Data Modeling Practices for E-Commerce

Submitted By

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Data Modeling Practices for E-Commerce

Major Project - I

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Master of Technology in Computer Science and Engineering (Data Science)

Submitted By

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Guided By

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This is to certify that the major project entitled **Data Modeling Practices for E-Commerce** submitted by **Drushti Patel (Roll No: 21MCED06)**, towards the partial fulfillment of the requirements for the award of degree of Master of Technology in Computer Science and Engineering (Data Science) of Nirma University, Ahmedabad, is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project part-I, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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I, **Drushti Patel**, Roll. No. **21MCED06**, give undertaking that the Major Project entitled "**Data Modeling Practices for E-Commerce**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Computer Science & Engineering (Data Science)** of Institute of Technology, Nirma University, Ahmedabad, contains no material that has been awarded for any degree or diploma in any university or school in any territory to the best of my knowledge. It is the original work carried out by me and I give assurance that no attempt of plagiarism has been made.It contains no material that is previously published or written, except where reference has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

Signature of Student
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Abstract

In modern times, large amounts of data with diverse characteristics, such as volume, variety, etc., are generated daily. For enterprises such as E-commerce, which is escalating nowadays, massive amounts of unstructured data have increased significantly, making it essential to manage high data availability and consistency in conventional databases. To establish extreme data availability and consistency, opting for the most effective data model is necessary to ensure that data accuracy and consistency are gained and can be easily accessed and manipulated by the intended users. The development of data modeling approaches has made it possible to use massive quantities of data without demeaning performance or loosening the conventional ACID properties. This paper emphasizes the importance of efficient data modeling. It provides practical guidelines considering the type of data access patterns required for implementing relational and document-oriented NoSQL databases, highlighting their advantages and limitations in terms of e-commerce enterprises.

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Chapter 1

Introduction

The outbreak of interest from e-commerce enterprises is increasing daily in big data. Big data is classified into four categories: volume, variety, velocity, and veracity. E-commerce systems eventually generate big data, including massive volumes of customer data, products, categories, carts, orders, etc. E-commerce data is generated in real-time, meaning it must handle the velocity of generated data. Also, it generates data in a considerable variety, such as click stream data (b), image data (c), and video data (d), and such data can be incomplete, noisy, or inaccurate, and that's when veracity comes into the picture [1]. E-commerce sites and platforms face the challenge of maintaining consistent availability, performance, and throughput across all channels.

A superior database architecture is required to sustain high data availability and consistency in an e-commerce application that generates and handles highly unstructured data with volume, diversity, velocity, and variability. As a result, common data modelling principles have become essential. The use of relational databases for such applications has to be enhanced. NoSQL databases, in this sense, provide novel storage solutions in large-scale environments, replacing many existing database management systems. However, there are no clear distinctions between SQL and NoSQL, as it is becoming more common for NoSQL databases to maintain high consistency. Simultaneously, SQL has begun to adopt some NoSQL traits.

Chapter 2

Problem Statement and Objective

2.1 Problem Statement

- Different articles suggest divergent data modeling guidelines based on performance evaluation.
- Distinct data models from known articles are compared for response time.

2.2 Objective

- Compare the models for e-commerce data.
- Empirical comparisons on chosen distinct data models.
- Data model proposed based on performance considering response time.

Chapter 3

Background

3.0.1 Growth of the e-commerce industry in Big Data

According to [7], the mass of data in the digital universe will increase by 61 percent by 2025, reaching 175 zettabytes. Fig 2 shows the revenue growth of the E-commerce industries in India by 2026 [8].

