An Adversarial Attack Analysis on Malicious Advertisement URL Detection Framework

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Abstract—Malicious advertisement URLs pose a security risk since they are the source of cyber-attacks, and the need to address this issue is growing in both industry and academia. Generally, the attacker delivers an attack vector to the user by means of an email, an advertisement link or any other means of communication and directs them to a malicious website to steal sensitive information and to defraud them. Existing malicious URL detection techniques are limited and to handle unseen features as well as generalize to test data.

In this study, we extract a novel set of lexical and web-scrapped features and employ machine learning technique to set up system for fraudulent advertisement URLs detection. The combination set of six different kinds of features precisely overcome the obfuscation in fraudulent URL classification. Based on different statistical properties, we use twelve different formatted datasets for detection, prediction and classification task. We extend our prediction analysis for mismatched and unlabelled datasets. For this framework, we analyze the performance of four machine learning techniques: Random Forest, Gradient Boost, XGBoost and AdaBoost in the detection part. With our proposed method, we can achieve a false negative rate as low as 0.0037 while maintaining high accuracy of 99.63%. Moreover, we devise a novel unsupervised technique for data clustering using K-Means algorithm for the visual analysis. This paper analyses the vulnerability of decision tree-based models using the limited knowledge attack scenario. We considered the exploratory attack and implemented Zeroth Order Optimization adversarial attack on the detection models.

Index Terms—Malicious advertising URL, cybersecurity, machine learning, web-scrapped features, classification, clustering, adversarial attack.

I. INTRODUCTION

N recent years, the network of web pages has grown faster with the expansion of the Internet. Online services, business, banking, and online marketing have made the Internet an integral part of our lives. Because of the numerous advantages of this platform for online advertising, it has also become a primary source of malicious activities. Attackers deliberately put malicious links in online advertisements that, when visited,

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redirect the users to unauthorised websites. Attackers make it easy for people to be steered to phishing or malware websites to steal their confidential data, make a fast buck, or defraud them by injecting dangerous code into these websites. Every year, such illegal activities cost billions of dollars [1]. Most harmful websites are almost identical to genuine websites, and the user cannot distinguish between them. In order to minimise the effects of this scam, organisations and enterprises are investing a significant amount of money in keeping their systems secure against these harmful links and URLs.

The researchers made several attempts to distinguish the malicious URL using statistical analysis and the popularity feature of the domain name [2]. Though most phishing and malicious sites have a short lifespan, these features may not be available to them for analysis. As a result, the rate of misclassification rises. The creation of new URLs daily makes the job more challenging. URL analysis also serves as a barrier between the victim and the malicious website. There are currently two primary trends in identifying malicious URLs: the first is detecting malicious URLs based on rule's set, and the second is based on a behavioural analysis approach. The approach based on rules set can efficiently and precisely detect harmful URLs. However, this strategy cannot recognise latest malicious advertisement URLs which do not match any of the specified indicators. Deep learning and machine learning algorithms have wide use in categorising malicious URLs based on their behaviour analysis techniques. Classification tasks across a wide range of domains have been found to perform better with deep learning approaches than featurebased learning approaches. Nevertheless, the performance of every deep learning model is determined by a variety of aspects such as hyper-parameter tuning, neural network design, and more.

A. Contribution

The following is a summary of our contributions to this article:

- We devise and integrate the collection of innovative lexical and web-scrapped features [3] for the precise categorisation of legitimate and malicious advertisement URLs. Additionally, we utilize several essential humanengineered and URL segmentation features. Furthermore, we examine a range of statistical properties of the URL for a brief idea about the malicious and legitimate class of URL.
- We conduct our study on a number of datasets with various URL schemes and orientations, and we analysed

our model's performance on these datasets. This method aims to train machine learning models for all URL forms thoroughly.

- We investigate the performance of our four distinct classifiers using a range of parameters and the detection results using a balanced matched and mismatched URL dataset. With the right combination of features, we achieve the highest detection accuracy up to 99.63% and the lowest false negative rate as low as 0.0037 in detection.
- We use the K-Means clustering technique to integrate the result in a visual comprehension with the formation of clusters. We also make use of the elbow approach to determine the number of cluster classes.
- We analyse how adversarial attacks affect our ensembles and our classifiers' vulnerability. We use the Zeroth Order Optimization black-box approach on our models to account for the limited knowledge scenario.

B. Organisation

This paper is divided into six sections that begin with the Introduction section, afterwards the related work in Section III, Background task and knowledge of our framework in Section II, followed by the feature extraction process, machine learning-based malicious URL detection model, prediction, clustering, and adversarial attack implementation in Section IV, then presenting the outcomes of our approach, as well as a comparative study of past work's results, and discussion in Section V, and lastly, we discussed the conclusion of our research and future work in Section VI. Our code and all the datasets are available on GitHub [4].

II. BACKGROUND

Here, we lay out the background information of datasets used in our experiment in Section II-A, statistical properties in Section II-B, and pre-processing task in Section II-C. Here, we will also talk about classification methods in Section II-D and the setting of an adversarial attack in Section II-E.

A. Datasets

The experiment setup for advertising URLs from 12 distinct datasets includes 3980870 URLs. There are two kinds of URLs in these contained in these datasets: benign and malicious. Furthermore, the malicious URL dataset includes four distinct sub-categories: spam, defacement, malware, and phishing. We also examined all of the URLs using the VirusTotal [5] tool to confirm their authenticity. Each URL is labelled with '0' for benign and a '1' for malicious in the dataset. The URLs that performed the classification task are divided into two categories listed here.

1) **Benign Dataset:** The benign URLs were gathered from available sources on the Internet. Table I gives an overview of the six benign URL datasets. In Alexa, [6] traffic rating is used to rate the URLs, which is calculated by a combination of the browsing behaviour of online users, the total unique visitors, and the number of site traffic. CrowdFlower [7] is a large-enhanced dataset of categorised websites; contributors

visited supplied links and chose a primary and sub-category for URLs. DMOZ [8] is a big open directory that is communally managed and categorises web material. The information is presented in a sophisticated XML format. Benign set URL [9] and Non-malicious URL [10] are the open-source datasets available on Kaggle. ISCX-URL-2016 [11] is produced by the research and development unit Canadian Institute for Cyber-security that draws on the experience of social researchers, business researchers, computer scientists, engineers, lawyers, and scientists. [12]. If we talk about the format, Alexa and CrowdFlower datasets have sub-domain and domain in the URL, DMOZ and Benign set URLs (Benign) have protocol and hostname, and Non-malicious_url and ISCX-URL-2016 (Benign) have all URL components.

TABLE I BENIGN DATASETS

Sr. No.	Dataset Name	Volume	Year
1	Alexa [6]	1000000	2019
2	CrowdFlower [7]	31084	2020
3	DMOZ [8]	1048576	2019
4	Benign set URL [9]	345737	2019
5	Non-malicious URL [10]	344821	2019
6	ISCX-URL-2016 [11]	35378	2016

2) Malicious Dataset: We gather the malicious URL datasets from various open sources on the Internet and divide into four sub-categories: spam, defacement, phishing, and malware. Table II contains the summary of the six malicious URL datasets. As an open community website, Phishtank [13] is a free service for sharing phishing URLs, and users can send suspicious URLs to Phishtank for verification. Cisco Talos Intelligence Group updates data on this website on an hourly basis. Phishstrom [14] is a malicious dataset with features built and used for evaluation in the paper [15]. Phishing Site URL [16], Malicious data URL [10], and Malicious set UR1 [9] are the open-source datasets available on the web. ISCX-URL-2016 (malicious) [11] dataset of malicious URLs contains four different sub-categories of malicious URLs. All of the malicious datasets in this section have complete URL components.

TABLE II MALICIOUS DATASETS

Sr. No.	Dataset Name	Volume	Year
1	Phishing Site URL [16]	549347	2020
2	Phishtank [13]	223056	2021
3	Malicious data URL [10]	75643	2019
4	ISCX-URL-2016 [11]	129988	2016
5	Phishstrom [14]	47909	2013
6	Malicious set URL [9]	104438	2019

The six benign and six malicious URL datasets are combined to create six balanced datasets which contain an equal number of malicious and benign URLs with a split size of half of the benign data. The benign datasets are then combined based on their resemblance to malicious datasets. The combined information from the merged datasets is also displayed in Table III.

TABLE III MERGED DATASETS

Dataset Name	Merged Dataset
Dataset 1	Alexa + Phishing Site URL
Dataset 2	Crowdflower + Phishtank
Dataset 3	DMOZ + Malicious data URL
Dataset 4	Benign set URL + ISCX-URL-2016 (Malicious)
Dataset 5	Non-malicious URL + Phishstrom
Dataset 6	ISCX-URL-2016 (Benign) + Malicious set URL

B. Statistical Characteristics of the Datasets

To better understand our data, we perform a statistical study of legitimate and malicious advertisement URLs based on lexical properties here. In this analysis, we discovered that the length of malicious ad URLs has a broader range of dispersion than benign URLs. The majority of benign URLs are between 25 and 50 characters long, with an average length of 44.28 characters. The average number of special characters in a benign URL is 8.64, with a path length of 17.54 characters. Fig. 1 shows the frequency distribution of benign URL lengths.

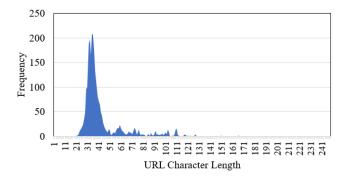


Fig. 1. Frequency Distribution of URL Length - Benign

The majority of malicious ad URLs are between 25 and 105 characters long, with an average length of 63.14 characters. Malicious URLs have 13.98 special characters on average and a path length of 42.60 characters. We also discovered that less than 2 per cent of malicious ad URLs use IP as a domain name. Fig. 2 presents the frequency distribution of malicious URLs.

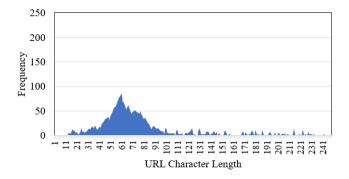


Fig. 2. Frequency Distribution of URL Length - Malicious

C. Preprocessing of Datasets

Our prototype platform's implementation accepts a specified shape of the input dataset. As a result, to acquire more precise outcomes, the dataset must be modified and reshaped to meet our reliance's required input format. We scale the data using the interquartile range method during the preprocessing stage. All redundant and raw valued cells were removed, and repeated hostname URLs were excluded. The URL datasets were then shuffled, and samples were taken from the datasets for further investigation.

D. Classification Techniques

The Classification method is a Supervised Learning technique that uses training data to identify the category of new observations. Predictive models train from a given dataset or collection of observations and afterwards categorize subsequent observations into one of many classes or groupings. Classes are sometimes known as targets/labels or categories. Boosting is an ensemble modelling approach that aims to construct a robust classifier from many weak classifiers. This task is performed by building a model by sequentially connecting weak models. First, a model is constructed using the training data. Then the second model is constructed to address the faults in the previous model. The is repeated again and again until the entire training data set is adequately predicted or the maximum number of models added. Here, we discussed some of the classifications and boosting techniques we used in our research.

