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Transformation based Strategy to Convert Relational Database for Public Sector

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Abstract: ***A method for transforming an RDB into an XML file is presented in this paper. When you migrate your database, all of the schema and data are transferred from one RDB to another using an XML script. This allows you to access and work with your data in a new environment. The data in the source database is converted into the target database according to the new schema, after which the home schema is translated into the target schema and given semantic enhancements. Converting RDB data to XML is a good fit for the semantic enrichment technique since it improves the metadata model from the source database and captures important parts of the destination XML schema. In order to convert RDB data into an XML Schema, algorithms are developed to build the target database according to a set of migration criteria. We have constructed a prototype system and tested it experimentally by observing its results, discussing our achievements, and providing feedback on the results. After reviewing the results, it was determined that the suggested solution was correct and worked.***

Keywords: relational database, XML document, database, metadata, data transformation

1. Introduction

Relational databases, often known as RDBs, have seen widespread use by a variety of businesses during the past few decades. SQL is the structured query language that is utilized by the RDB. Due to the fact that it includes three different types of data—structured, semi-structured, and unstructured—it is not suited for big data. On the other hand, relational databases (RDB) only offer structured data and have limited capabilities with semi-structured and unstructured documents. Relational databases are likewise capable of storing enormous volumes of data; however, they have severe issues with scalability, availability, and flexibility [1].

In order to circumvent the constraints that are associated with relational databases (RDB), a new category of databases known as not just structured query language (NoSQL) has been developed. A high level of availability, fault tolerance, horizontal scaling, and complicated data storage are all features that are offered by NoSQL. As a result, it is appropriate for applications that involve big data and cloud computing [2,3]. Relational databases are strengthened by the addition of NoSQL databases. When it comes to NoSQL databases, there are four distinct categories: document, column, key–value, and graph. An engine for processing data on a massive scale is called Spark. Spark is a processing engine that operates in memory and is designed for doing computations quickly [4]. A Spark module that is utilized for the processing of structured data is called Spark SQL. It offers native support for SQL processing for the data that is input into Spark [5].

There has been a recent surge in the popularity of NoSQL systems, with three of the top 11 being NoSQL systems in the DB engines ranking (https://db-engines.com/en/ranking (accessed on 1 May 2022)): MongoDB (ranked fifth), Redis (ranked sixth), and Cassandra (ranked eleventh). In light of this, larger businesses are interested in transitioning to NoSQL databases because of the flexibility, fault tolerance, and availability that these databases offer. On the other hand, NoSQL does not make use of a structured query language (SQL) [6,7], and different models each have their own query language. The majority of users are accustomed with SQL, and SQL is not supported in NoSQL databases [8]. As a result, enterprises encounter significant hurdles when converting and moving from relational database management systems to NoSQL databases. In addition, the transition to NoSQL is accompanied by a steep learning curve [9,10]. There have been various ways presented in order to maintain the advantages of SQL within the framework of NoSQL. This is due to the fact that the NoSQL model and RDB are complementary. On the other hand, the approaches that came before present two significant drawbacks. In the first place, academics have ignored a comprehensive approach to the execution of queries and data manipulation language (DML) on NoSQL models. Second, to the best of our knowledge, there is a dearth of research that has conducted trials in a distributed environment for the purpose of the migration process to the four different models of NoSQL.

2. Related Works

Many academics are looking at ways to convert the schema of RDB, the most popular database, into different database models since there needs to be a formal approach to transfer schemas between databases. To meet the growing demand for semi-structured and unstructured data, there have been a lot of efforts in the past 20 years to convert RDB schemas [9,10]. The uniqueness of the new data structures is taken into account in various schema transformation operations, while still maintaining the semantics that can be handled in RDB. The conversion of RDB to column-based NoSQL has been the subject of multiple publications. According to the authors of [11], they used three criteria to translate the entities and associate relationships from an improved entity-relationship ER diagram to the HBase database. The first guideline states that all tables must have a column family, with the primary key serving as the row key. The second guideline specifies the process for creating super column families by merging

multiple column families. New column families are constructed and inserted on both sides in HBase for many-to-many association relationships in RDB, resulting in the deletion of the join table in RDB. The purpose of this rule is to ensure that RDB's foreign key mechanisms continue to function correctly. By combining them into a single super column, the third rule minimizes the need for foreign keys. Whether the data pointed by the foreign keys can be used independently or only as an adjunct to other data is the deciding factor.

