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Stress detection using ECG signals with machine learning techniques

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Abstract

Stress poses major risks to mental and physical health. Electrocardiogram (ECG) signals, which reflect the heart's electrical activity, offer a non-invasive approach to stress detection. This study proposes a machine learning-based method for classifying stress levels using ECG signals, leveraging support vector machines (SVM) and neural networks. By automating feature extraction and classification, the model achieves improved accuracy and adaptability over traditional handcrafted approaches. The system is evaluated through a comprehensive pipeline including data collection, preprocessing, feature selection, and classification, demonstrating high performance and clinical potential.

Keywords: ECG, machine learning, techniques, Z-score, SVM

1. Introduction

1.1 Stress and its impact: Chronic stress is linked to cardiovascular diseases, anxiety, and cognitive issues.
Why ECG? The autonomic nervous system affects heart function, making ECG a reliable signal for stress analysis.
Research gap: Traditional models rely on handcrafted features, which are often rigid and fail to capture nuanced data patterns.

2. Literature Review

A variety of approaches have been used for stress detection:

- EEG-based models: Offer high accuracy but can be invasive.
- Multimodal systems: Combine sensors like EDA, HRV, and BVP for robust classification.
- Deep learning in plant/crop stress: Demonstrates potential of image-based stress detection.
- Machine Learning with wearables: Shows promise in daily, real-time stress monitoring.

This study builds on these by focusing on ECG and ML hybridization, targeting continuous, personalized, and scalable stress detection.

3. Materials and Methods

3.1 Data Collection: ECG data from diverse participants using clinical databases and wearable devices.

3.2 Data Preprocessing

- Noise filtering (baseline correction, artifact removal)
- Normalization (Z-score, min-max scaling)
- Segmentation of ECG into R-R intervals

3.3 Feature Extraction and Selection:

- Time-domain and frequency-domain metrics (e.g., heart rate variability)
- Selection via wrapper/filter methods and expert domain knowledge

3.4 Classification

- Models: SVM, Neural Networks, XGBoost
- Performance evaluated using accuracy, F1 score, AUC-ROC

4. Results and Discussion

- Best performing model: SVM combined with XGBoost showed the highest classification accuracy.

- Stress level granularity: Multi-class classification (low, medium, high) improves interpretability for healthcare applications.

4.1 Advantages
- No need for handcrafted features
- Adaptability to various datasets
- Higher robustness in real-world scenarios

5. Testing and Validation
- **Split testing:** Training, validation, and external testing datasets used
- **Cross-validation:** 10-fold cross-validation ensures robustness
- **Metrics used:** Accuracy, Precision, Recall, F1-score, AUC
- **Challenges:** Class imbalance, signal noise, and overfitting were managed using augmentation and regularization.

6. Conclusion and Future Work
The study successfully demonstrates a machine learning-based framework for stress detection using ECG signals. It offers improved adaptability, accuracy, and potential for integration into real-time systems.

6.1 Future directions
- Integration of additional physiological signals (e.g., skin temperature, EDA).
- Development of mobile applications.
- Personalized stress response modeling.
- Real-time monitoring and feedback systems.

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