SafeSpaceAI

THAPAR INSTITUTE x ELC EXPERIENTIAL LEARNING CENTRE TIET, PATIALA

Multimodal Stress Detection System using Explainable AI

Concept Deck

Group 1

INTRODUCTION

‘NEED’??

Stress is a pervasive public health issue, contributing to cardiovascular, hormonal, and psychological disorders.

Real-time stress monitoring is essential for early intervention but is rarely available in daily life.

SOLUTION?

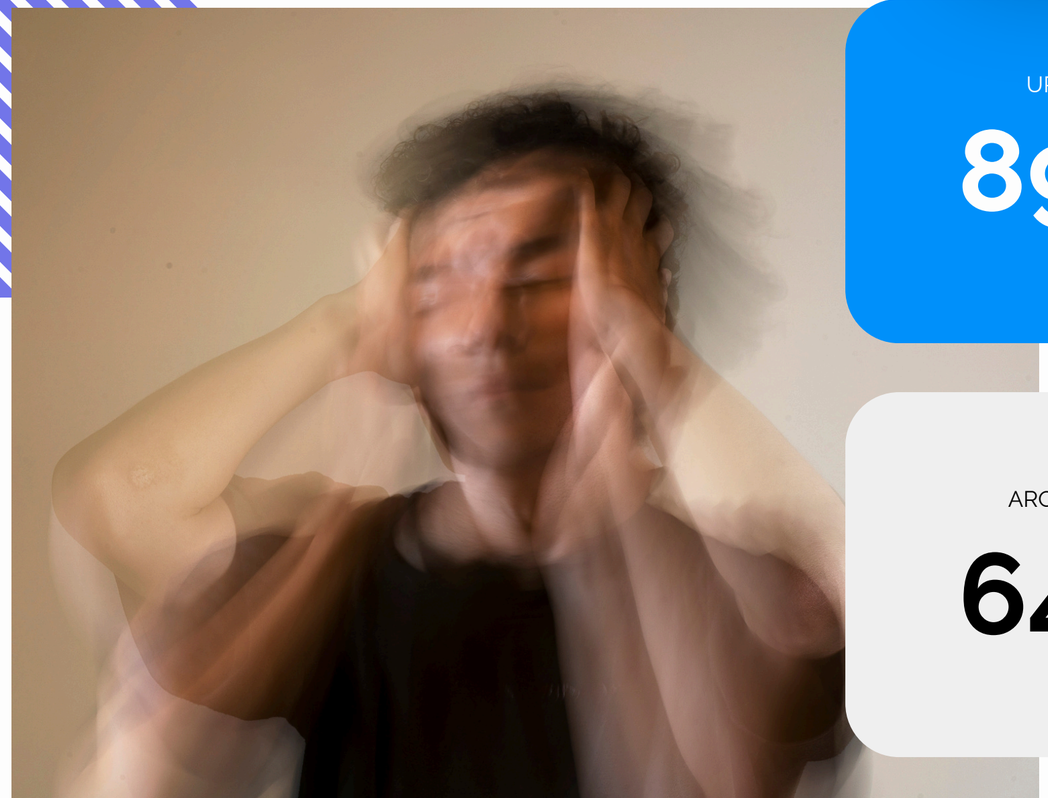
Introducing SafeSpace AI, a next-generation, explainable, multimodal system for stress detection.

Integrates biosignals (ECG, EDA, EMG, Temperature), voice emotion cues, and self-assessment (DASS-21).

Provides real-time analysis and natural-language explanations using Explainable AI.

Deploys via wearable hardware, a cloud backend, and a user-friendly web dashboard.

Challenges Faced by Present Research Works



NEARLY

72%

Limited to Single-Modal Data

Most existing systems rely on only one type of data (e.g. only physiological), reducing accuracy and robustness in real-world scenarios.

https://pmc.ncbi.nlm.nih.gov/articles/PMC8568542/

UPTO

89%

Lack Explainability

A large portion of ML-based stress detection models function as black boxes, making it hard to trust or understand predictions.

