Grenze International Journal of Computer Theory and Engineering , Feb 2016

Exclassifier: A Novel Technique for Detecting Extremist Videos in Social Media

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***Abstract*—With the growing popularity of social media, social network (you tube) remains the largest as well as the most popular video sharing site. However, terrorists groups have made YouTube as a focal point for targeting innocent and vulnerable people. They propagate their ideologies to mainstream audience who otherwise would not visit their website. Hence, there is a need to detect such videos to prevent online radicalization among the users. The paper proposes a metadata and audio based classification method for detecting such videos which promote hate and violence by mining the user generated metadata such as title, description which the uploader of the video adds along with finding patterns to classify an audio into violence class such as gunshots and screams.**

***Index Terms*— Social Media privacy, web security, extremism detection.**

I. INTRODUCTION

As social media is growing very rapidly, people are spending significant amount of time on these websites. Specifically some social networking sites such as Facebook, Twitter, YouTube, and LinkedIn have become the most used way of interaction among the people in the worldwide.

YouTube is one of the most popular social networking website where users easily upload the video, watch the video and share videos on other social networking websites. YouTube have no limitation on number of videos users can watch, upload and share.

According to the YouTube statistics:

1. Over 1 billion unique users visit YouTube each month[9] ;
2. About 6 billion hours of video are watched each month on YouTube [9].
3. 100 hours of video are uploaded to YouTube every minute [9].

This statistics [9] shows the high popularity of YouTube on internet also, users can comment in textual form, subscribe for any channel, can search videos on keyword & category, like or dislike the videos. Since YouTube allow easy upload and downloading of videos, thus some users use YouTube to spread Hate and extremism among people by uploading videos having hurtful and provoking contents. These videos are not allowed according to YouTube privacy policy. Further these videos waste the bandwidth for the users who are not willing to watch these videos.

Since, there is no proper mechanism for automatic identification to detect objectionable videos that a user is uploading; extremist groups put forth hateful speech, offensive comments and messages focusing their

Grenze ID: 01.GIJCTE.2.1.23

mission. This material is used to facilitate recruitment, gradually reaching worldwide viewers, connecting to other hate promoting groups, spreading extremist content and forming their communities sharing a common agenda. The presence of hate producing users in large amount is major concern of YouTube, government and law enforcement agencies [2]. Even after many community guidelines and administrative efforts made by YouTube, there are still huge amount of extremism and crime producing videos on YouTube. Because identifying these Hate producing videos became technically challenging problem [2], a solution for this challenge is needed to combat and counter online radicalization. We categorized the data into two parts: training data and testing data. In order to identify, we extract the metadata of YouTube videos such as video-id, title, likes, dislikes, description etc. Training data is used for calculating threshold value (with the help of manually created lexicon lists) while testing data is compared with calculated threshold. The audio based classification is done as some users may write misleading titles and description due to which the videos will be difficult to detect. Hence, combination of the meta-based and the audio based classifier is an effective solution to such a problem.

II. Related Work & Research Contributions

This section gives an overview of the previous works in the area of detecting extremists and violent content online.

