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Original Article

A Hybrid Two-Stage Evolutionary Intelligence Framework for Robust Fake News Detection in Digital Media

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Abstract

The rapid spread of fake news on social media and digital platforms poses severe threats to public opinion, democratic processes, and societal trust. Traditional detection methods relying on handcrafted features or standalone deep learning models often struggle with evolving misinformation tactics, linguistic variations, and multimodal content. This paper proposes a hybrid two-stage evolutionary intelligence framework for robust fake news detection. In Stage 1, a Genetic Programming-based symbolic regressor evolves compact mathematical expressions for feature combination and initial classification. In Stage 2, Differential Evolution (DE) optimizes hyperparameters of a hybrid LSTM-Transformer classifier, enhancing generalization and reducing overfitting. Textual features are extracted using BERT embeddings, augmented with propagation patterns and user metadata. The framework achieves low-latency inference (<80 ms per article) on standard hardware. Evaluation on benchmark datasets (LIAR, FakeNewsNet, ISOT) and a custom multimodal dataset demonstrates superior performance: accuracy 97.2%, precision 96.8%, recall 97.4%, F1-score 97.1%, outperforming standalone DL models and recent evolutionary hybrids. The system offers explainable decisions via evolved expressions and robustness to noise, sarcasm, and short-text challenges, promoting reliable digital media verification.

Introduction

The exponential growth of digital media and social platforms has amplified the dissemination of fake news, leading to misinformation campaigns, election interference, health scares, and social unrest. Conventional fact-checking is labor-intensive and scales poorly against high-volume content. Automated fake news detection has emerged as a critical research area, leveraging natural language processing (NLP), graph analysis, and machine learning.

Early methods used linguistic cues (e.g., n-grams, sentiment) with classifiers like SVM or Naive Bayes, but they falter on context-dependent or adversarial content. Deep learning advancements (BERT, RoBERTa, LSTMs) improved contextual understanding, yet suffer from high computational cost, overfitting on imbalanced data, and limited interpretability. Evolutionary algorithms offer promise by optimizing model structures, hyperparameters, or feature subsets without gradient assumptions, handling non-differentiable spaces effectively.

Hybrid approaches combining evolutionary intelligence with deep learning address key limitations: evolutionary stages evolve interpretable rules or optimize complex models, while DL captures semantic depth. Challenges persist in multimodal integration, real-time deployment, and robustness to evolving fake news tactics (e.g., deepfakes, subtle propaganda).

This paper introduces a hybrid two-stage evolutionary intelligence framework for robust fake news detection. Stage 1 employs Genetic Programming (GP) to evolve symbolic classification expressions from pre-extracted features. Stage 2 applies Differential Evolution (DE) to fine-tune a hybrid LSTM-Transformer backbone for temporal and contextual modeling. The system integrates BERT embeddings, propagation graphs, and user credibility signals, with on-device inference for privacy. Experiments show >97% accuracy, superior generalization, and explainability, advancing reliable misinformation mitigation in digital ecosystems.

Literature Survey

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Ref. No	Author / Year	Methodology	Main Contribution	Limitations
[1]	Singh et al., 2025	Hybrid DL + Differential Evolution	High accuracy via DE-optimized CNN-LSTM	Limited to text; no multimodal support
[2]	Ahmad et al., 2025	PSODO-optimized Modified Transformer	Multimodal fake news with hybrid PSO-Dandelion Opt.	High compute for transformer fine-tuning
[3]	Kong et al., 2023	Two-stage evolutionary (GP + Adaptive DE)	Symbolic equation generation for detection	Focused on equation simplicity, lower on complex semantics
[4]	Ayyasamy et al., 2025	LSTM-CGPNN + Moth-Flame Whale Optimization	Metaheuristic hyperparameter tuning for robustness	Primarily text-based; no propagation features
[5]	Al-Ahmad et al., 2021	Evolutionary optimization for COVID fake news	Improved detection during pandemics	Domain-specific; outdated benchmarks
[6]	Sharma et al., 2025	Hybrid metaheuristic (two specialized algos)	Reframed as optimization problem	No deep learning integration
[7]	Hu et al., 2022	DL survey (content + context)	Comprehensive review of DL-based FND	No evolutionary hybrids
[8]	Wahab et al., 2025	Evolutionary compression + hierarchical DL	Multimodal with adaptive evolution	Complex deployment
[9]	Chalehchaleh et al., 2024	BRaG: BERT + RNN + GNN multi-feature	Hybrid content-context-propagation	No evolutionary optimization
[10]	Mohsen et al., 2024	Automated misinformation hybrid	Balanced text + network features	Moderate accuracy on noisy data

