

Web Video Object Mining: Expectation Maximization and Density Based Clustering of Web Video Metadata Objects

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Abstract—Nowadays YouTube becoming most popular video sharing website, and is established in 2005. The YouTube official website is providing different categories videos including Science and Technology, Films and Animation, News and politics, Movies, Comedy, Sports, Music etc. Each video hosted in website such as YouTube have its own identity and features. The identity and features of each video can be described by web video metadata objects such as- URL of each video, category, length of the video, rating information, view counts, comment information, key words etc. Using extracted web video metadata objects, we present an in-depth and systematic clustering study on the metadata objects of YouTube videos using Expectation Maximization (EM) and Density Based (DB) clustering approach. Distinct web video metadata object clusters are formed based on different category of web videos. The resultant clusters are analyzed in depth as a step in the KDD process.

Index Terms—Web Videos, Clustering, Metadata, EM Clustering, Density Based Clustering, Web Video Metadata Objects.

I. INTRODUCTION

The amount of video content on the Internet has amplified dramatically in the recent years. New generation of high speed Internet connectivity, ubiquitous use of smart phone devices, and the popularity of video websites such as YouTube, Yahoo Screen etc, are being contribute to the rapid increase of video content over the Internet [1]. According to the surprising statistic of the YouTube [2], the web videos can be considered as ‘Big Data’. YouTube is one of the most popular and largest video sharing website (with social networking features) on the Internet [3][4]. According to official declaration by the YouTube authority [2], it has more than 1 billion users. Every day, people are spending hundreds of millions of hours on YouTube videos. More than 300 hours of video are uploaded to YouTube every minute,

and also YouTube is available in 75 countries with 61 languages. Approximately 300 hours of video are uploaded to YouTube every minute [2]. This statistics shows that, how YouTube is popular day by day in a rapid increasing way. Hence, the social media researchers are attracting towards YouTube video which contains huge unstructured complex data.

Obviously, The domain ‘Big Data’ is recognized as - emerging, interesting and challenging research area due to its complex and unstructured nature.

In this work is continuation of our previous works [5][6] to discover knowledge from web videos using metadata objects such as ‘Category’, ‘Length’, ‘Number of Comments’, ‘View counts’, ‘Number of rates’, and ‘Rating’. Using such web video metadata objects, we made an attempt to form unsupervised clusters to discover knowledge from web videos.

The three main contributions of our work are as follows:

- Given a large collection of web video metadata objects dataset with ‘Category’ as nominal and remaining metadata object values are numeric, we train ‘Category’ based unsupervised clustering model using EM and DB clustering methods.
- The trained/built unsupervised clustering models using EM and DB are tested for large collection of web video metadata object dataset.
- The resultant unsupervised clusters of EM and DB are analyzed in depth to discover knowledge from web videos.

Many clustering models/algorithms and data mining machine learning tools are developed in recent years. Using different data mining algorithms and machine learning tools, it is possible to clustering the web videos based on their features/metadata objects.

The rest of the paper is organized as follows: The section 2 represents related works on the clustering of web videos, section 3 represents proposed web video clustering methodology, section 4 represents performance

evaluation analysis of cluster models and comparison of efficiency of cluster models, and finally section 5 represents conclusion and future enhancements.

II. RELATED WORKS

This section represents some related previous works which are implemented to cluster web videos using metadata objects.

In accordance with clustering of web videos, the authors C.F-Hsu, James C., and E. Khabiri [3] proposed by means of comment term normalization and key term extraction via KL-Divergence for distilling noisy comments. The authors [3] also developed an incremental insertion component for updating the comments-based hierarchy. The advantage of this technique is- resources can be efficiently placed in the hierarchy. This is because, comments arise and without the need to re-generate (potentially) the expensive hierarchy. The experimental study over YouTube provides proof that the proposed approach can lead to comments-based video management in social video sharing websites such as YouTube-like environment.

The authors Siddu P. Algur, Prashant Bhat and Suraj Jain [5], worked on implication of web video descriptive metadata and presented a useful and proficient method for construction and extraction of web video descriptive metadata. The presented method recognized the effectiveness of constructing the descriptive metadata with timeline for some domain specific web videos. The work of [5] also recommended the construction of event specific and objects specific metadata and which are considered to be very useful. With the proposed descriptive metadata model, users may process the video contents effectively and efficiently.

Xu Cheng, Cameron Dale, and Jiangchuan Liu [7] proposed a detailed analysis of the characteristics of YouTube, which is known to be most popular Internet short video sharing website. Through investigating the massive amounts of data collected in a 3-month period, the authors [7] verified that, while sharing certain similar features with traditional video repositories, YouTube reveals many exclusive characteristics, particularly in access pattern, length distribution, and growth trend. Such traits establish new challenges and opportunities for optimizing the performance of small video sharing services. The authors [7] also examined the social network among YouTube videos, which has most unique and interesting characteristics, and is substantially contributed to the achievement/success of new generation of service. Also the authors [7] found that the systems of interrelated videos, which are selected based on user-generated content, have both small-world uniqueness of a short characteristic path length linking any two videos, and a large clustering coefficient indicating the grouping of videos. These uniqueness can be exposed to assist the design of novel caching or peer-to-peer approach for short video sharing.

