International Journal of Modern Trends in Engineering and Research
www.ijmter.com
e-ISSN: 2349-9745
p-ISSN: 2393-8161

Study Of The ANSI/SPARC Architecture

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Abstract - The ANSI/SPARC three-level database architecture proposes an architecture layer which decouples external views on data and the implementation view of data. It is one of the classic fundamental database architectural models. In this paper we shall study the ANSI/SPARC database architecture and its various components and applications.

Keywords - ANSI/SPARC ,database systems - DBS, database management systems – DBMS, database – DB, Conceptual view, data models, database design, relational database, internal view, external view, distributed systems, advanced database systems.

I. INTRODUCTION

DBS architecture is a graphical and suggestive representation of the system elements and of the links between them. [1] From their appearance up to present, DBMS have known a great variety, and therefore it is difficult to give a unique architecture, valid for all their types, because are frequently appearing features from one system to another. There are concerns about the standardization of DBMS architecture, which seeks to define a general framework. Among them, two reference architectures of DBMS are proposed by the researchers group of CODASYL and ANSI / SPARC. [1]

II. HISTORY

The ANSI-SPARC three layer database architecture was proposed in 1975, and is still used in modern RDBMS. The three proposed layers were a physical schema which defined how the data is actually stored (inode information), a conceptual schema which represented how information was related and indexed, and an external schema which represented how information was presented. The architecture was designed to provide immunity to change: the physical schema defined how the actual information was stored, and could be changed without effecting how external applications interacted with the data; and the external schema could be changed to define richer APIs, without having to change the underlying storage mechanism.[6]

The multiple schema approach adopted by CODASYL undoubtedly influenced the conclusions of the ANSI/ SPARC study group who met to discuss which areas of database technology were amenable to standardization. [5]

The outcome was a three-schema approach [4], which continues to influence database system architects. The three schemas were the internal, the external and the conceptual. The internal schema describes the physical storage of data. The external schema describes a user view of data (there may

e-ISSN: 2349-9745
p-ISSN: 2393-8161

be many of these in a given system). The conceptual schema provides a community view of the database. The mappings between the schemas are responsible for making applications independent from the storage of the data. [5]

The CODASYL Proposal represents a database system architecture of two-levels. Later, in ANSI/X3/SPARC [ANS-75] and in 'niAM I [SEN-72] the two-level ' architecture was expanded and three or four levels of data descriptions within a data base management system were proposed.[8]

The ANSI-SPARC DBMS reference architecture was conceived as a standardization architecture for multiple organizations [18]]. The design team was composed of user, software, and research organizations. The architecture specifies components and interfaces. It is abstract, semi-detailed, and semiformal.[17]

Based on these values, the architecture can be classified as Type 1 architecture with a variation in the C2 sub-dimension (involvement of researchers). However, as its designers concluded ‘post-factum’, the existing technology was not able to support it [18]. In the newly defined context, the architecture became preliminary, facilitation architecture positioning itself as a Type 5 reference architecture. The mismatch of its values and Type 5 values occurs in the D1 subdimension, which as a result of the initial confusion of goals and context of the architecture, defines components and interfaces instead of components and algorithms. This misalignment decreased the effectiveness of the architecture as the support for certain components had to be further investigated beyond this design effort (which has significantly delayed the usage of the complete architecture in practice). However, the congruence of goals, context and the other design dimensions (as defined in Type 5) contributed to the success of the design principles of the ANSI-SPARC architecture (well-known as the “ANSI-SPARC three-layer model”) which became a fundamental model for the design of database management systems. [17]

Some may argue that the ANSI/SPARC reference model is overly idealistic (or even dated). Other options were indeed also available to use as basis for the exploration of Database Forensics. The original ANSI/SPARC architecture (SIGMOD Record, 1982) specified 42 interfaces between various components.[15]

The ANSI/SPARC report was intended as a basis for interoperable computer systems. All database vendors adopted the three-schema terminology, but they implemented it in incompatible ways. Over the next twenty years, various groups attempted to define standards for the conceptual schema and its mappings to databases and programming languages. Unfortunately, none of the vendors had a strong incentive to make their formats compatible with their competitors'. A few reports were produced, but no standards.[14]

The ANSI/SPARC Report suggested the conceptual level as a part of the data base management system, and describes it by a number of purposes:

"- It should provide a description of the information of interest to the enterprise.

