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Review Article

Revolution of Database Management System: A literature Survey

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Abstract *- Database technology is a very essential need to meet several requirements of software engineering applications in a satisfactory manner. Database Technology has revolutionary transformations over time. Every era brings with it a new set of issues and challenges for databases. As a result of these requirements, challenges and issues, people are being encouraged to develop a variety of DBMSs, and hence numerous database management systems are implemented and being implemented. As there are a number of DBMSs available, each has its own features, benefits, and drawbacks. To analyze various kinds of DBMSs, their features, and their properties, the authors performed a literature survey. The main aim of this survey is to discuss various database management systems from 1960 to 2022. This research presents the literature on various database management systems in depth. In addition, this paper includes the advantages and disadvantages of various database management systems. This survey will help researchers to explore the various research issues with the alertness for the presented systems.*

Keywords *- Modern database system, NoSQL, NewSQL, ORDBMS, OODBMS, RDBMS.*

1. Introduction

Data is essential for any modern software application, and databases are the most frequent means for applications to store and handle data. A database is a collection of well-organized data; here, data is stored in a structured manner, and the interrelationship among data is well-defined. To maintain large databases, authors need tools that are reliable, secure, and easy to use. A database management system is a tool that provides the facility to manage databases. According to H. F. Korth, a database management system is an assembly of interrelated data and a set of programs to update or retrieve that data [31]. Here interrelated data is known as a database; usually, it contains information about any enterprise. Ultimately DBMS is software that provides the facility to access the database; authors can create, access, update and delete databases using it.

Figure 1.1 shows/defines the database management system.

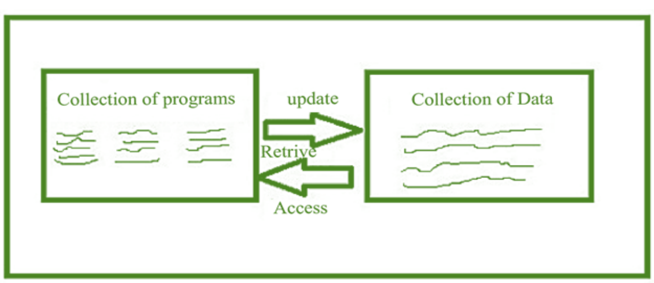

Fig. 1 Database management system

Database management systems have taken the position of file system data management by providing a pool of data that numerous application programs and users can share at once. As time went on, innovative technologies were devised. Databases have progressed from traditional relational databases to more advanced databases such as NoSQL, NewSQL, and distributed databases because of the proliferation of web and cloud technologies. These advanced database systems can handle structured, semi-structured and even unstructured data. These advanced types of databases are also known as modern database systems.

Every database system has a particular function, and each one is reliant on the deployment environment as well as various user interactions.

Various surveys are available that deal with the evolution of database management systems. [99] describes the development of DBMSs and gives a comparative study among various DBMSs. In [100] author focused on a detailed study of DBMS, advantages, and functions of DBMS. [97] surveyed the database standardization arena. [63] provided an overview and history of DBMS. Although these surveys have been done, a systematic literature survey is needed to explore each side of various DBMSs with detailed statistics. Earlier, the literature surveys were done, but they included a few DBMS and its comparison. Authors are surveying many Databases Management System's journey with taking maximum aspects.

Along with the description of each database, the authors have wrapped the data model, research work in past, year-wise research work distribution, related products, advantages, and disadvantages of each database management system.

This research paper is organized as follows: Section 2 comprises the description of various database management systems. In Section 3, the authors have introduced methodology, followed by section 4, which presents literature on various database management systems. Analysis and discussion are presented in sections 5 and 6, respectively, and finally, the conclusion is given in section 7.

2. Methodology

This study employs a mix of qualitative and quantitative methodologies. In the qualitative method, a literature survey is used to locate relevant publications related to existing database management systems. Authors used searching on platforms like ACM digital library, Scopus, WoS and Google Scholar to identify related research work. The authors presented a description of identified research work in section 4. In quantitative methods, pre-existing statistical data is manipulated using computational methods and analysis tools like cross-tabulation.

