Article

Social Sentiment Sensor in Twitter for Predicting Cyber-Attacks Using ℓ_1 Regularization

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Abstract: In recent years, online social media information has been subject of study in several data science fields due to its impact on users as a communication and expression channel. Data gathered from online platforms such as Twitter has the potential to facilitate research over social phenomena based on sentiment analysis, which usually employs Natural Language Processing and Machine Learning techniques to interpret sentimental tendencies related to users opinions and make predictions about real events. Cyber attacks are not isolated from opinion subjectivity on online social networks. Various security attacks are performed by hacker activists motivated by reactions from polemic social events. In this paper, a methodology for tracking social data that can trigger cyber attacks is developed. Our main contribution lies in the monthly prediction of tweets with content related to security attacks and the incidents detected based on ℓ_1 regularization.

Keywords: security; social sentiment sensor; hackers; social media; statistics; L1 regression; twitter; cyber attacks

1. Introduction

Online Social Networks (OSN) are platforms designed as communication channels for information exchange in real-time. Web services like Twitter [1] are expected to generate approximately 1 billon of user-generated content per month around the world. Twitter statistics [2] report the generation of 313 million posts monthly, better known as tweets, over different countries, which is advantageous for data gathering mechanisms because large volumes of data can be collected over different time intervals.

Different topics in Twitter reflect polarized opinions from celebrities, corporations and regular users about daily life aspects [3], some of them with well defined geographic embedded data (assisted gps coordinates). Streams of tweets generate valuable information which can be modeled as a *social sentiment sensor* for real-world event detection [4] by analyzing topic clustering like rumour spreading analysis [5], human mobility sensing [6], spam & botnet detection [7] and disaster response [8].

Correlation between high impact social events and sentimental polarity extracted from user groups from Twitter can be interpreted by probabilistic and classification models [9], whose results are predictive by nature and can be used as a social behavior warning tool. In [10], an early warning process related to abnormal behavior is developed relating intrusion techniques and terrorist attacks.

Regional language and lexical variations derived from users are key factors in searching patterns related to sentimental tendencies. For example, natural language processing has shown that negative-oriented textual features [11] related to information security lexicons used by *hacktivists* groups can send warning alarms to sysadmins to mitigate web attacks. Political, religious and cultural events can serve as predictive targets for data extraction in social media platforms, noting that malicious users may redirect such contexts to negative-oriented ones [12].

This paper focuses on sentiment analysis extracted from tweets, which are processed with probabilistic techniques [13] in order to measure the correlation among user groups within a common context; specifically, those who use Twitter in a regular basis and those who generate content with malicious intentions related to *hacktivism*, which according to [14] is the marriage of hacking and social activism.

Tweets are analyzed to create security warnings based on sentimental response on users. The latter is done comparing three supervised learning algorithms [15–18] daily corpus of tweets. A statistical model is created with the assumption that given the volumes of tweets with sentimental polarity there is a response from security attacks.

2. Related Work

According to [19], cyber attacks are increasing as a result of global insurgency given geopolitical contexts. These attacks pose major concerns due to their potential effects in denial of service, data leaking and application compromising. Alternative security measures, like forecasting threatening security events, are thus gaining credibility.

Data from OSNs is useful for extending capabilities from intrusion detection systems (IDSs) and intrusion prevention systems (IPSs) from outer-level networks. In [20], an LDA-based (*Latent Dirichlet Allocation*) model is proposed to discover semantically related concepts to analyze cyber-crime forensics. More recently, a bipartite and monopartite network analysis is achieved by crawling hackers forums to identify members by specific malicious tool usage [21]. A list of anti-threats strategies is proposed in [22] to prevent and visualize common practices regarding privacy, spamming and malicious attacks.

In [23], the authors present a relationship of social unrest between countries and directed cyber attacks. These works proves that Arbor Networks data is useful to determine if attacks such as DDoS (*Distributed Denial-of-Service attacks*) are expected to grow if radical or extremist sentiments from users are perceived in streams of OSNs posts.

Predictive analysis has an important concept in Twitter, due to the fact that certain elements such as retweets, favorites and replies can be characterized, which, together with the polarity of the text, can provide data that increases the forecasting of events [24] such as political elections and product outcomes. According to [25] the predictive power in social networks has two important aspects, those based on the human factor (inspection of publications) and statistical models, which through a list of predictors on measures of opportunity as number of followers, and favorite publications , can be modeled to predict an increase in users influence. In [26] a ℓ_1 regularized regression model was presented in order to predict Influenza-like Illness by training data from Twitter and comparing outcomes with official health reports.

3. Proposed Algorithm

The work flow of the proposed algorithm is depicted in Figure 1. In a first instance a query is requested from the Twitter search endpoint, then, a response containing blocks of tweets is processed by a web scrapping engine and then stored in a local database. Before stored tweets are handled by statistical methodologies , a set of pre-selected tweets is prepared for training and testing by supervised learning algorithms to create a set of classifier models. When the classifier models are ready, stored tweets are tested by each model and the one with the best classification results is chosen. Finally scores from daily classified tweets are feed to a regularized regression algorithm obtaining predictive results. In a first instance a query is requested from the Twitter search endpoint, then, a response containing blocks of tweets is processed by a web scrapping engine and then stored in a local database. Before the stored tweets are handled by a ℓ_1 regularization a set of pre-selected tweets is prepared for training and testing by three supervised learning algorithms [15–18] to create a set of classifier models. When the classifier models are ready, stored tweets are tested by each model and the one with the best classification results is chosen. Finally scores from daily classified tweets are feed to a ℓ_1 regularization obtaining predictive results.