The experimental results of C. Ramachandran, R.Malik, Xin Jin and Jing Gao [8] showed that the Video- Mule has a

good accuracy, precision and recall than individual classifiers and clustering algorithms. Also in future the authors [8] have strategy to expand the evaluation process with data from other video-sharing websites using Video-Mule.

The authors Alex Hindle, Jie Shao Dan Lin, Jiaheng Lu and Rui Zhang [9] developed a web video search system which has extra post-processing functionality of clustering results. This facilitates users to recognize their preferred videos more suitably. The planned information integration framework of [9] is- first attempt to examine the fusion of the diverged information from different sources for clustering. The major infrastructure of the proposed system is completed and is readily extendible to integrate and check other video clip and text comparison algorithms, as well as clustering algorithms, which may be further look up the quality of clustering.

The authors [10] defined a method to produce Visual Affinity Graphs, revealing dissimilar kinds of visual associations between elements in the network. Approximately 38,000 videos, comprising over 2,800 hours, were taken from the website and analyzed. The resultant visual affinity graphs showed considerable quantities of noise/redundancy in the set, with over a third of the results were visually linked to others. The experiments of classification and clustering showed that the supplementary information obtained by automatic tagging can considerably improve the automatic structuring and organization of content; The primary user assessment point outs an information gain for viewers of the videos.

The authors Gloria Chatzopoulou, Cheng Sheng, Michalis Faloutsos [11] analyzed attractiveness in an all-inclusive fashion by searching properties and patterns in time and considering different popularity metrics. The authors [11] further studied the relationship of the popularity metrics and found that four metadata are highly correlated -view count, comments, ratings and favorites while the fifth one, the average rating, and reveals very little correlation with the other metrics. The [11] also found "magic number" in the average behavior of videos- for every 400 times a video is viewed, the authors have one of each of the following user actions- writing a comment, rating the video and adding to one's favorite set.

III. PROPOSED METHODOLOGY

This section presents novel methodology of the proposed work. The metadata objects of online videos are extracted using *Info Extractor* tool [12]. This metadata includes uploader information, category, comments, ratings, length of the video, descriptions about content of the video etc. We propose a novel and effective methodology to cluster large scale web videos using metadata objects such as length, view counts, number of comments and rating information by applying data mining techniques. For experimental purpose, out of the total metadata object dataset, 60% are used for training and remaining 40% are used for testing the cluster model built using Expectation Maximization and Density Based

clustering methods. The cluster results of each considered metadata objects are analyzed in depth. The system model of the proposed technique is represented in Fig. 1, and it consists of the following components:

- A) Web video metadata object extraction
- B) Web video metadata object refinement
- C) Cluster models
- D) Resultant cluster analysis

A). *Web Video Metadata object Extraction*

The different kind of web video metadata objects are extracted using a tool called *InfoExtractor* [12]. The extracted web video metadata objects include- length, rating information, category, etc. The web video metadata objects are then stored in a disk [13] with CSV or ARFF file format for experimental purpose.

format conversion and to recognize the irrelevant metadata objects for the clustering experiment. The WEKA tool is used for file preprocessing and to build cluster models. The extracted raw metadata objects are converted to ARFF or CSV format from the text format to form effective clusters. Some web videos might have less metadata objects information, whereas some web videos might have more metadata objects information [14]. Through interpretation, it is found that, all web videos contains minimum metadata object information such as- length, view counts, ratings, average ratings and number of comments, author information and URL. Among these minimum metadata object information of web videos, only the numeric and nominal metadata objects -length, view counts, ratings, average ratings, category and number of comments are considered for clustering experiment and structure of the dataset considered is represented in Table 1 [14].

