SUPER RELATIONAL APPROACH FOR EFFICIENT EXTENSIBLE MARKUP LANGUAGE (XML) QUERY PROCESSING

BY

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DECLARATION

I declare that the work in this thesis entitled 'SUPER RELATIONAL APPROACH FOR EFFICIENT XML QUERY PROCESSING' has been performed by me in the Department of Mathematics under the supervision of Dr. S.E. Abdullahi and Prof. O.S. Adewale. The information derived from the literatures has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

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CERTIFICATION

This thesis entitled 'SUPER RELATIONAL APPROACH FOR EFFICIENT XML QUERY PROCESSING' by **Sabitu ABDU** meets the regulations governing the award of the degree of Master of Science (M.Sc) in Computer Science of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Today's database is associated with interoperability between different domains and applications. This consequently, results in the importance of data portability in database. XML format fits the requirements and it has been increasingly used for serving applications across different domains and purposes. However, querying XML documents effectively and efficiently is still a challenging issue. Several researches have been conducted on XML query techniques of which many are inclined to Native Approach technique in which specialized storage and query processing systems are tailored for XML data from scratch to improve XML query processing. In this research we introduce Super Relational Approach (SRA) techniques in which XML document is automatically stored and queried using relational database with a view to fully utilize the superb capabilities of relational database since native databases are still in immaturity stage. In spite of the long time it takes SRA to shred XML document, the shredding has less impact on the query execution time saved by the technique. In this regard, the shredding is justifiable because once document is shredded it can be queried as many times as possible. The proposed technique (SRA) outperforms Native Approach in terms of speed, deletion, insertion and replacement by 24.23%. Hence, it is recommended for query processing in large XML documents with fixed structure.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Extensible Markup Language (XML) is emerging as a de factor standard for information exchange among various applications on the worldwide web due to XML's inherent data self-describing capability and flexibility of organizing data. There has been need to identify the best techniques to query large XML data repositories efficiently.

First, data in XML documents are self-describing. Similar to the popular Hypertext Markup Language (HTML), XML is based on so called nexted tags. Figure 1.1 shows an example of an XML document, which records information about publishers. However, unlike HTML, in which tags associated with data express the presentation style (for example, font sytle) of data , tags in XML describe the semantics of data. For example, lines 1 – 3 in figure 1.1 say that "Cambridge" is an address of a publisher whose name is "MIT Press". This self describing capability of XML data helps applications on the web "understand' the content of XML documents published by other applications.

Second, XML is flexible in organizing data. The hierarchy formed by nexted tags structures the content of XML documents. The role of nexted tags in XML is some what similar to that of schemas in relational databases. At the same time, the nexted XML model is far more flexible than the flat relational model. In an XML document, object of the same type might have different types of subobjects or different numbers of subobjects of the same type. For example in Figure 1.1a and b, the first publisher, but not the second publisher, has

an address subelement. The book under the first publisher has two author subelements, but the book under second publisher has only one.

```
<publishers>
        <publisher @name='MIT Press'>
                <address> Cambridge </address>
                <book>
                        <title> Database </title>
                        <author> Tom</author>
                        <author>Joh<author>
                </book>
        </publisher>
        <publisher>
                <book>
                        <title> Life </title>
                        <author>
                                <name> Smith </name>
                                <age>18</age>
                        </author>
                </book>
                <name>NY Press</name>
        </publisher>
<publishers>
```

Figure 1.1a Example of XML Document without ID/IDREF (Source: Gov G. and Chikova R. (2007))

```
<publishers>
        <publisher @name='MIT Press'>
                <address> Cambridge </address>
                <book>
                        <title> Database </title>
                        <author friend =1> Tom </author>
                        <author id=1 loves=2>John<author>
                </book>
        </publisher>
        <publisher>
                <book>
                        <title> Life </title>
                        <author id=2 friend=1>
                                <name> Smith</name>
                                <age>18</age>
                        </author>
                </book>
                <name> NY Press </name>
        </publisher>
<publishers>
```

Figure 1.1b Example of XML Document with ID/IDREF (Source: Gov G. and Chikova R. (2007))

1.2 XML DATA MODEL

1.2.1 BASIC MODEL: TREES

The basic data model of XML is a labeled and ordered tree. Figures 1.2a and 1.2b show the data tree of XML document in Fig 1.1a. Fig 1.2a is based on the edge-labeled model, with labels on edges. These two models are equivalent. There are basically threee types of models in a data tree:

1. Element nodes (internal nodes). These correspond to tags in XML documents, for example publisher.

2. Attribute nodes (internal nodes). These correspond to attributes associated with tags in XML documents, for example "@name". In contrast to element nodes, attribute nodes are not nexted (that is an attribute cannot have any subelements) are not repeatable (that is, two same-name attribute cannot occur under one element), and are unordered (that is, attributes of an element can freely interchange their occurance location under the element)

3. Value nodes (leaf nodes). These correspond to data values in XML documents, for example, "MIT Press".

Edges in a data tree represent structural relationships between elements, attributes, and values. In an XML data tree, some nodes with the same name might be nested on the same path. This phenomenon is called recursion. Recursion in XML data significantly increases the complexity of efficiently querying XML data.

1.2.2 EXTENDED MODEL: DIRECTED ACYCLIC GRAPHS (DAGs) AND GENERAL GRAPHS

XML documents allow users to define ID/IDREF attributes of elements, where an ID attribute uniquely identifies an elements, and IDREF attributes refer to other elements that are explicitly identified by their ID attributes. Fig. Ib shows an XML document with ID/IDREF attributes. ID/IDREF attributes increase the flexibility of the XML data model and extend the basic model to DAGs or to even more general directed graph with cycles. Fig. 1.2c shows an XML data graph with cycles, which corresponds to the XML document in Fig 1.1b.

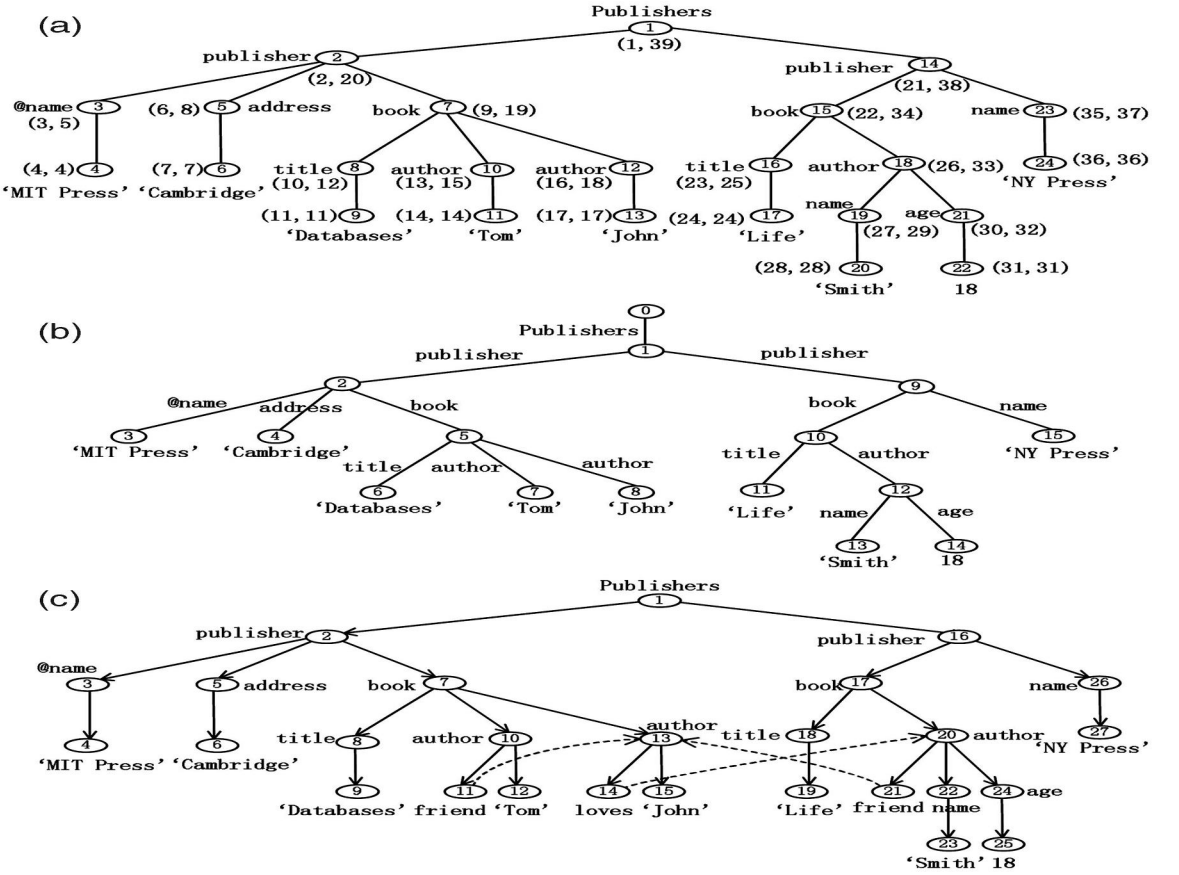


Figure 1.2. The XML data model (a) Node-labeled XML data tree (b) Edge-labeled XML data tree. (c) Node-labeled XML data graph with ID/IDREF edges (Source: Gov G. and Chikova R. (2007))

1.3 XML QUERIES

Unlike (flat) text documents, XML documents have nexted structure. Thus, XML queries concern not only the content but also the structure of XML data. Basically, the queries can be formed using twig patterns, which nodes represent the terms that the user is interested in, that is, the content part of queries, and edges represent the structural relationships that the user wants hold between the terms, that is, the structural part of queries.

