A Hypermedia Design Methodology for the Knowledge Capitalization on Data Warehousing System

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Abstract

Recently, many enterprises have attempted to capitalize knowledge assets on data warehouse (DW). It has been recognized as strategic core process to create corporate competitive advantage and implement enterprise e-biz strategies. However, most approaches to represent knowledge and decision process have limits in considering various knowledge types, their relationships and continuity in knowledge formulation. In addition, they are so inclined to one side such as concept-oriented frameworks or technology-oriented ones. They lack universal and wide-ranging features. This paper presents a comprehensive methodology to accumulate knowledge capital on DW via a properly grained hypermedia model. The methodology consists of three phases: knowledge requirement elicitation, hypermedia modeling, and system implementation. A real-life case for medical DW development is presented to demonstrate the usefulness of the proposed methodology. This methodology is effective when an organization accumulates knowledge assets to put the corporate e-biz or cre-biz strategy into practice.

Keywords:

Knowledge; Hypermedia; Data Warehouse; Medical

Introduction

As the importance of enterprise knowledge management (KM) is increased, effective acquisition, accumulation, and utilization of knowledge assets based on data warehouse (DW) have been recognized as a strategic core process to create corporate competitive advantage. In implementing corporate e-business or business creation strategy, organizational knowledge infrastructure is being considered as essential and fundamental resource [1]. Besides, digitalization of knowledge asset on data warehouse can encourage manager's excellent decision-making by supplying context-specific data, models, statistics, knowledge and optimization. Consequently, it enables an organization to convert knowledge into basis for action.

But in fact, implementation of knowledge capitalization on DW is indeed challenging activity. Recognition of decision problems and formulation of decision models would possess high complexity, dynamic risk, uncertainty, and moreover diverse preference of decision makers. In addition, knowledge representation requires explicit description of concept space and decision process of involved persons. Furthermore, the fit between knowledge management scheme and technical implementation architecture should be considered seriously.

So far, a lot of approaches have been suggested to find the way representing and managing decision process and knowledge in the form of methodology and framework. But most of conventional methodologies and frameworks are so polarized into concept-oriented and technology-oriented ones that they lack universal and wide-ranging features. Conceptual KM frameworks do not explicitly address systematic chain of actions to implement technical KM operating environment. Similarly, technical methodologies such as hypermedia and DW design methodologies are insufficient to incorporate intensive knowledge requirement analysis task. Moreover, physical DW architectures also neglect their role as knowledge management platform. Obviously, those efforts have clear limitations in considering various types of relationship and continuity in knowledge formulation.

To cope with these shortcomings, a universal and systematic course of action should be designed considering diverse aspects from various works including KM frameworks, hypermedia design methodologies, and DW related methodologies. Namely, interdisciplinary and integrative approach is essential to get excellent knowledge intensive application features such as hierarchical hypermedia functionality on knowledge architecture. In addition, a systematic framework for intensive modeling of relationships across knowledge is also mandatory.

The objective of our research is to suggest a hypermedia design methodology facilitating corporate-level knowledge management environment and decision support. We also propose innovative DW architecture incorporating hyper-knowledge layer to support the migration of methodology outputs into operational components. The methodology with proposed architecture has the ability to find a context-specific hypermedia model including chunking relationships and navigation routines across diverse knowledge objects produced from operational data store into which various knowledge sources are integrated. The hypermedia model is derived by the proper description of concept space of knowledge consumer by allocating knowledge artifacts on the hyperspace.

For the advancement of our research, we present a framework for knowledge capitalization, which includes various theoretical principles to be employed in a methodology in next section. Proposed methodology section explains methodology architecture, physical implementation platform, and mapping structure. In case section, development process of real-life medical data warehouse application is described for the purpose of proof on proposed methodology's actual effectiveness. The application supports complete knowledge capitalization and sharing process in hospital. Section of discussion presents methodology comparisons to distinguish advantages of proposed methodology. Finally, conclusion section details contribution of this work and future research directions.

