

SSM-DENCLUE: Enhanced Approach for Clustering of Sequential Data: Experiments and Test Cases

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ABSTRACT

Clustering web usage data is useful to discover interesting patterns related to user traversals, behavior and their characteristics, which helps for the improvement of better Search Engines and Web personalization. Clustering web sessions is to group them based on similarity and consists of minimizing the Intra-cluster similarity and maximizing the Inter-group similarity. The other issue that arises is how to measure similarity between web sessions. There exist multiple similarity measures in the past like Euclidean, Jaccard, Cosine and many. Most of the similarity measures presented in the history deal only with sequence data but not the order of occurrence of data. A novel similarity measure named SSM (Sequence Similarity Measure) is developed that shows the impact of clustering process, when both sequence and content information is incorporated while computing similarity between sequences. SSM (Sequence Similarity measure) captures both the order of occurrence of page visits and the page information as well, and compared the results with Euclidean, Jaccard and Cosine similarity measures. Incorporating a new similarity measure, the existing Density clustering technique DENCLUE is enhanced and the new named as SSM-DENCLUE for Web personalization. The Inter-cluster and Intra-cluster distances are computed using Average Levenstien distance (ALD) to demonstrate the usefulness of the proposed approach in the context of web usage mining. This new similarity measure has significant results when comparing similarities between web sessions with other previous measures, and provided good time requirements of the newly developed SSM-DENCLUE algorithms. Experiments are performed on MSNBC.COM website (free online news channel), in the context of Density based clustering in the domain of Web usage mining.

General Terms

Sequence Mining, Clustering, Density Based Clustering

Keywords

Data Mining, Clustering, similarity measures, Web Personalization, DENCLUE, SSM-DENCLUE.

1. INTRODUCTION

1.1 Data Mining

Data mining, called Knowledge Discovery in Databases (KDD) an interdisciplinary subfield of computer science is the process of identifying knowledge / patterns in large heterogeneous data sets. The goal of the Data mining process is to extract information from a data set, preprocess and transform it into an understandable structure for further use. Various stages of Data mining are Selection, Preprocessing, Transformation, Data mining, Interpretation and evaluation. The various Data mining techniques are

Classification, Clustering, Prediction, Association and Discrimination.

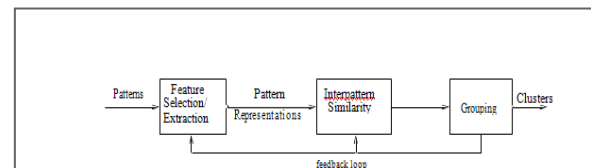


Figure 1: Data Mining Architecture

1.2 Clustering

Is a process of categorizing the data into multiple clusters where all the patterns lying in one cluster are similar to one another and dissimilar when compared to the patterns lying in the other cluster. Different types of clustering techniques are partitioning, Hierarchical, Density-based, Grid-based and Model-Based algorithms. In Density-based clustering, clusters are defined as areas of higher density than the remainder of the dataset. The most popular Density based clustering method is DBSCAN, OPTICS and DENCLUE. They start with an arbitrary starting point P that has not been visited and its e-neighborhood is retrieved, and if it contains sufficient number of points, a cluster is started. Otherwise, the point is labeled as noise.

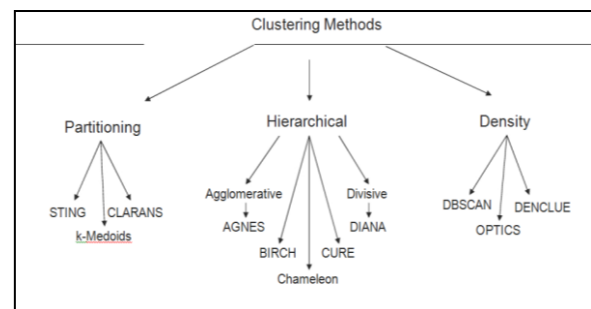


Figure 2: Types of clustering techniques

1.3 Sequence Mining

Sequential Pattern mining is interdisciplinary subfield of Data mining concerned with finding relevant patterns described in a sequence. Given a sequence database $D = \{S_1, S_2, \dots, S_n\}$ where each sequence S is an ordered list of events/items $\langle i_1, i_2, \dots, i_n \rangle$. There are several key traditional computational problems addressed within this field. These include building efficient databases and indexes for sequence information, extracting the frequently occurring patterns, comparing sequences for similarity, and recovering missing sequence numbers. In general, sequence mining problems can be classified as string mining which is typically based

on string based algorithms and itemset mining which is typically based on association rule mining.

