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A Comparative Study on Hybrid Deep Learning Models for Depression Detection

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***Abstract*—- Depression is the one of most common mental condition worldwide and it has considerable consequences. Early identification and intervention are key to a successful treatment. The aim of this review is to provide an exhaustive research on the development and status of hybrid deep learning models for depression diagnosis through 2017–2024. We explore various hybrid architectures which combine multiple deep learning techniques, such as Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks and transformer models, often fused with traditional machine-learning algorithms. These data sources are largely qualitative in nature, and include social media, electronic health records, speech tendencies (sarcasm), facial expressions and physiological signs. In practice, we evaluate the performance of and interpretability of these hybrid models in various data sets and cultural settings. It focused particularly on multimodal methods that combine (several) datatypes to increase the accuracy of (anomaly) detection. Key trends that are highlighted cover the increasing use of attention processes, the incorporation of explainable AI methods and models capable to diagnose early-stage depression. We also look at the ethical implications of these devices including data privacy problems and the potential for real-world, clinical application. This comprehensive review highlights the significant step in hybrid deep learning models on depression detection in seven years. It addresses the current constraints and points to future research desires anchoring on the need of bigger, more holistic datasets as well as more interpretable models needed for transforming conceptual findings into practical tools for psychiatric care.**

***Keywords*—- Depression detection, hybrid deep learning, machine learning, social media analysis, multimodal approaches, mental health informatics.**

I. INTRODUCTION

Depression is a common mental health disorder that globally affects more than 264 million individuals and poses a major public health concern. According to the World Health Organisation (WHO), over 300 million people worldwide suffer from depression. The growing prevalence emphasizes an immediate requirement for successful early diagnosis and interventionism to avert devastating outcomes including suicidal risk [3]. Studies even show high rates of depression associated with heavy social media use [4]. Despite the benefits that may come from using social media, it is not without issues, particularly concerning mental health [5].

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One novel setting for studying mental health is the rise of social media platforms. These user-generated platforms form an extensive corpus of text, cross-sectioned with pictures and behavioural patterns that may contain substantial evidence on affective states [6]. Since social media data include large amounts of diverse information, they are a valuable resource for detecting markers related to depression [7].

Recent development in AI and ML is going to hybrid deep learning model which came up with multi neural network frameworks for accuracy of identifying the diseased like depression. Deep Learning models using architectures such as Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks, and attention mechanisms. [8] They perform well for analyzing visual data, where Convolutional Neural Networks (CNNs) excel. For depression diagnosis, CNNs can be applied to images/videos shared via mainstream social media channels to detect emotional cues and visual features associated with depressed symptoms [9].

This is suitable for text and audio streams where the LSTM network is good at dealing with sequence data. LSTMs could be capturing temporal dependencies in text and voice tone for subtle variations of language change that are indicative of a more-downbeat mood [10]. Hybrid models benefit from the use of attention mechanisms, which increase efficacy by focusing on relevant segments and ignoring irrelevant information. This ability comes in handy especially when dealing with multi-modal data; due to a number of reasons various factors may hold an effect on the identification of depression [11].

Gathering data from multiple sources such as text, audio, and video on depression allows a comprehensive understanding of this illness. Multi-modal approaches combine the strengths of multiple data sources to get a complete view of an individual's mental state [12]. Combining text analysis with behavioural cues and audio-visual signals might increase the sensitivity to capture subtle indicators of depression, which could have gone unnoticed if examined based on a single data modality [13].

Review Outline: Hybrid Deep Learning Models for Depression Detection Hybrid deep learning frameworks that integrate Convolutional Neural Networks (CNNs) with Deep Neural Networks (DNNs).

Benefits of Combining Text, Audio, Video and Behaviour patterns for Comprehensive Analysis Strategies to make hybrid deep learning models interpretable. The importance of transparency and explainability in using models for mental health applications. Approaches to evaluating the performance and effectiveness of a model. Existing gaps in hybrid deep learning algorithms that cause insufficiency to identify depression. Future avenues of research and forward-thinking developments in this field.

This increasing focus on 'interpretable models' is of critical importance for driving institutional and public trust in AI systems, particularly when applied to sensitive areas like mental health. Understanding the decision policy that these models come up with can help physicians and researchers validate them, as well as fix biases or mistakes [14]. Therefore, Explainable AI is crucial to ensuring the trustworthiness and societal acceptability of automated models regarding the classification of depression.