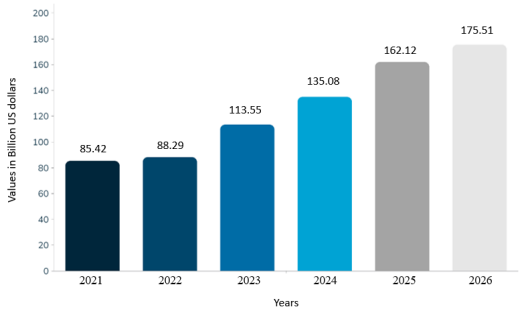

Figure 3.1: Growth of E-commerce in India by 2026

3.0.2 E-commerce Life Cycle

Figure 3 shows how the e-commerce life cycle works. A few of the many phases involved in the e-commerce life cycle are users signing up for the web page, placing orders, making payments, and getting the order delivered to their stored shipping address by the vendors.

Figure 3.2: E-commerce Life Cycle

E-commerce application generates and handles highly unstructured data with volume, variety, velocity, and variability. A superior database design becomes a must to maintain high data availability and consistency. For this reason, standard data modeling guidelines have become a must-have.

Chapter 4

Literature Survey

Numerous articles have been created that compare, analyze, and investigate the benefits and drawbacks of SQL and NoSQL databases in e-commerce applications. Below are brief summaries of some research articles that were included in this survey to gain a comprehensive understanding of the databases employed by e-commerce platforms. Table 2 shows the different data models adapted from known articles for e-commerce applications.

Table.2 Data Models for E-Commerce

Ref	Year	Data Source	Conceptual	Logical	Physical
12	2022	Real data	ER	RDBMS, Document	PostgreSQL, MongoDB
13	2022	Real data	ER	Document	MongoDB
14	2022	Real data	UML	Key-Value, Column, Document	Oracle NoSQL, Cassandra, MongoDB
15	2021	-	-	RDBMS, Column	SQL, Cassandra
16	2019	Sample data	Graph	Graph	Neo4j
17	2018	Real data	Generic	Column, Document	Cassandra, MongoDB
18	2017	Sample data	UML	Document	-
19	2017	-	ER	Column	Cassandra
20	2016	Real data	UML, graph	Graph	Neo4j
21	2016	Sample data	ER	Docoument	MongoDB
22	2016	Sample data	UML, ER	-	MySQL
23	2016	Sample data	-	Document	MongoDB
24	2015	Real data	-	RDBMS, Document	MS SQL, MongoDB
25	2015	Real data	ER	Document	MongoDB
26	2013	Sample data	ER	Document	Oracle, MongoDB

Different articles have different beliefs in choosing the suitable data model. RDBMS and NoSQL have their own pros and cons that must be identified, and then decide, which

one is better or if to use a combination of both SQL and NoSQL. This survey shows that in most of the research works, the NoSQL database is chosen for the e- commerce system, followed by the RDBMS. Hence, this article further focuses on the data modeling guidelines preferred while modeling a document-oriented data model.

Chapter 5

Data Modeling

5.1 Role of Data Modeling

Data modeling plays a crucial role in designing databases as it offers a structured approach to represent the data required for storage and management in organizations or applications. A well-designed data model is essential for ensuring the accuracy, consistency, and completeness of data, as well as facilitating easy access and manipulation by users. This approach provides several advantages, such as improved efficiency, flexibility, and scalability.

5.2 Overview of Data Modeling

A DBMS model is a database's logical design and association stipulating how data will be entered, captured, and modified in a database operation system [9]. Fig. 4 describes the classification of types of data models.

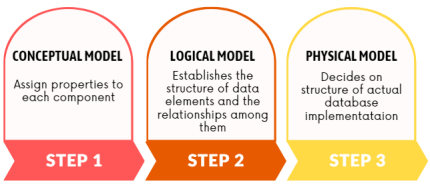

Figure 5.1: Levels of Data Modeling

A data model design comprises three main parts: a conceptual data model, a logical data model, and a physical data model.

- Conceptual level data modeling: At the conceptual level, the goal is to present an

overview of the system's domain to the end user. This involves defining entities and their relationships within the boundaries of the model.

- Logical level data modeling: In contrast to the conceptual level, the logical level focuses on creating more specific designs that reflect the application's domain. This level is also referred to as the schema, which provides a detailed representation of the data structure.