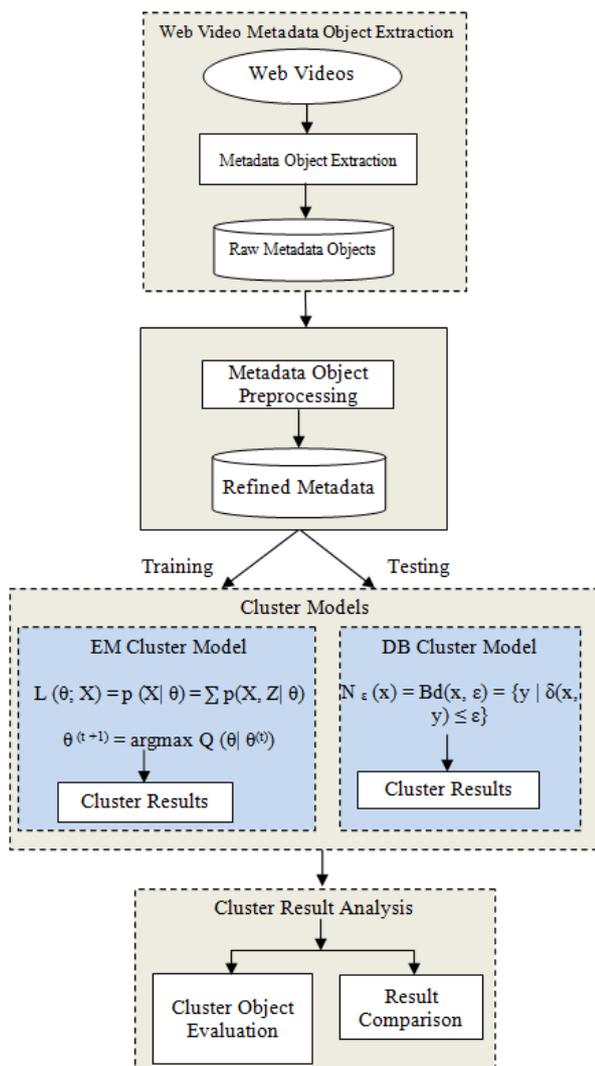


Fig.1. System Model of the Proposed Methodology

B). *Metadata Refinement*

The input to this component is raw metadata objects extracted from the web videos. This raw metadata objects has to be preprocessed for the refinement such as file

Table 1. Structure of Web Video Metadata Dataset

Category	Length	Views	Rate	Ratings	Comments
People & Blogs	217	1157	3.6	5	3
Comedy	426	667	4	4	4
Entertainment	237	1063	4.8	30	10
Sports	294	274	1	1	2
.....
.....

The missing values are replaced by mean of each numeric metadata object and the missing values of the metadata object ‘category’ are replaced by most repeated values.

C). *Building the cluster models*

Two clustering models are used in the proposed method.

- i) Expectation Maximization cluster model
- ii) Density Based cluster model.

The functionality of each cluster model is discussed as follows.

• *Building the Expectation Maximization cluster model*

Expectation Maximization clustering approach is an iterative process [15]. It begins with a primary parameter presumption. Expectation Maximization (abbreviated as ‘EM’) clustering algorithm assigns a probability distribution to each web video metadata object which indicates the probability of it belonging to each of the clusters. The EM algorithm can decide how many clusters to generate by cross validation method. In this experiment, the training set is split randomly into 10 folds.

The cross validation performed to determine the numbers of clusters generated is according to the following steps:

1. By default, the number of clusters is set to 1.

2. The training set is split randomly into 10 folds.
3. EM is performed 10 times using the 10.
4. The log likelihood is averaged over all 10 results.
5. If log likelihood is increased the number of clusters by 1 then the program continues at step 2.

The number of folds is fixed to 10, as long as the number of instances in the training set is not smaller 10. If this is the case the number of folds is set equal to the number of instances.

The parameter values of web video metadata objects are used to compute the likelihood of the current model. This is known as 'Expectation Step'. Given a statistical model which generates a set 'X' of observed data, a set of unobserved latent data or missing values 'Z', and a vector of unknown parameters ' θ ', along with a likelihood function,

$$L(\theta, X, Z) = p(X, Z | \theta) \quad (1)$$

Then the maximum likelihood estimate (MLE) of the unknown parameters is determined by the marginal likelihood of the observed data

$$L(\theta; X) = p(X | \theta) = \sum_z p(X, Z | \theta) \quad (2)$$

Under the current estimate of the parameters $\theta^{(t)}$, the 'Expectation Step' can be calculated by

$$Q(\theta | \theta^{(t)}) = E_{Z|X, \theta^{(t)}} [\log L(\theta, X, Z)] \quad (3)$$

The parameter values are then recalculated to maximize the likelihood. This is known as 'Maximization Step'. The new parameter estimates are used to calculate a new expectation, and then they are optimized again to maximize the likelihood. The parameter which maximizes the given quantity is

$$\theta^{(t+1)} = \underset{\theta}{\operatorname{argmax}} Q(\theta | \theta^{(t)}) \quad (4)$$

This iterative method continues until model convergence. The following is the algorithmic steps to form clusters using Expectation Maximization method.

1. The parameters (θ) of metadata objects of web video are initialized to some random values.
2. For the given parameter values of metadata objects of web video, calculate the best value for missing or unobserved latent values (ie. Z).
3. Then, use the just-calculated values of missing or unobserved latent values (Z) to calculate a better estimate for the parameters of web video metadata object values (θ). Parameters associated with a particular value of missing or unobserved latent values Z will use only those data points whose associated latent variable has that particular value.

4. Iterate steps 2 and 3 until convergence.

- *Building the Density Based cluster model*

Rather than using only the distance between points, Density Based clustering approach uses the local density of points to determine the clusters. In a circle (cluster shape) of radius ϵ around a point x , called the ϵ -neighborhood of x can be calculated as follows:

$$N_\epsilon(x) = Bd(x, \epsilon) = \{y | \delta(x, y) \leq \epsilon\} \quad (5)$$

Here $\delta(x, y)$ is the Euclidean distance between x and y .

