BROTHER: Behavioral Recognition Optimized Through Heterogeneous Ensemble Regularization for Ambivalence and Hesitancy

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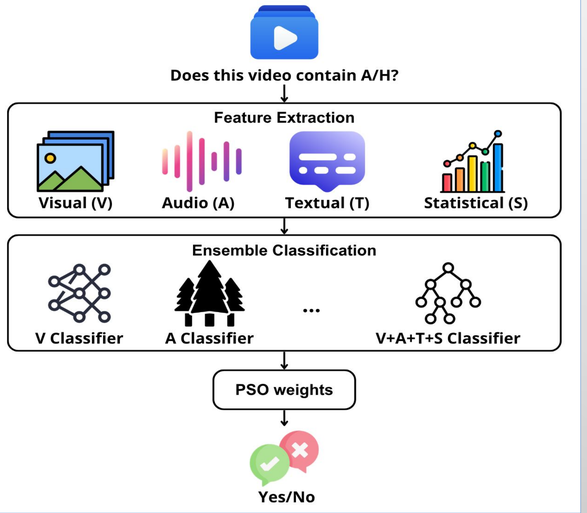
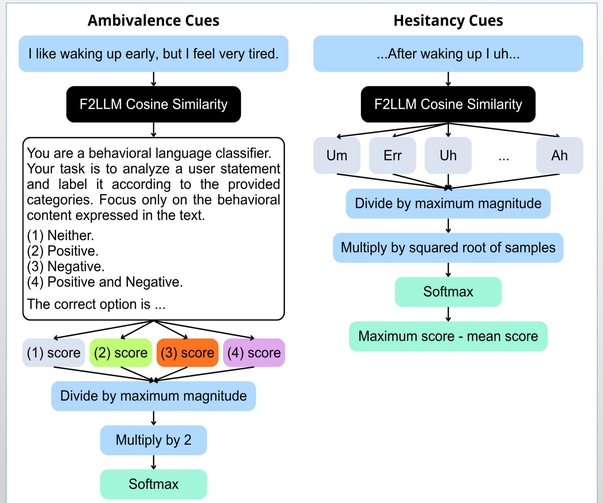
Abstract

- **Ambivalence and hesitancy (A/H)** are complex psychological states marked by conflicting behaviors, making them difficult to detect in real-world settings.
- Current multimodal systems often overfit constrained datasets and lose important cues during feature fusion.
- We propose **BROTHER**, a multimodal ensemble that combines visual, audio, textual, and statistical cues while using PSO to silence overfitted models.

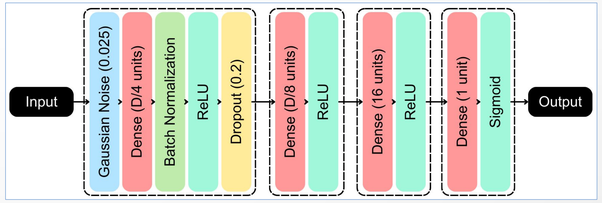


Methods and Materials

- **Visual features:** The person's face is cropped and encoded with **SigLip2**, followed by frame filtering, pooling, and PCA reduction.
- **Audio features:** Extracted with **HuBERT**, a non-supervised embedding model.
- **Textual features:** Encoded using **F2LLM**, a model trained exclusively on non-synthetic data.
- **Statistical features:** Analytics from the three previous modalities, including **frame similarity**, **audio features**, **textual patterns** and prompting for **A/H cues**.



- For each of the 15 modality combinations, three candidate architectures are trained: **Multi-Layer Perceptron**, **Random Forest**, and **Gradient Boosting Decision Tree**. The best architecture for each subset is selected by validation loss.



- The chosen models are fused using PSO-based hard voting. Each particle defines the influence of a model towards the final decision.

$$Fitness = \frac{2 \cdot F1_{val} \cdot F1_{train}}{F1_{val} + F1_{train}} - (\lambda \cdot |F1_{train} - F1_{val}|)^2$$

Results

- On the official hidden final test set, **BROTHER** achieved **0.7266 Macro F1**, obtaining **1st place in the challenge**.
- Text was the strongest standalone modality, while the Statistical modality improved stability and strengthened weaker visual and audio combinations.

Team	Val	Test	Final Test
VisPBF (Ours)	0.7355	0.7465	**0.7266**
Fennec	0.7460	0.6940	0.7151
LEYA	0.8300	0.8077	0.7142
Lenovo PCIE	–	–	0.6748
Time Visão	0.6524	0.6808	0.5362

Discussion

- Our findings suggest that A/H recognition benefits from treating **behavioral cues** as **complementary** and **unevenly distributed** across modalities.
- Instead of forcing all features into one model, the ensemble allowed **stronger combinations** to **contribute more** while limiting the effect of overfitted ones.

Conclusions

- BROTHER presents a framework for **A/H detection** in **real-world videos** by combining foundation model embeddings with a dedicated statistical modality.
- Its performance in the challenge highlights the value of designing A/H recognition systems around subtle behavioral conflict, rather than treating it as a standard emotion classification task.

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