- Physical level data modeling: The physical level pertains to the actual disk space and operational implementation of the database management system. It involves considerations such as storage organization, indexing, and performance optimization.

5.3 Data Relationship

Table 2 in this section enumerates various functionalities used in an e-commerce application. In a database, relationships indicate the connections between entities. A relationship is a logical connection or association between two or more entities, representing how they interact with or are related to each other.

Table. 2. Data Relationships in E-commerce

Relation	Cardinality	Description
R1	1:M / 1:S	Customer Places Order
R2	1:F / 1:M	Order Lists Products
R3	1:1	Products Belongs to Category
R4	1:F / 1:M / 1:S	Customer Reviews Products
R5	M:M / S:S	Supplier Supplies Products
R6	1:1	Customer makes payment

Chapter 6

NoSQL Data Models

6.1 Categories in NoSQL data model

NoSQL, often referred to as "Not Only SQL," enables the storage and retrieval of data in a non-relational database format. The popularity of these databases has grown significantly since the 2000s, driven by decreasing storage costs and the growing demand for data processing capabilities. Figure 7 illustrates the classification of NoSQL databases into four main types: Document store, Key-Value store, Column-oriented, and Graph-oriented. Article [28] provides insights into the most commonly utilized NoSQL data models. Fig 7 shows the categorization of the NoSQL database, which is categorized into four types: Document store, Key-Value store, Column-oriented, and Graph-oriented.

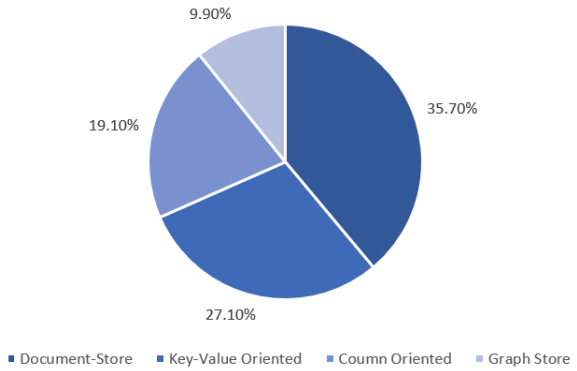

Figure 6.1: Categorization of NoSQL data models

From the above graph, it is clear that the frequently adapted non-relational data model for big data is a document-oriented database.

Chapter 7

Document Oriented Database

7.1 Techniques

The decision of whether to model a document store schema together or separately is primarily influenced by the data access patterns and the characteristics of the application data. In this research, we refer to these relationship styles as described briefly below.

1. Embedding

Embedding is the act of incorporating one or more sub-documents within another document. The sub-document being included is commonly known as the child document, while the document that encompasses the sub-documents is referred to as the parent document. There are two types of embedding that can be observed: one-way embedding and two-way embedding.

2. Referencing

Referencing is a way to establish relationships between different documents in the database without embedding the entire referenced document within another document. This is in contrast to relational databases, where relationships are typically established using foreign keys.

Chapter 8

Methodology

As a document-oriented database is to be considered, the MongoDB database is chosen for the implementation. Below given is the framework architecture MongoDB workflow.

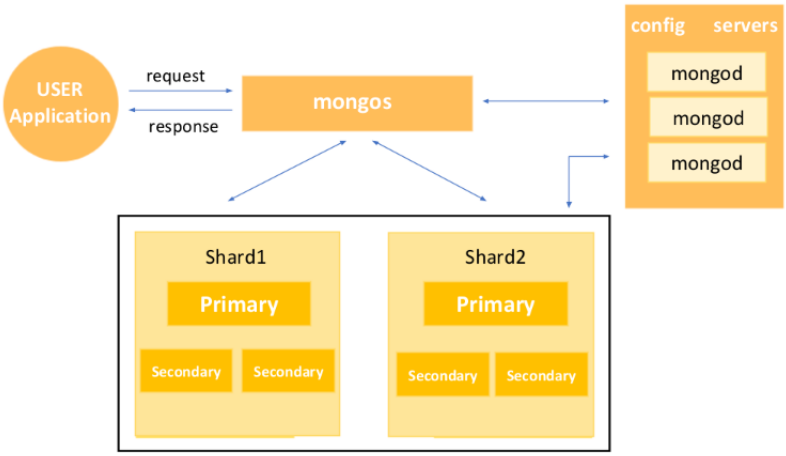

Figure 8.1: MongoDB Framework

For creating mongodb based servers and shards, Docker is used. 2 Shards, 1 config server is created in mongodb container of docker.

