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EFFECTIVE QUERY STRUCTURING WITH RANKING USING NAMED ENTITY CATEGORIES FOR XML RETRIEVAL

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To my mother for without her support this thesis would not have been possible

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

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Chairman : Associate Professor Shyamala Doraisamy, PhD
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A large number of documents are now represented and stored using an XML document structure on the web. Thus, there is a need for effective and user-friendly search systems for XML document search. Query languages are largely used to compose structured queries by users to extract data from XML documents. However, using query languages to express queries prove to be difficult for most users since this requires learning a query language and knowledge of the underlying data schema. On the other hand, the success of Web search engines has made many users to be familiar with keyword search and therefore prefer to use a keyword search query interface to search XML data. Keyword queries are inherently ambiguous and it is difficult for users to clearly state their intentions, which causes keyword search systems to inevitably return irrelevant results, making search engines less effective. Therefore, to improve the effectiveness of search engines, keyword search systems are highly needed.

Query structuring system is one of the keyword search systems recently used for effective retrieval of XML documents. The systems focus on user query representation, user search intention identification and ranking algorithms to improve keyword search. However, firstly, existing systems return wrong query representation because of their inability to put keyword query ambiguity problems into consideration during query pre-processing. For example, none of the systems consider the following ambiguities: (i) a query term can appear as the text values of different XML nodes and having different semantics (ii) a query term can appear as both a tag name and as part of text content of some node. Secondly, the systems return wrong user search intention. Specifically, the systems return irrelevant predicates as well as non-informative entity nodes. Thirdly, the systems fail to generate and select best structured query that match a user input keyword query. Finally, the systems' ranking functions ignore to consider the semantics of XML tags into account which leads to irrelevant results. These problems are addressed as follows:

Firstly, an enrichment method has been proposed to investigate whether enriching document content with semantic tags improves the performance of keyword queries. The method employs Semantic Tags Extraction (STSE) algorithm to extract semantic tags of an element and Element Enrichment (EERM) algorithm to enrich the elements.

Secondly, a XML Keyword Query Structuring System (XKQSS) has been developed to relegate the task of generating structured queries from a user to itself while retaining the simple keyword search query interface that allows users to submit a schema independent keyword query. The XKQSS uses a Semantic Aware Index scheme (SAIS) to record the proportion of Named Entity Categories (NECs) and an Entity based Query Segmentation (EBQS) method to interpret the user query as a list of keywords and named entities (resolves ambiguity). Furthermore, it employs Predicates Identification Algorithm (PIA) and Entity Identification Algorithm (EIA) to identify user search intention. Finally, the system utilizes a query formulation algorithm (QRYF) to select the structured queries that best interpret user query.

Thirdly, a modification to XKQSS called Ranking Aware XML Keyword Query Structuring System (RAXKQSS) has been developed to effectively return a ranked list of elements as answer to a user query. The RAXKQSS, first, introduces an improve SAIS (ISAIS) to record the Named Entity Category (NEC) of each indexed term, in addition to the usual information such as term frequencies, term position, as well as element that contains the term in the inverted index. Then, the system uses a ranking function *rk*_BM25TOPF to assign relevance scores to XML fragments with respect to a query and an N-gram based Query Segmentation (NBQS) method to interpret the user query as a list of N-grams (resolves ambiguity). Next, it introduces an Improved PIA (IPIA) and a Compute Return Node Algorithm (CRNA) to return relevant predicates and return node, respectively. Finally, the system employs a query formulation via node algorithm (QRYFv) algorithm to improve the selection of structured queries that best match user query

Experiments have been conducted to evaluate the performance of the proposed enrichment method, XKQSS and RAXKQSS. The experimental results have shown that the enrichment method has an insignificant improvement compared with the baseline in terms of Mean Average Precision (MAP). The results also demonstrated that the propose XKQSS outperforms XReal and StruX in terms of precision. Moreover, the results also illustrated that the proposed RAXKQSS achieved higher precision when compared with the StruX, the SLCA.