The use of AI for mental health evaluation is an ethical quandary, including privacy concerns, bias in data collection, and the possibility of misuse. At the bare minimum, data needs to be both collected and used ethically: with respect for individual rights and welfare.

The impact of global events, such as the COVID-19 pandemic has influenced how often (prevalence) and well depression can be measured further emphasizing the need for adaptive and stable models [16]. In the future, we need to continue our efforts on increasing the resilience of hybrid deep learning models and dealing with legal issues. Improving interpretability in models and safeguarding data privacy, as well as reducing bias are crucial in developing effective and equitable depression detection systems. In addition, continuous monitoring of the external environment and its impact on depression recognition will be essential for adapting strategies to changes in circumstances.

II. Background and Related Works

In short, we introduce an automated method to identify depression by taking full advantage of natural language processing on top of more sophisticated deep learning! This method is based on a rigorously annotated set of tweets that takes into account implicit and explicit settings of depression.

The model consists of a hybrid Sequence, Semantic, Context Learning (SSCL) Framework is created that deploys features learned from deep learning and self-attention mechanisms with GloVe embeddings for feature extraction. The method achieves a noted accuracy of 97.4% for binary-labeled data and 82.9% for ternary-labeled data, outperforming state-of-the-art methodologies. In light of the increased performance, the lower generalizability on ternary-labeled data of note may reflect a limitation in handling more complex classification tasks albeit its upward accuracy tendency [18].

Another study proposed a novel state-of-the-art hybrid model that combines CNN and LSTM networks to detect sadness from conversational text data on Twitter. This model was a much better predictor than traditional statistical models, accurately predicting whether rates were on the rise or falling 92% of the time compared with only 83% accuracy for machine learning techniques alone. Hybrid model: In practice, the hybrid model might work, although its success seems to hinge on the quality of input data provided — a difficult task, given that social media language tends to be quite colloquial [19].

To fill the gap and to obtain efficient models for automatic early detection of depression, a research brought forward a hybrid deep learning architecture called RoBERTa-BiLSTM which combines Transformer with sequence architectures. It aims to leverage both the long-range contextual semantics of Transformer models and their parallel processing power. The model performed really well on the DAIC-WOZ and EATD-Corpus benchmarks. However, the model was limited to process sequential data which can be a disadvantage for real-time applications as it will slow down the calculations [20].

Another study has examined to predict depression using a machine learning model by integrating Convolutional Neural Networks (CNN) with different Recurrent Neural Network (RNN)forums. It also leverages a hybrid approach to both effectively extract geographic attribute and hierarchical characteristics from different kinds of data styles. While the model shows promise for an early warning system, its complexity and need for large datasets could limit its use in low data settings [21].

Another study examined the early detection of depression in seniors by utilizing a two-layer hybrid machine learning framework. The authors used LSTM to detect risk factors, then trained three machine learning classifiers using cross-validation. While the study did robustly identify predictors of depression, nonetheless, the prediction accuracies (AUCs between 0.703 and 0.749) suggest there is scope for improvement in predictive performance [22].

It is an article about diagnosing depression using a deep learning approach with a novel hybrid feature selection strategy working on preprocessed social media data to extract relevant dimensions. The result shows the use of a TFIDF-MIG methodology with Improvised Elephant Herding Algorithm (IEHA) achieved a higher classification accuracy. The complexity of the feature selection process limits its scalability and also ensures that it may not be easily generalizable to other datasets [23].

It presents a hybrid deep learning model that combines SBERT and CNN for detecting sadness in Reddit postings. This method outperformed previous approaches with an accuracy and F1 score of 0.86. Although the SBERT-CNN model is strong, it has only been tested on one data set and remains to be generalized across multiple other social media platforms and languages [24].

An increasing number of studies have proposed hybrid models that integrate deep learning and machine learning techniques to improve the detection of various subtypes of depression [12-21]. Predicting Depression through Kaggle dataset used XGBoost with Bi-LSTM and had a 94% accuracy. We used deep learning model for feature extraction and machine learning models for classification. This hybrid approach outperformed separate models, demonstrating the need to combine complementary approaches for depression detection [25].

