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A Preliminary Review of Web-Page Recommendation in Information Retrieval Using Domain Knowledge and Web Usage Mining

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Abstract: With the rapid growth of internet technologies, The web has become the world's largest repository of knowledge. So it is challenging task of the webmasters to organize the contents of the particular websites to gather the needs of the users. This paper presents a new framework for a semantic-enhanced Web-page recommendation (WPR), and a suite of enabling techniques which include semantic network models of domain knowledge and Web usage knowledge, querying techniques, and Web-page recommendation strategies. It enables the system to automatically discover and construct the domain and Web usage knowledge bases, and to generate effective Webpage recommendations. The experimental comparisons with existing WPR approaches convincingly prove the significantly improved performance of WPR based on the framework and it's enabling techniques.

Keywords: Semantic network, Web-page recommendation, Domain knowledge, knowledge representation, Web usage mining.

I. INTRODUCTION

The explosive growth of information on the World Wide Web with the development of advanced electronic devices has made Web information increasingly important in almost everybody's life. The rapid introduction of current websites has overwhelmed Web users by offering many choices. Consequently, Web users tend to make poor decisions when surfing the Web due to an inability to cope with enormous amounts of information. Web-page recommendation has proved in recent years to be a valuable means of helping Web users by providing useful and effective recommendations or suggestions. The core techniques in web-page recommendation are the learning and prediction models which learn users' behaviour and evaluate what users would like to view in the future. In particular, it can suggest interesting items from a large set of items based on the knowledge gained about an active user.

Web-page recommendation can automatically recommend Web-pages that are most interesting to a particular user based on the user's current Web navigation behaviour. Good Web-page recommendations can improve website usage and Web user satisfaction.

How to make effective Web-page recommendations to Web users without excessive input from those users is a hot research topic. Significant effort has been devoted to developing effective Web-page recommender systems; however, a number of challenges or problems, have been encountered in the development of contemporary Web-page recommender systems.

"New page" (cold-start) problem

If a user is visiting a Web-page that has not been accessed before, e.g. a newly-added Web-page, the user cannot obtain a recommendation. This phenomenon is often referred to as the "new page" problem. The reasons why such a phenomenon occurs are threefold: (i) the recommendations are generated based on the recommendation rules obtained from the frequent Web access patterns discovered from the Web usage dataset; (ii) the new page is not included in the Web usage dataset so it cannot appear in any discovered patterns; and (iii) the systems do not have a recommendation rule corresponding to the new page.

Challenges of manual ontology construction

The backbone technology for semantic knowledge representation is ontologies. Ontologies in Web-page recommendation have to date mainly been constructed manually by system developers in consultation with domain experts. Ontology construction is a complex development process which is costly and labour-intensive, and demands a high level of proficiency in the domain (Grimm et al. 2011; Gündüz-Ögüdücü 2010). It is a big challenge to design and construct a perfect ontology for a website because there are a huge number of pages on one website and some important concepts in the ontology may be overlooked by developers

This paper proposes a framework for a new semantic-enhanced Web-page recommendation (SWR) and a suite of techniques to resolve or alleviate the above problems. Based on the framework, an effective Web-page recommendation can be developed to offer Web users the top-*N* most commonly visited Web-pages from the currently visited Webpage. The knowledge bases used in the system, including the website domain and Web usage knowledge bases, are represented by ontological-style semantic networks which can be implemented consistently in a formal Web Ontology Language (OWL).

II. Literature Review

The literature review covers the background, latest development of and related techniques for semantic-enhanced recommender systems. Web mining (WM) is the process of discovering useful knowledge from Web data. Depending on different types of Web data, appropriate mining techniques are selected. There are three main broad categories of Web mining.

» Web content mining (WCM) is used to mine Web content, such as HTML or XML documents.

» Web structure mining (WSM) focuses on Web structure, such as hyperlinks on Web-pages.

