Symmetry of STRUCTURE

an interdisciplinary Symposium

Abstracts

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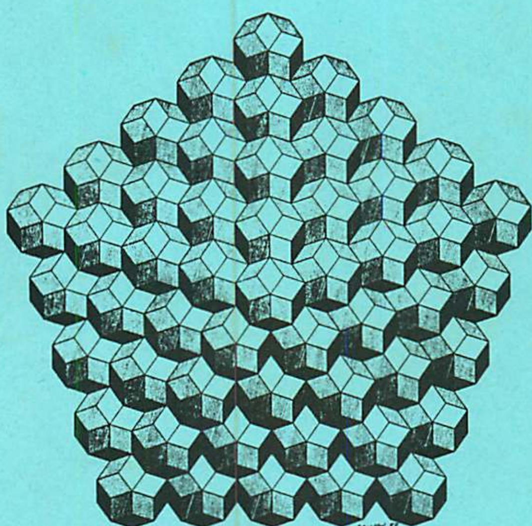

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GENERIC KNOWLEDGE REPRESENTATION AND FUSION USING SYMMETRY IN METASTRUCTURES

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New insights into morphological properties of higher spaces (principally symmetry) are employed to create a knowledge representation environment of substantial capability. This environment implicitly provides an underlying methodology for indexing, data structuring, and generic conceptual modeling. An explicit common grammar, expressible in Ada, has been devised to support cooperative, integrated application systems. A general model for universal data and knowledge modeling and expression results. This general model can form the basis for a global enterprise framework for information systems in support of interdisciplinary design, manufacturing and support of complex systems.

BACKGROUND: This research relates to, and combines innovations from three technical areas which occasionally overlap: morphology (the science of form and symmetry as a basis for structured relationships); knowledge representation (the science of understanding and recording information for directed, automated manipulation); and the areas of conventional computer science which deal with data/ information modeling, and associated specialized languages.

The primary application of the research is to allow the creation of languages and modeling systems for the communication of information. Advanced morphology can be employed to enable robust, generic modeling, processing and communication. The results of the research are the subject of both patent activity and policy considerations by the US Defense Advanced Research Projects Agency.

The common unifying element which underlies the research is the concept of grammatic principles which directly result from morphological primitives in symmetry spaces. This forms the basis of a conceptual modeling approach for knowledge representation which can be expressed in a large class of ordered special purpose application languages, primarily using Ada. These models and languages are related by use of the grammatical foundations and common abstract data type vocabularies.

DISCUSSION OF THE BACKGROUND: A commonly discussed problem in computer science concerns the need for knowledge representation technology which is at once applicable to more generic application domains and advanced reasoning techniques, while simultaneously integrating the increasingly diverse and sophisticated data, process, product and index modeling technologies coming into use.

More specifically, the general field of artificial intelligence and its collected sciences of "conceptual modeling" have been identified in technical literature as the single greatest limit to progress for advanced computer applications. Consequently, a great deal of attention has been given the problem in the past decade, largely under government funding for research primarily performed by universities. Two broad approaches have resulted.

A first group of investigators has produced a large number of interim, special purpose approaches to the problem. These intermediate approaches each have applicability in specialized domains or applications, and are optimized for specific processing by special purpose programs which have formed the basis of a viable market in artificial intelligence. In general, these approaches combine logical calculii, semantic association models and networks, with specific chunking rules to produce "frames", "cases", and "scripts". Elements of these special approaches have been patented or otherwise protected, but are widely used in applications.

A second community of investigators has been studying the nature of the limits of these interim approaches which, by themselves, do not appear to be extensible to more general, broadly applicable uses. At the same time, other stronger, competitive trends in specific computer applications are increasing the distance among fundamental approaches of the artificial intelligence, programming language, and database communities. This branch of investigation has, however, resulted in an understanding of the nature of the requirements for high level unifying principles. The literature now includes a generalized statement of need for the underlying principles, and a vocabulary of terms to describe the open issues.

In general, the problems can be described in terms of underlying, common grammars which provide the generating foundation for characterizing and relating knowledge elements, and accessing and manipulating these elements and their structured combinations. Currently, it appears that if the grammar is sufficiently complex to describe special cases and qualifiers common to everyday knowledge, they become computationally large, ambiguous and inefficient. On the other hand, compact, ordered special purpose grammars are not sufficiently fundamental for broad applicability.