XML queries could be categorized into two classes: database-style queries and Information Retrieval (IR)-style queries. Database-style queries return all query results that precisely match (the content and structure requirements specified by) the queries, which is similar to SQL query semantics in relational databases. On the other hand, IR-style queries allow "imprecise" or "fuzzy" query results, which ranked based on their relevance to the queries. Only the top-ranked results are returned to users, which is similar to the semantics of keyword search queries in the traditional IR context.

1.3.1 DATABASE-STYLE XML QUERIES

XML Path Language (Xpath) and Xquery, originally developed and recommended by the W3C Consortium, are today's mainstream (database-style) XML query languages.

Xpath. Xpath is a basic XML query language that select nodes from XML documents such that from the root to each selected node satisfies a specific pattern. A simple Xpath query is formulated as sequence of alternating axes and tags. Two most commonly used axes are the child axis "/", where "A/B" denotes selecting B-tagged child nodes of A-tagged nodes, and the descendant axis "//", where "A//B" denotes selecting B-tagged descendant nodes of A-

tagged nodes. Consider an Example: An Xpath query "/publisher//title" would return all title elements under all top-level publisher elements. The result of this query on the data tree in Fig. 1.2a is two title nodes that have values "Databases" and "Life", respectively.

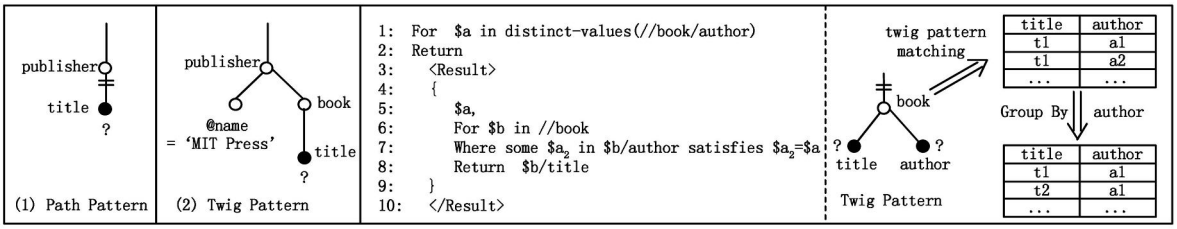


Figure. 1.3 Examples of (a) XPath and (b) Xquery (Source: Gov G. and Chikova R. (2007))

The above Xpath query can be formalized as a simple path pattern, as shown in Fig.1.3a(1), where the single-line edge represents the "/" axis, the edge with "=" represent the "//" axis, and the shade node is an output node. Generally, an Xpath query can specify a more complex twig pattern by using predicates in its expression. One example is "/publisher[@name=MIT Press]/book/title" (Fig. 1.3a (2)), in which "/publisher/book/title" is main path of the query, and the content between "[" and "]" is a predicate. This query returns all book titles of the publisher with name "MIT Press". Generally an XPath query might involve more predicates.

From the above, it can be noticed that the core of an XPath query is a twig pattern that includes exactly one output node. Further, nodes in query twig patterns is called query and node in data trees is called data nodes.

In addition to the child axis and descendant axis, XPath defines eleven (11) other axis types namely: parent, ancestor, descendant-or-self, ancestor-or-self, following, preceding, following-sibling, preceding-sibling, self, attribute, and namespace. In most occasion

attention has been concentrated on child (/) and descendant (//) axes because they are most commonly used in practical applications and have been of the most interest to researchers.

Xquery. Query language Xquery is more expressive than XPath. An Xquery is composed of For-Let-Where-Return (FLWR) clauses, which can be nexted and composed with full generality; that is each clause in itself can include sub-Xquery queries. The For and Let clauses bind nodes selected by XPath expressions to user-defined node variables. The Where clauses specify selection or join predicates on variables. The Return clauses operate on node variables to format query results in the XML format (rather than in the simple tuple format, as in the context of answering relational queries). Fig. 3b shows a simple Xquery query, which groups book titles by author, on the XML data in Fig. 1a, which instead groups authors by book.

Although the nested/compositional syntax of Xquery makes it much more expressive than XPath, the rich semantics also significantly increases the optimization and evaluation complexity of Xquery. Although an Xquery query can be evaluated simply clause by clause by using the nested-loop procedure implied by its syntax, such a naive syntax-driven evaluation plan usually results in poor query performance. For example, whereas the query in Fig. 3b involves four path expressions (in lines 1, 6, 7, and 8, respectively), it is really unnecessary to evaluate these four path expressions over the XML data separately. Indeed, these path expressions have overlapping parts, and evaluating them seperately would result in unnecessarily repeated accesses to the same data nodes.

In fact, by carefully analyzing the semantics of the Xquery query in this example, an intelligent Xquery optimizer would be able to find an efficient evaluation plan such as the

plan shown on the right side of Fig. 3b. By assembling the four path expressions into a single twig pattern, the plan avoid repeated evaluation of these path expressions. Considerable effort has been devoted to developing such intelligent Xquery optimizers for finding efficient XQuery evaluation plans.

1.3.2 INFORMATION RETRIEVAL (IR)-STYLE QUERIES

IR-Style XML queries are mainly used to query text-dense XML data repositories whose value elements typically involve long texts. For example, the XML document in Fig. 1a is not text dense, since most of its value elements, for example "Databases", "Tom", and "John" include only very short texts. However, this document would become text dense if some new review elements containing long texts were added under book as subelements.

Unlike database-style XML queries, there is no commonly agreed standard language for expressing IR-style XML queries. There are two classes of IR-style XML queries namely: DB+IR queries and IR-only queries.

DB+IR queries. DB+IR queries enhance database-style XML queries such as XPath and Xquery queries with IR style characteristics. For instance, it is common to enhance XPath or XQuery queries with a contains function to perform IR-style keyword search. A simple example is "//publisher[contains("Databases," "Tom")]/@name." It returns the names of all publishers whose (child or descendant) subelements contain approximate matches to keywords "Databases" and "Tom." Such contains-Super DB+IR queries have been considered, for instance, in XIROL, CtreeIR and FleXpath.

IR-only queries. The format of IR-only queries is less rigid than that of DB+IR queries: IR-only queries do not have the structural part and specify the content part as a set of

keywords K = {K1, K2, ..., Kn} (this is similar to keyword search queries in the traditional IR context). The candidate answers of IR-only queries are from the set of Lowest Common Ancestor (LCA) of those data nodes that correspond to the keywords in K, since LCAs typically represent the most specific answer elements that are relevant to the given keywords. For example, an IR-only query {“Database,” “Tom”} over the data tree in Fig. 2a will retrieve the book node under the first publisher node, whereas the first publisher node is not retrieved although it is a common ancestor of the “Databases” and “Tom” than the first publisher element. IR-only queries have been considered in, for instance, XRANK and XKSearch (Gou and Chirkova (2007)).

Ranking. In addition to finding candidate query result, IR-style XML queries (both DB+IR queries and IR-only queries) need to rank the candidate query results based on their relevance to the queries and to return to the user only the top-ranked results, as in the traditional IR context. Many relevance measures developed in the traditional IR context such as keyword proximity and weighted term frequency are applicable to building ranking functions in the XML IR context is result specific, which ranks more specific results higher than less specific results. The motivation is similar to that of computing LCAs for IR-only queries.

1.4 RESEARCH MOTIVATION

Today’s database is associated with interoperability between different domains and applications. This consequently results in the importance of data portability in database. XML format fits the requirements and it has been increasingly used for serving applications across different domains and purposes. However, querying XML document effectively and

efficiently is still a challenging issue and hence serves as the motivation for proposing Super Relational Approach for Efficient XML query processing.

1.5 RESEARCH QUESTIONS

The study is set up to answer the following questions:

a. Why XML?

b. Is it possible to introduce relational approach technique that can compete favourably with native approach in XML query processing?

1.6 RESEARCH AIM AND OBJECTIVES

The main aim of this research is to propose a technique for efficient XML query processing. The specific objectives of the research are:

a. Defining relational approach and native approach in XML query processing

b. Propose Super Relational Approach for efficient XML query processing

1.7 RESEARCH METHODOLOGY

The following are the steps that are set out to answer the above research questions:

a. Review literature to understand the two query techniques: relational approach and native approach
b. Propose Super Relational Approach for efficient XML query processing
c. Implement the Super Relational approach for efficient XML query processing using mySQL5.5.16, script files and XML documents.
d. Compare the performance of the Super Relational Approach with Native approach
e. Evaluate the performance of the Super Relational Approach

1.8 CONTRIBUTION TO KNOWLEDGE

The thesis provided an additional technique for efficient XML query processing.

CHAPTER TWO

LITERATURE REVIEW

2.1 XML QUERY LANGUAGES

According to World Wide Web Consortium (W3C), since 2007 XQuery which is an extension of Xpath has been recommended by W3C as query language for XML document. However, prior to the establishment of W3C standard, there had been several researches proposing query languages for XML.

Maier (1998) elaborated desired characteristics of XML query language. His criteria were massively used as reference for development of some XML query languages. Important criteria in his proposal include XML output of the query, independence of schema, schema exploitation if possible, and optimized query operations. The operations defined in the proposal are selection which is choosing document or document element, extraction which is pulling out elements of a document, reduction that is realized as removing sub-elements, restructuring or constructing a new set of element instances, and combination as merging operation carried out over two or more elements resulting in only single element.

Deutsch et al (1999) proposed XML-QL which is an XML query language that provides support for querying, constructing, transforming and integrating XML data. This language reflects XML as semi-structured data that have irregular or rapidly evolving structure. XML-QL uses element patterns to match data in an XML document. An extension of XML-QL named Elixir was proposed by Chinenyanga T and Kushmerick (2002) to support ranked queries based on textual similarity. The prons of this language is its schema awareness and can implement nested queries. While it cons are heavily pattern based, priori knowledge of data structure is usually required and cumbersome syntax.

