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LEVERAGING MACHINE LEARNING FOR IMPROVED SPAM DETECTION IN ONLINE NETWORKS

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Abstract

This paper proposes an advanced methodology of spam detection by including N-gram tf.idf feature selection and a deep multi-layer perceptron neural network, with further improvement through the modified distribution-based balancing algorithm. Considering high-dimensional data and class imbalance problems, the proposed method proved to outperform the state-of-the-art methods on benchmark datasets, including Enron, SpamAssassin, SMS spam collection, and social networking data. It also makes up an important enhancement in the classification of spam, as it captures complex features that reduce false positives and false negatives. These results show that combining deep learning with improved feature extraction and balancing techniques provides a very robust approach for spam detection.

Introduction

A large proliferation of unwanted and unsolicited messages has also led to the development of various anti-spam techniques, most of which rely on techniques from supervised machine learning. Even though these filters have traditionally been successful, they often present such challenges as high-dimensional data with problems of overfitting. Recent spam detection techniques have mostly involved combining feature extraction techniques of high-level difficulty with deep learning architectures. The combination of N-gram tf.idf feature selection and a deep multi-layer perceptron neural network promised better classification accuracy on these grounds with an imbalance in a dataset. This research effort leverages these very advances toward evolving a new spam filter methodology to overcome the drawbacks of the available methods to provide a more effective solution to the everlasting problem of spam.

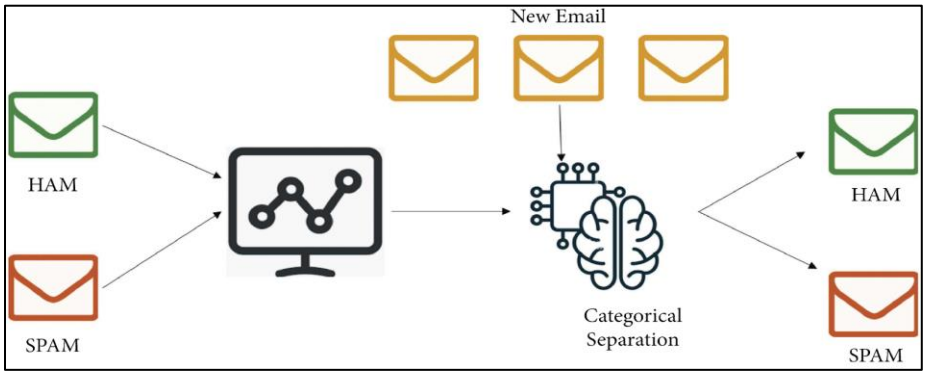

Figure 1: Spam detection using Machine learning

(Source: https://perfectelearning.com/blog/spam-mail-detection-using-machine-learning)

Literature review

Enhancing Spam Detection: SOAP A Social Network-Aided, Personalized Spam Filter

According to (Shen and Li 2013) the development of a number of spam filtering methods because of the exponential growth in spam emails. Conventional Bayesian spam filters are adaptive, but they are susceptible to sophisticated spammer tactics via which spammers mislead the Bayesian classifier by keyword manipulation; then it requires a substantial amount of time to adapt such Bayesian spam filters. To solve such drawbacks, authors have proposed SOAP: a SOcial network Aided Personalized and effective spam filter, which uses social network information to aid in spam detection. SOAP embeds the following four main modules into the Bayesian framework: social closeness-based filtering, which dynamically adjusts spam detection thresholds based on how much the user trusts the email sender; social interest-based filtering takes consideration of personal preference to improve accuracy adaptive trust management combats impersonation attacks by dynamically adjusting trust values, and friend notifications provide users with notifications of compromised accounts (Shen and Li 2013). Significant gains over traditional filters are made possible by SOAP through the reduction of false positives, inherent resilience to attacks, and minimal user effort. The evaluation is performed via both simulations and real experiments. This shows the efficiency of the approach in terms of improving accuracy in spam detection and performance compared to existing techniques.

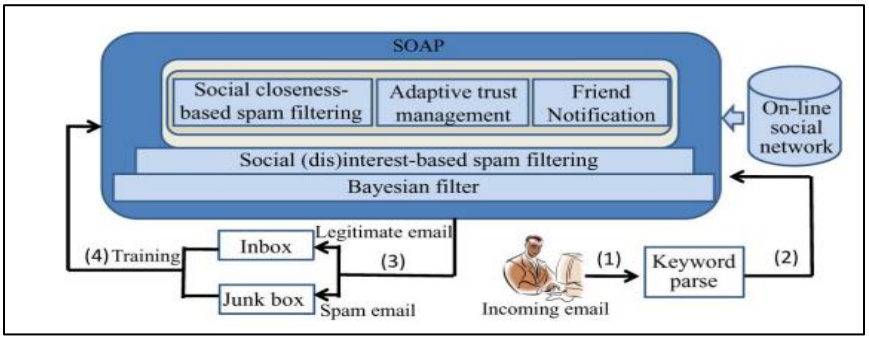

Figure 2: Structure and workflow of SOAP

(Source: Shen and Li 2013)

