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Keyword Search In Top Down Xml

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ABSTRACT: *Efficiently answering XML keyword queries has attracted much research effort in the last decade. The key factors resulting in the inefficiency of existing methods are the common-ancestor-repetition (CAR) and visiting-useless-nodes (VUN) problems. To address the CAR problem, we propose a generic top-down processing strategy to answer a given keyword query w.r.t. LCA/SLCA/ELCA semantics. By "top-down", we mean that we visit all common ancestor (CA) nodes in a depth-first, left-to-right order; by "generic", we mean that our method is independent of the query semantics. To address the VUN problem, we propose to use child nodes, rather than descendant nodes to test the satisfiability of a node v w.r.t. the given semantics. We propose two algorithms that are based on either traditional inverted lists or our newly proposed LLists to improve the overall performance. We further propose several algorithms that are based on hash search to simplify the operation of finding CA nodes from all involved LLists. The experimental results verify the benefits of our methods according to various evaluation metrics.*

1 INTRODUCTION

XML has been successfully used in many applications, such as that in scientific and business domains, as the standard format for storing, publishing and exchanging data. Compared with structured query languages, such as XPath and XQuery, keyword search is also gained popularity on XML data as it relieves users from understanding the complex query languages and the structure of the underlying data, and has received much attention due to that results are not the entire documents anymore but nested fragments. Typically, an XML document can be modeled as a node labeled tree T. For a given keyword query Q, several semantics have been proposed to define meaningful results, for which the basic semantics is Lowest Common Ancestor. Based on LCA, the most widely adopted query semantics are Exclusive LCA (ELCA) [2], and Smallest LCA (SLCA) [5], [7], [8], [9], [11]. SLCA defines a subset of LCA nodes, of which no LCA is the ancestor of any other LCA. As a comparison, ELCA tries to capture more meaningful results, it may take some LCAs that are not SLCAs as meaningful results. Assume that for a given query Q ¼ fk1; k2…..kmg, each keyword appears at least once in the given XML document. Intuitively, to get all CA nodes of Q, our method takes all nodes in the set of inverted IDDewey label lists as leaf nodes of an XML tree Tv rooted at node v, and checks whether each node of Tv contains all keywords of Q in a "top-down" way. The "top-down" means that if Tv contains all keywords of Q, then v must be a CA node. We then remove v and get a forest Fv ¼ fTv1; Tv2 ; . . . ; Tvng of subtrees rooted at the n child nodes of v. Based on Fv, we further find the set of subtrees FCA v Fv, where each subtree Tvi 2 FCA v contains every keyword of Q at least once, i.e., node vi is a CA node. If FCA v ¼ ;, it means that for Tv, only v is a CA node, then we can safely skip all nodes of Tv from being processed; otherwise, for each subtree Tvi 2 FCA v , we recursively compute its subtree set FCA vi until FCA vi ¼ ;. Let SiðvÞ denote, for v, the set of child nodes that contain ki, ScaðvÞ the set of child CA nodes of v, and CAðTvÞ the set of CA nodes in Tv. Formula 2 means that the set of CA nodes of Q equals the set of CA nodes in Tr, where r is the document root node. CAðTrÞ can be recursively computed according to Formula 3. Formula 3 means that for a given CA node v, the set of CA nodes in Tv is equal to the union of fvg and the set of CA nodes in subtrees rooted at v's child CA nodes, which can be further computed by Formula

2 RELATED WORKS

DIL [2] sequentially processes all involved Dewey labels in document order, its performance is linear to the number of involved Dewey labels. IS [3] sequentially processes all Dewey labels of the shortest list L1 one by one. In each iteration, it picks from L1 a Dewey label l and uses it to probe other lists to get a candidate ELCA node. As the basic operations of the two algorithms are OP1 and OP2, they heavily suffer from both the CAR and VUN problems. JDewey-E [7] computes ELCA results by performing set intersection operation on all lists of each tree depth from the leaf to the root. For all lists of each level, after finding the set of common nodes, it needs to recursively delete all ancestor nodes in all lists of higher levels. As a node could be a parent node of many other CA nodes, and the deletion operation needs to process each parent-child relationship separately, JDewey-E suffers from the CAR problem. Meanwhile, as it performs set intersection on all lists of each tree depth fromthe leaf to the root, they will firstly visit nodes of V2 for Q2, thus it also suffers from the VUN problem. As some node IDs appear in many different IDDewey labels of the same inverted list, and HC [4] processes each IDDewey label of the shortest list separately, it still suffers from the CAR problem. Moreover, HC needs to push each component of every IDDewey label of the shortest inverted list into a stack, it also suffers the VUN problem when the pushed components are UNs.