In a web video metadata object database D , for any web video metadata object value $x \in D$, we say that x is a core point if there are at least minimum y metadata object values in its neighborhood. In other words, x is a core object value if $|N_\epsilon(x)| \geq y$, where y is a user-defined local density or frequency threshold. A border object value is defined as a object value that does not meet the y threshold. That is, it has $|N_\epsilon(x)| < y$, and is belongs to the neighborhood of some core object value z , i.e., $x \in N(z)$. Finally, if an object value is neither a core nor a border value, then it is called an outlier or a noise object value.

We say that an object value x is directly density reachable from another object value y , if $x \in N_\epsilon(y)$ and y is a core object value. Further, the object value x is density reachable from another object value y , if there exists a chain of points, $x = x_0, x_1, \dots, x_k = y$, such that x_i is directly density reachable from x_{i-1} . Meaning that, there is set of core object values leading from y to x . Finally, define any two points x and y to be density connected if there exists a core point z , such that both x and y are density reachable from z . We can now define a

Density-based cluster as a maximal set of density connected points.

D). Resultant Cluster Analysis

The automatic formed clusters are analyzed in depth for knowledge discovery process. Normal distributions for each cluster are measured. Also structure of resultant cluster objects are analyzed in terms of different web video metadata objects considered for the experiment.

IV. RESULTS AND DISCUSSIONS

This section is focused on in-depth study of cluster analysis of web video metadata objects. The metadata object 'Category' which has different nominal classes, is chosen for cluster evaluation. The 60% of the web video metadata object dataset [16] are trained and 40% are tested for the evaluation of cluster objects.

A. Cluster Analysis using Expectation Maximization Approach

The Table 2 and Table 3 represent cluster result obtained by the Expectation Maximization Approach. Five cluster objects are automatically formed namely,

Cluster 0, Cluster 1, Cluster 2, Cluster 3 and Cluster 4 during the unsupervised clustering method using Expectation Maximization Approach. The properties of each clustered object are discussed as follows:

The ‘Cluster 0’ has least cluster probability and the ‘Cluster 3’ has the highest cluster probability among formed five cluster objects. All the five cluster objects have cluster centroid as – ‘Music’ category web videos.

The detailed ‘category’ based cluster analysis is represented in Fig.2. In Fig.2, the X – axis represents web video metadata object counts and Y-Axis represents 16 different categories of web videos as listed in Table 2 (from ‘People and Blogs’ to Science and technology’ respectively). Also, the Fig.3 represents normal distribution in terms of mean and standard deviation of each numerical web video metadata object.

Table 2. Unsupervised Automatic EM Cluster Objects

Sl.No		<i>Cluster 0</i>	<i>Cluster 1</i>	<i>Cluster 2</i>	<i>Cluster 3</i>	<i>Cluster 4</i>
	Cluster Probabilities →	0.06	0.19	0.23	0.35	0.17
	Category					
1	People & Blogs	125.8543	605.7934	506.889	782.1828	364.2806
2	Comedy	175.6425	451.095	331.6086	637.9954	294.6584
3	Entertainment	415.4066	1358.424	1770.909	2744.796	1301.465
4	How-to & Style	46.9774	298.1039	350.5691	490.9575	167.3921
5	Music	495.999	1327.863	2322.67	3355.796	1756.672
6	Sports	83.6863	374.4819	465.8565	653.9774	273.9979
7	News & Politics	85.2809	233.391	236.486	318.405	177.437
8	Film & Animation	226.061	359.8495	574.4305	1155.5	743.1588
9	Nonprofits & Activism	5.5086	18.6773	31.9984	26.4706	14.3451
10	UNA	49.9197	5.6252	8.7039	47.0667	62.6846
11	Travel & Events	14.7746	216.9608	135.3613	157.9615	61.9417
12	Autos & Vehicles	21.6471	134.2016	90.5184	171.2573	52.3756
13	Education	16.8447	118.144	100.7993	99.1903	30.0218
14	Pets & Animals	22.9445	158.9762	112.2925	214.0684	68.7184
15	Gaming	6.7311	83.5574	80.4027	72.8108	28.498
16	Science & Technology	17.2891	242.7793	127.4119	131.4901	57.0296
	Total	1810.568	5987.923	7246.907	11059.93	5454.676

Table 3. Normal Distribution of Metadata Objects in Resultant EM Clusters

Sl.No	Metadata Objects	Normal Distribution	Cluster 0	Cluster1	Cluster 2	Cluster 3	Cluster 4
1	Length	Mean	246.3689	160.3732	216.6672	218.4776	305.6104
		Std. Deviation	277.7578	144.4847	159.2349	153.8294	377.4888
2	Views	Mean	96418.1841	664.6557	1317.3737	5096.2072	21873.3883
		Std. Deviation	121090.4299	793.9686	1375.036	4741.9052	18530.9799
3	Rate	Mean	4.0289	1.092	5	4.2235	4.6821
		Std. Deviation	1.1642	1.6169	1.6731	0.9131	0.3133
4	Ratings	Mean	170.8535	0.7951	3.1132	10.1359	40.4014
		Std. Deviation	232.5451	1.2307	2.3756	6.6112	26.1341
5	Comments	Mean	158.6655	0.7184	2.5087	8.2193	32.4498
		Std. Deviation	233.9087	1.1161	2.6406	6.9219	25.5269

The ‘Cluster 0’ has ‘Music’, ‘Entertainment’ and ‘Films and Animation’ categories as its major part. The ‘Cluster 0’ contains web videos which are most viewed, good ratings and large number of comments. Meaning that, the popular videos are clustered as ‘Cluster 0’ using metadata objects.