1. H. Chen et al discuss the classification of online videos by extraction of user-generated text data title. Meta-description & comments and three types of text feature (lexical, syntactic, content-specific features). Extremist videos were classified using three classification techniques C4.5, Naïve Bayes and SVM. According to experimental results SVM performed better than C4.5 and Naïve Bayes classifiers [1]. But this technique does not involve the non-text features of video such as audio, video, colour, texture and motion vectors.
2. A. Surekha et. al proposed an approach to discover hate and extremist videos, central and influential users and communities from YouTube by data mining as well as social network analysis techniques using friends, subscription, favourites and related video concept [2].
3. W. Chung in their case study of jihad on web developed a useful methodology to collect and analyse dark web information. Terrorist clusters and their use of web are identified using Information Visualization such as multi-dimensional scaling and snowflake visualization. This methodology was applied on 39 jihadist websites and developed visualization of site contents, relationships and activity levels [3]. This method is not scalable and it doesn't take into account the volatile nature of jihad websites.
4. A. Bermingham exploits the potential for the online radicalization by using social network analysis. Sentiment analysis of profiles and comments suggests that female users have most extreme and less tolerant views. Lexical analysis suggests that two most frequently used words are Allah and Islam. Social network analysis indicates an increased leadership role of women online. According to study the topics of discussion on the YouTube groups were mainly on America, Christianity, Islam, Israel, al-Qaeda [7]. The breath of the corpus is small and the lexicon used for sentiment analysis is not domain specific for the problem.It does not take into account the non-english text for sentiment analysis algorithm
5. T. Chalothorn used sentiwordnet to detect the opinions and emotions for the radical web forums by assigning positive and negative score to each wordnet. Words were stored on a BOW (bag of words and POS (part of speech) was used for tagging words. By sentiment analysis of sentence score it was concluded that Qawem web forum has more radical content than montada web forum [8]. This approach is a comparative study of only two web forums, other radical web forums are not considered.
6. T. Giannakopoulos et. al proposed a methodology to detect violent scenes in movies using twelve audio features and visual features combined together. The video features included certain motion specific features such as average motion, motion oriented variance and detection features for the face detection in the scenes. The performance of the system is 83%and only 17% of the scenes are not detected.[11]
7. Xingyu Zou et. al in this paper proposes a text, audio, visual based violence content classification. The first stage is a text based classifier to identify potential movie segments. The second stage used a combination of audio and visual cues to detect violence. Audio features like audio energy, energy

entropy and visual features like motion intensity, colour of the flame, bleeding and shot lengths are extracted to enhance the classification task.[12]

8. L. Gerosa et. al in their approach trained two parallel GMM classifiers to differentiate gunshots and screams from noisy environment which belong to the class of violence. A set of 47 audio features were used for the classification and the proposed system guarantees a precision of 90 %.[13]
9. T. Giannakopoulos, D. Kosmopoulos used frame level time domain and frequency domain features along with the SVM classifier to detect violence content. The recall rate was 90.5% which could be further improved by MFCC coefficients.[10]
10. E. Vozarikova et. al presents a methodology to detect dual gunshots in noisy environment using features such as MFCC, MELSPEC, skewness, kurtosis and ZCR. The combination of different features were evaluated by the HMM classification technique.[15]
11. Pikrakis identified gunshots by dynamic programming and Bayesian network. The posterior probabilities were calculated by combing the decisions from a set of Bayesian network combiners and 80% of the gunshots were correctly detected.[14]

III. Proposed Work

Proposed work in this research proposes a novel technique (Exclassifier) to detect hate and violence producing videos. Architecture of Exclassifier is shown in figure1. The whole process is divided into 4 main components: Metadata based classification, Audio based classification, Analyzer and Final classification. Working of various components of the proposed system is discussed in next sections.