- It should provide a stable platform to which internal schemas and external schemas may be bound.

- It should permit additional external schemas to be defined or existing ones to be modified or augmented, without impact on the internal level. It should allow modifications to the internal level to be invisible at the external level.

e-ISSN: 2349-9745
p-ISSN: 2393-8161

- It should provide a mechanism of control over the content and use of the data base." [ANS-75] , [ANS-77] .[8]

III. THE NEED

The ANSI/SPARC architecture has been developed for database systems that operate in the business domain.[16] The need for a reference framework for software product management is found in the desire to get an understanding of its complete domain.

Varying research contributions and developments in the software industry can be positioned in it to interpret their consequences in a uniform context. Furthermore, such a reference framework also provides a starting point for:

- Definition of key terms and the identification of open research questions;

- Education of product managers and competence building;

- Development of improved, integrated tool support.[9]

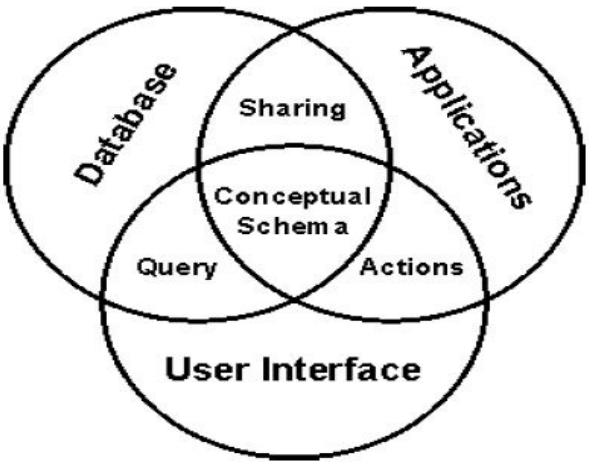
The ANSI/SPARC Interim Report [ANS-75] proposes an architecture for a data base management system. Such a data base management system is said to handle data structures at three levels. an ANSI/SPARC type of data base system is regarded as handling and using data structures at two levels, the type level and the instance level~ In an ANSI/SPARC type of data base system however, there exist three different levels of data structures used for three different purposes. As the "levels" of an ANSI/SPARC type data base management system have different purposes it is here assumed that appropriate modeling concepts will be different for the three "levels".[8]

IV. WORKING

Three levels of data description within management system was proposed by the Report [ANS-75]. The three levels conceptual-, external- and internal level. The three levels are said to correspond to different views of the data in the data base. The conceptual level, expressed in the conceptual schema, is the enterprise's "real world" view of the data in the database. This view is shared among the various users who agree on the abstractions and classifications of real world phenomena represented by the enterprises "real world" view.[8]

Different users' will operate on different, possibly overlapping subsets of the enterprise~ real world model.

e-ISSN: 2349-9745
p-ISSN: 2393-8161



The figure above shows the 3 Schema ANSI/SPARC approach

The application programmers might want these subsets of the real world model to be structured and described in ways which are adequate to their intended operations and to the programming languages that they use. These, possibly differently structured and described, subsets or mappings of the real world model are called external schemas.

It should be noticed that the conceptual schema, in the ANSI/X3/SPARC Interim Report, is regarded as a "real and tangible item" which is proposed to exist in machine readable form.[8]

Three administrator roles have been identified, each with the responsibility of describing and maintaining the schema corresponding to their view.[8]

It is possible to identify and describe the conceptual level services that are provided, how they are physically realized in terms of the physical level services, and what external views of the conceptual services can be constructed to provide external services to the end-user. [2] Furthermore, the reference model can be used in another way by identifying the interfaces to those services. At each level a data definition language (DDL) and a data manipulation language (DML) provide an interface to the services. Different database products can be examined and the DDL and DML they provide at each of the three levels can be determined. Of course, it would be helpful if different database products implemented the same DDL and DML at each of the three levels (i.e., if they supported the same interfaces). This would ensure that applications built on those products are portable across the different implementations. In fact, there have been attempts at standardizing the interfaces, and there are different possible standards that a database may implement at each of the three levels of this reference model.