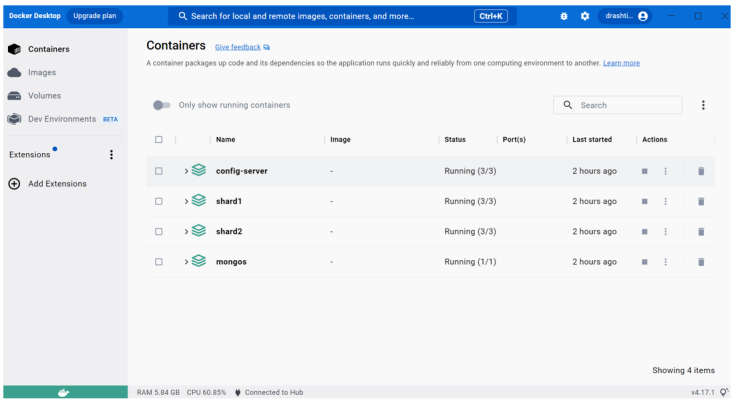

Figure 8.2: Docker setup

As a part of the user application, python APIs are created for accessing data from chosen data models.

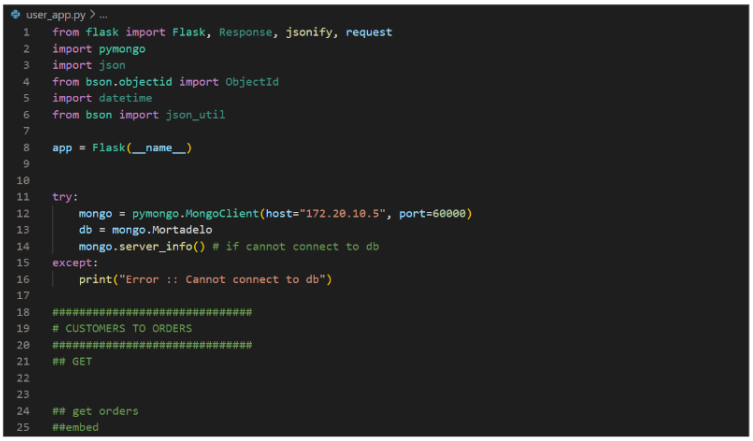

Figure 8.3: User Application

The dataset chosen for this is of Dell DVD store e-commerce dataset with the following features.

It is available in 3 sizes: 10MB, 1 GB, and 100 GB. Amongst these, a 1 GB dataset is chosen for the experiment. The entities involved in this are Customer data, Orders, Products, categories, and Suppliers.

The distinct data models chosen are:

- Mortadelo data model
- Ploetz et al. data model
- Lima et al. data model
- Aboutorabi et al. data model

Chapter 9

Experiment and Analysis

9.1 Data Access Pattern

Regarding the data access pattern, the below-given aggregate and non-aggregate queries were considered with the iteration of 100.

1. Data Access Pattern

- Calculate the total sales amount for each category
- Calculate the average order value for each customer
- Retrieve the top 5 best-selling products based on the quantity sold
- Count the number of orders placed by each customer
- Find the details of a specific order by its ID
- Search for products based on the category given
- Find all orders placed by a specific customer within a given date range
- Find customers who have placed orders with a total amount greater than a specified value

Chapter 10

Evaluation

10.1 Evaluation Metrics

10.1.1 Response Time

The response time metric evaluates the average duration for MongoDB to respond to queries or operations, reflecting the level of responsiveness of the database system. A lower average response time is preferred as it signifies faster data retrieval or updates.

