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Peter P. Chen   Leah Y. Wong (Eds.)

Active Conceptual Modeling of Learning

Next Generation Learning-Base System Development

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Volume Editors

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Preface

This volume contains a collection of the papers presented during the 1st International ACM-L Workshop, which was held on November 8, 2006 during the 25th International Conference on Conceptual Modeling, ER 2006, held November 6–9, 2006, in Tucson, Arizona, plus several invited papers. From 26 papers submitted to the workshop, a total of 11 papers were selected for inclusion in this volume. These papers plus the invited papers represent the current thinking in conceptual modeling research.

To achieve the ACM-L goals, we need the participation of many research groups with different skill sets. The active model can only be realized through technology integration (e.g., AI, software engineering, information technology, cognitive science, art and sciences, philosophy, etc.) and by combining related modeling techniques. The current state of the art in conceptual modeling can be used as the starting point. Modeling techniques will need to be combined to model different characteristics of the world (e.g., temporal, multimedia, spatial, cognitive, philosophical, historical, etc.) in a holistic and visualized manner.

One of the suggested action items of the workshop participants was to have more workshops and working sessions on this topic. The first International ACM-L Workshop was organized to follow on from a smaller workshop on the same subject held several months earlier. This volume includes the paper presentations, panel discussions, research findings, and future directions. The organization of the workshop involved many colleagues and valuable contributions from a number of persons. We would like to thank the ER 2006 Conference Co-chair, Sudha Ram (University of Arizona, USA) and Mohan R. Tanniru (University of Arizona, USA), the Workshop and Tutorial Chair, John Roddick (Flinders University, Australia), Publicity Chair and Webmaster, Huimin Zhao (University of Wisconsin, Milwaukee, USA), and Local Arrangements and Registration, Anji Siegel (University of Arizona, USA) for their support. We would like to especially express our thanks to members of the Program Committee, external referees, and workshop session chairs, who contributed to the success of the workshop. We also would like to thank Arthur Shr of LSU, who directed a group of student helpers to assist in editing this volume.

November 2006

P.P. Chen
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Proceedings of Active Conceptual Modeling-Learning (ACM-L) Workshop, November 8, 2006, Tucson, Arizona, USA

Invited Paper

Overview of Papers in 2006 Active Conceptual Modeling of Learning (ACM-L) Workshop

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Abstract. This is a summary of the papers presented at the Active Conceptual Modeling of Learning (ACM-L) Workshop, November 8, 2006, Tucson, Arizona, USA, and several invited papers.

1 Introduction

As a result of the call for papers, the Program Committee received 26 submissions from 10 countries, and after rigorous refereeing 11 papers were eventually chosen for presentation at the workshop. The workshop program was enriched by a keynote address given by Professor Peter Chen, the Honorary Chair of the workshop. The first part of this paper is a summary of the papers in the order of the presentations at the workshop. The second part describes the invited papers.

2 Summary of Regular Papers

Understanding the Semantics of Data Provenance to Support Active Conceptual Modeling
Sudha Ram and Jun Liu, University of Arizona, Tucson, AZ, USA

The paper provides a comprehensive approach for recording how data changes overtime based on the W7 model conceptualizing dimensions of data provenance. The authors introduce how data provenance could generalize the data-centric and process-centric approaches by using ontology to represent semantics of provenance.

* The research of this author was partially supported by National Science Foundation grant: NSF-IIS-0326387 and Air Force Office of Scientific Research (AFOSR) grant: FA9550-05-1-0454.
** Contributions to this article by co-author Leah Wong constitute an original work prepared by an officer or employee of the United States Government as part of that person's official duties. No copyright applies to these contributions.

P.P. Chen and L.Y. Wong (Eds.): ACM-L 2006, LNCS 4512, pp. 1–6, 2007.

They suggest that tracking data provenance could enable users to share, discover, and reuse data, thus streamlining collaborative activities and facilitating learning. The authors propose to use the provenance-based conceptual modeling approach to capture "what" events/changes have happened to the data, identify "where", "when", "how", "who", and "why" behind the "what"; and represent events as entities with attributes and relationships without adding additional constructs. The paper also uses a homeland security example to illustrate how current conceptual models can be extended to embed provenance in order to provide integrated information in a holistic manner.

