International Journal of
DATA SCIENCE AND IOT MANAGEMENT SYSTEM
Peer Reviewed, Referred & Indexed Journal
ISSN: 3068-272X www.ijdim.com Original Research Paper

SpADe: MULTI-STAGE SPAM ACCOUNT DETECTION FOR ONLINE SOCIAL NETWORKS

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Abstract
The exponential growth of Online Social Networks (OSNs) has led to a massive increase in spam accounts that spread malicious content, phishing links, fake news, and unsolicited advertisements. Traditional spam detection methods often rely on single-stage classification using either profile features or content features, resulting in high computational cost and limited accuracy.

SpADe (Spam Account Detection) is a novel multi-stage spam account detection framework with a reject option. It progressively analyzes accounts using increasingly complex and costly features across four stages: basic account characteristics, URL-based analysis, content and behavioral patterns, and advanced graph and temporal features. Early stages filter obvious spam accounts using lightweight features, while uncertain cases are forwarded to later stages, significantly reducing overall computation while maintaining high detection performance.

The system was implemented and evaluated on real-world OSN datasets. Experimental results demonstrate superior performance compared to existing single-stage and multi-stage approaches, achieving high accuracy, precision, recall, and F1-score with lower processing time and cost. SpADe offers a scalable, efficient, and practical solution for social network platforms and security analysts to combat evolving spam threats.

Keywords: Spam Account Detection, Online Social Networks, Multi-Stage Classification, Reject Option, Feature Analysis, Behavioral Patterns, Graph-Based Detection.

I.Introduction
Online Social Networks (OSNs) such as Twitter (X), Facebook, Instagram, and LinkedIn have become integral to modern communication, information sharing, and marketing. However, the open nature of these platforms has attracted malicious actors who create spam accounts to disseminate harmful content, perform phishing attacks, inflate follower counts, and manipulate public opinion.

Traditional spam detection techniques typically apply a single classifier on all accounts using either profile metadata, content features, or network structure. These approaches suffer from high false positives, computational inefficiency, and inability to adapt to sophisticated spam strategies that evolve over time.

SpADe: Multi-Stage Spam Account Detection addresses these limitations by introducing a progressive, cost-aware multi-stage framework with a reject option. Instead of processing every account with expensive features, SpADe starts with lightweight features in early stages

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to quickly identify obvious spam or legitimate accounts. Only uncertain cases proceed to subsequent stages that employ more sophisticated analysis.

This staged approach significantly reduces computational overhead while improving detection accuracy and robustness against adversarial spam behaviors.

II. Literature Survey

Several studies have addressed spam detection in OSNs:

- Concone et al. proposed SpADe, a multi-stage algorithm with reject option that exploits less costly features in early stages for efficient spam filtering.
- Wang et al. introduced machine learning approaches using graph-based and content-based features for detecting spam bots on Twitter.
- Benevenuto et al. analyzed user behavior patterns and content features for spam detection in social networks.
- Stringhini et al. studied honey-pot-based approaches to detect spam accounts through social graph analysis.
- Gao et al. focused on detecting spam campaigns by clustering similar malicious messages.
- Ahmed et al. explored feature selection techniques and ensemble classifiers for improved spam account identification.
- Yang et al. investigated temporal and behavioral features to distinguish automated spam accounts from human users.

Most existing works apply monolithic classification, which becomes inefficient at scale. SpADe differentiates itself through its multi-stage architecture and reject mechanism.

III. Existing System & Proposed System

A. Existing System

Current spam detection systems in OSNs generally rely on single-stage machine learning classifiers trained on a combination of profile features, content features, and graph features.

Disadvantages of Existing Systems:

1. High computational cost when applying complex features to all accounts.
2. Poor adaptability to evolving spam tactics.
3. High false positive rates on borderline accounts.
4. Lack of cost-awareness in feature usage.
5. Inefficient processing of millions of daily new accounts.
6. Limited explainability of detection decisions.