- 1) Random Forest: A Random Forest is a large collection of decision trees that differ slightly from the others. Random Forest is based on the premise that while every tree may predict quite well, it almost certainly overfits some data. Overfitting can be limited by averaging the outcomes of numerous trees that all operate well and overfit in different ways. This reduction in overfitting can also be demonstrated while keeping the predictive power of the trees. The important parameter to alter are n_estimators, max features, and prepruning settings such as max depth. For n_estimators, larger value is preferred. As more trees are averaged, an ensemble becomes more robust as overfitting is reduced. However, more trees require more memory and training time.
- 2) Gradient Boost: Gradient boosting is another ensemble approach that combines numerous decision trees to generate a more significant model. Unlike the Random Forest method, Gradient Boosting works by successively creating trees for every tree, attempting to fix the flaws of the preceding one. Randomization is not employed by default in Gradient Boost regression trees; instead, severe pre-pruning is used. Gradient Boost trees usually employ extremely shallow trees with depths ranging from one to five, reducing memory needs and speeding up the prediction. Gradient Boost tree models depend on three primary parameters: n_estimators, number of trees, and learning rate, that deduce the extent by which new tree corrects the errors of the previous one. It is common practice to fit n_estimators for learning rates according to a time and memory budget and then comparing.

- 3) AdaBoost: Another ensemble method in Machine Learning, AdaBoost, or Adaptive Boosting, is a boosting algorithm. During the data training period, it generates *n* decision trees. When the first decision tree/model is constructed, the incorrectly classified record in the first model is prioritised. Only these records are sent to the second model as input. The process is repeated until we specify how many base learners we want to create. With all boosting techniques, record repetition is permitted. The incorrectly classified record is used as input for the next model. This process is repeated until the specified condition is met.
- 4) XGBoost: XGBoost, or extreme Gradient Boosting, enhances performance and speed aspects of Gradient Boost decision trees implementation. To create a machine learning algorithm, it used a Gradient Boost framework. The regularisation term reduces over-fitting by smoothing the final learned weights. Models using basic, predictive functions will be favoured by the regularised objective. Here, the model is taught additively instead of the traditional optimization method for the tree ensemble model in the Euclidean space. Due to its simultaneous and distributed processing, XGBoost is faster than other algorithms.

E. Adversarial Attack

Adversarial machine learning technique aims to exploit models by developing harmful attacks using accessible model information [17]. The main reason for exploitation is to affect machine learning and fail it. Here, we will examine the adversarial attack on our models. It has been discovered that an intelligent malicious URL generating system can generate URLs that can pass machine learning classifiers at a low rate. White-box, gray-box, and black-box attacks are the three main types of adversarial attacks.

- White-Box Attack: In a white-box attack, the attackers have complete access to the model's architecture, parameters, weights. L-BFGS [18] black-box constrained method was proposed to minimise the additive perturbation based on classification restrictions; however, it was inefficient. The Fast Gradient Sign Method [19] eventually conquered it, followed by the primary iterative method of adding perturbations iteratively. Other white-box adversarial attacks include JSMA, BIM & ILCM, ATNs, and DeepFool.
- Black-Box Attack: In black-box attacks, the attacker have no access to the system. The system's parameters and weights cannot be obtained here, opposite to whitebox attack, which need the target neural networks to be differentiable. Zeroth Order Optimization may directly approximate the gradients of the target network using zeroth order stochastic coordinate descent. Other examples of black-box adversarial attacks include One-pixel, UPSET, and ANGRI.
- *Grey-Box Attack*: The grey-box attacks use only training access to the target model to create adversarial samples.

Counter-Forensic Attack Model: Here we shall formulate the universal adversarial paradigm for counter forensic attacks

in this text. An adversarial model is characterised by demonstrating adversary's goal, system's knowledge, and capacity of corrupting the system through data manipulation [20], [21].

- Attacker's goal: It describes the type of security violation and the type of error the attacker seeks. Counter forensic attacks are often either integrity violations or evasion attacks. The adversary's goal determines the loss function that the adversary seeks to maximise.
- Attacker's knowledge: This deals with if the attack has a limited amount of knowledge about the model or perfect knowledge. The attacker is fully aware of the forensic algorithm in a perfect knowledge scenario and aware of a few details or settings relevant to the forensic algorithms in a restricted knowledge scenario.
- Attackers capability: It refers to the adversary's level
 of control over training and testing data. The attacker's
 capability in the exploratory attack paradigm is restricted
 to modifications to test data, whereas modifications to
 training examples are still not permissible. The attack
 can interrupt the training process in a causative attack
 scenario, referred to as a poisoning attack.

This article considers the exploratory attack scenario and shall discuss the ZOO attack. The ZOO attack is a version of the C&W attack [22] that employs ADAM coordinate descent to perform numerical gradient estimates. As with any tree attack, there is the risk of misclassification of objects or data. It can also involve picture captioning, voice recognition misclassification, and data regression effects. Because a white-box attack relies on the model's overall knowledge growth, this black box attack has just a limited knowledge of the targeted model. It has an unknown training technique as well as data. It also includes unidentified output classes and model confidence.

Many research challenges are concerned with complex data creation processes that, although analytically explainable, can provide types of measurements such as measures from physical surroundings or predictions from deploying machine learning techniques. In black-box models, these kinds of challenges are incorporated into Zeroth Order Optimization (ZOO). These sorts of issues are put into Zeroth Order Optimization in black-box models. The ZOO Attack, also known as Derivative-Free Optimization, solves problems that do not have direct access to gradients.

III. RELATED WORK

Significant research has been conducted earlier to detect malicious advertising and phishing websites in a variety of ways. The traditional approach of blacklisting the malicious ads related sites gives out as the list consists of only known malicious URLs [23]. Although it is a powerful feature indication, it takes several hours for a malicious URL to be banned, and its implementation is infeasible. As a result, the system fails when a new malicious URL is encountered. Researchers later proposed URL analysis based on lexical aspects [24], statistical properties [25], host-based features [26], content features [27], and popularity-based factors [28]. Thomas et al. [29] developed a real-time URL spam filtering process that involved based on IPs, lexical and HTML parameters. The

TABLE IV LEXICAL FEATURE GROUP

Sr. No.	Feature Subgroup	Feature Name	Data Type	Feature Description
1		URLLength	Integer	Compute length of the URL e.g. the URL length is 51 of
				https://www.example.com/seo-tools/count-characters/
2		CheckIPAsHostName	Binary	Check if IP address is used as hostname e.g. www.192.168.0.1
3		CheckEXE	Binary	To look the presence of .exe in URL
4		DigitAlphabetRatio	Float	To compute the ratio of number of digit to alphabets in URL
5		Specialchar Alphabet Ratio	Float	To compute the ratio of number of special characters to alphabets in URL
6		UppercaseLowercaseRatio	Float	It computes ratio of uppercase characters to lowercase characters in URL
7		DomainURLRatio	Float	To compute the ratio of domain length to URL length
8		NumericCharCount	Integer	Number of numeric character viz. 0,1,2,,9
9		EnglishLetterCount	Integer	Number of English letter viz. a,b,c,,z and A,B,C,,Z
10		SpecialCharCount	Integer	Number of special character viz. !,\$,",etc.
11		DotCount	Integer	Number of '.' characters
12		SemiColCount	Integer	Number of ';' characters
13		UnderscoreCount	Integer	Number of '_' characters
14		QuesMarkCount	Integer	Number of '?' characters
15		HashCharCount	Integer	Number of '#' characters
16		EqualCount	Integer	Number of '=' characters
17		PercentCharCount	Integer	Number of '%' characters
18		AmpersandCount	Integer	Number of '&' characters
19	Linguistic Features	DashCharCount	Integer	Number of '-' characters
20	Linguistic reatures	DelimiterCount	Integer	Number of the dilimeter characters in URL viz. (),{}[],,/*,*/,etc.
21		AtCharCount	Integer	Number of '@' characters
22		TildeCharCount	Integer	Number of '~' characters
23		DoubleSlashCount	Integer	Number of '//' characters in the link path
24		IsHashed	Binary	To check if URL is hashed (If any hash function is used to convert URL)
25		TLD	String	To look for top level domain of URL e.gcom, .us, .org
26		DistDigitAlphabet	Float	Distance between number to alphabet
27		HttpsInUrl	Binary	Check the presence of https in URL
28		FileExtension	String	To check the extension of the file in URL
29		TLDInSubdomain	Binary	Check whether subdomain have TLD or ccTLD as its part
30		TLDInPath	Binary	Check whether subdomain have TLD or ccTLD in link of URL
31		HttpsInHostName	Binary	Check for the disarrangement of https in URL e.g. 'www.wordforhttps.in'
32		HostNameLength	Integer	Hostname length of URL
33		PathLength	Integer	Path length of URL
34		QueryLength	Integer	Length of the query In URL
35		DistWordBased	Binary	Check if URL is contain anonymous words (personal, .bin, abuse etc.)
36		URLWithoutwww	Binary	To check if www is present in the URL
37		FTPUsed	Binary	Check if "ftp://" is there in the URL
38		JSUsed	Binary	Check if ".js" is there in the URL
39		FilesInURL	Binary	Check if files is there in the URL
40		CSSUsed	Binary	Check if ".css" is used in the URL
41		IsDomainEnglishWord	Binary	Check if domain name is English language word as per US/UK dictionary
42		IsDomainMeaningful	Binary	To check if domain name is English language word and meaningful
43		IsDomainPronounceable	Binary	To check if domain name can be pronounced
44	Human-Engineered	IsDomainRandom	Binary	To compute the randomness of the URL string
45	Features	Unigram	Float	To calculate uni-gram probability
46	2 0000100	Bigram	Float	To calculate bi-gram probability
47		Trigram	Float	To calculate tri-gram probability
48		SensitiveWordCount	Integer	Sensitive words in URL (i.e., "secure", "account", "webscr", "login" etc)
49		InSuspiciousList	Binary	To check if URL is present in suspicious list from malicious dataset

popularity features are the details about the URL's position on social media or its rating. Choi et al. [30] used URL lexical analysis to identify multiple forms of malicious assaults. Xiang et al. [31] employed machine learning algorithms with a large collection of rich features. In Twitter streams, Lee and Kim [32] discovered suspicious URLs by examining and analysing associated redirect chains of URLs in several tweets. Furthermore, determining which features are valuable necessitates specialist topic knowledge, yet our strategy of combining the innovative combination of rich features proved to be thoughtful exertion.