Adaptive and Context-Aware Reconciliation of Reactive and Pro-Active Behavior in Evolving Systems
Peter Scheuermann and Goce Trajcevski, Northwestern University, USA

The authors introduce the $(ECA)^2$ model, which extended active databases and focused on streaming data, for modeling reactive behavior with pro-active impact of evolving systems including hypothetical reasoning, dynamic trigger reordering, and context-aware adaptation. Proactive impact of the reactive behavior includes:

1. Modification of the events/conditions/actions as the system under consideration evolves
2. Dynamic ordering of the execution of the "awaked" triggers
3. Push-based notification of the satisfaction of the continuous queries (condition part) of the triggers.

A Common Core for Active Conceptual Modeling for Learning from Surprises
Stephen W. Liddle and David W. Embley, Brigham Young University, USA

This paper introduces a formal foundation for active conceptual modeling in terms of meta-modeling, formal representation, and mathematical model theory based on the Object-oriented Systems Modeling (OSM) approach with examples of executable models, and a set of suggested common ACM-L core concepts for representing the structural and dynamic aspects of a system. The authors call the ACM-L community to agree on a common core model that supports all aspects—static and dynamic— needed for active conceptual modeling in support of learning from surprises. It is the authors' position that we have the building blocks for realizing ACM-L, but they need to be put together in a suitable way.

Actively Evolving Conceptual Models for Mini-world and Run-time Environment Changes
P. Radha Krishna and Kamalakar Karlapalem, Institute for Development and Research in Banking Technology, Hyderabad, India

This paper introduces an ER* methodology for evolving applications that implicitly handle changes and synchronization at various levels from the mini-world to run-time environments through layers of models and systems. A suite of ER Models, which act as a template for modeling the change requirements during application evolution, is used to describe various requirements. An ER* model will be instantiated by invoking the most appropriate template that best meets the requirements of the changed environment. The methodology is iterative in nature and is driven by the structured, functional, and behavior validation steps, along with the Event-Condition-Action (ECA) rules for monitoring and execution of an application. This methodology facilitates capturing active behavior from run-time transactions and provides a means of using the knowledge to guide subsequent application design and its evolution. An e-contract was provided as an example.

Achievements and Problems of Conceptual Modeling
Bernhard Thalheim, University Kiel, Olshausenstrasse Kiel, Germany

This paper introduces state-of-the-art and open problems in structuring, functionality (behavior), advanced views and media types, distribution, and interactivity in conceptual modeling. Twenty open problems with respect to the achievements of conceptual modeling were introduced. These achievements, which demonstrated the maturity towards a science of modeling, have laid a foundation for database technology in support of a large class of applications. The open problems include issues in database design, information architecture, information quality, specification language development, conceptual modeling theory, constraints and consistency management, theory of extended operations for object-oriented models and database behaviors, mapping to triggers, and adaptable delivery of content to the user.

Metaphor Modeling on the Semantic Web
Bogdan D. Czejdo, CASS, San Antonio, TX, USA, Jonathan Biguenet, Tulane University, USA, and John Biguenet, Loyola University, USA

This paper introduces the use of the extended Unified Modeling Language (UML) for metaphor modeling. It further discussed how to create UML diagrams to capture knowledge about metaphors for defining complex meaning. The phases of metaphor modeling include stating the metaphor, identifying similarity of attribute types, the role of matching attributes for a metaphor, and explaining the non-matching attribute role for the metaphor. The authors suggested application of metaphor-based systems in education and surprise detection. However, the changes of metaphor and the underlying ontology remained challenging issues that need to be addressed.

Schema Changes and Historical Information in Conceptual Models in Support of Adaptive Systems
Luqi, Naval Postgraduate School, USA and Douglas S. Lange, Space and Naval Warfare Systems Center San Diego, USA

The authors point out software engineering, which is an example of learning activity, could be used as an ACM-L use case capturing the essence of version control, software merge, reuse, and generation. While mapping changes of the real world domain to software world requires theory and methodologies, this paper describes several aspects of active conceptual modeling that have been studied in software engineering and suggests further investigation when applying ER models to active conceptual learning. Specifically, uncertainty and time models need to be incorporated.