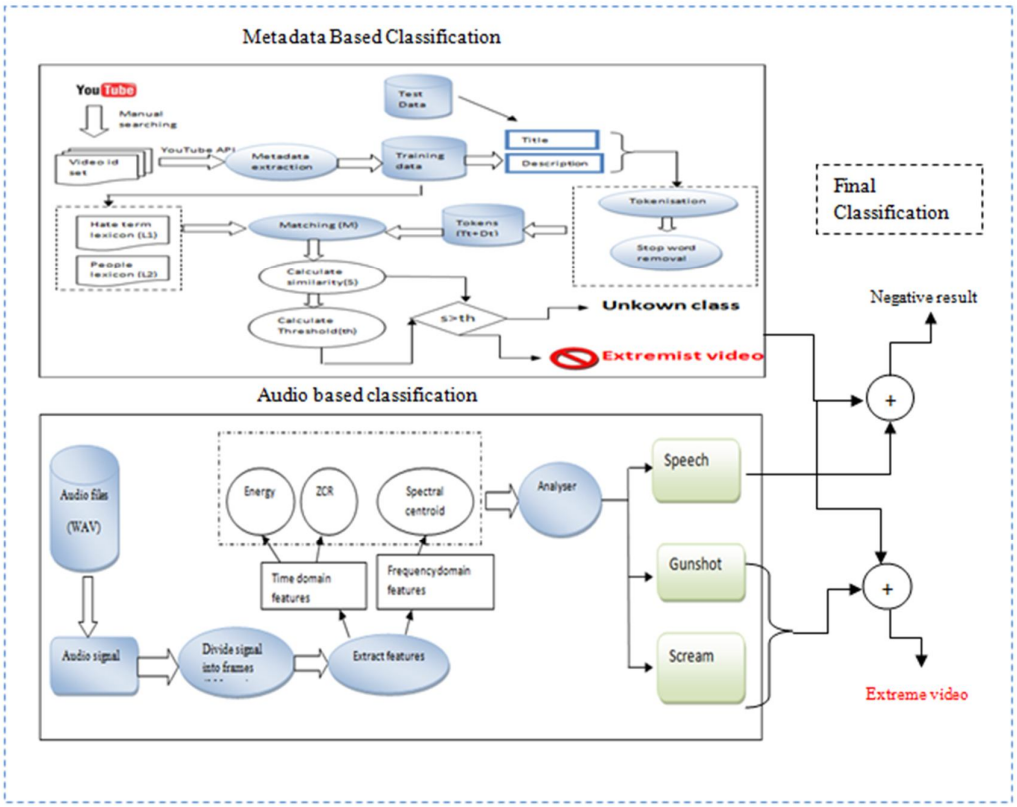


Figure 1. ExClassfier (Extremist video classifier)

A. Metadata based classification

The first component of the system interacts with social media site (i.e YouTube in our case). The detailed discussion of all components is given in next session.

B. Video Collection

For the training purpose, the task of data collection is done manually by querying the YouTube search interface using the keywords hate, behead, kill, bomb etc. The video ids for the videos which produce hate and extremism are collected by inspecting the query result.

C. Metadata extraction

This module extracts user generated text data for each video id obtained from the video collection step, using YouTube API. The linguistic based features such as the title and the description added by the uploader of the video along with duration of video, category, ratings, number of comments, likes and dislikes are extracted.

D. Prepare training dataset

The training dataset is prepared using video collection and metadata extraction step discussed above. The extracted metadata for each video id is added to this set .The outline of the training dataset is shown in Fig 2.

Vid	Title	Description	category	duration	comments	likes	dislikes	rating

Figure 2: Training dataset Data-Structure

E. Data Pre-processing

The extracted title and description undergo a preprocessing step which consists of two steps:

1. Tokenization:
   The process of tokenization involves breaking a stream of text into words, phrases or meaningful elements called tokens. The text of title and description are broken into tokens {t1, t2... tn} taking the whitespace character as a delimiter.
2. Stop word removal:
   Stop words are the most common words which have little value in classification process. This step filters stopwords using a list of standard English stop word list. The stop word list comprises of articles (a, an, the), prepositions (to, from, on, by etc), pronouns (I, we, your, us etc)

F. Construction of Hate Term Lexicon & People Term Lexicon

The two lexicons (Hate term list, People term list) are being constructed in this step. The construction of initial hate term lexicon is done by adding the most frequent hate terms involved in the training dataset. The lexicon list grows in size by adding synonyms as well as hyponyms for the existing terms.
The people type lexicon involve the proper nouns i.e. the name of the terrorist groups, jihadist, words like Muslim, Hindu, etc and the people who spread jihadist ideologies. Initial hate term and people term lexicon lists are shown in Table 1.