Approaches to Knowledge Capitalization

Overview

This section aims to provide review on activities, methods and techniques concerned with the systematic identification, modeling, and storage of organizational knowledge resources. Without the fundamental framework integrating various knowledge related disciplines, successful knowledge capitalization might be impossible. So the establishment of systematic framework based on interdisciplinary studies about KM frameworks, hypermedia modeling, and data warehousing system is prerequisite to advance this research. This work also helps find required artifacts and tasks for the new methodology. Subjects related to knowledge accumulation range from conceptual level to physical level as shown in figure 1. This hierarchical scheme should be organized in a seamless and integrative manner. Thus, development of mapping rules among heterogeneous disciplines is essential requirement for this work.

The major objective of the conceptual level study is finding knowledge supply and demand mechanisms. Supply side studies address knowledge inventory techniques including determination of knowledge description level, identification of knowledge assets, and knowledge typing. On the other hand, demand side research is mainly about identification of knowledge consuming activities. To find systematically organized group of activities in an organization, value chain analysis [2] has been commonly applied. The most important task in this level is joining supply and demand facets of knowledge management together. It is a process of finding utilization correspondence relationship and KM episodes by linking knowledge assets to business processes. Related studies on this level are reviewed in sub-section of conceptual level knowledge management framework.

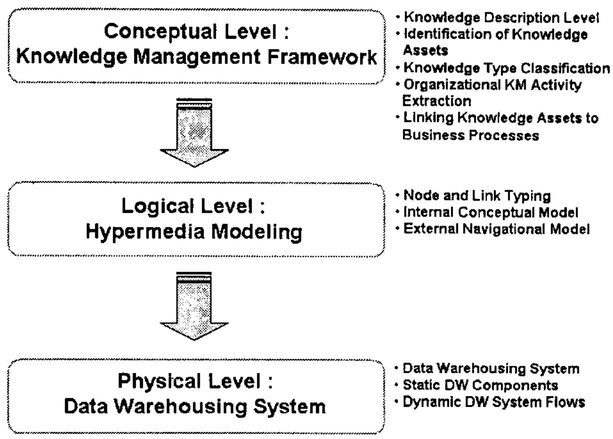

Figure 1 – A Framework for Systematic Capitalization

The goal of logical level work is to develop context-specific and task-supporting hypermedia model. Knowledge modelers can design various knowledge structures on hyperspace using node and link artifacts. Subsequently, decision makers can possess many diverse and interrelated cognitive pieces of knowledge in structured hyperspace. They also actively acquire and author desired pieces of knowledge using well-designed navigation links [3]. Usually, the knowledge modeling process on hyperspace can be divided into two steps. The first step is constructing internal conceptual model, which is a meaningful organization of base classes representing contents semantics. The next step is developing external navigational model, which is built by defining derived perceptible objects and their navigation mechanisms [4]. Related works about hypermedia modeling are reviewed in sub-section of logical level hypermedia modeling.

In physical system level, dynamic flows and static data warehousing components are defined to implement knowledge management operating platform. The objective of this level study is to propose a novel and innovative DW system to map the logical design results such as nodes and links into physical system components and procedures without missing of information. Related concepts for data warehousing are reviewed in sub-section of physical level data warehousing system.

Conceptual Level Knowledge Management Framework

Major issues about supply side KM study include determination of knowledge description level, identification of knowledge assets, and knowledge classification system. Wiig [5] concentrates the importance of determining appropriate knowledge description level. To provide sufficient details, description level should not be too general. But, excessively specific description level will limit KM activity to just microscopic operational movement. Thus, deliberate decision on knowledge description level should be made to get the quality and cost of organizational knowledge capitalization manageable.

Widespread methods for knowledge identification include questionnaire-based knowledge surveys, knowledge mapping, and knowledge scripting/filing [6,7]. Questionnaire-based knowledge survey is used to obtain broad overview of an operation's knowledge status. It may provide information to almost any other KM activity and provides responses from many areas and viewpoints categorized from the questions asked. Knowledge mapping method is used to develop concept maps as hierarchies or nets. It supplies highly developed procedure to elicit and document concept maps from knowledge workers. Finally, knowledge scripting and profiling method is employed to identify the elements of knowledge intensive work. Analysis used in this method is based on interviews, simulations, observations, and interactive work sessions.