To know more, there was a specific research focused on early depression detection using an innovative Deep Learning Multi-Aspect Depression identification with Hierarchical Attention Network (MDHAN). The authors used Twitter data and also used tokenization, stop word removal, and stemming and all the other preprocessing methods. The hybrid approach recommended used optimisation approaches like Adaptive Particle and Grey Wolf for testing, verifying 99.86% precision which winds up extreme. [26].

A few studies have concentrated on adding an attention mechanism to the ensemble deep learning (EDL) models, in order to create a more stable framework. For example a recent research claimed that systems like aeEDL which can employ attention mechanisms that are expected to outperform solo deep learning (SDL) models without any dedicated attention. They verified this in their investigations: The resulting aeEDL models offer higher accuracy compared to the baseline models over various datasets, even in cross-domain scenarios. This provides an example for how attention mechanisms can be used to potentiate depression detection models by improving their discriminability[27].

In addition, precision psychiatry has opened up unique possibilities for more personalised mental health treatment. An investigation highlighted the application of artificial intelligence (AI) and machine learning in depression detection, diagnosis, and treatment. Nevertheless, while these improvements were noted in the study it uncovered some areas lacking including no empirical proof and improved patient outcomes. Those studies identified the following as primary foci for future research: interdisciplinary collaboration, data availability across different carriers and standardization in the field [28].

The research offers a hybrid model, fused with deep-learning approaches for making the depression diagnosis better. Model flow : Three models like Textual CNN model, Audio CNN Model, LSTM based Hybrid model

that will use textual and audio feature information from DAIC-WoZ database. Results have shown that, the maximum performance achieved by the audio CNN model with accuracy at 98%, in comparison to textual CNN model with 92% accuracy. Results: Deep learning including the audio CNN were effective in recognizing depression However, limitations of the study are potential overfitting introduced by multiple layers in the models and limited focus on other datasets. Relying on a single database (DAIC-WoZ) might not generalize well to other datasets or real-world conditions [29].

TABLE I. SURVEY FROM THE DIFFERENT AUTHORS

Sno.	Title	Methodology	Result/Accuracy	Limitations
1	Multimodal Measurement of Depression Using Deep Learning Models	Logistic Regression, SVM, KNN	SVM achieved highest accuracy of 92.7%	Governed by dataset limitations and features
2	Machine learning-based approach for depression detection in Twitter using content and activity features	Light Gradient Boosting Model (LGBM), Catboost, Extreme Gradient Boosting (XGB)	Naive Bayes classifier achieved 96.49% accuracy	Limited to feature selection; may not generalize to other datasets
3	Mixed Deep Learning Based Model to Early Detection of Depression.	Bidirectional Long Short-Term Memory (Bi-LSTM), Convolutional Neural Network (CNN)	Bi-LSTM-XGBOOST achieved 94% accuracy	Limited by dataset scope and pre-processing methods
4	Machine learning-based approach for depression detection in Twitter using content and activity features.	Deep Learning Multi-Aspect Depression Detection with Hierarchical Attention Network (MDHAN)	99.86% accuracy	May not generalize across different datasets and contexts
5	"A Neural Network Based Hybrid Model for Depression Detection in Twitter.	Ensemble Deep Learning (EDL) with attention mechanisms	Mean increase in accuracy for EDL over SDL was 4.49%	Variability in performance across datasets; reliance on specific architectures
6	Depression Detection with Multi-Modalities Using a Hybrid Deep Learning Model on Social Media	Machine Learning techniques, including CatBoost, Random Forest, XGBoost, SVM	CatBoost achieved 93.1% accuracy	May not generalize to diverse clinical settings
7	A novel hybrid neural network for electroencephalogram (EEG)-based screening of depression, Biomedical Signal Processing and Control	Deep Learning and Machine Learning methods on EEG data	2DCNN-LSTM model achieved 95.1% accuracy	Requires specific preprocessing and is limited to EEG data
8	Explainable depression detection with multi-modalities using a hybrid deep learning model on social media	Hybrid model combining textual and audio features with deep learning	Textual CNN: 92%, Audio CNN: 98%	Limited to the DAIC-WoZ database; may not generalize to other settings
9	Explainable depression detection with multi-modalities using a hybrid deep learning model on social media.	Hybrid model with Improved Bi-directional LSTM and Transfer Learning	Superior precision, recall, accuracy, and F1-score	Relies on UCI dataset; may not generalize to other contexts
10	Hierarchical convolutional attention network for depression detection on social media and its impact during the pandemic.	Hybrid deep learning model SBERT-CNN	Achieved accuracy of 0.86 and F1 score of 0.86	Limited to Reddit posts; may not generalize to other platforms