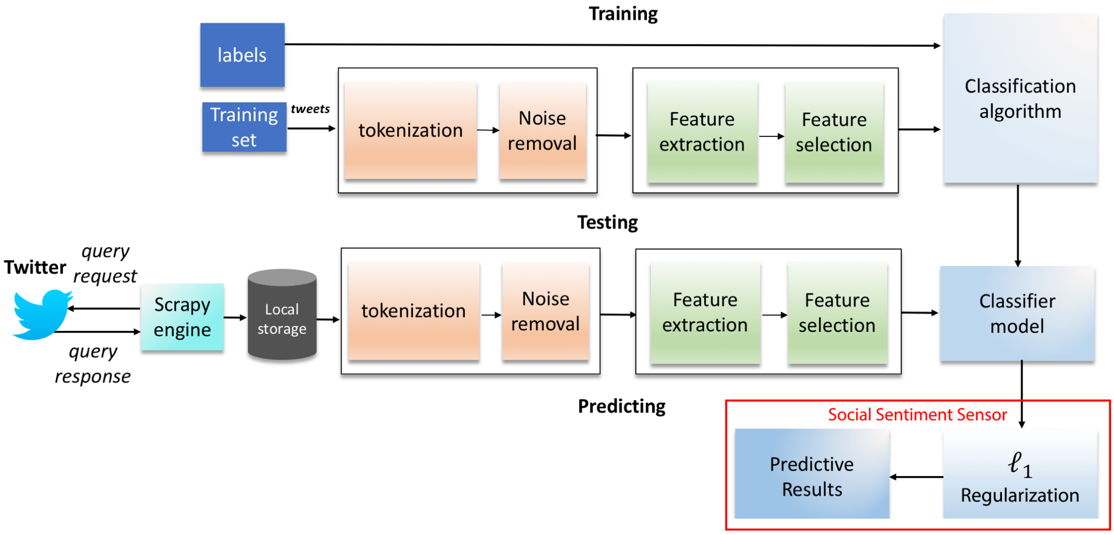


Figure 1. Proposed algorithm steps.

4. Data Gathering and Pre-Processing

4.1. Data Acquisition

Data gathering schemes are designed for querying Twitter endpoints to obtain chronological tweets. Notorious works in sentiment analysis [27–29] use a public information streaming platform known as Twitter Standard Search API, which is an interface that has capabilities for information retrieval in chronological order for no longer than seven days [30]. In this paper is used an approach for historical retrieval by querying Twitter search endpoints proposed in [31]. The web crawling tasks are done with web spiders engines designed for document scraping in an automated and efficient manner. Information is processed by Scrapy, a Python Web Scraping Framework that extracts embedded text in HTML tags and simultaneously uses recursive functions to analyze each link to follow other tweets. This data gathering scheme is depicted in Figure 2.

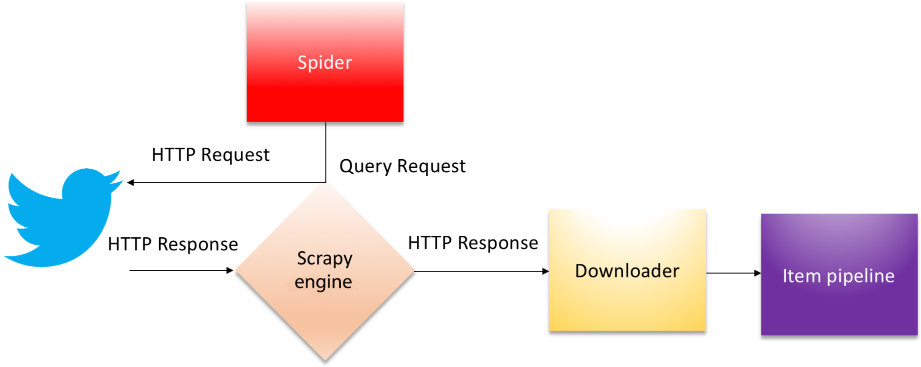


Figure 2. Data gathering scheme.

Collecting data is achieved by querying the endpoints in time intervals sorted by days. Each query q is based on *n-grams* (set of co-occurring words within a given text) bags of words related to specific events defined as $q = [\{\ \textit{1-gram}, \textit{2-gram}, \textit{3-gram}, \ldots, \textit{n-gram}\ \}, \{\textit{date}\}]$.

Queries responses are processed by a web spider towards the endpoint and redirected to a Scrapy download layer, finally feeding unprocessed data into the Scrapy engine in order to strip hypertext tags and retrieve each tweet in plain text. As depicted in Figure 3, retrieved text is processed independently in Scrapy pipes that handle data streams into objects to be stored in a relational database.

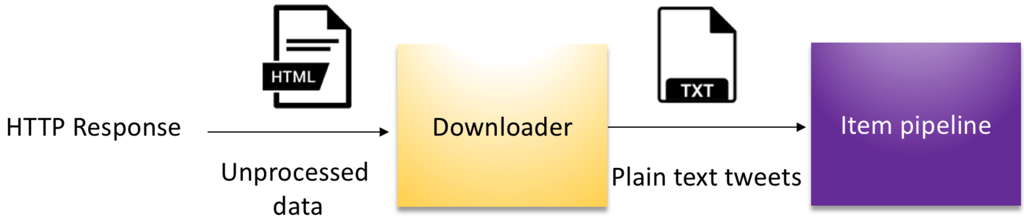


Figure 3. Embedded Text in HTML.