One useful technique for relating special purpose grammars has been the creation of meta-grammars, or grammars which abstract information from lower level, more application specific modeling and representation approaches. But as the levels of abstraction increase, a similarly cumbersome superstructure of qualifiers and singularities increases which chokes the process.

Compelling mathematical arguments have been made to suggest that the complexity of the representation information grows in "size" faster than the information being represented, if existing approaches to fundamental grammars are employed. The general problem is analogous to the search for a grand unified theory in physics, which can be used to express or predict any physical phenomenon. In fact, the understanding of what such a "metaphysical" approach would necessarily entail for a grand unified theory is similar to the projected requirements for a grand unifying grammar for generic knowledge representation.

In both cases, there is a predicted reliance on the most fundamental operations of the phenomenological world, expressed best by simple symmetries, and other primitive relationships which are found in morphological studies. A fundamental grammar for advanced conceptual modeling devised from morphological research must be orthogonal, that is complete within the target universe while each of the other primitive elements is independent. The grammar must itself be simple, but capable of directly expressing complex relationships. This principle allows the representation information to grow less fast in "size" than the information being represented. It also must be applicable, without modification, at arbitrary levels of abstraction. The grammar must be capable of modeling itself an unlimited number of times using the same methodology and tools as for external modeling.

Finally, as a practical concern, the grammar must be easily and unambiguously expressed using abstract data types which can be effectively manipulated by software engineering methodologies (such as those related to Ada) and practices coming into widespread use. An example is the "object oriented" methodology.

The need exists for a novel approach to understanding the underlying morphological principles at work (ie "metamorphology"), extracting the appropriate grammatical primitives to form a complete, succinct, orthogonal modeling environment, and providing a broad approach to applying this in common computer and communication environments, as a basis for "MetaSystems".

FIRST AREA OF INNOVATION: MORPHOLOGY (This section describes the morphological principles involved and the innovative primary morphological concepts claimed, both in pure morphology, and in the knowledge representation context. The contribution of H. Lalvani is emphasized. Structural Fundamentals of N-Dimensional Metasystems; Fundamental Regions as Lower Dimensional Structural Primitives; Polygonal and Polyhedral Generation to Cluster Primitives; Affine, Polyhedral, and Nonperiodic Pattern Generation; Periodic/Nonperiodic Space Fillings as Lattices; Infinite Polyhedral Lattice Symmetries; and Intersymmetry Saddle Lattices/Labyrinths; are briefly viewed as foundations for the

MetaStructure of symmetry.)

KNOWLEDGE SYMMETRY PRIMITIVES: The existence of symmetry operators which are both comprehensive and fundamentally atomic is of profound significance for conceptual and modeling grammars. Recent mappings of cognitive grammars to morphological primitives provides an enabling basis for conceptual modeling when given the results of advanced morphological discoveries. In this context, semantic networks of great conceptual density can be sustained. These networks are of substantially greater complexity and generic applicability than those networks generatable by conventional LISP, or similar, unstructured facilities.

A grammar results from this application of morphological primitives to describe network or framework relationships among existing knowledge representation schemes, allowing a number of innovative developments in metastructures, the subject of the present research. Specific results dealing with underlying morphological principles of MetaSystems, and which are to be discussed in the lecture include:

The MetaSystems concept which assigns morphological structures to elements of a metastructure as an ordered way of describing and exploring classification and generation of structures; The application of the MetaSystems concept to relate components of differing symmetry class, intermediate symmetries, and "trans"-symmetries; the application of the MetaSystems concept in extending to higher dimensions and projecting into lower dimensions; and the codification, in the MetaSystems context, of the decomposed elements of the structures, fundamental cells, regions and primitives.

Specific results dealing with utilization in the context of conceptual modeling include the following: The specification of a set of grammatical primitives which are at once orthogonal in the large application domain and applicable to efficient execution on a wide range of computer architectures as basis for an instruction set architecture; the mapping of this grammar to generalized semantic networks, metanetworks, and the operations and manipulations of those networks in the knowledge representation environment; an annotation of Ada, to "extend" the language to allow direct manipulation of the network/metanetworks in the programming environment; The combination of these elements as a conceptual modeling methodology, covering traditional bounds of complexity found in the artificial intelligence and data engineering domains; and a detailed mapping of the elements of the conceptual modeling methodology (via the grammar) to the continuing discoveries in abstract metamorphological research, which allows for discovery of additional classification schemes and representational innovation.