https://arxiv.org/html/2412.14009v1

AROUND

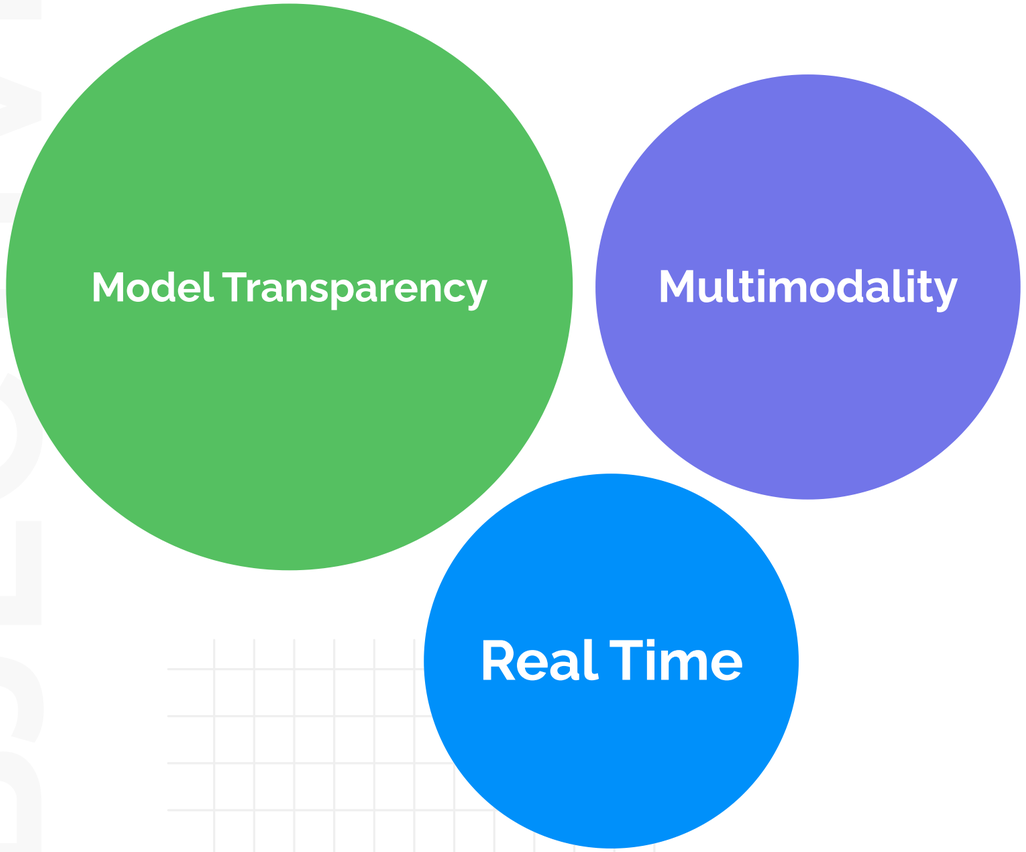
64%

Non-Deployable Prototypes

Many research systems are designed for lab environments only, with no real-time capabilities or hardware integration for real-world use.

https://www.ijsrtjournal.com/article/Unveiling-the-Mind-A-Survey-on-Stress-Detection-Using-Machine-Learning-and-Deep-Learning-Techniques

OBJECTIVES



Multimodal Integration

Goal: Seamlessly combine physiological biosignals, voice data, and self-assessment (DASS-21) questionnaires.
Purpose: Improve the accuracy and robustness of stress detection by fusing insights from multiple sources.