Using Active Modeling in Counterterrorism
Yi-Jen Su, Hewijin C. Jiau, and Shang-Rong Tsai, National Cheng Kung University, Taiwan

This paper proposes using active modeling in analyzing unconventional attacks in the design of counterterrorism system. The authors combined terrorist network analysis and active modeling for an Intelligent Terrorism Detection System including intelligence evaluation and information binding. It uses the Threat Factor and Threat Pattern Finding (TFIDF) to classify the category of potential and Graph-Based Mining to recognize the frequent threat patterns from the past incidents. Inexact graph matching is then applied to detect the potential threat from suspicious terrorist networks. Terrorism ontology is used to capture the semantic content of the terrorist domain. Based on time sequence, snapshots are used to describe the activity sequence of a terrorist attack.

To Support Emergency Management by Using Active Modeling: A Case of Hurricane Katrina
Xin Xu, Louisiana State University, USA

The author discusses the issues of how to deal with surprises and determine changes, which lead to influence relationships among entities using a case study of Hurricanes Katrina. Current work in disaster process modeling needs to be enhanced to include a conceptual model for emergency management by integrating data from historical information (experience, crisis, and surprise), and representing relationship from all aspects of a domain in a dynamic way. The paper proposes a process framework that would help predict surprises within upcoming natural disaster. This framework assumes all types of natural disasters have occurred, and corresponding information, experience, and lessons have been classified and stored; and that we only focus on the major upcoming disaster. Specific issues that need to be further explored include: (1) How to capture the right information from changes during emergency situation, (2) How to adapt to new situation by learning from past experience, (3) How to predict potential changes by integrating current and past knowledge.

Using Ontological Modeling in a Context-Aware Summarization System to Adapt Text for Mobile Devices
Luís Fernando Fortes Garcia, Lutheran University of Brazil, Brazil, Faculdade Dom Bosco de Porto Alegre, Brazil, José Valdeni de Lima, Federal University of Rio Grande do Sul, Brazil, Stanley Loh, Lutheran University of Brazil, Brazil, Catholic University of Pelotas, Brazil, and José Palazzo Moreira de Oliveira, Federal University of Rio Grande do Sul, Brazil

The authors introduce context awareness for dealing with linking changes in the environments with computer systems, which are otherwise static. The paper illustrates the use of ontological modeling for context-aware summarization to present users' interests, and spatial and temporal localizations in order to adapt text for mobile devices. The paper proposed the use of contextual information to determine "what", "where", and "when" should be delivered to the user in different environments according to the user's profile. Domain ontologies are structured as concept hierarchies with each concept being described by a set of keywords with weight assignment to determine how much the word identifies the concept, which in turn derives the summarization. An open architecture consisting of the user's profile management module, context management module, and context-aware summarization modules and automated text summarization process based on context and personal information is presented. Results of experimentations are also presented.

Accommodating Streams to Support Active Conceptual Modeling of Learning From Surprises
Subhasish Mazumdar, New Mexico Institute of Mining and Technology, USA

This paper proposes an enhancement of ER modeling with active constructs in order to permit data streams, which can only be queried by context, to have context-based relationship with standard data.

3 Summary of Invited Papers

Approaches to the Active Conceptual Modelling of Learning
Hannu Kangassalo, University of Tampere, Finland

This paper studies that collection on several levels of abstraction of human cognition and knowledge. These processes can be performed through various approaches, on several levels, and by using several perspectives. The paper concentrates on active conceptual modelling, which is a process of recognition, finding or creating relevant concepts and conceptual models which describe the UoD, representing the conceptual content of information to be contained in the IS. This characterisation contains the construction of new concepts, too. The author studies methods for collecting information from various sources in the UoD and accumulating it as possibly actual instances of various types of pre-defined concepts. Some of these instances may be cases of sudden events or processes. They should be recognised as concepts and included in to the conceptual schema. To some extent, some concepts may be constructed which fit to this collected information. During the adaptation process it is recommended that we are applying active conceptual modelling for learning, which organises our conceptual schema in a new way. Learning is a process in which a learner re-organises, removes or refills his knowledge structures by applying his newly organised conceptual schema.

