Modeling a Terminology-based Electronic Nursing Record System: Object-Oriented Approach

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Abstract

Computer-based nursing records offer information that is more accurate, accessible, and timely information than that available from paper-based records, and they have been introduced as a strategy for maximizing the usefulness of nursing record. Nursing terminology is used in electronic nursing records for data sharing and reuse. This article describes the use of an object-oriented approach in the Rational Unified Process to develop and implement a terminology-based nursing-records system, and discusses the lessons learned during development.

***Key words**:*
system modeling, electronic nursing record, nursing terminology applications

Introduction

The nursing record is the formal documentation associated with nursing care. In the past, the nursing record was merely a data repository that helped nurses to recall what they had done, whereas currently the record represents a resource for the reuse of primary information. To maximize the usefulness of the nursing record, computer-based nursing records have been introduced as a part of the computer-based patient record. The computer-based nursing record is more than a series of documents in electronic form – it will be the cornerstone of a new way of managing nursing information. With an electronic nursing record, data collected at the point of care can be used to assist nursing care at all levels of aggregation. As in an electronic patient record system, the electronic nursing record has the ability to capture clinical information and represent it using controlled terminology, which is widely recognized as a necessity.1

Nursing terminology has seen much progress over the past 10 years. Several national and international nursing organizations have identified a need for standardized terminology to facilitate the description, comparison, and communication of nursing-care activities across settings, population groups, and countries.2 The recent trend toward developing a more rigorous foundation for nursing terminology brings with it a number of potential benefits, including greater expressiveness and more extensive reuse of data from heterogeneous sources. 3–5

However, the existence of appropriate terminology for capturing nursing information does not necessarily solve the problem of how the information will be transformed from concepts in the nurses' minds to codes in the computer's database. Users of existing nursing information systems typically enter and retrieve structured data using so-called interface terminologies – terminologies that are optimized for end-user utilization, such as menu-driven data entry.6 These terminologies generally take the form of enumerated classifications, such as the North American Nursing Diagnosis Association Taxonomy I. But it is now recognized that these kinds of terminologies may not be able to represent clinical information in sufficient detail,5,7,8 nor provide sufficient coverage.9 The International Classification for Nursing Practice (ICNP), a combinatorial terminology, represents one attempt to address some of the problems associated with these traditional representations. However, the combinatorial nature of the ICNP makes it difficult for direct use, and this now appears to represent a barrier to acceptance by nurse users.5

The purpose of this article is to describe how object-oriented analysis and design can be used in developing and implementing a terminology-based electronic nursing-record system (ENRS). This work describes how to design domain models and implement a model database that allows greater expressiveness and reuse of data. In addition, this work can be used to improve a multidisciplinary development team's understanding of the functions and data processing procedures in the design and development stage, as well as of future maintenance procedures.

Background

A terminology-based electronic nursing record was developed based on the model shown in Figure 1. For the development of this terminology-based electronic nursing record, nursing notes were analyzed and cross-mapped with the ICNP, a terminology server was developed to manage nursing terminology, and precoordinated phrases and an ENRS were developed to document nursing notes using precoordinated phrases.10

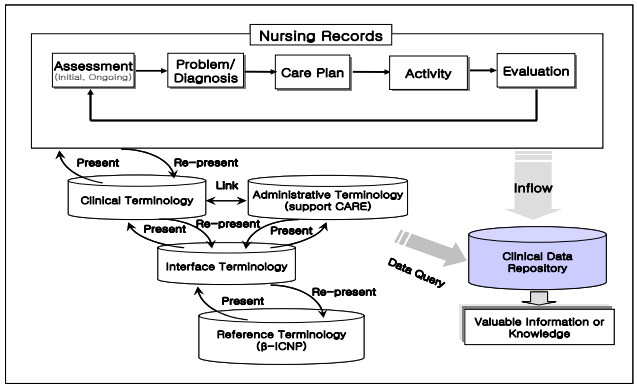

Figure 1. Nursing information model for an electronic nursing-record system (from11). CARE: clinical practice, administration, research, and education

User requirements for an electronic nursing record were extracted from previously published studies. A business model for the electronic nursing records came from Cho's study,11 which proposed a logical information model and provided definitions of the information components and their relationships. In this model, functions of the business logic layer and the data management layer were described independently. In particular, the role and function of standard terminology in the data layer were defined conceptually.

