodology

The methodology encompasses three key areas: voice data collection and analysis using Librosa for feature extraction, text classification employing advanced NLP techniques for sentiment analysis, and keystroke data collection and analysis focusing on behavioural markers. Voice data is transcribed and analysed for patterns, while text data undergoes sentiment classification and categorization. Keystroke dynamics are captured and studied for insights into user behaviour. By integrating these approaches, the project aims to bridge the gap in mental health care by providing early detection and intervention opportunities for common mental disorders.

1. Voice Data Collection and Analysis [BUCKET-1]
    - Utilise a microphone setup for voice data collection, ensuring clear and consistent audio quality.
    - Transcribe voice recordings using speech recognition technology, converting them into text data for further analysis.
    - Use the Librosa library in Python for audio feature extraction, focusing on Mel-Frequency Cepstral Coefficients (MFCCs) and other relevant features.
    - Analyse extracted voice features to identify patterns and insights related to mental health indicators, such as pitch variations, speech rate, and intonation.

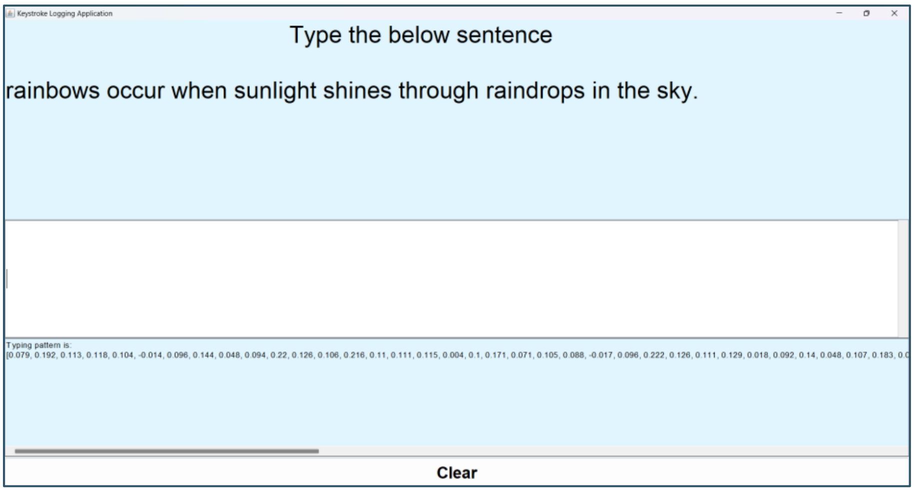


Spectrogram of the voice sample

2. Text Classification [BUCKET-2]
    - Implement sentiment analysis techniques to classify transcribed texts into positive, negative, or neutral sentiments.
    - Employ advanced Natural Language Processing (NLP) methods, including tokenization, part-of-speech tagging, and named entity recognition, for accurate sentiment identification and context understanding.

Text classification implementation

3. Keystroke Data Collection and Analysis [BUCKET-3]
    - Develop a keystroke logging application to collect timing and frequency features of keystrokes during text input.
    - Integrate tools like KeyDataStore for capturing and storing keystroke dynamics, including key press duration, intervals, and patterns.
    - Analyse keystroke data to identify behavioural markers, such as typing speed variations, pause durations, and error rates, which may indicate cognitive or emotional states.

