The IDC Story: The First Successful AI Based Multi-Expert System In Arizona

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Industrial Design Corporation, Tempe, Arizona, a division of CH2M Hill Engineering Corporation, Portland, Oregon made the decision to invest in an expert system to help manage the need for human engineers against the dynamics of customer expectations and orders. IDC saw this as an approach to maintain the highest level of senior engineering. As winners of the Malcolm Baldrige National Quality Award, they embraced the founder's core values of integrity and ingenuity. They sincerely believe that good people, inspired and empowered with the proper environment and tools, would make every effort to exceed their client's requirements.

These reasons together with an ERP (Enterprise Resource Plan) initiative to integrate all engineering disciplines and sciences, IDC selected a multi-expert system generator. Within ninety days they had installed an AI based computer system that enabled IDC senior engineers to transfer much of their knowledge for arriving at solutions for particular customer specifications, to the computer system.

Rose Navigator

The Rose web site Navigator page (see Figure 1) illustrates the resulting knowledge groupings from the knowledge normalization process.

The IDC expert system, named Rose after the multi-expert system generator module called Rosetta-Stone, is a web based access portal to the knowledge domains of IDC's senior engineers. This system offered IDC the ability to:

1. Save the accumulative learned knowledge of all its managers and engineers, and through attrition increases the effect work force capability without increasing the staff.

2. The management team has access to real world, real-time processes and procedural management controls. This includes controls for the following business disciplines: ERP; charters, processes, procedures and job descriptions reengineering; project management and IT application and systems.

3. The company's business operation and engineering knowledge is saved, protected and available to all authorized employees.

4. Junior managers and engineers ask business operations and engineering questions, as though they were speaking with a senior manager or engineer, to make senior level decisions.

5. Senior managers and engineers can teach Rose the knowledge they use to make new business and engineering decisions.

6. The technology employed designs, constructs, programs and deploys a working knowledge-based Information Management system for: Business Continuity, Business Impact Analysis and Disaster Management.

7. The technology assists with the following issues:
a. Due to the cyclical nature of the semiconductor industry, IDC must hire and layoff engineers, forcing IDC to continually search for new talent.

b. The uniqueness of the skills required is compounded by the varying engineering disciplines and sciences involved in a single customer order.

c. IDC management has a strong ERP strategic direction that includes the automation and retrieval of the rules by which their business is conducted.

System Development

During Rose design, the IDC management team needed a common understanding of the goals for Rose and what its capabilities would be when completed. They also wanted to understand how to make Rose a part of their business planning process.

Analytical thinking requires the ability to compose business issues into logical and functional models that correctly reflect business processing, coupled with the skill to communicate the results to all levels of an organization.

As a technology tool to assist the IDC management team with analytical thinking, the team decided that Rose would be thought of as a full time employee available to all employees for explaining particular business activities and how they are performed. When addressing the issues of integrating Rose with business planning activities, the view of Rose as a new employee made it easy to establish the relationship between it and every aspect of operational procedures. For instance, Rose was included as a member for every project team. Rose attended all meetings dealing with business planning issues because of its knowledge of the business operational activities involved.

"Analytical thinking requires the ability to compose business issues into logical and functional models that correctly reflect business processing, coupled with the skill to communicate the results to all levels of an organization"

There are many descriptions given to expert systems - many view this technology as a learning and teaching tool. In this case, Rose is a reference library for employees to teach, learn and manage the manner in which IDC conducts business.

Return on Investment (ROI)

Whatever view of an expert system is used, the return on investment from this technology begins immediately. As knowledge engineering is applied to describing how the business is conducted, a better understanding of the business is obtained. Knowledge engineering seeks to identify, re-engineer, codify and teach business knowledge to an expert system. The processes of, engineering knowledge is very similar to that of Data Engineering; in that each contains a methodology together with techniques and tools that normalize elements into either a relational knowledge base or relational database.

