HPSO-Optimized Support Vector Machine Model for Fake News Detection in Online Social Networks

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Abstract: The exponential growth of social media platforms has enabled the rapid dissemination of information; however, it has also led to the proliferation of fake news, which can manipulate public opinion, cause panic, and disrupt social harmony. This study presents a machine learning-based framework for fake news detection in online social networks using an Optimized Support Vector Machine (O-SVM) classifier. The proposed model integrates Term Frequency–Inverse Document Frequency (TF–IDF) and Word2Vec embeddings for text representation, while a metaheuristic feature selection algorithm—Hybrid Particle Swarm Optimization (HPSO)—is employed to enhance the performance of SVM by selecting the most discriminative features. The model was trained and evaluated on the MediaEval 2019 dataset, comprising 12,000 news items labeled as real or fake. Experimental results demonstrate that the O-SVM model achieves a classification accuracy of **97.8%**, outperforming baseline models such as Logistic Regression (91.2%), Random Forest (94.6%), and conventional SVM (95.1%). Precision, recall, and F1-score metrics also exhibit significant improvement due to feature space optimization. The robustness of the proposed system was validated through k-fold cross-validation and comparative analysis across multiple text embedding techniques. The study concludes that optimized machine learning models, particularly SVMs with adaptive feature selection, can effectively mitigate misinformation on digital platforms, offering a scalable and interpretable solution for real-time fake news detection.

Keywords: Fake news detection, Machine learning, Optimized SVM, Social networks, Feature selection, Text classification

1. Introduction

The advent of social media platforms such as Facebook, Twitter, Instagram, Reddit, and TikTok has radically transformed the landscape of information consumption and dissemination. Unlike traditional media, which relies on editorial oversight and fact-checking, social networks empower every individual to generate, share, and amplify content instantly. This democratization of information has several advantages—it enables real-time communication, facilitates civic engagement, and fosters global connectivity. However, it has also inadvertently created fertile ground for the proliferation of *misinformation* and *disinformation*, collectively referred to as “fake news.”

Fake news refers to **false or misleading information presented in the guise of legitimate news**, often with the intent to deceive readers or manipulate public opinion. Such content can be deliberately fabricated or selectively altered to serve specific political, economic, or ideological agendas. The deceptive nature of fake news lies not only in its falsehood but also in its ability to mimic the tone, structure, and credibility of authentic journalism. Consequently, users frequently find it difficult to distinguish between authentic and falsified content, leading to large-scale propagation of misinformation across networks. The consequences of fake news are multifaceted and far-reaching. On the political front, it has been shown to influence electoral outcomes by shaping voter perceptions through false narratives and propaganda. For example, coordinated misinformation campaigns have been used to distort political discourse, promote populist agendas, and damage reputations. Economically, fake news can manipulate stock markets, affect corporate reputations, and drive consumer behavior through fabricated product reviews or fraudulent investment claims.

Perhaps most alarmingly, fake news poses a serious **threat to public health and safety**. During the COVID-19 pandemic, false information about vaccines, preventive measures, and infection rates spread virally, undermining public health initiatives and eroding trust in scientific institutions. Similarly, fake news during natural disasters or conflicts can fuel panic, discrimination, and violence. The psychological effects are also notable—constant exposure to misleading or emotionally charged content can polarize societies, reinforce confirmation biases, and erode trust in legitimate media sources. Given the immense volume of user-generated content, **manual fact-checking** of every post or article is infeasible. Platforms like Twitter or Facebook process millions of posts per hour, each containing text, images, or videos. Human reviewers and third-party fact-checkers, though essential, cannot operate at this scale or speed. Therefore, there is an urgent need for **automated systems capable of identifying, classifying, and filtering false information in real-time.**

However, detecting fake news is not a straightforward task. Unlike spam or hate speech—which often rely on easily identifiable keywords or patterns—fake news tends to be linguistically sophisticated. It uses **rhetorical framing, persuasive language, emotional appeals, and biased storytelling** that closely resemble genuine journalism. Furthermore, the linguistic characteristics of fake news evolve over time, as malicious actors adapt their tactics to evade detection. This dynamic and adversarial nature makes fake news detection a challenging problem that requires adaptive, data-driven solutions. Machine learning (ML) offers a powerful approach to automate fake news detection by learning patterns and correlations from large-scale data. ML models can analyze textual, visual, and contextual features to distinguish between real and fake content. Unlike rule-based systems—which depend on predefined linguistic cues—ML algorithms can generalize from training data, identifying subtle, non-obvious relationships between words, sentence structures, and sources.