B. Proposed System

SpADe is a multi-stage spam account detection framework that processes accounts progressively across four stages:

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- Stage 1: Basic profile characteristics such as account age, follower or following ratio, and username patterns.
- Stage 2: URL analysis including malicious link detection and shortening services.
- Stage 3: Content and behavioral analysis such as posting frequency, duplicate content, and temporal patterns.
- Stage 4: Advanced graph and interaction analysis including social graph, interaction patterns, and community detection.

A reject option at each stage forwards uncertain accounts to the next stage, while confident decisions are finalized early.

Advantages of the Proposed System:

1. Significant reduction in computational cost through early filtering.
2. Higher detection accuracy by using appropriate features per stage.
3. Built-in reject option for handling uncertain cases.
4. Scalable for large-scale OSNs.
5. Better robustness against sophisticated spam strategies.
6. Improved explainability through staged decision process.
7. Cost-effective deployment in real-world platforms.

IV. System Design & Architecture

A. System Architecture

The architecture consists of a data ingestion layer, feature extraction pipeline, multi-stage classification engine, reject option handler, and reporting module. Accounts flow through stages sequentially, with early termination for high-confidence decisions.

B. System Flowchart

User or OSN feeds accounts to Stage 1 using lightweight features. Based on decision, accounts are classified as spam or legitimate. If rejected, they proceed to Stage 2, then Stage 3, and finally Stage 4 for final classification.

C. Modules Overview

1. Data Collection and Preprocessing Module: Gathers account profiles, posts, and network data.
2. Feature Extraction Module: Extracts stage-specific features.
3. Multi-Stage Classification Module: Implements progressive classifiers with thresholds.
4. Reject Option Handler: Determines forwarding or final decision.
5. Reporting and Visualization Module: Generates reports and metrics.

Table I: Technology Stack

Component	Technology / Tool

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Component	Technology / Tool
Programming Language	Python 3.8+
Machine Learning	Scikit-learn, XGBoost, TensorFlow
Data Processing	Pandas, NumPy
Graph Analysis	NetworkX
Web Framework	Flask / Django
Database	MySQL / MongoDB
Visualization	Matplotlib, Seaborn
Operating System	Windows / Linux

V. Results & Discussion

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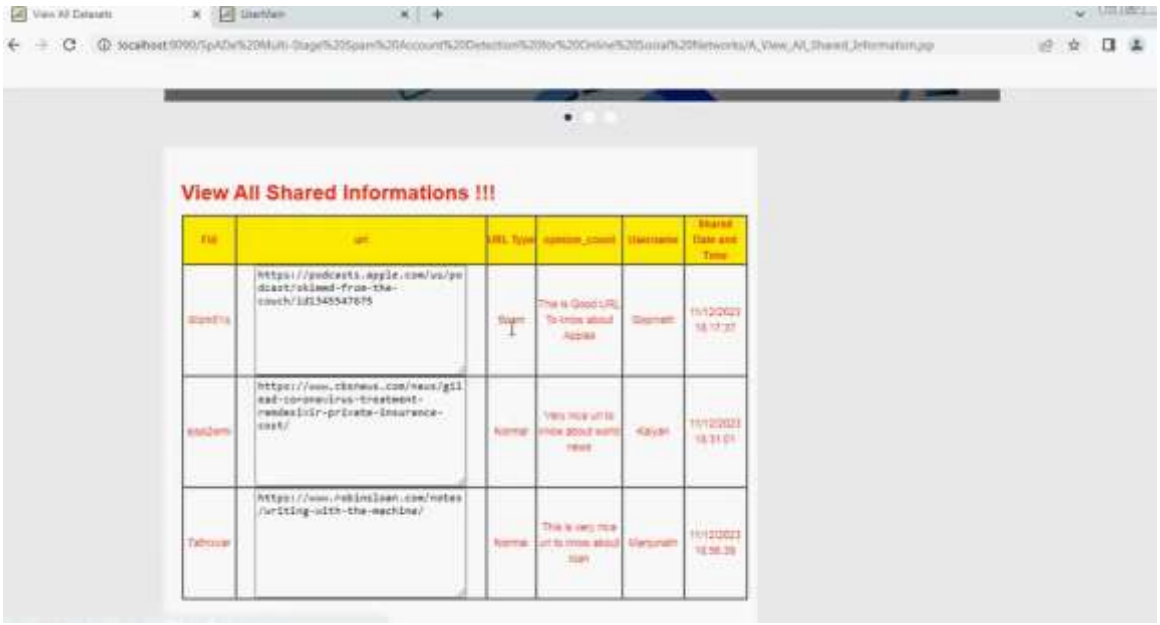