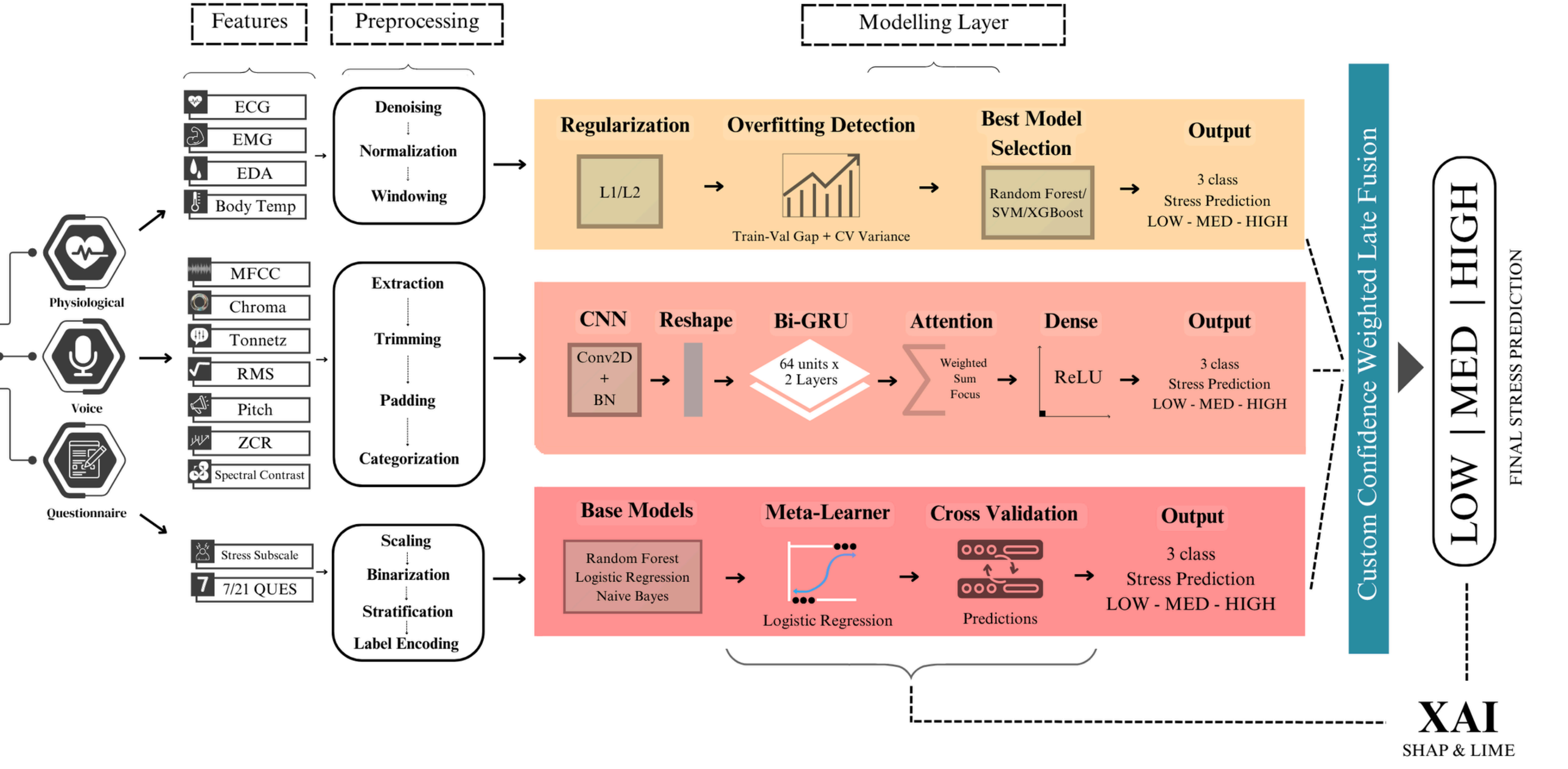
100% Model Transparency with XAI

Goal: Full transparency at every stage of AI prediction.
Implementation: Employ Explainable AI (SHAP)
Impact: Users and clinicians receive clear, actionable rationales behind every stress level prediction.

Real-Time with Custom Hardware

Goal: Enable live, in-the-moment stress detection leveraging dedicated hardware (ESP32-based wearable plus laptop microphone) and cloud infrastructure.
Implementation: Biosensor and voice data are streamed to a scalable backend for immediate analysis.
Outcome: Instant feedback empowers users with early intervention.

SYSTEM DIAGRAM



DATA **MODALITIES**

Physiological Biosignals

- Captured via: Custom ESP32-based wearable device.
- Sensors included:
  - **ECG (Electrocardiogram)**: Measures electrical activity of the heart.
  - **EDA (Electrodermal Activity)**: Reflects skin conductance and sympathetic nervous system activity.
  - **EMG (Electromyogram)**: Records muscle activity, sensitive to physical and psychological arousal.
  - **Body Temperature**: Assesses peripheral temperature shifts linked to stress responses.
- **Role**: Provides continuous, objective physiological indicators of stress with high temporal resolution.

Voice Signals

- **Input method**: Microphone/web audio interface.
- **Extracted features**:
  - **MFCCs (Mel-Frequency Cepstral Coefficients)**: Captures timbral and emotional qualities of speech.
  - **Pitch, energy, prosody, chroma, contrast**: Key vocal markers of stress and emotional state.
- **Role**: Offers non-invasive, contextual measurement of stress through vocal expression changes.

