A Comparative Analysis of Web Page Ranking Algorithms

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Abstract- Web is expending day by day and people generally rely on search engine to explore the web. In such a scenario it is the duty of service provider to provide proper, relevant and quality information to the internet user against their query submitted to the search engine. It is a challenge for service provider to provide proper, relevant and quality information to the internet user by using the web page contents and hyperlink between the web pages. This paper deals with analysis and comparison of web page ranking algorithms based on various parameter to find out their advantages and limitations for the ranking of the web pages. Based on the analysis of different web page ranking algorithms, a comparative study is done to find out their relative strengths and limitations to find out the further scope of research in web page ranking algorithm.

Keywords Web page ranking, Page Rank, HITS, WCM ,WSM,WUM.

I INTRODUCTION

As the volume of information on the internet is increasing day by day so there is a challenge for website owner to provide proper and relevant information to the internet user. Figure 1 [2] shows a working of a typical search engine, which shows the flow graph for a searched query by a web user.

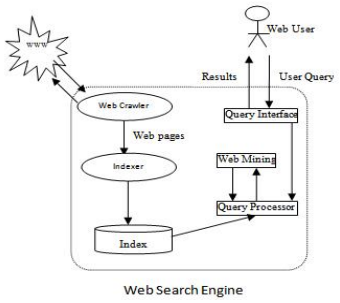

Figure 1: Working of Search Engine

An efficient ranking of query words has a major role in efficient searching for query words. There are various challenges associated with the ranking of web pages such that some web pages are made only for navigation purpose and some pages of the web do not possess the quality of self descriptiveness. For ranking of web pages, several algorithms are proposed in the literatures.

The motive behind this paper to analyze the currently important algorithms for ranking of web pages to find out their relative strengths, limitations and provide a future direction for the research in the field of efficient algorithm for ranking of the web pages [1][2]. The remaining part of this paper is organized as follows: Related work is summarized in Section II. A tabular summary is presented in section III, which summarizes the techniques, advantages and limitations of some of the important web page ranking algorithms. Based on the literature analysis, a comparison of some of various web page ranking algorithms is presented in section IV and a conclusion is given in section V.

II RELATED WORK

Web mining is the technique to classify the web pages and internet users by taking into consideration the contents of the
page and behavior of internet user in the past. Web mining helps the internet user about the web pages to be viewed in future. Web mining is made of three branches i.e. web content mining (WCM), web structure mining (WSM) and web usage mining
(WUM). WCM is responsible for exploring the proper and relevant information from the contents of web. WSM is used to find out the relation between different web pages by processing the structure of web. WUM is responsible for recording the user profile and user behavior inside the log file of the web. The WCM mainly concentrates on the structure of the document whereas WSM explore the structure of the link inside the hyperlink between different documents and classify the pages of web. The number of out links i.e. links from a page and the number of in link i.e. links to a page are very important parameter in the area of web mining. The popularity of the web page is generally measured by the fact that a particular page should be referred by large number of other pages and the importance of web pages may be adjudged by a large number of out links contained by a page. So WSM becomes a very important area to be researched in the field of web mining [1][2][3][4][5]. Figure 2 shows the general classification of web mining [2].

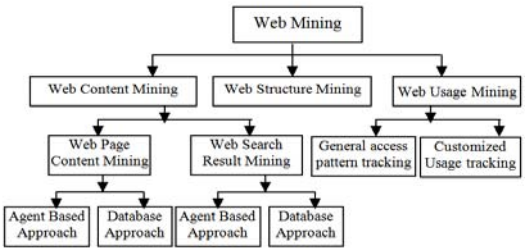

Figure 2: Classification of Web Mining

Two graph based page ranking algorithms i.e. google Page Rank proposed by Brin and Page in 1998 and Kleinberg's hypertext induced topic selection (HITS) algorithm proposed by Kleinberg in 1998 are used successfully and traditionally in the area of web structure mining. Both of these algorithms give equal weights to all links for deciding the rank score.