» Web usage mining (WUM) is applied to Web usage data, such as Web logs or clickstreams, from a website.

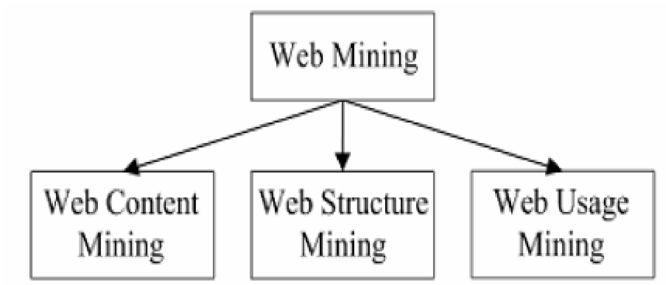

Fig: Taxonomy of Web Mining

Web Usage Mining

Web usage mining aims to discover some useful patterns from the Web usage data, such as, clickstreams, user transactions and users' Web access activities, which are often stored in Web server logs (Liu, Mobasher & Nasraoui 2011). A Web server log records user sessions of visiting Web-pages of a website day by day. It can be used to discover potentially useful Web usage knowledge, e.g. the navigational behaviour of Web users, (Mobasher 2007a). Generally speaking, a Web usage mining process includes three phases: pre-processing, mining, and applying mining results (Woon, Ng & Lim 2005). After pre-processing Web log files, Web access sequences (WAS), for example, are generated and filed in a dataset (Ezeife & Liu 2009). An element of this dataset is a sequence of representing a user browsing session. In the mining phase, some sequential pattern mining techniques, such as clustering, classification, association rules, and sequential pattern discovery (Pierrakakos et al. 2003), can be applied to the WAS to extract the frequent Web access patterns (FWAP), which is useful Web usage knowledge. In the third phase, the discovered knowledge will beused in a specific application, e.g., a Web-page recommender system, in which FWAP are used for generating the recommendation rules to support on-line Web-page recommendation. The mining phase using sequential pattern mining techniques is the core phase in a WUM process and plays a crucial role in a Web-page recommender system to support users to make better decision based on their current Web navigation history.

Recommender Systems

Recommender systems (Adomavicius & Tuzhilin 2005; Mobasher 2007b) were developed to learn Web user experience in order to model the interaction between users and items described on Web-pages and to recommend the interesting items to the users. The popularity of recommender systems is increasing with the rapid growth of the Internet since the mid-1990s. In the systems, recommended items may be Web-pages (links), articles, books or products. An intelligent recommender system will support Web users to make better decisions to rapidly reach their own target pages during a browsing session. recommender systems become more and more important Therefore, in Web-based applications, such as e-commerce, e-government, and e-services.

At the beginning, traditional recommender systems have been developed merely based on Web mining. Web recommendations mostly rely on the informally represented data patterns which are discovered from Web data, e.g., Web server log files, user profile, and Web content. In the 2000s, the advent of the Semantic Web has changed the World Wide Web. The Semantic Web offers a good basis to enrich Web mining by discovering the "semantics" in the data and make the discovered knowledge explicit. Semantic Web mining (Kolari & Joshi 2004; Stumme, Hotho & Berendt 2006) has emerged as an advanced technique which can improve the effectiveness of Web mining based on the ontology technology. Ontology has significantly contributed to semantic knowledge representation in order to semantically enhance information process in recommender systems, as known as semantic (enhanced) recommender systems.