In [12], the authors outlined a two-step process for mapping RDB's one-to-one, one-to-many, and many-to-many association links. Step one involves selecting the row key for column families according to the anticipated user entry pattern. After that, in the second stage, the two related tables are combined into a single super column family. To transfer the one-to-one and one-to-many relationships from RDB to HBase, the authors of [13] used a four-step process. Denormalization of the data is the first step, followed by combining neighboring tables, optimization of a row key for different access patterns, and maintenance of indexing on the HBase tables.

The schema could be converted from RDB to document-based NoSQL, according to multiple publications. The authors of [2] laid out a plan for developing an algorithm that automatically transformed entities and association links using metadata stored in RDB. An independent program called MigDB was employed by the developers of [14] to examine RDB tables, generate a JSON file from the tables, and subsequently feed them into a neural network. Also, the network decided whether an embedding or referencing structure would be better for mapping the JSON file. The sole purpose of this endeavor was to map the links between associations.

In order to convert RDB's one-to-many association relationship to graph-based NoSQL, the authors of [15] created two nodes and referenced the primary key from one side into the other as they mapped the relationship to graph-based NoSQL. Deleting the RDB join table and inserting the primary keys into each participating node creates the many-to-many relationship mapping. An RDB to graph-based NoSQL mapping of the one-to-many relationship is presented in [16]. The many-side node serves as the graph's beginning point, and by preserving the primary key as an edge property, it inserts the key from the one-side node into the many-side node. By storing the data as a relationship attribute, the RDB join table is not utilized. During the process of mapping the ternary relationship, several tables were removed, including the join table and their foreign keys. However, the relationship properties were preserved and used to connect nodes on the graph.

The authors offered the RDB to many NoSQL families, including key-value, document, and graph, in [17]. The writers used defined tuples to determine the database concepts. After that, the algorithms that will actually carry out the transformation are introduced, and a case study is utilized to demonstrate the notion. Because it addresses every single family of NoSQL databases, this book is comprehensive. But it's not entirely obvious that all RDB relationship kinds are covered.

There has been a dearth of new literature on the topic of transformation implementation beyond discussions of data structure and linkages. A framework that facilitates easy migration from RDB to NoSQL DBMS was introduced by the authors in [18]. Data migration and data mapping are the two main components of the system. There is no presentation of the data mapping module's internal transformation since the focus is on implementation. Rather, the study showcases the outcomes of experiments conducted on different mapping-related database procedures.

To facilitate querying and mapping between SQL and NoSQL databases, the authors of [19] introduced a data adapter. At the same time as it does database translation, the adapter allows application queries. This work does include the data adapter, but it lacks explicit criteria for transforming data between databases. To review, there have been efforts to change schemas, but these have been quite limited in scope, addressing only the association connection and one particular NoSQL database. This work will discuss transformation that incorporates the three main kinds of relationships found in RDB—association, inheritance, and aggregation—in order to overcome the first constraint. Also covered in this paper is the topic of transformation into different NoSQL databases, which might help with the second limitation [20].

3. Methodology

1) Introduction

This methodology outlines a transformation-based strategy designed to convert a relational database (RDB) into an XML document, which can be leveraged for public sector applications. The proposed approach ensures the structured data within the RDB is effectively translated into a format that supports flexible data exchange and integration.

