Organization of Information for the Web using Hierarchical Fuzzy Clustering Algorithm based on Co-Occurrence Networks

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Abstract—In this paper, we present a Hierarchical Fuzzy Clustering algorithm which uses domain knowledge to automatically determine the number of clusters and their initial values. The algorithm is applied on a collection of web pages and the results are compared with existing algorithms in the literature.

Keywords—Web Mining; Fuzzy and Hierarchical Clustering; Information Retrieval

I. INTRODUCTION

Searching information on the web is a common task where the goal is to return a number of web pages corresponding to the searched keywords entered by the user. Typically, document clustering techniques consider *documents* as entities and calculate a similarity between documents based on the *keywords* appearing in these documents. This similarity is further used to group similar documents together to obtain clusters. Intuitively, an alternative approach is to consider *keywords* as entities related to each other if they appear in a single document. Clustering keywords can group *Themes* together such that when a keyword is searched, its theme can be identified from the cluster it belongs to. Obviously documents can be associated to these *themes* and returned as search result to the user. There are a number of issues that need to be addressed before selecting the right clustering methodology which are discussed below.

An important issue is whether the clustering algorithm should generate Hard clusters or Soft clusters i.e. documents (or web pages) should belong to unique clusters or may be associated to more than one cluster. Researchers have shown that very often, a web page can belong to more than one category and thus it is more useful to use Soft or Fuzzy clustering algorithms [1]. Another important decision is to choose between Hierarchical or Flat clustering. Naturally, information around us is organized in a hierarchical manner. Again this claim is supported by many researchers that tend to organize documents and web pages in hierarchies [6].

Having said that we need hierarchical and fuzzy clustering approaches to cluster web pages, we would like to point out some other requirements induced by the domain, that is, the web. In terms of hierarchical clustering, generating a hierarchy of high depth is not suitable, as the famous Three-Click Rule [13] suggests, users tend to abandon a site if they

don't find their required information within three clicks. Another requirement from the fuzzy perspective is that once we have calculated the degree of similarity of a web page to various clusters, we need to find a threshold which assures that only the relevant pages are grouped together. Finally the classical problem of deciding the number of clusters to be generated, in case of a hierarchical algorithm, the number of clusters generated at each level are also important.

In this paper, we take a different approach to solve all these issues by looking at the co-occurrence network of the keywords of the web pages. A co-occurrence network is a graph where the nodes are represented by *keywords* and edges between keywords imply that they appear together at least once in a web page. These networks have some interesting properties that can be used to devise heuristics which can eventually help us resolve issues described earlier. Based on these properties, we propose a new Hierarchical Fuzzy Clustering Algorithm based on Co-Occurrence Networks (HFC-CN) where we claim that the algorithm does not require any parameter as input. The performance of the proposed algorithm is compared with other existing algorithms and the results are quite satisfactory.

For experimentation, we have used three different data sets. These data sets are a collection of web pages found on Wikipedia encyclopedia. These web pages were returned as a search result when *Jaguar*, *CAC40* and *Hepburn* were launched as a query on the Exalead (<http://www.exalead.com/search/wikipedia/>) search engine. In each case, the top 50 results were considered and *keywords* from these web pages were extracted by the Exalead Search Engine.

II. RELATED WORK

There are a number of document clustering algorithms present in the literature. An exhaustive overview of these algorithms remains out of the scope of this paper. Our focus in this paper is information retrieval, which in the current context means that a user has one or more than one keywords and the goal is to search for documents containing those keywords within a collection of documents.

As described previously, in this paper, we present a new approach to document clustering which is based on clustering keywords. These clusters are then used to regroup

Figure 2. Degree Distribution of Jaguar Co-Occurrence Network.

used to calculate the centroid of the cluster for this theme. The algorithm to detect the number of clusters and their centroids is listed below:

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Input  $G(V, E)$ 
 $var = MaxDeg$ 
while  $var \geq cutoff$  do
   $G' = calculate(Min_{var} - DIS)$ 
  if  $isNotClique(nodes(G'))$  then
    Call Procedure  $IdentifyThemes(G')$ 
  end if
   $var = var - 1$ 
end while
Procedure  $IdentifyThemes(G')$ 
for all  $i$  such that  $i$  not connected to all nodes in  $G'$  do
  Find Nodes connected to  $i$  at distance 1 in  $G$ 
  Group Nodes as a Centroid
end for

```

Algorithm: Detection of Number of Clusters and their Centroids.

The above algorithm requires a parameter *cutoff* as input which represents the value up to which the Min_d -DIS is calculated. To determine this value, we use a heuristic proposed by [12] to determine the high degree nodes in a scale free network. Looking at Figure 2, it is quite clear that there are nodes that dominate the number of connections by having a high node degree. Semantically, it is quite obvious, if we search for the word *Jaguar* on the web, all the pages returned will surely have this word and thus would have a very high degree as compared to the other words appearing in this collection of web pages.

To find out these high degree nodes, we calculate the slope of every two consecutive points of the degree distribution. At point *a* in Figure 2, the slope becomes equal to zero. The heuristic suggests that as the slope becomes zero or close to zero (values of -1 or -2) the point can be considered as the cutoff point where the nodes lying after this point represents the nodes that have relatively high node degree as compared to other nodes in the network. Since our goal is to generate a hierarchical clustering, we need to generate

Figure 3. Min_{80} -DIS for the Jaguar example

Figure 4. Min_{50} -DIS for the Jaguar example

different *cutoff* points to incorporate the multilevel structure. Another point that stands out in the degree distribution of these co-occurrence networks is at some value for node degree, the number of nodes attain a maximum number, as pointed by *b* in Figure 2. Since our goal is to generate a hierarchy of up to three levels, the second cutoff is considered to be the arithmetic mean of point *a* and *b* where as the third cutoff is the point *b*.

B. HFC-CN Algorithm

Once we have calculated the cluster centroids, the remaining algorithm to generate a fuzzy clustering is quite simple. First we cluster all the remaining nodes in the co-occurrence network by assigning them to one of the centroids. As a result, we generate a hard and partitional clustering for the network. We then calculate for each document in the collection its degree or relevance to these centroids giving us a fuzzy clustering where a document can belong to more than one centroid. To generate a hierarchical clustering, we run the algorithm for different values of *cutoff* where at each level, only the nodes belonging to a cluster are considered as compared to the whole network.

The resulting algorithm gives us a divisive hierarchical fuzzy clustering for the document collection. Each document has an associated degree of relevance to the other cluster centroid which in some cases can be 0 as well. The results of the quality of clustering produced are tabulated in Table I.

IV. EXPERIMENTATION AND RESULTS

To measure the validity of the clustering produced by the proposed algorithm as compared to the FAHC and H2D-

Partition Coefficient	Clustering Algorithms		
	FAHC	H2D-FCM	HFC-CN
Jaguar	0.415	0.357	0.349
Hepburn	0.385	0.317	0.357
CAC40	0.279	0.252	0.279
Partition Efficiency			
Jaguar	0.566	0.736	0.607
Hepburn	0.438	0.479	0.463
CAC40	0.456	0.504	0.495

Table I
COMPARING THE RESULTS OF CLUSTERING ALGORITHMS USING
PARTITION COEFFICIENT AND PARTITION EFFICIENCY.

FCM algorithms, we use two validity indices used in the fuzzy environment. The Partition Co-efficient(PC) [8] and Partition Efficiency(PE) [3]. Both these methods are based on only the membership values[9] of an artifact to various clusters. The PC index indicates the average relative amount of membership sharing done between pairs of fuzzy subsets. The values range in $[1/c, 1]$ where c is the number of clusters. The PE index is a scalar measure of the amount of fuzziness in a given fuzzy clustering where the values range in $[0, \log c]$. In both these cases low values indicate high clustering quality. To handle the hierarchical clustering, for each level we compute these validity indices and then we take the average over the different hierarchical levels. Recall that we have forced the algorithms to produce a hierarchy of at most 3 levels.

Table I shows the results obtained by the HFC-CN algorithm as compared to the other two clustering algorithms using Partition Coefficient and Partition Efficiency respectively. It can easily be concluded that the algorithm performs as well as the other algorithms and determines correctly the number of clusters as well as the cluster centroids.

An important feature of the proposed algorithm as compared to other algorithms is the way the initial centroids are calculated. The other algorithms use only one single document as a centroid either chosen randomly, or based on the dissimilarity of existing centroids and a new document. The proposed method identifies important keywords and then calculates the initial cluster centroids based on a number of documents containing those keywords. Moreover, since the clustering is based on similarity of words as compared to similarity of documents, the topics that are similar based on some theme are grouped together and we only calculate the similarity of documents to the set of words that are clustered together. This seems to work well as semantically when we look at the clusters produced by the clustering algorithm, they are indeed coherent.

V. CONCLUSION

In this paper, we have presented a divisive fuzzy clustering algorithm for documents using graph theoretical concepts on the co-occurrence network of keywords obtained from a

collection of web pages. We have addressed the well know problems of the detection of number of clusters, the initial centroids and the depth of hierarchy to be generated in the context of information retrieval and web pages. Comparative results show that the proposed method performs well as two other well known algorithms used to produce Hierarchical Fuzzy Clustering for documents.

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