These results have shown that the enrichment method is ineffective in improving retrieval performance while the proposed systems XKQSS and RAXKQSS have proved effective compared to the StruX and the SLCA in terms of retrieval performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PERTANYAAN PENSTRUKTURAN BERKESAN DENGAN KEDUDUKAN MENGGUNAKAN KATEGORI ENTITI DINAMAKAN UNTUK DAPATAN SEMULA XML

Oleh

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Sebilangan besar dokumen kini diwakili dan disimpan dengan menggunakan struktur dokumen XML di laman web. Oleh itu, terdapat keperluan sistem carian yang berkesan dan mesra pengguna bagi carian dokumen XML. Bahasa pertanyaan sebahagian besarnya digunakan untuk mengarang pertanyaan berstruktur oleh pengguna untuk mengekstrak data dari dokumen XML. Walau bagaimanapun, menggunakan bahasa pertanyaan untuk menyatakan pertanyaan terbukti sukar bagi kebanyakan pengguna kerana ini memerlukan mereka untuk belajar bahasa pertanyaan dan pengetahuan skema data asas. Sebaliknya, kejayaan enjin gelintar laman web telah menyebabkan ramai pengguna untuk membiasakan diri dengan carian kata kunci dan seterusnya lebih cenderung untuk menggunakan carian pertanyaan kata kunci antara muka untuk carian data XML. Pertanyaan kata kunci sememangnya tidak jelas dan ia adalah sukar bagi pengguna untuk menyatakan dengan jelas niat mereka menyebabkan enjin gelintar kata kunci untuk menjana hasil yang tidak relevan, menjadikan enjin gelintar kurang berkesan. Oleh itu, untuk meningkatkan keberkesanan enjin gelintar, sistem carian kata kunci adalah sangat diperlukan.

Sistem penstrukturan pertanyaan adalah salah satu sistem carian kata kunci baru-baru ini digunakan bagi dapatan semula dokumen XML yang berkesan. Sistem yang sedia ada memerlukan pengguna untuk memberikan petunjuk berstruktur dalam input pertanyaan kata kunci mereka walaupun antara muka sistem ini adalah kata kunci asas. Limitasi lain sistem ini juga termasuk, pertama ketidakupayaan untuk mempertimbangkan meletakkan masalah kekaburan pertanyaan kata kunci semasa pra-pemprosesan pertanyaan. Sebagai contoh, tiada sistem mempertimbangkan kekaburan berikut: (i) istilah pertanyaan boleh muncul sebagai nilai teks bagi nod XML berbeza dan mempunyai semantik yang berbeza (ii) istilah pertanyaan boleh muncul sebagai tag nama dan sebahagian daripada kandungan teks sesetengah nod. Kedua, sistem memulangkan hasrat carian pengguna yang berlainan. Ketiga, sistem gagal untuk menjana dan memilih pertanyaan berstruktur terbaik yang sepadan dengan pertanyaan kata kunci yang diberikan. Akhir, sekali fungsi kedudukan sistem

mengabaikan pertimbangan tag semantik XML yang membawa kepada hasil yang tidak relevan. Masalah-masalah ini ditangani seperti berikut:

Pertama, kaedah pengayaan telah dicadangkan untuk mengkaji sama ada memperkaya kandungan dokumen dengan tag semantik meningkatkan prestasi pertanyaan kata kunci. Kaedah ini menggunakan algoritma Pengekstrakan Tag Semantik (STSE) untuk mengekstrak tag semantik elemen dan algoritma Elemen Pengayaan (EERM) untuk memperkayakan elemen-elemen.

Kedua, Sistem Pertanyaan Kata Kunci Berstruktur (XKQSS) telah dibangunkan untuk membuang tugas menjana pertanyaan berstruktur daripada pengguna kepada dirinya dalam masa yang sama mengekalkan carian pertanyaan kata kunci antara muka mudah yang membolehkan pengguna untuk mengemukakan skema kata kunci pertanyaan bebas. XKQSS menggunakan Skim Indeks Mengetahui Semantik (SAIS) untuk merakam perkadaran Kategori Entiti Dinamakan (NECs) dan kaedah Entiti berdasarkan Segmentasi Pertanyaan (EBQS) untuk mentafsir pertanyaan pengguna sebagai senarai kata kunci dan entiti yang dinamakan (mengatasi kekaburan). Tambahan pula, ia menggunakan Algoritma Pengenalan Predikat (PIA) dan Algoritma Pengenalan Entiti (EIA) untuk mengenal pasti hasrat carian pengguna. Akhirnya, sistem ini menggunakan Algoritma Formulasi Pertanyaan (QRYF) untuk memilih pertanyaan berstruktur yang terbaik mentafsir pertanyaan pengguna.