3 THE BASELINE ALGORITHM

Our baseline ELCA algorithm recursively gets all CA nodes in a top-down way, then checks the satisfiability of each CA node, which works on the traditional inverted lists of labels w.r.t. Dewey or one of its variants. To do so, it needs to solve two problems: ðP1Þ identify the set of child CA nodes for each CA node v, ðP2Þ check v's satisfiability w.r.t. ELCA semantics. For P1, given a query Q with m keywords, we know that 8i 2 ½1;m_; ScaðvÞ SiðvÞ. Thus given a CA node v and its subtree set Fv ¼ fTv1; Tv2 ; . . . ; Tvng, to get ScaðvÞ, we do not need to check whether each subtree contains all query keywords; instead, we just need to check whether each node in SminvÞ, which contains least number of child nodes of v w. r.t. kmin, appears in SiðvÞði 2 ½1;m_ ^ i 6¼ minÞ. Even if we know the lengths of all child lists, it's difficult to know which one is SminðvÞ. Fortunately, as all node IDs in each child list of v are sorted in ascending order, our newly proposed set intersection algorithm guarantees that the number of processed child nodes for each CA node v is bounded by jSminðvÞj. For P2, we use the following Lemma to check the satisfiability of v, which is similar to .Lemma 1. Given a query Q ¼ fk1; k2; . . . ; kmg and CA node v,

3.1 The Algorithm

Based on the above description, Algorithm 1 recursively gets all CA nodes in a top-down way. For each CA node v, it finds out the number of occurrences of each query keyword in its subtree, i.e., the length of each of its child list, then gets v's child CA nodes by intersecting v's child lists using binary search operation. After that, it checks the satisfiability of v by Lemma 1. To do so, each inverted list Li is associated with a cursor Ci pointing to some IDDewey label of Li, Ci½x_
denotes the xth component of the IDDewey label that Ci points to, and posðCiÞ is used to denote Ci's position in Li. Given a node v, we use lðvÞ to denote the IDDewey label of v, v:Ni denotes the number of keyword occurrences w.r.t. ki in the subtree rooted v. As shown in Algorithm 1, it firstly initializes the subtree rooted at the root node of the given XML tree in line 1, then calls the procedure processCANodeðÞ to recursively get all CA nodes in line 2.

```
Algorithm 1. TDELCA($Q = \{k_1, k_2, \ldots, k_m\}$)
 1 initialize $v$ as the root, $L_i(v) = L_i$, $v.N_i = |L_i(v)|$,
   and $C_i$ points to the first IDDewey label of $L_i(v)$.
 2 processCANode($v$)
Procedure processCANode($v$)
 1 $chL \leftarrow |l(v)| + 1$
 2 while($\neg$ eof($v$)) do
 3     $u \leftarrow$ getNextChildCA($v, chL$)
 4     if ($u = -1$) then break
 5     initializeChildCA($v, chL, u$)
 6     $v.[N_1, \ldots, N_m] \leftarrow v.[N_1, \ldots, N_m] - u.[N_1, \ldots, N_m]$
 7     processCANode($u$)
 8 if ($\forall i \in [1, m]$, $v.N_i > 0$) then
 9     output $v$ as an ELCA node
Function getNextChildCA($v, chL$)
 1 $j \leftarrow 1$; $n \leftarrow 1$; $x \leftarrow \text{argmax}_i\{C_i[chL]\}$
 2 while ($n < m$) do
 3     if ($j = x$) then $j \leftarrow j + 1$
 4     use $C_x[chL]$ as the eliminator to do binary
       search on the $chL^{th}$ level of $L_j(v)$
 5     if (pos($C_j$) is out of $L_j(v)$) then return $-1$
 6     if ($C_x[chL] = C_j[chL]$) then $j \leftarrow j + 1$; $n \leftarrow n + 1$
 7     else $x \leftarrow j$; $j \leftarrow 1$; $n \leftarrow 1$
 8 return $C_x[chL]$
Procedure initializeChildCA($v, chL, u$)
 1 for each ($i \in [1, m]$) do
 2     set the start position of $L_i(u)$ as pos($C_i$)
 3     binary search the end position of $L_i(u)$ by using
       $u + 1$ to probe the $chL^{th}$ level of $L_i(v)$
 4     $u.N_i \leftarrow |L_i(u)|$
Function eof($v$)
 1 if (exists $L_i(v)$, such that all nodes are processed) then
 2     return TRUE
 3 return FALSE
```

The procedure processCANodeðÞ works as follows. Itfirstly gets the depth of v’s child nodes in line 1. In lines 2-7, it repeatedly gets all child CA nodes of v. For each child CA node u got in line 3, it firstly gets the values of variables associated with v in line 5; in line 6, it excludes the occurrences of all query keywords under u from that under v. In line 7, it calls processCANodeðÞ to recursively process u.