The ‘Cluster 1’ has ‘Music’, ‘People and Blog’ and ‘Entertainment’ categories as its major part. The ‘Cluster 0’ contains web videos which are least viewed, less ratings and less number of comments. Meaning that, the

non-popular videos are clustered as ‘Cluster 1’ using metadata objects.

The ‘Cluster 2’ has ‘Music’, ‘Entertainment’ and ‘Films and Animation’ categories as its major part. The ‘Cluster 2’ contains web videos which are most viewed, high length, average number of rates and ratings, and less number of comments. Meaning that, the high lengths with non-popular videos are clustered as ‘Cluster 2’ using metadata objects.

The ‘Cluster 3’ has ‘Music’, ‘Entertainment’ and

‘Films and Animation’ categories as its major part. The ‘Cluster 3’ contains web videos which are most viewed, high length, average number of rates and good ratings, and less number of comments. Meaning that, the high lengths, most viewed with non-popular videos are clustered as ‘Cluster 2’ using metadata objects.

The ‘Cluster 4’ has ‘Music’, ‘Entertainment’ and ‘Films and Animation’ categories as its major part. The ‘Cluster 4’ contains web videos which are most viewed, high length, high rates and ratings, and average number of comments.

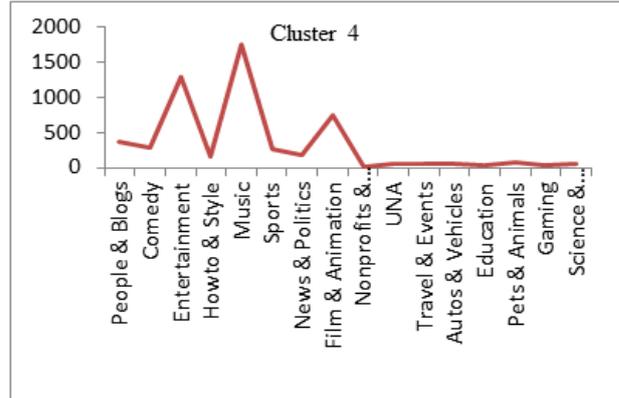
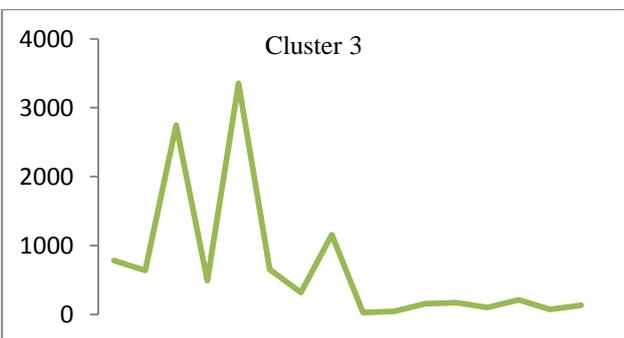
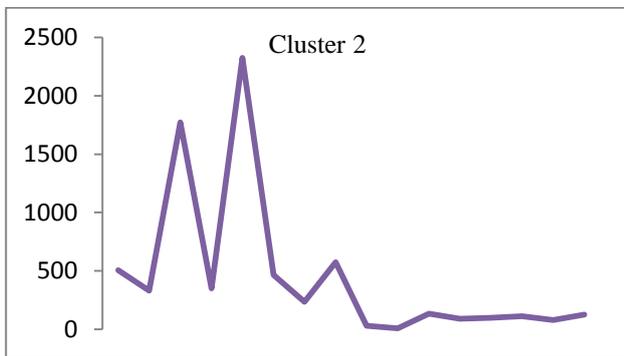
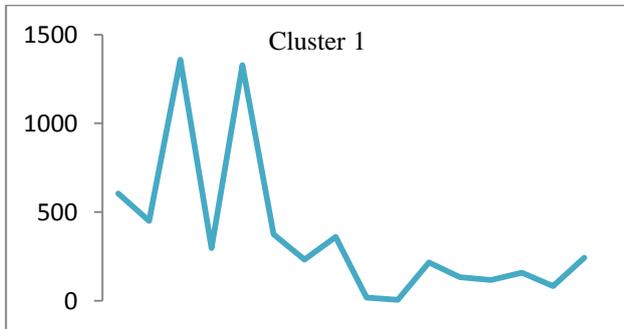
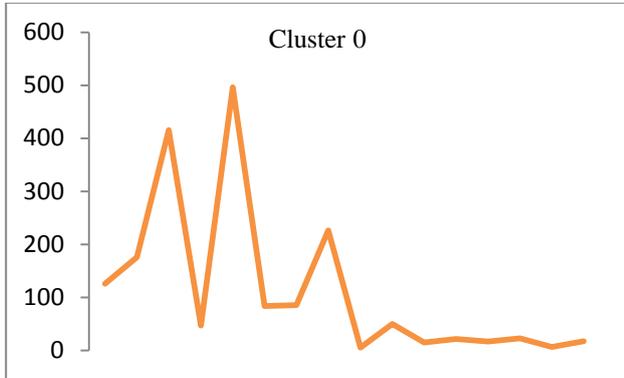
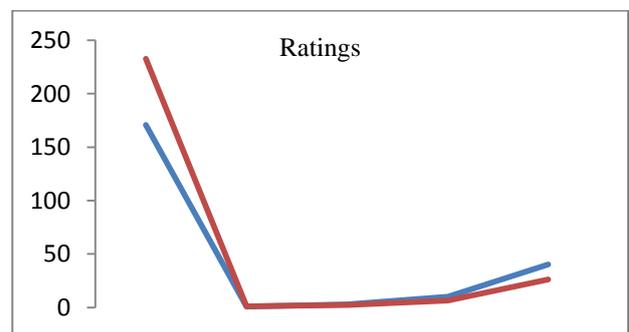
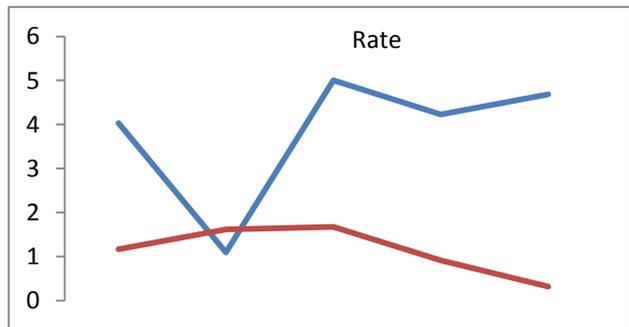
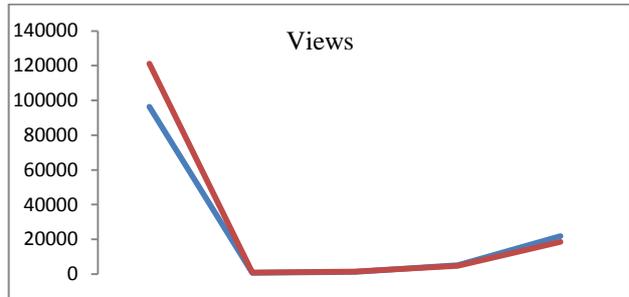
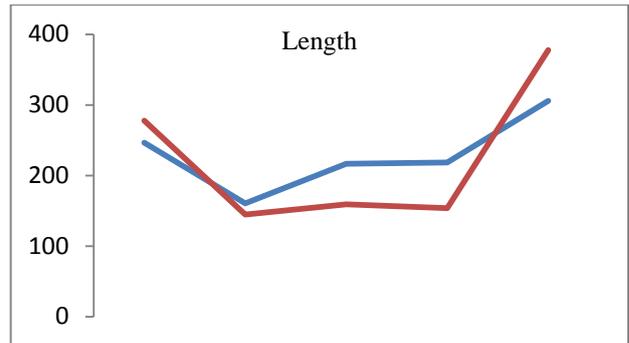


Fig.2. EM Cluster Analysis using ‘Category’



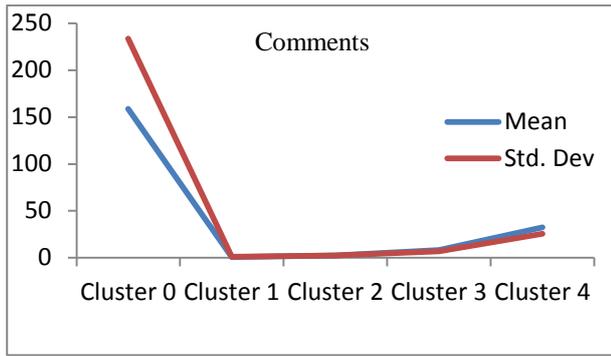


Fig.3. EM Cluster Analysis using Normal Distributions

Meaning that, the high lengths, most viewed with average-popular videos are clustered as ‘Cluster 4’ using metadata objects.

The normal distribution of metadata object ‘Length’ is found well in ‘Cluster 3’ and ‘Cluster 1’ as compared to remaining resultant clustered objects, as shown in Fig. 3 and Table 3. Similarly, the normal distribution of ‘Views’, ‘Ratings’ and ‘Comments’ is found well only in ‘Cluster 0’. In ‘Cluster 2’, the normal distribution is considerable found good for the metadata object ‘Rate’. Also we found that, the Log likelihood of the Expectation Maximization clustering model is: **-27.07905**.