The set of retrieved queries q is the *corpus of tweets*, $\mathcal{C}$, and is directly proportional to the daily number of tweets stored for query. According to each tweet can be represented as a structure containing fundamental attributes depicted in Table 1.

Table 1. Tweet object.

Attribute	Description
id	the integer representation of the unique identifier for this Tweet
created_at	UTC time when a tweet was created
text	The actual UTF-8 text of the status update

Each tweet is stored with its own *id* as a primary key, that is used to sort them in a sequentially and non-repeatable way, and is denoted by $\mathcal{C}(q) = c_i \in \{t_{id}, t_{text}, t_{date}\}_{i=1}^{n}$.

4.2. Tokenization and Noise Removal

A cleaning task is applied to a corpus $\mathcal{C}$ to generate individual arrays of words (i.e., tokens) for each tweet. A normalization step is required to transform each token into lower case words, a dimensional reduction [32] of $\mathcal{C}$ is important to reduce textual noise. Noise is considered as frequent *uni-grams* or *stop-words* (very commonly used words) that do not provide valuable information as candidate textual markers. In the case of the English language, sets of *stop-words* widely used in Natural Language Processing are used in text cleaning tasks. This work uses a the publicly-available English stop-words set published in [33], and each word is weighted by textual and lexical functions in a sentence [34]. URL patterns are removed from the corpus and other expressions, such as retweets *RT* and appearances of *@username*, are considered non-informative attributes and are deleted in the same way.

4.3. Lexical Derivations

Textual markers have lexical derivations as part of ungrammatical text structures written by most of users. Grammatical restriction is performed to stem each token, thus avoiding repeated samples from the same grammatical root and bias in the training step for classification. An example of stemming is shown in Table 2.

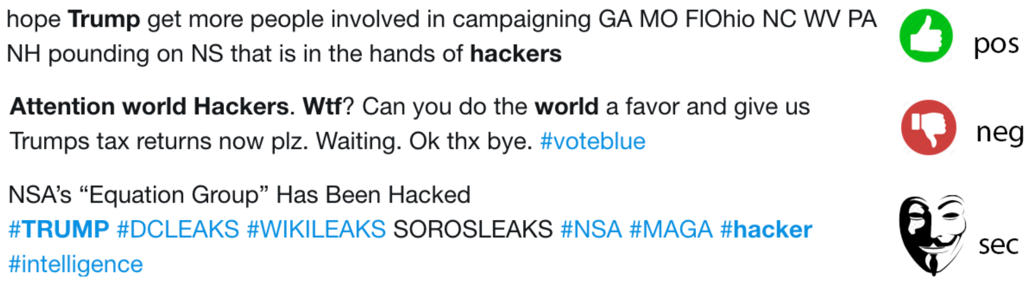
Table 2. Stemmed lexical variations.

Prefix	Root	Sufix
n/a	corrput	tion
n/a	corrupt	ed
n/a	incorrupt	ibility

We use Snowball Stemmer for lexicographical lemmatisation, which is a set of probabilistic algorithms based on Porter stemmer [35] of Indo-European languages and has been shown to attain high capabilities for searching pattern inflections into roots from composed words [36].

5. Pre-Classification and Class Labeling

Supervised classification provides predefined class labels given specific inputs, where each class must be independent from the others. Selecting relevant and high impact tweets are important for good training performance due to the fact that some words give most information about a particular context. We use The Stanford sentiment corpus [37] along with tweets crawled by our own scraping approach in a first instance, tweets are labeled as negative (neg) or positive (pos) based on users emotions. A second set of tweets related to cyber-security and cyber-attacks topics is scraped by querying terms contained in The Glossary of Common Cybersecurity Terminology [48], and other manually annotated hacker-activists terms [11]. Crawled tweets where labeled by a $sec(security - oriented)$ tag. The set of labels is then denoted by $label = \{pos, neg, sec\}$ and the corpus for a training task is denoted by $T = \tau_i \in \{tweet^{label}_{text}\}^{n}_{i=1}$, where τ_i is the ith tweet text and label on the training set. In Figure 4 are depicted some examples regarding class labeling.



hope **Trump** get more people involved in campaigning GA MO FlOhio NC WV PA NH pounding on NS that is in the hands of **hackers**

Attention world Hackers. **Wtf**? Can you do the **world** a favor and give us Trumps tax returns now plz. Waiting. Ok thx bye. #voteblue

NSA's "Equation Group" Has Been Hacked #**TRUMP** #DCLEAKS #WIKILEAKS SOROSLEAKS #NSA #MAGA #**hacker** #intelligence

Figure 4. Example of labeling for the three observed classes.

6. Supervised Classifier

Building a supervised classifier is achieved by first transforming each input of textual markers into features, followed by a training step with labels. Features extracted from T contain basic information that allows for $\mathcal{C}$ to be successfully classified. The work flow is graphically depicted in Figure 5.

Features and labels from T are processed by the supervised learning algorithms [15–18] to generate classifier models. A feature extractor computes features based on words by the the term frequency–inverse document frequency (*Tf-idf*) algorithm [38]. A label for each tweet of $\mathcal{C}$ is then predicted.