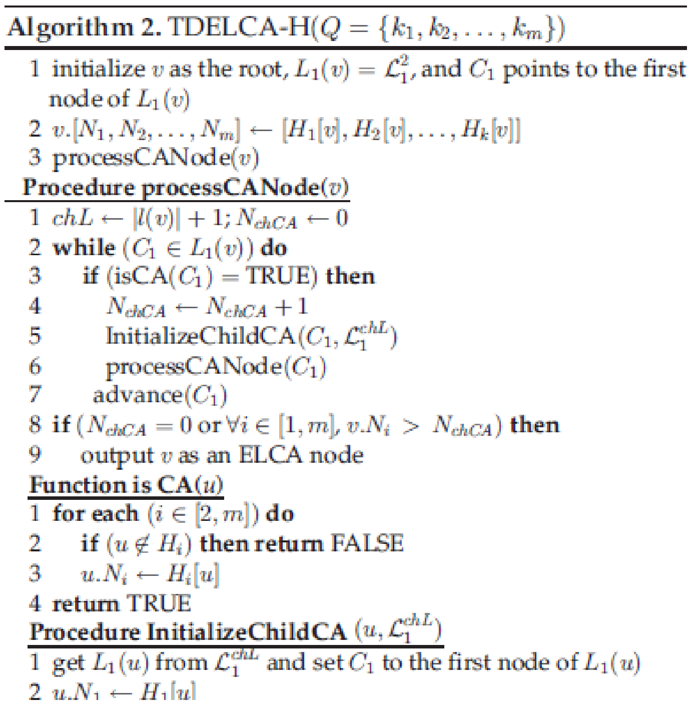
After processing all childCA nodes of v, if 8i 2 ½1;m_; v:Ni > 0, according to Lemma 1, v is an ELCA node and outputted in line

4. THE HASH SEARCH BASED ALGORITHMS

Even though TDELCA-L reduces the time complexity compared with TDELCA, it relies on the probe operation (implemented by binary search) to align the cursors of inverted lists. To further improve the overall performance, we consider the existence of additional hash indexes [4], [11], [17] on inverted lists, such that each probe operation takes time without using binary search operation. the first hash table HF records the number of nodes in each Li, which is used to choose the shortest LList. For each Li, another hash table Hi records, for each node of Li, the number of its child nodes that contain ki. Note that Hi in our methods is different with that of [4], [11], [17], where Hi records, for each node v, the number of v’s descendant nodes that directly contain ki., we know that the number of nodes of L1 is 11, which can be denoted as HF ½k1_ ¼ 11. According node 1 has three child nodes containing k1(“Tom”), which can be denoted as H1½1_ ¼ 3. Node 5 does not have child nodes containing k1, thus H1½5_ ¼ 0. Similarly, node 3 does not contain k1, which is denoted as 3 62 H1.

4.1 The Baseline Hash Search Algorithm

Assume that jL1j _ jL2j _ __ _ _ jLmj, the main idea of our baseline hash search algorithm is: take the shortest LList L1 as the working list and recursively process all CA nodes in top-down way. For each CA node v, sequentially check whether each of its child nodes in L1 is a CA node, then output v if it is an ELCA result.



```
Algorithm 2. TDELCA-H($Q = \{k_1, k_2, \ldots, k_m\}$)
1 initialize $v$ as the root, $L_1(v) = \mathcal{L}_1^2$, and $C_1$ points to the first
  node of $L_1(v)$
2 $v.[N_1, N_2, \ldots, N_m] \leftarrow [H_1[v], H_2[v], \ldots, H_k[v]]$
3 processCANode($v$)
Procedure processCANode($v$)
1 $chL \leftarrow |l(v)| + 1$; $N_{chCA} \leftarrow 0$
2 while ($C_1 \in L_1(v)$) do
3     if (isCA($C_1$) = TRUE) then
4         $N_{chCA} \leftarrow N_{chCA} + 1$
5         InitializeChildCA($C_1, \mathcal{L}_1^{chL}$)
6         processCANode($C_1$)
7     advance($C_1$)
8 if ($N_{chCA} = 0$ or $\forall i \in [1, m]$, $v.N_i > N_{chCA}$) then
9     output $v$ as an ELCA node
Function isCA($u$)
1 for each ($i \in [2, m]$) do
2     if ($u \notin H_i$) then return FALSE
3     $u.N_i \leftarrow H_i[u]$
4 return TRUE
Procedure InitializeChildCA ($u, \mathcal{L}_1^{chL}$)
1 get $L_1(u)$ from $\mathcal{L}_1^{chL}$ and set $C_1$ to the first node of $L_1(u)$
2 $u.N_1 \leftarrow H_1[u]$
```

Algorithm 2 shows the detailed description of the TDELCA-H algorithm. Compared with TDELCA and TDELCA-L, for a given query Q, TDELCA-H only needs to process all CA nodes and their child nodes in L1. For each processed node v in L1, TDELCA-H checks whether v is a CA node by hash probe operations, rather than set intersection operations on a set of child lists9

5 CONCLUSIONS

Considering that the key factors resulting in the inefficiency for existing XML keyword search algorithms are the CAR and VUN problems, we proposed a generictop-down processing strategy that visits all CA nodes only once, thus avoids the CAR problem. We proved that the satisfiability of a node v w.r.t. the given semantics can be determined by v's child nodes, based on which our methods avoid the VUN problem. Another salient feature is that our approach is independent of query semantics. We proposed two efficient algorithms that are based on either traditional inverted lists or our newly proposed LLists to improve the overall performance. Further, we proposed three hash search-based methods to reduce the time complexity. The experimental results demonstrate the performance advantages of our proposed methods over existing ones. One of our future work is studying disk-based index to facilitate XML keyword query processing when the size of indexes becomes too large to be completely loaded into memory.

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