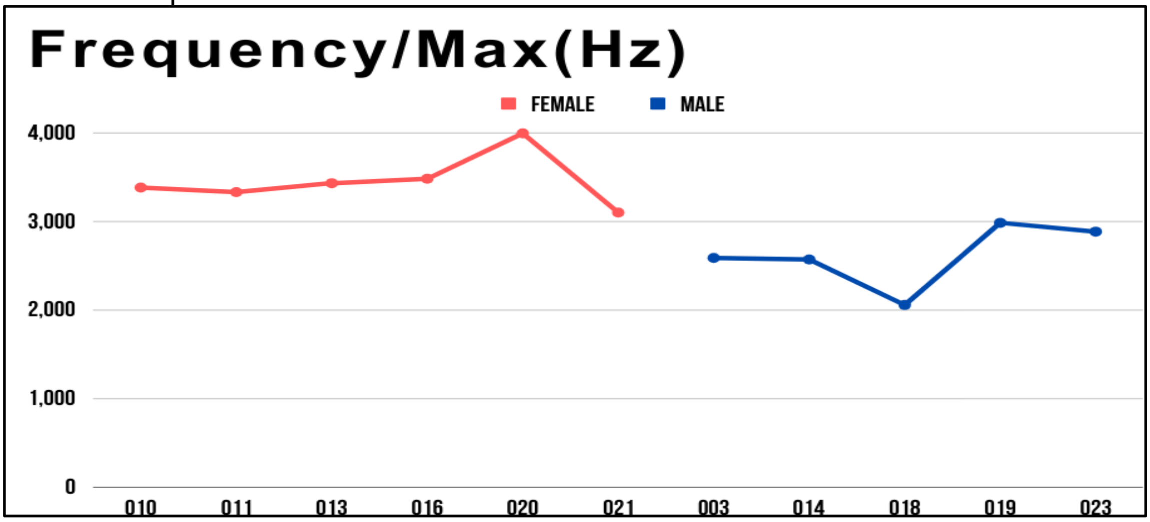


Results And Discussion

Spectrogram Analysis

The speech data from 11 representative samples were analyzed using Praat software, generating spectrograms that displayed key features such as pitch, frequency, and decibel levels:

Frequency: Representing the number of sound wave cycles per second, measured in Hertz (Hz), with a range of 0 - 5000 Hz.
Pitch: Indicating the highness or lowness of a tone, measured in Hertz (Hz), with a range of 50 - 100 Hz.
Amplitude: Representing the loudness, measured in decibels (db).
The average pitch, frequency, and loudness were plotted separately for male and female samples.



Voice sample frequency chart

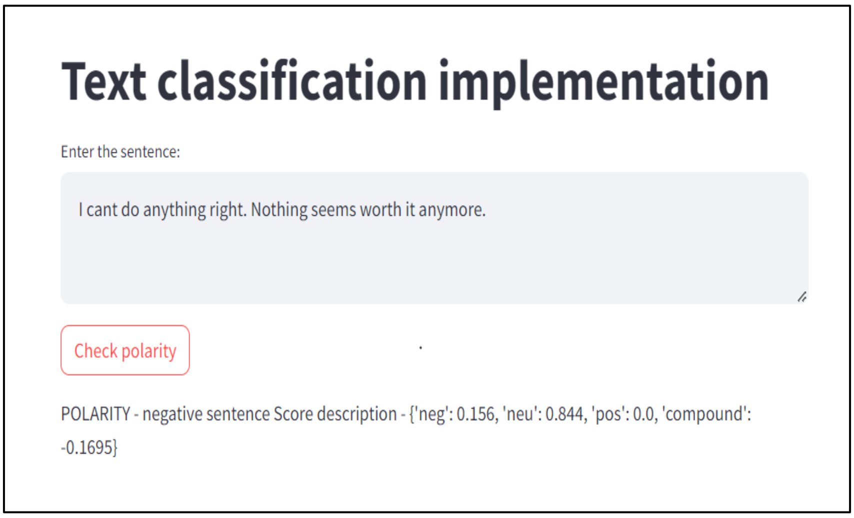
Text-Based Classification - Algorithm Analysis

For sentiment analysis, we employed VADER and TextBlob libraries. VADER provided more accurate results using a compound score ranging from -1 (most negative) to +1 (most positive).

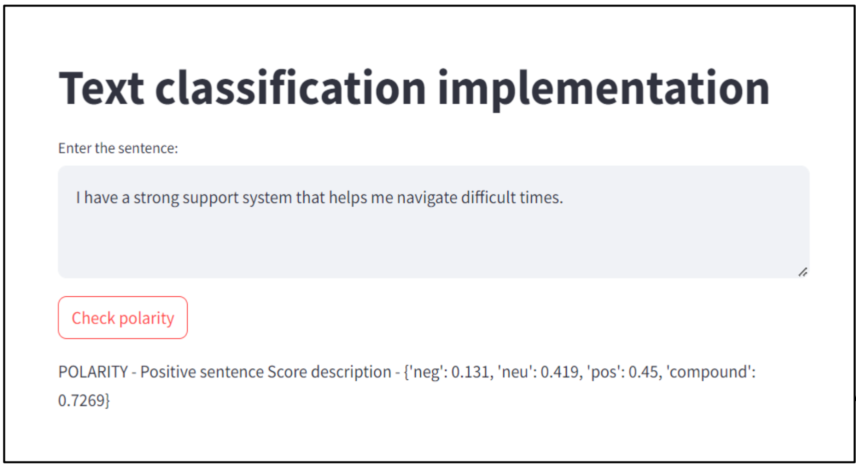
Depression Classification: Naïve Bayes model outperformed others, achieving a 68% accuracy rate.
Multi-Class Classification: RoBERTa-based classifier excelled with an F1 score of 0.86, surpassing LSTM and BERT models.