CANDIDATE SCHEMA: The candidate lattice schema as a basis for advanced conceptual modeling and very high level language grammars can employ a lattice as complex as the 3 hyper-schwarz types (infinite polyhedral labyrinth) described previously, because of the well developed integration of symmetries among the lattice and their lower dimensional articulations, minimal surfaces. The minimal surface operators of the hyper-schwarz surfaces themselves closely follow established computational trends in abstraction methods. Reflexive algorithms which reflect the ambidimensional transpolyhedra symmetry are a distinct possibility. Provisions for the representation of "doubt" by fractal resolution of the multiscale lattice can follow.

The resulting could appropriately be termed an Ada/Lattice Integrated Conceptual Environment (A/LICE). Features of A/LICE include: The relational function set is extended into an operator language of high level primitives, the language having a base logic (of some undetermined and flexible order). A transportable, underlying abstraction grammar which has a direct mapping to the network lattice transforms exists, and can be supported using the same facilities as the "application" features. These transforms have topological equivalences, a unique and interesting feature which allows the rules of operation among the fabric of abstraction layers to be ambiguous when mapping "up", but precise when mapping "down", or out of abstracted spaces. The grammar must be conceived with sensitivity to a number of related disciplines, described by Goranson in research and planning reports for the Defense Advanced Research Projects Agency.

The morphological equivalence across the various views also allows resolution at the machine level into a few simple operations (including as a subset, analog photonic operators). This is of interest for high speed, concurrent (artificially intelligent) processing in Ada on traditional and advanced parallel and optical environments in mixed mode. Having established a metalanguage with a corresponding metanet formal methodology for morphologically rigorous models and languages, the software engineering tool community will be faced with exciting possibilities. Because of the generic nature of the technology, knowledge of any kind can be "fused" and managed by simple procedures if the source calculus is known. These techniques can be used to support national distributed knowledge bases of heterogeneous origin, medium or domain, providing a flexible unifier for information modeling and a semantic unifier for abstraction grammars.

A PRIMITIVE GRAMMAR AND INSTRUCTION SET ARCHITECTURE: (This section describes the specification of a set of grammatical primitives which are at once orthogonal in the large application space and applicable to efficient execution on a wide range of computer architectures as an instruction set architecture.)

SEMANTIC NETWORK INSTANTIATIONS, LATTICES: (This section describes the mapping of the grammar to generalized semantic networks, metanetworks, and the operations and manipulations of those networks in the knowledge representation environment.)

THE ADA/LATTICE ANNOTATION: (This section describes an annotation of Ada, to "extend" the language to allow direct manipulation of the network/ metanetworks within the programming environment. Issues revolve around duplicating the special intimacy the LISP language has with LISP environments. A facility for "tagging" objects within validatable Ada is described.)

THE ADA/LATTICE INTEGRATED CONCEPTUAL ENVIRONMENT (A/LICE): (This section describes the prototype combination of all of the elements as a fully instantiated conceptual modeling methodology, covering a level of complexity beyond that normally found in the artificial intelligence and data engineering domains.)

IMPLEMENTATION COMPONENTS OF THE TECHNOLOGY: (This section describes the components in an implemented environment. Components in Data Modeling; Index Modeling; Product Modeling; Process Modeling; Horizontal Abstraction Facility; Vertical Abstraction Facility; Constraint Management Facility; and Administrative History Management Facility are discussed.)

IMPLEMENTATION COMPONENTS RELATED TO INTERNATIONAL STANDARDS: (This section decsribes the components of an environment as they are represented in international standards of interest. Components in User/Display Standards; Physical Data Standards; Programming Language Standards; Communication Standards; Operating System Standards; Database/Query Standards; File/Transfer Standards; and Information Modeling Approaches are discussed.)

OTHER APPLICATIONS: (This section describes some of the related research currently sponsored in the United States, which are to be affected by the national framework reference model. Efforts in Neural Nets; Aero and Hydrodynamic Design; Software Engineering Tools; Optical Computer Instruction Sets; and Architectural Design and Engineering are discussed.)