Based on the machine learning approaches, a number of fraudulent advertisements URL detection systems were created, including logistic regression [33], Nave Bayes [34], decision trees, and ensembles [35]. Garera et al. [36] research is

based on logistic regression, with a few variables incorporated in the extraction to categorise harmful URLs [16]. Fette et al. [37] classify phishing emails using statistical approaches from machine learning. The classifiers examine the structure and content of the email. Bergholz et al. improve on the technique mentioned above's accuracy by incorporating text classification algorithms to examine email content [38]. Abu-Nimeh et al. [39] compares multiple classifiers on a database of phishing emails, using the frequency of the corpus's top 43 keywords as attributes. Numerous online tools are available on the web that can help detect malicious URLs, such as URL Void, UnMask Parasites, Norton Safe Web, Google Safe Browsing Diagnostic, SiteAdvisor, VirusTotal, and Browser Defender. However, their effectiveness is limited due to their signature-based nature. In this article, we will look at the most

popular ensemble strategies and compare the accuracy of all the models.

Extensive research has been conducted on the adversarial attack on deep learning models [22]. An investigation of the robustness of deep neural networks was conducted when they were exposed to small simulated perturbations [40]. In this context, the adversarial robustness of machine learning models was also investigated. Barreno et al. work's [41] is part of a series of security evaluations of machine learning algorithms that includes various attacks on machine learning techniques and systems. Huan and Wardey-paper Farley's [42] laid the groundwork for such work using sophisticated model architecture and parameters, including the use of adversarial examples to improve the classifier's robustness. A reliable technique for identifying adversarial perturbations is required to investigate and assess the robustness of different classifiers to adversarial perturbation.

IV. METHODOLOGY

In this section, we present our working mechanism with feature extraction procedure in Section IV-A, empirical study in Section IV-B, and adversarial attack on our detection models in Section IV-C.

A. Feature Extraction

This phase of research aims to gather important information about the URL string. It entails a set of features with distinguishing characteristics used to specify different dataset categories. Since we wish to differentiate between fraudulent and genuine advertisement URLs, we do this work using two key feature categories: lexical and web-scrapped features. These are covered in the next section.

1) Lexical Features: We used the fundamental features from the URL string for easy demonstration and some advanced aspects for an unconventional approach in this set of

Algorithm 1: Check domain is English language word

INPUT: domain_name

OUTPUT: Meaningful, English word, Pronounceable,

Random string

break domain_name in words = words[]

IF domain_name belongs to wordnet.synsets

Return TRUE

ELSE

Return FALSE

IF words[] is not NULL

Check for parts of speech

IF words[] has Noun, Pronoun

Return Meaningful

ELIF words[] has Verb, Adjective

Return Pronounceable

ELSE

Rerurn Random string

END

features. These are further classified into two types: linguistic features and human-engineered features. Linguistic features comprise essential URL string qualities such as length-based features (length of the URL string, domain length, etc.), presence of an object (.exe presence in the string, etc.), count-based features (alphabet, special character count, etc.), and TLDs. In this scenario, features such as the digits-to-alphabet ratio are also relevant because most malicious algorithmically created domains have considerably more digits than alphabets. Aside from the bag-of-words features, statistical features help significantly in gaining a quick understanding of the path, query, and URL length.

If the domain name has any credibility in terms of being a meaningful, easy-to-pronounce, and random string, as proven in Algorithm 1, **Human-Engineered Features** perform well enough in this classification task. We considered the UK/US English dictionary to state the domain name as a meaningful, pronounceable or random string in the identification process. We also collect "n-gram" data for both legitimate and nonlegitimate advertising URLs. We generate the bag-of-words by extracting 2-gram and 3-gram tokens from the data mentioned above sources. This allows us to break each input URL into two or three token sequences and verify the presence of the target token in the bag. The sensitive words contained domains have a high chance of being malicious, and we created it as a feature. We also check whether the domain name is present in the list of suspected lists. Please see Table IV for a complete list of lexical feature groups as well as an overview of the features.

2) Web-scrapped Features: In this feature group, we would like to extract the web information of the URL's domain name and deal with the obfuscation problem. Some harmful URLs overlap lexical features with benign URLs. As a result, web scraping of URLs will offer us the required solution. URL-segmentation, deep-web features, host-based features, and content-based features are the four subgroups of our web-scrapped feature group. We want to identify ways to that spoof a domain name in **URL** segmentation. Whence, with Python, the domain name is sent as a query request in the Google search engine, and the first 60 results are collected for the process of hit counts. If the exact domain name exists, it is recorded as a count. This approach takes a little time, but it significantly influences the straightforward categorisation procedure. If similar name is found in netloc, it is an excellent chance to be a clean domain name. In Deep-Web Features, we create a list of 11 distinct types of typosquats of the searched domain name (see Table V) and examine all registered domain names among them. We also created a fuzzer for this step, which attempts to find typosquat domain names for each searched domain name. The phishing domains can be identified using above technique. We also computed the Lavenshtein distance and Shannon entropy with the most comparable query request results and saved it as a feature using the same method. The Lavenshtein distance between two words is the number of single-character modifications necessary to transform one term into another. In the Host-based Features subgroup, we included URL host-name attributes such as WHOIS information, IP address,

TABLE V Web-Scrapped Feature Group

Sr. No.	Feature Subgroup	Feature Name	Data Type	Feature Description
1		LevenshteinDistance	Float	To calculate Levenshtein distance
2		Entropy	Float	To calculate shannon entropy of the URL
3		Hyphenstring	String	To get hyphenated domain name of URL for typosquat
4	1	Homoglyph	String	To get homoglyph string for typosquat
5		Vowel	String	To get vowel swap string for typosquat
6		Bitsquatting	String	To get bitsquatting string for typosquat
7	Deep-Web Features	InsertionString	String	To get insertion string for typosquat
8		Omission	String	To get omission string for typosquat
9		Repeatition	String	To get repitition string for typosquat
10		Replacement	String	To get replaced string for typosquat
11		Subdomain	String	To get subdomain string for typosquat
12		Transposition	String	To get transposition string for typosquat
13		AdditionString	String	To get addition string for typosquat
14	URL Segmentation	GoogleSearchFeature	Integer	Array of top 60 results of URL querying the Google search engine
15		IPAddress	Numeric	To get the IP address of the host name
16		ASNNumber	Numeric	To get the ASN number of the URL
17		ASNCountryCode	Numeric	To get ASN country code
18	Host-Based Features	ASN_CIDR	Numeric	To get the CIDR number of the host name
19	nost-based reatures	ASNPostalCode	Numeric	To get ASN postal code
20		ASNCreationDate	Numeric	To get the creation date of the domain name
21		ASNUpdationDate	Numeric	To get the updation date of the domain name
22		DomainAgeInDays	Numeric	The duration of a domain's registration
23		ImgCount	Integer	To count the images in the webpage
24		TotalLinks	Integer	To count links in the webpage
25		NumParameters	Integer	Number of parameters of the URL
26		NumFragments	Integer	Number of fragments of the URL
27		BodyTagCount	Integer	Counting the body tag in webpage's html source code
28		MetaTagCount	Integer	Counting the meta tag in webpage's html source code
29		DivTagCount	Integer	Counting the div tag in webpage's html source code
30		FakeLinkInStatusBar	Binary	Check whether display of fake URL JS command on MouseOver
31	Content-Based Features	RightClickDisabled	Binary	Check the presence of command to disable right click
32	Content-Dascu Features	PopUpWindow	Binary	Check the presence of command to start popup window
33		CheckMailto	Binary	Whether "mailto" is present in HTML source code
34		CheckFrametag	Binary	Whether frame or iframe used in HTML source code
35		TitleCheck	Binary	In HTML source codes, see whether title tag is empty
36		SourceEvalCount	Integer	Count of eval () functions in HTML source code
37		SourceEscapeCount	Integer	Count of escape () functions in HTML source code
38		SourceExecCount	Integer	Count of exec () functions in HTML source code
39		SourceSearchCount	Integer	Number of search() functions HTML source code
40		ImageOnlyInForm	Binary	Check whether only image are present in HTML source code

location details, and country code. These include registration details, domain age, country code, location, and registrant company. As these attributes have identity-related qualities, they are recorded in numerical vectors with unique identities. For malicious URLs, the time-to-live from domain registration is nearly instantaneous. Many of them employed botnets for hosting for themselves on machines spread across various countries. As a result, host-based characteristics play an essential role in detecting malicious URLs. When the web page is completely downloaded, **Content-Based Features** are gained. Our research extracts HTML document-level information of the web page i.e. total images, the total links, and different tags from the source code. If malicious URLs remain undetected by URL-based features, then these attributes will function effectively in detecting threats by analysing the web page.

B. Empirical Study

This section describes our suggested supervised URL classification and unsupervised clustering approaches for detecting fraudulent advertisement URLs. We intend to assess if a given URL is benign or malicious by making binary classification problem. Consider the following collection of *N* URLs:

 $(u_1, y_1), ..., (u_n, y_n)$. Here, n = 1, ...N specifies a URL, and URL label is denoted by y_h , with y = 0 denoting the benign URL and y = 1 denoting the malicious URL. The first step is to represent the features $u_n \to a_n$, where a_n is *n*-dimensional feature vector corresponding to the URL u_n . The problem can be expressed as a function $y_n = sign(L_f(a_n))$. We may reduce the overall number of errors in the classification process by minimising the loss function. We retrieved 89 features from each URL and processed them for the classification phase based on the previous section. A balanced dataset of both legitimate and non-legitimate URLs is used to detect the fraudulent URL. We used 1000 URLs from each of our six balanced merged datasets to train our four classifiers with appropriate parameters. Depending on the simulation task, we used a split size of around 0.7 for training and 0.3 for testing. These 89 features will be used by classifiers to differentiate between clean and malicious URLs. In contrast to prior research that only considered a restricted element of the feature categories, we created a unique set of these highly influential feature categories and attempted to combine a good combination. For supervised machine learning methods, we used Random Forest, Gradient Boost, AdaBoost, and XGBoost

approaches. For each of our datasets, we examined the relative performance of all models. Then, to study the accuracy behaviour, we trained our models on mismatched datasets, training the complete one dataset and evaluating it on the other five. This procedure is carried out on all datasets with all model selections. We continued our research by testing our models on unlabeled datasets. We took all of the necessary criteria for the categorisation stage, as discussed in the previous section.

The process of grouping data points such similar data points are placed in same group and dissimilar from other data points in different groups is known as clustering. We employed the K-Means clustering method in this unsupervised learning strategy to better visualise malicious and benign data. The method will classify the objects into k groups of similarity, with an optimal value of k equal to 2 expected for exact results. The euclidean distance will be used as a measurement to calculate that similarity. The Elbow approach is used to do this assignment. We cycle through the k values from 1 to 9 to calculate the distortion for each k value in the defined range. To get the optimal number of clusters, we must determine the value of k at the elbow or the point where the distortion begins to drop linearly.

