Executive Summary

This project presents a **Convolutional Neural Network (CNN)–based facial expression recognition system** developed using the **CK+ (48×48) dataset**. The primary objective is to improve classification performance on **imbalanced emotion classes** by incorporating **class balancing techniques** and comparing results against a standard baseline CNN.

Dataset & Preprocessing

- Dataset: CK+ facial expression dataset organized into 7 emotion classes.
- Images converted to **48×48 grayscale** to reduce computational complexity.
- **Histogram equalization** applied to enhance contrast.
- Pixel normalization (0–1 scaling).
- **Stratified train–validation split (80/20)** ensures balanced distribution across classes.

Baseline CNN Model

A standard CNN architecture was implemented:

- 3 convolutional layers (32 → 64 → 128 filters)
- Max pooling for spatial reduction
- Fully connected dense layer (256 units)
- Dropout (0.5) for regularization
- Softmax output for multi-class classification
- Adam optimizer + categorical cross-entropy loss
- Early stopping to prevent overfitting

This model serves as the **performance benchmark**.

Class Imbalance Challenge

The CK+ dataset contains **uneven class distributions**, which can bias the model toward majority classes and reduce minority-class recall.

Proposed Solution: Class-Balanced CNN (CB-CCNN)

To address imbalance, two techniques were introduced:

1. **Class Weights**
    - Computed using sklearn's balanced class weighting
    - Assigns higher importance to minority classes during training
2. **Focal Loss**
    - Replaces cross-entropy loss
    - Focuses learning on difficult and misclassified samples
    - Reduces dominance of easy/majority examples
    - Parameters: $\gamma = 2.0$, $\alpha = 0.25$

The architecture remains identical to the baseline to ensure a **fair comparison**, with only the loss strategy modified.

Evaluation Metrics

Models were evaluated using:

- Overall accuracy
- Precision, recall, F1-score
- Macro F1-score
- Per-class recall comparison

Results & Findings

- The **baseline CNN** performs well overall but shows weaker recall on minority classes.

- The **CB-CCNN improves minority-class detection**, increasing:
    - Macro F1-score
    - Per-class recall balance
    - Robustness to skewed distributions
- The class-balanced approach produces **more equitable performance across emotions**, rather than optimizing only overall accuracy.

Conclusion

The proposed **class-balanced CNN with focal loss** effectively mitigates dataset imbalance and enhances generalization. It demonstrates that:

- Loss engineering + class weighting improves fairness and reliability
- Minority classes benefit significantly
- Architecture complexity does not need to increase to gain performance

This approach provides a **simple, efficient, and scalable solution** for imbalanced facial emotion recognition tasks and can be extended to other real-world classification problems with skewed data distributions.