B. Cluster Analysis using Density Based Approach

The Table 4 and Table 5 describes cluster result obtained by the Density Based clustering Approach. Three cluster objects are automatically formed namely, Cluster 0, Cluster 1, and Cluster 2 during the unsupervised clustering method using Density Based clustering Approach. The properties of each clustered object are discussed as follows:

The ‘Cluster 1’ has least cluster probability and the ‘Cluster 0’ has the highest cluster probability among formed five cluster objects. The cluster centroid of ‘Cluster 0’ is ‘Music’ category, the centroid of ‘Cluster 1’ is found ‘Films and Animation’ category, and the cluster centroid of ‘Cluster 2’ is found ‘Entertainment’ category.

The detailed ‘category’ based cluster analysis is represented in Fig.4. In Fig.4, the X – axis represents web video metadata object counts and Y-Axis represents 16 different categories of web videos as listed in Table 4 (from ‘People and Blogs’ to Science and technology’ respectively). Also, the Fig.5 represents normal distribution in terms of mean and standard deviation of each numerical web video metadata object. In Fig.5, X-axis represents distribution units in terms of mean and standard deviation, Y-axis represents ‘Cluster 0’, ‘Cluster 1’ and ‘Cluster 2’ respectively.

The ‘Cluster 0’ has ‘Music’, ‘Sports’ and ‘People and Blogs’ categories as its major part. The ‘Cluster 0’ contains web videos which are High length, most viewed, good rated, average ratings and less number of comments. Meaning that, the popular videos with less number of comments are clustered as ‘Cluster 0’ using metadata objects.

The ‘Cluster 1’ has ‘Films and Animation’, ‘Sports’ and ‘Comedy’ categories as its major part. The ‘Cluster 1’

contains web videos which are High length, large number of viewed, average rated, average ratings and less number of comments. Meaning that, the average -popular videos with less number of comments are clustered as ‘Cluster 0’ using metadata objects.

The ‘Cluster 2’ has ‘Entertainment’, ‘Sports’ and ‘People and Blogs’ categories as its major part. The ‘Cluster 2’ contains web videos which are comparatively small in length, less viewed, poor rated, less ratings and very less number of comments. Meaning that, the non-popular videos with less number of comments are clustered as ‘Cluster 0’ using metadata objects.

Table 4. Unsupervised Automatic DB Cluster Objects

	Cluster 0	Cluster 1	Cluster 2
Cluster Probabilities →	0.5001	0.1423	0.3576
Category			
People & Blogs	1353	252	778
Comedy	965	277	647
Entertainment	1	1	7587
How-to & Style	820	157	375
Music	9255	1	1
Sports	1166	233	451
News & Politics	628	140	281
Film & Animation	1	3055	1
Nonprofits & Activism	62	8	25
UNA	92	38	42
Travel & Events	309	55	221
Autos & Vehicles	252	60	156
Education	191	41	131
Pets & Animals	278	97	200
Gaming	141	22	107
Science & Technology	247	57	270
Total	15761	4494	11273

Table 5. Normal Distribution of Metadata Objects in Resultant DB Clusters

Metadata Objects	Normal Distribution	Cluster 0	Cluster 1	Cluster 2
Length	Mean	239.871	245.5234	192.352
	Std. Dev	211.736	260.9182	214.25
Views	Mean	11937.57	15878.49	9123.86
	Std. Dev	37663.23	48179.50	31252.79
Rate	Mean	4.431	4.1397	2.9945
	Std. Dev	1.1959	1.1414	2.0184
Ratings	Mean	24.1054	28.3618	14.1239
	Std. Dev	75.9427	88.1207	45.3857
Comment	Mean	20.1799	22.0386	14.0359
	Std. Dev	72.6342	74.4091	56.0402

Also we found that, the Log likelihood of the Density Based clustering model is: **-33.64669**. Note that, the

difference between log likelihood of Expectation Maximization cluster model and density Based cluster model is approximately 6.