Page Rank Algorithm

Page Rank algorithm is the most commonly used algorithm for ranking the various pages. Working of the Page Rank algorithm depends upon link structure of the web pages. The Page Rank algorithm is based on the concepts that if a page contains important links towards it then the links of this page towards the other page are also to be considered as important pages. The Page Rank considers the back link in deciding the rank score. If the addition of the all the ranks of the back links is large then the page then it is provided a large rank [1][6][7][8]. A simplified version of PageRank is given by:

$$PR(u) = \sum_{v \in B_u} \frac{PR(v)}{L(v)}$$

Where the PageRank value for a web page u is dependent on the PageRank values for each web page v out of the set B_u (this set contains all pages linking to web page u), divided by the number L(v) of links from page v.

An example of back link is shown in figure 3 below. U is the back link of V & W and V & W are the back links of X.

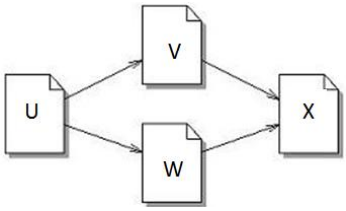

Figure 3: Illustration of back links

HITS Algorithm

HITS algorithm ranks the web page by processing in links and out links of the web pages. In this algorithm a web page is named as authority if the web page is pointed by many hyper links and a web page is named as HUB if the page point to various hyperlinks. An Illustration of HUB and authority are shown in figure 4.

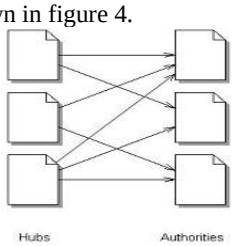

Figure 4: Illustration of Hub and Authorities

HITS is technically, a link based algorithm. In HITS [9] algorithm, ranking of the web page is decided by analyzing their textual contents against a given query. After collection of the web pages, the HITS algorithm concentrates on the structure of the web only, neglecting their textual contents. Original HITS algorithm has some problems which are given below.

(i) High rank value is given to some popular website that is not highly relevant to the given query.

(ii) Drift of the topic occurs when the hub has multiple topics as equivalent weights are given to all of the outlinks of a hub page. Figure 5 shows an Illustration of HITS process.

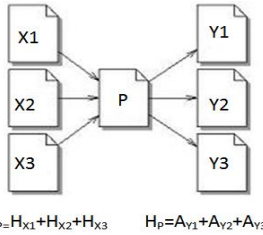

Figure 5: Illustration of HITS process

To minimize the problem of the original HITS algorithm, a clever algorithm is proposed by reference [10]. Clever algorithm is the modification of standard original HITS algorithm. This algorithm provides a weight value to every link depending on the terms of queries and endpoints of the link. An anchor tag is combined to decide the weights to the link and a large hub is broken down into smaller parts so that every hub page is concentrated only on one topic.

Another limitation of standard HITS algorithm is that it assumes equal weights to all the links pointing to a webpage and it fails to identify the facts that some links may be more important than the other. To resolve this problem, a probabilistic analogue of the HITS (PHITS) algorithm is proposed by reference [11]. A probabilistic explanation of relationship of term document is provided by PHITS. It is able to identify authoritative document as claimed by the author. PHITS gives better results as compared to original HITS algorithm. Other difference between PHITS and standard HITS is that PHITS can estimate the probabilities of authorities compared to standard HITS algorithm, which can provide only the scalar magnitude of authority [1].