C. ZOO - Adversarial Attack

This section will investigate our ensembles' vulnerability to adversarial attack. Unlike white-box attack approaches, which need the target network to be differentiable, in black-box ZOO attack the gradients are estimated uning zeroth order stochastic coordinate descent of the targeted network. Here, for this reason, we will select a loss function that is only dependent on the output of the targeted network in order to compute the gradient by using the finite difference method. We will use zeroth order optimization to solve the optimization problem. Here, for the input vector a, the loss function L_f can be defined for output O_f as

$$L_f(a,b) = \max\{\max_{j \neq b} \log[O_f(a)]_j - \log[O_f(a)]_b, -\rho\}, \ (1)$$

where $\rho \geq 0$ and $\log a \rightarrow -\infty$ whenever $a \rightarrow 0$. Because the log function is a strictly monotonic function, max = 0 follows. As a result, a has the greatest confidence score for targeted class label b. Strictly monotonic functions are those function which for x > y satisfy f(x) > f(y). Here, the dominant influence is decreased by the log operator and maintain the confidence order due to monotonicity. For untargeted attacks, if a is classified as any different from original label b_0 , then adversarial attack will be considered successful. For untargeted attack, the most probable pridicted class after eliminating b is

$$L_f(x) = \max\{\log[O_f(a)]_{b_0} - \max_{i \neq b_0} \log[O_f(a)]_j, -\rho\}, \quad (2)$$

where original class label for a is denoted by b_0 , and the most probable predicted class is represented by $\max_{j\neq b_0} \log[O_f(a)]_j$ other than b_0 . The attack employs the optimization technique for the general L_f . If a function's symmetric derivative exists at point a, it is symmetrically differentiable at that point. Therefore, the symmetric difference quotient is:

$$\hat{g}_{j} := \frac{\partial L_{f}(a)}{\partial a_{j}} \approx \frac{L_{f}(a + ke_{j}) - L_{f}(a - ke_{j})}{2k}, \quad (3)$$

for gradient estimation. Here, we use k as a very small constant and standard basis vector is denoted by e_i where only the jth component have value 1 and all other components equal to 0. Although numerical precision is important, predicting the gradient precisely is typically not required for efficient adversarial attacks. In the coordinate descent approach, one variable is chosen at random at each iteration and changed by minimising the objective function along that coordinate. We can obtain the estimated optimum delta by estimating the gradient and Hessian for a_i . Here, Hessian estimate is

$$\hat{h_j} := \frac{\partial^2 L_f(a)}{\partial^2 a_{jj}^2} \approx \frac{L_f(a + ke_j) - 2L_f(a) + L_f(a - ke_j)}{k^2},$$
(4)

The stochastic coordinate descent method in Algorithm 2 and the ADAM optimizer in Algorithm 3 increased the speed of the ZOO attack [43]. The ZOO attack is more dependable to utilise than frequently used gradient-based techniques in this context due to its computational efficiency approximation and ease of implementation with only minor modifications.

Algorithm 2: SCD - Stochastic Coordinate Descent

Initialise $l \leftarrow 0$;

WHILE $l \leq K$ DO

Choose j(l) out of $\{1, ..., m\}$ with same probability Evaluate and update η^*

 $\underset{j}{arg\,\min_{\eta}L_{f}\left(a+\eta e_{j}\right)}$ Updating $a_{j}\leftarrow a_{j}+\eta^{*}$

 $l \leftarrow l + 1$

END WHILE

Algorithm 3: Coordinate-wise ADAM Zeroth Order

Requirement: Set step size h, ADAM hyper-parameters $\alpha_1 = 0.9, \ \alpha_2 = 0.99, \ \epsilon = 10^{-8}, \ \text{and set ADAM states}$ $N, \tau \in \mathbb{R}^{\wp}$

Initialise $N \leftarrow 0$, $\tau \leftarrow 0$, $U \leftarrow 0$

WHILE diverges DO

Choose j(l) out of $\{1, ..., m\}$ with same probability

Evaluate $U_i \leftarrow U_i + 1$

Approximate g_i by using equation (3)

Evaluate $N_j \leftarrow \alpha_1 N_j + (1 - \alpha_1) g_j$

Evaluate $\tau_j \leftarrow \alpha_2 \tau_j + (1 - \alpha_2) g_j^2$

Evaluate $\hat{N}_{i} = N_{i}/(1 - \alpha_{1}^{U_{i}}), \hat{\tau} = \tau_{i}/(1 - \alpha_{2}^{U_{i}})$

$$\eta^* = -h \frac{\hat{N}_j}{\sqrt{\hat{\tau}_i + \epsilon}}$$

Update $a_i \leftarrow a_i + \eta^*$

END WHILE

V. RESULTS AND DISCUSSION

Here, we will sum up and discuss our study results by inspecting the effectiveness of several classifiers, clustering techniques, and the effects of adversarial attacks on ensembles. To assess our suggested system, we run a set of rigorous tests on a desktop computer. The system's setup is Intel(R) Core(TM) Intel Core i5-4300M 2.6GHz, Ubuntu 20.04 LTS with 4GB RAM, and Python version 3.8.10.

TABLE VI MATCH CASE DETECTION RESULT

Random Forest									
Dataset	Folds	Accuracy	Precision	FPR	FNR				
D-44 1	5	98.72	98.98	0.0104	0.0152				
Dataset 1	10	99.13	99.42	0.0059	0.0115				
D-44 2	5	98.78	98.77	0.0120	0.0123				
Dataset 2	10	99.07	99.37	0.0062	0.0125				
D-44 2	5	99.06	99.37	0.0063	0.0125				
Dataset 3	10	99.13	98.86	0.0116	0.0057				
Dataset 4	5	98.42	98.95	0.0107	0.0208				
Dataset 4	10	98.91	98.93	0.0112	0.0107				
Dataset 5	5	98.84	98.86	0.0115	0.0114				
Dataset 3	10	99.18	98.92	0.0112	0.0057				
Dataset 6	5	98.58	98.27	0.0175	0.0116				
Dataset 6	10	99.07	99.38	0.0061	0.0123				
	•	AdaB	oost						
Dataset 1	5	98.98	98.97	0.0101	0.0103				
Dataset 1	10	99.23	98.97	0.0101	0.0052				
Dataset 2	5	99.10	99.54	0.0048	0.0136				
Dataset 2	10	99.45	99.47	0.0052	0.0053				
Dataset 3	5	99.13	98.58	0.0149	0.0048				
Dataset 3	10	99.56	99.53	0.0048	0.0047				
Dataset 4	5	99.01	99.53	0.0050	0.0140				
Dataset 4	10	99.27	99.52	0.0050	0.0095				
Dataset 5	5	99.04	99.53	0.0099	0.0094				
Dataset 3	10	99.35	99.07	0.0091	0.0047				
Dataset 6	5	99.14	99.53	0.0047	0.0141				
Dataset 0	10	99.46	99.48	0.0051	0.0052				
		Gradien							
Dataset 1	5	99.11	99.12	0.0091	0.0088				
	10	99.31	99.55	0.0045	0.0090				
Dataset 2	5	99.14	99.56	0.0044	0.0131				
	10	99.46	99.38	0.0041	0.0085				
Dataset 3	5	99.19	99.57	0.0042	0.0127				
	10	99.60	99.60	0.0041	0.0081				
Dataset 4	5	99.04	99.14	0.0062	0.0124				
	10	99.39	99.59	0.0043	0.0043				
Dataset 5	5	99.11	99.55	0.0045	0.0131				
	10	99.38	99.15	0.0083	0.0043				
Dataset 6	5	99.29	99.53	0.0047	0.0093				
	10	99.54	99.55	0.0047	0.0045				
	-	XGB		0.0072	0.0075				
Dataset 1	5	99.26 99.59	99.25 99.59	0.0073	0.0075				
	5	99.39	99.39	0.0041	0.0041				
Dataset 2	10	99.24	99.23	0.0077	0.0073				
	5	99.47	99.03	0.0036	0.0075				
Dataset 3	10	99.27	99.23	0.0071	0.0073				
	5	99.03	99.03	0.0037	0.0037				
Dataset 4	10	99.13	99.14	0.0083	0.0086				
	5	99.38	99.38	0.0041	0.0042				
Dataset 5	10	99.33	99.13	0.0089	0.0043				
	5	99.42	99.24	0.0078	0.0038				
Dataset 6	10	99.45	99.25	0.0076	0.0038				
	10	99.03	99.03	0.0057	0.005/				

A. Experimental Results

We pick 1000 URLs from each balanced dataset with an equal number of malicious and benign advertisement URLs

for the experiment. The experiment is performed on each of our four classifiers with 5 and 10 folds. We also consider the runtime complexity, which grows as the number of folds increases. It is a problem throughout the training stage but not during testing. Each of the six datasets took roughly 150 minutes to process. However, the model's remarkable accuracy is worth it in the end. We used Python's Sciket-learn package and the GridSearchCV library function to cycle over predefined hyperparameters, selecting 1, 100, 200, 500, 1000, and 1500 n estimators to fit on our training set. We got more precise results as the number of trees increased. The sampled datasets were examined using the Random Forest model, and we noticed a gain in accuracy and precision as we moved to AdaBoost, Gradient Boost, and XGBoost, as well as a drop in FPR and FNR. We discovered that the ten folds of the XGBoost classifier had the best detection accuracy. We created the evaluation matrix using the following formulas.

FPR: The false positive rate is calculated as the proportion of malicious data that is mistakenly recognised as benign.

FNR: The false negative rate is the proportion of data that is wrongly classified as non-malicious but is, in fact, malicious.

$$FPR = \frac{FP}{FP + TN}, \quad FNR = \frac{FN}{TP + FN}$$

Accuracy: Accuracy is calculated as the ratio of accurately predicted examples to total examples.

Precision: The percentage of malicious data that was successfully categorised out of all malicious URLs labelled by the classifier.

$$Precision\& = \frac{TP}{TP + FP}, \quad Accuracy\& = \frac{TP + TN}{TP + TN + FP + FN}$$

1) **Detection Results:** We have discussed the accuracy and precision of our ensembles by using the confusion matrix in this section with the discussed machine learning techniques.

Matched Case

In the matched scenario, the classifier is trained and tested on a single dataset. The results for all classifiers are shown in Table VI.

Mismatched Case

The classifier is trained on one full dataset and evaluated on the remaining five datasets in the mismatched case. Table VII shows the results tables for various classifiers for mismatched datasets.

2) Clustering Results: In this section of our research, we choose cluster formation to distinguish between two types of malicious and non-malicious URLs. We employ the K-Means clustering technique for visual comprehension for this purpose. We determine the number of clusters necessary to cluster the dataset using the elbow technique of K-Means. We discover a gap between the two groups and make a clear distinction. This creation is seen in Fig. ??, where red represents benign and blue represents malicious.