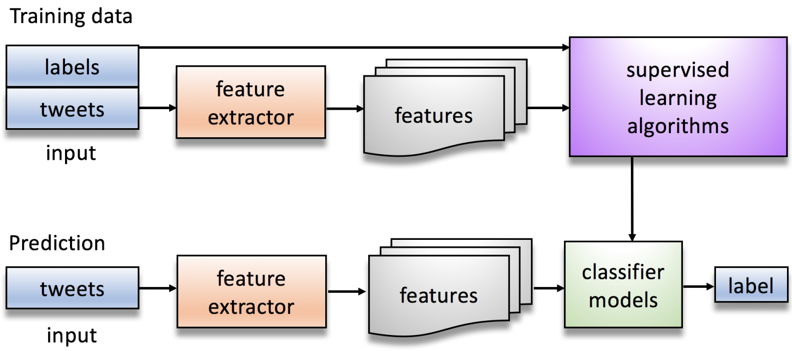


Figure 5. Training and Label Prediction.

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Feature Extraction and Selection

Features are based on sentimental relevance; i.e., words that better describe a user's sentiment about a specific context are selected. As proposed in [39], identifying raw *n-grams* is more useful for feature extraction than using speech tagging, because supervised classifiers tend to attain a higher accuracy with grammatical and positional independence in sentences.

In order to avoid over-fitting, we perform a model selection procedure to split data into random matrices for training and testing. By performing a *train-test* selection procedure with Python sklearn library, we divide T into a 80% training and 20% validation subsets. Training and validation tweets from regular users merged with security oriented users are denoted by X_T, which contains pre-processed text from tweets, while y denotes their respective labels. Resulting subsets from T are denoted by X_T, y_T, which are the training subset tuples, and X_V, y_V, the validation subsets tuples selected to evaluate the classifier model.Word particles contained in tweets from the training set are extracted and transformed into to *Tf-idf* term weights [40] using sklearn *Tf-idf* vectorizer, then each resulting vector is normalized by an ℓ_2 norm.

7. Classification Baseline

Choosing a good classifier is an important task to generate a robust model for testing corpus $\mathcal{C}$. In other words, results must be accurate enough to eventually find relationships between the users sentiments and cyber attacks responses. In [37,41,42], different classifiers such as Naive Bayes, Maximum Entropy and Support Vector Machine are proposed and evaluated; results show that for noisy labels and the case of emotions in tweets, Support Vector Machine attains better results than other text classifiers.

7.1. Naive Bayes Classifier

Classifiers based on the Bayes theorem are widely used in text classification [15] for short messages like tweets, because of the simplicity in computing probabilistic evidence for class prediction given independent text features. This method contrasts with those that employ Bernoulli models [43], which are based in document counts for each class. Having a set label containing c classes, we can define parameters to calculate the probability of a class c given a tweet by:

$$P_{NB}(c|t) = \frac{(P(c)) \sum_{i=1}^{m} p(f_i|c)^{n_{i(t)}}}{P(t)} \tag{1}$$

where t is a tweet, c a class (label), $f_i \in f(X_T)$ is the feature, $n_{i(t)}$ is a word presence given t and m is the number of features.

7.2. Support Vector Machine

Support Vector Machines [16] are suitable for bounding data in linear and non-linear ways. By its nature SVM is a binary classifier, meaning that data is separated into two labeled classes. For a multi-class approach for the training set (X_T, y_T) with labels $y_T \in \{0, 2\}$, an optimization approach is proposed by solving:

$$\phi(w, \xi) = \frac{1}{2}\|\mathbf{w}\|^2 + C \sum_{i=1}^{\ell} \sum_{m \neq y_i} \xi_i^m \tag{2}$$

constrained to $(w_y \cdot t_i) + b_{y_i} \geq (w_m \cdot t_i) + b_m + 2 - \xi_i^m$, $\xi_i^m \geq 0, i = 1, \ldots, \ell, m \in \{1, \ldots, k\}$, thus this, we can find an optimized decision function by finding the saddle point of the Lagrangian:

$$f(x, \alpha) = \underset{n}{\text{argmax}}[\sum_{i=1}^{\ell}(c_i^n A_i - \alpha_i^n)(t_i \cdot t) + b_n] \tag{3}$$

where w is the hyper plane, α_i is the non-negative Variable Lagrange Multiplier, y_i is the ith input class (label) from the label set, t are input tweets, b denotes the hyper-plane parameters (bias), ξ is a slack variable ($0 < \xi \leq i$ is the point between the margin and the correct side of the hyper-plane with $\xi > 1$ mean a misclassified point) and C is the regularization parameter.

7.3. Maximum Entropy Classifier

Maximum Entropy classifiers are widely used for learning from input features in a weighted manner, such that it results in a discriminative model that evaluates possible values from possible classes [17,18]. The model is represented by:

$$P_{ME}(c|t) = \frac{1}{Z(t)} exp(\sum_{i=1}^{n} \lambda_{i,c} F_{i,c}(t,c)) \tag{4}$$

In the previous formula c denotes the class (label), t is a tweet, λ is the weight vector (considering that a higher weight assumes a strong indicator about the class), $Z(t)$ is the normalization function given t, and $F_{i,c}$ is the feature-class function for a feature $f_i \in f(X_T)$.