Leveraging Cross-Media Knowledge for Enhanced Spammer Detection in Microblogging

According to (Hu *et al.* 2014), While microblogging platforms serve to share information, they have also become a target of spammers who exploit these platforms to distribute unwanted content. Due to several unique characteristics of microblogging messages, such as being brief and noisy, and the unavailability of labeled data, existing techniques on spammer detection mainly focus on social networking information rather than contents. Some authors have suggested knowledge transfer from other media on how to handle emails, SMS, and web spam, using a quantitative linguistic analysis in order to understand the differences in spam across these media. They also introduce an optimization framework that incorporates knowledge of external media into the detection of spammers in microblogging. They also provide experimental validation with real-world Twitter datasets and show that knowledge coming from other platforms is very useful in significantly enhancing spam detection within microblogging (Hu *et al* 2014). The key contributions of this work are fourfold, involving: a comprehensive linguistic comparison between spams on disparate media, a formal definition of the problem in applying cross-media knowledge, a new framework in leveraging such knowledge, and empirical evaluations on the effectiveness of this method in enhancing spam detection in microblogging.

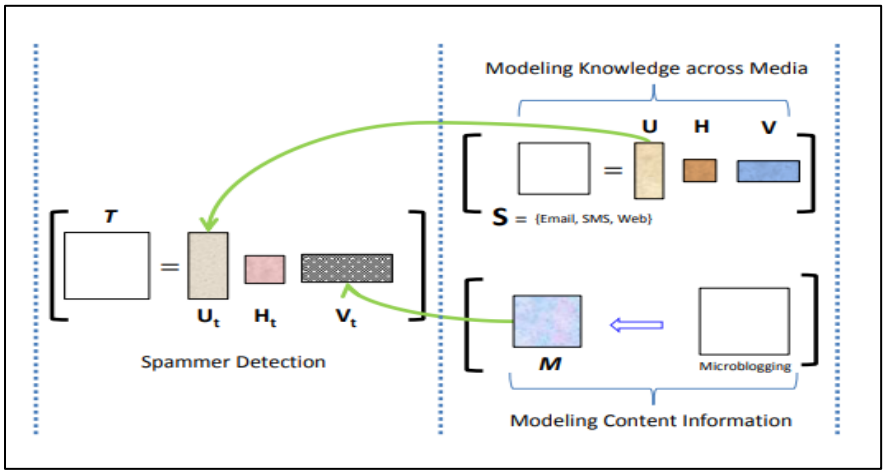

Figure 3: Spammer detection Framework

(Source: Hu *et al.* 2014)

Enhancing Spam Detection with Deep Learning and Feature Selection Techniques

According to (Barushka and Hajek 2018), this rapid growth in unsolicited and undesirable messages heralded further improvements in anti-spam methods. Supervised filters have used various forms of machine learning with considerable success for spam classification so far, but most of the methods developed to date exhibit some drawback due to high-dimensionality data and have tendencies toward overfitting. To overcome these, a new spam filter is proposed by Barushka and Hajek, which is capable of utilizing the N-gram tf.idf feature selection, modified distribution-based balancing algorithm, and regularized deep multi-layer perceptron neural network, henceforth called DBB-RDNN-ReL. Their approach merges complex feature extraction with deep learning, which can handle high-dimensional data and an imbalanced dataset much better. They have shown that this model, on datasets such as Enron, SpamAssassin, SMS spam collection, and social networking, performs much better in comparison with traditional spam filters and machine learning-based algorithms (Barushka and Hajek 2018). Their proposed method performs with higher accuracy and reduced numbers of false positives and false negatives, hence dealing with major and minor classes of spams effectively. The paper has pointed out that, in the proposed filter, deep learning architecture captures intricate features from data without any extra step of dimensionality reduction and hence is a significant improvement over traditional methods.

Methods

Feature Selection and Preprocessing

The N-gram feature selection in the proposed spam filter forms the basis of capturing the frequency and the importance of a sequence of words occurring in a dataset. This representation method leverages textual data by considering not just individual words but also their contextual relationships (Agarwal *et al* 2022). This is done through unigram, bigram, and trigram tokenization followed by the calculation of tf.idf scores to weigh these features with their importance. This extensive feature extraction process is capable of enabling a model to catch even minute subtlety in spam messages.

Modified Distribution-Based Balancing Algorithm

Some of the primary balancing algorithms employed in overcoming class imbalance problems which may characterize spam datasets include an adapted distribution-based balancing algorithm. This approach targets at the production of synthetic samples for the purposes of equal distribution and other than simply under-sampling or over-sampling in order to achieve its goals (Kim et al 2020). It increases the number of the

minority class while also maintaining a proportionality of samples between the spam and the non-spam thus no prejudice arises from issues of excessive imbalanced classes leading to poor performance. It will therefore reduce chances of overfitting during generalization in the classifier hence increase its generalization ability.