A multi-expert system generator contains the methodology for normalizing knowledge (from any source: business management rules, scientific rules, engineering rules, etc.) into knowledge

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Figure 1: The ROSE web site NAVIGATOR page.

Multi-Expert System Generators: Solving the Mystery of Normalizing Knowledge

In the mid-1980s', Teknowledge Corporation, a seed company of Stanford University, Palo Alto, California, filed the first United States Patents for single-expert system generation. The following patent titles described a methodology; techniques and tools for the generation of a single-Expert system.

Patent ID	Patent Title
4,648,044	Basic Expert System Tool. (June 6, 1984)
4,658,370	Knowledge Engineering Tool. (June 7, 1984)
4,783,752	Knowledge Based Processor for Application Programs using conventional Data Processing Capabilities. (1986). 1983, Mr. Frank Burt
4,595,982	Expert System and Method for Making Decisions in Accordance with the Decisions of a Mentor.1986, I.B.M. Corporation
4,763,277	Method for Obtaining Information in an Expert System.1986, Neuros Data, Incorporated, Palo Alto, California
4,752,889	Dynamic, Interactive Display System for a Knowledge Base.

Also in the mid-1980s', the Jet Propulsion Labs, Pasadena, California, under the design direction of Dr. Steven Vere, designed a multi-expert system generator to manage the mission of the spacecraft Voyager. The name of the multi-expert system was DEVISER III.

Deviser III: An AI Planner for Spacecraft Operations.

Abstract

Within the field of artificial intelligence, a "planner" is a type of knowledge-based system that generates a sequence of actions to achieve specified goals. DEVISER III is a general-purpose automatic planner prototype developed at JPL to plan and schedule onboard action sequences for planetary spacecraft such as Voyager.

The difference between these two events is the methodologies that were formulated to "Normalize Knowledge".

The single-expert system generator methodology models knowledge to satisfy the requirements of teaching a computer the knowledge of a single *Subject Matter Expert (SME)*, then seeks to identify relationships between SMEs'.

The multi-expert system generator methodology models knowledge to satisfy the requirements of teaching a computer the knowledge of many different Subject Matter Experts, then seeks to manage the relationships between SMEs'.

The single-expert system generator methodology became the foundation for the development of application software products that help business enterprise manage knowledge. Examples such as

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Multi-Expert System Generators: Solving the Mystery of Normalizing Knowledge (Continued)

SAP, SAS, IEF, ORACLE, SYBASE, PeopleSoft, Microsoft Office, Microstrategy, AION and others demonstrate both the need for Knowledge management as well as the software industry's success at applying the principles of single-expert system generation to enterprise knowledge management.

The multi-expert system generator methodology views the expression of knowledge as the spoken language used to communicate knowledge, and begins the process of knowledge normalization by expressing a knowledge element as a *grammatical sentence*. 5th generation programming languages such as: LIPS1 (Logical Instructions Per Sentence) and LIPS2 (Logical Inferences Per Sentence) continue the normalization process to a web access portal and Knowledge Base.

The difference between methodologies in single versus multi-expert system generators are dramatic in the manner by which users communicate with the system in conversational English.

Knowledge Base Architectural Design

A multi-expert knowledge base is structured to organize knowledge that is expressed in English grammatical sentences. To accomplish this requires an understanding of the concept for the construction and association of sentences and how to project the derived patterns of logic onto a dimensional matrix. A simple view of this formulae, is dividing all knowledge into primary domains, under which all knowledge is grouped and normalized.

An example of this structure is in the product CAMBO, a multi-expert system generator, in which all knowledge is divided into four primary domains. Each primary domain divides knowledge into the first level of knowledge normalization. Each domain contains grammatical sentences organized into rule sets that combine into conversational English.

The function of the knowledge base architecture is to create and support a unique view of "warehousing" knowledge elements as memory cells connected by a dendrite type system of ontological relationships.