3. Background

From the mid-1960s forward, the availability of direct-access storage (discs and drums) corresponded with the introduction of the term database. Many database technologies have been developed since 1960 and are constantly being developed.

A database type known as a navigational database is where records or objects are primarily found.[1]. Hierarchical and network databases are navigational databases. Further, the RDBMS, OODBMS concept has been developed. NoSQL and NewSQL are in trend in this decade. Designing real-time applications with deterministic, predictable database management is also a need today [103]. In this section, the authors discussed various database management systems.

3.1. Hierarchical Database Management System

From the mid-1960s forward, the term database was introduced, and a hierarchical database system was developed. IBM devised a hierarchical structure that was employed in early mainframe databases. This database system represents data in a tree-like form. In these systems, the information is kept in the form of records that are linked together.

A record is a collection of fields, each of which has a single value. The type of a record determines which fields are included in the record. Each child record has just one parent in the hierarchical database architecture; however, each parent record might have one or more child entries. One of the most popular hierarchical database systems is IBM IMS.

3.2. Network Database Management System

In 1969, Charles Bachman invented the network model, which was later fully fledged by him into a standard specification by the Conference on Data Systems Languages (CODASYL) Consortium and published. It is also known as CODASYL DBMS. These database systems were designed to improve performance through the available hardware at that time. Network database management systems are built on a network data model that allows for numerous parent and child records for each entry. Integrated Data Store (IDS) was an early network database management system that was primarily utilized by the industry and was recognized for its speed.

3.3. Relational Database Management System

In 1970, E. F. Codd invented the relational database management system. It is a system for maintaining relational databases. It is based on a relational model and follows codd’s rule. This system stores the information in a table format with rows and columns. An entity is represented by a table. A table is also known as a relation. It is made up of rows and columns. A table’s columns indicate the entity’s attributes, often known as fields or properties. A record is also known as a tuple; basically, it is a row in a table. Each relation has a unique key, also known as the primary key. This key can uniquely identify a row or a record in a relation. RDBMS is a widely used and popular type of DBMS. MySQL, Oracle and many more RDBMSs are available in the market.

3.4. Object-Oriented Database Management Systems

Object-oriented database blends the most successful programming paradigm with database technology, thus solving the impedance mismatch. Object-oriented database management systems (OODBMS) arose from research in the early to mid-1970s, and around 1985, the term “object-oriented database system” was coined. As in object-oriented programming, information is represented here as objects. OODBMS unite databases capabilities and object-oriented programming capabilities. An object database directly contains complex data and relationships between data. It is done without mapping to relational rows and columns so that it becomes ideal for applications that deal with complex data.

3.5. Object Relational Database Management Systems

RDBMS and OODBMS both have been used widely by companies, but still, there was a need for the middle ground between relational databases and object-oriented databases. To achieve this middle ground, in 1990, a new approach to database management systems was proposed known as an object-relational database management system (ORDBMS). According to this new approach, object features can be added to RDBMS [35]. An object–relational database is a type of database that sits halfway between relational and object-oriented databases. The majority of ORDBSs are based on relational models and only provide minimal support for simple object types. Software developers can use object–relational

DBMS to integrate their own types and methods into the database. ORDBMS can store complex data and include OOP features such as inheritance polymorphism and object behavior with support for data types, tabular structures etc., like Relational data models.

3.6. NoSQL

The diversity of data and the requirement for Rapid development have created the need for a new database system, resulting in NoSQL. In 1998, Carlo Strozzi coined the term "NoSQL" to describe an open-source relational database that lacked a SQL interface [25]. Johan Oskarsson reintroduced the term NoSQL in early 2009. NoSQL, also known as Not Only SQL, is a database system that stores data other than in tabular form and can horizontally extend "basic operation" throughput over multiple servers and replicate and distribute data across multiple servers [7].