For example, the CODASYL Network Data Language (NDL) and ANSI Structured Query Language (SQL) are such standards. Both of them actually provide operations at each of the three levels, with NDL concentrating mainly on the conceptual and physical levels and SQL on the conceptual and external levels.[2]

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p-ISSN: 2393-8161

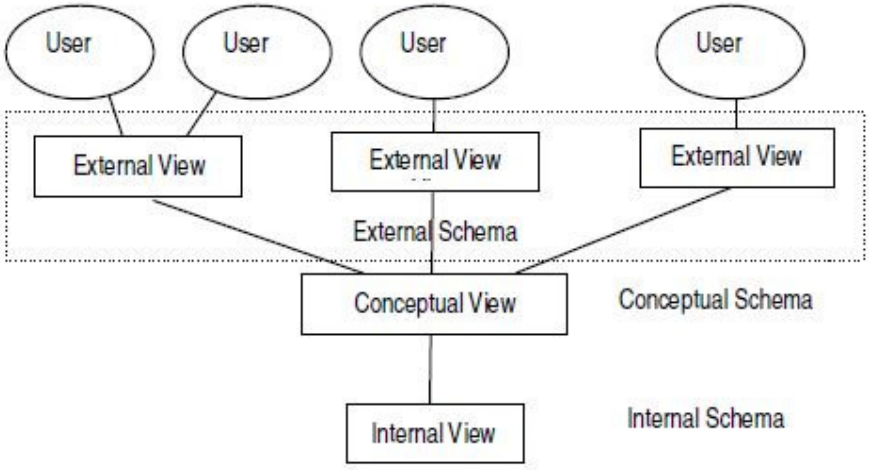
4.1. The Importance of semantic models

The separation of storage concerns from mechanisms for representing real world information found in the ANSI/ SPARC architecture and the relational model allowed a number of researchers to concentrate on so called "semantic" models. The purpose of these models was not necessarily to produce something that could be immediately implemented but rather to provide a mechanism through which the structural aspects of a real world situation could be captured. [5]

The number of people involved in the design of information systems .and of data base systems have increased. In information systems design of today, all people affected by the system being implemented should take part of and influence its design. The design level that is of most importance to influence by the non-technicians is the conceptual level. Although the responsibility of the conceptual level design may be in the hands of an "enterprise administrator" (as suggested by ANSI/SPARC) the methods and models ought to be understandable and adapted to be used by persons of different background, knowledge and interest.[8]

4.2. Explanation of the 3 levels

In the ANSI/SPARC architecture, a database can be seen at three levels, known respectively as physical, logical, and view. For each level, there is a schema: internal, conceptual, and external.



The figure above shows the ANSI/SPARC Architecture model.

4.2.1. Internal Schema

The internal schema, represents the "machine view" of the data in the data base, and describes how data is stored and accessed in the data base. [8]

The logical and the physical data access paths are defined in the internal schema of an ANSI/SPARC architecture. Logical access paths refer to aspects like partitioning and materialization, while the physical access paths define low level access structures like indexes.[15]

e-ISSN: 2349-9745
p-ISSN: 2393-8161

The internal schema describes the storage structures of the database. [12] At the internal level, the modeling concepts should be adapted to description of the way in which data are encoded, stored and accessed in the data base. [8]

4.2.2. Conceptual Schema

During the late 1970's a number of data models and intended for the conceptual level have been suggested. [8]

The "conceptual level" of a data base .system is an undefined but often used expression. In 1975 ANSI/X3/SPARC Study Group propo9ed an architecture for data base management systems. The most important aspect of this proposal was the introduction of the so called "conceptual level". [8]

The conceptual schema is a distinguished property of an ANSI/SPARC type data base management system. Independent of the data base management systems used to implement an information system, the designers will need and use an implicit or explicit conceptual data structure. When a data base management system of ANSI/SPARC type is used, the conceptual data structure is not only made explicit but also made known to and used by the data base management system in its operation.