Weighted Page Rank Algorithm

Weighted Page Rank [1] Algorithm is proposed by Wenpu Xing and Ali Ghorbani. Weighted page rank algorithm (WPR) is the modification of the original page rank algorithm. WPR decides the rank score based on the popularity of the pages by taking into consideration the importance of both the in-links and out-links of the pages. This algorithm provides high value of rank to the more popular pages and does not equally divide the rank of a page among its out-link pages. Every out-link page is given a rank value based on its popularity. Popularity of a page is decided by observing its number of in links and out links. Simulation of WPR is done using the website of Saint Thomas University and simulation results show that WPR algorithm finds larger number of relevant pages compared to standard page rank algorithm. As suggested by the author, the performance of WPR is to be tested by using different

websites and future work include to calculate the rank score by utilizing more than one level of reference page list and increasing the number of human user to classify the web pages.

Weighted Links Rank Algorithm

A modification of the standard page rank algorithm is given by Ricardo Baeza-Yates and Emilio Davis [13] named as weighted links rank (WLRank). This algorithm provides weight value to the link based on three parameters i.e. length of the anchor text, tag in which the link is contained and relative position in the page. Simulation results show that the results of the search engine are improved using weighted links. The length of anchor text seems to be the best attributes in this algorithm. Relative position, which reveal that physical position does not always in synchronism with logical position is not so result oriented. Future work in this algorithm includes, tuning of the weight factor of every term for further evolution.

EigenRumor Algorithm

As the number of blogging sites is increasing day by day, there is a challenge for service provider to provide good blogs to the users. Page rank and HITS are very promising in providing the rank value to the blogs but some limitations arise, if these two algorithms are applied directly to the blogs The rank scores of blog entries as decided by the page rank algorithm is often very low so it cannot allow blog entries to be provided by rank score according to their importance. To resolve these limitations, a EigenRumor algorithm [14] is proposed for ranking the blogs. This algorithm provides a rank score to every blog by weighting the scores of the hub and authority of the bloggers depending on the calculation of eigen vector.

Distance Rank Algorithm

An intelligent ranking algorithm named as distance rank is proposed by Ali Mohammad Zareh Bidoki and Nasser Yazdani [15]. It is based on reinforcement learning algorithm. In this algorithm, the distance between pages is considered as a punishment factor. In this algorithm the ranking is done on the basis of the shortest logarithmic distance between two pages and ranked according to them. The Advantage of this algorithm is that it can find pages with high quality and more quickly with the use of distance based solution. The Limitation of this algorithm is that the crawler should perform a large calculation to calculate the distance vector, if new page is inserted between the two pages.

Time Rank Algorithm

An algorithm named as TimeRank, for improving the rank score by using the visit time of the web page is proposed by H Jiang et al.[16] Authors have measured the visit time of the page after applying original and improved methods of web page rank algorithm to know about the degree of importance to the users. This algorithm utilizes the time factor to increase the accuracy of the web page ranking. Due to the methodology used in this algorithm, it can be assumed to be a combination of content and link structure. The results of this algorithm are very satisfactory and in agreement with the applied theory for developing the algorithm.

TagRank Algorithm

A novel algorithm named as TagRank [17] for ranking the web page based on social annotations is proposed by Shen Jie,Chen Chen,Zhang Hui,Sun Rong-Shuang,Zhu Yan and He Kun. This algorithm calculates the heat of the tags by using time factor of the new data source tag and the annotations behavior of the web users. This algorithm provides a better authentication method for ranking the web pages. The results of this algorithm are very accurate and this algorithm index new information resources in a better way. Future work in this direction can be to utilize co-occurrence factor of the tag to determine weight of the tag and this algorithm can also be improved by using semantic relationship among the co-occurrence tags.

Relation Based Algorithm

Fabrizio Lamberti, Andrea Sanna and Claudio Demartini [18] proposed a relation based algorithm for the ranking the web page for semantic web search engine. Various search engines are presented for better information extraction by using relations of the semantic web. This algorithm proposes a relation based page rank algorithm for semantic web search engine that depends on information extracted from the queries of the users and annotated resources. Results are very encouraging on the parameter of time complexity and accuracy. Further improvement in this algorithm can be the increased use of scalability into future semantic web repositories.

