

Hybrid Deep Learning and Fuzzy-Based Domain Adaptation for Multilingual Sentiment Analysis of Twitter Data

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Abstract: ***Background:** With the rapid rise of social media platforms like Twitter, the need for accurate sentiment analysis across multiple languages has become critical. However, traditional sentiment analysis methods are limited by linguistic variability, cultural nuances, and contextual ambiguity inherent in multilingual data. These challenges are further compounded by sarcasm, slang, and code-mixed expressions that are common in real-time social interactions. **Aim:** The primary objective of this study is to develop a hybrid deep learning and fuzzy-based domain adaptation model that can enhance multilingual sentiment analysis on Twitter data. This model aims to improve classification accuracy, contextual understanding, and adaptability across diverse languages and domains. **Methods:** The methodology integrates transformer-based contextual embeddings (mBERT and XLNet) with Convolutional Neural Networks (CNNs), BiLSTM layers, and a fuzzy inference system for adaptive sentiment reasoning. A multilingual Twitter dataset comprising 20,000 manually annotated tweets in English, Hindi, Tamil, and Bengali was used. The model was trained using Adam optimization and evaluated through accuracy, precision, recall, and F1 scores under both intra-domain and cross-domain conditions. **Results:** The proposed hybrid model achieved an average accuracy of 86.7%, outperforming traditional classifiers and standard transformer models. The fuzzy logic mechanism improved interpretability and reduced misclassification in ambiguous cases, especially where mixed emotions or sarcasm were present. **Conclusion:** The study contributes an innovative framework that bridges deep learning with fuzzy reasoning for more reliable multilingual sentiment analysis. Its ability to adapt to domain shifts and linguistic diversity makes it suitable for real-world applications in marketing, public policy, and social media analytics.*

Keywords: Multilingual Sentiment Analysis, Deep Learning, Fuzzy Logic, Domain Adaptation, Twitter Data, Natural Language Processing (NLP), Hybrid Models