Recursive XML Schemas, Recursive XML Queries, and Relational Storage: XML-to-SQL Query Translation

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Outline

- Introduction
- Formal Model
- Query Translation Over Recursive XML schemas
- Extensions to more complex path expressions
- Conclusions

Introduction – Problem

- Translate path expression queries to SQL
  - Schema-based XML Storage shredding of XML into relations
  - Recursion in the schema
  - Recursive XML queries
    - Path expression queries having the descendant axis (//)

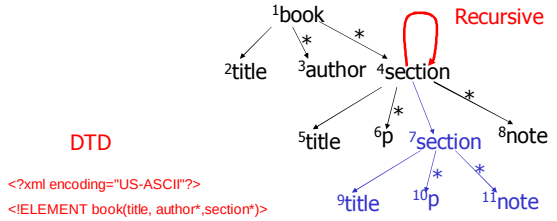
Introduction – Related Work

- Shredding XML data into relations
  - Schema-based techniques
  - Schema-oblivious shredding
- Translating XML queries into SQL
- Claim of this paper
  - None of previous work solves the query translation problem for schema-based shredding in the presence of recursion in the XML schema

Formal Model – XML Schema Graph

- A directed graph (V, E)
  - V: vertices corresponding to elements and attributes
    - Labeled with name of the element or attribute
  - E: edges representing parent-child relationships
    - Have a label from {?, *, +, ε}

Formal Model – XML Schema Graph



DTD

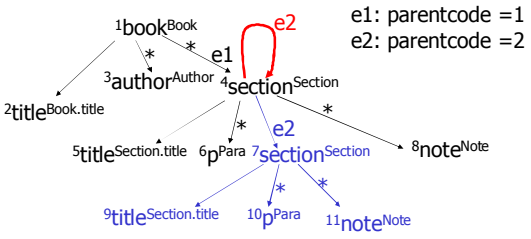
```
<?xml encoding="US-ASCII"?>
<!ELEMENT book(title, author*,section*)>
<!ELEMENT title (#PCDATA)>
<!ELEMENT author (#PCDATA)>
<!ELEMENT section (title, p*, section?, note*)>
<!ELEMENT note (#PCDATA)>
```

XML Schema Graph

Formal Model – Relational Schema

- Mapping XML elements and relational columns
- Method: annotate XML schema graph
  - Non-leaf (internal) node <= Relation name
  - Leaf node <= column name
  - Node n has multiple incoming edges
    - parentcode = val

Formal Model – Annotated XML Schema Graph



Annotated XML Schema Graph

Formal Model – XML to Relational Mappings

- Relation has an id field (primary key)
- Preserve Document structure
  - Parentid
  - parentcode

Formal Model – Relations

Book

id	title

Author

id	parentid	...

Para

id	parentid	...

Section

id	parentid	parentcode	title

Note

id	parentid	...

Path Expression Queries

- Simple path expression (SPE)
  - $s_1 l_1 s_2 l_2 \ldots s_k l_k$
  - s_i is / or //
  - l_i is a tag name
  - $s_i l_i$ represents a navigation step of the path expression
- Generalized simple path expression (GSPE)
  - $p_1 p_2 \ldots p_k$
  - Each p_i denotes a disjunction of simple path expressions

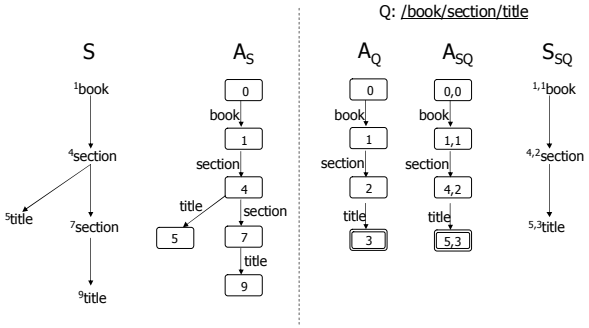
Query Translation Over Recursive XML Schemas

- PathId stage
  - Identify the paths in the XML schema graph that satisfy the query
- SQLGen stage
  - Construct an equivalent relational query from the XML-to-Relational mapping

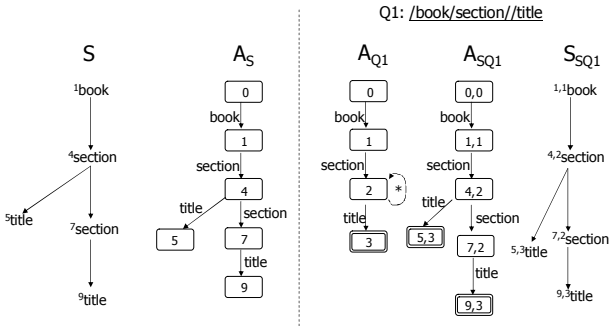
Query Translation – PathId

- Query Q = $p_1 p_2 \ldots p_k$
- The path in schema graph satisfy Q
  - Problems
    - Could be infinite for recursive schema!
    - Could be exponential for DAG schema graphs!
  - Solution
    - Representing the matching paths as a graph!