Spatio-Temporal and Multi-Representation Modeling: A Contribution to Active Conceptual Modeling
Stefano Spaccapietra, Ecole Polytechnique Fédérale de Lausanne, Switzerland, Christine Parent, University of Lausanne, Switzerland, and Esteban Zimányi, Université Libre de Bruxelles, Belgium

Worldwide globalization increases the complexity of problem solving and decision-making, whatever the endeavor is. This calls for a more accurate and complete understanding of underlying data, processes and events. Data representations have to be as accurate as possible, spanning from the current status of affairs to its past and future statuses, so that it becomes feasible, in particular, to elaborate strategies for the future based on an analysis of past events. Active conceptual modeling is a new framework intended to describe all aspects of a domain. It expands the traditional modeling scope to include, among others, the ability to memorize and use knowledge about the spatial and temporal context of the phenomena of interest, as well as the ability to analyze the same elements under different perspectives. This paper shows how these advanced modeling features are provided by the MADS conceptual model.

Postponing Schema Definition: Low Instance-to-Entity Ratio (LItER) Modelling
John F. Roddick, Aaron Ceglar, Denise de Vries and Somluck La-Ongsri, Flinders University, South Australia

There are four classes of information system that are not well served by current modeling techniques. First, there are systems for which the number of instances for each entity is relatively low resulting in data definition taking a disproportionate amount of effort. Second, there are systems where the storage of data and the retrieval of information must take priority over the full definition of a schema describing that data. Third, there are those that undergo regular structural change and are thus subject to information loss as a result of changes to the schema's information capacity. Finally, there are those systems where the structure of the information is only partially known or for which there are multiple, perhaps contradictory, competing hypotheses as to the underlying structure.
This paper presents the Low Instance-to-Entity Ratio (LItER) Model, which attempts to circumvent some of the problems encountered by these types of application. The two-part LItER modeling process possesses an overarching architecture which provides hypothesis, knowledge base and ontology support together with a common conceptual schema. This allows data to be stored immediately and for a more refined conceptual schema to be developed later. It also facilitates later translation to EER, ORM and UML models and the use of (a form of) SQL. Moreover, an additional benefit of the model is that it provides a partial solution to a number of outstanding issues in current conceptual modeling systems.

4 Conclusion

We have summarized 11 regular papers and 3 invited papers for the 2006 First International Workshop on Active Conceptual Modeling of Learning. These papers represent some of the most current ideas and research results on this very important subject.

Architecture for Active Conceptual Modeling of Learning

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Abstract. The concept of Active Conceptual Modeling of Learning (ACM-L) has been explored in order to capture content and context changes that permit a comprehensive learning from the past, understanding the present, and forecasting the future. Such capability has not been fully explored and it is not available with today's static oriented database system. The potential of creating a "database of intention" that can have its own aim to understand the intentions of its users and the changes to their environment. This paper explores an architectural approach for the "database of intention" with predictability power. The proposed architecture is presented, illustrated, and discussed.

1 Introduction

Human beings use lessons learned from past successes and failures in order to make better future decisions. The idea of learning from the past for future actions is not new, but the comprehensive collection and understanding of dynamic data and their environment has not been fully explored. The concept of "Active Conceptual Modeling of Learning" (ACM-L) has been explored for effectively capturing the dynamic data and changes in their environment so that it permits to learn comprehensively from them in order to understand the present, and predict the future [1-6].

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Having a clear understanding of the changing real world state is essential for intelligent decision making. Decision makers must be able to detect critical factors and events in the evolving domain of the real world and to learn from them in order to better plan for and handle the future. This intellectual capability can be augmented by a “database of intention” that can help in collecting and analyzing past events in the real world environment and in assisting human users for their decision making. Recent surprising incidents (e.g. September-11, Tsunami, Katrina, etc.) have motivated us to examine and reexamine what facts, activities, and trends that led to past incidents in order to better prepare for and manage similar events in the future. Predictive, preventive, and reactive strategies could be developed for better managing reoccurrences of similar incidents. When we review events, we turn back the clock relative to the timeframe and relate past information of events and facts with multiple perspectives, orientations, and view points to help clarify what we didn’t and/or failed to see before. This “Enhanced Rewind” Paradigm within the framework of Conceptual Modeling of Learning enhances our intellective capability by reviewing the history of past events and their newly-discovered relationships, so that we are better equipped to learn lessons that will affect our responses to similar mishaps in the future.

1.1 The Challenge

The current information processing technologies can support only “simple rewind.” For example, it is possible to use computer backup files to a certain date in the past, and it is also possible to retrieve a previous day's newspaper contents, etc. However, the detailed changes leading to most recent contents were often omitted. Therefore, the existing database and information system technology do not support the learning from the past very well.