Ketiga, satu pengubahsuaian kepada XKQSS dipanggil Sistem Kedudukan Sedar Pertanyan Kata Kunci Berstruktur (RAXKQSS) telah dibangunkan bagi mendapatkan semula secara berkesan satu senarai elemen tersusun sebagai jawapan kepada pertanyaan pengguna. The RAXKQSS, pertamanya memperkenalkan SAIS diperbaik (ISAIS) untuk merakam Kategori Entiti Dinamakan (NEC) bagi setiap istilah diindeks, sebagai tambahan kepada maklumat biasa seperti kekerapan istilah, kedudukan istilah, dan juga elemen yang mengandungi istilah yang ada pada indeks songsang. Kemudian, sistem menggunakan fungsi kedudukan *rk*_BM25TOPF untuk menetapkan skor kaitan fragmen XML berkenaan dengan pertanyaan dan N-gram berdasarkan kaedah Segmentasi Pertanyaan (NBQS) untuk mentafsir pertanyaan pengguna sebagai senarai n-gram (mengatasi kekaburan). Seterusnya, ia memperkenalkan PIA diperbaik (IPIA) dan Algoritma Pengiraan Pulangan Nod (CRNA) untuk mengembalikan predikat relevan dan nod kembali, masing-masing. Akhirnya, sistem ini menggunakan algoritma Formulasi Pertanyaan melalui Algoritma Nod (QRYFv) untuk meningkatkan pemilihan pertanyaan berstruktur yang terbaik menandingi pertanyaan pengguna.

Eksperimen telah dijalankan untuk menilai prestasi kaedah pengayaan yang dicadangkan, XKQSS dan RAXKQSS. Hasil eksperimen telah menunjukkan bahawa kaedah pengayaan mempunyai peningkatan yang tidak ketara berbanding garis asas dari segi Min Purata Persis (MAP). Hasil juga menunjukkan bahawa XKQSS yang dicadangkan melebihi performa XReal dan StruX dari segi ketepatan. Selain itu, hasil juga menggambarkan bahawa RAXKQSS yang dicadangkan mencapai ketepatan yang lebih tinggi jika dibandingkan dengan StruX dan SLCA.

Hasil ini menunjukkan bahawa kaedah pengayaan adalah tidak berkesan dalam meningkatkan prestasi dapatan semula manakala sistem XKQSS dan RAXKQSS yang

dicadangkan telah terbukti berkesan berbanding dengan StruX dan SLCA dari segi prestasi dapatan semula.

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I certify that a Thesis Examination Committee has met on 15 September 2016 to conduct the final examination of Abubakar Roko on his thesis entitled "Effective Query Structuring with Ranking using Named Entity Categories for XML Retrieval" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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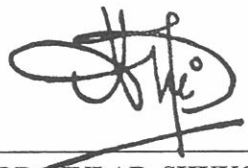

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LIST OF ABBREVIATIONS

Term	Description
AST	Annotated Semantic Tag
CRNA	Compute Returned node algorithm
EBQS	Entity based query segmentation
EIA	Entity Identification Algorithm
IPIA	Improved Predicate Identification Algorithm
LCA	Lowest Common Ancestor
NBQS	N-gram based query segmentation
NEC	Named Entity Category
NER	Named Entity Recognition
PIA	Predicates Identification Algorithm
RAXKQSS	Rank Aware XML Keyword Query Structuring System
SAIS	Semantic Aware Index Scheme
SII	Search Intention Identification
SLCA	Smallest Lowest Common Ancestor
tf-idf	Term frequency - inverse document frequency
XKQSS	XML Keyword Query Structuring System

CHAPTER 1

INTRODUCTION

1.1 Background

The exponential growth of the Internet and the Web has tremendously increased the volume of information. To manage this information, Information Retrieval (IR) systems are required to extract data from the Web. These systems return a ranked list of relevant result to users based on their information needs. The information is in different formats and on a variety of subjects, which can be categorised into three groups: unstructured documents, semi-structured documents and structured documents. The unstructured documents have no fixed pre-defined format e.g. a flat-files containing textual information. In contrast to unstructured documents, the structured documents have a fixed pre-defined format, e.g. Database records. While the semi-structured documents have more tight structure than unstructured documents, but the structure is not as tight as in structured documents. Recently, structured documents and semi-structured documents are commonly represented using eXtensible Mark-up Language (XML).

XML is a mark-up language with some apparent similarities to HyperText Markup Language (HTML), but XML imposes a more rigorous structure than HTML. Unlike HTML, XML allows user-defined tags which are used to specify meaning to the data contained between them. The XML has been proposed by World Wide Web Consortium (W3C) in 1990 to specify the logical or tree structure of documents, in which separate document parts (e.g. section, paragraph, chapter, article) and their logical structure (e.g. a section and its title, a chapter made of sections) are clearly marked-up. As more and more documents are being represented in XML format, methods to retrieve them are required.