TABLE I. LEXICON LISTS

Hate term List	People term List
Attack, behead, bomb, threat, terror, kill, jihad etc	Osama, Muslim, Hindu, Isis , sayeed , lashkar, Allah

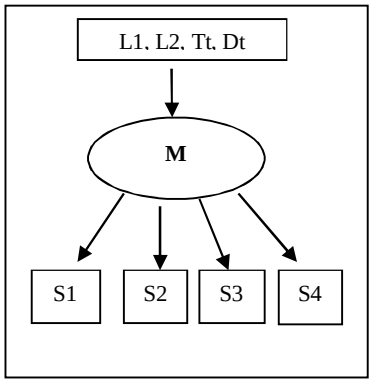


Figure 3. Score Calculation

F. Matching Function

The tokens for the title (T_t) and the description (D_t) are compared with the lexicon L1 (Hate term lexicon) and L2 (People term lexicon).
The inputs to the matching function M (T_t, D_t, L1, L2):

T_t: Title tokens
D_t: Description tokens
L1: Hate term lexicon
L2: People term lexicon

The matching function returns a similarity score (S_i) for each video- id *i* in training set.
The similarity score shown in Figure3 is calculated as follows:
For the video-id *i* ,

TL1 = number of title tokens (T_t) matching lexicon L1
TL2 = number of title tokens (T_t) matching lexicon L2
DL1= number of description tokens (D_t) matching lexicon L1
DL2 = number of description tokens (D_t) matching lexicon L2

1. Similarity score S(Title)
   $S1 = TL1/Tt$ (Ratio of hate terms in title)
   $S2 = TL2/Tt$ (Ratio of people terms in title)
2. Similarity score S(Description)
   $S3 = DL1/Tt$ (Ratio of hate terms in description)
   $S4 = DL2/Tt$ (Ratio of people term in description)

G. Calculate Threshold

The threshold of training set is calculated using the score S assigned by the matching function M.
The arithmetic mean of the scores is computed for title and description shown in table 2.
The threshold value for each type is calculated. The values obtained by the experimental results are shown below in Table 3 where, Type 1: hate terms Type2: people terms.

TABLE II. THRESHOLD FORMULA

Title	Description
$th1 = \sum S1_i/N$	$th3 = \sum S3_i/N$
$th2 = \sum S2_i/N$	$th4 = \sum S4_i/N$

TABLE III. THRESHOLD VALUES

Feature	**Type 1**	**Type 2**
Title	.21(th1)	.13(th2)
Description	.10(th3)	.05(th4)

H. Classification

The classification of the videos into extremist class or unknown class is done by training the one-class classifier with the positive class examples where the positive examples are the videos that depict extremism. After training task, the test videos are checked one by one for extremism by undergoing the same process of metadata extraction, pre-processing, and matching function to calculate scores.

The scores of the test video s1, s2, s3, s4 (section 3.4) are compared with th1, th2, th3, th4 (threshold values from Table II and Table III) as shown below.

1. If (s1>th1 || s2>th2) **and** (s3>th3 || s4>th4) we classify video as ***extremist video***.
2. If (s1 > th1 || s2> th2) **or** (s3 > th3 || s4 > th4) we classify the video as ***unknown class*** but the content analysis of video can be used to correctly classify this video content.
3. If neither condition 1 nor condition 2 satisfy the video is classified as ***safe video.***

IV. AUDIO CLASSIFICATION

This module of the proposed work inputs a segment of the audio and divides it into frames. The extremist videos are detected using time domain features and frequency domain features.

A. Time Domain Audio Features

Energy

Let x_i (n), n = 1,…….,N the audio samples of the i^{th} frame, of length N. Then, for each frame i the energy is calculated according to (1):