1.4 Web Personalization

Web personalization is the process of identifying what users are exactly looking for on the web, their traversals and their behavior. Due to the continuous growth of the Web data , Web personalization has become one of the challenging task for the researchers and commercial areas. The steps of a Web personalization process include: the collection of Web data, modeling and categorization of these data (preprocessing phase), the analysis of the collected data, the determination of the actions that should be performed. Web data are collected and used in the context of Web personalization. These data are classified in four categories .web Structure data represent how pages are linked to one another. Web usage data represents what users are exactly looking for on the Web and their characteristics such as a visitor’s IP address, time and date of access, complete path (files or directories) accessed, referrers’ address, and other attributes that can be included in a Web access log.

1.5 Similarity Measures

Similarity measure are used to find out how similar are two sequences are. In the history many similarity measures exist, and they are Euclidean, Jaccard, Cosine, Manhattan and Minkowski measures. These similarity measures are vector based. Euclidean distance measure is frequency based similarity measures for two sequences S_1 and S_2 in an N- dimensional space. It is defined as the square root of the sum of the corresponding dimensions of the vector. The Euclidean distance between sequences $S_1=(p_1, p_2, \dots, p_n)$ and $S_2=(q_1, q_2, \dots, q_n)$ is defined as

$$\begin{aligned} Sim(S_1, S_2) &= \frac{S_1 S_2}{\sqrt{(S_{11} - S_{21})^2 + (S_{12} - S_{22})^2 + \dots + (S_{1n} - S_{2n})^2}} \\ &= \frac{S_1 S_2}{\sqrt{\sum_{i=1}^n (S_{1i} - S_{2i})^2}} \end{aligned}$$

Jaccard similarity measure is defined as the ratio of the intersection of items between the two sequences to the union of items of the two sequences.

$$(Sim(S_1, S_2)) = \frac{S_1 S_2}{|S_1|^2 + |S_2|^2 - S_1 S_2}$$

Cosine similarity measure is the angle between two vectors. The cosine measure is given by

$$Sim(S_1, S_2) = \frac{\sum_{i=1}^n (S_1 \times S_2)}{\sqrt{\sum_{i=1}^n (S_{1i})^2} \times \sqrt{\sum_{i=1}^n (S_{2i})^2}}$$

1.6 SSM-Sequence Similarity Measure

In this work a novel similarity measure [2] is used that captures both the order of information as well as content(information) called the SSM(sequence similarity measure).

$$\begin{aligned} SSM(S_1, S_2) &= \frac{S_1 \cap S_2}{S_1 \cup S_2} * FC(S_1, S_2) \\ &+ \frac{LLCS(S_1, S_2)}{\sqrt{\sum_{i=1}^n (S_{1i})^2} \times \sqrt{\sum_{i=1}^n (S_{2i})^2}} \end{aligned}$$

2. EXISTING METHODOLOGY

Usually when dealing with sequences, the data is converted into n-dimensional frequency vectors. The vector representation can be either indicating presence or absence of symbol in a sequence, or, indicating frequency of symbol within a sequence. While computing similarity between sequences they either consider the content /information or the order information. In the existing work the sequences are converted to intermediate representations and the similarity between any two sequences is calculated using any of the similarity measures like Euclidean, Jaccard, Cosine. DENCLUE can be applied for clustering. Similarity are calculated which illustrates the similarity between the sequences. And the Inter cluster similarity has to be maximized and Intra cluster similarity has to be minimized.