Simpler "horizontal" scaling to clusters of machines, tighter control over availability, and minimizing the object-relational impedance mismatch are all advantages of the NoSQL technique. Data structures used by NoSQL databases are very flexible. NoSQL stores data in various ways like key–value pair, wide columns, graphs, or document styles.

3.7. NewSQL

In 2011, 451 Group analyst Matthew Aslett coined the term NewSQL [11]. NewSQL is a kind of database management system that aims to combine the scalability of NoSQL systems with the ACID guarantees of a traditional database system for online transaction processing (OLTP) workloads. NewSQL is a subset of relational database management systems that aims to combine scalability with the ACID guarantees for online transaction processing (OLTP) workloads. NewSQL systems can be classified into three groups: new architectures, SQL engines, and transparent sharding. NewSQL systems have taken up different internal architectures, for example, clusters of shared-nothing nodes. NewSQL systems have programming interfaces like SQL but scale better than built-in engines. This system partitions databases over numerous nodes automatically.

From Figure 2 Authors can see the journey of database technology and the basic structure of each database technology.

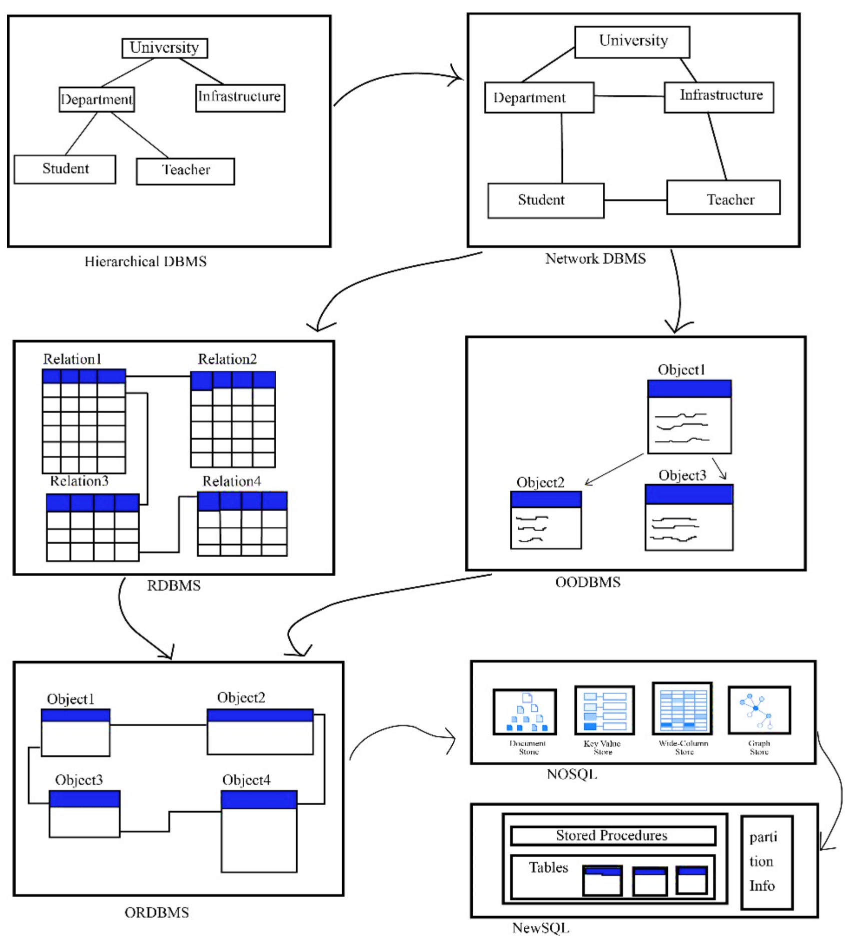

Fig. 2 Journey of database technologies

4. Literature Survey

Various research works are available in the literature regarding database management systems. In 1969, GEORGE G. DODD discussed the purposes of data management systems and primitive data management techniques [12]. After that, in 1974, Everest G.C introduced the objective of a database management system. This research work was aimed at business executives and technical information specialists [13]. In 1976, James P. Fry and Edgar H. Sibley presented the evolution of database management systems. [63]. Abraham Silberschatz, Henry F. Korth and S. Sudarshan published their research work in 1996 describing databases, DBMS, and data Models [32]. Authors have unfolded different types of data models, kinds of databases, their applications, and the history of database technology. In [96] author outlines a process for evaluating and selecting database management software that was designed and implemented. In [103], it is stated that a Deterministic Real-Time Database Management System is required

4.1. Hierarchical DBMS

In 1960, IBM developed a hierarchical structure in early DBMS. IBMIMS and RDM mobiles both are examples of hierarchical DBMS. In [2], D.C. Tschiritzis presented a survey on hierarchical DBMS. They discussed features and facilities followed by techniques of implementation of hierarchical DBMS. Further, in 1967 Bilier gave an approach, TSDMS (Time Shared Data Management System) [8]. In 1976, J. M. Engel described a method to use APL programs to access hierarchical databases [3]. In 1980, a locking protocol was proposed for hierarchical databases [14].

4.2. Network DBMS