TABLE VII
MISMATCH CASE DETECTION RESULT

Part		Random Forest							AdaBoo	ost		
Dataset Dataset Dataset September Oscillation	Trained	Tested	Accuracy	Precision	FPR	FNR	Trained	Tested	Accuracy	Precision	FPR	FNR
Datasect Datasect Datasect 98.81 99.99 0.00090 0.00090 0.00090 0.00090 0.00080		Dataset 2	98.69	98.77	0.0121	0.0143		Dataset 2	98.70	98.89	0.0131	0.0129
Dataset Parameter Parame		Dataset 3	98.89	99.18	0.0083	0.0143		Dataset 3	98.93	98.81	0.0140	0.0079
Dataset Part Part	Dataset 1	Dataset 4	98.81	99.09	0.0091	0.0150	Dataset 1	Dataset 4	98.84	98.81	0.0140	0.0096
Dataset 1 98.78 98.95 0.0113 0.0141		Dataset 5	98.92	98.69	0.0129	0.0093		Dataset 5	98.99	98.83	0.0142	0.0068
Dataset 1 98.70 98.88 0.0112 0.0150 Dataset 2 98.80 99.12 0.0103 0.0105 0.01051 0.0154 0.0157 0.0157 0.0157 0.0157 0.0157 0.0157 0.0157 0.0157 0.0158		Dataset 6	98.65	98.79	0.0119	0.0154		Dataset 6	98.77	98.89	0.0131	0.0117
Dataset 2 Dataset 4		Dataset 1	98.78	98.95	0.0103	0.0141		Dataset 1	98.86	99.06	0.0111	0.0117
Dataset 6 98.56 98.81 0.0158 0.0104		Dataset 3	98.70	98.88	0.0111	0.0150		Dataset 3	98.92	99.12	0.0103	0.0105
Dataset 6 98.68 98.41 0.0157 0.0104 Dataset 1 98.88 99.20 0.0027 0.0121	Dataset 2	Dataset 4	98.70	98.75	0.0123	0.0137	Dataset 2	Dataset 4	98.96	99.29	0.0084	0.0122
Dataset 1 98.83 98.59 0.0138 0.0194 Dataset 2 98.656 98.81 0.0118 0.0147 Dataset 4 98.39 98.04 0.0104 0.0106 Dataset 5 98.61 98.37 0.0161 0.0177 Dataset 6 98.77 98.59 0.0104 0.0106 Dataset 6 98.77 98.59 0.0103 0.0181 Dataset 6 98.77 98.59 0.0163 0.0181 Dataset 1 98.55 98.59 99.11 0.0009 0.0181 Dataset 1 98.65 0.0164 0.0106 Dataset 1 98.65 0.0164 0.0106 Dataset 1 98.67 99.91 0.0082 0.0177 Dataset 6 98.77 98.89 0.0139 0.0105 Dataset 1 98.67 98.60 0.0131 Dataset 1 98.67 98.60 0.0131 Dataset 1 98.67 98.60 0.0131 Dataset 1 98.67 98.60 0.0134 Dataset 1 98.67 98.60 0.0134 Dataset 1 98.67 98.60 0.0134 Dataset 1 98.67 98.81 0.0104 Dataset 1 0.0184 Dataset 2 98.31 0.0164 0.0106 Dataset 6 98.71 98.81 0.0164 0.0106 Dataset 6 98.71 98.81 0.0164 0.0106 Dataset 6 98.72 0.0184 0.0184 Dataset 5 0.0184 0.0184 Dataset 6 0.0184 0.0184 0.0184 Dataset 6 0.0184 0.0184 0.0184 Dataset 6 0.0184 0.01		Dataset 5	98.56	98.16	0.0181	0.0106		Dataset 5	98.87	99.25	0.0088	0.0135
Dataset 1 Pataset 2 98.66 98.81 0.0118 0.0128 Dataset 5 98.61 98.37 90.016 0.0115 Dataset 6 98.77 98.59 0.0104 0.0106 Dataset 1 98.57 98.58 0.0104 0.0134 Dataset 1 98.57 98.58 0.0104 0.0134 Dataset 3 98.59 98.58 0.0104 0.0134 Dataset 6 99.71 99.85 0.0104 0.0134 Dataset 6 99.71 99.85 0.0104 0.0134 Dataset 7 98.77 98.50 0.0103 0.0161 Dataset 8 99.71 99.86 0.0103 0.0161 Dataset 9 98.77 98.56 0.0124 0.0188 Dataset 1 98.67 98.58 0.0124 0.0188 Dataset 1 98.67 98.50 0.0144 0.0184 Dataset 6 99.73 98.55 0.0104 0.0104 Dataset 6 98.73 98.55 0.0104 0.0104 Dataset 6 98.73 98.35 0.0029 0.0105 Dataset 1 98.87 98.50 0.0029 0.0105 Dataset 4 98.67 98.55 0.0104 0.0104 Dataset 5 98.71 0.088 0.0029 0.0105 Dataset 6 98.73 98.55 0.0129 0.0105 Dataset 6 98.73 98.55 0.0129 0.0105 Dataset 7 98.60 0.0105 0.0105 Dataset 8 98.78 98.78 0.0029 0.0105 Dataset 9 98.88 0.0029 0.0105 Dataset 1 98.87 98.50 0.0224 0.0085 Dataset 4 98.60 0.0137 0.018 Dataset 5 98.78 98.85 0.0029 0.0105 Dataset 6 98.78 98.85 0.0029 0.0105 Dataset 6 99.88 0.0009 0.0105 Dataset 6 99.88 0.0009 0.0105 Dataset 7 98.89 0.0009 0.0008 Dataset 8 Palaset 9 0.0008 0.0008 Dataset 9 98.88 0.0009 0.0008 Dataset 1 98.87 98.87 0.0010 0.0012 Dataset 1 98.87 98.87 0.0010 0.0008 Dataset 2 98.89 98.89 0.0009 0.0008 Dataset 3 98.89 98.89 0.0009 0.0008 Dataset 4 98.87 98.87 0		Dataset 6	98.68	98.41	0.0157	0.0104		Dataset 6	98.76	98.92	0.0127	0.0121
Dataset 4 98.39 98.04 0.0194 0.0128 Dataset 5 98.79 0.0103 0.0181 Dataset 6 98.77 98.59 0.0104 0.0106 Dataset 6 98.77 98.59 0.0103 0.0181 Dataset 1 98.55 98.58 0.0139 0.0104 0.0106 Dataset 2 98.43 98.58 0.0139 0.0143 Dataset 1 98.65 0.0141 0.0164 Dataset 5 98.71 98.98 0.0109 0.0160 Dataset 5 98.70 99.19 0.0050 0.0181 Dataset 1 98.67 98.50 0.0139 0.0079 0.0160 Dataset 5 98.70 99.31 0.0070 0.0211 Dataset 1 98.67 98.50 0.0139 0.0079 0.0160 Dataset 5 98.70 99.35 0.0140 0.0181 Dataset 1 98.67 98.50 0.0137 0.0128 Dataset 5 98.70 99.37 0.0064 0.0174 Dataset 2 98.87 98.50 0.0140 0.0181 0.0181 Dataset 6 98.04 99.21 0.0078 0.0114 Dataset 3 98.49 98.13 0.0164 0.0190 0.0181 Dataset 6 98.71 98.98 0.0164 0.0090 0.0181 Dataset 6 98.73 98.35 0.0164 0.0090 0.0182 Dataset 6 98.73 98.35 0.0194 0.0095 0.0195 0.0184 0.0181 0.0182 0.0184 0.0181 0.0184 0.018		Dataset 1	98.83	98.59	0.0138	0.0094		Dataset 1	98.88	99.20	0.0082	0.0141
Dataset 5 98.61 98.37 0.0161 0.0107		Dataset 2	98.66	98.81	0.0118	0.0147		Dataset 2	98.68	99.00	0.0103	0.0161
Dataset 98.77 98.59 0.0140 0.0106 Dataset 98.95 98.71 0.0131 0.0081	Dataset 3	Dataset 4	98.39	98.04	0.0194	0.0128	Dataset 3	Dataset 4	98.59	98.99	0.0103	0.0181
Dataset 1 98.53 98.64 0.0166 0.0131 Dataset 2 98.84 99.11 0.0090 0.018 Dataset 3 98.59 98.58 0.0174 0.0143 Dataset 3 98.59 98.58 0.0139 0.0164 Dataset 3 98.71 98.69 99.31 0.0065 0.0141 Dataset 6 99.04 98.84 0.0113 0.0079 Dataset 6 99.04 98.84 0.0113 0.0079 Dataset 6 99.04 98.85 0.0139 0.0164 0.0184 Dataset 1 98.67 98.60 0.0137 0.0085 0.0141 Dataset 1 98.67 98.60 0.0137 0.0085 0.0141 Dataset 5 98.60 99.31 0.0065 0.0141 0.0181 Dataset 5 98.60 99.37 0.0064 0.0174 0.0181 Dataset 5 98.60 0.0182 0.0183 Dataset 1 98.60 99.37 0.0064 0.0181 Dataset 6 98.60 0.0182 0.0183 Dataset 1 98.60 0.0182 0.0183 Dataset 1 98.60 0.0183 0.0184 0.0181 Dataset 6 98.79 98.60 0.0123 0.0184 0.0181 Dataset 6 98.79 98.79 0.0123 0.0184 0.0181 Dataset 6 98.60 0.0182 0.0075 Dataset 6 99.00 0.0076 Data		Dataset 5	98.61	98.37	0.0161	0.0117		Dataset 5	98.70	99.19	0.0082	0.0177
Dataset Dataset 2 98.45 98.55 0.0174 0.0143 Dataset 4 Dataset 5 98.70 99.85 0.0164 0.0065 0.0141 Dataset 5 98.71 98.98 0.0099 0.0160 0.0		Dataset 6	98.77	98.59	0.0140			Dataset 6	98.95	98.71	0.0131	0.0081
Dataset Dataset 2 98.45 98.55 0.0174 0.0143 Dataset 4 Dataset 5 98.70 99.85 0.0164 0.0065 0.0141 Dataset 5 98.71 98.98 0.0099 0.0160 0.0		Dataset 1	98.53	98.64	0.0166	0.0131		Dataset 1	98.64	99.11	0.0090	0.018
Dataset 5 98.71 98.98 0.0099 0.0160 Dataset 6 99.04 99.23 0.0064 0.0174 Dataset 1 98.67 98.66 0.0137 0.0128 Dataset 2 98.70 98.56 0.0137 0.0128 Dataset 3 98.49 98.13 0.0184 0.0118 Dataset 4 98.63 98.27 0.0170 0.0104 Dataset 4 98.63 98.27 0.0170 0.0104 Dataset 5 98.89 98.33 0.0164 0.0099 Dataset 1 98.38 98.05 0.0229 0.0105 Dataset 1 98.38 98.05 0.0229 0.0105 Dataset 5 98.81 98.72 0.029 0.0125 Dataset 5 98.81 98.72 0.029 0.0125 Dataset 6 98.81 98.72 0.029 0.0125 Dataset 7 98.16 98.39 0.0190 0.0179 Dataset 8 Palaset 9 98.81 0.0184 0.0181 Dataset 9 0.0184 0.0181 Dataset 1 98.38 98.05 0.0229 0.0195 Dataset 1 98.38 98.05 0.0229 0.0125 Dataset 2 98.81 98.79 98.79 0.0193 0.0094 Dataset 5 98.16 98.39 0.0190 0.0179 Dataset 6 98.86 98.39 0.0164 0.0091 Dataset 7 98.16 98.39 0.0190 0.0179 Dataset 8 Precision FPR FNR Dataset 9 Precision FPR FNR Dataset 1 98.95 98.88 0.0122 0.0089 Dataset 1 98.95 98.87 0.0100 0.0123 Dataset 2 98.81 98.91 0.98.87 0.0100 0.0080 Dataset 3 99.15 0.088 0.0099 0.0076 Dataset 4 99.87 98.87 0.0100 0.0080 Dataset 5 98.91 98.87 0.0100 0.0080 Dataset 6 98.91 98.87 0.0100 0.0080 Dataset 6 98.91 98.87 0.0100 0.0080 Dataset 7 99.91 99.91 0.0090 0.0076 Dataset 8 98.91 98.87 0.0100 0.0080 Dataset 9 98.91 98.87 0.0100 0.0080 Dataset 1 98.97 98.97 0.0100 0.0080 Dataset 4 99.98 99.98 0.0090 0.0076 Dataset 5 99.99 99.91 0.0090 0.0076 Dataset 6 99.91 98.87 0.0100 0.0080 Dataset 6 99.91 98.89 99.91 0.0090 0.0076 Dataset 6 99.91 98.89 99.91 0.0090 0.0076 Dataset 6 99.91 98.95 0.0083 0.0090 0.0076 Dataset 6 99.91		Dataset 2	98.43	98.58	0.0174			Dataset 2	98.59	99.31	0.0070	0.0211