Traditionally, a query language such as XPath or XQuery is used to compose queries called structured queries to access information from documents formatted with XML (Lian, Mamoulis, Cheung, & Yiu, 2005; K. Nguyen & Cao, 2012). These queries retrieve precise answers because the queries contain specifications of what to return and where in the document to find it (Y. Li et al., 2004). However, using query languages to express queries prove to be difficult for most users since writing them requires learning a query language and knowledge of the underlying data schema. Structural heterogeneity of XML data also complicates the ability to express a query using a query language. For example, the *author* or *au* tags are often used to tag the author of a book or journal paper in an XML data. But which one of these tags will be used to compose the query? Another problem with structured queries is with regard to the way the returned results are presented to the users. A structured query returns a set of results; meaning that, the results are not presented to the user in any particular order.

An alternative approach that can overcome the problems of unknown schema and/or structure heterogeneity of XML data is the keyword search. This is where the users pose queries using a set of free formatted keywords. The difficulty in expressing user query in the form of structured queries and the success of web search engine have made many users to be familiar with keyword search (Lou, Li, & Chen, 2012; Ya-hui Chang, Cheng-Yi Wu, 2012). Consequently, users prefer to use a keyword search query interface to search XML data. Keyword search requires a user not to learn a query language and/or know the schema of the underlying documents. Although, keyword query can be issued easily, it has an inexpressive side-effect, i.e. ambiguity of expressing user's search intention (X. Lin, Wang, Xu, & Zeng, 2010). The ambiguity of the keyword query may cause large number of results to be returned and thus makes keyword query not effective (He, Wu, Chen, Zhou, & Chen, 2013; Li, X., Li, Z., Wang, P., & Chen, Q., 2010). Therefore, search systems that enhance the effectiveness of keyword queries are highly needed (X. Liu, Wan, & Chen, 2011; Zhong, Minjuan, 2012).

Several systems are proposed to improve the keyword search. These systems are categorized into three: *Lowest Common Ancestor* (LCA) *based* systems (Cohen, S., Mamou, J., Kanza, Y., & Sagiv, 2003; G. Li et al., 2007; Xu & Papakonstantinou, 2005), q*uery structuring* (Da C. Hummel, Da Silva, Moro, & Laender, 2011; Gan & Phang, 2014; J. Li, Liu, Zhou, & Ning, 2009; X. Li, Li, Wang, & Chen, 2010; Petkova, Croft, & Diao, 2009) and *statistical based* approaches (Bao, Lu, Ling, & Chen, 2010; Bao, Lu, Ling, Xu, & Wu, 2010; G. Li, Li, Feng, & Zhou, 2009; Lou et al., 2012). Among these systems, Query Structuring is the most effective because it combines the capability of user friendly nature of keyword search with effectiveness of XML query languages (e.g. XQuery). Also, (Tahraoui M. A. et al., 2013), averred that structured queries contain structured constraints which help reduce the size of irrelevant results and limit the search to document components that are relevant.

1.2 Research problem

Numerous studies have been conducted on effective query structuring for XML retrieval systems (Petkova et al., 2009, J. Li et al., 2009, Da C. Hummel et al., 2011). These studies focus on query representation, user search intention identification and ranking algorithms to improve keyword search. Despite these studies, several challenges are left unresolved in the main research issue of query structuring, which include:

Existing query structuring systems are ineffective because the systems fail to put query keyword ambiguities into consideration. The system (Petkova et al., 2009) groups the query keywords into the query keywords that match tag name of an element and the query keywords that match the data value of an element. However, the system fails to classify a query keyword that appears both as a tag name and data value of an element. The StruX system (Da C. Hummel et al., 2011) also split a query into sequence of segments, where each segment consists of a query keyword or a sequence of keywords. In this case, the system ignores to identify that a query keyword can appear in different parts of an XML document having different semantics because it

considers a query just as a sequence of keywords not as a sequence of semantically related terms.

The StruX system (Da C. Hummel et al., 2011) is impractical to be used in an environment where DTD is not part of the XML document because entity nodes in the target XML document are computed based on the heuristics apply on the document DTD. Also, the heuristics classified multi-valued attributes and grouping nodes as entity nodes and cannot handle the situation where a node's tag name belong to three classes of nodes: **-node* node, *connection* node, and *attribute* node at the same time. These lead to results that is not informative.

The systems select structured queries that fail to match user's input query because their scoring functions ignore to consider the semantics relationship between context node and predicate nodes.