Query Translation – PathId



Query Translation – PathId



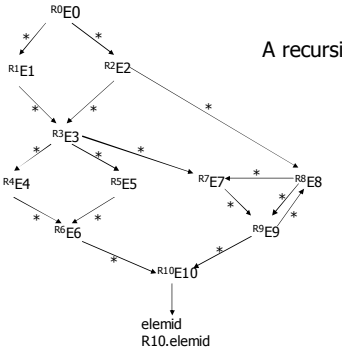
Query Translation - PathId

- Result from PathId
  - Cross product schema S_{SQ}
  - Matching paths encoded in S_{SQ}
  - Union of all root-to-leaf paths in S_{SQ} corresponds to the query result

Query Translation – SQLGen

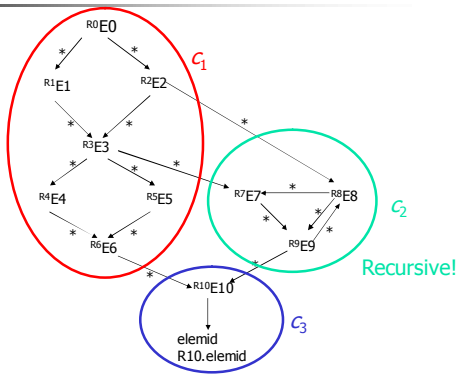
- SQLGen steps
  1. Identify strongly connected components (SCCs) in S_{SQ}
  2. Merge adjacent SCCs based on dominance
  3. For each SCC
     - Generate the query for this SCC
     - A relational query T(*n*) is associated with each left node *n*
  4. finalQ = U $_{\text{n is a leaf node}}$ "select * from T(*n*)"
  5. Output results
     - If duplicate elimination needed, output "select distinct(*) from finalQ"
     - Else, "select * from finalQ"

Query Translation – SQLGen



A recursive Schema

SQLGen – Steps 1 and 2



Step 1
and Step2

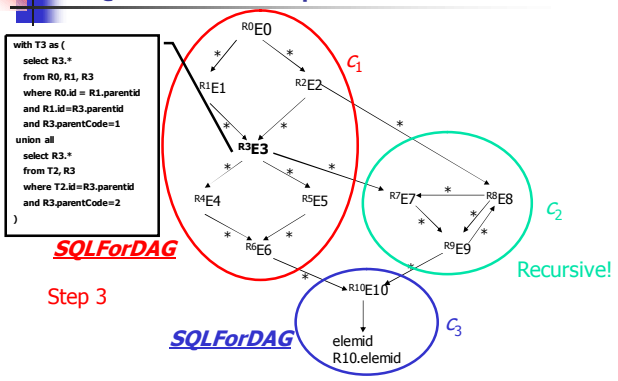
SQLGen – Step 3

- Generate the query for SCCs
  - If a SCC *c* is not recursive
    - SQLForDAG(*c*)
  - If a SCC *c* is recursive
    - SQLForRecursive(*c*)

SQLGen – Step 3: SQLForDAG(*c*)

- Associate a temporary relation T(*n*) with a node *n* which
  - is leaf node, or
  - has a parent or child in a different component, or
  - has multiple incoming/outgoing edges
- T(*n*) is the union of all SQL generated along possible paths

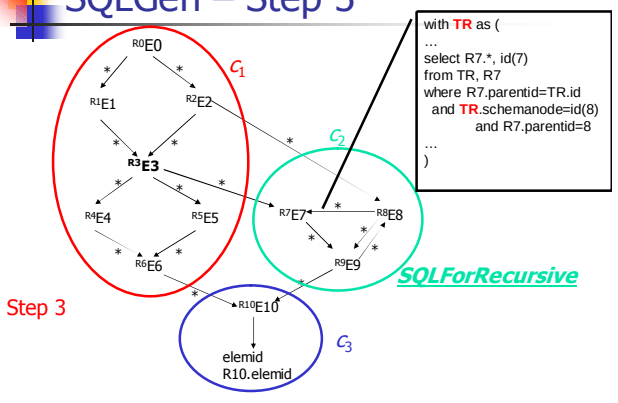
SQLGen – Step 3



SQLGen – Step 3: SQLForRecursive(*c*)

- Associate a temporary relation T_R to *c*
  - Initialization part
    - Captures all incoming edges into *c* from a different component, (2,8) and (3,7)
  - Recursive part
    - The union across all edges within the component

SQLGen – Step 3



Extensions to more complex path expressions

- Branching path expression queries
  - $p_1[p_2]$ or $p_1[p_2$ op value], p_1 and p_2 are GSPE queries
  - PathId stage
    - Deal with p_1 first, let F be the final states
    - Compute an automaton for p_2 with a f in F as start state
  - SQLGen stage
    - Deal with p_1 and p_2 consecutively

Handling Order

- Handling order in XPath semantics
  - Queries need to return results in document order
  - XML into relations with positions
    - Maintain the relative position among sibling XML elements
    - Not the focus of this paper

Conclusions

- An algorithm to translate path expression queries to SQL
  - Recursion in the XML schema
  - Recursion in the queries
- This algorithm is not quite general
  - Apply to SPE and GSPE
- Linear recursion in SQL99 is sufficient for this translation

Discussions

- XML-to-Relational mapping
  - There must be no data in the relations other than that which is present in the XML document? **True**?
- SPE and GSPE are quite similar to regular expressions
  - Why not just use regular expression approach?
- More complex applications
  - FLWR