In the ANSI/SPARC Interim Report, 1975, design of a conceptual schema was relatively summarily described as the task of the enterprise administrator to decide what entities, properties and relationships in the enterprise to represent in the data base.

In a later version [ANS-77] the task of designing a conceptual schema has approached the area of information system design.[8]

"Current data base management systems envision a two level organization: the data as seen by the system and the data as seen by the programmer. A plethora of confusing terminology has been employed to distinguish between these views. The Study Group has chosen to employ the neutral terms "internal" and "external" to make this distinction. In addition, the Study Group has taken note of the reality of a third level, which is called the "conceptual". It represents the enterprise's description of the information as modelled in the database. This description is that which is informally involved when there is a dispute between the user and the programmer over exactly what is meant by program specifications. The Study Group contends that in the data base world this description must be made explicit and in fact, made known to the data base management system. 11 [ANS-75).[8]

The conceptual schema describes the logical model of the database. [12] The ANSI/SPARC description of conceptual level data base design has the advantage of being independent of any data model used to express a conceptual data structure or any specific method for design of conceptual data structures.[8]

An ANSI/SPARC type data base system will have one conceptual data structure declared 1n the conceptual schema. The conceptual schema is used by the data base management system in its operations.

The conceptual level design is concerned with specification, determination, formal description and analysis of information to be contained in a (database) system. When data is shared between different persons and used for different purposes it is important that the meaning of the data can be precisely

e-ISSN: 2349-9745
p-ISSN: 2393-8161

described. It is important to organize the data in an economical way. At the conceptual level, economy in data organization concerns the efforts that persons involved in the information system have to spend on finding and understanding which information that is (to be) contained in the system, and with the accuracy, consistency and semantics~ integrity of the information (to be) contained in the system.[8]

One part of an ANSI/SPARC type data base management system which is not clearly defined is the mapping functions. Mapping functions exist between the external and the conceptual models as well as between the conceptual and internal models. Detailed specification of an ANSI/SPARC type data base management system will require specification of mapping functions. Research concerning these mappings will involve the conceptual level data definition. In this case, the conceptual level data definition and the mapping functions are means for acchieving data independence in a data base management system. [8]

At the conceptual level, the modeling concepts should be adapted to description of the semantics of the data stored in the data base.[8]

Analogous to the distinction between internal, external and conceptual data models and data structures there exists an internal schema, a set of external schemas and a conceptual schema in an ANSI/SPARC type data base management system.

The conceptual level is common for all the database environment, while the external level consists of particular views (subschemata) dedicated to particular client applications or particular users. In relational databases the external level is implemented by two kinds of facilities: access privileges to particular resources granted by a database administrator (DBA) to particular users, and SQL views that customize, encapsulate and restrict resources to be accessed. Such an approach has proven to be enough simple and satisfactory for majority of applications of relational databases. [10]

End-users perceive the database in terms of a set of external services. These can be different for each class of end-user. The external services are presentations of a single set of conceptual services. These provide a common basis for discussing the database at a logical level, independent of implementation considerations. Finally, the conceptual services are implemented in terms of a set of physical services. These may be specific to a particular database management system (DBMS) and/or platform.

The data model used to express the conceptual data structure need not be the same as the one(s) used to express user's views and/or information requirements.