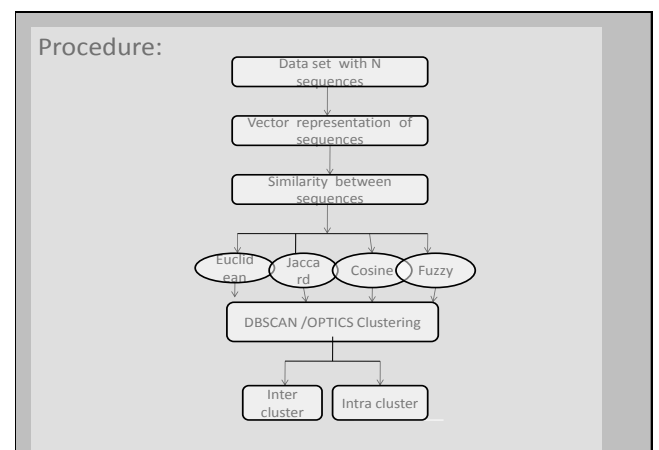


Figure 3: Existing Work Procedure

3. PROPOSED WORK

The work concentrates on Clustering technique on the domain of web usage data . A new similarity measure [6] is used to measure similarity/distance between two sequences and experiments are conducted on Density -based clustering using existing clustering called DENCLUE and the enhanced Density clustering algorithm like SSM-DENCLUE respectively .In all the experiments the running time of the new similarity measure is as accurate as the best compared to the earlier similarity measures . An experimental framework for sequential data stream mining on clustering on web usage data is built.

3.1 Experimental Results

3.1.1 Web Navigation dataset used for Testing

MSNBC is a joint venture between Microsoft and NBC(National Broad casting) is a famous online news website with has different news subjects. There are 17 categories of news like frontpage,news,tech,local,opinion,onair,weather,health,living, business,sports,summary,bbs,travelmisc,msn-news and msn-sports. For example, ‘frontpage’ is coded as 1, ‘news’ as 2,

'tech' as 3, etc. Web Navigational dataset is considered in Table 5.1

Table 1. Web Navigational Dataset

T1	on-air misc misc misc on-air misc
T2	news sports tech local sports ,sports
T3	Sports bbs bbs bbs bbs bbs bbs
T4	frontpage frontpage sports news news local
T5	on-air weather weather weather sports,sports
T6	on-air on-air on-air on-air tech bbs
T7	frontpage bbs bbs frontpage frontpage news
T8	frontpage frontpage frontpage frontpage frontpage bbs
T9	news news travel opinion opinion msn-news
T10	frontpage business frontpage news news bbs

Table 2. Converted Web Navigational dataset

Sequence	Order of page visists
T1	6,15,15,15,6,15
T2	2,11,3,4,11,11
T3	11,13,13,13,13,13
T4	1,1,11,2,2,4
T5	6,7,7,7,11,11
T6	6,6,6,6,3,6
T7	1,13,13,1,1,2
T8	1,1,1,1,1,13
T9	2,2,14,5,5,16
T10	1,10,1,2,2,13

3.2 DENCLUE and SSM-DENCLUE Clustering Technique

3.2.1 Experiments on Synthetic web Navigational Dataset for DENCLUE

Consider arbitrarily 200 records of web transactions from MSNBC.COM website. The transactions are converted to vector representation, and a 200 X 200 similarity matrix is computed using any of the existing similarity measures mentioned above. In the step two after applying existing Denclue clustering technique the clusters formed are 17. Table 7.4, 17 X 17 matrix which shows the inter cluster distance using Euclidean distance measure. For example, the inter cluster distance (C1,C2)=0.15. and inter cluster distance between the clusters (C3,C16)=0.31. That is the patterns lying in the cluster C3 are more dissimilar when compared to the patterns lying in the cluster C16.

Table 3: Inter Cluster Distance Using Euclidean Distance Measure for Denclue

C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
X																	
C																	
i																	

C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	5	6	6	6	6	7	7	8	8	9	9	9	1	2	2	3	4
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
5	6	3	2	4	5	5	5	6	7	9	1	6	7	7	1	1	1
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
8	6	4	4	8	6	6	6	6	7	8	8	9	1	2	2	2	2
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
11	6	3	5	8	6	6	7	8	1	2	3	4	4	5	5	5	5
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2
14	7	3	5	8	6	6	1	1	2	3	4	5	5	5	6	6	6
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2	2
17	7	4	5	9	6	7	1	8	8	8	8	9	9	9	1	1	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2	2
20	8	5	6	9	7	8	1	8	1	2	4	5	6	7	1	1	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	1	1	1	1	1	2	2	1	2	2	2	2	2	2	2	2	2
23	8	6	7	9	7	1	2	8	1	2	3	3	4	4	5	5	5
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	1	1	1	2	1	2	2	1	2	2	1	1	1	1	2	2	2
26	9	7	9	1	8	2	3	8	1	2	8	9	9	1	1	2	2
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	1	1	2	2	1	2	2	1	2	2	1	1	1	1	2	2	2
29	9	8	1	1	8	3	4	8	2	3	8	9	4	4	1	4	4
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	2	2	2	2	1	2	2	1	2	2	1	1	1	2	2	2	2
32	1	1	6	2	9	4	5	9	4	3	9	9	1	2	3	4	4
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	2	2	2	2	2	2	2	1	2	2	1	1	2	2	2	2	2
35	2	2	7	3	1	4	5	9	5	4	9	4	1	5	6	6	6
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	2	2	2	2	2	2	1	2	2	2	1	2	2	2	2	2	2
38	3	3	7	4	2	5	5	9	6	4	1	4	2	5	4	4	4
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
41	4	4	1	4	2	5	6	1	7	5	1	1	3	6	4	1	9