Access portals to a multi-expert system knowledge base are layered through a Search engine, an Inference engine and a RDB engine.

Summary

This introduction to multi-expert system generation demonstrates the next level of computer intelligence as a normalized knowledge interchange between human inquiry and computer response. The concepts expressed are from real world examples of the scientific and practical application of a multi-expert system generator.

The Holy Grail of AI is to instill a computer with wisdom, derived from human intelligence, expressed in knowledge about the manner in which the world around us operates.

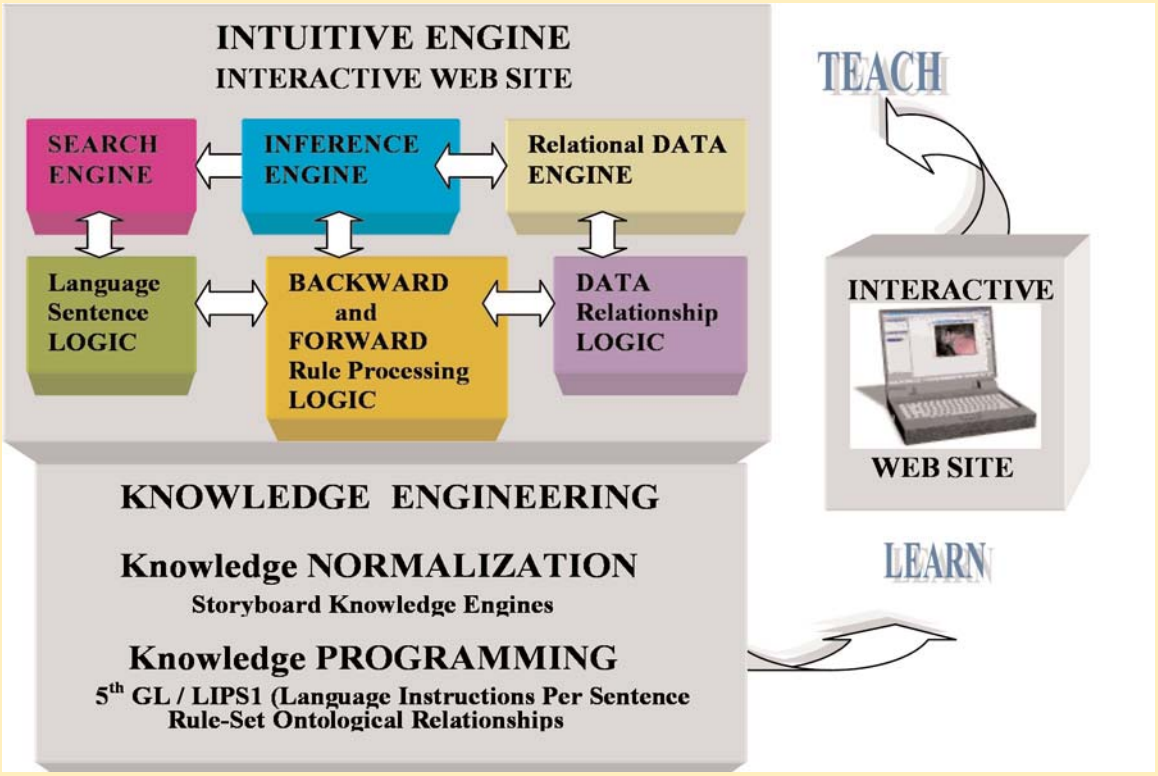

Figure 2: This knowledge engineering model examines a structured approach to organizing the ERP processing modules.