Semantic-enhanced Web-page recommendation is more powerful with the help of ontology. Integration of domain ontology with recommender systems can enrich the semantics of Web usage data to make valuable recommendations and produce promising results. In particular, ontology is used to represent an application domain and is used to express the meaning of Web-pages, so that the semantic information is able to be effectively integrated into the Web-page recommendation process (Gündüz-Ögüdücü 2010). For example, Rios and Velasquez (2008) use a concept-based approach to add semantics into the Web usage mining process; and Mabroukeh and Ezeife (2009) use semantic information to improve selective Markov models for Web prefetching. Moreover, Wei and Lei (2009) construct a website's ontology using the concepts and significant terms extracted from documents, and online recommendations are generated by semantically matching and searching frequent pages discovered from the Web usage mining process. This approach achieves the effectiveness of the precision rate, coverage rate and matching rate. On the other hand, ontology is able to be used to map semantic information to Webpages in order to represent frequent navigational patterns extracted from WUM in the form of ontology instances, and to reason for Web-page recommendation more accurate (Salin & Senkul 2009).

III. PROPOSED METHODOLOGY AND DISCUSSION

a) Sequential Pattern Mining For Web Usage

The goal of WUM is to capture, model, and analyse the behavioural patterns and profiles of users interacting with a website (Liu, Mobasher & Nasraoui 2011). The discovered patterns are usually a set of sequences of pages that are frequently accessed by groups of users with common interests. Sequential pattern mining algorithms are appropriate for this purpose since they can take the Web access sequences (WAS) as the input and output the frequent Web access patterns (FWAP).

The sequential pattern mining algorithms can be roughly classified as the Apriori-based, pattern-growth, and Web access pattern (WAP)-tree based approaches (Mabroukeh & Ezeife 2010; Zhou 2004). The WAP-tree based approach often achieves higher performance in sequential pattern discovery, especially the PLWAPMine (Ezeife & Lu 2005) and CS-Mine (Zhou, Hui & Fong 2004) algorithms.

Pre-order Linked Web Access Pattern Tree Mining

The PLWAP-Mine algorithm scans the database of WAS twice to find all frequent individual events and construct a PLWAP-tree over the set of individual frequent events (Ezeife & Lu 2005). While constructing the PLWAP-tree, the binary position codes are assigned to each node of the tree. The binary code assignment technique is performed by using a rule similar to Huffman code generation (Huffman 1952). Based on the position codes, the algorithm can determine the suffix trees of any prefix event of frequent patterns. Therefore, the algorithm can recursively mine the PLWAP-tree using common prefix pattern search to find out all FWAP. Frequent *m*-sequences are computed and discovered using frequent *(m-1)*-sequences and the appropriate suffix sub-trees. As a result, a complete set of frequent patterns are efficiently discovered from the search space, i.e., the PLWAP tree.

b) Semantic Network Modelling For Webpage Recommendation

Traditional ontology construction is a labour-intensive and time-consuming task and highly relies on human experts. Moreover, such constructed ontologies are often fixed to a specific domain of interest. This often leads to the difficulties of reusing existing ontologies. Therefore, it has become highly desirable to develop an efficient method to automate knowledge acquisition, representation and application.

A semantic network of Web-pages is a kind of knowledge map which refers to domain concepts and the relations between these concepts as well as Web-pages and the links between the domain concepts and Webpages. The automatic approach to the semantic network construction of Web-pages aims at supporting automated knowledge discovery and knowledge representation in Web-page recommender systems.

First, we collect the domain terms from the Web-page titles based on the assumption that a well-designed Webpage should have an informative title; then we extract the relations between these terms from the following two aspects: (i) the collocations of terms which are determined by the co-occurrence relations of terms in Web-page titles; and (ii) the associations between terms and Webpages.In addition, the domain terms and co-occurrence relations are weighted to provide a rough indication of how much these terms are associated with each other semantically. Based on the relations between the terms and Web-pages, we can infer how closely the Web-pages are semantically related to each other. Using this model, we can query about the relations between terms and Webpages, such as the relevant pages for a given page, the key terms for a given page, and the pages for given terms, to infer the semantics of Web-pages to achieve semanticenhanced Web-page recommendations. This semantic network is referred to as TermNetWP.