$$E(i) = \frac{1}{N}\sum_{n=1}^{N}|x_i\ (n)|^2 \qquad (1)$$

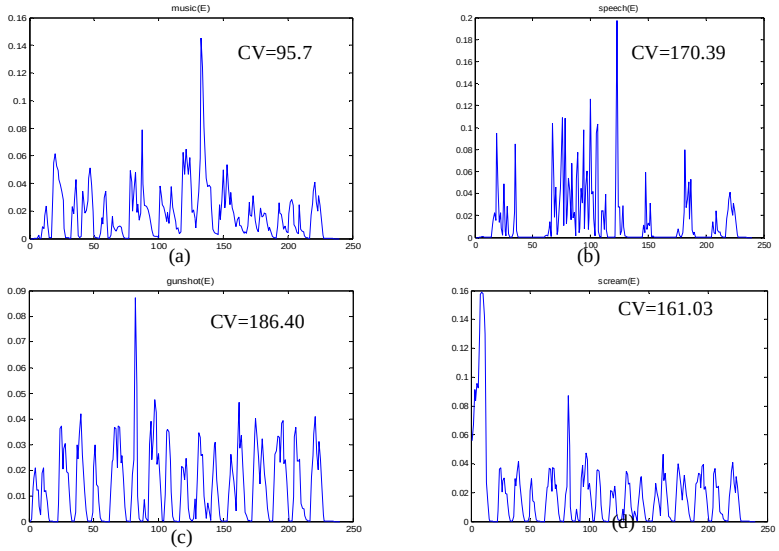


Figure 4. Energy waveforms (E) for music, speech, gunshot, scream

The extracted energy feature is used to detect silent segments in the audio signal as well as to differentiate between audio classes. The variation of energy(CV) in the speech segment is higher than music signal as its energy alternates from high to low. The statistics calculated for energy is the CV(coefficient of variation.
Energy waveform (E) of (a) music (b) speech (c) gunshot (d) scream is shown in figure 4 shown above. According to the CV values the order of audio signal is is Music < scream < speech<Gunshot. Gunshot has the highest value for CV and music the lowest CV.

B. Zero Crossing Rate

Zero crossing rate (ZCR) is the measure of the number of times the signal alternates from positive to negative and back to positive. The ZCR value of periodic signal is less as compared to noisy signal. This feature has been used extensively to identify speech and music segments. The formula (2) to calculate ZCR is given below:

$$Z(i) = \frac{1}{2N}\sum_{n=1}^{N}|sgn[x_i(n)] - sgn[x_i(n-1)]\ | \qquad (2)$$

The CV value of the ZCR sequence of the speech segment is higher than the music segment due to abrupt changes from positive to negative. Statistics calculated for ZCR is CV and Mean.
The Figure 5 depicts the waveform for the ZCR values for Music, speech, gunshot, scream. According to the experimentation value of ZCR_{CV} is in the following order: - Scream< Music < Speech<Gunshot. The highest value of ZCR_{CV} is for gunshot and the lowest is for Scream. The mean value of the zero crossing rate is computed and according to this statistics if we arrange the series in increasing order of mean values, the order is:-Music <speech <scream < gunshot.

C. Energy Entropy

Energy entropy is a time domain feature which measures abrupt changes in the energy level of an audio signal. It is calculated by dividing each frame into K fixed duration sub-frames. The energy e_j^2 is calculated (3) for each sub-frame by dividing the sub-frame's energy, by the whole frame's energy.

$$e_j^2 = \frac{Esubframe_j}{Eshort\ frame_i} \tag{3}$$

The energy entropy of the sequence of frames (4) is calculated by the noramalized energy e_j^2 calculated in (3).

$$En(i) = -\sum_{i=0}^{K} e_j^2 . \log_2(e_j^2) \tag{4}$$

The statistics value of the energy entropy is taken as the coefficient of variation. According to the experimentation the audio signals with abrupt changes has a higher value for CV. Gunshots and speech have larger value for the coefficient of variation compared to screams and music.