Query Dependent Ranking Algorithm

Lian- Wang Lee, Jung- Yi Jiang, ChunDer Wu and Shie-Jue Lee [19] have presented a query dependent raking algorithm for search engine. In this approach a simple similarity measure algorithm is used to measure the similarities between the queries. A single model for ranking is made for every training query with corresponding document. Whenever a query arises, then documents are extracted and ranked depending on the rank scores calculated by the ranking model. The ranking model in this algorithm is the combination of various models of the similar training queries. Experimental results show that query dependent ranking algorithm is better than other algorithms.

Ranking and Suggestive Algorithm

M Vojnovic et al. [20] have proposed a ranking and suggestive algorithm for popular items based on user feedback. User feedback is measured by using a set of suggested items. Items are selected depending on the preferences of the user. The aim of this technique is to measure the correct ranking of the items based on the actual and unbiased popularity. Proposed algorithm has various techniques for suggesting the search query. This algorithm can also be used for providing tag suggestion for social tagging system. In this algorithm various techniques for ranking and suggesting popular items are studied and results are provided based on their performance. Results of this

algorithm demonstrate that randomized update and light weight rules having no special configurations provide better accuracy.

Comparison and Score Based Algorithm

NL Bhamidipati et al. [21] have proposed a more common approach whereby the scoring scheme may be perceived to be dissimilar if they induce identical ranking. In this algorithm a metric has been proposed to compare score vectors and the similarity and dissimilarity are measured on the basis of score fusion. Experimental results are in agreement with the theory applied and results demonstrate the various applications of the metric used in the theory applied for the proposed algorithm.

Algorithm for Query Processing in Uncertain Databases

Xiang Lian and Lei Chen [22] have proposed an algorithm for ranked query processing in uncertain databases. Uncertain database management is used in various areas such as tracking of mobile objects and monitoring of sensor data. Due to intrinsic difference between certain and uncertain data. To remove these limitations authors have proposed a novel algorithm. Uncertain database are not exact points and generally occurs within a limited region. Existing algorithms for rank query processing are generally developed for exact or certain data but they cannot be applied directly to uncertain database due to accelerate the probabilistic rank query with monotonic preference functions over the uncertain databases. Authors have proposed two effective techniques named as probabilistic and spatial to reduce the PRank search space. Exhaustive experiment results show that proposed algorithm is very effective and efficient with respect to number of PRank candidates to be refined and wall clock time.

Ranking of Journal based on Page Rank & HITS Algorithm

Su Cheng, Pan YunTao, Yuan JunPeng,Guo Hong,Yu ZhengLu and u ZhiYu [23] have used page rank and HITS algorithm for ranking of the journal and also compared ISI impact factor with page rank and HITS algorithm for ranking the journal. The advantages, limitations and scope of various algorithms used are discussed for ranking the journal. Impact factor is a very popular for ranking the journal but it has intrinsic limitations that the ranking is based on counting the in degrees of the nodes in the network and it does not consider the impact of prestige of the journal in which the citations are present. To minimize these limitations authors have used page rank and HITS algorithm for ranking the journal. Fundamentally the ranking of the journal is very similar to the ranking of the web page. So page rank and HITS algorithm can be used for ranking of the journal.

III SUMMARY OF VARIOUS WEB PAGE RANKING ALGORITHMS

By going through the literature analysis of some of the important web page ranking algorithms, It is concluded that each algorithm has some relative strengths and limitations. A tabular summary is given below in table 1, which summarizes the techniques, advantages and limitations of some of important web page ranking algorithms.