III. SYSTEMATIC LITERATURE REVIEW

Systematic literature review (SLR) is a critical step to harmonize the current literature, providing an overview of the advancement made, problems identified and roads that may be taken in a subject field. In this research, a systematic literature review was conducted on hybrid deep learning models for depression identification. This is intended to assess the current state of research, identify past challenges and determine where future opportunities lie for enabling the development new generation of prediction models for detection and management of depression that are accurate, interpretable and clinically relevant.

A. Data Sources and Search Strategy

The review involved a comprehensive search across major databases such as Google Scholar, IEEE Springer, and ResearchGate, Science Direct focusing on publications from 2019 to 2024. Keywords used included " depression detection," "explainable machine learning in mental health," "depression diagnosis models," “DL-

based Depression Detection," and "interpretable AI for mental health predictions.The search was enhanced by incorporating these terms with Boolean operators (AND, OR). Only publications from peer-reviewed journals, conference proceedings, and technical reports were included, while non-peer-reviewed materials were excluded. Abstracts were initially reviewed for relevance, followed by full-text reviews to ensure they met the research criteria. Additionally, citation tracking and manual searches were conducted to identify recent advancements and relevant studies not captured in the initial search.

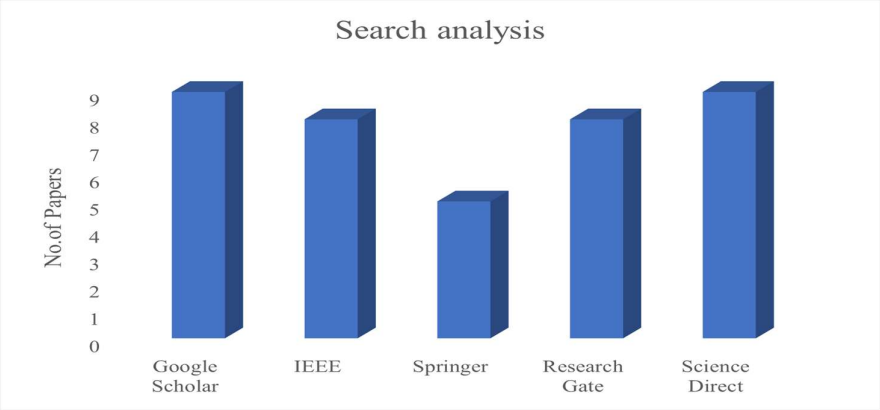

Figure 1. Illustrates the process of organizing and selecting the studies

B. PRISMA Methodology

The PRISMA methodology was adopted to ensure a systematic and transparent review process. The PRISMA flowchart (Figure 2) outlines the stages of the review, from the initial identification of studies to the final selection for in-depth analysis.

Search Results and Study Selection

The search yielded a total of 560 articles from the selected databases. After duplicates were excluded and relevant criteria enforced, 145 articles were shortlisted for detailed review. Following thorough abstract and full-text evaluations, 31 sources were determined to be relevant and factored into the final synthesis.