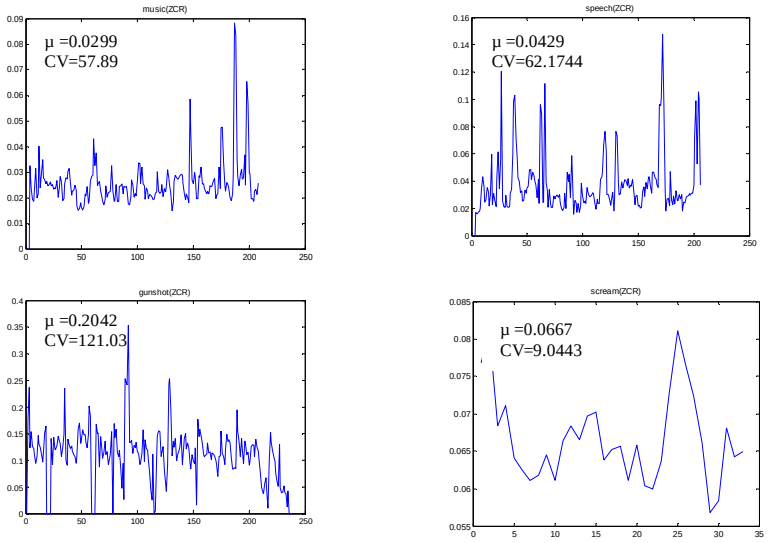


Figure 5. Waveform for the ZCR values for Music, speech, gunshot, screams

D. Frequency Domain Audio Features

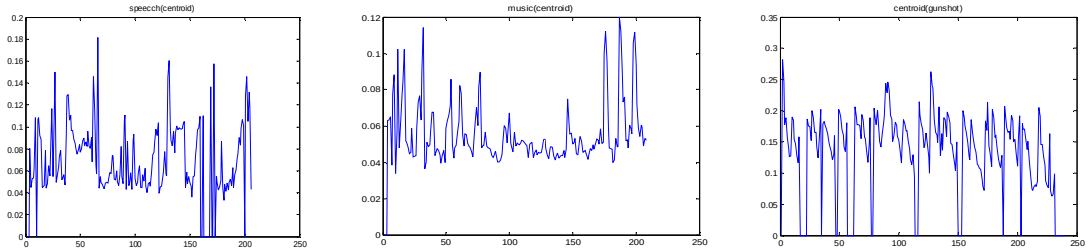
This domain refers to the analysis of the audio signal based on the frequency values rather than the time domain. It gives information regarding the signal's energy distribution over a range of frequencies. A time domain signal can be converted into a frequency domain by applying transforms on the signal values (FFT). The Fourier transform is a mathematical operation which converts a time domain signal into its corresponding frequency domain.

E. Spectral Centroid

It is measure used in digital signal processing to identify a spectrum. It signifies the concentration of the centre of mass of the spectrum. This feature gives higher values for the intensity of sound spectrum. Spectral centroid for screams has a low deviation and speech signals have highly variated spectral centroid. Spectral Centroid for speech, scream and gunshot is shown in the above figure 6. Gunshot has the highest CV value and Scream has the lowest CV value, hence the order is: Scream<speech<gunshot

The equation (5) is given below:

$$C_i = \frac{\sum_{k=1}^{N}(K+1)X_i(k)}{\sum_{k=1}^{N}X_i(k)} \quad (5)$$



SPEECH
CV=75.727

SCREAM
CV=7.5851

GUNSHOT
CV=113.209

Figure 6. Spectral Centroid for speech, scream and gunshot

F. Analyzer

The new audio which is to be assigned a label from the following labels {music, speech, scream, gunshots}. Before the function of the analyzer the statistics (refer Table 4) used for each feature is calculated

For an audio with a sampling rate 44.1 KHz the calculated statistics value of each feature is passed to the analyzer for the classification task.