8. Prediction—Statistical Analysis

ℓ_1 Regularized Regression

Regression is suitable for prediction and forecasting events given multiple inputs, better known as observations, that are linearly independent from each others [44]. A lineal model is interpreted as:

$$f(X_{\mathcal{C}}) = \widehat{y_{\mathcal{C}}}_{security\_oriented} = \beta_0 + \beta_1 X_{\mathcal{C}_{pos}} + \beta_2 X_{\mathcal{C}_{neg}} + \varepsilon \tag{5}$$

where:

1. $X_{\mathcal{C}}$ is the observation matrix of all classified tweets from corpus
2. $X_{\mathcal{C}_{pos}}$ and $X_{\mathcal{C}_{neg}}$ are the observations total with daily scores
3. $X_{\mathcal{C}}$ is the observation matrix of all classified tweets from corpus $\mathcal{C}$
4. $X_{\mathcal{C}_{neg}}$ are the observations total with daily sentiment scores
   (a) $X_{\mathcal{C}_{pos}} = \sum_{i=1}^{n} \mathcal{C}_i(positive)$
   (b) $X_{\mathcal{C}_{neg}} = \sum_{i=1}^{n} \mathcal{C}_i(negative)$
5. $\widehat{y_{\mathcal{C}}}_{security\_oriented}$ the fitted security-oriented response from regression coefficients $[\beta_1, \beta_2]$ extracted from $y_{\mathcal{C}_{security\_oriented}} = \sum_{i=1}^{n} \mathcal{C}_i(security\_oriented)$

Because of the negative effect on computing regression by ordinary least squares over highly correlated observations and an increase of variance, a regularized regression using selection and reduction is proposed. Regression based on vector norm ℓ_1 can adjust the linear model by making some coefficients zero, which is suitable for large multivariate observation matrices. LASSO (Least Absolute Shrinkage and Selection Operator) is an adaptation to linear models that minimizes the error in the limit of absolute values from prediction coefficients:

$$\widehat{\beta}^{lasso} = \arg\min_{\beta \in \mathbb{R}^P} \|X_{\mathcal{C}}\beta - y_{\mathcal{C}}\|_2^2 + \lambda \|\beta\|_{\ell_1} \tag{6}$$

where λ is the tuning parameter for shrinking coefficients $[\beta]$.

9. Experimental Results

This section shows the evaluation of the proposed sensor for sentiment analysis, using a total of 1,800,000 tweets in English. One million were extracted using the method proposed in [31] from regular and cyber-security-related accounts and 800,000 belonging to the Stanford dataset [45]. In Table 3 some well identified Twitter accounts related to hackers activists, cyber-security feeds, researchers and enthusiasts users are presented.

Table 3. Identified Twitter accounts related to hacking and cyber security.

Account Type	Identified Accounts
hacktivism	anonymouspress, youranonglobal, wapoanon, werallanonymous, observingsentin, theanonmovement, freeanons, global_hackers, anonymousvideo, anonrrd
cyber-security feeds and sensors	nitdefender, malwarebytes, oinionid, moixec, uscert_gov, nakedsecurity, kaspersky, fsecure, nortononline, nsc
researchers and enthusiasts	peerlyst, cyber, mikko, briankrebs, nieljrubenking, dangoodin001, gcluley, campuscodi, peterkruse, e_kaspersky, troyhunt, swiftonsecurity, icheylus

In Table 4. the results using Support Vector Machine, Naive Bayes and Maximum Entropy classifiers for training (X_T, y_T) as well as testing (X_V, y_V) are shown. These results were obtained using parameters related to document frequency (df) which is a threshold for support applied to weight terms where the minimum and maximum support are in the interval [0.5, 0.95].

Table 4. Classification Results. The Maximum Entropy classifier show the best classification result.

Classifier	Class	Precision	Recall	F_1 Score
NB	negative	0.77	0.80	0.79
	positive	0.76	0.76	0.76
	security-oriented	0.94	0.91	0.93
SVM	negative	0.80	0.80	0.80
	positive	0.78	0.80	0.79
	security-oriented	0.95	0.94	0.95
ME	negative	**0.81**	**0.80**	**0.80**
	positive	**0.78**	**0.80**	**0.79**
	security-oriented	**0.96**	**0.94**	**0.95**

9.1. Testing the Proposed Model: A Case Study

During United States of America presidential campaigns and post election time an important set of polarized opinions was generated from Donald Trump polemic speeches. Speculations about the winning candidate increased by adding financial, political, immigration, religious and sexist comments towards her opponent, Hillary Clinton, during the campaign. Hackers activists with hash-tags like $\#OpTrump$ and $\#OpDrumpf$, generated public threats towards Donald Trump. In addition, rumors with some evidences about hackers manipulating electoral campaigns increased users negative reactions towards both candidates. In the next table (Table 5), positive and negative sentiment is depicted for classified opinion flows per day, those who tweet regularly and hacker activists, both contained in C, we denote X_C as the testing set to perform this case study. In order to appreciate better daily sentimental average scores extracted from $X_{C_{neg}}$, $X_{C_{pos}}$ and $y_{C_{security\_oriented}}$, the total track of 486 days between 9 January 2016 and 1 May 2017 is divided into six time-intervals, and classified tweets are presented for positive sentiment (POS), negative sentiment (NEG) , and security oriented

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(SEC) classes with its corresponding classifiers: Naive Bayes (NB), Maximum Entropy (ME) and Support Vector Machine (SVM).

Table 5. Classified tweets over time series.