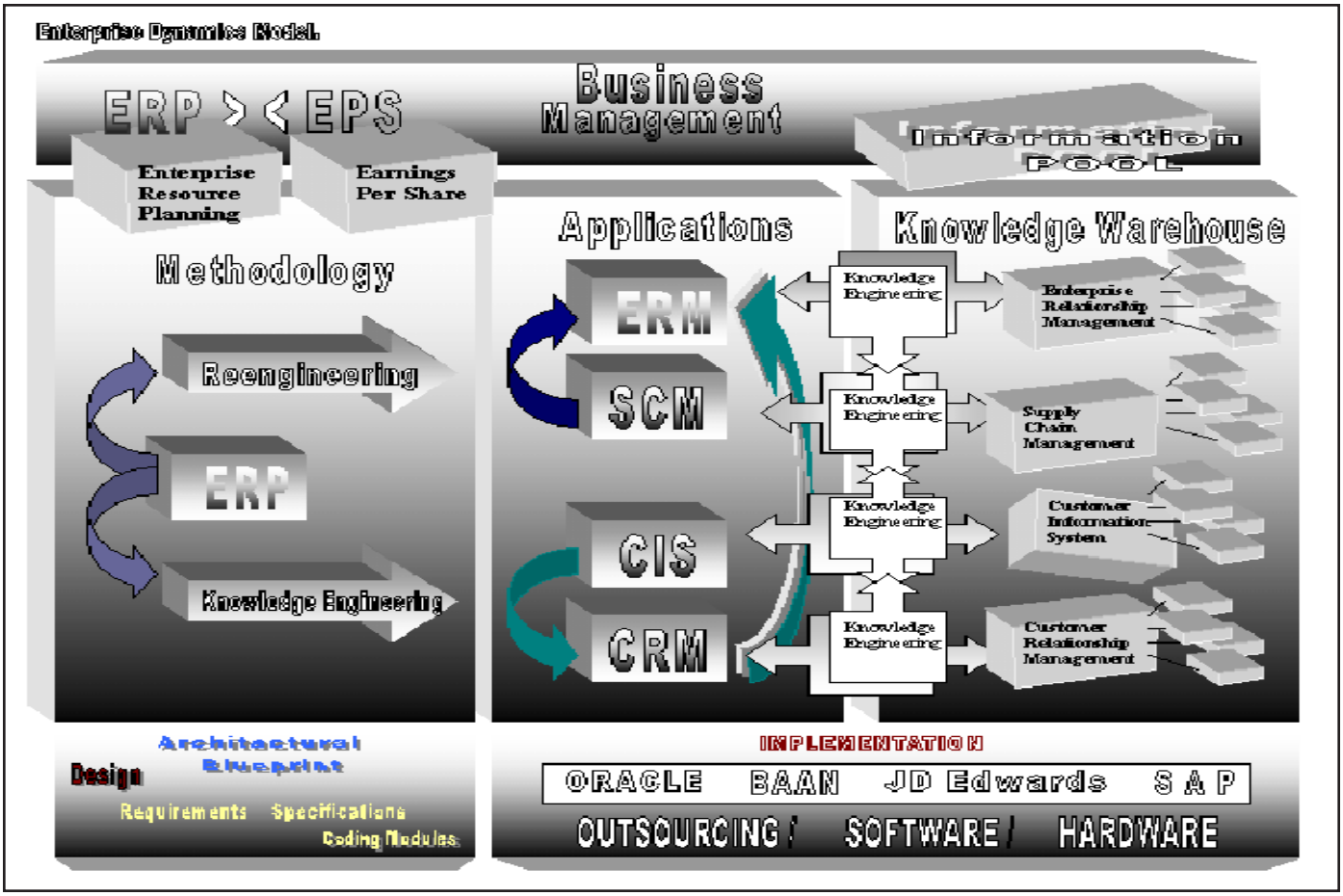

Figure 3: This knowledge engineering model examines a structured approach to organizing the ERP processing modules.

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domains. Historically we rely on methodologies such as: canonical synthesis, entity relationship, etc. to perform a heuristic approach to normalizing data elements into relationships where they are projected onto a database. Knowledge normalization performs this same function to normalize knowledge elements and project them onto a knowledge base.