In 1970, network database systems became popular on mainframe and minicomputers. Charles Bachman is the author of the Network database model, and in 1969 it was published in the Conference on Data Systems Languages (CODASYL). During the 1970's many network DBMSs were developed, for example, IDMS, Univac, and DMS-1100. In [15] author presented the principles, notation, and database languages established by the CODASYL Data Description Language and Programming Language Committees in a teaching format in 1976. In [16], the author introduced two new database query languages, SSL and J, and used the denotation approach to determine their semantics. In [17], SUBIETA, K. presented High-level navigational facilities for network and relational databases to improve network database query languages. In [19], the authors described the network data model and its features. In [20], researchers investigated and evaluated network database security mechanisms.

4.3. RDBMS

Numerous research papers have been released on relational database management systems. In [43], E. F. Codd developed the concept of relational models and RDBMS in the 1970s and described them in a very well manner. In 1971, he presented one more research work that illustrated removing repetitive groupings, creating hierarchic and plex structures, and cross-reference structures [21]. Stonebraker and Eugene Wong also started research on relational databases to develop an efficient and practical implementation after following Edgar F. Codd's research work on the relational model [27]. They developed INGRS stands for "Interactive Graphic and Retrieval System ". The principles employed in the creation of DBDSGN, an experimental physical design tool for relational databases created at the IBM San Jose Research Laboratory, were discussed by FINKELSTEIN and his colleagues in [37]. 1n 1979, E, F. Codd proposed extensions to the relational model to support certain atomic and molecular semantics. These additions provide a synthesis of numerous concepts from the semantic modelling literature. [44]. Table 1 describes how much research work has been done.

4.4. OODBMS

During the 1970s, object-oriented database management systems grew out of research, and as a result, in 1985, OODBMS was developed and became very popular [39][41]. Further in [38], Banciihon described what should be considered the main characteristic of an object-oriented system, i.e. those which may be important to integrate into a database system: encapsulation, object identity, inheritance, overriding and late binding. He also differentiates between an object-oriented system and an object-oriented database system. In [40], F. Manola and U. Dayal described the development of the data model of PROBE, a knowledge-oriented DBMS being developed at GGA. In 1990 David D. Straube and M. Tamer did research based on query processing methodology complete with an object calculus and a closed object algebra [36]. In [4], the main features and characteristics are described. In [60], The O2 system, an object-oriented database system, is described in detail. It also includes a suite of tools for creating user interfaces as well as a complete programming environment. Further, a lot of research work has been done on object-oriented databases. It is mentioned in Table 1.