Abiteboul et al (1997) proposed Lorel which is early query language for semi-structured data. It uses Object Exchange Model (OEM) as the data model for semi-structured data. For querying the elements, Lorel extends Object Query Language (OQL) by relying on coercion at a number of levels to restrain the strong typing of OQL. Lorel also extends OQL with path expressions so that users can specify patterns that are matched to actual paths in referred data. Pros: easy syntax; Cons: dependent on OQL parser, limited functionalities.

Chamberlin et al (2000) introduced Quilt which is a functional language in which a query is represented as expression. There are seven principal forms of Quilt expressions which are path expressions, element constructors, For Let Where Return (FLWR) expressions, expression with operator and functions, conditional expressions, quantifiers and variable bindings. Beside join operations, quit also support nested expressions hence it basically support subquery within a single query. Significant features of Quilts were used for development of Xquery. Pros: robust functionalities, sub-queries; Cons; no support for textual similarity.

Robie et al (1999) came up with XQL wich uses path expressions hence its basic constructs correspond directly to the basic structures of XML. Due to this nature, XQL is closely related to Xpath. In XQL, document nodes play a central role. Nodes have identity and they retain their identity, containment relationships, and sequence in query results. The nodes themselves may come from variety of different sources. However, XQL does not specify how these nodes are brought to the query. XQL also support joins and some functions. Pros: shorter expression; Cons: semantics may not be very intuitive.

Xquery according to W3C had been a moving target for sometime before it was established as W3C recommendation in 2007. A big part of Xquery semantics adopts Quilt. XQuery

uses Xpath for path expressions and FLWR structure for describing the whole query. As a recommended standard, a lot of researches, nowadays discuss the method of optimizing XQuery translation and processing by a query processor and integrating XQuery into a full-fledged XML database management system. Pros: clear semantics, integration with Xpath; Cons: intersection XSL.

2.2 COMPARISM OF XML QUERY LANGUAGES

Simalango (2010) compared XML query languages as shown in table 2.1

Table 2.1 XML query languages in comparison

Query Language	Lang. Type	Input Model	Class of Query	Public Recognition
XML-QL	Functional	XML	Pattern Matching	1998
Lorel	Declarative	OEM	Path expression wihin OQL	1997
Quilt	Functional	XML	Quilt expression	2000
XQL	Functional	XML	XQL based on path expressions	1999
XQuery	Functional	XML	XQuery	2007

2.3 XML QUERY PROCESSING: THE RELATIONAL APPROACH

According to Gou & Chirkova (2007) many of today's commercial database systems are relational database management systems (RDBMSs), and examples include IBM DB2, Microsoft SQL Server, MySQL and Oracle DB. For more than 30 years of academic and industrial efforts, RDBMSs have acquired strong capabilities in storage management, query

processing and optimization, and concurrency control and recovery. Motivated by this fact, a number of research projects have addressed storing and querying XML data in RDBMSs.

2.3.1 The Edge Approach

2.3.1 (a) The Basic Edge Approach

Florescu and Kossmann (1999) proposed a simple approach to shredding XML data into relations. This approach places all edges in an edge-labeled XML data tree into a single relational table Edge. The key idea here is using an attribute which represents the two end points of each edge. Label represents the tag on an edge, whereas Flag and Value give the type and value, respectively, of the target node of an edge. Two edges A and B can be joined together if and only if A:Target ¼ B:Source. Based on this property, it is easy to transform XML queries without "//" axes into SQL queries.

2.3.1 (b) The Binary Approach

Executing part 1 of the basic Edge approach can be avoided by using the Binary approach proposed by Florescu and Kossmann (1999), which pregroups all edges in the Edge table by their Labels and creates one table for each distinct Label. Each table has the schema Source; Target; Flag; Value with Label dropped from the Edge schema. In addition to improving query performance, the Binary approach also saves storage space, since the Label attribute is not stored.

2.3.2 The Node Approach

Zhang et al. (2001) developed a Node approach, in which all internal nodes (that is, the element and attribute nodes) in a node-labeled XML data tree are stored in a relational table

Node. The key idea here is using the attribute triple Start;End; Level. "//"-axis queries can be answered efficiently by using the ðStart;EndÞ pairs. Level is used along with Start;End to answer "/"-axis queries.

2.3.3 The Path Materialization (PM) Approach

2.3.3 (a) The Basic PM Approach

To reduce the number of node joins, Yoshikawa et al. (2001) proposed a PM approach, in which internal nodes in a node-labeled XML data tree are stored in a relational table Path. The Path table is very similar to the Node table. The difference is that rather than storing the tag of each node in the Label attribute, the PM approach stores the tag path from the root to each node (called root path) in a Path attribute.

2.3.3(b) The Reversed-Path (RP) Approach

Pal et al. (2004) proposed an RP approach, which overcomes the main drawback of the PM approach. The RP approach uses the relation schema. The key idea of RP is storing reversed root paths of data nodes in a ReversedPath attribute. In addition, RP uses an ORDPATH attribute instead of the Start;End; attributes of the PM approach. ORDPATH coding is a variant of the Dewey coding (Gov and Chirkova (2007)). Similar to PrePost coding, it can be used to determine reachability between nodes.

2.3.3 (c) The Basic Linear Algebra Subprograms (BLAS) Approach

Chen et al. (2004), in addition to discovering RP independently, proposed a sophisticated BLAS approach to implement statistical parametric mapping (SPM) efficiently. The schema of the BLAS table is given as displayed in table 2.2.

Table 2.2: Schema of BLAS table

PLabel	Start	End	Level	Flag	Value

The key idea of BLAS is encoding each ReversedPath string into a PLabel value. This encoding is a variant of the reversed arithmetic encoding developed by Min et al. (2003)

2.3.4 Document Type Descriptor (DTD) Approach

According to Gou & Chirkova (2007) all the above approaches address storing and querying general (schemaless) XML data. In many practical applications, XML data also conform to a "schema" to some extent because a common agreement on the schemas of the data would facilitate significantly the data exchange among various applications. Such schema information provides extra opportunities for more compact storage and more efficient querying of XML data. The DTD approach utilizes such crucial schema information.

2.4 XML QUERY PROCESSING: THE NATIVE APPROACH

According to Gou & Chirkova (2007) many native techniques have been developed to query XML data efficiently and call these techniques native approaches, since their query processing (and, perhaps, also storage) mechanisms are developed from scratch, without involving relational databases. Native approaches are driven by the belief that a storage and query processing system specifically tailored for XML data will improve XML query performance significantly.

2.4.1 The Join Approach

2.4.1 (a) The Multi-Predicate MerGe JoiN (MPMGJN) Approach

Zhang et al. (2001) proposed an MPMGJN algorithm, whose implementation is some what similar to the classical mergejoin algorithm developed in relational query optimizers for equijoins. To answer a query "A==B" or "A=B," first, two cursors are created to point to the heads of listA and listB, respectively. Then, the two cursors are compared with each other and are advanced as needed to implement the merge join. In contrast to the standard merge-join implementation for equijoins, MPMGJN has its own cursor advancing mechanism, which is tailored to efficiently support structural joins.

2.4.1 (b) The StackTree Approach

Al-Khalifa et al. (2002) observed that MPMGJN fails to process "/"-axis queries efficiently in some cases. A motivating example is shown in figure 2.1. In the example, a1 has only two B children: b1 and b6. However, in MPMGJN, the inner loop join at a1 also visits unnecessarily b2 through b5, which are proper descendants but not children of a1.

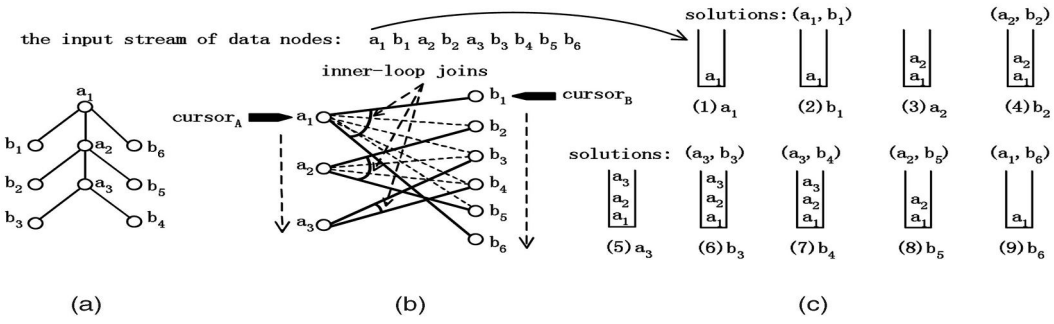


Figure 2.1 Stack Tree Approach (Source: Al-Khalifa et al (2002)

Al-Khalifa et al. (2002) proposed a StackTree approach that can avoid such visiting of unnecessary nodes. StackTree uses a stack structure to cache those A nodes that are nested on the same path in data trees.

2.4.1 (c) The Holistic Approach

Bruno et al. (2002) proposed a Holistic approach, whose key idea is pipelining, that is, joining multiple inverted lists at a time to avoid generating intermediate join results.

2.4.1 (d) The Index-Graph-Aided (IGA) Approach

According to Gou & Chirkova (2007) the IGA approach is not an independent approach. Rather, it is coupled with other approaches to facilitate query processing whenever some type of index graph GI of the original XML data—P-index or T-index is available and is small enough (for example, due to the coarse structure of XML data) to navigate efficiently.

2.4.2 The Sequence Approach

Wang et al. (2003) proposed a method, which is call the sequence approach, for twig pattern matching. The motivation is to avoid the expensive path-solution-joining step used in the second phase of TwigStack by using the entire query twig rather than paths as the basic unit of answering twig queries.