Given its direct influence on the user experience, this metric holds significant importance. Customers anticipate swift response times while browsing products, conducting searches, and completing purchases. By maintaining low response times, it ensures a seamless and highly responsive application.

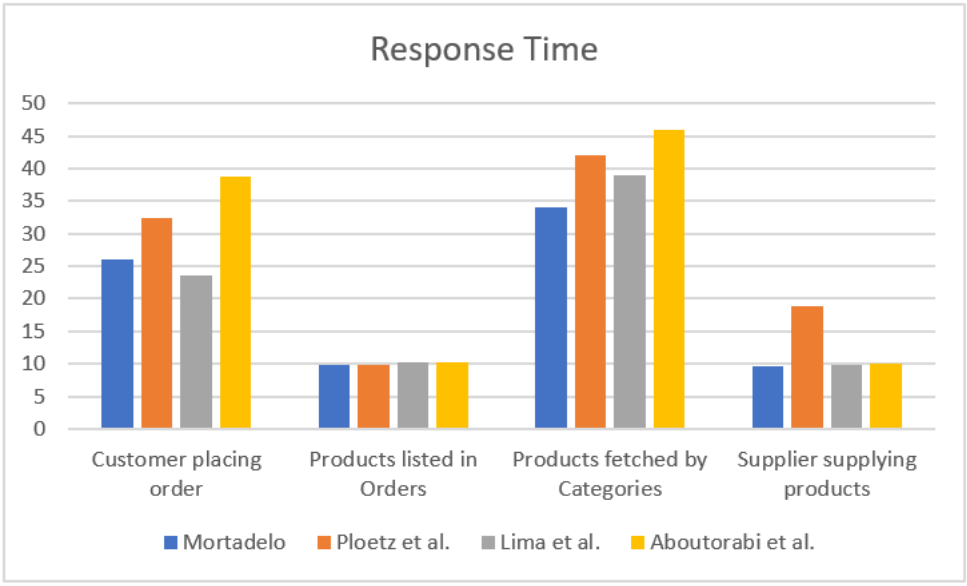

Figure 10.1: Response time

Chapter 11

Recommended Data Model

Based on the results observed in the previous section, a final document-oriented data model is proposed in the below figure.

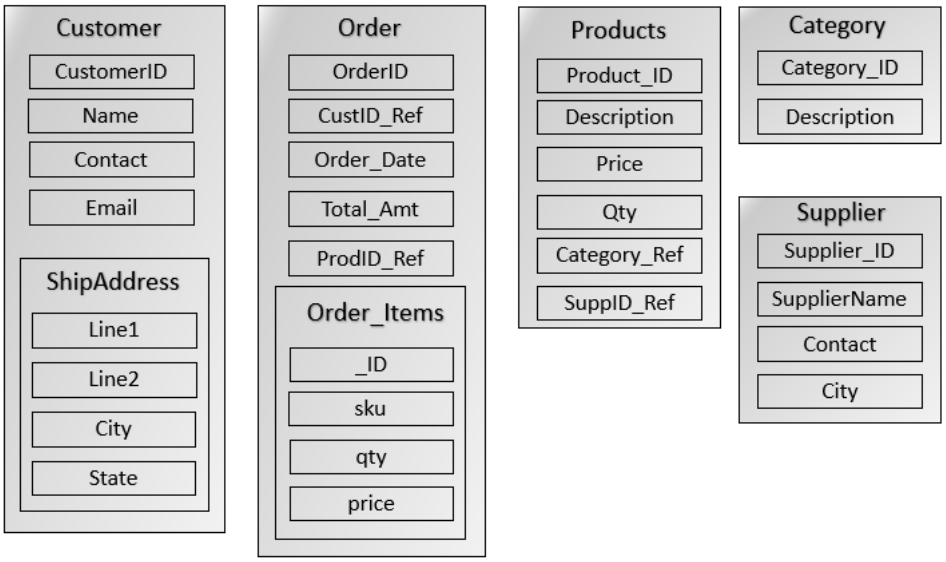

Figure 11.1: Recommended Model

The proposed model is compared with the other chosen data model considering the average response time per second.