Dates	Classifier	POS	NEG	SEC
9 January 2016 to 23 March 2016	NB	1,858,329	2,143,213	535,449
	ME	26,451,360	2,920,311	450,793
	SVM	2,792,088	2,346,357	540,059
24 March 2016 to 12 June 2016	NB	1,909,028	1,969,211	1,969,211
	ME	24,294,780	2,384,148	569,337
	SVM	2564449	2,347,377	682,077
13 June 2016 to 1 September 2016	NB	1,957,351	2,428,557	1,208,306
	ME	24,017,220	27,840,39	1,013,131
	SVM	2,535,151	2,740,485	1,213,509
2 September 2016 to 21 November 2016	NB	2,290,596	2,966,951	951,907
	ME	28,019,700	3,308,982	802,142
	SVM	2,957,635	3,257,319	961,466
22 November 2016 to 10 February 2017	NB	2,456,003	3,217,832	985,666
	ME	30,309,120	3,480,291	827,089
	SVM	3,199,296	3,420,468	923,691
11 February 2017 to 1 May 2017	NB	2,436,753	3,464,375	237,160
	ME	29,392,200	3,703,008	198,667
	SVM	3,102,510	3,626,100	238,128

9.2. Regularized Regression Approach

Prediction over high volumes of scores can be difficult with ordinary regression due to unbiassed coefficients. By computing LASSO (east Absolute Shrinkage and Selection Operator) [46] we can shrink coefficients in order to optimize our prediction model. Moreover, regularized regression tasks can be only implemented in multivariate sets, as presented in Table. the Maximum Entropy (ME) classifier showed better accuracy results, so we propose an ℓ_1 normalization for overall daily ME [47]. Given the transition over presidential elections, normalized scores from $X_{\mathcal{C}}$ are divide into monthly prediction tasks, a statistical report containing the following measures is depicted in Table 6:

- *M.S.E.* (Mean Squared Error): shows the difference or loss of the predicted scores with the inputs between the actual scores $y_{\mathcal{C}_{security\_oriented}}$ and the predicted $\widehat{y_{\mathcal{C}}}_{security\_oriented}$.
- *p*-value (probability value): determines how well the observations ($X_{\mathcal{C}_{neg}}$, $X_{\mathcal{C}_{pos}}$) are adjusted in the predictive model, thus rejecting the null hypothesis, that related to the low effectiveness of the samples, the lower the probability value (p-value ≈ 0), the greater adjustment in the model.
- R^2 (coefficient of determination): explains the proportion of adjustment from the observations ($X_{\mathcal{C}_{neg}}$, $X_{\mathcal{C}_{pos}}$) with respect to the outputs $\widehat{y_{\mathcal{C}}}_{security\_oriented}$.
- Detected Attacks : the total number of security attacks detected.

Table 6. Regularized Regression Measures Report.

Months	MSE	β_1	β_2	p-Value	R^2	$yc_{security\_oriented}$	$\widehat{yc}_{security\_oriented}$	Detected Attacks
Jan. (2016)	0.00243	1609.36	845.54	0.0	0.61	116,910	70,146	2
Feb. (2016)	0.00223	1609.36	845.54	0.0	0.63	210,874	132,850	1
Mar. (2016)	**0.00001**	1 **609.36**	845.54	**0.0**	**0.81**	**317,625**	**257,276**	**6**
Apr. (2016)	0.00314	1609.36	845.54	0.0	0.54	372,438	249,533	2
May (2016)	0.00141	1609.36	845.54	0.0	0.67	122,674	83,531	2
June (2016)	**0.00002**	**1609.36**	**845.54**	**0.0**	**0.89**	**223,674**	**199,069**	**6**
July (2016)	**0.00008**	**1609.36**	**845.54**	**0.0**	**0.86**	**230,655**	**198,363**	**1**
Aug. (2016)	**0.00009**	**1609.36**	**845.54**	**0.0**	**0.85**	**410,874**	**349,242**	**3**
Sep. (2016)	0.00015	1609.36	845.54	0.0	0.77	291,643	224,565	2
Oct. (2016)	0.0004	1609.36	845.54	0.0	0.71	241,438	188,321	2
Nov. (2016)	0.00054	1609.36	845.54	0.0	0.79	230,123	181,797	2
Dec. (2016)	0.00312	1609.36	845.54	0.0	0.53	229,451	121,609	2
Jan. (2017)	0.00144	1609.36	845.54	0.0	0.69	378,286	261,017	1
Feb. (2017)	0.00334	1609.36	845.54	0.0	0.52	107,933	56,125	1
Mar. (2017)	0.00339	1609.36	845.54	0.0	0.51	96,973	49,456	1
Apr. (2017)	0.00330	1609.36	845.54	0.0	0.56	94,961	53,178	1

Bold rows represent the maximum correlation between users sentiment and a security oriented response given by R^2. Historical data extracted from Google News can help to determine if R^2 values related to users sentiment can trigger an alarm related to hacking incidents. During mid-March 2016, Trump's comments and behaviors regarding abortion, the violence on his rallies and his declarations about Brussels terrorist attacks, increase users negative opinions towards him and, in retaliation, hackers started a raid under the banner of $OpTrump$ and election sites, voice-mails and public information was threatened. June 2016 was also a hard month during the election; rumors about hackers hijacking elections by cyber-intrusions increase people's reaction by posting DNC compromised servers revealing Hillary Clinton's private emails. The observations obtained in these time series show that there is a relationship between the negative opinions regarding the tweets by activist hackers. A chronological time-line for users negative, positive and security oriented classified tweets by Maximum Entropy; as well as important incidents (with their respective index), as reported by Google News is presented in Figure 6. News titles and original source from Google News describing Security-oriented incidents are depicted and mapped in Table 7.