Author/Year	Technique	Advantages	Limitations
S. Brin et al. 1998	Graph based algorithm based on link structure of web pages. Consider the back links in the rank calculations.	Rank is calculated on the basis of the importance of pages.	Results are computed at the indexing time not at the query time.
Jon Kleinberg, 1998	Rank is calculated by computing hub and authorities score of the pages in order of their relevance.	Returned pages have high relevancy and importance.	With less efficiency and problem of topic drift.
Sung Jin Kim et al. 2002	This algorithm probabilistically estimates that clear semantics and the identified authoritative documents correspond better to human intuition [12].	Well defined semantics with clear interpretation. Efficiently provide answer to quantitative bibliometric questions.	Priori should be decided on the number of factors to model. Trades computational expense for the risk of getting stuck in local maxima.
Wenpu Xing et al. 2004	Based on the calculation of the weight of the page with the consideration of the outgoing links, incoming links and title tag of the page at the time of searching.	It gives higher accuracy in terms of ranking because it uses the content of the pages.	It is based only on the popularity of the web page.
Ricardo BaezaYates et al. 2004	This algorithm ranks the page by providing different weights based on three attributes i.e. relative position in page, tag where link is contained & length of anchor text.	It has less efficiency with reference to precision of the search engine.	Relative position was not so effective, indicating that the logical position not always matches the physical position
Ko Fujimura et al. 2005	Use of the adjacency matrix, constructed from agent to object link not by page to page link. Three vectors i.e. hub, authority and reputation are needed for score calculation of the blog.	Useful for ranking of blog as well as web pages because input and output links are not considered in the algorithm.	Specifically suited for blog ranking.
Ali Mohammad Zareh Bidoki et al. 2007	Based on reinforcement learning which consider the logarithmic distance between the pages.	Algorithm consider real user by which pages can be found very quickly with high quality.	A large calculation for distance vector is needed, if new page inserted between the two pages.

Hua Jiang et al. 2008	Visitor time is used for ranking. Use of sequential clicking for sequence vector calculation with the uses of random surfing model.	Useful when two pages have the same link structure but different contents.	It does work efficiently when the server log is not present.
Shen Jie et al. 2008	The algorithm is based on the analysis of tag heat on social annotation web.	Ranking results are very exact and new information resources are indexed more effectively.	Co-occurrence factor of tag is not considered which may influence the weight of the tag.
Fabrizio Lamberti et al. 2009	Ranking of web pages for semantic search engine. It uses the information extracted from the queries of the user and annotated resources.	Effectively manage the search page. Ranking task is less complex.	In this ranking algorithm every page is to be annotated with respect to some ontology, which is the very tough task.
Lian-Wang Lee et al. 2009	Individual models are generated from training queries. A new query ranked according to the combined weighted score of these models.	It gives the results for user's query as well as results for similar type of query.	Limited numbers of characteristics are used to calculate the similarity.
Milan Vojnovic et al. 2009	Suggest the popular items for tagging. It uses the three randomized algorithms i.e. frequency proportional sampling, move-to-set and frequency move-to-set.	Tag popularity boost up because large number of tag are suggested by this method.	Does not consider alternative user choice model, alternative rules for ranking and alternative suggestive rules.
Narayan L Bhamidipati et al. 2009	Based on the score fusion technique.	It is used when two pages have same ranking.	Does not consider the case when score vector T generated from specific distribution.
Xiang Lian et al. 2010	Retrieval of moving object in the uncertain databases. It uses the PRank (probabilistic ranked query) and J- Prank (probabilistic ranked query on join).	It is fast because it uses the R-Tree.	Experimental results are very promising only with limited number of parameters such that. wall clock time and number of Prank candidate.

Table 1 Summary of various web page ranking algorithms

IV COMPARISON OF VARIOUS WEB PAGE RANKING ALGORITHMS

Based on the literature analysis, a comparison of some of various web page ranking algorithms is shown in table 2 and in table 3. Comparison is done on the basis of some parameters such as main technique use, methodology, input parameter, relevancy, quality of results, importance and limitations.