Several KM frameworks accompany knowledge classification system for the practical purpose like implementation of decision support systems. Both Wiig [6]'s knowledge description frame and Holsapple and Joshi [8]'s knowledge attributes are beneficial in studying, comparing and evaluating knowledge resources. Holsapple and Whinston [9] define six types of knowledge a knowledge model could possess - descriptive, procedural, reasoning, linguistic, presentation, and assimilative. The first three are termed primary types and the remainders are secondary (i.e. derived from the primary). This classification system has been actively used as the theoretical fundamental in the implementation of knowledge intensive application. Table 1 explains the taxonomy in more detail.

Table 1 - Knowledge types [9]

Classification		Description
Primary	Descriptive	Information about past, present, future and hypothetical states of relevance to a decision making situation: 'knowing what'
	Procedural	Procedures, steps or strategies which specify incremental processes to accomplish tasks: 'knowing how'
	Reasoning	Valid conclusions under which circumstances produced from variable relationships or rules: 'knowing why'
Seconda ry	Presentation	Facility for communication from one entity to another
	Linguistic	Interpretation of communication received
	Assimilative	Maintenance of knowledge relationships

In terms of demand side, most KM efforts are devoted to the extraction and classification of knowledge consuming activities in the organization. For the systematic carrying out of this job, Porter [2]'s value chain analysis has been widely used. The value chain model, a basic tool for diagnosing competitive advantage and finding ways to enhance it, identifies technologically and economically distinct value activities that an organization performs in the course of doing business. These value activities fall into nine generic categories: five primary and four secondary.

At last, separate works performed in each demand and supply side should be joined together by relating knowledge artifacts with each activity. Methods related to this issue include knowledge management episode (KME) analysis [8], task environment analysis, critical knowledge function analysis, knowledge use and requirement analysis, knowledge flow analysis [6], and knowledge chain model [10].

KME concept refers to a pattern of activities performed by multiple processors with the objective of meeting some knowledge need. A KME involves KM influences, configuration of knowledge manipulation activities, portfolio of knowledge resources, and user's need recognition/learning/projection on knowledge. For example, decision-making episodes which are special cases of KMEs involve one or more of decision-making participants, their problem solving activities, and some portion of knowledge resource portfolio to get an optimal solution on the specific problem.

Logical Level Hypermedia Modeling

Garzotto et al. [11] identified five dimensions to consider in designing hypermedia applications: content, structure, presentation, dynamics, and interaction. Firstly, content design is pretty important dimension in envisioning a hypermedia application's overall feature. Content design requires an application domain specialist and a deep knowledge on that field. Structure dimension considers the internal organization of the application's contents and functions. On the other hand, presentation dimension is concerned about how application content and functions are shown to readers. Lastly, dynamics and interaction dimension define both an application's dynamic functionalities and user's interaction scheme.

Typically, most of hypermedia design methodologies divide the design process into two phases. The first phase focuses on contents and structure dimensions while the second phase considers presentation, dynamics and interaction dimensions. The first phase performs planning, analysis, and organization of contents with the help of conventional design techniques such as ER design or OO design methodologies. The second phase carry out design of abstract navigation model that describes dynamic aspects of the hypermedia application using artifacts derived from the first phase.

Establishment of a domain-specific type classification system for nodes and links is the most important process in hypermedia application development. Types capture semantics of elements at the logical level. They also bridge the abstractions of conceptual model to those of the hypermedia logical model, and then to its implementation [12]. Nodes have been generally conceived as units of information, hypermedia fragments, fragments of information, or basic information containers in hypermedia applications [13]. Links are used to make relationships between pieces of information.

Physical Level Data Warehousing System

Data warehousing is an advanced approach for the integration of data from multiple, possibly very large, distributed, heterogeneous databases and other information sources [14]. The term "data warehousing" is used to emphasize the dynamic characteristics of DW [15]. The dynamics of DW are expressed by 5 flows. Inflow feeds data from legacy systems and other external sources into the informational database or user's application. Upflow aggregates and summarizes the highly detailed data. Downflow purges or archives data into storage media such as magnetic tape. Outflow implies that users utilize data from the informational database by a simple or an advanced tool with functions ranging from basic management reporting to complex analytical processing.

A Proposed Methodology

In this section, we suggest the methodology architecture with description of task, proposed target implementation architecture, and mapping structure. Methodology architecture denotes the relationships among tasks and specifies their input/output artifacts. Proposed data warehouse implementation architecture suggests optimized operational environment for knowledge capitalization. Mapping structure shows transformational relationship across all kinds of artifact in whole layers.