The challenge is the development of next generation of information system that it will keep and provide detailed changes on records and their corresponding real world environment under which the changes were made. We are proposing to take the features of Active Conceptual Modeling that could capture and represent both the static and dynamic aspects of the real world domain. The persistently stored changes would be organized and interconnected for permitting effective learning from the collection. The traces of past data could be done with multiple dimensions and perspectives so that questions on “who, what, where, when and how” changes occurred could be answered. Significant sequences of events could be extracted from the comprehensive collection for intense review, analysis, and compare so that potentially hidden factors and implicit relationships could be uncovered.

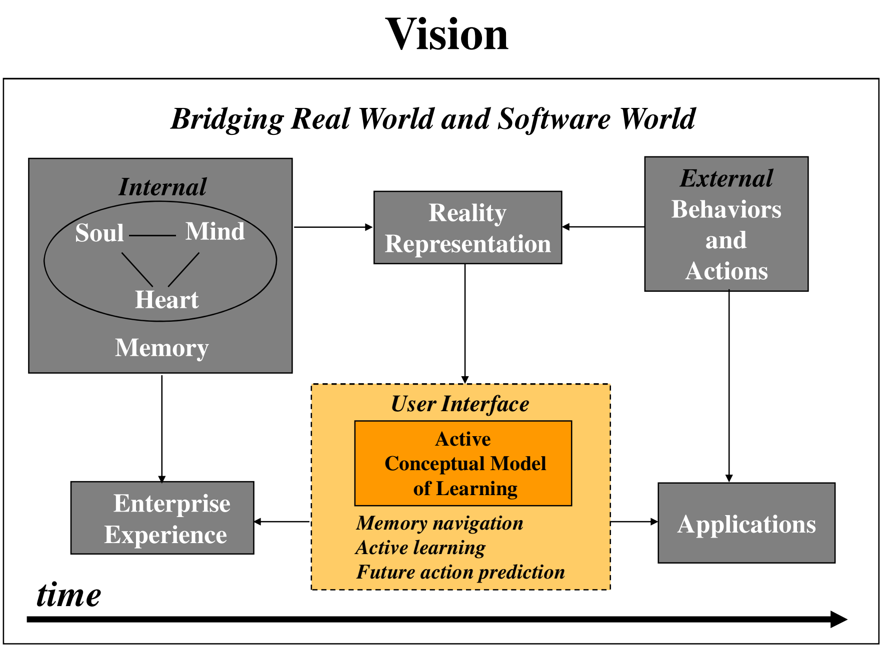
1.2 An Enhanced Rewind Paradigm for Learning

An Enhanced Rewind Paradigm for Learning as one of the approaches in response to the challenge is identified and illustrated. The required features of the paradigm are as follows:

1. A continual process of modeling events and their changes within a given domain.
2. Backtracking of the events to the point and time of interest.
3. Identification of related and parallel events during the period when an incident occurred for possible hidden facts and relationships.
4. Modeling and learning of historical information from different perspectives.
5. Generating and triggering alerts on potentially incidents based on past experiences.

Active Conceptual Model of Learning is incorporated into the Paradigm to ensure the presentation of the real world dynamic environment. Multi-level and multi-perspective learning strategies are integrated and included for examining the dynamic collection with different learning logic and approaches. The goals and objectives of planners and decision makers and environmental constraints can be entered into the paradigm for providing guidance and focus of the learning and monitoring processes.

The following diagram depicts the Enhanced Rewind Paradigm for Learning.



1.3 The Concept of "Database of Intention"

Based on the proposed paradigm, a "database of intention" could be created based on the proposed paradigm for collecting and storing past actions and changes in environments, and learning from them. Such a database system focuses on the prediction of future intentions on users and their environmental changes based on their past behaviors. It augments human decision makers for taking planned actions. The system continuously monitors on going changes and continuously learning from the conceptually modeled dynamic real world environment for providing hints and alerts to human decision makers and planners. Specific constraints and conditions could be entered by human decision maker so that the system may learn from the past activities within the set of constraints provided by the human decision makers. The system is mainly for augmenting the human decision maker's intellectual capability for decision making under constraints. The "database of intention" expands the current database system into a new dimension for handling both static as well as dynamic data and information.

Based on the concept of "database of intension", a high level architecture for the next generation of database information technology is proposed. In this paper, the key technologies and components of the architecture are identified, illustrated, and discussed.