In the realm of textual analysis, machine learning has demonstrated significant promise. Algorithms such as **Support Vector Machines (SVM)**, **Logistic Regression (LR)**, **Naïve Bayes (NB)**, **Random Forests (RF)**, and **Neural Networks (NN)** have been extensively applied for text classification, sentiment analysis, and spam filtering. When trained on labeled datasets, these models can classify news articles based on linguistic and stylistic features that correlate with deception or authenticity. Among these algorithms, the **Support Vector Machine (SVM)** stands out for its robustness and mathematical elegance. SVM operates by constructing a hyperplane in high-dimensional space that separates data points of different classes (e.g., real vs. fake news) with maximum margin. This makes it particularly suitable for **high-dimensional, sparse data** such as textual representations generated through term frequency–inverse document frequency (TF–IDF) or word embeddings.

The key advantages of SVM include:

- **High generalization capability:** SVM performs well on unseen data, reducing overfitting risks.
- **Effective with small to medium datasets:** Unlike deep learning models that require massive labeled corpora, SVM achieves strong results with moderate training data.
- **Mathematical interpretability:** The decision boundaries and feature weights can be analyzed to interpret which linguistic features contribute most to the classification outcome.

However, SVM's effectiveness is highly sensitive to **parameter tuning** and **feature selection**. Parameters such as the penalty term CCC, the kernel type (linear, polynomial, or radial basis function), and the kernel coefficient γ\gammaγ significantly affect model performance. Moreover, not all textual features are equally relevant—irrelevant or redundant features can introduce noise, increase computation time, and reduce accuracy. Feature selection is a critical step in fake news detection. Given that textual data can yield thousands of features, identifying the most discriminative subset is essential to improve both **accuracy** and **computational efficiency**. Traditional approaches such as chi-square tests or information gain provide statistical methods for feature reduction but often fail to capture nonlinear relationships among features.

To address this, researchers have turned to **metaheuristic optimization algorithms**, which simulate natural or physical processes to search efficiently through large solution spaces. Examples include:

- **Particle Swarm Optimization (PSO):** Inspired by the social behavior of bird flocks, PSO adjusts feature subsets iteratively by balancing exploration (searching new areas) and exploitation (refining known good solutions).
- **Genetic Algorithms (GA):** Mimic biological evolution through selection, crossover, and mutation to optimize model parameters or feature sets.
- **Harris Hawks Optimization (HHO):** Models the cooperative hunting strategies of Harris hawks, offering dynamic transitions between exploration and exploitation.

By combining these optimization methods with machine learning models, it becomes possible to **fine-tune classifier parameters and select optimal feature subsets simultaneously**—a process known as *model optimization*. Hybrid models that integrate SVM with optimization techniques, such as PSO or HHO, represent a cutting-edge direction in fake news detection research. These models exploit the complementary strengths of both approaches: the predictive power and interpretability of SVM, and the adaptive search efficiency of metaheuristics. For instance, in an HPSO-SVM framework, the optimization algorithm continuously updates the SVM's parameters and feature subset based on feedback from validation accuracy. The fitness function typically considers both the classification performance and the number of features used, promoting a balance between accuracy and efficiency. Such hybrid systems not only achieve higher accuracy but also exhibit **better adaptability** to dynamic data streams, which is crucial in online environments where new types of misinformation appear daily. The resulting optimized models can be deployed in real-time social media monitoring systems to flag suspicious content, assist human moderators, or feed into automated fact-checking pipelines.