9	1	1	1	1	1	1	2	2		2	2	1	1	1	2	1
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	9	6	3	7	8	8	9	2	1		2	9	9	7	2	8
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	9	6	4	6	4	6	5	6	1	2	2	7	3	3	2	4
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	9	6	3	7	8	7	8	7	7	9	7	8	7	8	7	7
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	2	7	3	8	9	6	7	8	8	9	3	8		6	7	8
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	7	4	7	6	5	6	8	6	7	3	7	6		6	8
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	2	8	5	8	7	6	4	7	1	2	2	8	7	6		7
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	8	6	7	8	8	7	7	8	8	4	7	8	8	7	

3.2.2 Experiments on Synthetic web Navigational Dataset for SSM-Denclue

Consider arbitrarily 200 records of web transactions from MSNBC.COM website. The transactions are converted to vector representation, and a 200 X 200 similarity matrix is computed using any of the existing similarity measures mentioned above. In the step two after applying SSM-DENCLUE clustering technique the clusters formed are 15. Table 6 15 X 15 matrix which shows the inter cluster distance using Euclidean distance measure.

Table 6: Inter Cluster Distance Using Euclidean Distance for SSM-Denclue

	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	6	7	7	7	8	9	1	9	9	9	9	9	9	9	9
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
6	7	7	8	7	7	8	8	7	6	6	6	7	7	7	8
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
7	7	7	1	2	3	4	4	4	3	4	3	3	4	5	
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1

	7	8	1		1	2	4	6	8	2	4	5	5	5	6
C	0	0	0	0		0	0	0	0	0	0	0	0	0	0
5	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
7	7	7	2	1		7	6	7	7	6	6	6	7	7	8
C	0	0	0	0	0		0	0	0	0	0	0	0	0	0
6	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
8	8	7	3	2	7		1	2	2	3	4	3	3	4	5
C	0	0	0	0	0	0		0	0	0	0	0	0	0	0
7	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
9	8	4	4	6	1		9	8	9	7	9	2	2	1	2
C	0	0	0	0	0	0	0		0	0	0	0	0	0	0
8	2	1	1	1	1	1	1	0	1	1	2	1	1	1	1
1	1	8	4	6	7	2	9		7	6	1	7	8	8	8
C	0	0	0	0	0	0	0	0		0	0	0	0	0	0
9	1	1	1	1	1	1	1	1	0	2	2	1	1	1	2
9	7	4	8	7	2	8	7		1	2	7	8	8	2	
C	0	0	0	0	0	0	0	0	0		0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	2	0	1	1	1	1
0	9	6	3	2	6	3	9	6	1		7	7	8	8	9
C	0	0	0	0	0	0	0	0	0	0		0	0	0	0
1	1	1	1	1	1	1	1	1	1	2	1	0	1	1	1
1	9	6	4	4	6	4	7	1	2	7		6	4	6	5
C	0	0	0	0	0	0	0	0	0	0	0		0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
2	9	6	3	5	6	3	9	7	7	7	7		8	7	8
C	0	0	0	0	0	0	0	0	0	0	0	0		0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
3	2	7	3	5	7	3	2	8	8	8	8	4		6	7
C	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
4	1	7	4	5	7	4	1	8	8	8	8	6	7	6	
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
5	2	8	5	6	8	5	2	8	2	9	5	8	7	6	

3.2.2 Experiments on Standard web Navigational Dataset

Considered transactions of varying sizes of 5000, 10000,20,000,30000,40000 from MSNBC dataset. Table 7 shows the number of clusters formed by applying the existing DENCLUE clustering technique and enhanced SSM-DENCLUE. Using the different similarity measures like Euclidean, Jaccard, Cosine, the Inter cluster similarity and Intra cluster similarity are calculated.