Prtocedure of Automatically Constructing a Semantic Network of Web-pages (TermNetWP)

The purpose of the automated construction of semantic network of Web-pages to facilitate automated processes discovering and representing the semantic knowledge of visited Web-pages of a website for supporting more effective Webpage recommendations is fulfilled by a novel method that take Web logs of a given website as the input and produce the semantic network of Webpages automatically. The flow diagram of implementing this method consists of four processes: (1) accessed Web-page collection,(2) term extraction, (3) semantic network population of Web-pages, and (4) Implement an automatic construction of TermNetWP.

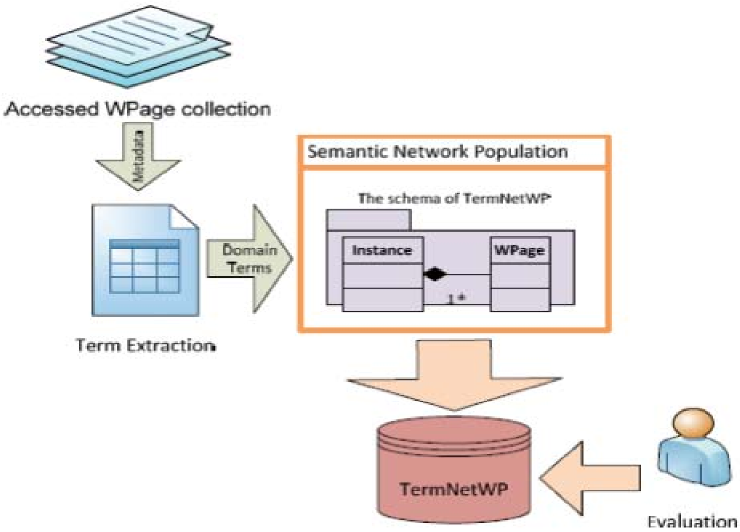

Fig: Flow Diagram for automatic Construction of a Semantic Network of Webages

1. Collection of Accessed Web-pages:

This process firstly pre-processes Web logs to extract the URLs of Web-pages that have been visited by users at the given website, and then the URLs are crawled to fetch the metadata of Web-pages, i.e. the titles of Web-pages based on the TITLE tag on the HTML documents of Web-pages.

2. Extraction of Domain Terms:

This process extracts the domain terms from the titles of Web-pages retrieved in the first process (1). A term extraction algorithm is designed to extract terms from the Web-page titles. With this algorithm, tokens are firstly extracted, and then domain terms are generated based on these tokens. The results of this process are domain term sequences, each of which is a list of terms in the order as they appear in the titles.

3. Construction of a Semantic Network of Web-pages:

Based on the term sequences obtained from Process (2), a semantic knowledge representation model is built according to a collocation map (Park, Han & Choi 1995) and the Markov models (Borges & Levene 2005), in which occurrence weights of terms and associations between terms are taken into account to assess the frequencies of terms and collocations in the domain. The schema of this model is designed to represent the domain terms, Web-pages, and the relationships between them which can be populated to form a semantic network of Web-pages, referred to as TermNetWP. This network is the domain knowledge base of this website.

4. Implement an automatic construction of TermNetWP

The TermNetWP is implemented in OWL to enable the domain term network to be reused and shared by other parts of a Web-page recommender system. The algorithm to automatically construct a TermNetWP is as shown below:

Algorithm to Automatically construct a TermNavNet WP

Input: TSC(Term sequence collection)

Output: G(TermNetWP)

Process:

Let TSC = {PageID, X= t1t2… tm, URL}

Initialize G

Let R= root or the start node of G

Let E= the end node of G

For eachPageID and each sequence Xin TSC{

Initialize a WPageobject identified as PageID

For eachterm ti ∈X{

If node tiis not found in G, then

- Initialize an Instanceobject Ias a node of G

- Set I.Name= ti

Else

- Set I= the Instanceobject named tiin G

Increase I.iOccurby 1

If (i==0) then

- Initialize an OutLink R-ti if not found

- Increase R-ti.iWeightby 1

- Set R-ti.fromInstance= R

- Set R-ti.toInstance= I

If (i>0& i<m) then

- Get preI= the Instanceobject with name ti-1

- Initialize an *OutLink ti-1-ti* if not found

- Increase *ti-1-ti.iWeight* by 1

- Set *ti-1-ti.toInstance* = *I*

- Set *ti-1-ti.fromInstance* = *preI*

If (*i*==*m*) then

- Initialize an *OutLink ti-E* if not found

- Increase *ti-E.iWeight* by 1

- Set *ti-E.toInstance* = *E*

- Set *ti-E.fromInstance* = *I*

-Set *I.hasWPage* = *PageID*

Add term *ti* into *PageID.Keywords*

}

}

The input data is a term sequence collection (*TSC*), in which each record consists of:

1) The PageID of a Web-page $d \in D$;

2) A sequence of terms $X = t1t2 \ldots tm \in TS, m > 0$, extracted from the title of the Web-page; and

3) The URL of the Web-page.

TermNetWP can be used effectively not only to model the term sequences in connection with Web-pages, but also to present the co-occurrence relations of terms in the term sequences based on the following features: (i) it allows a term node to have multiple in-links and/or out-links so we can easily describe the relationships among terms/nodes in the semantic network, i.e. one node might have previous or next nodes; and (ii) it includes the Web-pages whose titles contain the linked terms so that the meaning of Web-pages can be found through these terms by software agents/systems. More importantly, TermNetWP enables reasoning of relationships between terms and Web-pages within a specific domain

c) Concept Navigation Model Of Web Usage Of A Website For Prediction

In order to make betterWeb-page recommendations, we need semantic Web usage knowledge which can be obtained by integrating the domain knowledge model (DomainOntoWP) or the semantic network (TermNetWP) with Web usage knowledge that can be discovered from Web log files using a Web usage mining technique. A concept navigation model is proposed to automatically generate a weighted network of concept navigation. This model employ an advanced Web usage mining technique, namely PLWAPMine, to discover the Web usage knowledge, which is in the form of frequent Web access patterns (FWAP), i.e patterns of frequently visited Web-pages. We integrate FWAP with DomainOntoWP or TermNetWP in order to result in a set of frequently viewed term patterns (**FVTP**),This is the semantic knowledge of Web usage of a website.

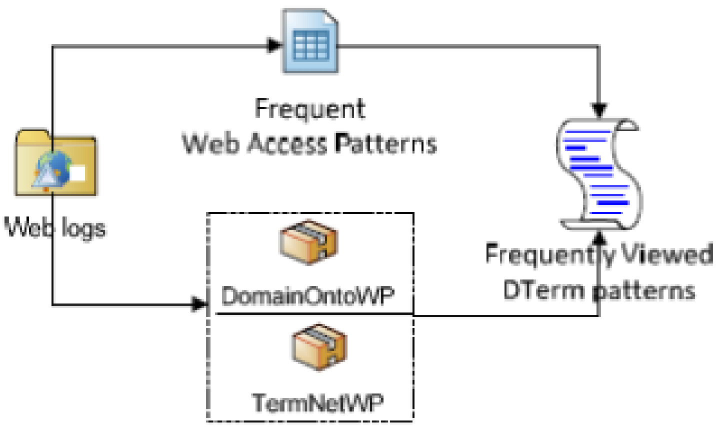

Fig: Frequently viewed domain term pattern discovery

Description of the FVTP is formalized in the following definition.

Definition: Let D = {dj : 1 □j □q} be a set of Web-pages, T = {ti : 1 □i □p} be a set of domain terms in the titles of the Web-pages, where ti □$Tman$ if DomainOntoWP is involved, or ti □$Tauto$ if TermNetWP is involved. Let P = {$P1$, $P2$, …, Pn} be a set of FWAP, where each pattern Pi (i = [1..n]) contains a sequence of Web-pages, n is the number of the patterns, and Pi = $di1di2$ … dim, dik □D, k = [1..m], m is the number of Web-pages in the pattern.