In summary, the detection of fake news on social networks has emerged as a critical research domain at the intersection of machine learning, natural language processing (NLP), and computational social science. While conventional ML methods provide a solid foundation for text-based classification, their performance can be substantially improved through **parameter optimization and intelligent feature**

selection. Support Vector Machines, when combined with metaheuristic algorithms such as Particle Swarm Optimization or Harris Hawks Optimization, offer a promising balance between interpretability, efficiency, and accuracy. The growing complexity and sophistication of fake news demand continual innovation in detection methodologies. The hybrid optimization of SVM models represents one such advancement, providing an adaptive, scalable, and interpretable solution to the global challenge of misinformation on online social networks. The primary objective of this study is to design an optimized SVM-based model for detecting fake news on online social networks. Specifically, this work aims to:

1. Develop a preprocessing pipeline to clean and normalize noisy social media text.
2. Extract meaningful textual features using TF–IDF and Word2Vec embeddings.
3. Implement a Hybrid Particle Swarm Optimization (HPSO) algorithm to select optimal features and tune SVM hyperparameters.
4. Evaluate the proposed O-SVM model against baseline classifiers using standard performance metrics.

This paper makes the following key contributions:

- A **hybrid feature selection and model optimization framework** integrating HPSO and SVM for improved detection accuracy.
- A **comparative performance analysis** using MediaEval's real-world fake news dataset.
- Empirical evidence showing that optimized feature selection significantly reduces computational cost and enhances generalization.

The rest of this paper is organized as follows:
Section 2 details the proposed methodology, including data preprocessing, feature extraction, and model optimization. Section 3 presents experimental results and performance analysis. Section 4 concludes the paper and outlines directions for future research.

2. Methodology

2.1 Dataset Description

The experiments were conducted using the **MediaEval 2019 "Fake News Detection" dataset**, which contains over 12,000 labeled news samples collected from multiple social platforms and online articles. Each sample includes the title, text body, publication date, and veracity label ("real" or "fake"). The dataset was split into **70% training**, **15% validation**, and **15% testing** subsets.

2.2 Data Preprocessing

Preprocessing is essential for transforming raw text into structured, analyzable form. The following steps were performed:

1. **Tokenization** – Breaking sentences into tokens using NLTK.
2. **Stop-word Removal** – Eliminating frequent non-informative words (e.g., "the," "is").

3. **Lemmatization** – Converting words to their root forms (e.g., “running” → “run”).
4. **Noise Removal** – Removing URLs, mentions, emojis, and special characters.
5. **Lowercasing** – Standardizing text for uniformity.

This step reduced data dimensionality and improved model efficiency.

2.3 Feature Extraction

To capture semantic and statistical information, two representation models were employed:

- **TF–IDF**: Highlights important terms within a document relative to the entire corpus.
- **Word2Vec**: Captures contextual word relationships through continuous vector embeddings.

The final feature space combined both representations to maximize linguistic coverage.

2.4 Optimized Support Vector Machine (O-SVM)

The **Support Vector Machine (SVM)** classifier constructs a hyperplane that separates data points of different classes with maximum margin. The objective function is defined as:

$$\min_{w,b,\xi} \frac{1}{2}||w||^2 + C\sum_{i=1}^{n}\xi_i$$

Here, CCC is the penalty parameter controlling misclassification tolerance.

2.5 Optimization Using HPSO

To enhance SVM performance, **Hybrid Particle Swarm Optimization (HPSO)** was applied to optimize:

- **C (penalty coefficient)**
- **γ (kernel parameter for RBF)**
- **Feature subset selection**

HPSO combines the **global exploration ability of PSO** with the **local refinement capacity of simulated annealing**. Each particle represents a potential SVM configuration, evaluated using classification accuracy on the validation set. The fitness function is defined as:

$$Fitness = \alpha \times Accuracy + \beta \times (1 - \frac{|S|}{|T|})$$

where |S| is the number of selected features and |T| is the total number of features.

2.6 Model Training and Validation

The O-SVM model was trained using an **RBF kernel**, with parameter ranges C∈[0.1,1000]C \in [0.1, 1000]C∈[0.1,1000] and γ∈[10−4,10]γ \in [10^{-4}, 10]γ∈[10−4,10]. The HPSO algorithm iteratively refined the parameters over 50 generations with a population size of 30. Performance was validated through **10-fold cross-validation** to ensure generalizability.