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Dataset 2 98.70 98.56 0.0142 0.0118 Dataset 3 98.49 98.13 0.0184 0.0118 Dataset 4 98.63 98.27 0.0170 0.0104 Dataset 5 98.73 98.35 0.0164 0.0090 Dataset 6 98.73 98.35 0.0164 0.0090 Dataset 1 98.83 98.05 0.0229 0.0105 Dataset 2 98.34 98.22 0.0209 0.0129 Dataset 3 98.76 98.55 0.0170 0.0121 Dataset 4 98.07 98.55 0.0170 0.0119 Dataset 5 98.16 98.39 0.0190 0.0179 Dataset 6 0.0000 Dataset 7 0.0000 Dataset 8 0.0000 Dataset 9 0.0000 Dataset 9 0.0000 Dataset 1 98.95 98.80 0.0129 Dataset 1 98.97 98.87 0.0100 Dataset 1 98.97 98.57 0.0100 Dataset 1 98.97 98.57 0.0140 0.0000 Dataset 1 98.97 98.57 0.0140 0.0000 Dataset 5 98.10 98.87 0.0100 0.0000 Dataset 6 98.87 98.87 0.0110 0.0000 Dataset 7 98.80 99.15 0.0102 0.0000 Dataset 8 98.91 98.87 0.0100 0.0000 Dataset 9 0.0000 0.0000 Dataset 1 98.97 98.59 0.0138 0.0006 Dataset 5 98.91 98.87 0.0100 0.0000 Dataset 6 98.96 98.97 0.0103 0.0000 Dataset 7 98.91 98.87 0.0100 0.0000 Dataset 8 0.0000 0.0000 0.0000 Dataset 9 0.0000 0.0000 0.0000 Dataset 1 98.97 98.59 0.0138 0.0006 Dataset 5 98.91 98.87 0.0100 0.0000 Dataset 6 0.0000 0.0000 0.0000 Dataset 7 0.0000 0.0000 0.0000 Dataset 8 0.0000 0.0000 0.0000 Dataset 1 0.0000 0.0000 0.0000 Dataset 1 0.0000 0.0000 0.0000 Dataset 2 0.0000 0.0000 0.0000 Dataset 3 0.0000 0.0000 0.0000 0.0000 Dataset 6 0.0000 0.0000 0.0000 0.0000 Dataset 7 0.0000 0.0000 0.0000 0.0000 Dataset 8 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 Dataset 6 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.00000 0.0000 0.00000 0.		Dataset 6	99.04	98.84	0.0113	0.0079		Dataset 6	98.04	99.23	0.0078	0.0114
Dataset 2 98.70 98.56 0.0142 0.0118 Dataset 3 98.49 98.13 0.0184 0.01018 Dataset 4 98.63 98.27 0.0170 0.0104 Dataset 6 98.73 98.33 0.0164 0.0090 Dataset 1 98.83 98.05 0.0229 0.0105 Dataset 2 98.34 98.22 0.0209 0.0129 Dataset 3 98.70 98.55 0.0170 0.0121 Dataset 4 98.77 98.55 0.0170 0.0121 Dataset 4 98.78 98.87 0.0100 Dataset 5 98.66 98.39 0.0194 Dataset 6 98.79 0.0293 0.0094 Dataset 7 98.55 0.0170 0.0121 Dataset 8 98.85 98.84 0.0118 Dataset 9 Dataset 1 98.87 98.87 0.0100 Dataset 1 98.87 98.87 0.0100 0.0080 Dataset 1 98.87 98.87 0.0118 0.0009 Dataset 1 98.87 98.87 0.0100 0.0080 Dataset 1 98.87 98.87 0.0100 0.0080 Dataset 3 98.91 98.87 0.0100 0.0080 Dataset 5 98.91 98.87 0.0100 0.0080 Dataset 6 98.89 99.87 0.0138 0.0066 Dataset 7 98.87 98.87 0.0100 0.0080 Dataset 8 0.0184 0.0185 0.0086 Dataset 9 0.0184 0.0185 0.0086 Dataset 1 98.87 98.87 0.0100 0.0080 Dataset 5 98.91 98.87 0.0103 0.0066 Dataset 6 98.89 99.87 0.0138 0.0066 Dataset 7 0.0084 0.0087 Dataset 8 0.0087 0.0087 Dataset 9 0.0088 0.0097 0.0088 Dataset 1 0.0088 0.0098 0.0098 Dataset 1 0.0088 0.0098 0.0098 Dataset 6 0.0088 0.0098 0.0098 Dataset 7 0.0088 0.0098 0.0098 Dataset 8 0.0088 0.0098 0.0098 Dataset 9 0.0088 0.0098 0.0098 0.0098 Dataset 1 0.0088 0.0098 0.0098 0.0098 0.0098 Dataset 1 0.0088 0.0098 0		Dataset 1	98.67	98.60	0.0137	0.0128		Dataset 1	98.70	98.44	0.0158	0.0103
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Trained Tested Accuracy Precision FPR FNR Trained Tested Accuracy Precision FNR FNR Trained Tested Accuracy Pack			98.16		0.0190				98.58	98.39		
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Dataset 6 98.87 98.97 0.0100 0.0123 Dataset 6 99.01 98.97 0.0100 0.0097	Trained	Dataset 2	Accuracy 98.58	Precision 98.84	0.0118	0.0129	Trained	Dataset 2	Accuracy 98.91	Precision 98.81	0.0116	0.0102
Dataset 1 98.95 98.89 0.0109 0.0101 Dataset 2 Dataset 3 99.11 98.87 0.0100 0.0080 Dataset 4 99.12 98.98 0.0099 0.0076 Dataset 5 98.12 98.12 0.0102 0.0117 Dataset 6 98.91 98.57 0.0139 0.0076 Dataset 1 98.97 98.59 0.0138 0.0066 Dataset 2 98.84 98.44 0.0151 0.0079 Dataset 5 98.94 98.85 0.0113 0.0100 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 6 99.15 98.57 0.0140 0.0086 Dataset 1 98.75 98.54 0.0143 0.0106 Dataset 2 98.79 98.57 0.0140 0.0103 Dataset 3 Dataset 2 98.99 98.57 0.0140 0.0103 Dataset 4 99.16 99.05 99.08 0.0090 0.0078 Dataset 5 98.91 98.44 0.0152 0.0065 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 1 98.89 99.15 0.0083 0.0139 Dataset 1 98.89 99.15 0.0083 0.0139 Dataset 1 98.89 99.15 0.0083 0.0139 Dataset 2 98.99 98.75 0.0122 0.0078 Dataset 3 Dataset 4 99.05 99.03 99.01 0.0095 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 1 98.89 99.15 0.0083 0.0139 Dataset 2 98.99 98.75 0.0122 0.0078 Dataset 4 99.05 99.01 0.0095 Dataset 5 98.96 98.95 0.0103 0.0106 Dataset 6 98.96 98.95 0.0103 0.0106 Dataset 7 98.96 98.95 0.0103 0.0106 Dataset 8 0.0104 0.0107 Dataset 9 0.0058 0.0059 Dataset 1 98.95 98.94 0.0104 0.0107 Dataset 6 98.96 98.95 0.0103 0.0106 Dataset 1 98.75 98.26 0.0170 0.0078 Dataset 1 98.75 98.86 0.0103 0.0106 Dataset 2 98.89 98.85 98.66 0.0150 0.0065 Dataset 4 98.95 98.94 0.0103 0.0106 Dataset 4 98.95 98.94 0.0103 0.0106 Dataset 5 98.96 98.95 0.0103 0.0106 Dataset 6 99.03 98.87 0.0103 0.00078 Dataset 7 98.96 98.95 0.0103 0.0106 Dataset 8 0.0065 0.0065 Dataset 9 0.0065 0.0065 Dataset 4 0.0065 0.0065 Dataset 4 0.006		Dataset 2 Dataset 3	98.58 98.96	98.84 98.75 98.80	0.0118 0.0127	0.0129 0.0081		Dataset 2 Dataset 3	98.91 99.10	98.81 99.14	0.0116 0.0084	0.0102 0.0096
Dataset 2 Dataset 3 99.11 98.87 0.0100 0.0080 Dataset 4 99.12 98.98 0.0099 0.0076 Dataset 5 98.12 98.12 0.0102 0.0117 Dataset 6 98.91 98.57 0.0139 0.0076 Dataset 1 98.97 98.59 0.0138 0.0066 Dataset 2 98.84 98.44 0.0151 0.0079 Dataset 5 99.91 98.57 0.0140 0.0086 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 6 99.15 98.77 98.59 0.0113 0.0100 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 1 98.97 98.57 0.0140 0.0086 Dataset 2 98.89 99.85 0.0113 0.0100 Dataset 5 98.97 98.57 0.0140 0.0103 Dataset 5 98.97 98.57 0.0140 0.0103 Dataset 5 98.97 98.57 0.0140 0.0103 Dataset 5 99.90 99.15 0.0083 Dataset 5 99.90 99.01 0.0088 0.0069 Dataset 6 99.16 99.89 0.0109 0.0058 Dataset 5 99.90 99.01 0.0088 0.0069 Dataset 6 99.16 99.89 0.0108 0.0087 Dataset 6 99.16 99.89 0.0103 0.00100 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 1 98.89 99.15 0.0083 0.0110 Dataset 6 99.16 98.89 0.0103 0.0078 Dataset 6 99.89 99.875 0.0122 0.0078 Dataset 6 99.89 98.95 0.0103 0.0106 Dataset 6 99.03 99.01 0.0088 0.0069 Dataset 7 98.79 98.79 0.018 0.0065 Dataset 8 Dataset 9 0.0065 0.0065 Dataset 9 0.0065 0.0065 Dataset 1 98.89 99.15 0.0083 0.0110 Dataset 4 98.95 98.94 0.0104 0.0107 Dataset 5 0.0083 0.0106 0.0065 Dataset 6 99.03 0.0090 0.0090 Dataset 7 98.90 99.15 0.0083 0.0110 Dataset 8 0.0065 0.0065 0.0065 Dataset 9 0.0065 0.0065 Dataset 1 98.90 98.90 0.0090 0.0090 Dataset 1 98.90 98.90 0.0090 0.0090 Dataset 2 98.90 98.95 0.0103 0.0106 Dataset 3 0.0065 0.0065 0.0065 Dataset 4 98.95 98.66 0.0131 0.0099 Dataset 6 99.00 0.0065 0.0065 Dataset 6 99.00 0.0065 0.0065 D		Dataset 2 Dataset 3 Dataset 4	98.58 98.96 98.95	98.84 98.75 98.80	0.0118 0.0127 0.0122	0.0129 0.0081 0.0089		Dataset 2 Dataset 3 Dataset 4	98.91 99.10 99.07	98.81 99.14 98.85	0.0116 0.0084 0.0112	0.0102 0.0096 0.0073
Dataset 2		Dataset 2 Dataset 3 Dataset 4 Dataset 5	98.58 98.96 98.95 99.05	98.84 98.75 98.80 99.22	0.0118 0.0127 0.0122 0.0081	0.0129 0.0081 0.0089 0.0109		Dataset 2 Dataset 3 Dataset 4 Dataset 5	98.91 99.10 99.07 99.13	98.81 99.14 98.85 98.93	0.0116 0.0084 0.0112 0.0104	0.0102 0.0096 0.0073 0.0069
Dataset 5 98.12 98.12 0.0102 0.0117 Dataset 6 98.91 98.57 0.0139 0.0076 Dataset 1 98.97 98.59 0.0138 0.0066 Dataset 2 98.84 98.44 0.0151 0.0079 Dataset 3 Dataset 4 98.87 98.57 0.0140 0.0086 Dataset 5 99.08 99.08 99.08 0.0090 0.0114 Dataset 5 99.08 99.08 0.0090 0.0114 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 1 98.75 98.54 0.0143 0.0106 Dataset 2 98.79 98.57 0.0140 0.0103 Dataset 3 Dataset 4 98.97 98.97 0.0118 0.0087 Dataset 5 99.16 98.89 0.0109 0.0058 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 6 99.16 98.89 0.0102 0.0078 Dataset 6 98.96 98.95 0.0103 0.0106 Dataset 6 98.96 98.95 0.0103 0.0106 Dataset 6 98.96 98.95 0.0103 0.0106 Dataset 7 0.0182 0.0078 Dataset 8 0.0182 0.0078 Dataset 9 0.0182 0.0078 Dataset 1 98.95 98.94 0.0104 0.0107 Dataset 2 98.95 98.96 0.0103 0.0106 Dataset 3 99.04 99.15 0.0083 0.0110 Dataset 4 98.95 98.96 0.0103 0.0106 Dataset 5 0.0132 0.0078 Dataset 6 0.0131 0.0099 Dataset 7 0.0182 0.0078 Dataset 8 0.0103 0.0106 Dataset 9 0.0083 0.0110 Dataset 1 0.0083 0.0110 Dataset 2 0.0078 0.0083 0.0110 Dataset 3 0.0084 0.0084 0.0084 Dataset 4 0.0152 0.0078 Dataset 5 0.0163 0.0106 Dataset 6 0.0151 0.0087 Dataset 7 0.0123 0.0095 Dataset 8 0.0104 0.0107 Dataset 9 0.0085 0.0085 Dataset 1 0.0085 0.0085 Dataset 2 0.0084 0.0085 Dataset 3 0.0084 0.0085 Dataset 4 0.0152 0.0078 Dataset 4 0.0152 0.007		Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6	98.58 98.96 98.95 99.05 98.87	98.84 98.75 98.80 99.22 98.97	0.0118 0.0127 0.0122 0.0081 0.0100	0.0129 0.0081 0.0089 0.0109 0.0123		Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6	98.91 99.10 99.07 99.13 99.01	98.81 99.14 98.85 98.93 98.97	0.0116 0.0084 0.0112 0.0104 0.0100	0.0102 0.0096 0.0073 0.0069 0.0097