4.5. ORDBMS

In [35], the author described ORDBMS. It might be a good choice for systems that handle a large amount of complex data and queries. In [34] author explained why object-relational technology is excellent for a wide range of data types and application sectors, including financial services and multimedia data. A next-generation DBMS was necessary to meet dynamic environment demands such as fast, cost-effective time-to-market of new or changed business processes and services. To satisfy these demands in 1996, UniSQL's commercial object-relational database administration system was developed, briefly described in [67]. Further, in [71], authors suggest a full investigation of partial rollback techniques for OO/ORDBMSs with a dual buffer. The suitability of combining two prominent scientific formats, NetCDF and HDF, into an object-relational system is investigated in [72].

4.6. NoSQL

The diversity of data and the requirement for Rapid development have created the need for a new database system that provides a lightweight form of data management for large and flexible data. In 1998, Carlo Strozzi coined the term "NoSQL" to describe an open-source relational database that lacked a SQL interface [25]. Johan Oskarsson reintroduced the term NoSQL in early 2009[26]. In 2018 Davoudian and his team published his survey on NoSQL databases [6]. In [23], authors presented many proposals aimed at unifying all or most NoSQL databases under a single design methodology. In [73], authors proposed a cloud-enabled framework for adaptive monitoring of NoSQL systems. Further, in [75] authors gave a comparative study of the performance of various NoSQL databases based on how they are often used to store and retrieve data. In [80] author described a uniform architecture for NoSQL databases that allows them to handle regular SQL (Structured Query Language) operations. In [82], the author demonstrated how to integrate Attribute-Based Access Control (ABAC) into NoSQL databases, notably MongoDB, which normally only offers Role-Based Access Control (RBAC). In [101], a study to examine the state of the art for NoSQL database-specific security and privacy solutions is presented.

4.7. NewSQL

NewSQL database offers scalability and flexibility while retaining the support for SQL queries and ACID [24]. The ten rules have been outlined to define the properties that any SO datastore should have [93]. In 2016 Andrew Pavlo and Matthew Aslett published a research work that includes a detailed explanation of what the term NewSQL means and the different categories of systems that fall under this definition [11]. In [85], the authors presented Lambda architecture, CouchDB architecture, how to manage huge data with NewSQL Solutions (dbShards), and the future of NewSQL and Big Data processing. In [86], authors talked about modern NewSQL systems, emphasizing the underlying architecture and concurrency management mechanisms. In [92], authors have built the case for NewSQL by introducing its core ideas from distributed database systems and demonstrating them with Spanner and LeanXcale, two of the most advanced systems for scalable transaction management. In [102] presents a study that assesses consistency guarantees and the performance of the VoltDB NewSQL database.

Table 1. Collected research work

DBMS	Research Work
Hierarchical Database Management System	[2],[3],[8],[14],[30]
Network Database Management System	[15],[16],[17],[20],[98]
Relational Database Management System	[21],[22],[29],[31],[37],[42],[43],[44],[45],[46],[47],[48],[50],[51],[52],[53],[54],[55],[56],[57],[58],[59],[104],[105]
Object Oriented Database Management System	[4],[27],[35],[36],[38],[39],[40],[41],[60],[61],[62],[64],[65], [66],[71]
Object Relational Database Management System	[34],[67],[68],[69],[70],[71],[72],[95]
NoSQL	[6],[7],[10],[18],[23],[24],[25],[26],[73],[74],[75],[76],[77],[78],[79],[80],[81],[82],[83],[93],[101]
NewSQL	[5],[11],[24],[84],[85],[86],[87],[88],[89],[90],[91],[92],[93],[102]