Table 7. Inter and Intra cluster distance for DENCLUE and SSM-DENCLUE

DENCLUE -CLUSTERING RESULTS USING EUCLIDEAN					
No of Samples	5000	10000	20000	30000	40000
No of clusters formed	82	124	155	116	189
Inter cluster	4.5	4.9	5.124	6.893	6.989
Average inter cluster	0.056	0.037	0.031	0.061	0.039
Average Intra cluster	4.27	4.000	4.989	6.867	5.896
CLUSTERING RESULTS USING JACCARD					
No of samples	5000	10000	20000	30000	40000
No of clusters formed	99	114	147	135	197
Inter cluster	4.281	4.317	5.213	8.153	7.298
Average Inter cluster	0.043	0.037	0.035	0.060	0.037
Average Intra cluster	4.013	4.291	5.222	7.293	8.123
CLUSTERING RESULTS USING COSINE					
No of samples	5000	10000	20000	30000	40000
No of clusters formed	96	123	156	115	191
Inter cluster	4.6	6.367	7.214	8.135	6.721
Average Inter cluster	0.047	0.051	0.039	0.070	0.035
Average Intra cluster	4.25	4.285	6.279	7.284	6.912
(SSM-DENCLUE) CLUSTERING RESULTS USING SSM					

Size of sequences	5000	10000	20000	30000	40,000
No of clusters	94	126	149	141	187
Inter cluster	4.681	4.317	5.213	8.153	7.298
Average Inter cluster	0.043	0.037	0.035	0.060	0.037
Average Intra cluster	4.013	4.291	5.222	7.293	8.123

4. TIME REQUIREMENTS

Experiments were performed on the above mentioned dataset of varying sizes ,to see the performance of proposed clustering algorithm. The number of clusters formed using DENCLUE for varying sizes of 5000, 10000, 20000, 30000 and 40000 transactions are recorded. The execution time taken for these varying sizes of samples are recorded.

Table 8 Time Requirements of DENCLUE And SSM-DENCLUE

DENCLUE					
Size of sequences	5000	10000	20000	30000	40,000
No of clusters	83	123	156	115	191
Time taken in seconds	1566	2665	2785	3218	3196
SSM-DENCLUE					
Size of sequences	5000	10000	20000	30000	40,000
No of clusters	94	126	149	141	187
Time taken in seconds	1085	1879	3643	1956	2498

5. CONCLUSIONS

Considered arbitrarily web transactions of equal length from the MSNBC dataset and performed the experiments DENCLUE and SSM-DENCLUE clustering techniques. We used previously existing four different distance/similarity measures namely Euclidean , Jaccard, Cosine, and the newly developed measure called SSM. In DENCLUE the number of clusters are 21,18,18 using Euclidean, Jaccard and Cosine respectively . For good clustering algorithm, the intra cluster distance should be minimum. SSM measure which is a combination of sequence as well as set measure, confirms that the web clustering should consider the sequence as well as set

value. For example in SSM-DENCLUE for 5000 samples ,the time taken for execution are 1085,1879,3643,1956,2498 respectively. The time taken to execute the algorithm SSM-DBSCAN is less when compare to other clustering techniques .

A variety of experiments are performed in the context of Density based clustering. A new similarity measure for sequential data (*SSM*) is devised and incorporated SSM with DENCLUE for Web Usage sequential data. Our results by the way of explanations and list of conclusions, finally showed behavior of clusters that made by enhanced SSM-DENCLUE clustering technique on a sequential data in a web usage domain. This new SSM-DENCLUE required less time complexity than the existing.. This experiment shows that, in addition to the content if Sequential Information is also added it improves the quality /accuracy of the clustering. So Sequential information is important as well as Content information is also important.

5.1 Future Work

we extend our work in future to other clustering techniques and to other domains as well.

- Developing new similarity measures for continuous and discrete sequential data.
- Applying these new clustering techniques to the domains like medical, defense, bioinformatics etc.
- This work can be extended to sequences of unequal length.

- The time complexities of the proposed algorithms can be improved further.

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