1. IF $E_{CV}(a)$ > 100 && ($ZCR_{CV}(a)$ > 100 || ZCR mean > 0.1000) && $En_{CV}(a)$ >200 && $C_{CV}(a)$ > 100 || ($RO_{\mu}(a)$ > 0.50 || $Ro_{med}(a)$ > 0.50) → GUNSHOT
2. IF (E_{CV}(a) >100 && (ZCR_{CV}(a) <100 || C_{CV} <100)) , entropy of the audio is calculated

   If $entropy_{CV}$> 200 && ZCR_{Mean} > 0.1000 →GUNSHOT audio with multiple shots
3. IF E_{CV} > 100 && ZCR_{CV} < 100 audio may belong to any of the three classes {music, speech, scream} then centroid C is checked.
   1. IF ZCR_{CV} < 20 && ZCR_{Mean} >0.060 && C_{CV} is <10 (ZCR value is low and mean value is high centroid CV value is as low as less than 10) →**SCREAM**

      If this condition does not hold go to step 4
4. Now two labels are left {music and speech}
   1. E_{CV}(speech) > E_{CV}(music). If Ecv < 100 audio may be a music signal
   2. ZCR_{CV} , ZCR_{mean} ,C_{CV} is lower for music signal than speech signal
   3. Compare the calculated value for the audio with the vector for speech signal and music signal. The vector is represented as shown below

      < ZCR_{CV}, ZCR_{Mean} , C_{CV}>

      SPEECH SIGNAL: < 76.30, 0.0429, 75.72>

      MUSIC SIGNAL: <57.89, 0.0299, 23.54>

      Calculate the difference of the values from the respective vectors.

Percentage of silence intervals in speech is more than music. Speech contains a series of discontinuous unvoiced and voiced segments. The graphical representation of the waveform is shown in Fig 7 and Fig 8 which depicts the silence interval in music and speech signals respectively.

$$SI = \frac{\text{Number of signal values with amplitude} < 0.01}{\text{Length of signal(L)}} \times 100$$

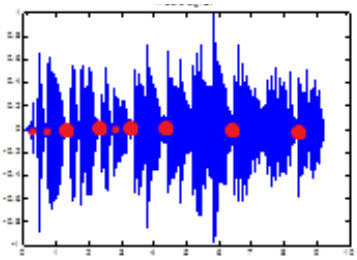


Figure 7
Silence interval in music signal

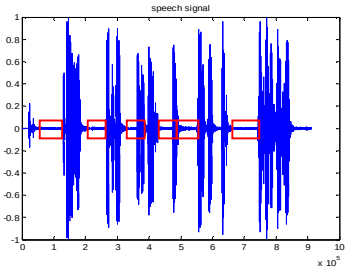


Figure 8
Silence interval in speech signal

Table IV: Statistics

Feature	Statistics
Energy	CV
ZCR	CV , mean(μ)
Centroid	CV

5. The classification of audio signal into music or speech is done by using the difference of values of audio signal from the vectors and the silence interval.
If difference is less for music signal && SI <3.00 →MUSIC ELSE IF
Difference is less for the speech signal && SI> 3.00 → SPEECH
Otherwise the audio is classified as unknown class.

V. Final Classification Step

1. If from stage 1(metadata based classification) the video is classified extremist then the video is labelled as 1 otherwise 0.
2. The second stage classifies audio as either music, speech, scream, or gunshot
3. If video labelled as 1 during stage 1 contains scream or gunshot or both then according to the classifier the video is classified as extreme video Else
   If the audio has speech segment the classifier returns negative result concluding that the audio is a news channel video showing extremist content.
4. If the video labelled as 0 in the first step contains gunshots and screams is assigned the extremist class.

VI. Experimental Results

For detecting the extremist videos, test run is carried on 50 Videos of YouTube , the experimental results are shown in Table V. Exclassfier technique is applied to all videos. Results are shown in fig 9, fig 10, and fig 11. The meta-classifier which is the first stage of the Exclassifier has a recall rate of 72 %. For testing of the audio classifier 25 audio segments containing speech, scream, music and gunshots were taken, the classifier performed with a recall rate of 76 %. The combined approach of the meta-classifier and the audio based classifier is an effective method to detect extremism video with a recall rate of the Exclassifier 84%.