Self Assessment Cues

- **Instrument**: DASS-21 Stress Subscale (7 items).
- **Collection method**: Integrated web-based assessment.
- **Scoring**: Responses mapped to three stress categories (Low, Medium, High).
- **Role**: Captures subjective, self-reported stress perception, complementing sensor data for a holistic assessment.

MULTIMODAL **LATE FUSION**

IMPORT & DATA PREPARATION

The code loads softmax outputs from all three modalities (physiological, voice, questionnaire), standardizes their formats, and performs augmentation to balance class distributions for robust learning.

PHYSIOLOGICAL-DOMINANT FUSION MODEL

A custom fusion model is defined that gives the highest weight to physiological predictions, with fixed, smaller weights for survey and voice. Class probabilities from all modalities are validated and fused, with confidence-based scaling.

WEIGHTED PROBABILITY AGGREGATION

For each sample, the model multiplies each modality's predicted probabilities by both its fixed weight and its confidence, sums them, and then normalizes the result to output the final fused class probabilities.

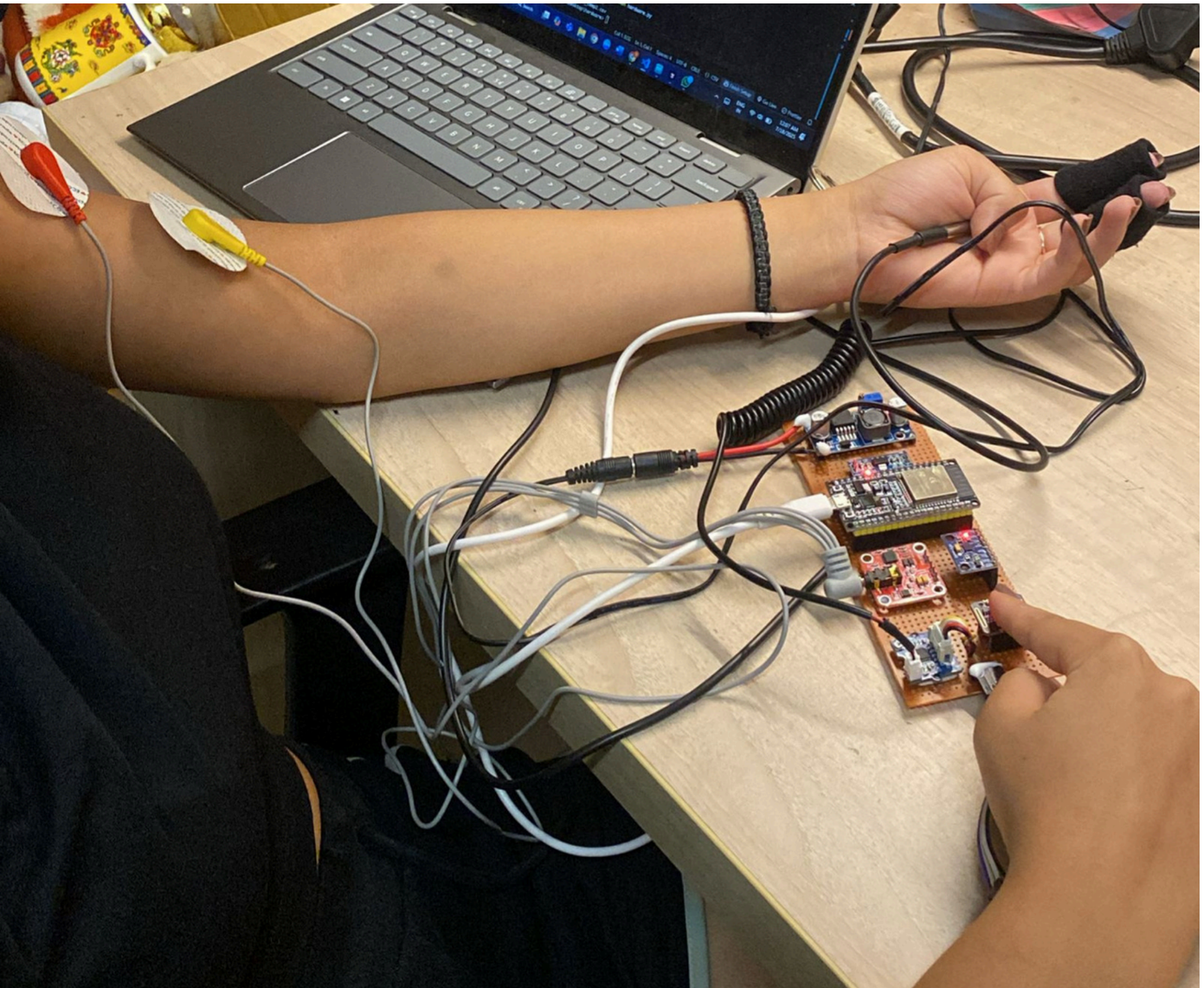
RESULT EVALUATION & EXPLAINABILITY

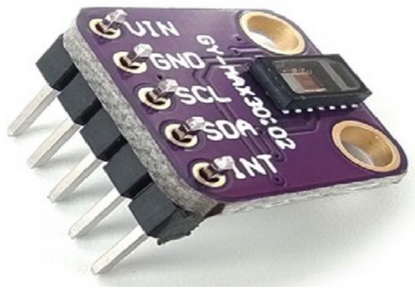
The final fused outputs are compared with ground truth to generate metrics such as accuracy, balanced accuracy, confusion matrices, ROC curves, and XAI visualizations (like SHAP summaries) for full transparency and interpretability.

MODEL **DEVELOPMENT**

Modality	Model Type	Features Used	Datasets
PHYSIOLOGICAL	RF/SVM/XGB/ET (ensemble)	Time, Frequency, HRV, Wavelet	WESAD
VOICE	CNN-BiGRU-Attention	MFCCs, Pitch, Energy, Chroma	IEMOCAP, RAVDESS
SELF ASSESSMENT	Stacking (RF/LR/NB + meta-LR)	DASS-21 (Numeric)	DASS-21
LATE FUSION	Confidence-Weighted Aggregation	Softmax Outputs from All	All Combined

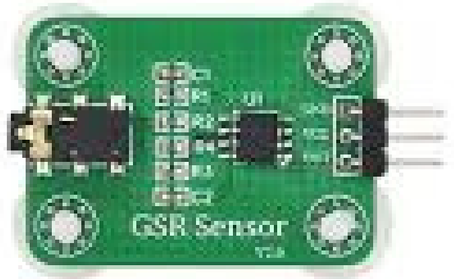
HARDWARE USED





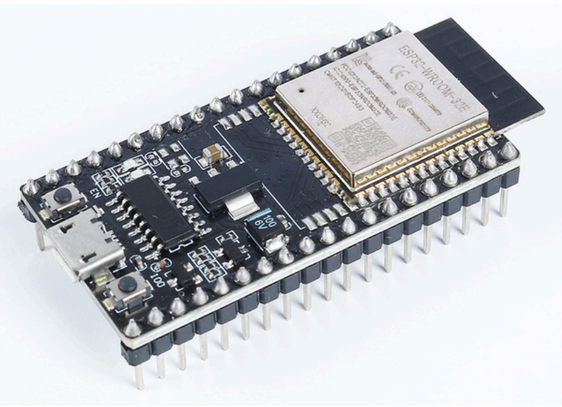
MAX30102 (ECG)

EMG sensor



GSR sensor (EDA)

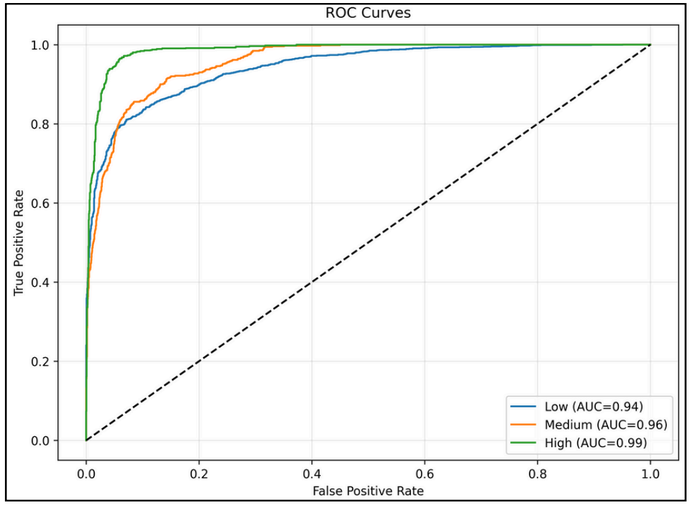
DS18B20 (TEMP)