Text Classification Using VADER

Utilizing VADER, an open-source sentiment analysis tool, we determined the sentiment of text inputs on a scale from -1 to +1. For a better user experience, a custom web application was developed and deployed using Streamlit.



Test case showing negative polarity



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Data Preprocessing

Handling Missing Values: Missing keystroke data were imputed using the mean of other dwell and latency records.
Encoding: Categorical values in 'Sentiment' and 'phq9 score' columns were converted into integer codes via label encoding.

Feature Selection

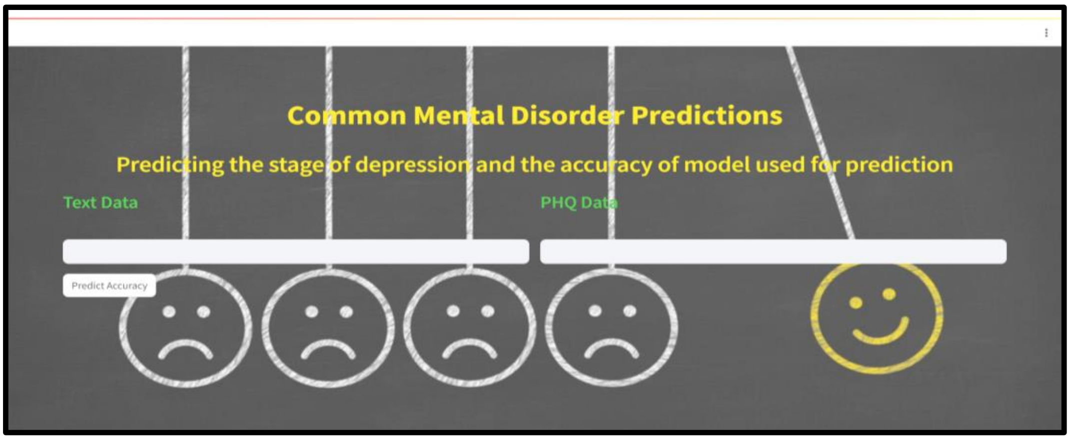
Removing Irrelevant Features: The text column was excluded from the training data to focus on relevant features.

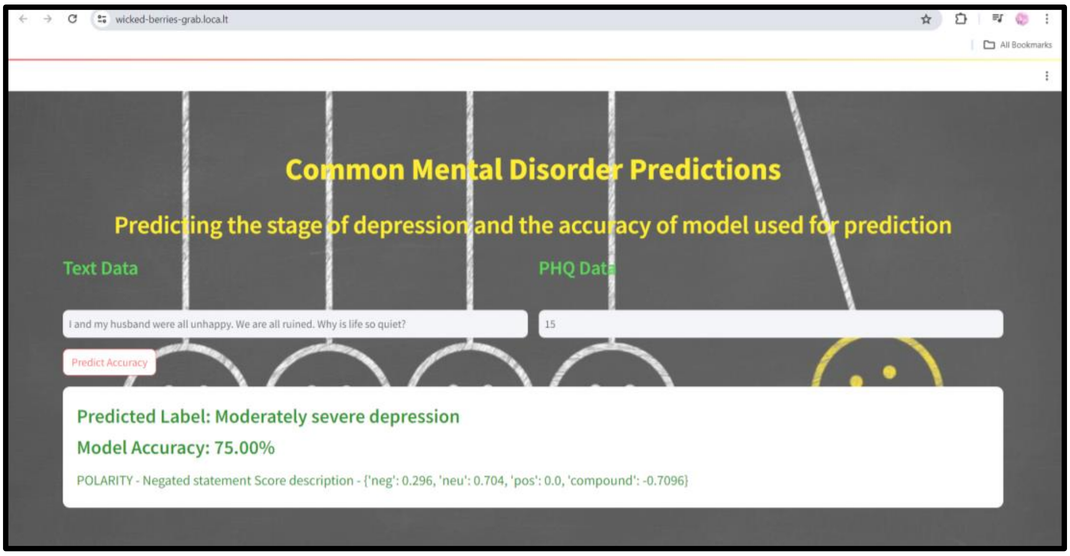
Hyperparameter Tuning - GridSearch was employed to exhaustively search over a specified parameter grid, leading to the identification of optimal parameters:

Best Parameters: {'max_depth': 10, 'max_features': 'auto', 'min_samples_leaf': 1, 'min_samples_split': 5, 'n_estimators': 100}

Major Conclusions

- Data Volume: Increasing the number of data records is expected to enhance model accuracy (current data consisted of no more than 40 records).
- Model Optimization: Further tweaking of the model parameters can potentially improve accuracy.
- Feature Selection: Analysis of average accuracy provides insights into which features to retain or eliminate, guiding feature selection for better performance.





Description Of the Innovation in Project

Our project, "Identifying and Predicting/Diagnosing Common Mental Disorders by Digital Phenotyping," introduces several innovative approaches, distinguishing itself by creating a custom dataset rather than relying on existing ones. We collected real-time patient data through visits to psychiatry departments in hospitals, employing random sampling techniques to build a robust dataset for predicting common mental disorders (CMDs).

By leveraging Praat software, we conducted detailed spectrogram analysis of voice data, extracting features such as pitch, frequency, and amplitude. This non-invasive method aids in the early detection and monitoring of mental disorders. Advanced natural language processing tools like VADER and TextBlob were utilized for sentiment analysis, combined with machine learning models tailored to our specific requirements.

Our approach includes extensive data preprocessing, handling missing values, and encoding categorical variables to ensure data integrity. We further refined machine learning models through hyperparameter tuning, adjusting parameters to optimize performance for CMD prediction. This customization enhances the predictive accuracy and relevance of the models.

The final product of this project aims to assist doctors in better diagnosing and addressing mental health issues, particularly by identifying severely depressed patients early. This innovative tool has the potential to improve diagnostic opportunities and enable timely intervention for those suffering from depression.

Future Work Scope

The future scope of our project, "Identifying and Predicting/Diagnosing Common Mental Disorders by Digital Phenotyping," encompasses several promising directions. By continuing to enhance and expand our current methodologies, we can significantly impact mental health diagnosis and treatment.

- Enhanced Treatment Plans - Our application can be further developed to provide personalized treatment recommendations. By integrating additional data points and improving predictive algorithms, the app can assist healthcare professionals in crafting tailored treatment plans, ensuring patients receive the most effective interventions based on their specific needs.

- Early Detection and Intervention - With continuous improvement in data collection and model accuracy, our application can be pivotal in detecting early signs of mental disorders. Early detection can lead to timely interventions, potentially preventing the progression of mental health issues and improving patient outcomes.

- Utilization in Mental Health Camps - The application can be deployed in mental health camps to assess the mental health status of the general population. This can raise awareness about mental health, help individuals recognize the need for professional assistance, and provide an initial diagnosis for those who might not have easy access to mental health services.

- Activity Suggestion for Patients - The app can evolve to include features that suggest activities as part of a treatment plan. These recommendations, based on patient data and under the guidance of healthcare professionals, can aid in the therapeutic process, promoting activities that enhance mental well-being and adherence to treatment plans.

- Broader Data Integration - Future work can involve integrating data from diverse sources, such as wearable devices and social media activity, to enrich the dataset. This will enable more comprehensive digital phenotyping, capturing a wider range of behavioural indicators for mental health analysis.

- Scalability and Accessibility - Efforts can be made to scale the application for widespread use, ensuring it is accessible to a broader audience. This includes developing user-friendly interfaces, multilingual support, and compatibility with various devices to reach diverse populations.

By pursuing these future directions, our project can significantly contribute to the field of mental health, offering innovative solutions for early detection, diagnosis, and personalized treatment of common mental disorders.