Furthermore, the systems' result ranking schemes are often expressed as functions based on the tightness of the XML elements and *tf-idf* score (Petkova et al., 2009, J. Li et al., 2009). However, these schemes ignore the semantics of XML documents and therefore the systems return misleading results because the functions are powerless in recognizing irrelevant results when XML fragments have highest term frequencies.

1.3 Motivation

The exponential growth of XML documents on the Web poses the challenge of how best these documents can be accessed. The effective search approach (i.e. structured query) to search these data proves to be difficult for most users (J. Li et al., 2009) while the keyword search approach proves to be ineffective (X. Lin et al., 2010). Therefore, an effective XML keyword search engine is needed that addresses the following challenges.

1. Resolves keyword ambiguity problem: (i) a query keyword can appear as a tag name as well as a data value of some nodes within an XML document. (ii) a query keyword can appear in different XML elements having different meanings in each element.
2. Identifies the user search intention, which includes finding the target XML nodes users are interested (i.e. returned nodes) and predicates.
3. Generates and selects the best generated structured queries that represent the user's original intention.
4. Ranking functions are needed to score each relevant XML element returned by the system.

Unfortunately, existing systems cannot thoroughly resolve these challenges and hence the outputs returned by the systems are still far from being satisfactory from user's perspective.

1.4 Research Objectives

Main Goal: To design and evaluate a query structuring system for XML Retrieval. Specific goals:

1. To propose a document enrichment method to investigate its effect on keyword queries.
2. To propose a query pre-processing methods to resolve keyword query ambiguities.
3. To propose algorithms to identify user search intention from a keyword query. Specifically, this includes an algorithm to identify predicates and an algorithm to identify the XML nodes users are searching for in order to make the system return informative result.
4. To propose a field weight ranking function, which includes not only the tf-*idf* score but also the weight of a query term based on its position and the query terms proximity in order to reduce the impact of terms with high frequencies.

1.5 Research Scope

This study mainly focuses on how to create an effective keyword query structuring system for the retrieval of documents formatted using XML where the system does not extend to the environment in which documents need regular updating because static labelling scheme is used to assign unique label to each element node in XML documents. The system receives a user queries formatted as a list of keywords not natural language, which denotes user's information need. The items retrieved by the system are either a documents or elements. The system also includes a ranking function, query segmentation, user search intention identification, and query formulation.

1.6 Research Contributions

1. A document enrichment method is proposed to investigate its impact on keyword queries using Semantic Tags Extraction method (STSE) and Element Enrichment Method (EERM).
2. A Semantic Aware Indexing Scheme (SAIS) is proposed to store the Named Entity Category (NEC) of each indexed term, in addition to the usual information such as term frequencies, term position, as well as an element that contains the term in the inverted index.
3. An Entity Based Query Structuring (EBQS) method is proposed based on NECs to re-express the user's query as a list of keywords and named entities.
4. An N-gram Based Query Structuring (NBQS) method is proposed based on N-grams to interpret user input query as a list of semantic units to help address keyword query ambiguities.
5. A Predicate Identification Algorithm (PIA) is proposed to compute relevant predicates.
6. An Improved Predicate Identification Algorithm (IPIA) is proposed to compute relevant predicates.

7. A Compute Return Node Algorithm (CRNA) is proposed to returns informative result.
8. An Entity Identification Algorithm (EIA) algorithm is proposed to compute entity nodes from XML data which makes a robust system.
9. A ranking function, *rk*_BM25TOPF, is proposed to mitigate the effect of terms with high frequencies.
10. A Query Formulation (QRYF) algorithm to select the best queries which reflect user search intention.

1.7 Thesis Organization

The rest of this study is organized as follows:

Chapter 2: Presents a descriptive illustration of the basic concepts of XML and discusses the related works on existing keyword search systems.

Chapter 3: Presents the methodology adopted in this study and the proposed framework.

Chapter 4: This chapter describes the preliminary study conducted to investigate the effect of using semantic tag as part of corresponding element text content for keyword search. The Chapter also presents the performance evaluation.

Chapter 5: Describes XKQSS, an XML keyword query structuring system for XML retrieval. The chapter also presents the experiments and compares the performance of XKQSS with the XReal and the StruX.

Chapter 6: Describes a Ranking Aware XKQSS (RAXKQSS) for XML retrieval. The chapter also presents the experiments and compares the performance of RAXKQSS with StruX and SLCA.

Chapter 7: Concludes the thesis and list several future research directions on the topic of keyword query structuring.

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