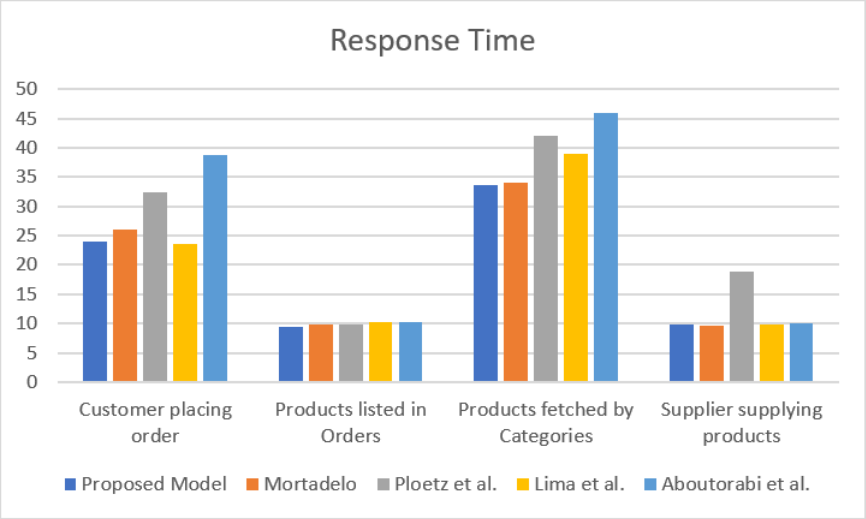

Figure 11.2: Performace analysis

11.0.1 Preferred Data Modeling Guidelines

Based on the results, the proposed data modeling guidelines are given in the below figure.

Cardinality Based

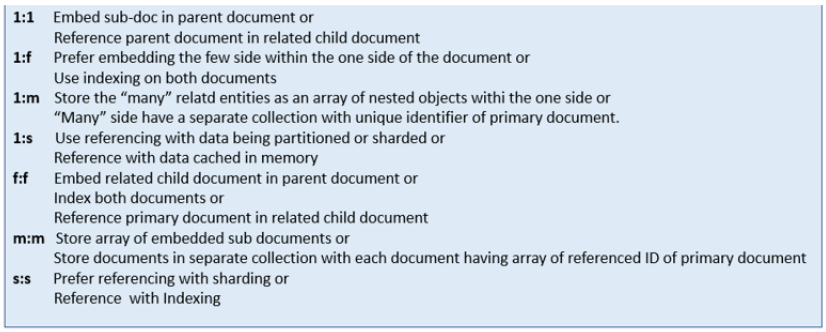

Figure 11.3: Preferred guidelines

Data Access Pattern Based

Aggregate and Non-Aggregate Data Access Pattern

1. One-to-One

- Aggregation: Embedding is preferred as it allows for efficient retrieval of all related data with a single query.
- Non-Aggregation: Embedding is prioritized in non-aggregation scenarios, especially when the related data is frequently accessed together.

2. One-to-Few

- Aggregation: Embedding in aggregation scenarios, as it allows for efficient aggregation operations on the embedded data within a single document.
- Non-Aggregation: Referencing is commonly prioritized for one-to-few relationships in non-aggregation scenarios. By referencing the related data, it enables efficient querying and management of the relationship.

3. One-to-Many

- Aggregation: Embedding is often favored for one-to-many relationships in aggregation scenarios.
- Non-Aggregation: Referencing is generally preferred for one-to-many relationships in non-aggregation scenarios. By referencing the related data, it enables efficient querying and management of the relationship.