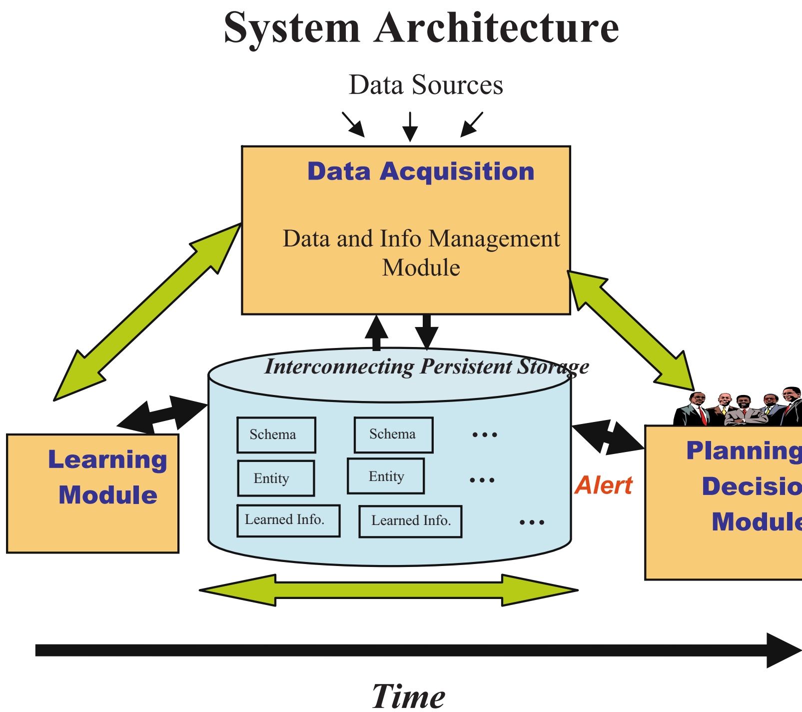
The proposed system architecture attempts to show the technical viability for the next generation of data and information system for providing a framework for the research and development community for the development of prototypes, experimental test beds, and eventually the full operational system in the not too distant future.

2 Proposed Architecture

System architecture is proposed to provide a framework for the development of the next generation of information system. The proposed system architecture is based on the core technology of an interconnected mass persistent storage that can store and organize massive changes data within the database and its domain data sources from the Internet and the real world. This mass persistent storage is managed by an executable conceptual model database management system so that it insures the consistency of data collection and data usage. The executable conceptual model database provides the flexibility for dynamically modeling the changing world by evolutionally changing the conceptual model as well as its associated data storage structures accordingly. The evolutional changes of the conceptual model are maintained in the persistent storage with their associated data to ensure that the changes in entity behavior as well as the traces and links that reveal "who, what, when, where and how" are directly associate with the correct version of the conceptual model in time.

The proposed architecture has three major interacting operational modules, namely, Data Acquisition Module, Learning Module, and Planning and Decision Making Module.

The following diagram depicts the proposed architecture.



2.1 Executable Conceptual Model Database Management System

The executable conceptual model data management system works more like an interpreter that directly interprets the actions specified in the conceptual model. It is different from the conventional database management system which uses the layered architecture for accomplishing data independence and the conceptual model is used as a database design tool for guiding the generation of different levels of schema. The executable conceptual model database management system is intended to execute the database management function directly through the conceptual model. The data collected in the interconnecting persistent storage can be linked directly with its corresponding elements in the conceptual model. This is necessary in order to make clear traces from applications through processes to entities and their instances. With the executable conceptual model database management system the instances of the entity are directly traceable to the entity and the entity is directly traceable to the conceptual model and applications. Therefore, the data in the persistent storage are closely coupled with the conceptual model. In a conventional database management system, the conceptual model is stored in database design or CASE tools, the physical data in the database management system is isolated from the conceptual model and the application programs. Therefore, the architecture of conventional database management system created the difficulty for tracing storage data element back to its corresponding entity in the conceptual model. Reverse engineering has been used to accomplish this task without much success. The conventional architecture also introduced the difficult for evolutional changes in conceptual schema. When necessary, the database must be reorganized and regenerated which is a costly and time consuming task. Another important function of the active conceptual model is that it requires the handling of dynamic changes of the change of conceptual model itself in an evolutional manner. Schema evolution in a conventional database management system is a major difficulty that it requires the reorganization of the database with each modification of the conceptual model. By linking and integrating the major components together, the executable conceptual model data management system accomplishes traceability between application, conceptual schema, and storage structure.