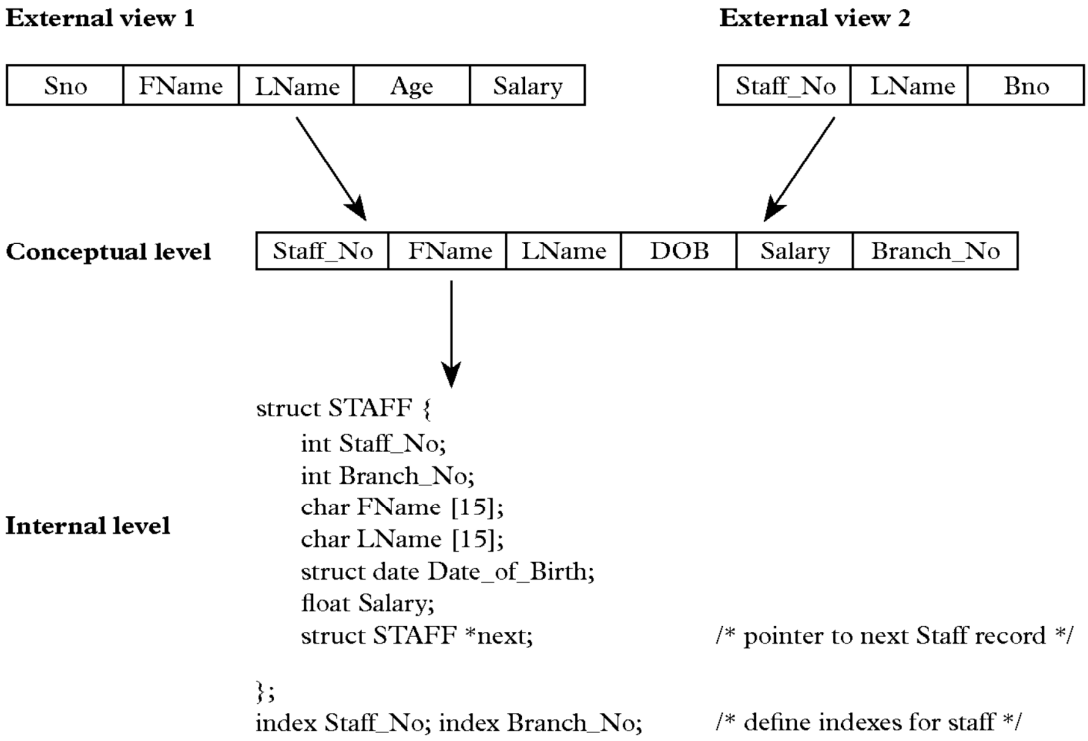
The data model must, however, support the purposes of the conceptual schema to constitute an interface between the external and internal data structures of the data base system. This indicates that the data model used for the conceptual schema must be suitable for the definitions of external-conceptual and conceptual-internal mappings.[8]

4.2.3. External Schema

The external schema in the ANSI/SPARC architecture comprises user-defined data views, which can be seen as virtual tables storing the results of specific queries. A view can comprise attributes of multiple tables as well as pre-defined aggregations or calculation results.[15]

e-ISSN: 2349-9745
p-ISSN: 2393-8161

External schemas describe different views of a database for particular users or groups of users, providing features such as logic independence, authorization, and integration of heterogeneous databases [Scholl91, Bertino92, Motschnig96].[12] At the external level, the modeling concepts have to be adapted to the various programming and query languages that are to be used in manipulation of the data base. [8]



The figure above shows the working of the 3 level ANSI/SPARC database management systems.

4.3. Implementations of ANSI/SPARC architecture

The WCRC architecture for a data base machine is one hardware version of the ANSI/X3/SPARC architecture or the coexistence model. It has an external level, a conceptual level, and an internal level. It can handle queries from several users simultaneously. It can support the three major data models-network, relational, and hierarchical-simultaneously on the same data at the internal level and may be used as a back-end to a host computer or as an independent data base computer for nonnumeric processing. [11]

Another example is the HCWS architecture.

The HCWS had a three-layer architecture consistent with the ANSI/SPARC standard [Brodie and Schmidt, 1982]: a user-interface layer, a functionality layer with the system's different functional modules (e.g., a booking module), and a data-model layer consisting of a generic clinical framework. The three layers also represented three different vendor units. The user-interface layer was used by the configurators to build the user interface for the specific customer. The functionality layer served

e-ISSN: 2349-9745
p-ISSN: 2393-8161

multiple healthcare customers and was maintained by a separate developer group. The data-model layer was maintained by a third developer group and served as a generic development tool potentially for all the vendor's healthcare customers.[13]

There are many more architectures which have been derived from the ANSI/SPARC reference model. These are designed to suit the specific domain of applications.

V. CONCLUSION

We have studied the ANSI/SPARC architecture in detail. We have seen the various schemas and how they function. Although the ANSI/SPARC architecture is not used nowadays we can observe how it has affected the successive architectural models. Many different changes can be made to the ANSI/SPARC architecture to suit a specific application domain. e.g. Healthcare, forensics, meteorology and weather stations, businesses etc.

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