Table 2. Data models and products

S.No.	DBMS	Product	Data Model
1.	Hierarchical Database Management System	IBM IMS, RDM	Hierarchical Data Model
2.	Network Database Management System	Integrated Data Store (IDS), Integrated Database Management SYSTEM (IDMS)	Network Data Model
3.	Relational Database Management System	MySQL, Oracle, SQL Server, IBM DB2	Relational Data Model
4	Object Oriented Database Management System	Realm, Objectivity/DB	Object-Oriented Data Model
5	Object Relational Database Management System	IBM's DB2, Oracle Database	Object Oriented Model
6	NoSQL	MongoDB, Oracle NoSQL, Cassandra DB	Schema less and scalable Database, At conceptual level ER Model and UML, are adopted
7	NewSQL	VoltDB, MemSQL and ClustrixDB, NuoDB	At the conceptual level, ER Model and UML are adopted

Table 3. Pros and cons

S.No.	DBMS	Pros	Cons
1.	Hierarchical Database Management System	1. Easy to understand because of its one-to-many relationships. 2. The ability to read tree structure databases is provided by a number of programming languages.[32]	1. Many- to- Many relationships are not supported. 2. Data redundancy 3. Less consistency and security [33]
2.	Network Database Management System	1. It supports many-to-many relationships and hence provides better flexibility and accessibility.[13]	1. Limited data independency, 2. Less consistency and security [33]
3	Relational Database Management System	1. Reduced data redundancy 2. Better data integrity 3. Better physical and logical data independency 4. Provides much better consistency and security [32]	1. It does not support unstructured, complex data. 2. Does not provide scalability.
4	Object Oriented Database Management System	1. Data abstraction and better integration[36] 2. It supports inheritance and overriding [38].	Lack of persistence and reliability, No mechanism for rollback [38].
5	Object Relational Database Management System	It supports 1.N-dimensional OO modeling, 2.2-dimensional relational modeling 3.OOP features 4.non-procedural query access [67]	It is a complex system and has the ambiguity of objects and relationships.
6	NoSQL	1. It provides horizontal scalability. 2. It supports Schema independence and better security	It does not guarantee for ACID properties.
7	NewSQL	1. It provides scalability. 2. It supports ACID properties	This technology is still new, lacking experience and lack of reliability.

Table 4. Research work distribution

DBMS	Research Work on Concurrency Control/Consistency	Research Work on Security issues	Research Work on Query Processing/ Operations	Research Work on database design, description, and feature analysis
Hierarchical Database Management System	1	0	2	3
Network Database Management System	0	1	2	2
Relational Database Management System	1	1	8	15
Object Oriented Database Management System	1	0	3	10
Object Relational Database Management System	1	0	1	5
NoSQL	1	1	3	16
NewSQL	2	0	1	11