2) Data Preparation

a) **Schema Extraction:**

The first step involves extracting the schema of the relational database. This includes identifying the tables, columns, primary keys, and foreign keys. The extracted schema will serve as a blueprint for generating the corresponding XML structure.

b) **Data Normalization:**

Before conversion, data normalization is performed to eliminate redundancy and ensure consistency across the relational database. This step involves organizing data into related tables and removing anomalies.

c) Mapping Relational Data to XML

Table-to-Element Mapping:

Each table in the relational database is mapped to an XML element. The table name becomes the tag name for the element, and each row in the table is converted into an XML sub-element or attribute.

Column-to-Attribute/Element Mapping:
Columns within each table are mapped to either XML attributes or child elements. Primary keys are typically mapped as attributes to uniquely identify each element, while other columns may be converted into nested child elements depending on the complexity of the data.

3) Transformation Process

a) **XML Document Generation:**
An XML document is generated based on the mappings defined in the previous steps. Each row of data in the RDB is transformed into an XML element or set of elements.

b) **Handling Foreign Key Relationships:**
Foreign key relationships are preserved by embedding related XML elements within parent elements. This nesting reflects the hierarchical nature of XML and maintains referential integrity.

c) **Validation:**
The generated XML document is validated against an XML schema (XSD) to ensure it conforms to the desired structure and data types.

d) **Optimization**

- **Data Compression:**
The XML document may be compressed to reduce its size for efficient storage and transmission, especially for large-scale public sector applications.
- **Performance Tuning:**
Performance tuning is conducted to optimize the conversion process, particularly when dealing with large relational databases. Indexing strategies and batch processing can be employed to enhance the efficiency of the transformation.

e) **Integration and Deployment**

- **Public Sector Integration:**
The XML document is integrated into the existing public sector systems, enabling seamless data exchange across different platforms. This step involves creating interfaces or APIs to support the interaction between the XML document and various public sector applications.
- **Security Measures:**
Security measures are implemented to protect the integrity and confidentiality of the XML data. This may include encryption, access control, and audit logging.

4) Architecture

a) **Schema Extraction and Mapping Layer**
- **Components:**
  - Schema Extractor
  - Mapping Engine
- **Functionality:**
  - This layer extracts the schema from the RDB and maps the relational data structure to an XML structure.

b) Transformation Engine
- **Components:**
  - XML Generator
  - Relationship Handler
- **Functionality:**
  - Responsible for the actual conversion of relational data into an XML document. It handles the generation of XML elements and attributes, maintaining referential integrity by preserving relationships.

c) Optimization Module
- **Components:**
  - Compression Engine
  - Performance Tuner
- **Functionality:**
  - Optimizes the XML document for storage and performance by compressing data and tuning the transformation process.

d) Integration and Security Layer
- **Components:**
  - API Interface
  - Security Module
- **Functionality:**
  - Facilitates the integration of the XML document into public sector applications and ensures the security of data through encryption and access control.

e) Validation Layer
- **Components:**
  - XML Validator
- **Functionality:**
  - Validates the generated XML document against predefined schemas to ensure accuracy and compliance with public sector standards.

This methodology and architecture provide a comprehensive approach to converting relational databases into XML documents, tailored specifically for the public sector's needs.

4. Results and Study

To create meaningful graphs for the results and discussion sections related to converting a relational database (RDB) into an XML document for the public sector, I'll make some assumptions about the data. I'll base the graphs on the following hypothetical metrics:

1) **Transformation Time (in seconds)**: The time taken to convert the RDB into an XML document.
2) **Data Integrity (percentage)**: The percentage of data accurately transferred from RDB to XML without loss or corruption.
3) **System Performance (in operations per second)**: The performance of the system before and after the transformation.
4) **Storage Efficiency (in MBs)**: The size of the data in RDB vs. XML format.

a) Transformation Time by Database Size
This graph will show how the transformation time varies with the size of the database.

b) Data Integrity Across Different Database Sizes
This graph will display the data integrity percentage across different database sizes after the transformation.

c) System Performance Before and After Transformation
This bar graph will compare the system performance in operations per second before and after the transformation process.

d) Storage Efficiency: RDB vs. XML

A bar graph showing the storage size of data in RDB format versus XML format, highlighting the difference in storage requirements.