The user-interface layer for the development of an electronic nursing record utilized the results from the study of Choi et al.12 The present study analyzed 69 nursing documentation forms from a tertiary hospital in South Korea. These nursing forms could be divided into structured and unstructured narrative types. The structured forms were analyzed using a data matrix based on data items. All of these nursing documentation forms were integrated and presented in eight major screens. The contents of narrative nursing notes were structured by nursing process, including nursing diagnosis, nursing intervention, and nursing outcome, based on a previous contents analysis of narrative nursing notes.13,14

In software development, there are several ways to develop a model. The two most common approaches are from an algorithmic perspective and from an object-oriented perspective. The traditional view takes an algorithmic approach, in which the main building block is the procedure or function. This view leads the developer to focus on issues of control and the decomposition of larger algorithms into smaller ones. Changes in requirements and system growth make it very hard to maintain systems built with an algorithmic focus.

The contemporary view of software development takes an object-oriented perspective. In this approach, the main building block is the object or class. An object is generally drawn from the solution space, and a class is a description of a set of common objects. Every object is characterized by its identity, state (i.e., there is normally some data associated with it), and behavior. This approach has become mainstream simply because it has proven effective in building systems in all sorts of problem domains and encompassing all degrees of size and complexity.15

In the 1990s various methodologies related to object-oriented technology were introduced with their own notation, out of which Unified Modeling Language (UML) was selected as a standard methodology by the Object Management Group in 1997.16–18 Booch, Bumbaugh, and Jacobson initiated UML, and they proposed the Rational Unified Process (RUP) at Rational®. They suggested that the UML is not a standard for the development process, but a standard for the artifacts of development (semantic models, syntactic notation, and diagrams), and that the RUP is a development process supporting the full features of UML. The RUP captures the best practices in modern software development in a form that can be adapted for a wide range of projects and organizations.

The above-mentioned features lead us to adopt the RUP as our project methodology. The RUP is a model-driven approach. Several models are needed to fully describe the evolving system. In this paper we used use case models to identify what the system is supposed to do and the system environment. We then identified the class diagrams as a design model describing the realization of use cases. The development of a terminology-based ENRS at the Bundang Seoul National University Hospital is going through several iterations. The first and second iterations involved the development of a prototype system and an electronic nursing record, respectively. In the near future, third iteration will be start with data warehouse development.

Methods

For the effective application of the RUP and an accurate extraction of requirements, a modeling team was formed comprising a project manager, systems analysts, user representatives, nursing informatics experts, and an object-oriented methodology expert as external consultants. The project manager was responsible for identifying the data flow and interface problems between the electronic nursing-record system and the legacy system. The systems analysts and nursing informatics experts identified user requirements through regular meetings with user representatives and visualizing such requirements with the aid of model elements. User representatives consisted of nine head nurses from major nursing units, such as internal medicine, general surgery, intensive care unit, gynecology, pediatrics, and special surgery. They involved in the identifying user requirements with us of research team. We selected existing relevant functional requirements (scenarios) extracted from previous studies,10 and then formulated use cases using these scenarios. The use cases for a given scenario became known as a use-case set. We recognized that use-case sets for a given scenario varied across operational environments and time. Operational environments could include such entities as inpatient and ambulatory departments. A use case describing a nurse's use of a computer could involve the use of a handheld computer at a patient bedside. Use-case sets for a given scenario also change with time. For example, as the technology emerges there may be an increasing trend toward voice data entry.

The use-case set reported here corresponded to a tertiary teaching hospital during 2003. Given these parameters, we wrote a scenario designed to highlight the functional area of focus (nursing note taking) within the specified operational environment (nurse station) and time frame (recently).

After the formulation of use cases, we identified classes and their relationships as one of the cornerstones of the object-oriented approach. In this article, we report class diagrams, which are divided into internal and external views. The external view contains external elements that correspond to the people and things engaged in information

exchange outside the electronic nursing-record system, whereas the internal view contains only elements from the ENRS. An object-oriented methodology expert reviewed modeling products and provided progressive feedback to the research team. This approach helped the team to look at the real world with object concepts and to describe the system whilst following the RUP.

Results

I. Use case view

The use-case view describes the behavior of the ENRS as seen by a nurse, a nurse manager, and a systems analyst. The static aspects of this view were captured in a use-case diagram (Figure 2), and the dynamic aspects of this view were captured in an activity diagram (Figure 3).