The results associated with *Google News* can help to create thresholds for detecting security attacks, which can be calibrated when the correlation of the attacks with respect to the sentiments of Twitter users, for example when the determination coefficients increase to above 80%. The results also show that there is a relationship between the increment of social unrest (negative sentiment) and hacker activist groups reactions generating a possible security warning sensing. In Figure 7 a PoC (probe of concept) of the previously described assumption is shown, which describes the attacks perpetrated from January to April 2016 with a threshold above 80% which could be a security warning.

Table 7. News Reporting Security Oriented Incidents.

Index	Date	News	Source	Negative Sample	Security-Oriented Sample
1	2 January 2016	'Anti-IS group' claims BBC website attack	BBC News	56,712	1573
2	2 January 2016	Hackers Shut Down Donald Trump Election Campaign Website	Hack Read	56,712	1573
3	29 February 2016	US Cyber Command launches hacking offensive against Islamic State	Washington Times	24,378	5929
4	4 March 2016	Donald Trump's voicemails hacked by Anonymous	The Independent	30,141	7744
5	15 March 2016	Anonymous Declares 'Total War' On Donald Trump With Cyber Attacks Planned For 1 April	Huffington Post UK	31,977	16,940
6	15 March 2016	Anonymous Just Declared War on Donald Trump With a Massive Cyberattack	MIC	31,977	16,940
7	17 March 2016	ANONYMOUS OPTRUMP: HACKERS LAUNCH 'TOTAL WAR' ON DONALD TRUMP IN REVENGE FOR 'HATEFUL' CAMPAIGN	The Independent	43,401	29,282
8	18 March 2016	Trump Under Attack: The Donald Is Hacked by Anonymous and Son Eric Receives Threatening Letter Containing White Powder	People Magazine	45,594	14,762
9	23 March 2016	Anti-Trump campaign sparks civil war among Anonymous hackers	The Guardian	41,922	8107
10	1 April 2016	Anonymous Will Begin Latest War on Donald Trump Friday, April Fools' Day	Inverse	40,188	7623
11	5 April 2016	Donald Trump's hotel chain HACKED for second time in six months	Mirror.co.uk	35,547	16,577
12	8 May 2016	Presidential candidates may be vulnerable to foreign hackers, US says	The Guardian	26,469	6534
13	31 May 2016	Hacked construction signs call Trump a 'shape shifting lizard'	FOX 4 News	26,979	6538
14	14 June 2016	Russian Spies Hacked Into the DNC's Donald Trump files	CNN	23,358	13,794
15	14 June 2016	Russian Gov Hacks DNC, Steal Trump Oppo	The Weekly Standard	23,358	13,794
16	15 June 2016	Donald Trump Lone Hacker Claim Responsability for Stealing Democratic Party's Data	ABC	34,221	14,762
17	21 June 2016	Russian hackers reportedly access Clinton Foundation	The Sidney Morning Herald	33,609	17,908
18	23 June 2016	Russian Hackers Targeted Hillary Clinton Campaign Google Accounts	Forbes	31,467	16,456
19	30 June 2016	Hacker Reveals New Trove of DNC Documents and Answers a Few Personal Questions	Mother Jones	32,487	
20	25 July 2016	FBI Suspects Russia Hacked DNC; U.S. Officials Say It Was to Elect Donald Trump	Daily Beast	29,427	12,826
21	4 August 2016	Hackers for Hillary: event attendance 'through the roof' after Trump remarks	The Guardian	38,505	8954
22	18 August 2016	Is Russia hacking the US election?	BBC News	40,494	9075
23	24 August 2016	No proof, but 'Russian hackers': CNN blunders with report on 'breach' at NYT–not even asking NYT	International RT	44,013	8833
24	2 September 2016	Putin on DNC hack: Let's talk content, not hackers' identity	International RT	28,560	9438
25	6 September 2016	Hillary Clinton Suggests Alleged Russian Hacking Is Designed to Help Trump	NBCNews.com	35,394	10,890
26	11 September 2016	CIA Director John Brennan warns of Russian hacking	NewsHour	33,762	9075

Table 7. *Cont.*

Index	Date	News	Source	Negative Sample	Security-Oriented Sample
27	14 September 2016	Trump a 'National Disgrace,' Colin Powell Wrote in Hacked Emails	ABC News	36,465	7865
28	17 October 2016	Could Russian hackers change the U.S. election result?	Aljazeera	50,184	11,374
29	31 October 2016	Was a Trump Server Communicating With Russia?	Slate Magazine	53,193	11,253
30	10 November 2016	Russian hackers throw Trump victory party with new spear phishing campaign	Ars Technica	45,849	11,011
31	11 November 2016	Russia-linked DNC hackers launched wave of cyberattacks hours after Trump victory	Ars Technica	34,170	11,737
33	2 December 2016	Trump condemns CIA Russia hacking report	BBC News	31,977	12,463
32	9 December 2016	Russian Hackers Acted to Aid Trump in Election, U.S. Says	New York Times	41,055	12,705
34	9 January 2017	Surprise! WikiLeaks' Assange Backs Trump on Russia Hacking Report	NY Times	36,771	11,132
35	22 February 2017	U.S. CyberCorps, ROTC For Hackers, In Disarray in Trump Admin	Vocativ	50,082	5929
36	5 March 2017	DeepStateGate: Democrats' 'Russian Hacking' Conspiracy Theory Backfires	Big Government	43,605	13,331
37	10 March 2017	Trump adviser admits to contact with DNC hacker	The Hill	42,891	1089
38	4 April 2017	Russian Hackers Are Working To Amplify Donald Trump's Wiretapping Claim, Expert Warns	HuffPost	47,481	1089
39	10 April 2017	Russian hacker arrested in Spain over 'links to Trump victory'	The Local	50,898	3388