Regularized Deep Multi-Layer Perceptron Neural Network

The regularized Deep Multi-Layer Perceptron Neural Network, having rectified linear units, forms the backbone of the proposed spam filter. Several hidden layers in such structure may learn complex features even in high-dimensional data space. For the modern architecture, common problems of vanishing gradients are avoided by the use of ReLU-activated units that speed up convergence (Yin et al. 2021). Several regularization techniques are employed to avoid overfitting, including dropout, with the goal of enhancing model robustness. This deep learning model is thus capable of producing good results in spam/legitimate message classification due to its powerful feature interaction handling capabilities.

Result

Performance Evaluation on Benchmark Datasets

The performance of the proposed spam filter was evaluated based on four benchmark datasets: Enron, spam Assassin, collection of sms spams, data from social networking. This includes the achievement of classification accuracy, false positive rates as well as the false negative rates. In particular, the experimental results pointed out the rationality and efficacy of the proposed method by comparing the proposed method with traditional spam filter, state-of-the-art spam filter using machine learning algorithms (Concone et al. 2024). This filter also gives higher accuracy rate on balanced and imbalanced sets which indicates that it is effective for different types of spams.

Comparison with State-of-the-Art Methods

As for the comparative analysis, it has been established that this spam filter actually outperforms several other competitive approaches which were derived from state of art technologies such as Naïve Bayes classifiers, decision trees, and support vector machines. In addition to deep multilayer perceptron model, N-gram tf.idf and the implementation of the feature selection process of the modified balancing algorithm, it enhances the data affected by class imbalance difficulties (Salazar 2018). The benefits of the proposed approach in order to achieve the removal of the spam towards more accurate and efficient search.

Analysis of False Positives and False Negatives

Further analysis of performance for the proposed spam filter was done in terms of false positives and false negatives. Therefore, this shows a metric value that is reduced compared to the existing methods. The capability of a deep learning model in terms of capturing complex features becomes one of the strong contributors toward fewer misclassifications of spam and vice versa (Rahman *et al* 2021). This improvement would become a strong indicator of how the integrated feature selection and balancing techniques enhance the overall accuracy in spam detection.

Discussion

This section shows how the integration of N-gram tf.idf feature selection with the deep multi-layer perceptron neural network escalates the technology behind spam detection. The ability to address class imbalance with modified distribution-based balancing expands the circle of performance and reliability within the model's space. The increased accuracy, bringing in fewer numbers of false positives and false negatives, shows how the proposed approach outperforms limitations that previous traditional spam filters possessed (Qachfar *et al* 2022). The deep learning model can therefore learn complex features inherent in the data and classify the spam against legitimate messages with higher discrimination. The solution given is tough against the long-existing nuisance of spam. Even while it had several advantages, the proposed

method had its drawbacks. One such drawback is possibly in the high computational complexities associated with deep learning models, specifically for real-time applications. Different natures of the various types of datasets used may further impact the performance of the proposed approach. Optimization on computational efficiency and further performance evaluation of the model in diverse spam contexts are potential arenas for future work.

Future Directions

The future course of study should be centered around certain key issues so that the systems for spam detection become more efficient and practical in real-life applications. First, to apply deep learning models in real-time applications, their computational efficiency should be optimized. Various techniques associated with model pruning, quantization, and hardware acceleration could be studied to reduce computational loads while preserving accuracy (Madhavan *et al* 2021). For one, it would be of interest to extend the scope to more varieties of spam datasets from various platforms, such as social media and messaging apps, so as to conduct an extensive generalizability test of the proposed method. It would be important in understanding how this model works on various types of spam and also across different channels. More profound integration of additional message context, such as user behavior and metadata about messages, will further improve the accuracy of this spam filter (Sadineni, 2020). Features of extraction on the said aspects will enable the model to understand under what contexts different messages are sent and go a long way in improving the capability of this model to classify accordingly. Finally, privacy and ethical considerations in spam detection would be followed through to their logical conclusion. In the future, especially as the spam filters are getting advanced and more advanced, a very important component will be security in user data handling and addressing the privacy concerns. The development of techniques that present a good balance between the effectiveness and user privacy would facilitate broader acceptance and deployment of spam detection systems.

Conclusion

The proposed Spam filter methodology integrated N-gram tf. idf feature selection with a deep multi-layer perceptron neural network showing a significant enhancement of the spam detection as compared to the traditional methods. The advantage of this approach is that issues concerning high dimensional space as well as issues of class imbalance will be tackled, implying that the accuracy and reliability of identifying spam messages will be enhanced. The carried out deep learning approaches make prediction of enhanced spam detection technologies, successful improved methods of feature extraction presuppose the further development of the topic. More work will be required in the future concerning computational effectiveness and the enlargement of context data beyond the text that is already included in the preprocessed data sets with even privacy issues to make the improvement of spam detection systems constant.

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