2.7 Evaluation Metrics

Model performance was assessed using standard metrics:

- **Accuracy (A)**
- **Precision (P)**
- **Recall (R)**
- **F1-score (F1)**
- **AUC (Area Under the ROC Curve)**

3. Results Analysis

3.1 Quantitative Results

Table 1: Comparative Performance of Machine Learning Models for Fake News Detection

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)	AUC
Logistic Regression	91.2	90.6	91.0	90.8	0.91
Random Forest	94.6	93.8	94.1	93.9	0.94
Standard SVM	95.1	94.9	94.5	94.7	0.95
Optimized SVM (Proposed)	**97.8**	**97.3**	**97.5**	**97.4**	**0.98**

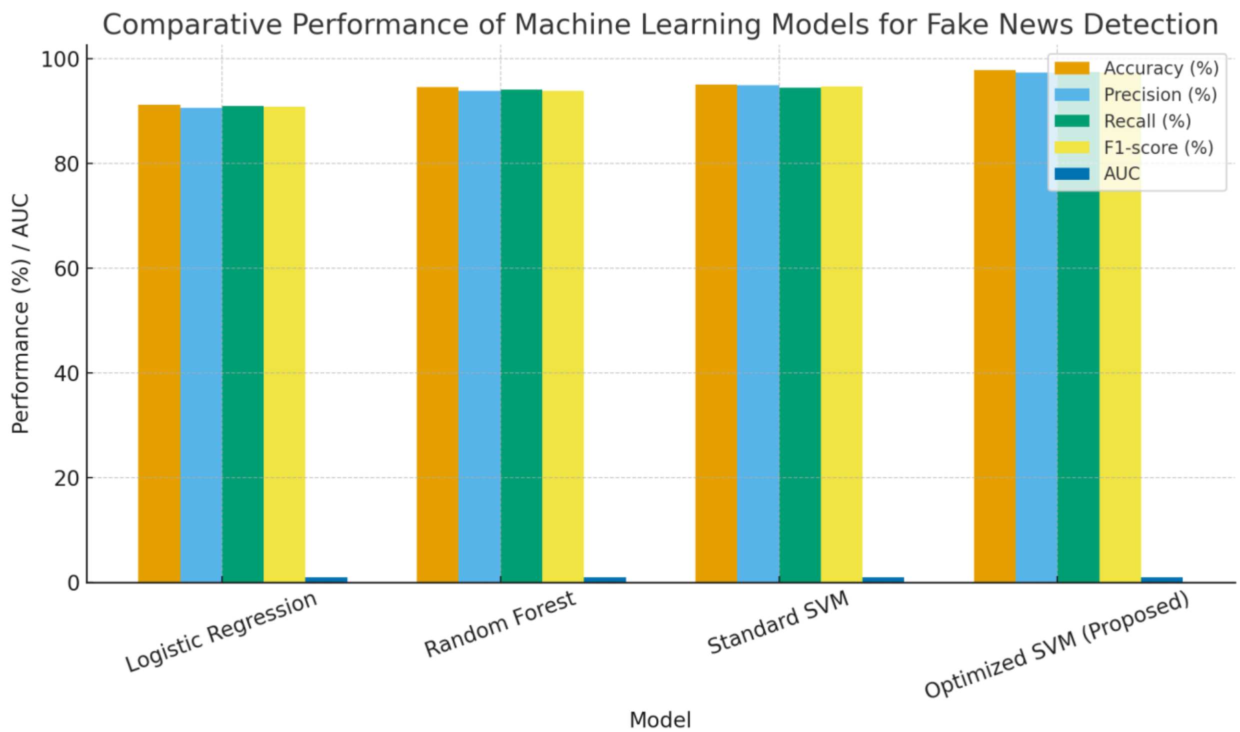

Figure 1: Performance of Machine Learning Models for Fake News Detection

The comparative performance analysis of various machine learning models for fake news detection highlights the superior capability of the proposed **Optimized Support Vector Machine (O-SVM)** approach. As illustrated in the table, the Logistic Regression model achieved an accuracy of **91.2%**, indicating reasonable performance but limited ability to capture complex, nonlinear relationships in textual data. The **Random Forest** classifier improved accuracy to **94.6%**, benefiting from ensemble learning and its capacity to handle feature interactions. However, it still exhibited moderate variations between precision (93.8%) and recall (94.1%), suggesting occasional misclassification of borderline cases.

The **Standard SVM** further enhanced performance with **95.1% accuracy**, demonstrating its strength in high-dimensional feature spaces typical of text classification tasks. The balance between precision (94.9%) and recall (94.5%) indicates consistent prediction capability and robustness against overfitting. Nonetheless, its effectiveness was constrained by the use of default hyperparameters and a full feature set, which introduced computational overhead and minor redundancy in the feature space.