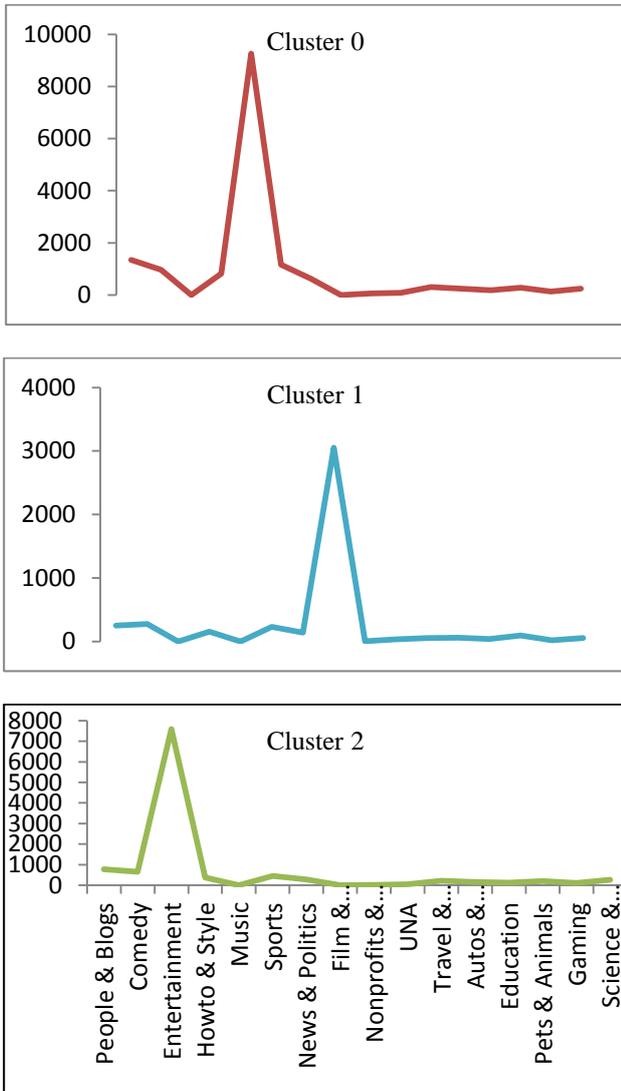


Fig.4. DB Cluster Analysis using 'Category'

V. CONCLUSION AND FUTURE WORK

In this work, effective attempts are made to cluster web videos based on metadata objects such as – category, view counts, length, number of comments, and rating information. The clusters are made to form automatically using unsupervised Expectation Maximization (EM) and Density Based (DB) clustering approach. Effective clustering models were built using EM and DB algorithms and applied on large scale web video metadata object dataset. Different clusters were formed according to the web video metadata objects. The each resultant clusters are analyzed in depth and normal distribution of each numerical metadata object within clusters are found. Also we found, the log likelihood of EM and DB cluster models. The future work is to enhance this experiment to detect and find out the outlier/abnormal web videos among large scale web video dataset.

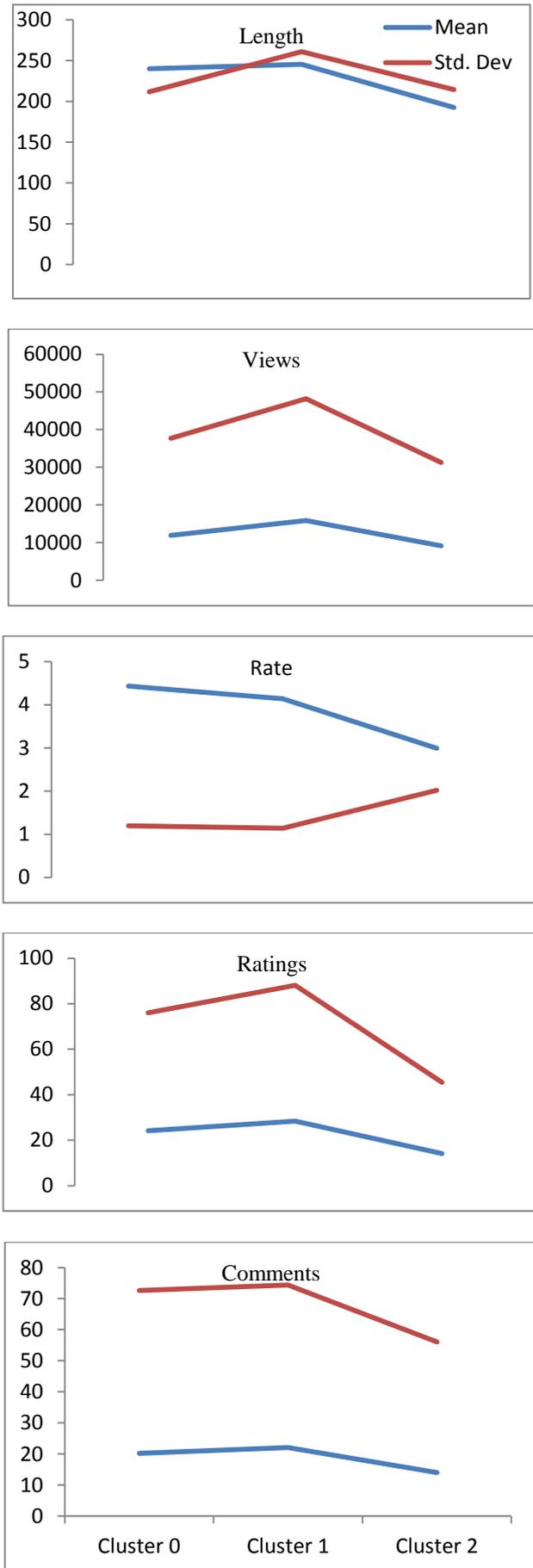


Fig.5. EM Cluster Analysis using Normal Distribution

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