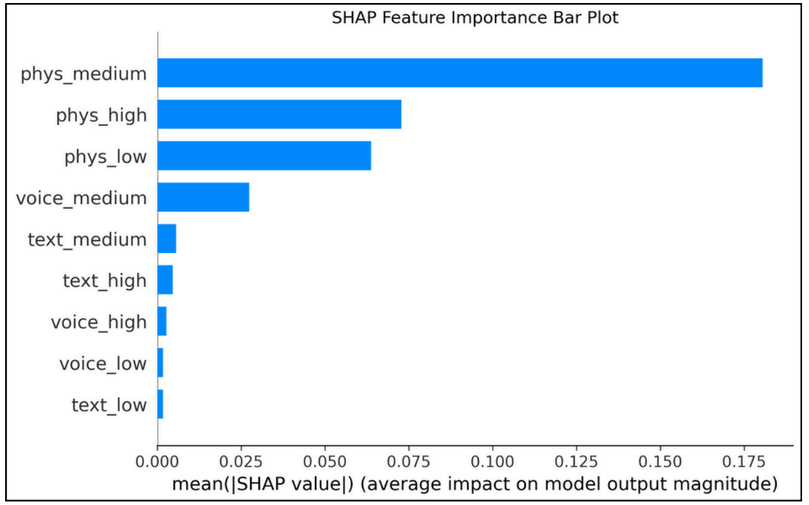


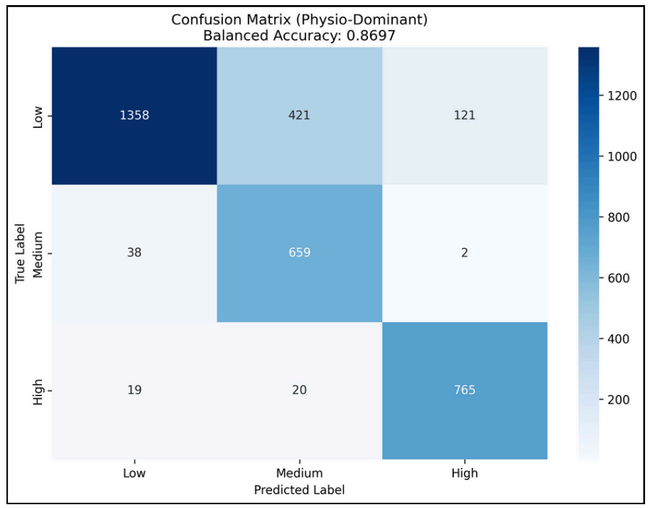
ESP 32

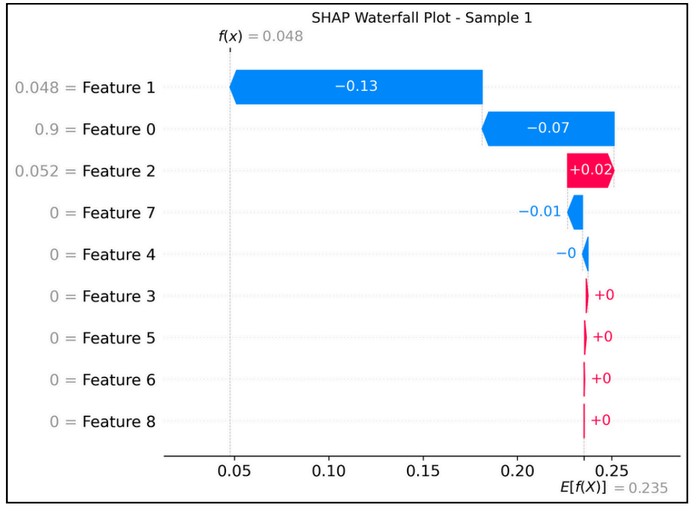
RESULTS & SAMPLE XAI

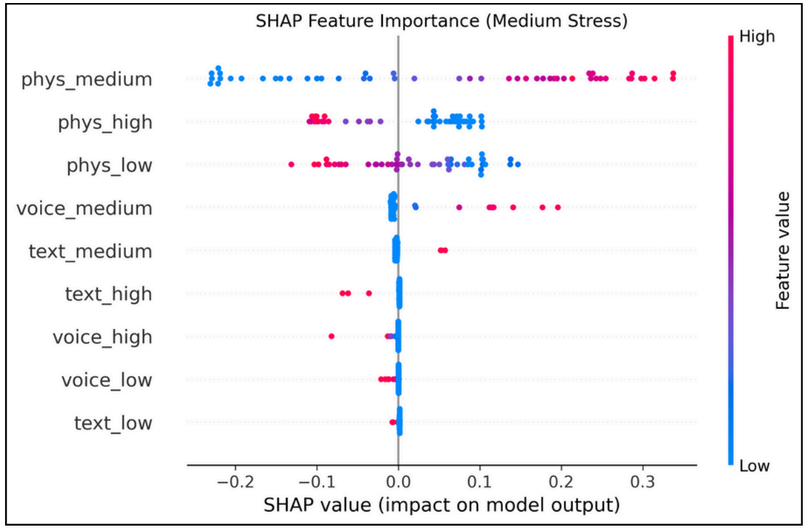
Modality	Accuracy (%)	Macro AUC	Balanced Accuracy	Key Highlight
Physiological	88.3	0.97	0.87	Best unimodal accuracy
Voice	87.8	0.97	0.86	Excels in detecting subtle stress