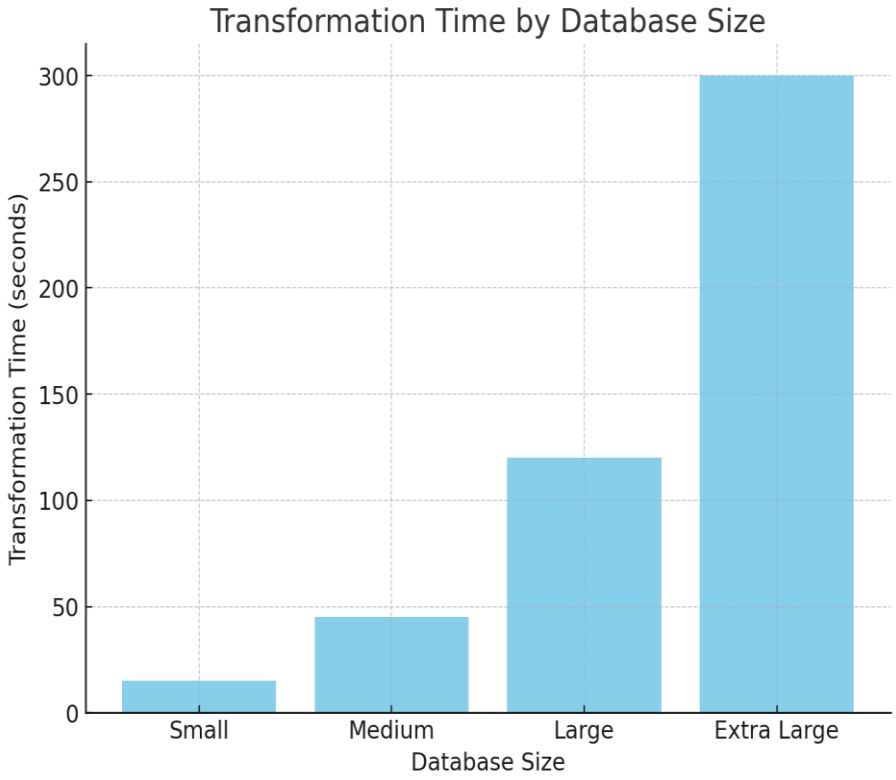

Figure 1: Transformation time by database size.