2.4.3 The Navigational Approach

According to Gou & Chirkova (2007), unlike the Join approach, which searches for twig matches by joining inverted lists, the Navigational approach does that by traversing the data tree along tree edges. Navigation is the only available option when filtering/ querying streaming XML data. In the streaming context, XML data arrive in the form of data streams, without any associated indexes, and the entire XML data tree has to be traversed node by node in the depth-first order, which preserves the original XML document order.

2.5 COMPARISM OF NATIVE DATABASE SYSTEM AND RELATIONAL DATABASE SYSTEM LEVEL OF ABSTRACTIONS

Simalango M.F. (2010) provided levels of abstraction in XML query processing in comparison with SQL abstraction levels as displayed in table 2.3.

Table 2.3 XDBS vs RDBS abstraction levels

LEVEL OF ABSTRACTION	**XDBS**	**RDBS**
Language Model	XQuery	SQL
Logical Access Model	XML query algebra	Relational algebra
Physical Access Model	Physical XML query algebra	Physical DB-Operators
Storage Model	XTC, natix shredded documents etc.	Record-Oriented DB-interface

From table 2.3 XDBS denotes XML database management system and RDBS is Relational Database Management System.

The language model is designed to meet the demands of which are reflected in the language ability to perform search functionality and document-order awareness hence document-centric characteristics which is associated with powerful selection and transformation. The semantic processing should then be able to analyze the query and transform it into an international representation to be used throughout subsequent optimization steps.

Logical access model should implement algebraic and non-algebraic procedure to optimize the internal representation of the query. Non algebraic optimization minimizes intermediary results by restructuring the query and executing most selective operations as early as

possible. Algebraic optimization will transform the internal expression into a more optimized expression in a semantic-preserving manner.

Physical access model is related to system-specific issue. At this level, each logical algebra operator will be decomposed into corresponding physical operators. The goal of this step of optimization is a query executing plan (QEP) which is arranged of chosen physical operators and their sequences of execution.

Finally, the storage model affects the rate of Query executing plan (QEP). For optimized query processing, appropriate storage model should be deployed in order to minimize I/O costs, CPU costs, storage cost for intermediary results, and communication cost. Currently, the major XML storage models are relational XML data model and native storage model which attract more attentions indicated by various proposals for respective overlying query processor.

CHAPTER THREE

SUPER RELATIONAL APPROACH FOR XML QUERY PROCESSING

3.1 INTRODUCTION

Today's database is associated with interoperability between different domains and applications. This consequently, results in the importance of data portability in database. XML format fits the requirements and it has been increasingly used for serving applications across different domains and purposes. However, querying XML document effectively and efficiently is still a challenging issue. Several researches have been conducted on XML query techniques which many are inclined to Native Approach technique in which specialized storage and query processing systems are tailored for XML data from scratch to improve XML query processing. However, in this research we proposed Super Relational Approach technique in which XML document is automatically stored and queried using relational database with a view to fully utilizes the superb capabilities of relational database since native databases are still in immaturity stage.

3.2 SUPER RELATIONAL APPROACH PROCESSES

The Super Relational Approach which is displayed in figure 3.1 is an automated technique that contains five processes which are executed continuously without interruptions. The processes are:

a. XML document taken as input
b. Relational schema generation
c. Shredding of XML document into rows of relational table

d. Use of structured query language (SQL) to query records in the relational table

e. Transformation and production of the query results in XML format.

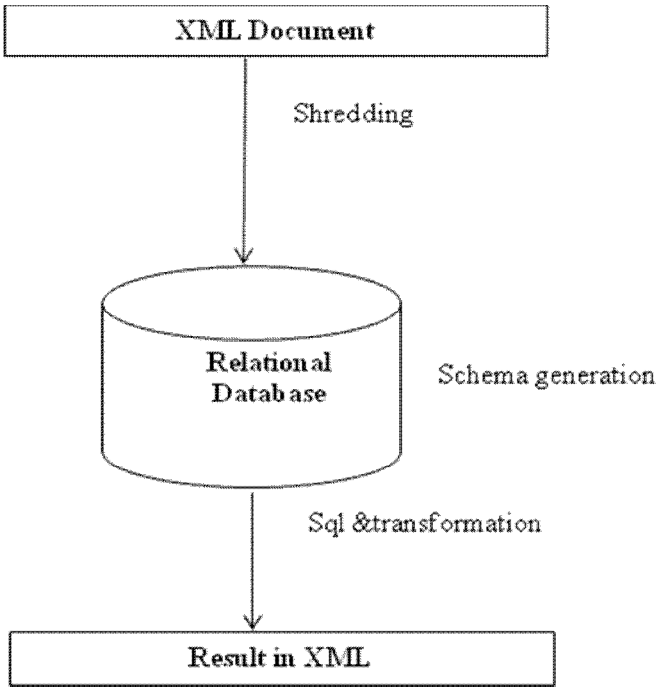


Figure 3.1 Model Architecture of Super Relational Approach

3.2.1 XML DOCUMENT INPUT

The XML documents to serve as input for Super Relational Approach are to be in one of the following format:

a. Column names as attributes and column values as attributes values:

<row column1=”value1”column2=”value2”.../>

b. Column names as tags and column value as the content of these tags:

<row>

<column1>value1</column1>

<column2>value2</column2>

<row>

c. Column names are the name attributes of <field> tags and values are the contents of these tags:

row>

<field name="column1">value1</field>

<field name="column2">value2</field>

<row>

3.2.2 RELATIONAL SCHEMA GENERATION

Relational schema generation is creation of table for the purpose of storing the XML document. For efficient mapping, the structure of XML document input is to be in conformity with the structure of the relational schema generated. The syntax for schema generation in the super relational approach technique is as follows:

```
CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
    { LIKE old_tbl_name | (LIKE old_tbl_name) }
create_definition:
    col_name column_definition
  | [CONSTRAINT [symbol]] PRIMARY KEY [index_type] (index_col_name,...)
      [index_option] ...
  | {INDEX|KEY} [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] UNIQUE [INDEX|KEY]
      [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | {FULLTEXT|SPATIAL} [INDEX|KEY] [index_name] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] FOREIGN KEY
      [index_name] (index_col_name,...) reference_definition
  | CHECK (expr)
```

```
column_definition:
    data_type [NOT NULL | NULL] [DEFAULT default_value]
      [AUTO_INCREMENT] [UNIQUE [KEY] | [PRIMARY] KEY]
      [COMMENT 'string']
      [COLUMN_FORMAT {FIXED|DYNAMIC|DEFAULT}]
      [STORAGE {DISK|MEMORY|DEFAULT}]
      [reference_definition]

data_type:
    BIT[(length)]
  | TINYINT[(length)] [UNSIGNED] [ZEROFILL]
  | SMALLINT[(length)] [UNSIGNED] [ZEROFILL]
  | MEDIUMINT[(length)] [UNSIGNED] [ZEROFILL]
  | INT[(length)] [UNSIGNED] [ZEROFILL]
  | INTEGER[(length)] [UNSIGNED] [ZEROFILL]
  | BIGINT[(length)] [UNSIGNED] [ZEROFILL]
  | REAL[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | DOUBLE[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | FLOAT[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | DECIMAL[(length[,decimals])] [UNSIGNED] [ZEROFILL]
  | NUMERIC[(length[,decimals])] [UNSIGNED] [ZEROFILL]
  | DATE
  | TIME
  | TIMESTAMP
  | DATETIME
  | YEAR
  | CHAR[(length)]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | VARCHAR(length)
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | BINARY[(length)]
  | VARBINARY(length)
```

3.2.3 SHREDDING OF XML DOCUMENT

Shredding is the mapping of XML to relations. In the Super Relational Approach XML document is shredded and stored in relational table. The key restriction is that the input XML format has to be flat and regular so that element trivially map to a relational target table. The column name in the target table must match the tag names in the XML data. For example if you want to shred name information to relational columns that are called

“firstname”and “lastname”, then the XML document must have one of the following options:

Option 1:

```
<row firstname=”Sabitu” lastname=”Abdu”/>
```

Option2:

```
<row>
    <firstname>Sabitu</firstname>
    <lastname>Abdu</lastname>
</row>
```

Option3:

```
<row>
    <field name=”firstname”>Sabitu</field>
    <field name=”lastname”>Abdu</field>
</row>
```

3.2.4 USE OF SQL TO QUERY RECORDS IN THE RELATIONAL TABLE

In Super Relational Approach, structure query language (SQL) is used to query records in the relational table. The SQL is a computer language aimed to store, manipulate, and query data stored in relational databases. The first incarnation of SQL appeared in 1974, when a group of IBM developed the first prototype of a relational database. The first relational database was released by Relational Software (later became Oracle).

Standards for SQL exist. However, the SQL that can be used on each one of the major relational databases (RDBMS) today is in different flavours. This is due to two reasons: 1) the SQL command standard is fairly complex, and it is not practical to implement the entire standard, and 2) each database vendor needs a way to differentiate its product from others. The commonly used SQL statements for this research work are:

a. SQL commands
b. Table manipulation
c. SQL string functions
d. Date functions

3.2.5 TRANSFORMATION AND PRODUCTION OF QUERY RESULTS IN XML

The query result in Super Relational Approach technique is transformed and produced in XML format by the use of the following syntax:

--XML --e="SELECT *FROM database_name.table_name where fieldname='...' >c:\directory-to-dump-the-file/name-of-the-dump-file.XML

The –XML convert the result of the query stored in variable –e to XML and dump it in the target directory with the name specified in the transformation statement.

3.5 AUTOMATION OF THE SUPER RELATIONAL APPROACH PROCESSES

The execution of the five processes of the Super Relational Technique is automated using some script files which appeared as Annex 'A'. This speed up the techniques operations and make it to compete favourably with Native Approach in XML query processing.