Self-Assessment	85	0.96	0.84	Strong for self-reported cases
Late Fusion	83.9	0.94	0.84	Top balance across all stress classes





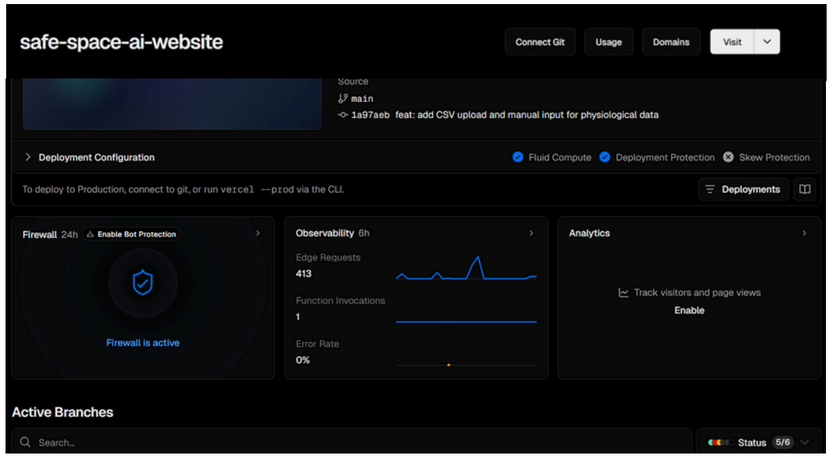




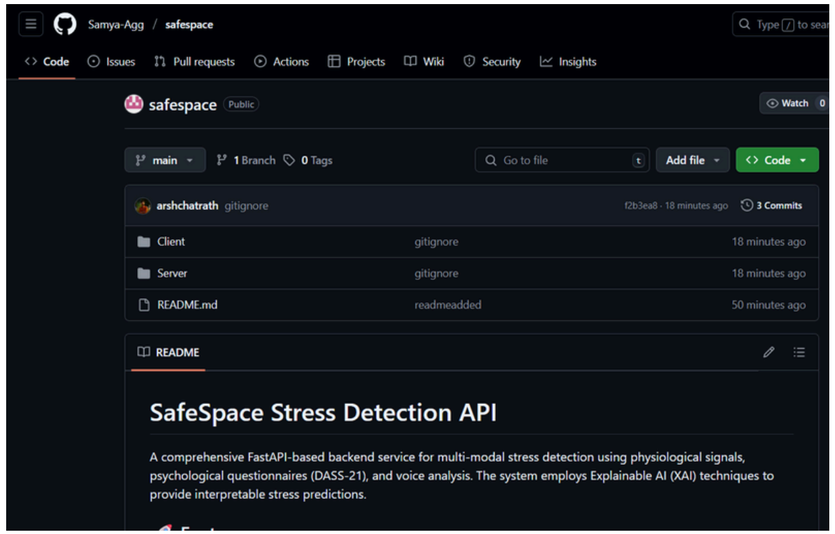


Results of all models alongside charts from Late Fusion Model. SHAP (XAI) was applied from a sample which predicted medium stress as shown in plots