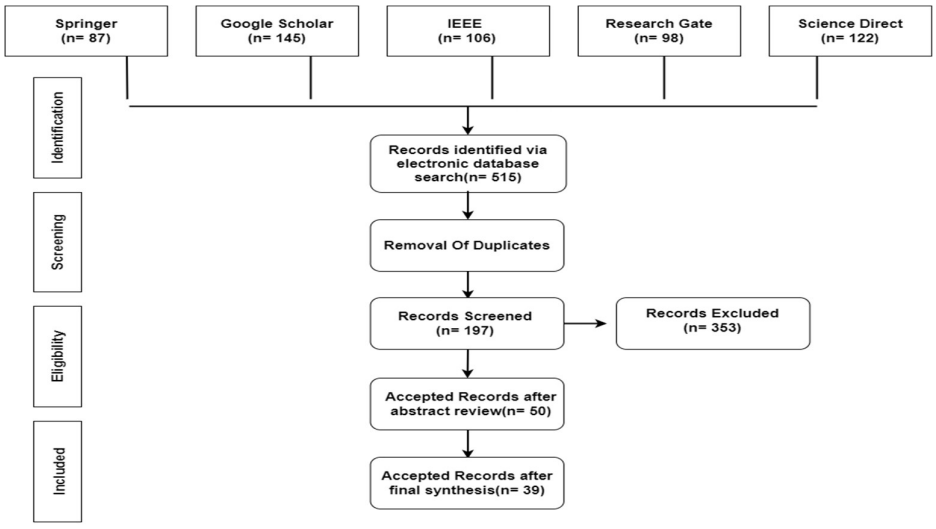

Figure 2. PRISMA Flowchart

C. Overview of Selected Studies

The selected studies cover various aspects of hybrid deep learning models, feature selection, and their applications in depression detection. Key observations include:

- Advancements in Hybrid Deep Learning Models: Recent research highlights significant progress in hybrid deep learning techniques, particularly in uniting distinct models to refine accuracy and robustness in depression diagnosis.
- Interpretable Machine Learning Models: Greater focus is being placed on developing machine learning models that are not only accurate but can be understood, thereby enabling mental health professionals to understand and place confidence in the decision-making process.
- Model Integration Challenges: Integrating feature selection with deep learning hybrid models are challenging prospects that involve balancing complexity and interpretability of the model as well substantiating its performance on different types of depression related datasets.

D. Comparative Analysis

- Based on the scrutinizing of methods used, hybrid deep learning models and measures of performance through all selected research it was found that:
- This significantly improves the prediction of depression diagnosis compared to single technique deep learning models, and aides model performance and reliability through leveraging the strengths of multiple techniques using hybrid deep learning models.
- Interpretability: For integration with mental health treatment, the decision process being close enough to a decision an expert would make is essential (This implies that AI models needs to be developed using the knowledge in this field). The extent to which the interpretations make sense are model-dependent, as well on how the methods were used to elucidate the predictions.
- Clinical Applicability: While the majority of hybrid approaches show strong performance in classification and interpretability, translational success into the clinic depends on various factors such as generalisability across data types, robustness to perturbations in model inputs and feasibility for deployment within existing mental healthcare pathways.

E. Summary of Findings

An in-depth examination of the 31 publications selected illustrates state-of-the-art hybrid deep learning models for depression diagnosis. Major Findings Include:

- Enhanced Model Accuracy: The use of hybrid DL models has decisively enhanced the correctness of depression detection, making these models more reliable for clinical and therapeutic use.
- Advances in Interpretability: Explainable AI models within hybrid frameworks offer transparent and understandable predictions, which are crucial for mental health professionals to make informed clinical decisions.
- Ongoing Challenges: Despite these advancements, challenges such as balancing model complexity with interpretability and ensuring that models are generalizable across diverse patient populations remain critical areas for future research.

F. Challenges

- Better Feature Extraction methods needs to be deployed for the effective detection of depression.
- Need for the severity grades detection of depression using the Hybrid Deep learning techniques.
- High Accurate Deep Learning Architectures are mandatorily required for the Depression detection process from increased versatile datasets.

G. Future work

- To design and development of Intelligent Deep learning Models for depression detection using the Larger datasets.
- To develop the Enhanced Deep learning Model for detection of severity grades in the depression and to develop model for early detection of depression.

IV. CONCLUSION

The effectiveness of hybrid deep learning models for identifying depression, focusing on integrating numerous neural network approaches to enhance diagnostic accuracy. The research demonstrated that combining different types of neural networks significantly improves the model's ability to identify patterns and features associated with depression. Our findings show that these hybrid models provide greater effectiveness than traditional methods, contributions greater robustness in varying data conditions and levels of noise. The inclusion of advanced mechanisms for feature interpretation further enhanced the model's accuracy and reliability. This work

underscores the value of a multi-dimensional approach to depression detection, emphasizing the need for sophisticated models that can handle the complexity of mental health data. By developing a model that captures both spatial and temporal aspects of the data, this research contributes to more effective early detection and intervention strategies. This study represents a remarkable enhancement in mental health informatics, a more accurate and scalable solution for detecting depression.

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