CHAPTER FOUR

IMPLEMENTATION AND TEST OF SUPER RELATIONAL APPROACH

4.1 INTRODUCTION

In this chapter we implement the proposed Super Relational Approach for XML query processing. The implementation is tested using some experiments and the results obtained are compared with the results obtained in Native Approach XML query processing. The results from the two techniques are analyzed and some interpretations are made.

4.2 IMPLEMENTATION REQUIREMENTS

The implementation of Super Relational Approach requires a relational database. For the purpose of the research work we choose MySQL5.5.16 as the relational database. For the implementation of Native Approach BaseX is used. In addition some script files are used for automation of the Super Relational Approach processes (See Appendix Á'). Graphs are also used for easy visualization and comparism of the two techniques.

4.2.1 MySQL5.5.16

MySQL software is an Open Source product under the terms of GNU General Public License. It delivers a very fast, multi-threaded, multi-user, and robust SQL (Structured Query Language) database server.

The choice of MySQL**5.5.16** for the research work among several relational databases is because of its popularity, easier to use and inbuilt ability to shred XML into rows of relational table. In addition, this version of mysql has some additional features such as

a. Scalability improvement

b. InnoDB I/O subsystem changes

c. Diagnostic and monitoring capabilities

d. Super Solaris Support

4.2.2 BaseX

BaseX is a light-weight, high performance and scalable XML database and an Xpath/Xquery processor with full support for the W3C update and full text extensions. It focuses on storing, querying and visualizing large XML documents and collections. A visual frontend allows users to interactively explore data and evaluate queries in real-time (i.e. with each key click). BaseX is platform independent and distributed under the free BSD licence.

The reason for the choice of BaseX among the four popular XML native databases is due to it highest performance when compares with other XML native databases as clearly show in the table 4.1.

TABLE 4.1 COMPARISM OF NATIVE DATABASES

XML Database	**License**	**Language**	**XQuery 3.0 Support**	**XQuery Update Support**	**XQuery Full Text Support**	**Xpath Extensions**	**Xquery Extensions**	**XSLT 2.0**
BaseX	BSD License	Java	Partial	Yes	Yes	Yes	Yes	Yes
Exist	LGPL License	Java	Partial	Partial	Proprietary	Yes	Yes	Yes
MarkLogic Server	Commercial	C++	Partial	Proprietary	Proprietary	NO	No	Yes
Sedna	Apache License	C++	No	Yes	Yes	No	No	No

Source: http://en.wikipedia.org/wiki/Line_chart accessed 27 December 2012

4.2.3 LINE GRAPH

The data collected in the experiment are visualized by the use of a line graph. A **line chart** or **line graph** is a type of chart which displays information as a series of data points connected by straight line segments. It is a basic type of chart common in many fields. It is an extension of a scatter graph, and is created by connecting a series of points that represent individual measurements with line segments. A line chart is often used to visualize a trend in data over intervals of time – a time series – thus the line is often drawn chronologically.

Structure of Line Graph

A line chart is typically drawn bordered by two perpendicular lines, called *axes*. The horizontal axis is called the *x-axis* and the vertical axis is called the *y-axis*. To aid visual measurement, there may be additional lines drawn parallel either axis. If lines are drawn parallel to both axes, the resulting lattice is called a *grid*.

Each axis represents one of the data quantities to be plotted. Typically the y-axis represents the dependent variable and the x-axis (sometimes called the abscissa) represents the independent variable. The chart can then be referred to as a graph of ``Quantity one versus quantity two, plotting quantity one up the y-axis and quantity two along the x-axis.

The individual axes represent number lines and so may contain small marks, called *ticks*, indicating significant values on the line. The ticks may be annotated with the value they represent. A short description of the axis is often used to annotate each axis, usually in the pattern ``Physical Quantity (physical unit). *These annotations are called* labels.

The chart may contain an overall description called a *title*, and if the chart contains more than one line, it may also contain a list describing each line, called a *key* or a *legend*.

Finally, the data to be presented is plotted at the intersection of the (imaginary) perpendicular lines extending from the axes, and straight line segments are drawn between those intersection points.

4.3 EXPERIMENTS

Five set of experiments were conducted. Each experiment begins with XML document (staff1) of size 1.25mb and records of 5,562 staff, and ended with XML document (staff9) with size 320mb and records of 1,423,872 staff. In totality documents of total size of 638.75mb and records of 2,842,182 staff were used for each experiment. The Super Relational Approach processing time included shredding and query execution time while Native Approach processing time included loading and query execution time. The results obtained for the five experiments and discussions on them are as follows:

4.3.1 EXPERIMENT 1

Relational Approach Processing Time (SRAPT) query (SQL) = select *from test1.staff... where state= 'KATSINA'

Native Approach Processing Time (NAPT) query (XPATH) = /staff.../row[state='KATSINA'.

The results obtained in the execution of the above query are displayed in the table 4.2 and figure 4.1.

TABLE 4.2 EXPERIMENT 1 SQL AND XPATH QUERY RESULTS

XML DOCUMENT	SIZE/MB	TOTAL NO. OF STAFF	SRA SHREDDING TIME (ms)	NO. OF RETRIEVED STAFF	SRAPT(ms)	NAPT(ms)
STAFF1	1.25	5,562	724	130	740	885.48
STAFF2	2.5	11,124	930	260	950	1437.07
STAFF3	5	22,248	1008	520	1030	5513.44
STAFF4	10	44,496	3699	1040	3780	7826.04
STAFF5	20	88,992	6988	2080	7140	8152.76
STAFF6	40	177,984	13672	4160	13970	37000.46
STAFF7	80	355,968	28118	8320	28730	62505.51
STAFF 8	160	711,936	60356	16640	61670	125728.58
STAFF 9	320	1,423,872	156719	33280	160130	288794.69
TOTAL	**638.75**	**2,842,182**	**272,214**	**66,430**	**278,140**	**537,844.03**

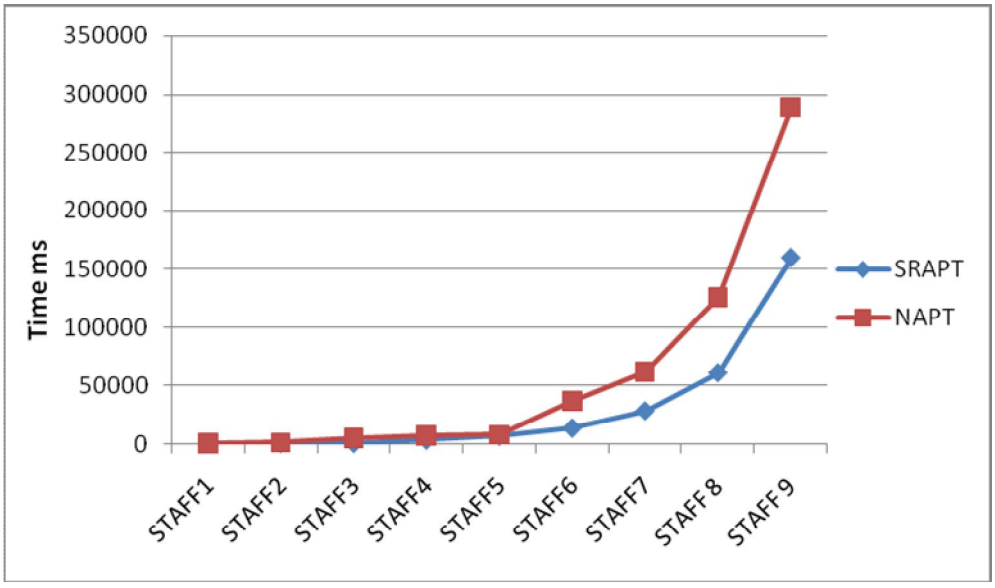


Figure 4.1: Experiment 1 SQL and XPath Query Results

4.3.2 EXPERIMENT 1 DISCUSSIONS

From Table 4.2 and Figure 4.1, the Super relational approach is 259,704.03ms faster than native approach in fetching 66,430 staff out of records of 2,842,182 staff using sql and xpath for the two approaches respectively.

At initial stage with few records the gap between the two approaches was minimal as the sizes of the XML document increases the gap becomes wider.

4.3.3 EXPERIMENT 2

Relational Approach Processing Time (SRAPT) query (SQL) = **select *from test1.staff... where rank= 'DRC'and state='JIGAWA' or rank='RC' and state='KANO'**

Native Approach Processing Time (NAPT) query (XQUERY) = **for $row in staff../row where $row/rank="DRC" and $row/state="JIGAWA" or $row/rank="RC" and $row/state="KANO".**

The results obtained in the execution of the above query are displayed in the table 4.3 and figure 4.2 .