The following excerpts from Wikipedia (*www.wikipedia.org*), the free encyclopedia represent the most widely accepted methodology for the normalization of Data Elements. Those readers unfamiliar with the discipline of normalizing data elements are advised to review the methodology described.

Data Normalization

A table in a relational database is in a certain normal form if it satisfies certain constraints. Edgar F. Codd's (*www.wikipedia.org/wiki/Edgar_F._Codd*) original work defined three such forms but there are now other generally accepted normal forms for which we offer a short overview of the most common ones. Each normal form represents a stronger condition than the previous one (in the order below). For most practical purposes, databases are considered normalized if they adhere to *Third Normal Form*.

First Normal Form (or 1NF) requires that all column values in a table are atomic (e.g., a number is an atomic value, while a list or a set is not). For example, normalization eliminates repeating groups by placing each into a separate table and connecting them with a primary key-foreign key relationship.

Second Normal Form (or 2NF) requires that there are no non-trivial functional dependencies of a non-key attribute on part of a candidate key.

Third Normal Form (or 3NF) requires that there are no non-trivial functional dependencies for non-key attributes on anything else other than a superset of a candidate key.

Boyce-Codd Normal Form (or BCNF) requires that there are no non-trival functional dependencies of attributes on anything other than a superset of a candidate key. At this stage, all attributes are dependent on a key, a whole key and nothing but a key (excluding trivial dependencies, such as A->A).

Fourth Normal Form (or 4NF) requires that there are no non-trivial multi-valued dependencies of attribute sets on anything other than a superset of a candidate key.

Fifth Normal Form (or 5NF or PJ/NF) requires that there are no non-trivial join dependencies that do not follow from the key constraints.

Domain-Key Normal Form (or DK/NF) requires that all constraints follow from then domain and the key constraints.

Knowledge Normalization

Knowledge engineering, which includes methodologies, techniques and tools, produces knowledge models for populating a storyboard layout for the design of a multi-expert system. Each knowledge engineering model is a particular life cycle view of activity and it models the functionality of a knowledge engine that drives the events within the life cycle. These models identify, capture, profile and relate the language of the enterprise for which the multi-expert system supports.

In this particular knowledge engineering model the relationship between the business practices of IDC Corporation and the functionality of an ERP methodology were examined and this information contributed toward the knowledge normalization process. (see figure 2).

The methodology for knowledge normalization expresses a knowledge element as an English grammatical sentence. Knowledge engineering codifies the business, science and engineering knowledge into its most basic form, the English Grammatical Sentence (EGS). Each EGS is grouped into rule-sets that become part of a knowledge domain and because the knowledge normalization process establishes cross-domain relationships, the knowledge of many disciplines unites to answer questions.

The procedure for asking questions is a simple, intuitive and interactive web based menu system that leads the user through a question and answer cycle - including a cross discipline review of the issues leading to a final answer. It responds as though the questions were asked of numerous engineers or business managers, in different disciplines, all contributing their knowledge towards identifying and answering issues on a specific business or engineering requirement.

However, while the methodology for data normalization remains as a standard for developing a relational data base, the processes described are integrated with the processes for knowledge normalization. Data element: definitions, profiles, format, relationships, where-used and ontological associations all derive from the process of knowledge normalization.

"The methodology for knowledge normalization expresses a knowledge element as an English grammatical sentence. Knowledge engineering codifies the business, science and engineering knowledge into its most basic form"

The status or condition of any individual data element is the result of a computer program, executing a series of knowledge elements. Knowledge elements contain the logic by which data elements are created and manipulated.

Knowledge engineering is used to front end the data methodologies for: ORACLE, SYBASE, DB2, FoxPro, SAS, SAP, IEF, Microstrategy and all application generating software.

The IDC Rose example is the first successful business application using an AI based, multi-expert system in the State of Arizona, and as more companies understand and appreciate the benefits of applying this technology to their business operations, Arizona could become a leader in the frontier of AI technology.

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