Dataset 6 98.91 98.57 0.0139 0.0076 Dataset 1 98.97 98.59 0.0138 0.0066 Dataset 2 98.84 98.44 0.0151 0.0079 Dataset 3 Dataset 4 98.87 98.57 0.0140 0.0086 Dataset 5 98.94 98.85 0.0113 0.0100 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 1 98.75 98.54 0.0143 0.0106 Dataset 2 98.79 98.57 0.0140 0.0103 Dataset 3 98.91 98.44 0.0152 0.0065 Dataset 5 99.01 98.65 0.0131 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 1 98.89 99.15 0.0083 0.0139 Dataset 2 98.99 98.75 0.0122 0.0078 Dataset 3 99.04 99.15 0.0083 0.0106 Dataset 4 98.95 99.04 99.15 0.0083 0.0106 Dataset 5 99.00 99.00 0.0058 Dataset 6 99.00 99.00 0.0058 Dataset 7 98.99 98.75 0.0122 0.0078 Dataset 8 98.96 98.95 98.96 0.0103 0.0106 Dataset 9 98.85 98.66 0.0131 0.0095 Dataset 1 98.85 98.66 0.0131 0.0095 Dataset 4 98.95 98.86 0.0103 0.0078 Dataset 5 98.96 98.95 98.86 0.0101 0.0078 Dataset 6 99.03 98.82 0.0116 0.0078 Dataset 7 98.86 98.96 0.0103 0.0006 Dataset 8 98.96 98.95 98.96 0.0103 0.0006 Dataset 9 98.85 98.66 0.0131 0.0095 Dataset 1 98.85 98.66 0.0131 0.0095 Dataset 4 98.95 98.86 0.0150 0.0065 Dataset 4 98.95 98.96 0.0103 0.0106 Dataset 4 98.95 98.66 0.0113 0.0095 Dataset 5 98.97 0.0120 0.0094 Dataset 6 98.96 98.95 98.66 0.0150 0.0065 Dataset 7 98.85 98.66 0.0150 0.0065 Dataset 8 98.96 98.95 98.66 0.0150 0.0065 Dataset 9 98.95 98.46 0.0150 0.0065 Dataset 4 98.95 98.74 0.0103 0.0106 Dataset 4 98.95 98.66 0.0150 0.0065 Dataset 4 98.95 98.94 0.0103 0.0106 Dataset 4 98.95 98.66 0.0150 0.0065 Dataset 4 98.95 98.94 0.0103 0.0106 Dataset 4 98.95 98.66 0.0150 0.0065 Dat		Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1	98.58 98.96 98.95 99.05 98.87 98.95	98.84 98.75 98.80 99.22 98.97 98.89	0.0118 0.0127 0.0122 0.0081 0.0100 0.0109	0.0129 0.0081 0.0089 0.0109 0.0123 0.0101		Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1	98.91 99.10 99.07 99.13 99.01 99.02	98.81 99.14 98.85 98.93 98.97 99.29	0.0116 0.0084 0.0112 0.0104 0.0100 0.0070	0.0102 0.0096 0.0073 0.0069 0.0097 0.0127
Dataset 1 98.97 98.59 0.0138 0.0066 Dataset 2 98.84 98.44 0.0151 0.0079 Dataset 3 Dataset 4 98.87 98.57 0.0140 0.0086 Dataset 5 98.94 98.85 0.0113 0.0100 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 1 98.75 98.54 0.0143 0.0106 Dataset 2 98.79 98.57 0.0140 0.0103 Dataset 3 98.91 98.44 0.0152 0.0065 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 1 98.89 99.15 0.0083 0.0110 Dataset 2 98.99 98.75 0.0122 0.0078 Dataset 3 99.04 99.15 0.0083 0.0110 Dataset 4 98.95 98.96 98.95 0.0103 0.0106 Dataset 5 98.96 98.95 0.0103 0.0106 Dataset 6 98.96 98.95 0.0103 0.0106 Dataset 6 98.86 98.96 0.0107 0.0078 Dataset 6 Dataset 3 98.64 98.44 0.0152 0.0078 Dataset 6 Dataset 3 98.64 98.44 0.0152 0.0078 Dataset 6 Dataset 3 98.64 98.44 0.0152 0.0107 Dataset 6 Dataset 3 98.66 0.0110 0.0078 Dataset 6 Dataset 3 98.64 98.44 0.0152 0.0078 Dataset 6 Dataset 3 98.64 98.44 0.0152 0.0121 Dataset 6 Dataset 4 98.95 98.66 0.0131 0.0095 Dataset 6 Dataset 7 98.85 98.66 0.0150 0.0065 Dataset 6 Dataset 7 98.85 98.94 0.0103 0.0065 Dataset 7 98.85 98.66 0.0131 0.0099 Dataset 8 Dataset 9 98.85 98.66 0.0150 0.0065 Dataset 9 0.0103 0.0065 Dataset 4 98.95 98.46 0.0150 0.0065 Dataset 4 98.95 98.94 0.0103 0.0065 Dataset 4 98.95 98.94 0.0103 0.0065 Dataset 6 Dataset 7 98.85 98.66 0.0131 0.0099 Dataset 6 Dataset 7 98.85 98.66 0.0131 0.0099 Dataset 6 Dataset	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3	98.58 98.96 98.95 99.05 98.87 98.95 99.11 99.12	98.84 98.75 98.80 99.22 98.97 98.89 98.87 98.98	0.0118 0.0127 0.0122 0.0081 0.0100 0.0109 0.0100	0.0129 0.0081 0.0089 0.0109 0.0123 0.0101 0.0080	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3	98.91 99.10 99.07 99.13 99.01 99.02 99.15	98.81 99.14 98.85 98.93 98.97 99.29 99.26	0.0116 0.0084 0.0112 0.0104 0.0100 0.0070 0.0072	0.0102 0.0096 0.0073 0.0069 0.0097 0.0127 0.0096 0.0076
Dataset 2 98.84 98.44 0.0151 0.0079 Dataset 4 98.87 98.57 0.0140 0.0086 Dataset 5 98.94 98.85 0.0113 0.0100 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 1 98.75 98.54 0.0143 0.0106 Dataset 2 98.97 98.57 0.0140 0.0103 Dataset 5 98.97 98.57 0.0140 0.0103 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 1 98.89 99.15 0.0083 0.0110 Dataset 1 98.89 99.15 0.0083 0.0109 Dataset 1 98.89 99.15 0.0083 0.0110 Dataset 2 98.99 98.75 0.0122 0.0078 Dataset 4 98.95 98.96 98.95 0.0103 0.0106 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 7 Dataset 8 0.0083 0.0110 Dataset 9 0.0083 0.0110 Dataset 1 98.95 98.94 0.0104 0.0107 Dataset 4 98.95 98.86 0.0170 0.0078 Dataset 6 0.0131 0.0095 Dataset 7 0.0123 0.0078 Dataset 8 0.0104 0.0107 Dataset 9 0.0104 0.0107 Dataset 9 0.0104 0.0107 Dataset 1 0.0083 0.0110 Dataset 2 0.0083 0.0110 Dataset 3 0.0084 0.0104 0.0107 Dataset 4 0.0103 0.0078 Dataset 5 0.0134 0.0095 Dataset 6 0.0131 0.0095 Dataset 7 0.0123 0.0078 Dataset 9 0.0104 0.0107 Dataset 1 0.0083 0.0110 Dataset 2 0.0083 0.0110 Dataset 3 0.0084 0.0104 0.0107 Dataset 4 0.0103 0.0106 Dataset 5 0.0134 0.0095 Dataset 6 0.0134 0.0095 Dataset 7 0.0123 0.0065 Dataset 8 0.0134 0.0105 Dataset 9 0.0134 0.0103 Dataset 4 0.0103 0.0106 Dataset 4 0.0103 0.0134 Dataset 4 0.0103 0.0134 Dataset 4 0.0103 0.0134 Dataset 4 0.0103 0.0106 Dataset 4 0.0103 0.0134 Dataset 4 0.0103 0.0106 Dataset 4 0.0103 0.0106 Dataset 4 0.0103 0.0106 Dataset 4 0.0103 0.0106 Dataset 5 0.0134 0.0103 Dataset 6 0.0134 0.0105 Dataset 6 0.0134 0.0105 Dataset 6 0.0134 0.0105 Dataset 7 0.0123 0	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3 Dataset 4 Dataset 5	98.58 98.96 98.95 99.05 98.87 98.95 99.11 99.12 98.12	98.84 98.75 98.80 99.22 98.97 98.89 98.87 98.98 98.12	0.0118 0.0127 0.0122 0.0081 0.0100 0.0109 0.0100 0.0099 0.0102	0.0129 0.0081 0.0089 0.0109 0.0123 0.0101 0.0080 0.0076	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3 Dataset 4	98.91 99.10 99.07 99.13 99.01 99.02 99.15 99.16 99.06	98.81 99.14 98.85 98.93 98.97 99.29 99.26 99.05 98.86	0.0116 0.0084 0.0112 0.0104 0.0100 0.0070 0.0072 0.0092	0.0102 0.0096 0.0073 0.0069 0.0097 0.0127 0.0096 0.0076
Dataset 3 Dataset 4 98.87 98.57 0.0140 0.0086 Dataset 5 98.94 98.85 0.0113 0.0100 Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 6 99.15 98.75 98.54 0.0143 0.0106 Dataset 1 98.75 98.57 0.0140 0.0103 Dataset 2 98.79 98.57 0.0140 0.0103 Dataset 5 99.02 99.15 0.0088 0.0069 Dataset 6 99.21 99.10 0.0088 0.0069 Dataset 6 99.21 99.10 0.0088 0.0069 Dataset 1 98.95 98.74 0.0123 0.0074 Dataset 1 98.95 98.65 0.0132 0.0074 Dataset 2 98.89 0.0118 0.0065 Dataset 5 99.01 98.65 0.0131 0.0065 Dataset 6 99.16 98.89 0.0109 0.0058 Dataset 6 99.20 99.38 0.0060 0.0102 Dataset 6 99.20 99.38 0.0060 0.0102 Dataset 6 99.90 99.90 0.0095 Dataset 6 99.90 0.0097 Dataset 6 99.90 0.0097 0.0096 Dataset 6 99.90 0.0097 0.0097 Dataset 6 0.0131 0.0097 Dataset 6 0.0131 0.0097 Dataset 6 0.0131 0.0097 Dataset 6 0.0131 0.0099 Dataset 6 0.0131 0.0099 Dataset 6 0.0131 0.0099 Dataset 6 0.0134 0.0095 0.0094 0.0094 0.0094 0.0094 0.0094 0.0094 0.0094 0.0094 0.0094 0.0095 0.0065 0.	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3 Dataset 4 Dataset 5	98.58 98.96 98.95 99.05 98.87 98.95 99.11 99.12 98.12 98.91	98.84 98.75 98.80 99.22 98.97 98.89 98.87 98.98 98.12 98.57	0.0118 0.0127 0.0122 0.0081 0.0100 0.0109 0.0100 0.0099 0.0102 0.0139	0.0129 0.0081 0.0089 0.0109 0.0123 0.0101 0.0080 0.0076	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3 Dataset 4 Dataset 5	98.91 99.10 99.07 99.13 99.01 99.02 99.15 99.16 99.06	98.81 99.14 98.85 98.93 98.97 99.29 99.26 99.05 98.86	0.0116 0.0084 0.0112 0.0104 0.0100 0.0070 0.0072 0.0092	0.0102 0.0096 0.0073 0.0069 0.0097 0.0127 0.0096 0.0076 0.0076
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Dataset 6 99.15 98.74 0.0123 0.0046 Dataset 6 99.21 99.10 0.0088 0.0069	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1	98.58 98.96 98.95 99.05 98.87 98.95 99.11 99.12 98.12 98.91 98.97 98.84	98.84 98.75 98.80 99.22 98.97 98.89 98.87 98.98 98.12 98.57 98.59 98.44	0.0118 0.0127 0.0122 0.0081 0.0100 0.0109 0.0100 0.0099 0.0102 0.0139 0.0138 0.0151	0.0129 0.0081 0.0089 0.0109 0.0123 0.0101 0.0080 0.0076 0.0117 0.0076 0.0066 0.0079	Dataset 1	Dataset 2 Dataset 3 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 3 Dataset 4 Dataset 5 Dataset 4 Dataset 5 Dataset 6 Dataset 1 Dataset 2	98.91 99.10 99.07 99.13 99.01 99.02 99.15 99.16 99.06 99.03 99.08 98.98	98.81 99.14 98.85 98.93 98.97 99.29 99.26 99.05 98.86 99.01 98.98 99.08	0.0116 0.0084 0.0112 0.0104 0.0100 0.0070 0.0072 0.0092 0.0092 0.0096 0.0100 0.0090	0.0102 0.0096 0.0073 0.0069 0.0097 0.0127 0.0096 0.0076 0.0076 0.0097 0.0083
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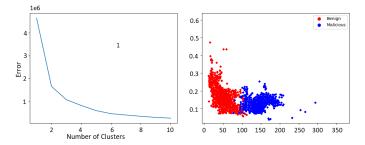