TABLE 4.3 EXPERIMENT 2 SQL AND XQUERY RESULTS

XML DOCUMENT	SIZE/MB	TOTAL NO. OF STAFF	SRA SHREDDING TIME (ms)	NO. OF RETRIEVED STAFF	SRAPT(ms)	NAPT (ms)
STAFF1	1.25	5,562	724	26	800	938.69
STAFF2	2.5	11,124	930	52	1150	1600.94
STAFF3	5	22,248	1008	104	2110	5134.25
STAFF4	10	44,496	3699	208	4230	8079.51
STAFF5	20	88,992	6988	416	10250	9278.27
STAFF6	40	177,984	13672	832	20080	36166.71
STAFF7	80	355,968	28118	1664	40770	60781.33
STAFF 8	160	711,936	60356	3328	93820	131262.44
STAFF 9	320	1,423,872	156719	6656	152700	281155.77
TOTAL	**638.75**	**2,842,182**	**272,214**	**13,286**	**325,910**	**534,397.91**

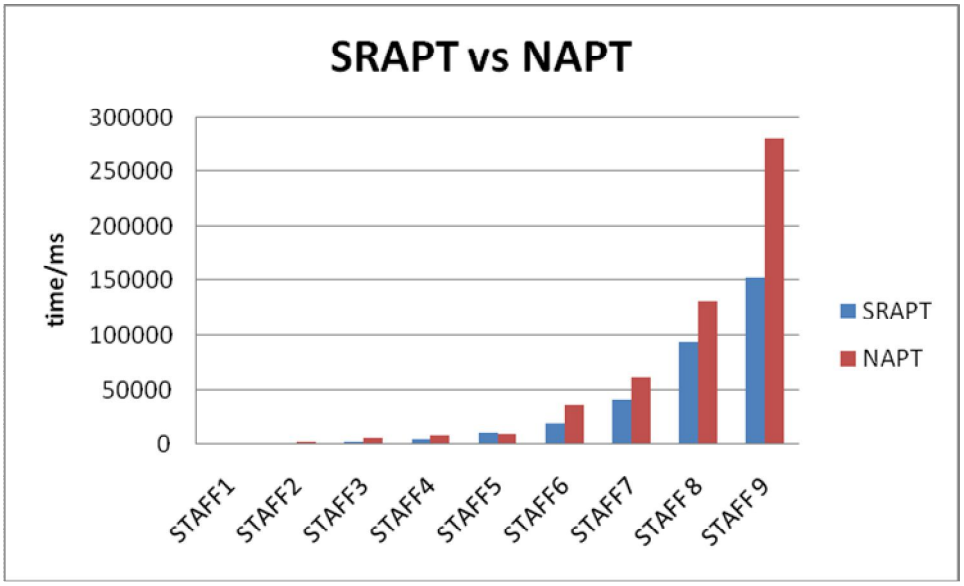


Figure 4.2: Experiment 2 SQL and XPath Query Results

4.3.4 EXPERIMENT 2 DISCUSSIONS

Similarly in the second experiment, we can see from Table 4.3 and Figure 4.2, the Super Relational Approach is also 208,487.9 ms faster than native approach in fetching 13,287 staff out of 2,842,182 staff records using SQL and xquery for the two approaches respectively.

In the same vein, in experiment 2, with few records the gap between the two approaches was minimal as the sizes of the XML document increases the gap becomes wider.

This clearly indicates that there is no significant difference between the speed of xpath and xquery in terms of native approach XML query processing and whatever query pattern is used the Super Relational Approach performs better than native approach.

4.3.5 EXPERIMENT 3

Super Relational Approach Processing Time (SRAPT) query (SQL) = **select *from test3.staff... where sex= 'M'.** Native Approach Processing Time (NAPT) query (Xpath) = **staff/row[sex="M"]**

The results obtained in the execution of the above query are displayed in the table 4.4 and figure 4.3.

TABLE 4.4 EXPERIMENT 3 SQL AND XPATH QUERY RESULTS

XML DOCUMENT	SIZE/MB	TOTAL NO. OF STAFF	SRA SHREDDING TIME(ms)	NO. OF RETRIEVED STAFF	SRAPT(ms)	NAPT(ms)
STAFF1	1.25	5,562	724	4559	1010	922.66
STAFF2	2.5	11,124	930	9118	1830	1684.87
STAFF3	5	22,248	1008	18236	3040	5170.47
STAFF4	10	44,496	3699	36472	8180	7892.74
STAFF5	20	88,992	6988	72944	16410	8718.05
STAFF6	40	177,984	13672	145888	34120	34691.26
STAFF7	80	355,968	28118	291776	66660	58868.25
STAFF 8	160	711,936	60356	583552	86760	124010.31
STAFF 9	320	1,423,872	156719	1167104	175500	261124.00
TOTAL	**638.75**	**2,842,182**	**272,214**	**2,329,649**	**393,510**	**503,082.61**

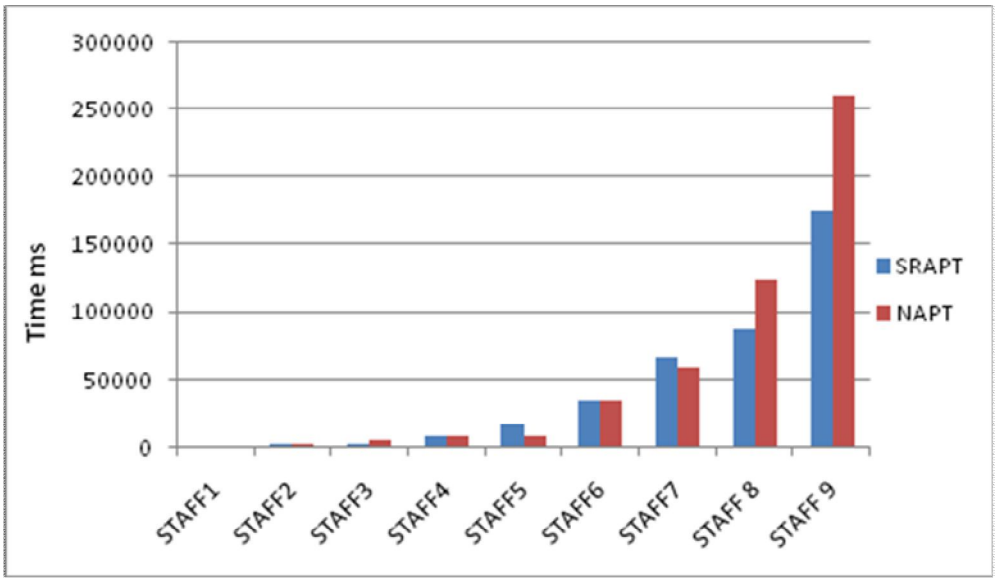


Figure 4.3 Experiment 3 SQL and XPath Query Results

4.3.6 EXPERIMENT 3 DISCUSSIONS

From Table 4.4 and Figure 4.3, Super Relational Approach (SPRA) runs faster than Native Approach (NA) in fetching 2,329,649 male staff records out of 2,842,182 staff records. While the SPRA fetched the stated records in 393,510ms it took the NA 503,082,69ms to fetch the same records.

Out of nine instances in the experiment, it is only in one instant the NA performs better than SPRA as clearly indicated in the chart.

4.3.7 EXPERIMENT 4

Super Relational Approach Processing Time (SRAPT) query (SQL)= **select *from test4.staff... where sex= 'F'.** Native Approach Processing Time (NAPT) query (Xpath) = **staff/row[sex="F"]**

The results obtained in the execution of the above query are displayed in the table 4.5 and figure 4.4.

TABLE 4.5 EXPERIMENT 4 SQL AND XPATH QUERY RESULTS

XML DOCUMENT	SIZE/MB	TOTAL NO. OF STAFF	SRA SHREDDING TIME(ms)	NO. OF RETRIEVED STAFF	SRAPT(ms)	NAPT(ms)
STAFF1	1.25	5,562	724	1003	1010	917.26
STAFF2	2.5	11,124	930	2006	1330	1466.00
STAFF3	5	22,248	1008	4012	2170	4999.88
STAFF4	10	44,496	3699	8024	3870	7970.23
STAFF5	20	88,992	6988	16048	7410	8396.05
STAFF6	40	177,984	13672	32096	15450	33870.98
STAFF7	80	355,968	28118	64192	31740	57037.29
STAFF 8	160	711,936	60356	128384	59140	120660.60
STAFF 9	320	1,423,872	156719	256768	142570	261289.47
TOTAL	**638.75**	**2,842,182**	**272,214**	**512,533**	**264,690**	**496,607.76**

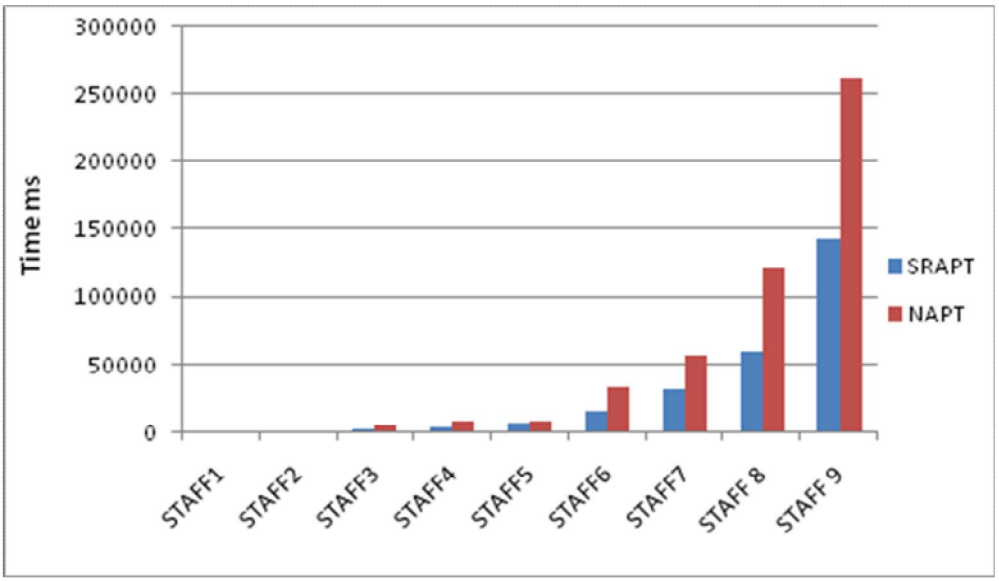


Figure 4.4 Experiment 4 SQL and Xpath Query Results

4.3.8 EXPERIMENT 4 DISCUSSIONS

From table 4.5 and figure 4.4, Super Relational Approach (SPRA) also runs faster than Native Approach (NA) in fetching 512,533 female staff records out of 2,842,182 staff records. While the SPRA fetched the stated records in 264,690ms it took the NA 496,607.76ms to fetch the same records.