Algorithm	Page Rank	HITS	Weighted Page Rank	Eigen Rumor	Web Page Ranking using Link Attributes
Main Technique	Web Structure Mining	Web Structure Mining, Web Content Mining	Web Structure Mining	Web Content Mining	Web Structure Mining, Web Content Mining
Methodology	This algorithm computes the score for pages at the time of indexing of the pages.	It computes the hubs and authority of the relevant pages. It relevant as well as important page as the result.	Weight of web page is calculated on the basis of input and outgoing links and on the basis of weight the importance of page is decided.	Eigen rumor use the adjacency matrix, which is constructed from agent to object link not page to page link.	it gives different weight to web links based on 3 attributes: Relative position in page, tag where link is contained, length of anchor text.
Input Parameter	Back links	Content, Back and Forward links	Back links and Forward links.	Agent/Object	Content, Back and Forward links
Relevancy	Less (this algo. rank the pages on the indexing time)	More (this algo. Uses the hyperlinks so according to Henzinger, 2001 it will give good results and also consider the content of the page)	Less as ranking is based on the calculation of weight of the web page at the time of indexing.	High for Blog so it is mainly used for blog ranking.	more (it consider the relative position of the pages)
Quality of results	Medium	Less than PR	Higher than PR	Higher than PR and HITS	Medium
Importance	High. Back links are considered.	Moderate. Hub & authorities scores are utilized.	High. The pages are sorted according to the importance.	High for blog ranking.	Not specifically quoted.
Limitation	Results come at the time of indexing and not at the query time.	Topic drift and efficiency problem	Relevancy is ignored.	It is most specifically used for blog ranking not for web page ranking as other ranking like page rank, HITS.	Relative position was not so effective, indicating that the logical position not always matches the physical position.

Table 2 Comparison of various web page ranking algorithms

Algorithm	Distance Rank	Time Rank	Tag Rank	Relational Based Page Rank	Query Dependent Ranking
Main Technique	Web Structure Mining	Web Usages Mining	Web Content Mining	Web Structure Mining	Web Content Mining
Methodology	Based on reinforcement learning which consider the logarithmic distance between the pages.	In this algorithm the visiting time is added to the computational score of the original page rank of that page.	Visitor time is used for ranking. Use of sequential clicking for sequence vector calculation with the uses of random surfing model.	A semantic search engine would take into account keywords and would return page only if both keywords are present within the page and they are related to the associated concept as described in to the relational note associated with each page.	This paper proposed the construction of the rank model by combining the results of similar type queries.
Input Parameter	Forward links	Original Page Rank and Sever Log	Popular tags and related bookmarks	Keywords	Training query
Relevancy	Moderate due to the use of the hyperlinks.	High due to the updation of the original rank according to the visitor time.	Less as it uses the keyword entered by the user and match with the page title.	High as it is keyword based algorithm so it only returns the result if the keyword entered by the user match with the page.	High (because the model is constructed from the training quires).
Quality of results	High	Moderate	Less	High	High
Importance	High. It is based on distance between the pages.	High., Consideration of the most recently visited pages .	High for social site.	High. Keyword based searching.	High because it gives the results for user's query as well as results for similar type of query.
Limitation	If new page inserted between two pages then the crawler should perform a large calculation to calculate the distance vector.	Important pages are ignored because it increases the rank of those web pages which are opened for long time.	It is comparison based approach so it requires more site as input.	In this ranking algorithm every page is to be annotated with respect to some ontology, which is the very tough task.	Limited number of characteristics are used to calculate the similarity.

Table 3 Comparison of various web page ranking algorithms

V CONCLUSION

Based on the algorithm used, the ranking algorithm provides a definite rank to resultant web pages. A typical search engine should use web page ranking techniques based on the specific needs of the users. After going through exhaustive analysis of algorithms for ranking of web pages against the various parameters such as methodology, input parameters, relevancy of results and importance of the results, it is concluded that existing techniques have limitations particularly in terms of time response, accuracy of results, importance of the results and relevancy of results. An efficient web page ranking algorithm should meet out these challenges efficiently with compatibility with global standards of web technology.

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