Methodology Architecture

Figure 2 shows the architecture of our methodology consisting of three phases and seven steps. In knowledge requirement analysis phase, two steps are identified; they are discovery of knowledge type classification system and utilization analysis with KMEs design. Traditionally, information system requirement analysis has been processed by user interview, form analysis, file specification analysis and so forth. But knowledge requirements are so complex and ill defined that conventional approaches would be ineffective.

It is desirable to separate knowledge requirement analysis phase into static and dynamic stage based on the previously examined KM techniques. The first step in this phase is the static stage collecting knowledge requirement in the form of knowledge type and their instances. This step carries out conceptualization, explicit specification, and categorization of the knowledge resources based on user interview analysis, literature survey, and feedback from subsequent steps as input. Feedback loop between two steps is shown by dashed line in figure 2. This step generates a set of knowledge object in the predefined format conforming to Table 1.

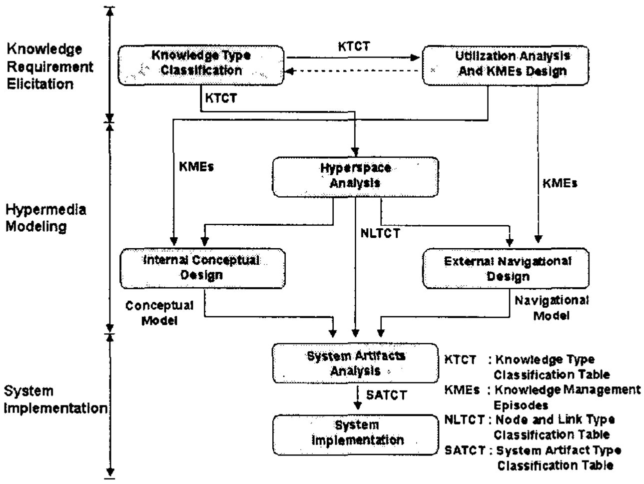

Figure 2 – Methodology Architecture

Next step tries to find dynamic utilization relationship between knowledge assets and manipulation activities. This step tries to identify the dynamic form of knowledge requirement in demand side. This step includes 3 sub activities. According to Porter [2]'s value chain model, knowledge manipulation activities are identified at first. Next, combination of activities and knowledge resources is carried out. Finally, specific dynamics and interaction scheme is defined in the form of episode. In brief, this step determines how both users and internal system interacts with individual pieces of knowledge and moves among them.

The goal of hypermedia modeling phase is classification, instantiation, and organization of hypermedia artifacts. Hyperspace analysis step produces tailored node and link types for knowledge modeling based on knowledge type classification system. In this step, intensive domain study brings node and link instances to be used during internal conceptual and external navigational design phase. Internal conceptual design step carries out structuring static relationships among knowledge objects. So this step employs node and link type instances derived from primary knowledge types: descriptive, reasoning, and procedural knowledge. External navigational design step models user involvement and navigational logics with the help of primitives obtained from secondary knowledge types. KMEs play an important role in the formulation of both conceptual and navigational model by providing associational and compositional relationships across knowledge objects.

During the implementation phase, conceptual and navigational model are mapped and fitted to customized data warehouse platform. For this purpose, system artifact type is classified at first. Then system implementation is performed through the iterative process of class generation, componentization and structured packaging. Advanced organization and deployment techniques are used to help practitioners to put designed hypermedia model into operation without information missing of any previous accomplishments.

Adopting interdisciplinary approach, our methodology produces three kinds of type classification table: knowledge type classification table (KTCT), node and link type classification table (NLTCT), and system artifact type classification table (SATCT). So the definite transformation and conversion rule among them is vital to maintain the consistency of the methodology.