A Domain Term Navigation Model

A domain term navigation model is proposed to automatically generate a weighted semantic network of frequently viewed domain terms with the weight being the probability of the transition between two adjacent domain terms based on FVTP. This weighted semantic network is the semantic Web usage knowledge of a website for Web-page recommendation refered to as TermNavNet.The Figure illustrates how the domain term navigation model acts as a formatter to convert FVTP into TermNavNet.

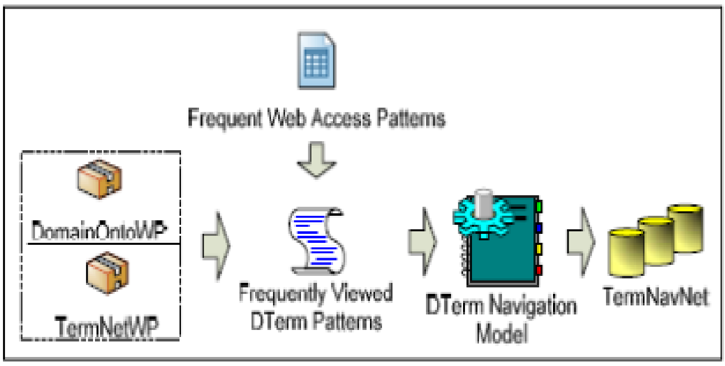

Fig: Building a domain term navigation network

Automatic Construction of Domain Term Navigation Model

The domain term navigation model for a website, i.e. TermNavNet, can be automatically constructed by populating the schema of the domain term navigation model with the given set of FVTP. An algorithm is designed to accomplish this task, as shown below.

Algorithm: WPNavNet construction

Input: P (*FWAP*)

Output: *M* (WPNavNet)

Process:

Initialize *M*

For each *P* = (*d*1...*dm*) Î P

For each *di* Î *P*, *i* = [1..*m*]

Initialize *cNode* objects with *NodeName* = *di*, *di*-1, *di+1* and *Occur* = 1 if they are not found in *M*

Initialize a *cOutLink* object with *Name* = *di_di*+1 and *Occur* = 1 if it is not found in *M*

Increase *di.Occur* and *di_di*+1.*Occur* if they are found in *M*

di_di+1.*linkTo* = *di*+1

di.outLink = *di_di+1*

di.inLink = *di-1*

Update all objects into *M*

Update transition probabilities in the *cOutLink* objects

Return *M*

IV. EXPERIMENTAL EVALUATION

In order to evaluate the effectiveness of the proposed models of knowledge representation and the recommendation strategies, these models and strategies are implemented to test their performance of Web-page recommendation.

Definition *(Web-page recommendation rules)*

Let $S = s1s2 \ldots sk\ sk{+}1 \ldots sn$ be a WAS. For each prefix sequence $Sprefix = s1\ s2\ \ldots sk$ ($1 \leq k \leq n$-1), a Web-page recommendation rule is defined as a set of recommended Web-pages which are generated by a Web-page recommendation strategy, denoted as $RR=\{r1, r2, \ldots, rM\}$, where ri (i=[1..M]) is a recommended Web-page.

A Web-page recommendation rule is deemed as *correct*, and/or *satisfied*, or *empty* based on the following conditions:

- If sk+1€ RR, RR is *correct*.

- If si € RR (k+ 1 ≤ i ≤ n), RR is *satisfied*.

- If M = 0, RR is *empty*.

Given a set of recommendation rules, $R = \{RR1, RR2 \ldots RRN\}$, where RRi ($1 \leq i \leq N$) is a recommendation rule, and $|R| = N$ is the total number of recommendation rules in R including *empty* rules.