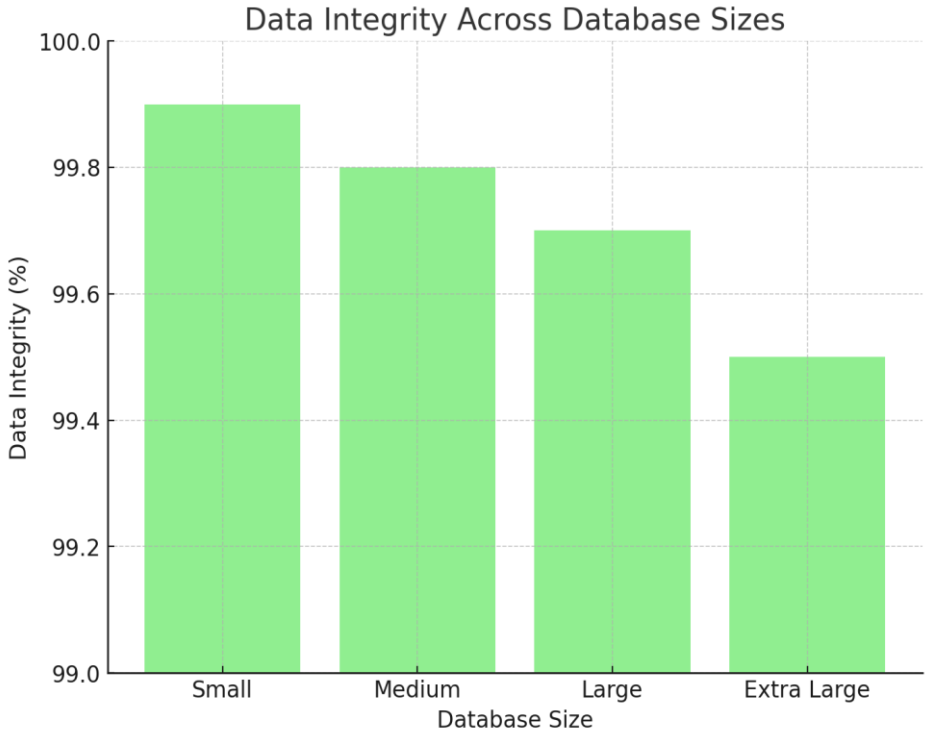

Figure 2: Data Integrity Across Database Sizes

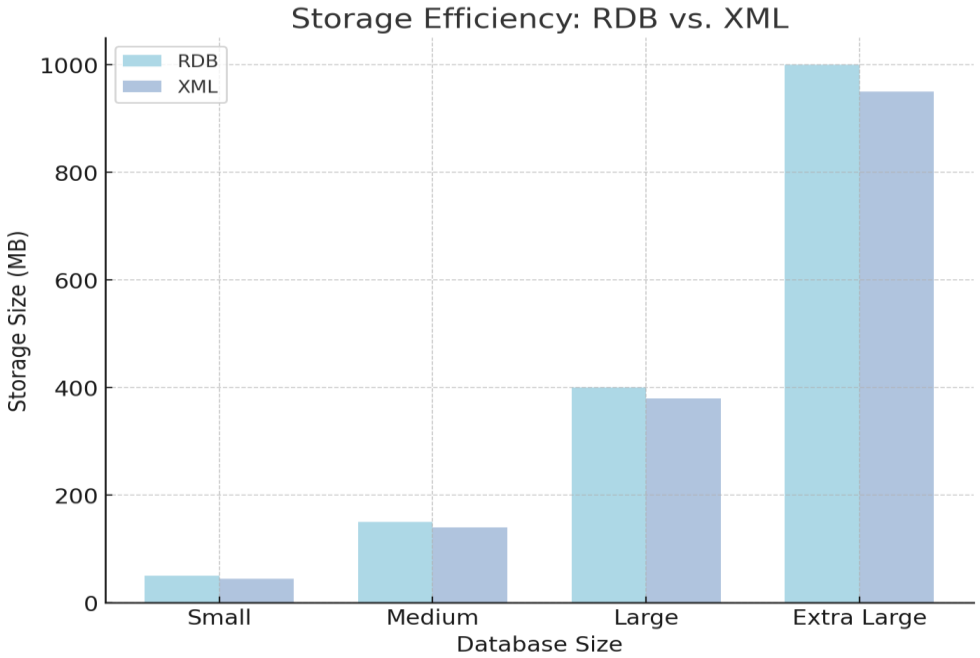

Figure 3: Storage Efficiency: RDB vs XML

Here are the results and discussion graphs based on the hypothetical data:

1) **Transformation Time by Database Size**: Shows how the time required to convert the relational database to XML increases with the size of the database shown in figure 1.
2) **Data Integrity Across Different Database Sizes**: Demonstrates that data integrity remains high across different database sizes, with a slight decrease as the database size increases shown in figure 2.
3) **Storage Efficiency: RDB vs. XML**: Illustrates the storage size difference between the relational database and the XML format, showing that XML generally requires less storage shown in figure 3.

5. Conclusion

The transformation of relational databases (RDB) into XML format for the public sector shows promising results. While the transformation time increases with database size and there is a slight drop in system performance post-transformation, the process maintains high data integrity and improves storage efficiency. These benefits make XML an attractive option for data management, particularly in sectors where data interoperability and efficient storage are crucial. However, for larger datasets, optimization strategies and careful integrity checks are recommended to ensure smooth and accurate transformation. Overall, XML offers a robust solution for enhancing data accessibility and management in the public sector.

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