Proposed Target Implementation Architecture

Effective design of methodology for organizational knowledge representation and construction needs architectural excellence. We suggest an advanced DW architecture by inserting hyper knowledge layer into conventional DW layer as shown in figure 3. So, this architecture consists of three layers: operational data store (ODS)/DW layer, hypermedia presentation layer, and metadata layer. ODS/DW layer keep source data in the raw or aggregated form. Hypermedia presentation layer contains classes for knowledge presentation and associated objects with persistence. This layer manages authoring of knowledge objects and complex chunking relationships among them. Hypermedia presentation layer also sets up relationships and interactions with data source, DW and presentation layer. Metadata layer provides hypermedia modelers a hyperspace by identifying artifacts in every layer and organizing relationships among them.

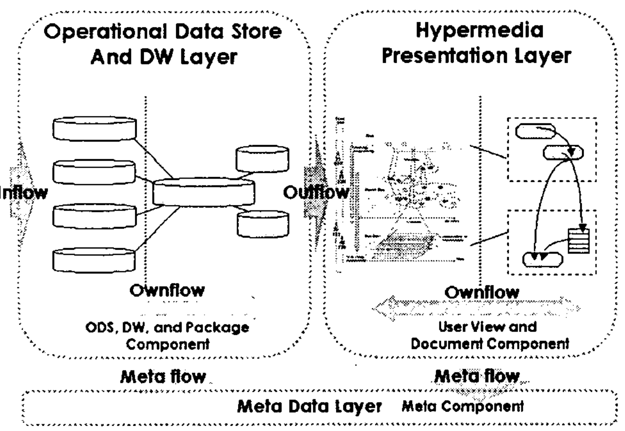

Figure 3- Target Implementation Architecture

All physical elements in this architecture are conceived as node or link holding chunking relationships. Static elements include ODS, DW, view, document, and metadata component. Dynamic elements are comprised of inflow, outflow, ownflow and metaflow. Hyperspace elicited by the elements has an important feature. It stresses store functionality in ODS/DW layer and computational functionality in hypermedia presentation layer.

Users or system can address their queries to the hypermedia presentation layer or to the global DW or even to ODS. These queries must be evaluated locally, at each layer, without accessing the remote data of other layers. When changes to the data in the lowest layer occur, they must be propagated to the data of the higher level.

Mapping Structure

Knowledge mapping structure specifies how the system artifacts in each phase have transformation relationships and how they are finally realized in the target hypermedia application platform. The specification is done via a set of conversion rules between different phases and steps. The goal of the mapping process is to translate the designed artifacts into a target hypermedia system that is tailored to the specific domain requirements. Generally, the final mapping process - from design artifacts to implementation platform - is highly dependent on actual hypermedia system.

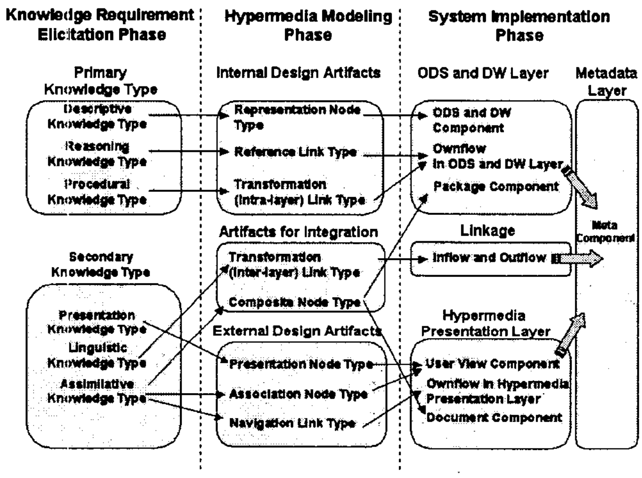

Figure 4 – Mapping Structure

The conversion and mapping process for this methodology consists of two stages, which are graphically illustrated in figure 4. The first stage performs transformation from knowledge type classification system to hypermedia artifact type classification system. In the second stage, generated hypermedia artifact types are changed into system classes, components, and packages through the process of composition, generalization, specialization, and collaboration.

In knowledge requirement elicitation phase, secondary knowledge types are derived from primary knowledge types as source. This kind of relationship proceeds to other two phases. External and integrative design artifact types in hypermedia modeling phase are produced from internal design artifact type. Likewise, components and packages in linkage and hypermedia presentation layer are generated from those of ODS/DW layer. A notable point is that there is a tendency of holding close mapping relationship among types of same nature. Namely, primary type in knowledge layer is kept as source type in other phases. The only exception is composite node type in hypermedia modeling phase. This node type is migrated into both package components in ODS/DW layer and document components in hypermedia layer. Another remarkable point is the importance of assimilative knowledge type. This kind of knowledge type is converted into three kinds of type in hypermedia modeling phase and subsequently four kinds of type in system implementation phase.