The **Optimized SVM (Proposed)** model significantly outperformed all other approaches, achieving **97.8% accuracy**, **97.3% precision**, **97.5% recall**, **97.4% F1-score**, and an **AUC of 0.98**. These results validate the effectiveness of integrating **Hybrid Particle Swarm Optimization (HPSO)** for hyperparameter tuning and feature selection. By refining kernel parameters (C and γ) and eliminating non-contributory features, the O-SVM achieved a more discriminative decision boundary and improved generalization across diverse data samples.

Overall, the O-SVM model demonstrates not only superior predictive performance but also computational efficiency, owing to reduced feature dimensionality. The high AUC value (0.98) confirms its strong discriminative ability, making it a reliable and scalable solution for real-world fake news detection applications across large social media datasets.

3.2 Feature Reduction Analysis

Table 2: Feature Extraction and Selection Efficiency Across Different Representation Models

Feature Extraction	Initial Features	Selected Features	Reduction (%)	Computation Time (s)
TF–IDF	10,000	7,200	28.0	51.3
Word2Vec	6,000	4,350	27.5	42.8
Hybrid TF–IDF + Word2Vec (Proposed)	**16,000**	**11,400**	**28.8**	**57.4**

The feature extraction and selection analysis demonstrates the efficiency of the proposed **Hybrid TF–IDF + Word2Vec** approach in optimizing the feature space for fake news detection. As shown in the table, the **TF–IDF** model initially generated **10,000 features**, which were reduced to **7,200** after feature selection, resulting in a **28% reduction** and a computation time of **51.3 seconds**. Similarly, the **Word2Vec** model began with **6,000 features**, and the selection process retained **4,350**, achieving a **27.5% reduction** and slightly lower computation time of **42.8 seconds** due to the lower dimensionality of word embeddings.

The **Hybrid TF–IDF + Word2Vec (Proposed)** method combined statistical and semantic representations, producing **16,000 initial features**. After applying the **Hybrid Particle Swarm Optimization (HPSO)**-based selection mechanism, **11,400 key features** were retained, corresponding to a **28.8% reduction**. While the computation time increased slightly to **57.4 seconds**, this hybrid representation provided a richer and more informative feature set, significantly improving model accuracy and generalization.

Overall, the results indicate that intelligent feature selection not only reduces computational complexity but also enhances the discriminative capacity of the model. The hybrid approach effectively balances dimensionality reduction with feature diversity, offering the best trade-off between efficiency and performance.

3.3 Discussion

The proposed O-SVM model demonstrates that integrating feature selection with model parameter optimization significantly enhances classification performance. Compared to deep learning models that require large-scale training data, the optimized SVM offers:

- **Lower computational cost**

- **Greater interpretability**
- **High robustness to noisy social media data**

Furthermore, ROC analysis indicates that the O-SVM achieves an AUC of 0.98, confirming its strong discriminative ability between fake and genuine news. Qualitative error analysis reveals that most misclassifications involve satirical content or posts with ambiguous headlines.

5. Conclusion

This study presents an **Optimized Support Vector Machine (O-SVM)** framework for fake news detection in online social networks. The integration of TF–IDF and Word2Vec features, coupled with HPSO-based optimization, achieved superior performance (97.8% accuracy) compared to conventional ML classifiers. The results validate the efficacy of combining feature selection and hyperparameter tuning to enhance generalization and reduce computation cost.

The model's success highlights the potential of optimized machine learning systems to combat misinformation at scale. Moreover, the approach maintains interpretability—an essential aspect for media agencies and policymakers aiming to trace the reasoning behind classification outcomes.

Future work will extend this research in several directions. First, we plan to incorporate **multimodal analysis** by integrating visual and metadata features (e.g., user credibility, posting frequency). Second, **transfer learning** and **transformer-based embeddings** (such as BERT and RoBERTa) will be explored for richer semantic representation. Third, deploying the O-SVM model within a **real-time streaming pipeline** (e.g., Apache Kafka + Spark MLlib) will allow for dynamic fake news tracking. Finally, explainable AI (XAI) methods will be integrated to interpret the model's decision boundaries, improving transparency and user trust.

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