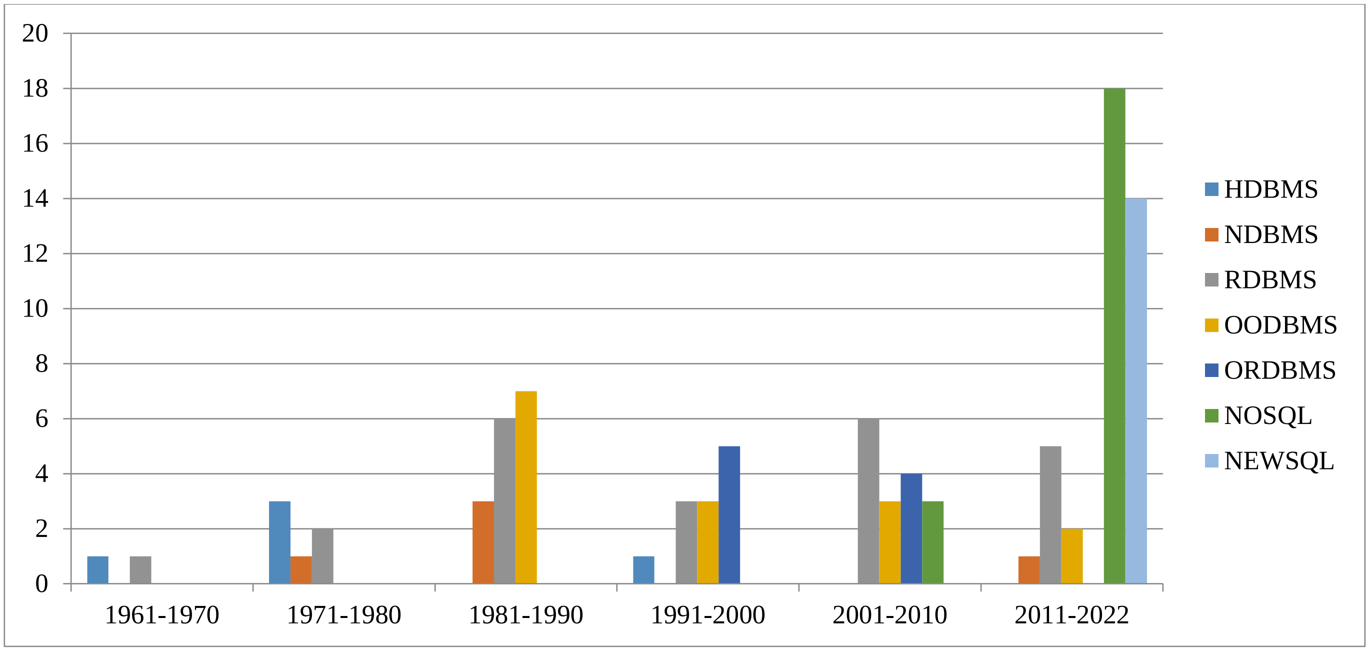

Fig. 3 Number of research papers in decades

5. Analysis

This section includes an analysis of various database management systems and the analysis of collected research work for various database management systems. Table 1 shows the past research work available for DBMSs. After studying and analyzing all this assembled research work, the authors got to know the features of each type of DBMS and the advantages and disadvantages of each DBMS. The authors also found information about the data models used for each DBMS. Table 2 presents the data model and products of various database management systems. Table 3 shows the advantages and disadvantages of various database management systems. From this survey, the authors found that research is done in many aspects, such as some authors describing databases and features of databases, some have given pros, cons and applications of various databases, and some of the authors working on concurrency control, recovery methods and security issues. The authors also found research work that focuses on query processing. Table 4 provides the research work distribution in different areas. The discussion on these tables is given in section 6.

6. Discussion

This section contains a detailed discussion of the analysis covered in section 5.

Figure 3 shows the distribution of research work over the decades.

It shows the number of research papers that we have found for each database management system in every decade. After analysis, we realized that there is the least amount of research work available for hierarchical and network database management systems.

The authors found a few research papers for both database systems. There is a scope to investigate these database systems. The growth in the number of research papers for RDBMS is continuing every decade. In our survey, the authors found that RDBMS has more research work than other database systems in all decades. Mostly, OODBMS and ORDBMS were investigated from 1990 to 2010. After 2010 there is less research work available for OODBMS. After 1998 NoSQL was invented, but very little research was available from 1998 to 2000; Further, NoSQL became famous and much more work was published from 2000 to 2022. NewSQL came to light in 2011; many researchers have been working on NewSQL. The authors found 13 research papers for NewSQL. A good amount of research work is available for NewSQL. Apart from that, the authors have seen various past research works, in which some describe databases and features of databases, some have given pros, cons and applications of various databases, and some of the authors worked on concurrency control, recovery methods and security issues. The authors also found research work that focuses on query processing. Figure 4 shows the research work distribution. There exists very few research done on security and concurrency control. Authors need quality research in this field of database security and concurrency control. After studying all these papers, the authors recognized that there is a need for much more advancement in DBMS, such as NoSQL and NewSQL. NewSQL needs some experience and a greater integrity approach with ACID properties. DBMS manufacturers must consider elements overlooked in non-real-time database systems to replace traditional concurrency control and scheduling methods and satisfy the essential criteria of predictability and temporal consistency of data.[103].