Case – Asan Medical Center

Real-life case about medical intelligence application in Asan medical center (AMC) is presented according to our proposed methodology to show the methodological and architectural excellence. AMC founded by Hyundai group is the largest hospital in Korea with 2,200 beds and 1,100 doctors. The case aims to show incremental application development schedule by applying analysis basis, guidelines and related tasks that are established from conceptual works.

In clinical settings, case is the most useful and popular form of medical knowledge. The purpose of the case presentation is to let the medical practitioner understand a patient from diverse points of view, making clear all the pertinent findings in chronological order. Categories of information commonly covered in case description are the patient's medical history, social history, presenting symptoms, physical examination, lab tests, preliminary diagnosis(es), final diagnosis(es), treatment, outcome, and the like. Compared to case level study, cluster level study is a method to find and trace pathological causes in a massive level. Cluster is made in the way of having statistical and practical significance.

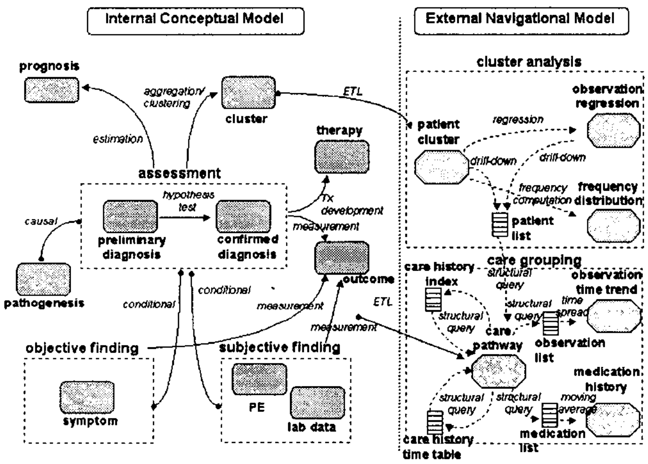

Figure 5 – Hypermedia model for AMC Case

In knowledge requirement phase in AMC example, list of knowledge object to represent and present concept of case and cluster is prepared at first. Next, Identification and grouping of knowledge manipulation activities was performed according to Porter's value chain model. This phase proceeds on associating value activities and knowledge resources to develop utilization correspondence relationship. The final job in this phase is KMEs design by grouping related knowledge objects and KM activities as well as specifying their interaction scenarios together with system involvement.

In hypermedia modeling phase, actual node and link instances are attained based on the analyzed knowledge requirement. They are used in the subsequent internal and external design process. Left part of figure 5 shows the internal conceptual model of AMC case portraying medical practitioner's conceptual pieces and their relationships. Representation nodes can be grouped into object finding, subject finding, assessment, and the rest. Objective finding and subjective finding composite nodes have conditional relationship with assessment composite node. Assessment node contains two representation nodes that are preliminary diagnosis and confirmed diagnosis resulted from hypothesis test procedure. Assessment node also has causal relationship with pathogenesis node. Based on assessment knowledge, prognosis, therapy, and cluster nodes are created thorough the estimation, Tx development, and aggregation/clustering intra-transformation links respectively. Assessment, objective finding, subjective finding nodes all affect the creation of outcome node. Right part of figure 5 depicts external navigational model of AMC case. Presentation nodes in this model are made from fragmentation and reassembly of representation nodes or presentation nodes. For instance, care pathway presentation node is produced by ETL link applied on representation nodes. Afterward, observation time trend node is obtained by the spread of values of specific variables in care pathway on time horizon. Principal nodes in the external model are patient cluster and care pathway.