Fig. 3. Elbow method and K-Means result.

3) Adversarial Attack Results: Here, we conduct technical investigations on our model and investigate the impact of adversarial training on our models. We used the ZOO attack to evaluate the susceptibility of various models. We trained our model first and then used the ZOO attack in the testing phase. The result for the ZOO attack is shown in Table VIII.

TABLE VIII ZOO ATTACK RESULT

Dataset	Confidence	Attack Accuracy Rate						
Dataset	Connuence	Random Forest	AdaBoost	Gradient Boost	XGBoost			
Dataset 1	50	95.85	95.62	95.30	93.15			
Dataset 1	100	94.33	95.31	94.87	93.86			
Dataset 2	50	95.18	94.50	94.41	95.16			
Dataset 2	100	93.80	94.33	94.66	93.05			
Dataset 3	50	96.05	96.18	95.30	94.82			
Dataset 3	100	96.00	95.95	95.73	93.78			
Dataset 4	50	96.67	95.31	94.44	93.70			
Dataset 4	100	96.50	95.12	94.66	93.40			
Dataset 5	50	95.74	95.29	94.30	93.64			
Dataset 3	100	94.60	94.56	94.30	92.61			
Dataset 6	50	95.20	95.12	95.35	92.20			
Dataset 0	100	95.05	94.66	94.88	92.18			

B. Discussion

The combination of lexical and web-scrapped features we collected is a good foundation for our analysis. Various machine learning techniques used for categorization give us light and profound output. We found that the XGBoost classifier with a maximum depth of ten yields the best outcomes in the classification process. When compared to other classifiers, XGBoost has the highest accuracy and precision, followed by Gradient Boost, AdaBoost, and Random Forest. If the number of folds in the simulation work increases, the FPR and FNR drop. The model grows more sophisticated and overfits the data as the maximum depth of the tree is increased. The same thing occurs with the other classifiers. Our findings and recommended techniques improve the accuracy of prediction and detection. The accuracy we discovered is substantially greater than prior efforts, and deploying machine learning systems in the identification of rogue advertisement URLs is a good concept. The visual comprehension in the elbow method cluster formation recommends the appropriate categories of data and low overlaps of both classes. The results of the adversarial attack indicate a comparison of the ensemble's susceptibility. We discovered that better predictive models are

less vulnerable to adversarial examples. Due to a lack of attack tools to test their resilience, studying robustness training techniques for tree ensemble models has been challenging. Our method can serve as a benchmark tool for robustness evaluation, stimulating research in tree ensemble robustness. The research on lowering time complexity and developing appropriate defence strategies will benefit our studies.

VI. CONCLUSION AND FUTURE WORK

In this paper, we developed a framework for identifying fraudulent advertisement URLs using innovative feature extraction, and we created a detection system with the highest accuracy results. We also looked into the vulnerability of various ensembles for adversarial training. We investigated novel feature extraction using an unconventional combination of six feature classes, including various advanced features. Most of the existing approaches were based on only the traditional features set like a bag of words, which were insufficient to make the detection system sufficiently efficient. We focused on handling the unseen features to test the URL's maliciousness. Our classifiers optimised the accuracy, which we can see in the clustering visualisation. The machine learning approaches we used are ideal for the purpose.

Although the web-scrapped features extraction process was a little time-consuming due to a number of ample features, we would take it to minimise with more resources and tactics in the upcoming time. We will also deploy the state of the art adversarial examples and compare the vulnerability and defence approaches in our future work.

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