Out of nine instances in the experiment, SPRA beat NA in all the instances. In fact the difference is clear as SPRA fetched records in almost half of the time taken by NA.

4.3.9 EXPERIMENT 5

Super Relational Approach Processing Time (SRAPT) query (SQL)= **select *from test4.staff... where rank= 'ARC'.** Native Approach Processing Time (NAPT) query (Xpath) = **staff/row[rank="ARC"]**

The results obtained in the execution of the above query are displayed in the table 4.6 and figure 4.5.

TABLE 4.5 EXPERIMENT 5 SQL AND XPATH QUERY RESULTS

XML DOCUMENT	SIZE/MB	TOTAL NO. OF STAFF	SRA SHREDDING TIME (ms)	NO. OF RETRIEVED STAFF	SRAPT (ms)	NAPT (ms)
STAFF1	1.25	5,562	724	2596	900.00	964.56
STAFF2	2.5	11,124	930	5192	1530.00	1585.25
STAFF3	5	22,248	1008	10384	2390.00	5117.44
STAFF4	10	44,496	3699	20768	4270.00	7787.48
STAFF5	20	88,992	6988	41536	9310.00	8758.88
STAFF6	40	177,984	13672	83072	17710.00	34649.91
STAFF7	80	355,968	28118	166144	35320.00	58637.67
STAFF 8	160	711,936	60356	332288	69820.00	124629.35
STAFF 9	320	1,423,872	156719	664576	145490.00	261315.81
TOTAL	**638.75**	**2,842,182**	**272,214**	**1,326,556**	**286740.00**	**503,446.35**

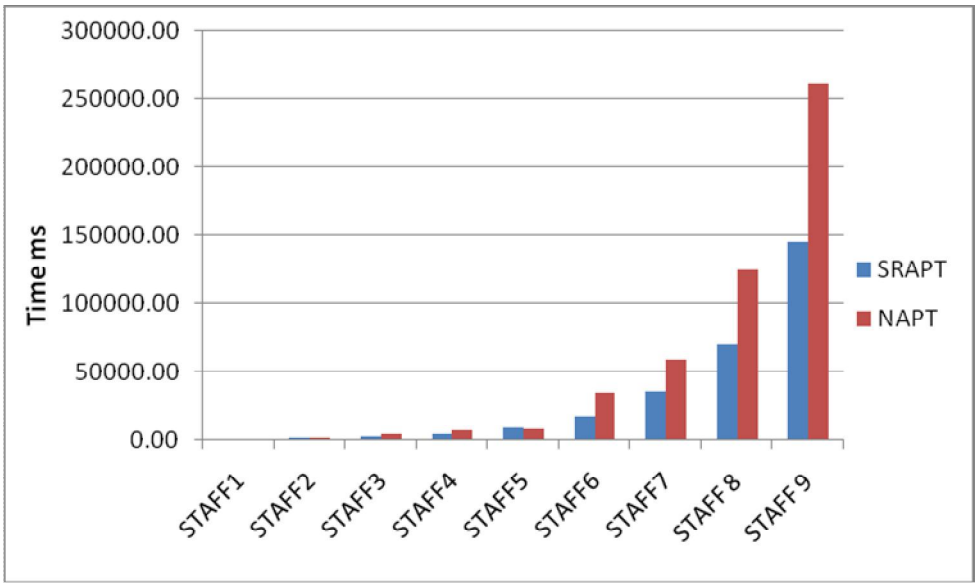


Figure 4.5 Experiment 5 SQL and Xpath Query Results

4.3.10 EXPERIMENT 5 DISCUSSIONS

From table 4.6 and figure 4.5, Super Relational Approach (SPRA) still has recorded higher performance than Native Approach (NA). The SPRA fetched records of 1,326,556 records of Officers who are on the rank of ARC in 286,740ms while NA fetched the same records in 503,646.35ms.

This experiment shows that ratio of SPRA and NA query processing time is almost 1:2 respectively.

4.4 COMPARISM OF SUPER RELATIONAL APPROACH AND NATIVE APPROACH

From experiments conducted Super Relational Approach performance is compared with Native Approach and the evaluation of the comparism is shown in table 4.7.

TABLE 4.7 SUPER RELATIONAL APPROACH VERSUS NATIVE APPROACH

ASSESSMENT PARAMETER	**SUPER RELATIONAL APPROACH**	**NATIVE APPROACH**
Selection (and/or) query	Faster	Slow
Full text query	Faster	Slow
Replacement	Possible for both part and whole document	Only possible for whole document
Deletion	Possible for both part and whole document	Only possible for whole document
Insertion	At any part of document	Only at the beginning and end of document

4.5 OBSERVATIONS

In some few instances Native Approach (NA) outperforms Super Relational Approach (SRA) because of the following factors:

a. The Query Content and Structure. It has been observed that the variation of the query content and structure causes NA to outperform SRA in some few instances. For example in Experiment 3 though the sizes of the queried documents are identical with the ones used in Experiment 1, the changes in the query content and structure caused NA to outperform SRA in five instances (staff1, staff2, staff4, staff5, staff6).

b. Size of the Queried Document. When the size of the queried document is small there is tendency in some few instances NA to outperform SRA. This is attested to in the experiments conducted in which NA outperformed SRA in only small size queried documents (staff1 to staff8). But with big size queried document (staff9) SRA outperformed NA in all the experiment conducted.

In spite of the long time it takes SRA to shred XML documents as shown in the experimental tables, the shredding has less impact on the execution time saved by SRA. Hence shredding is justifiable because once document is shredded it can be queried as many times as possible.

CHAPTER FIVE

SUMMARY, CONCLUSION, RECOMMENDATION, LIMITATION AND FUTURE WORK

5.1 SUMMARY

XML being a de facto standard for information exchange among various applications on the world wide web and with large amount of data represented as XML documents, it becomes necessary to determine the most efficient system for storage and query processing of data in XML format. So far there are two main processes of XML query processing thus relational approach and native approach.

In relational approach the XML document is shredded to rows of relational table and the stored document is queried using structured query language (SQL) and transforms the query result into XML while in native approach XML is treated as a first class citizen and is queried directly using xpath or xquery to produce desired result in XML without necessarily any transformation.

It has been observed that many researchers are now concentrating on native approach using native XML databases which has two potential disadvantages. Firstly, native XML database systems do not harness the sophisticated storage and query capability already provided by existing relational database systems. Secondly, native XML database systems do not allow users to query seamlessly across XML documents and other data stored in relational database. So in this research we proposed super relational approach which competes favourably with the native approach in XML query processing.

5.2 CONCLUSION

Taking cognisance of the problems definition in chapter one, the research has answered the stated problems it set out to answer. The Super Relational Approach (SRA) despite its longer processes of XML query processing, performs better than Native Approach (NA) in term of speed, deletion, insertion and replacement as attested in the experiments conducted. This performance is true, in most cases even when the shredding and query execution time are taken into account. In some few cases involving few records NA outperforms SRA.

5.3 RECOMMENDATION

Super relational approach system is recommended for whoever wants to process large XML document with fixed structure because of its higher performance compared to relational approach as attested to in the research work.

5.4 LIMITATION

In ability of the researchers to determine through experimentation why Native Approach outperforms Relational Approach in few instances when the size of the XML document is very small.

5.5 FUTURE WORK

For future work as related to this research, the following areas need to be looked into:

a. Possibility of enhancement of super relational approach to effectively handle XML document with flexible structure.
b. Integration of super relational approach with native approach

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ANNEX 'A' SCRIPTS USED FOR THE SUPER RELATIONAL APPROACH

```
USE test1;
CREATE TABLE staff1 (
        sn VARCHAR(10) NULL,
        name VARCHAR(80) NULL,
        rank VARCHAR(10) NULL,
        pin VARCHAR(10) NULL,
        sex VARCHAR(1) NULL,
        m_status VARCHAR(1) NULL,
        command VARCHAR(50) NULL,
        lga VARCHAR(30) NULL,
        state VARCHAR(20) NULL
);

USE TEST1;
LOAD XML LOCAL INFILE 'c:/sab/staff1.XML'
INTO TABLE staff1
ROWS IDENTIFIED BY '<Row>';

:: Store start time
set StartTIME=%TIME%
set H=%StartTIME:~0,2%
if "%H:~0,1%"==" " set H=%H:~1,1%
if "%H:~0,1%"=="0" set H=%H:~1,1%
set M=%StartTIME:~3,2%
if "%M:~0,1%"=="0" set M=%M:~1,1%
set S=%StartTIME:~6,2%
if "%S:~0,1%"=="0" set S=%S:~1,1%
set U=%StartTIME:~9,2%
if "%U:~0,1%"=="0" set U=%U:~1,1%
)
set /a Start100S=%H%*360000+%M%*6000+%S%*100+%U%

::
:: Add your script functionality here
::

cd C:\wamp\bin\mysql\mysql5.5.16\bin
mysql -u root -e "source c:\sab\createtable.bat"
mysql -u root -e "source c:\sab\load.bat"
mysql -u root --XML --e="SELECT * FROM test1.staff1  state='KATSINA'">c:\sab\dump/staff1dump.XML

:: Get the end time
set StopTIME=%TIME%
set H=%StopTIME:~0,2%
if "%H:~0,1%"==" " set H=%H:~1,1%
if "%H:~0,1%"=="0" set H=%H:~1,1%
set M=%StopTIME:~3,2%
if "%M:~0,1%"=="0" set M=%M:~1,1%
set S=%StopTIME:~6,2%
if "%S:~0,1%"=="0" set S=%S:~1,1%
set U=%StopTIME:~9,2%
if "%U:~0,1%"=="0" set U=%U:~1,1%
)

set /a Stop100S=%H%*360000+%M%*6000+%S%*100+%U%

:: Test midnight rollover. If so, add 1 day=8640000 1/100ths secs
if %Stop100S% LSS %Start100S% set /a Stop100S+=8640000
set /a TookTime=%Stop100S%-%Start100S%

echo Started: %StartTime%
echo Stopped: %StopTime%
echo Elapsed: %TookTime:~0,-2%.%TookTime:~-2% seconds
pause
```