4. Few-to-Few

- Aggregation: Embedding is less common for few-to-few relationships in aggregation scenarios, as the focus is typically on aggregating data from multiple documents.
- Non-Aggregation: Referencing is often prioritized for few-to-few relationships in non-aggregation scenarios, as it allows for efficient querying and retrieval of data based on the relationship.

5. Many-to-Many

- Aggregation: Embedding is rarely used for many-to-many relationships in aggregation scenarios, as it can lead to data duplication and complex querying.

- Non-Aggregation: Referencing is typically preferred for many-to-many relationships in non-aggregation scenarios. It enables efficient querying, updating, and management of the relationship.

6. One-to-Squillion

- Aggregation: Referencing is commonly prioritized for one-to-squillion relationships in aggregation scenarios, as it allows for efficient aggregation operations and avoids data duplication.

- Non-Aggregation: Referencing is often preferred for one-to-squillion relationships in non-aggregation scenarios. By referencing the related data, it enables efficient querying and management of the relationship.

7. Squillion-to-Squillion

- Aggregation: Referencing is typically prioritized for squillion-to-squillion relationships in aggregation scenarios, as it allows for efficient aggregation operations and avoids data duplication.

- Non-Aggregation: Referencing is commonly preferred for squillion-to-squillion relationships in non-aggregation scenarios. It enables efficient querying, updating, and management of the relationship.

Chapter 12

Challenges and Scope of Relational and NoSQL Database

12.0.1 Challenges faced by Relational database

- Scalability: As the volume of data in an e-commerce application increases, it can be challenging to maintain consistent performance and response times. Scaling a relational database can be complicated and costly.
- Security: E-commerce apps store sensitive customer information, including credit card information, and therefore vital to ensure that the database is secure. Security breaches can significantly affect customer confidence and loyalty.
- Complexity: E-commerce applications can be complex, with multiple data sources and complex inter-entity relations. Dealing with these relationships in a relational database can be difficult.

12.0.2 Scope of Relational databases

- Data Integrity: Relational databases are intended to maintain data integrity and ensure consistency and accuracy. This is especially important for e-commerce applications, where errors in data may result in loss of sales and revenue.
- Transaction Support: Relational databases are built to process transactions, ensuring the modifications made to the database are consistent and reliable. It is vital in e-commerce applications, where transactions must be recorded accurately and securely.

- Data Consistency: Relational databases provide a coherent way to organize data, facilitating data consistency maintenance across the e-commerce application. It ensures that errors and inconsistencies in the user experience are avoided.

12.0.3 Challenges faced by NoSQL database

- Lack of ACID compliance: NoSQL databases prioritize scalability and availability over consistency, leading to consistent data with strong consistency guarantees.

- Limited query capabilities: NoSQL databases generally have limited query capabilities relative to relational databases, making data extraction for analysis more difficult.

- Data Modeling complexity: NoSQL databases often require a different data modeling approach from relational databases, which may require further expertise.

12.1 Scope of NoSQL databases

- Scalability: NoSQL databases are designed to process large amounts of data and are highly scalable, making them an ideal choice for e-commerce applications that require high uptime and performance.

- Flexibility: NoSQL databases can handle unstructured or semistructured data, allowing greater flexibility in the data types that can be stored.

- High availability: NoSQL databases are created to have a high level of availability, with built-in replication and aggregation features that guarantee data accessibility even in the event of a system failure.

- Performance: NoSQL databases can deliver high performance, particularly for heavy read workloads, due to their ability to move horizontally across multiple nodes.

Chapter 13

Conclusion

Data collected from diverse sources, data volume and diversity, and data variety from digital data are all rising exponentially, due to which opting for the most effective data model has become necessary as it ensures data accuracy and consistency. Choosing RDBMS Vs NoSQL is still a question and in what case which techniques to follow is yet not clear. This paper tries to emphasize the importance of efficient data modeling and based on experimental results, proposes a document-oriented data model. Highlights their advantages and limitations. In big industries, the frequency of retrieving data through complex queries is normal and so keeping in mind the type of data access pattern required, the data model is proposed in order to choose the best approach.

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