TABLE 5. EXPERIMENTAL RESULTS

Feature	Correct	Incorrect	Recall
Title(T)	33	17	66%
Description(D)	19	31	38%
T + D	36	14	72%
T+D+ audio	42	8	84%

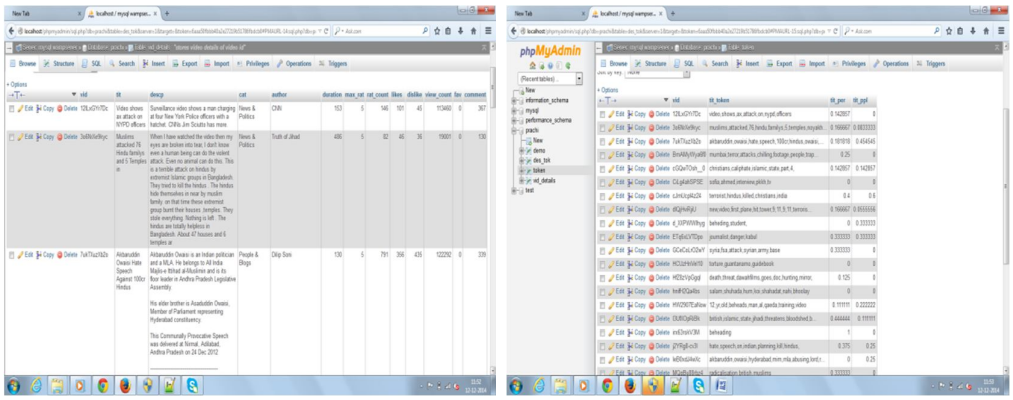


Figure 9. Title tokens

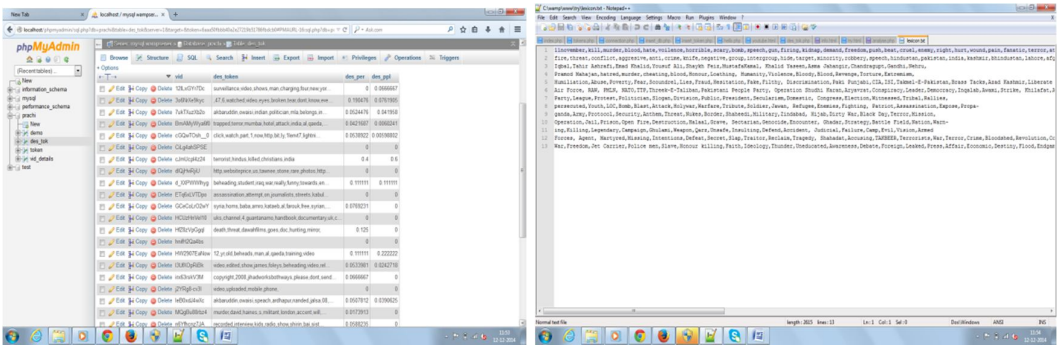


Figure 10. Description Tokens and word Lexicon

Figure 11. Detail Page and Result Page

VII. CONCLUSION

In this paper, a classifier (ExClassifier) is proposed to detect the privacy violating hate, extremism and crime producing videos having objectionable and crime content on YouTube. It indicates that the presence of bias features can be used to exploit the hate and extremism detection on YouTube. Many features based on metadata and audio signals along with our manual analysis and visual inspection for each category has been used and a threshold value for each video is calculated. Real world test dataset are analyzed using YouTube APIs. The performance of classifier reveals that certain features like presence of Hate-terms features of the video are important for the accuracy of the proposed approach. The recall rate of the classifier is 84% and the combination of metadata and audio performs better than only the textual metadata such as title and description. If the audio is labeled as extremist video in stage 1 and in stage 2 if the audio contains gunshots

and screaming the video is classified as extremist. Although our experiments show promising results, this research can be extended in future by taking video samples into consideration. The test bed can include videos from other social media websites. The meta-based classifier and the audio based classifiers can be extended by using new features for text and audio to further enhance the results.

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