2.2 The Mass Interconnecting Persistent Storage

The mass interconnecting persistent storage is organized by the conceptual model that represents the real world domain. This stored data is also operated by the same conceptual model that created the data store. Each database has a unified conceptual model that represents the domain of the real world of applications. When a data is changed in the persistent storage a link will be created to specify the current value and to link to its pass value. A time stamp will be inserted to indicate the time of the change with a link to the process that caused the change and the application and the user that activated the process. These links provide the trace to "what, when, how, where, and who" about the change.

The interconnecting persistent storage is designed to provide the sophisticated learning process to later analysis of changes. The interconnected persistent storage provides the needed links for comprehensive, multi-perspective, and multi-level learning to discover insights and clues from the past.

2.3 Three Interrelated Modules

The three interrelated modules each has a different mission governed by the executable conceptual model database management system. The data acquisition module identifies the data resources and captures the changes during the operations of the database. The learning module is the main learning engine for the analysis of the historical data. It may include multiple learning strategies and cognitive processes. The selected learning processes will be used during the conceptual modeling process so that characteristics of learning strategies can be incorporated into the conceptual model to be developed. Some of the learning processes that do not depend upon the structured data can also be included in the learning module but not used in conceptual modeling process. These learning processes, such as data mining, can be used to access the database, but not be governed by its structures and semantics by the conceptual modeling process. The planning and decision making module interface with the human decision makers for providing the decision makers with insights, clues, and alerts. Tools may be provided for validating results from different learning processes for their relevancy and accuracy and also allow decision makers to ask "what if" questions as well as focused questions about patterns concerning "who, what, where, when and how" changes occurred.

Data Acquisition Module. The data modeling and acquisition module controls the collection of dynamic data for storage in the interconnecting persistent storage and establishes the proper time stamps and links for every content and context changes. The collected active data in the interconnecting persistent storage are closely coupled with the conceptual model used so that their semantics would be consistent. Entities can be accessed only via the designated processes as indicated in the conceptual model so that the semantics of the accesses and data transformation are consistent as designed the conceptual modeling process. Data accesses that do not follow the pre-designed access patterns will have to be considered and recorded as unspecified accesses. Unspecified accesses are not traceable and therefore, the data sources could not be checked and verified. Access integrity is extremely important to ensure that the active data collected for later learning can have high reliability and accuracy. The key element of the data acquisition is the indices and links that created when a change is occurred. Precedent and antecedent relationships of changes allow the building of indices that can reveal "when, what, where, who, and how" the change occurred, facilitating "enhanced rewind" for later learning processes. The comprehensive set of indicators, links, and pointers are the core of the architecture for active conceptual modeling. The fiber of this interconnecting storage is the main feature for supporting the comprehensive learning and inference strategies which is the hallmark of the active conceptual modeling for the next generation information technology.

Learning Module. Learning is the key for the active conceptual model. There is a wide range of approaches in learning or cognition from ad hoc data mining that based on stochastic or chaos theory to well formulated time series that based on straight forward computation or observation. Different learning strategies offer certain advantages as well as having certain weaknesses.

The Inclusion of Multiple Learning Strategies. The learning module allows the inclusion of different learning strategies and approaches for accessing the interconnecting persistent storage. Enhanced rewind feature permits the learning from the past by following the time dimension or tracing a set of specially selected features from the interconnecting persistent storage.

Learning strategies that follow the structures and semantics of the conceptual model could produce reliable and interpretable results, but they may miss potential cues that were not expressed in the conceptual model. Other learning approaches such as data mining which treats the collection of data as an unstructured repository of data, may find relationships between various data elements that were not anticipated by the conceptual modeler. These seemly unrelated relationships may provide discoveries beyond the anticipation of the data model designer. However, the validity and relevancy of these discoveries need to be carefully checked, assessed, and interpreted. In order to have comprehensive learning capability learning strategies with different strategies of both types are included.

The Comprehensive Learning Engine. Users can be augmented by using various learning capabilities provided by different learning strategies and processes. The inclusion of multiple learning strategies can be used collectively and intelligently as a