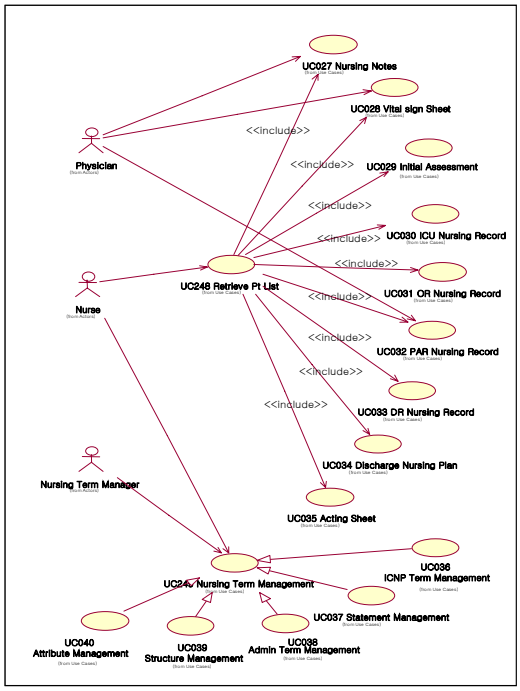

Figure 2. Use case diagram of the ENRS

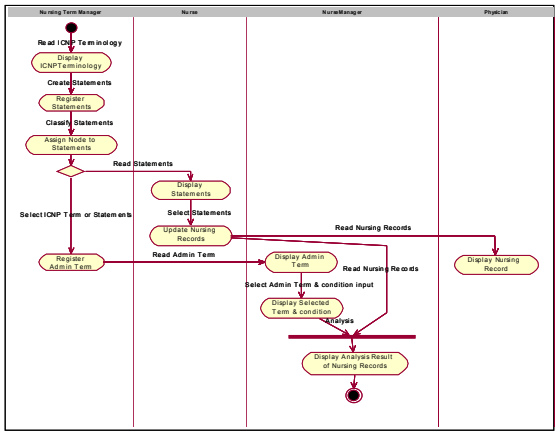

Figure 3. Activity diagram of the ENRS

The use-case diagram comprised nine use cases addressing nursing-record management and one use case addressing nursing terminology management. The part devoted to the management of nursing terminology was generalized to an ICNP Term Management use case, Statement (precoordinated nursing phrase) Management use case, and three other use cases supporting functions of terminology management. Physician, Nurse, and Nursing Term Manager were identified as the actors that use these use cases. The Physician is an actor who also represents other health-care professionals that need to refer to nursing documents, such as nutritionists, pharmacists, radiation therapists, and staff of the insurance department. The Nurse (including the nurse manager) is an actor who participates in writing nursing documents and supervises them for service quality assurance. The Nursing Term Manager is an actor that takes charge of terminology management, including ICNP terms and statements (precoordinated phrases).

Figure 3 shows the flow from an activity to an activity within the ENRS. In the activity diagram, the overall task flow of the ENRS was identified. The Nursing Term Manager is in charge of creating, updating, and maintaining nursing terminology and statements (precoordinated phrases). The nurse uses precoordinated nursing phrases in the data input process. The Admin terms(administrative terms) identified by the Nursing Term Manager are used in the analysis of nursing records for the various purposes of data aggregation. For example, the chief nurse manager of the internal medicine department wants to retrieve nursing-problem and nursing-activity lists identified in the patients admitted to the oncology nursing unit during specific periods. She will use such information to understand the trend of nursing problems or to distribute nursing resources during subsequent time periods. The ENRS performs the retrieval function of nursing problems and activities under the given conditions, and returns the result in abstracted forms using administrative terms. It is common for a nurse manager (a type of nurse) to use these administrative terms. The physician's role is simply retrieving and inquiring functions through the various user-interface displays.

We first wrote a brief scenario story describing a nursing-note-taking episode involving the taking of a patient's vital signs:

A nurse reads previous nursing notes for a patient. She takes the vital signs of the patient, documents them, and then signs her name.

