Knowledge Based System and Database Management System: An Integrative Framework

G. Premkumar
Iowa State University

Knowledge based management systems have gained significant importance in the last few years, primarily from the enhanced capabilities achieved through integration of the two technologies - artificial intelligence and database management systems. This paper develops a framework for integrating the two technologies. The three dimensional framework links the various knowledge representation schemes with the data models used in databases and the architectures used for linking the knowledge base with the database system. This framework facilitates in communicating the latest developments in the field of knowledge based management systems and also aids the designer in making the appropriate choice from the various options available within the two technologies.

The research systems in the field are mapped onto the framework. An analysis of the mapping reveals that some research areas are more popular than others. Rule-based knowledge representation with loose coupling to relational databases are found to be popular for integrating the two systems. Integrated solutions with object-oriented formalisms are also becoming common in recent years.

Potential areas for future research are identified. Also, the implications of the research for the practitioner and the strategies for commercial exploitation of KBMS are discussed.

The integration of artificial intelligence (AI) and database technologies has become an important stream of research in the two fields (Brodie & Mylopoulos, 1986; Kerschberg, 1986). A new class of information systems, capable of powerful and efficient knowledge based processing, called Knowledge Based Management System (KBMS) has become popular as a result of merger of these two technologies. KBMS is a system providing highly effective management of large shared knowledge bases for knowledge directed systems (Brodie, 1986).

A major reason for the integration of these two technologies is the realization that these are complementary technologies with the potential for enhancing the capabilities of AI systems with database features, and database management systems (DBMS) with learning and other features found in AI systems. On the database side, the ability to provide functionality in information systems using deductive, inductive and plausible reasoning, knowledge representation, heuristic search, knowledge validation and refinement provides opportunities to extend the scope and use of database management systems. On the AI side, the use of database features such as query optimization, concurrency, integrity constraints, data security, and error recovery, provide the facility to efficiently store and use the knowledge that is required for AI systems.

There have been criticisms in recent times of the failure of knowledge based systems (KBS)/expert systems delivering their promised potential and the slow growth in the use of these systems in actual practice. “Are these systems merely an intellectual exercise for the academic community with only marginal utility value for practitioners?” has been a major question facing the practitioner. Although many system shells and software are available in the market, users are yet to use these in a significant way in their...
IS applications. The reasons for these are slowly emerging. Most expert systems require rules (or a knowledge base) and facts (or a database) to be integrated to make an application useful in real-world. Success in the use of expert systems is hinged on effectively linking the KBS with the firm’s DBMS, that provides the “facts” component of the system and which is already existing in the organization. It is only recently that major efforts are focused on this integration, both in research and in practice. This paper proposes a framework for integrating the two technologies, DBMS and AI, and identifies the present status, problems, research issues, and future growth directions for this area.

Need for Integration

A major reason for the integration of KBS and DBMS is the significant enhancements brought to the individual subsystems by utilizing some of the features of one in the other. A brief description of the enhancements are discussed below.

DBMS Enhancement

Knowledge based systems can enhance the capabilities of the DBMS by providing:

a) Intelligent interface to database,
b) Natural language interface to database,
c) Query optimization,
d) Database maintenance, and
e) Data model development.

Intelligent interface to DBMS typically involves providing reasoning capabilities in query processing, and higher level query languages that allow for more powerful and complex operations with minimal programming skills. These interfaces basically simplify and improve the user interface to DBMS.

The natural language interface typically contains a reasoning front-end that accepts queries in natural language dialect, maps the query into a logical form, performs deduction, and then interacts with the DBMS to retrieve the information. KM-I (Kellogg, 1982) is a typical example of a natural language interface which uses an English-like dialect to interact with a front end AI machine that transforms the query and then retrieves the information from a relational database.

Query optimization using deductive reasoning (Reiter, 1978; Grishman, 1978), optimization of multiple queries and minimizing disk access, development of efficient access routes using historical data (Grant & Minker, 1981), improvement of response time for simple and repetitive queries by using an abstract of the database (Rowe, 1983) are but few of the uses of AI methods for efficient query processing.

Data maintenance operations such as integrity checking and data consistency maintenance can be supported using a knowledge based system. A rule based AI system (Goldstein & Bobrow, 1980) or a deductive logic based system (Nicolos and Yazdanian, 1978) is frequently used for checking and maintaining data integrity in the database. Another useful feature is the monitoring of temporal conditions in a database and taking appropriate actions such as updating the database or generating reports for users, whenever conditions are satisfied. Stonebraker (1982) describes a rule based system (RAISIN) which has some of these features incorporated in the query processing component of a relational DBMS.

The need to integrate the two systems has resulted in significant progress in the development of new data models that can capture the richness of knowledge representation required in AI systems. The limitations of the relational model have led to the development of the semantic data model (Hammer & McLeod, 1981; King & McLeod, 1985), functional data model (Shipman, 1981), and object oriented data model (Copeland & Maier, 1984). These models capture the information richness of the real-world, and thereby provide a better representation of the real world.

Enhancement of Knowledge Based Systems

A simple knowledge based system stores most of the relevant data in main memory while processing its applications. However, as these systems grow in size and the expertise domain expands, it becomes necessary to store the data in a secondary storage such as an external DBMS. The facilities provided by the DBMS in terms of data management, concurrent access, and query optimization provide robustness for the KBS to handle large volumes of knowledge. Also, this provides flexibility for the KBS to access a central DBMS that is used for other applications in the organization. Steinberg (1990) describes an expert system in American Express that provides credit authorization by using a corporate customer database that is used for various other applications.

Deductive databases with enhancements to access an external device are common examples of extension of KBS capabilities using the DBMS features. Parsaye (1983) discusses the use of database concepts such as schemas, functional dependencies, integrity constraints etc., in a Prolog based system. Carey, Dewitt, and Graefe (1986) discuss the use of concurrency control and error recovery mechanism for a Prolog based system, using a two-phase locking concept, that is very similar to mechanisms used in DBMS. STROBE (Lafue & Smith, 1986) is a knowledge based system where the database concepts of semantic integrity checking, and file management are integrated into an object oriented environment. Dahl (1982), and Lafue (1983) also provide examples of KBS where the capabilities have been enhanced using DBMS concepts.
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