Performance Evaluation

The performance of Web-page recommendation strategies is measured in terms of two major performance metrics: *Precision* and *Satisfaction* according to Zhou (2004).. The precision is useful to measure how probable a user will access one of the recommended Web-pages. Besides, we also need to consider if a user accesses one of the recommended Web-pages in the near future. Actually, the next page accessed by a user may not the target page that user wants. In many cases, a user has to access a few intermediate pages before reaching the target page. Hence, the satisfaction is necessary to give the precision that the recommended pages will be accessed in the near future. In order to calculate these two metrics, this sub-section first introduces a definition of Web-page recommendation rules

Definition *(Precision)* Let Rc be the sub-set of R, which consists of all *correct* recommendation rules. The Web-page recommendation *precision* is defined as:

$$precision = \frac{|R_c|}{|R|}.$$

Definition *(Satisfaction)* Let Rs be the sub-set of R, which consists of all *satisfied* recommendation rules. The *satisfaction* for Web-page recommendation is defined as:

$$satisfaction = \frac{|R_s|}{|R|}.$$

V. CONCLUSION AND FUTURE RESEARCH

This paper aims to address the challenges in developing Web-page recommendation such as the "new page" problem and manual knowledge construction. The study has developed a conceptual framework to facilitate the discovery, representation and integration of the useful knowledge of a website, including the domain and Web usage knowledge, to support effective Webpage recommendations.

The Web usage knowledge is the frequent Web access patterns (FWAP) of website users, which is discovered from Web logs using an advanced sequence mining technique, namely PLWAP-Mine. The Web usage knowledge is then transformed into a weighted network of Web-pages, namely WPNavNet. Each node in the network represents a Web-page and each edge represents the transition from one Web-page to another; the weight of each edge represents the transition probability.

The domain knowledge is the knowledge about the titles of Web-pages within the specific website represented by a semantic network model, namely TermNetWP in which the domain terms and the associations between these terms are automatically extracted from the titles of Web-pages from the given website, and the semantic network of Web-pages can be automatically built up for the given website. It is then used to interpret Web-pages in FWAP by the mapping between Web-pages and domain terms to generate frequently viewed domain term patterns (FVTP). Given the FVTP, the domain term navigation model has been proposed to automatically build a weighted network of domain term navigation, namely TermNavNet.

To use TermNavNet for Web-page prediction, the system needs to (i) extract the domain terms of the input Web-pages based on the domain knowledge base, (ii) predict the next most likely viewed domain terms based on TermNavNet, and (iii) map the predicted domain terms back to the Web-pages, using the domain knowledge base to offer Web-page recommendations.

Future research can be considered as:

(i)Multi-site

The proposed framework and enabling techniques can be extended to make Web-page recommendations for multiple websites in the same domain. Along this direction, the system should take the log files from these websites as the input.

(ii)Web usage data

The current system works with static Web-pages. With the advancement in Web technology, pages have been evolving into pages with dynamic structures. To offer more effective Web-page recommendations, it will be highly desirable to develop advanced tools to identify and collect more appropriate Web usage data than Web logs, such as clickstream data.

(iii)Web usage knowledge base update

Websites have been evolving over time therefore the knowledge bases,i.e. domain and Web usage knowledge bases, need to be updated accordingly. Considering the traditional Web usage data source, which is the Web log file, the system can only take a limited segment of the log file to build the Web usage knowledge base due to the fact that the size of the log file can be huge. To ensure that the discovered Web usage knowledge is up-to date, new methods need to be developed to dynamically update the knowledge bases. For example, an incremental mining method, e.g. PLWAP For UPdate (PL4UP) (Ezeife & Liu 2009), can be utilised to update FWAP, which is discovered from the Web usage data.Updating the WPNavNet and TermNavNet models will be taken into account; for example, the generated WPNavNet can be updated when there are changes to FWAP

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