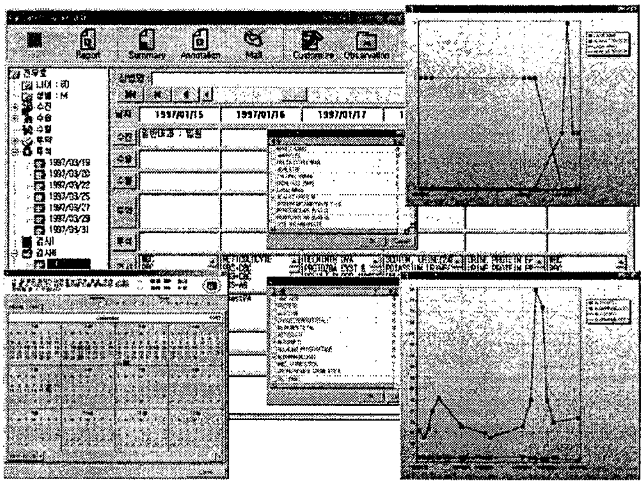

Figure 6- Care Grouper Document

In the implementation phase, all the hypermedia nodes and links are transformed to system artifacts according to pre-designed mapping rules. Nodes are converted to components in ODS/DW layer and views in hypermedia presentation layer. Links are changed to the procedures in linkage part and the two layers. Particularly, composite nodes are mapped to packages grouping components and documents collecting views.

In this case, 10 components, 7 procedures, and 3 packages are implemented in ODS/DW layer. In addition, 12 views, 7 procedures, and 2 documents in hypermedia presentation layer as well as 3 linkage routines are also developed. All the elements followed design process proposed in conceptual study. Procedures and logics are described as object interactions implementing data access, time series generation, statistical calculation, reporting, graphing, and so on. Components include classes managing persistent or transient objects to achieve data storage functionality. Packages facilitate efficient management environment for components. Documents collect and display views, which are customized fragment of data store component. Figure 6 shows care grouper document mapped from care grouping composite node in hypermedia model. It contains views such as care pathway, observation, time trend, medication history, observation list, medication list, care history index, and timetable.

Discussion

This section compares proposed methodology with conventional hypermedia design methodologies. For the convenience of comparison, hypermedia design methodologies are grouped into 4 categories: ER based, object-oriented (OO), content oriented, and interdisciplinary approach.

ER based methodologies contain relatively easy activities, methods, and tasks to learn. They are mainly useful in building presentation-oriented application. But ER based methodologies are so poor in semantics that they are inappropriate to represent complex computational logics. In contrast, OO methodologies are difficult to learn and have low readability. But they have rich semantics to describe complex phenomena delicately. OO methodologies are mainly useful in developing navigation-oriented applications. Content oriented methodologies attempt to express nature of contents substantially by incorporating hierarchical feature on knowledge structure. They uses index node, which is specially designed artifact for content management. Interdisciplinary approach focuses on collective exploitation of advantages from existing methodologies. So, the design of mapping rules among heterogeneous disciplines is mandatory and may be a big load. But this approach allows customization of design artifacts and has rich semantics. It is also beneficial in building a bridge between conceptual discipline and technical work.

Conclusion

Without the elaboration of carefully devised hypermedia design methodology, effective and efficient knowledge asset accumulation is not possible. But most nicely designed hypermedia design methodology would be ineffective if it misses supplying semantic-rich knowledge artifacts and hypermedia modeling primitives. It also requires incorporation of hypermedia layer in data warehousing system to get the architectural fitness with the proposed methodology.

Therefore, our work suggests proposed optimal software development course of action and architecture to acquire enterprise wide knowledge management environment. It supports a step-by-step migration process from conceptual knowledge to system elements. We find that it is essential to employ interdisciplinary approach harmonizing KM techniques, hypermedia design methodologies, and data warehousing concepts. Our research also links concept-oriented knowledge management/generation works and technology-oriented ones in the coherently organized methodological framework. Besides, we proposed customized knowledge warehousing architecture by inserting hyper knowledge layer to typical data warehouse architecture.

To verify our methodological and architectural excellence, a real-life medical intelligence application was constructed according to the proposed methodology. Through the development process, methodological framework and physical architecture for knowledge management were accommodated for hospital environment and knowledge intensive clinical activities. We tried to find a hypermedia model describing concept space of medical practitioners effectively.

Additional works are needed to improve several deficiencies of our methodology. These would include managerial strategy establishment for the flexible project operation, design of knowledge distribution and security model, and metadata management. Moreover, development of knowledge verification process is important.

Acknowledgments

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