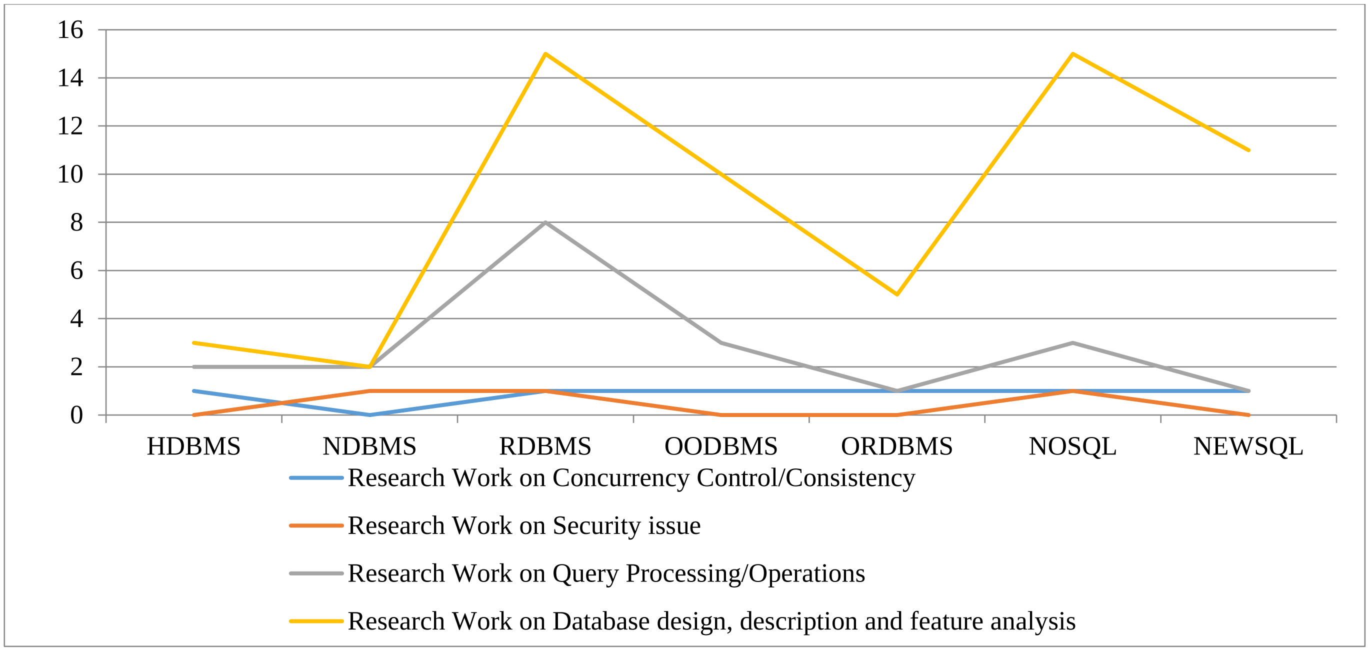

Fig. 4 Research work distribution

7. Conclusion

This survey presented a revolution in database technology. The authors described various database management systems. The description of the database management system is followed by the literature survey of each database management system. This research also discusses the advantages and disadvantages of each database management system. The authors listed the data models of various database management systems. After, the author presented the analysis and discussion part, where the authors discussed what was already done and now what research was needed. One of the main objectives of this literature survey was to determine the current trend in database technology by investigating older technology. The authors explored research issues with the alertness of the current state of research. Hierarchical database management systems and network database management system are not fulfilling current requirements, and both are the least explored database technologies among the six authors mentioned. RDBMS is widely used and most explored by researchers, yet it cannot handle today's massive amounts of structured and unstructured data. According to the findings of this study, there is still a long way to go before authors have a mature and reliable database management system; DBMS such as NoSQL and NewSQL require much more development. With ACID characteristics, NewSQL requires some experience and a higher level of integrity.

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