Then we described this brief scenario in details. Each scenario story was used to verify the user requirements. After obtaining approval for the scenario story, we documented use-case properties in use-case specifications, which include name, a brief description, the event flows, alternative flows, special requirements, preconditions, and postconditions. Each flow of events was described in narrative. Figure 5 shows the specification of the Nursing Notes use case. In this specification, the event flows comprise the normal data input, retrieve, and update scenario, while alternative flows contain exceptional scenarios such as

deleting or modifying the statements or attributes stored in the database. The special requirements address items such as the statement management method of the individual patient for already selected statements to support easier data input, special remarks on night duty charting or free text input, and the progress note display method used in psychiatric nursing units.

II. Design View

The design view supports the functional requirements of the system, which are the services that the system should provide to its end users. With the UML, the aspects of this view were captured in electronic nursing-record class diagrams. The use cases of the ENRS can be divided functionally into two packages (Figure 4): Nursing Records and Nursing Term Management. Each package includes a Nursing Records class diagram and a Nursing Term Management class diagram.

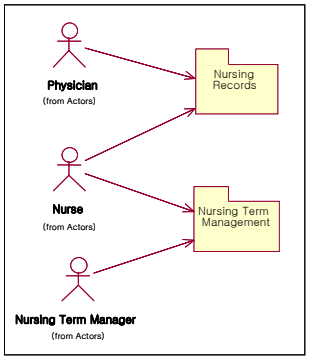

Figure 4. External elements of the ENRS

Figure 5 shows the one part of the Nursing Rrecords class diagram, which consists of seven entity classes, four boundary (user interface) classes, four control classes, and their interrelationships. The upper left quadrant shows Initial Assessment use case, in which nurse enters the assessment data into a structured screen. For example, the level of patient consciousness is entered by checking one of four values: clear, confused, semicoma, or coma. The upper right quadrant shows the Vital sign Sheet use case and the ICU Nursing Record use case. The Nursing Notes use case is depicted in the lower right quadrant. Figure5 also displays the relations with the Statement class..

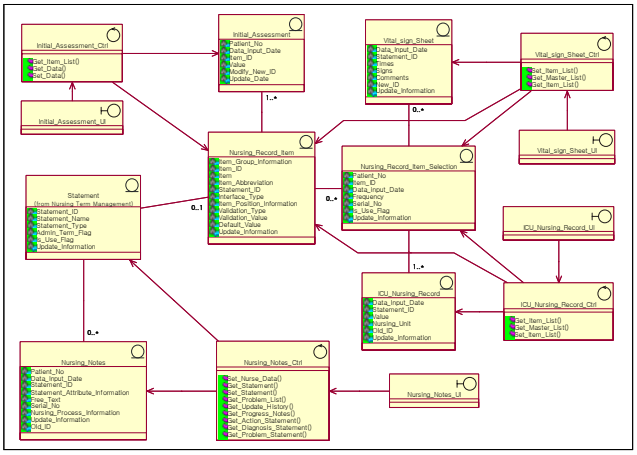

Figure 5. Internal class diagram of Nursing Records package

Figure 6 shows the Nursing Term Management class diagram, which consists of six entity classes, four control classes, and three boundary classes. Each boundary class requests specific operations related to control classes, and then each control class manipulates the data received from the related entity classes. For example, a nurse or a group of nurses who have responsibility for managing nursing terminology can manage the terms and structure of ICNP and precoordinated phrases. The notation of the unified modeling language used in the class diagrams is as follows. The rectangles provide information about each class. The top tier in the rectangle contains the name of the class, and the middle tier contains the information items identified in the use cases. Information items are not synonymous with data elements – data elements are more detailed and discrete than information items in this project.