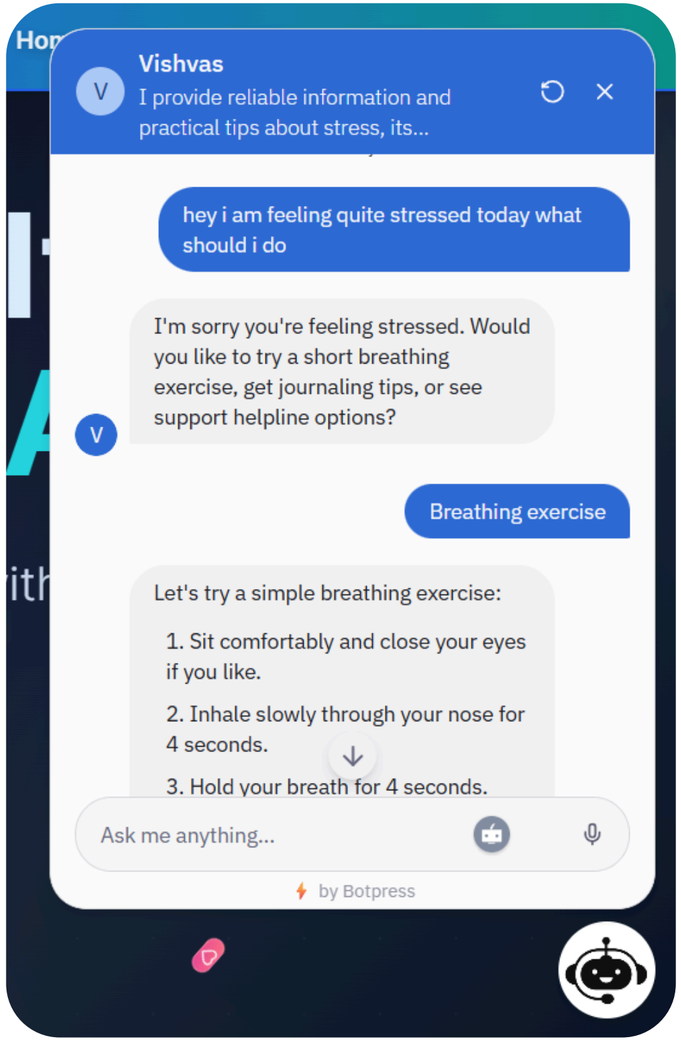
MODEL **DEPLOYMENT**



Vercel Deployment



Structure Git repo with md file



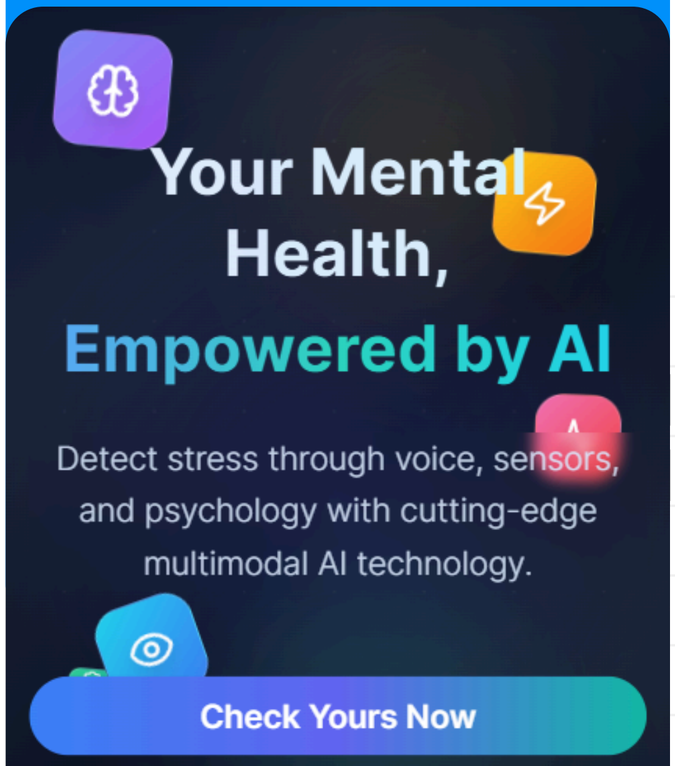
Personal AI Chatbot

WEB INTERFACE

SaaS???

www.safespaceai.vercel.app

We are building a website so that this whole software can be provided for use to other people as a service



Our Team

Team **SafeSpace**

Team

www.safespaceai.vercel.app

Technical Report

Current Website

Scan to open

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY

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THANK YOU

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