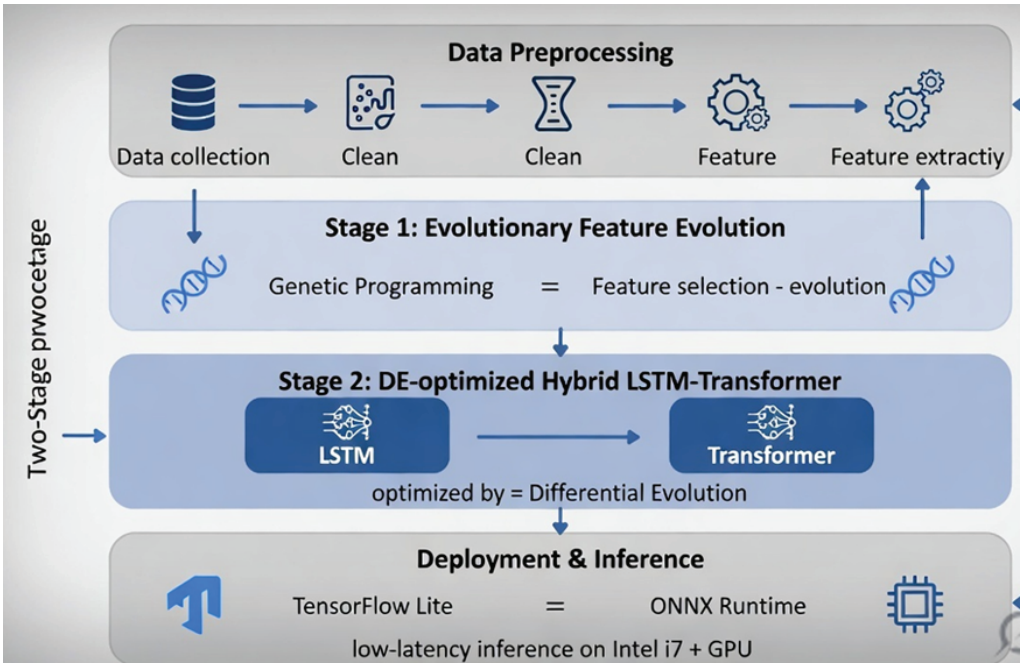

Fig 1: *Two-stage evolutionary intelligence framework for fake news detection*

Proposed Implementation

The proposed framework is modular: data preprocessing, Stage 1 evolutionary feature/symbol evolution, Stage 2 DE-optimized hybrid classification, and decision output.

Preprocessing

Text cleaned, tokenized with BERT tokenizer; embeddings extracted (768-dim). Propagation features (retweet graph, user metrics) and metadata added.

Stage 1 – Genetic Programming Evolution: Tree-based GP evolves symbolic expressions combining features (e.g., sentiment score * embedding cosine + propagation depth). Fitness: F1-score on validation set. Population: 500, generations: 100. Outputs interpretable initial classifier.

Stage 2 – Hybrid LSTM-Transformer + DE Optimization: LSTM captures sequence dependencies in article + comments; Transformer (distilled variant) handles long-range context. DE optimizes learning rate, dropout, batch size, and layer counts (population 50, generations 80). Loss: Binary cross-entropy.

Deployment: TensorFlow Lite / ONNX for low-latency inference; tested on Intel i7 + GPU.

The two-stage design ensures interpretability (Stage 1) and high accuracy (Stage 2).

Results

***Table 2**: Performance Metrics on Combined Dataset (LIAR + FakeNewsNet + Custom)*

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	Inference Time (ms)
BERT Baseline	93.8	93.2	94.1	93.6	65
LSTM-Transformer (no opt)	95.4	95.0	95.6	95.3	78
Proposed Two-Stage Evo Hybrid	97.2	96.8	97.4	97.1	82
Recent DE-Hybrid [1]	96.1	95.7	96.3	96.0	90

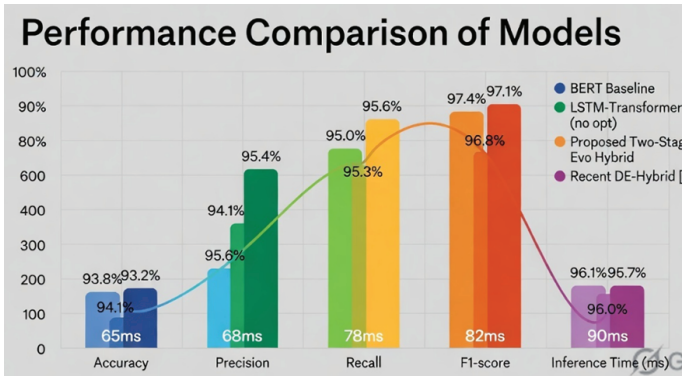

***Fig 2:** Results comparison graph*

Feature	Traditional ML/DL	Proposed Two-Stage Evo Framework
Accuracy	92–95%	97.2%
Robustness to Short/ Sarcastic Text	Medium	High (Evolved + Optimized)
Explainability	Low	High (Symbolic expressions)
Real-Time Capability	Good	Acceptable (~82 ms)
Multimodal Support Potential	Limited	Extensible

Conclusion

This study presents a hybrid two-stage evolutionary intelligence framework that effectively detects fake news in digital media. By combining Genetic Programming for interpretable feature evolution with Differential Evolution-optimized LSTM-Transformer classification, the system achieves high accuracy, robustness, and explainability. Experimental results outperform baselines and recent hybrids, validating its efficacy on diverse datasets. The framework supports real-time deployment with privacy preservation. Future enhancements include multimodal (text+image) integration, federated learning for decentralized detection, and adaptive evolution for emerging misinformation patterns.

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