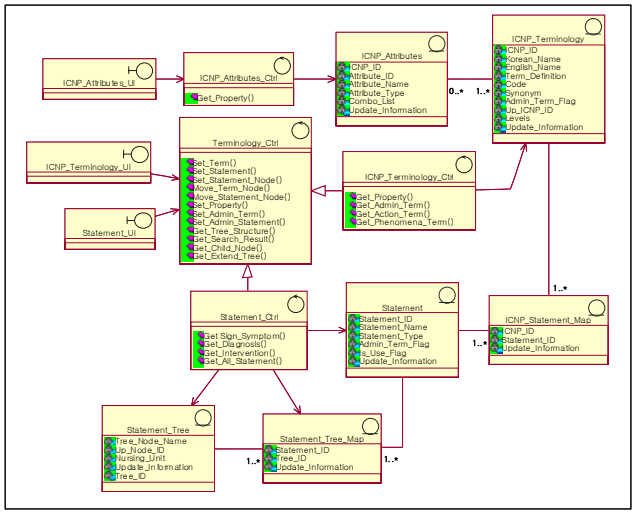

Figure 6. Internal class diagram of Nursing Term Management package

III. Process View

The process view encompasses the thread and processes that form the system's concurrency and synchronization mechanisms. This view primarily addresses the performance, scalability, and throughput of the system. With the UML, the static and dynamic aspects of this view are depicted using the same types of diagrams as for the design view, but with a focus on the active classes that present these threads and processes. Figure 7 shows the process of recording nursing notes as one process diagram example of the ENRS. The class on the left side of the figure is used only to display data of the selected patient, and the right-hand one is used when additional event requests have occurred. Such an approach improves the system performance.

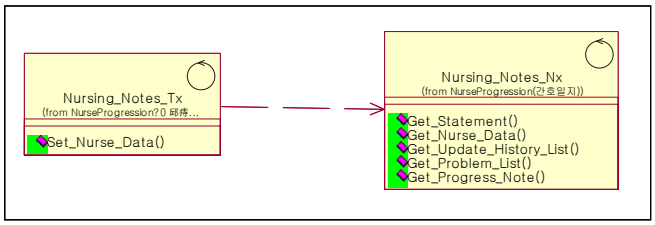

Figure 7. Process diagram of Nursing Notes use case in the ENRS

Discussion and Conclusion

The current use of SNOMED® clinical terms in electronic medical records marks a shift in emphasis away from the notion of a mere "reference terminology" towards a terminology system for direct use in clinical applications.19 The use of the ICNP marks the same type of shift in nursing. However, there are concerns that the size and inherent complexity of this emerging combinatorial nursing terminology language system make its direct application awkward. In order to ameliorate this awkwardness, the combinatorial terminology has been mapped "behind the scenes." 20,21 However, one criticism of this approach is that it prevents users from exploiting the full potential of the terminology system.

In the present study, a terminology-based electronic nursing record was developed using an object-oriented approach. Specifically, the RUP methodology was used to describe user requirements and system design and development. Similar studies have been carried out by Egyhazy et al.,22 Johnson,23 and Gu et al.24 The study of Egyhazy et al. proposed methodology for modeling computer-based patient records in a military health services system, and highlighted the usefulness of an object-oriented analysis and design. However, they did not use a controlled vocabulary for the terminology. Johnson's study dealt with data modeling communications through a conventional approach, and the study of Gu et al. addressed the issue of controlled medical terminology management through an object-oriented database representation. The latter two studies focused on data modeling, and did not consider the systems' procedures in model formulation but designed them separately with data. In contrast, the class model used in the object-oriented approach helps in the understanding of both the static and dynamic aspects of the target system, by regarding them simultaneously at the modeling level. Given the current trend of increasing complexity of hospital information systems, due to the increased needs of integrated hospital information systems of electronic patient record and an intelligent health analysis and a decision support system, the object-oriented approach aids communication between domain experts and software experts. That is, through the object-oriented approach we could identify clearly the structural and behavioral states of our terminology-based electronic nursing-records system, and used five artifacts to explain them to software experts. Additionally this approach provides a systematic method for evolving our model continuously with consistent concepts. This characteristic is very important for a terminology-based system since nursing terminology evolves.

During program development we encountered a few problems, including interfacing with the legacy system that used an order communication system, and adapting complex nursing terminology into an electronic nursing record. Our strategy was to use an interface approach applying standard statements as clinical terminology in the application. Standard statements were precoordinated using ICNP as a reference terminology. For this strategy, systems analysis and design were described using object-oriented methodology covering all of the structured and unstructured nursing records. One important characteristic of the interface approach proposed in this study is that it employed a nursing terminology manager to reflect the changes that occur in nursing practice and the environment, who defined a continuous feedback relationship between reference terminology and clinical terminology. Another characteristic is its modeling of the behavior of electronic nursing-record system by defining administrative terms to allow data aggregation from the nursing record at an abstract level, and describing this utilization process as a system flow. This approach allows users to manage the complexity of reference terminology centrally, and provides users at various levels with a user-friendly interface for the clinical terminology. This enhances the utility of the system in nursing practice and provides a mechanism for the continuous feedback from practice into terminology. Since the system is terminology based, data can be reused; and being objected oriented, the system can follow an iteration process of system development such as data warehouse..

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