ANNEX 'B' SAMPLE OF THE SUPER RELATIONAL APPROACH QUERY RESULT

```
<?XML version="1.0"?>

<resultset statement="SELECT * FROM test1.staff1 where state='KATSINA'
" XMLns:xsi="http://www.w3.org/2001/XMLSchema-instance">
 <row>
        <field name="sn">19</field>
        <field name="name">AK  HASSAN</field>
        <field name="rank">ACM</field>
        <field name="pin">C-00424</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">ZCO, RS3HQ YOLA</field>
        <field name="lga">MATAZU</field>
        <field name="state">KATSINA</field>
 </row>

 <row>
        <field name="sn">86</field>
        <field name="name">UMAR SHEHU USMAN</field>
        <field name="rank">CC</field>
        <field name="pin">C-00499</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">SC RS12.3 YOBE</field>
        <field name="lga">KAFUR</field>
        <field name="state">KATSINA</field>
 </row>

 <row>
        <field name="sn">204</field>
        <field name="name">GD ALIYU</field>
        <field name="rank">DCC</field>
        <field name="pin">C-02084</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">SHOOPS RS10.1 SOKOTO</field>
        <field name="lga">FASKARI</field>
        <field name="state">KATSINA</field>
 </row>

 <row>
        <field name="sn">262</field>
        <field name="name">SABE KABEER JIBIA</field>
        <field name="rank">ACC</field>
        <field name="pin">C-00579</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">UC RS1.17 BIRNIN YERO</field>
        <field name="lga">JIBIA</field>
        <field name="state">KATSINA</field>
 </row>

 <row>
        <field name="sn">284</field>
        <field name="name">BELLO DANJUMA</field>
        <field name="rank">ACC</field>
        <field name="pin">C-00684</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">RS10.3 ZAMFARA, AHR</field>
        <field name="lga">KANKIS</field>
        <field name="state">KATSINA</field>
 </row>

 <row>
        <field name="sn">285</field>
```

<field name="name">IBRAHIM KABIRU</field>
<field name="rank">ACC</field>
<field name="pin">C-00686</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">SO OPS RS10.2 KEBBI</field>
<field name="lga">KATSINA</field>
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</row>

<row>
<field name="sn">290</field>
<field name="name">HS DALHATU</field>
<field name="rank">ACC</field>
<field name="pin">C-00707</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">UC RS1.12 B/GWARI</field>
<field name="lga">SAFAWA</field>
<field name="state">KATSINA</field>
</row>

<row>
<field name="sn">341</field>
<field name="name">SHEHU LAWAL DAN-ASABE</field>
<field name="rank">ACC</field>
<field name="pin">C-01452</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">GSO RSHQ, CS</field>
<field name="lga">Bakori</field>
<field name="state">KATSINA</field>
</row>

<row>
<field name="sn">374</field>
<field name="name">MB BATURE</field>
<field name="rank">ACC</field>
<field name="pin">C-00685</field>
<field name="sex">M</field>
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<row>
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<field name="name">A SANUSI</field>
<field name="rank">ACC</field>
<field name="pin">C-00879</field>
<field name="sex">M</field>
<field name="m_status">M</field>
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<field name="lga">INGAWA</field>
<field name="state">KATSINA</field>
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<row>
<field name="sn">412</field>
<field name="name">DANLADI IRO</field>
<field name="rank">ACC</field>
<field name="pin">C-00161</field>
<field name="sex">M</field>
<field name="m_status">M</field>
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<field name="lga">Katsina</field>
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<row>
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<field name="rank">ACC</field>
<field name="pin">C-01450</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">UC RS1.25 CHIROMWA</field>
<field name="lga">Matazu</field>
<field name="state">KATSINA</field>
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<row>
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<field name="name">AS ABDUSSAMADU</field>
<field name="rank">ACC</field>
<field name="pin">C-00158</field>
<field name="sex">M</field>
<field name="m_status">M</field>
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<row>
<field name="sn">554</field>
<field name="name">AHMED SAIDU DAURA</field>
<field name="rank">ACC</field>
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<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">SO OPS II RS8.3 KOGI</field>
<field name="lga">Daura</field>
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<row>
<field name="sn">555</field>
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<field name="pin">C-01455</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">SHSMP RS3.3 TARABA</field>
<field name="lga">Bindawa</field>
<field name="state">KATSINA</field>
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<row>
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<field name="name">MUKTARI MOHAMMED MUSA</field>
<field name="rank">ACC</field>
<field name="pin">C-00876</field>
<field name="sex">M</field>
<field name="m_status">M</field>
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        <field name="pin">C-00886</field>
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        <field name="name">L UMAR MOHAMMED</field>
        <field name="rank">CRC</field>
        <field name="pin">C-01453</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">UTHOOPS RS12.12 DARAZO</field>
        <field name="lga">Daura</field>
        <field name="state">KATSINA</field>
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<row>
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        <field name="name">MS ALIYU</field>
        <field name="rank">CRC</field>
        <field name="pin">C-00706</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">RS7.1 FCT (SHIPC)</field>
        <field name="lga">SAFAWA</field>
        <field name="state">KATSINA</field>
</row>

<row>
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        <field name="name">Y SA'ADU</field>
        <field name="rank">CRC</field>
        <field name="pin">C-01051</field>
        <field name="sex">M</field>
        <field name="m_status">M</field>
        <field name="command">UTHOOPS RS10.33 TSAFE</field>
        <field name="lga">FUNTUA</field>
        <field name="state">KATSINA</field>
</row>

<row>
        <field name="sn">829</field>
        <field name="name">MOHAMMED AMINU IBRAHIM</field>
        <field name="rank">CRC</field>
        <field name="pin">C-01618</field>
        <field name="sex">M</field>
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        <field name="command">SHPRS RS10.1 SOKOTO</field>
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        <field name="sn">846</field>
        <field name="name">JIBIR MOHAMMED NAFIU</field>
        <field name="rank">CRC</field>
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        <field name="sex">M</field>
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```

<field name="lga">DARA</field>
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<row>
<field name="sn">871</field>
<field name="name">M MOHAMMED</field>
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<row>
<field name="sn">913</field>
<field name="name">BELLO KABIRU BATSARI</field>
<field name="rank">CRC</field>
<field name="pin">C-01616</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">UH (IPC) MISAU RS12.1 BAUCHI</field>
<field name="lga">BATSARI</field>
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<row>
<field name="sn">925</field>
<field name="name">YK ABDULLAHI</field>
<field name="rank">CRC</field>
<field name="pin">C-00875</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">RS4.3 NASARAWA, UH (W/S) DOMA</field>
<field name="lga">DANDAMU</field>
<field name="state">KATSINA </field>
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<row>
<field name="sn">932</field>
<field name="name">I UMAR</field>
<field name="rank">CRC</field>
<field name="pin">C-00815</field>
<field name="sex">M</field>
<field name="m_status">M</field>
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<field name="lga">KURFI</field>
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<row>
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<field name="name">ABDULRAHAMAN I</field>
<field name="rank">CRC</field>
<field name="pin">C-01027</field>
<field name="sex">M</field>

<field name="m_status">M</field>
<field name="command">RS1.2 KANO, UH (W/S)BICHI</field>
<field name="lga">DAURA</field>
<field name="state">KATSINA </field>
</row>

<row>
<field name="sn">960</field>
<field name="name">MUSA K</field>
<field name="rank">CRC</field>
<field name="pin">C-01031</field>
<field name="sex">M</field>
<field name="m_status">M</field>
<field name="command">UTHOOPS RS3.13 GIREI</field>
<field name="lga">KANKIA</field>
<field name="state">KATSINA </field>
</row>

<row>
<field name="sn">1013</field>
<field name="name">LAWAL G</field>
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<row>
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<row>
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<row>
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        <field name="rank">CC</field>
        <field name="pin">C-00499</field>
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        <field name="rank">DCC</field>
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        <field name="rank">ACC</field>
        <field name="pin">C-00579</field>
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        <field name="rank">ACC</field>
        <field name="pin">C-00684</field>
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<row>
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<row>
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<row>
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<row>
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<row>
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        <field name="rank">SRC</field>
        <field name="pin">C-01067</field>
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<row>
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        <field name="name">ABDULLAHI TU</field>
        <field name="rank">SRC</field>
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<row>
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        <field name="name">U SALMANU</field>
        <field name="rank">SRC</field>
        <field name="pin">C-01992</field>
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<row>
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<field name="rank">RC</field>
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<row>
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<field name="rank">RC</field>
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<field name="sex">M</field>

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<row>
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<field name="name">ABBATI MUHAMMED</field>
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<row>
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<row>
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<field name="name">ZAIYANA IBRAHIM</field>
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<row>
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<field name="name">ADOH GAZALI</field>
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<field name="pin">C-04719</field>
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<row>
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<field name="name">NUHU MARWANA</field>
<field name="rank">DRC</field>
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<field name="lga">KATSINA</field>
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<row>
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<field name="name">ISMA'ILA M</field>
<field name="rank">DRC</field>
<field name="pin">C-02880</field>
<field name="sex">M</field>
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<row>
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<field name="rank">DRC</field>
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<field name="m_status">M</field>
<field name="command">FIELD OPS & RES) RS10.33 TSAFE</field>
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<field name="name">IMAM ALIYU AHMED</field>
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<field name="command">Ag (ADMIN) RS1.17 BIRNIN YERO</field>
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<field name="sex">M</field>
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