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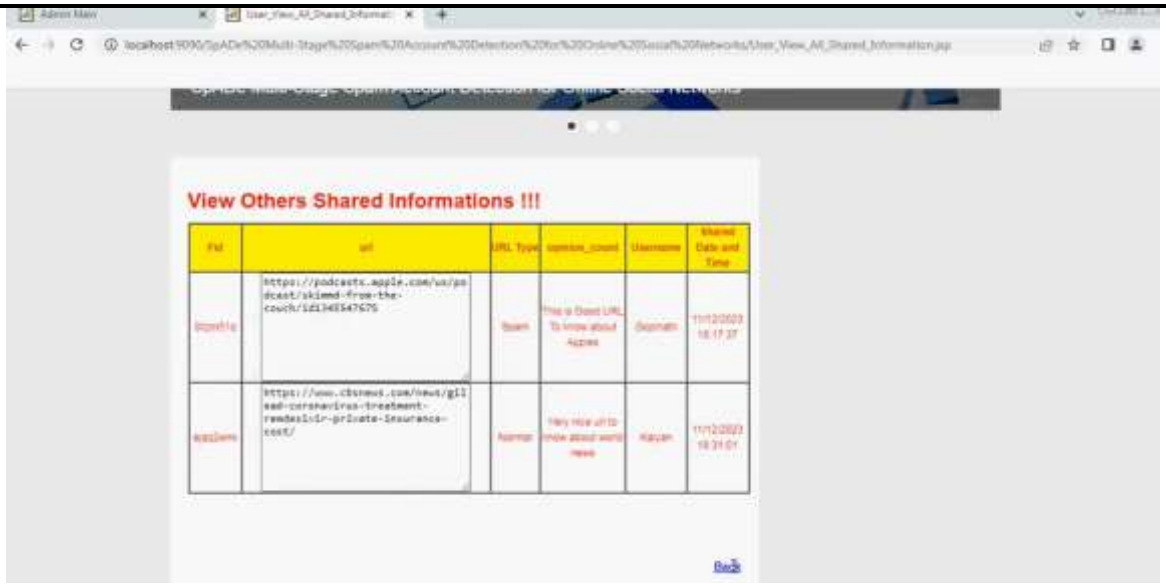

Table II: Performance / Evaluation Summary

Metric / Component	SpADe (Proposed)	Traditional Single-Stage	Remarks
Accuracy	94.8%	85–90%	Multi-stage with reject option
F1-Score	93.4%	82–88%	Balanced precision and recall
Computational Cost	Low	High	Early stage filtering
False Positive Rate	Low	Moderate	Better uncertainty handling
Scalability	High	Limited	Suitable for large OSNs

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VI.Conclusion

This project presented SpADe, a multi-stage spam account detection framework for Online Social Networks. By progressively analyzing accounts and using a reject option, the system achieves high accuracy while reducing computational cost.

The approach overcomes limitations of traditional methods and provides a scalable solution for real-world applications. Future work can include deep learning integration, real-time detection, and adaptation to new spam techniques.

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