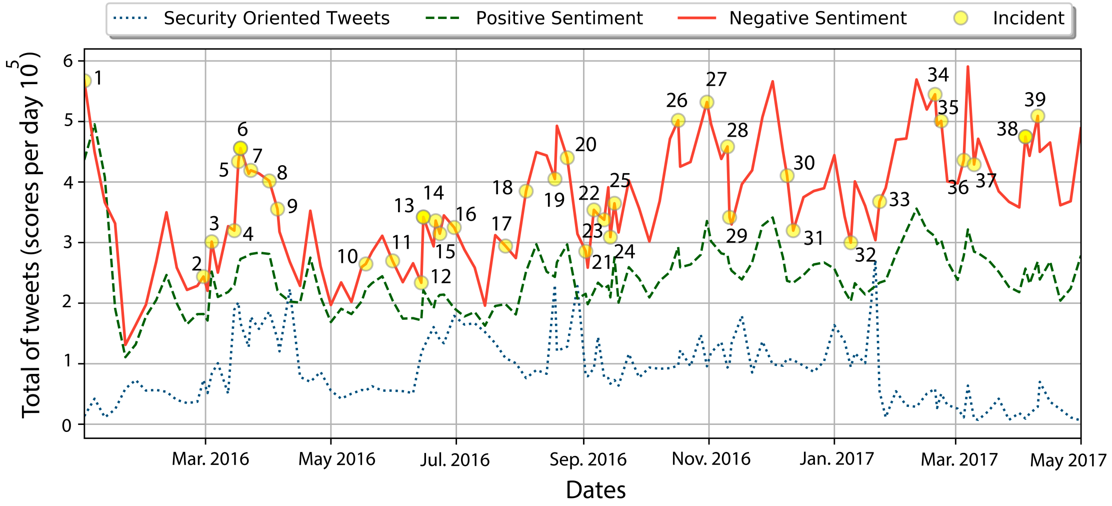

Figure 6. Users Chronological Sentiment with reported Security Incidents.

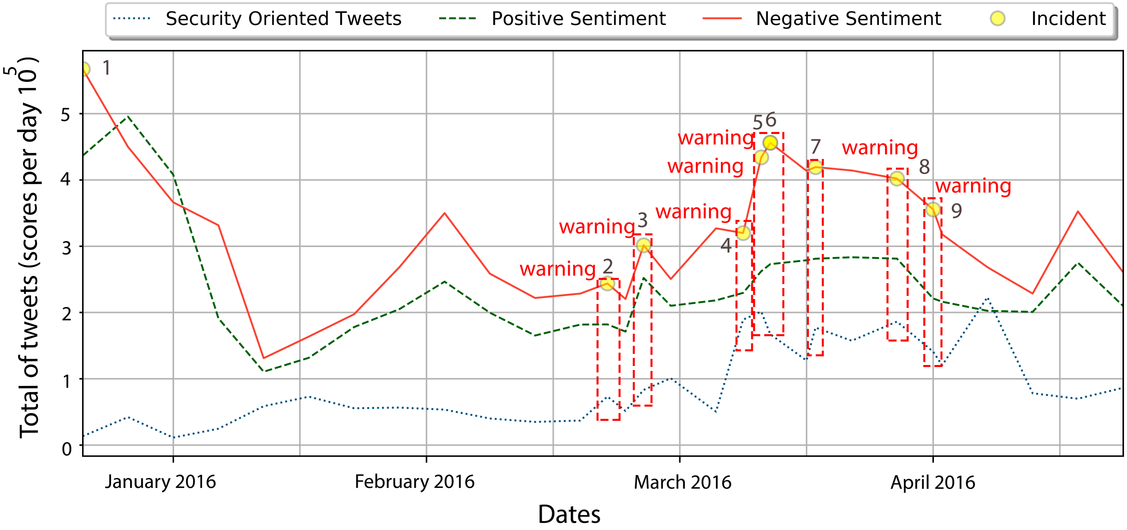

Figure 7. Propossed model PoC.

10. Conclusions

In this paper, a Social Sentiment Sensor in Twitter is proposed collecting historical tweets using [31] in order to classify negative, positive and security-oriented tweets. After comparing three different classification algorithms [15–18] the evaluation results show that the Maximum Entropy provides the most effective results than Naive Bayes and the Support Vector Machine for negative, positive and security oriented tweets. The use of the ℓ_1 regularization helped to improve the estimation of optimal prediction coefficients, which the *social sentiment sensor* could achieve 80% of precision between a cyber-attack and a Twitter social context. For the PoC 2016 USA election campaign, politicians appear to have influenced the sentiment of users and in response, hackers reacted as part of the opposition by threatening public information. Information leaking events like those that took place in June, July and August 2016 help to confirm if such acts increase users polarized opinions, this can be a subject of matter considering R^2 results of June (0.89), July (0.86) and August (0.85) which can serve as thresholds, which can issue alerts if the opinions have to be correlated with tweets related to security attacks. The implementation of the proposed method is not limited to cyber-attacks, as future work intends to reproduce the proposed method to predict events in real life such as pandemics, prognosis, political alignment and market analysis.

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